**PhD Dissertation**

**International Doctorate School in Information and Communication Technologies**

DIT - University of Trento

# ACTIVELIFESTYLE: A PERSUASIVE PLATFORM TO MONITOR AND MOTIVATE PHYSICAL TRAINING PLAN COMPLIANCE IN ELDERLY PEOPLE

Patrícia Souza Silveira

Advisor:

Prof. Dr. Fabio Casati, Università degli Studi di Trento

Co-Advisors:

Dr. Florian Daniel, Università degli Studi di Trento

Prof. Dr. Eling D. de Bruin, ETH Zürich

March 2013

## Abstract

*The primary public health goal is to increase the number of years of good health and, therefore, maintain independence and quality of life as long as possible. Healthy ageing is characterized by the avoidance of disease and disability, the maintenance of high physical and cognitive function, and sustained engagement in social and productive activities. These three components together define successful ageing.*

*An important part of successful ageing, hence, is maximisation of physical performance. The ability to fully participate in productive and recreational activities of daily life may be affected when the capacity to easily perform common physical functions decreases. Health status, thus, is an important indicator of quality of life among older people. It appears that especially components of health-related fitness and functional performance, or serious, chronic conditions and diseases that directly influence the components of fitness and performance, are related to perceived health among middle-aged and older adults.*

*Regular physical activity or exercise substantially prevents the development and progression of most chronic degenerative diseases. In summary, it is evident that to increase older adults' quality of life and fitness, we need to encourage the elderly to become more physically active and increase their fitness through training.*

*Home environmental interventions to prevent functional decline seem to be effective and are, furthermore, preferred by elderly. Such interventions with integrated assistive technology devices have, in this context, the potential to further help in overcoming some of the barriers to start training and, thereby, maintaining physical independence for independently living elderly. Hence, the objective of this thesis is to identify how, through IT or IT-mediated persuasive software applications, we can enable independently living and healthy elderly people to perform balance and strength training plans autonomously at home and keep them motivated, in order to increase their compliance toward the plans*



**Keywords**
*Motivation instruments, physical exercises, elderly, tablet, prevention, healthcare, mobile development, mobile software application*

*To Luiz and my family*

*If you hear a voice within you say 'you cannot paint'*
*then by all means paint, and that voice will be silenced*
*Vincent Van Gogh*

# Acknowledgments

This achievement would not have been possible without the help and support of many people, and this page is here to thank them all.

First, I would like to thank my advisor, Prof. Dr. Fabio Casati for the opportunity of doing my Ph.D. at the University of Trent, and for being always very accessible, comprehensive and having a huge heart.

I would like to thank Prof. Dr. Eling de Bruin, who also advised me during the period abroad at the ETH Zürich. Eling you gave me "light at the end of the tunnel", and more than that, provided the means in which I could develop a rewarding job in Switzerland, where I had the pleasure to meet enthusiastic and lovely elderly people.

A special thanks goes also to Dr. Florian Daniel, who followed and motivated me during this long period of my Ph.D. Florian, without you I would be lost! Thank you so much!

I also want to thank the Active Lifestyle team - Kasia, Diana, Michele, Massimo, Eugenio, Rodrigo, and specially Ivan, for your hard work and support, without you guys this work would not have been possible in this short period of time. Thank you so much!

Equally important to the conclusion of this thesis were the fellowship, German language support, and excellent teamwork with Maria Messmer-Capual. You are the best! Together with Maria are all the elderly participants of the ActiveLifestyle study, who followed our training plans and used our app with a great enthusiasm, even feeling pain or having difficulties to manage all the technological aspects of our study. I am so proud of you all, and, at the same time, glad for having met you during my Ph.D.

Não posso deixar de agradecer ao meu grande amor, Luiz, por todo o apoio e compreensão dispensados durante esses longos e duros anos de doutorado. Juntamente com ele, a minha família merece um agradecimento especial, por terem me apoiado e me encorajado a concluir mais esta etapa da minha vida. Obrigada Mãe, Pai, Duza, Vó Ostília, Vô Assis, Tio Mico, Dinda Leda, Dindo Gordo, Pokelherme, Leandrinho, Tio Coutelle, Tânia, Tia Celina, e Cléia. Vocês também fazem parte desta vitória. Sem vocês eu já teria desistido há muito tempo.

Roberta Guidolin também merece um agradecimento mais do que especial, por ser o meu anjo Italiano, sempre pronta para me ouvir, me abraçar e me distribuir sorrisos. Não tenho palavras para agradecer tudo que fizestes por mim! És minha irmã de coração e minha consciência.

I also want to thank all my friends who supported me in this period and with who I had great moments in Trento. Guys you are the best: Leandro, Kétner, Huguinho, Carlos, Delsi, Alethia, Edu, Christian, Majo, Marcos, Alejandro, Jorge, Carla, Sylvia, Elda, Berni, Zita, Csaba, Paolo, Cinzia, and Gianluca.

Anche meritano un ringraziamento speciale i miei coinquilini di Via Vittorio Veneto. Grazie di cuore per tutto! Gloria, Stefano, Luca, and Jacopo siete stati la mia famiglia in questi anni.

Finalmente, Débora, Fernandinha, Júlia, e Vanessa. Queridas vocês são minhas conselheiras oficiais. Obrigada por estarem sempre on-line, por toda a atenção e carinho que vocês tem por mim!

# Contents

## Structure of the Thesis

This thesis is structured as a collection of scientific articles reviewed and accepted by peers in the scientific community[1] during my years of Ph.D. Chapter 1 presents an executive summary of our research work, providing an overview of the main problems and solutions and the references to our articles describing in deeper details the various parts of the work. The executive summary chapter is structured as follows: first, we provide the context and the problem (Section 1.1), then the research objectives and challenges (Section 1.2). After that, we introduce our solution, named ActiveLifestyle (Section 1.3), followed by its contributions and results (Section 1.4). Finally, we draw the conclusions (Section 1.5), introduce ActiveLifestyle at Apple's App Store (Section 1.5.1), present the lessons learned (Section 1.5.2), introduce the limitations of our research (Section 1.5.3), and point out our looking ahead points (Section 1.5.4). Chapter 2 introduces the road to ActiveLifestyle, together with our background in compliance governance (Section 2.2) and in a platform to support and motivate adults' compliance to a training plan (Section 2.3). All the scientific articles composing this work (illustrated in Figure 2) are included as annexes at the end of this document.

[1] The work documented in [14] is not yet published. It was submitted to the Journal of Internet Medical Research and is waiting for review.

# Chapter 1

# Executive Summary

## 1.1. Context and Problem

Health is an important indicator of quality of life among older adults [1][2]. Inactivity, on the other hand, is at the origin of several chronic diseases [3], and regular physical activity substantially prevents the development and progression of most chronic degenerative disease states [4]. For older people, a sedentary lifestyle especially increases the risk of falls, whereas physically active older people have a clear reduced risk of falls with injuries [5]. In summary, it is evident that in order to increase elders' quality of life and fitness, we need to encourage them to become more physically active.

To promote health, wellbeing, and functional independence of the elderly, the specialized healthcare professionals (i.e., sport medicine, gerontologists, physiotherapists and human movement scientists) strongly recommend physical training programs that especially focus on traditional components of exercise such as muscle strength and balance [6]. However, there are a variety of barriers that make it hard for elderly people to maintain or increase their physical activity level. In general elderly people face lack of motivation to exercise regularly during long periods (e.g., they lack company and interest), which might be reinforced by poor health (e.g., daily pain, chronic diseases) [7] [8], by fearing an injury or fall due to the exercises, or by insufficient understanding about physical activity and its benefits [9]. Chronic medical conditions, daily unbearable pain, and previous surgeries require a careful design and planning of how to exercise [10]. Moreover, healthcare experts may lack time or expertise to address problems of physical inactivity among their older patients. Such experts often lack information about quality programs, materials, and how to make referrals to community resources [11].

Home environmental interventions that are based on different forms of assistive technology devices have, in this context, the potential to overcome some of the barriers to start training and maintain physical independence for independent living elderly [12]. However, the effectiveness of such approach has not yet been demonstrated to a large extent. Modern exercise equipment may not always be suitable for elderly individuals, who might be concerned about the intensity of training sessions and may rather express to have a preference for more traditional therapy approaches [13].

The objective of this thesis is *to assist and motivate independently living and healthy elderly to perform strength and balance exercises autonomously at home.*

This thesis is a collaboration effort between the LifeParticipation research group[2] of the University of Trento (UNITN), Italy and the Institute of Human Movement Sciences and Sport (IHMS), Department Health Science and Technology, "Eidgenössische Technische Hochschule" (ETH) Zürich, Switzerland[3]. The ETH human movement experts provided the necessary expertise in strength-balance training plans for elderly people, and in physical home environmental interventions. Our research group designed, developed, and tested a persuasive software application to enable and motivate independently living and healthy elderly people to perform balance and strength trainings autonomously at home.

## 1.2. Research Objectives and Challenges

The objective of this research is *to identify how, through IT or IT-mediated persuasive software applications, we can enable independently living and healthy elderly people to perform balance and strength trainings plans autonomously at home and keep them motivated, in order to increase their compliance toward the plans*.

The objective encompasses the following sub-objectives:

- To understand strengths and weaknesses of balance and strength training software and of IT or IT-mediated persuasive motivation strategies in previous studies;

- To create a software application to support users to performance balance and strength exercises training sessions autonomously at home. Having elderly as target users is a challenging task. Elderly possibly suffer from cognitive impairments and have few or no computer skills (e.g., typically elderly people might not hear and see well, they may have difficulty to interpret charts, or to navigate through the Internet). Hence, the software's user interface has to be simple enough to be used by elderly without previous computer experience, and, at the same time, be attractive and stimulating for the expert ones;

- To equip the software application with IT or IT-mediated persuasive technologies, specially social persuasion strategies, to increase elderly's motivation to exercise, and consequently their compliance toward the physical training. For that, it is necessary to under-

[2] LifeParticipation website: lifeparticion.org
[3] IHMS, ETH – Zürich website: www.ibws.ethz.ch

stand the complex and large sociological and psychological motivation aspects in order to select and design a set of persuasive technologies for elderly, which also need to cope with their possible cognitive impairments and lack of computer skills, and yet being instigating for computer expert and mentally sharp elderly users; and

- To demonstrate the effectiveness of the persuasive motivation strategies and the effectiveness of IT-assisted home training by the challenging task of designing and performing a physical intervention study with real elderly users.

## 1.3. Solution: ActiveLifestyle

In order to enable independently living and healthy elderly people to perform balance and strength training plans autonomously at home, the first step is to conceptualize the problem scenario and the possible software solution. The intuition is to design a tablet application, since tablets are relatively robust, and using fingers instead of a mouse or a touch pad make them much more intuitive and easy to use by elderly compared to smartphones, notebooks, and desktops.

We followed a mockup-based and interactive designed methodology for the development of our solution. In a first moment, we designed and created static mockups of the tablet application and validated them internally in our research group and with the ETH experts. In a second moment, more advanced mockups running on a hardcoded tablet application were presented to elderly users. After this incremental designing process, we reached the first stable version of a tablet application prototype, which followed, in addition to the ETH experts and the potential users tips, some well-known Human Interaction Computer (HCI) usability goals (i.e., effectiveness, efficiency, utility, learnability, and memorability). The design of the application followed a simple and intuitive user interface logic, containing video and audio features to guide the users through the workout sessions. In addition, it is important to use big font sizes and larger buttons, together with intuitive and well-designed icons in order to allow the users to easily navigate through the different menu options.

Regarding the motivation, the approach is to leverage on individual and social persuasive motivation instruments to increase the elderly's training compliance. *Individual motivation* strategies aim to convince someone to do something because it is inherently enjoyable for this person, independently of any social pressure (e.g., *Conditioning through positive and negative reinforcement*, *Goal-setting*, *Self-monitoring*, and *Awareness*). *Social motivation* strategies are built on social psychology. An individual's social network (other trainees) may act as source of motivation (e.g., *Comparison*, *External Monitoring*, *Emotional Support*, and *Collaboration*[4]*)*. All the motivation strategies are explained and illustrated in [14]. In order to test the persuasive instruments, the approach is to divide the application in two versions. The Individual version contains only the above mentioned individual motivation strategies. The Social version supports the aforementioned individual and social motivation strategies, and, in addition, a virtual training plan community (i.e., other users following the same training plans) and communication features.

The goal of this work is to support three levels of balance and strength training plans (a detailed description of each level is documented in [14]). The complete training plan procedure, as well as the whole set of strength and balance exercises are available on YouTube[5,6].

We implement all these concepts and design approaches into ActiveLifestyle, a software for active ageing, aiming at assisting, monitoring and motivating elderly during autonomous home-based physical workouts [14][15][16]. The software takes usability aspects into account, to ensure that users can use it independently and adopts motivation strategies to stimulate elderly users to exercise regularly.

ActiveLifestyle was tested twice with real users. At the first time, during a Pilot Study, 13 independently living and healthy elderly followed autonomously at home a 2-weeks strength and balance training plan supported by our tablet application. The main objective of this first study was to investigate the feasibility of ActiveLifestyle for assisting the autonomous physical training of independently living elderly. This pilot was essential to confirm our impression that ActiveLifestyle was indeed useful to support elderly people to perform strength and balance training plan autonomously at home. In addition, it was very useful to detect some development problems and design limitations. And, even more, it was very important to receive encouraging and supportive comments from our elderly participants who really enjoyed this initial experience. The complete description of our first and exciting study with real elderly users, as well as its main findings and lessons learned are documented in [16]. In addition, some supplementary and interesting material about this Pilot study are available on the Internet:

---

[4] Video introducing the ActiveLifestyle collaboration game: y2u.be/21ffbRcMCa0
[5] ActiveLifestyle training plan procedure: youtu.be/XSFjHcUtt_A
[6] Balance and Strength exercises videos: www.youtube.com/user/psilvieraf81?feature=results_main

- A video showing the first reaction of an elderly woman (89 years old) with no previous computer experience using ActiveLifestyle[7];

- A video showing the previous and reduced version of ActiveLifestyle used during the Pilot study[8] (such version does not support most of the social motivation instruments);

- A video showing the participants attending the classes before the Pilot study physical intervention[9]; and

- Paper news at Höfner Volksblatt advertising our study in Wollerau, Switzerland[10].

The second test, a Controlled Clinical Trial, was 12 weeks long and involved 44 independently living and healthy elderly participants divided in three groups: i) using ActiveLifestyle and its individual persuasive motivation instruments, ii) using ActiveLifestyle and its social and individual persuasive motivation instruments, and iii) following the training plan with a printed guideline and with no motivation instruments. The main objective of this study was to investigate which IT-mediated persuasive strategies increase compliance to physical exercise training plans in elderly, as well as to discover whether ActiveLifestyle induces physical activity behaviour change; and whether the ActiveLifestyle training improves gait speed[11]. As the Pilot study, this experience was very rewarding and stimulating, most of the participants presented physical improvements and felt motivated by using ActiveLifestyle. A complete description of this Controlled Clinical Trial physical intervention, encompassing its research methods, statistical analyses, outcome measure and results, as well as the elderly comments about the study are documented in [14]. As before, some complementary material about this second study is available on the Internet:

- A video showing the social version of ActiveLifestyle used during this Controlled Clinical Trial[12];

- A video showing part of the participants attending the classes before the physical intervention study[13];

---

[7] Old woman testing ActiveLifestyle for the first time: y2u.be/bapMu6WlUhw
[8] ActiveLifestyle version used on the Pilot Study: y2u.be/ahc-bqiCpV4
[9] Elderly participants during the initial classes of ActiveLifestyle Pilot study: y2u.be/pgyYSjAR6h4
[10] Paper news about ActiveLifestyle: www.lifeparticipation.org/images/news/patriciaLarge.jpg
[11] Gait speed is a clinically relevant indicator of functional status associated with important geriatric health outcomes (i.e., impact healthcare activities have on people) [1][18]
[12] ActiveLifestyle version used on the Clinical Controlled Trial: y2u.be/XSFjHcUtt_A
[13] Elderly participants during the initial classes of ActiveLifestyle Controlled Clinical Trial: y2u.be/mNaIOYqN6tU

- Paper news advertising our study in Horgen and Zürich, Switzerland[14,15,16]; and

- A report on a dedicated Swiss elderly website, named SeniorWeb[17].

This second test was more challenging than the Pilot study for many aspects. First of all, it was much longer (12 weeks) and involved a larger sample of participants (44 independently living elderly residing in small cities around Zürich, Switzerland), which increased the amount of effort to prepare the physical intervention (e.g., set and install the software in the tablets; buy and distribute the physical training material, which consists of ankle weights, Pilates ball, and resistance band; print all the user guides and evaluation questionnaires, and perform the pre and post physical evaluation tests for all the participants).

## 1.4. Research Contributions and Results

The design, development, and assessment of ActiveLifestyle embraces the following scientific contributions:

- The design and implementation of an easy to use and intuitive tablet application to assist independently living elderly people to perform strength and balance exercises autonomously at home. All the participants of our both studies, even the ones without previous computer experiences, were able to follow the training plan using the application [16][14]. According to the usability aspects of the application explored in the Pilot study [16], all the participants said ActiveLifestyle was easy to use. All the participants were able to read messages on the *Bulletin board*, and most of them (90.9%) were able to navigate through the *Bulletin board* (i.e., scrolling it up and down). However, due to shyness and some difficulties to use the tablet keyboard, approximately half of the participants were able to send private messages (63.3%) and write on the *Bulletin board* (45.5%). More details about these usability aspects as well as the intention of use of our participants are described in [14][16];

- The design and implementation of a private and public communication channel among elderly users and their healthcare experts. ActiveLifestyle supports two important communication features. One is the *Bulletin board* an open and social com-

---

[14] Zürichsee-Zeitung: www.lifeparticipation.org/images/2012-zsl-ZSLX_005_1306.png
[15] Neue Zuercher Zeitung: www.lifeparticipation.org/images/Neue_Zuercher_Zeitung_vom_04.09_Senioren_mit_iPad.pdf
[16] Zürichsee-Zeitung: www.lifeparticipation.org/images/2012-zsl-ZSLX_005_0711.pdf
[17] SeniorWeb report: www.seniorweb.ch/type/magazine-story/2012-07-24-fit-bis-ins-hohe-alter

munication channel where all the participants of the training plan community can send and receive written messages to/from other participants and to/from the healthcare and IT experts (e.g., the last in case of technical problems). The other is the *inBox* a private bidirectional communication channel, where the participants can send and receive written messages to or from a specific person without sharing its content with the rest of the group. Both features were described and tested in [14][16];

- A software application able to promote new social ties. ActiveLifestyle was able to extend the virtual training plan community to the real life. During the Controlled Clinical Trial study [14] some participants, who did not know each other before, started to meet to perform the workout sessions together or to help each other with the tablet;

- The design, development, and validation of a set of individual and social persuasion technologies able to motivate elderly people to follow balance and strength training plan autonomously at home. The findings of both of our studies [14] support the notion that it is advantageous to combine physical training with specifically targeted IT motivation instruments that offer the possibility to socialize in a group in clinical practice. The combination seems to have a positive influence on older adults' training compliance in comparison to more traditional exercise. Typical physical interventions present 10% of attrition rate[18], while the group following the training plan with the social version of ActiveLifestyle presented 8% of attrition. Moreover, the compliance to the training plan was higher than in the traditional physical interventions that typically reach 50% of compliance. The ActiveLifestyle Social group reached 73% and Individual 68%, while the Control group 54%. The complete statistical analysis of the results are available in [14];

- A set of social persuasion instruments that seemed to change the physical behavior of the participants. At the end of the physical intervention described in [14], 50% of the participants following the training plan using the tablet application with social persuasion technologies changed their behaviour according to the Trans-Theoretical Model – which assesses how people modify or acquire behaviour as described in [17].

[18] Number of participants lost at final follow-up

At the beginning these participants were at the Contemplation or Preparation stages (thinking about or already being somewhat physically active), and they were classified as being on the Maintenance stage (making physical activity a habit) by the end. However, a further longitudinal study with a bigger sample, and counting with evaluation after the end of the intervention is required to ensure change of physical behaviour; and

- The physical exercise training plans supported by ActiveLifestyle are effective to improve the participants' lower body muscle strength and balance, and consequently their preferred and fast gait speed, which may reduce their risk of falling. In average our participants improved 0.152 $m \cdot s^{-1}$ for preferred and 0.135$m \cdot s^{-1}$ fast gait speed, which are good results for a short 12 weeks physical intervention. Large epidemiological studies reveal that significant increments of 0.1 $m.s^{-1}$ in walking speed are related to a 12% decrease in mortality [18].

It is important to keep in mind that such results were obtained from a rather small sample of elderly users, due to that we can only point out tendencies. Further longitudinal studies with more significant samples of users are required in order to state more concrete results.

## 1.5. Conclusions

ActiveLifestyle successfully enables and motivates independently living elderly people to perform balance and strength trainings autonomously at home and keeps them motivated, in order to increase their compliance towards the training plans.

### 1.5.1. ActiveLifestyle at Apple's App Store

The final version of ActiveLifestyle can be downloaded for free from Apple's App Store[19], as illustrated in Figure 1. Its current version supports multiple languages (i.e., English, Italian, and German), different levels of strength and balance training plans (i.e., Beginner, Intermediate, and Advance), and two user interfaces (i.e., one with individual persuasion strategies, and another with individual and social strategies). In order to follow balance and strength training plans autonomously at home, using ActiveLifestyle, the user requires: an iPad with iOS 6.0 or more, a

[19] ActiveLifestyle at Apple's App Store: itunes.apple.com/it/app/it4life-activelifestyle/id465295073?l=it&ls=1&mt=8

Google Gmail and an Apple-ID accounts, an Internet connection (either 3G or Wi-Fi), and training equipment (e.g., a resistance band, a Pilates ball, and, in case of an advanced training plan, a pair of ankle weights).


**Figure 1** Final version of ActiveLifestyle available at Apple's App Store.

### 1.5.2. Lessons Learned

The whole ActiveLifestyle design, development and testing period was very exciting and rewarding. The opportunity to involve not only real, but also elderly, users to test the system and see their happiness, motivation, and, even more, their physical improvement, was by far the best part of our work. In addition, such experience was also an excellent opportunity to learn that:

- A Controlled Clinical Trial involving assistive technology devices, like ActiveLifestyle, demands a 24 hours technical and dedicated support. Elderly users are very sensible and can easily get stressed when technical devices do not work as expected. So, it is very important to avoid additional stress associated to technical failures and mistakes, since they are already overwhelmed and possibly stressed dealing with the new device and its learning process;

- Tablets are highly recommended for elderly people, they are by far easier to use than normal computers that leverages on touch pads or mouse. However, they are not so intuitive as we originally imagined. Regarding the iPad, it was possible to identify the following usability problems: difficulties to understand all the steps required to create an apple-ID and a valid password, distinct iOS versions present different graphical interfaces that caused some confusion (e.g., different accessibility options, for example, to share a picture; different icons);

- The virtual community supported by the Social version of ActiveLifestyle was an opportunity to improve social ties among the participants outside the virtual world. Some trainees started to visit each other for training or spend time together. However, most of the participants are against famous networking tools as Facebook mainly due to privacy and usability issues, which gives space to further researches for social networks specially designed for elderly people;

- Interestingly, even if most of the participants felt motivated for being part of a training community, a small portion does not want to socialize and share their workout sessions and thoughts with strangers. It may happen because they already have strong social ties, or the other way around, they might face difficulties to socialize (e.g., fear of being rejected, lack of self-efficacy, shyness) which gives space to further investigation about how to socially integrate these people not only to motivate them to follow a medical advice, like physical exercises, but also to improve their connectedness and well-being; and

- In addition to the physical improvement supported by the current version of ActiveLifestyle aiming at preventing diseases and the risk of fall with injuries, it is equally important to maintaining elderly's mind sharp to also prolong their independence, and avoid, or at least, reduce the risk of diseases. For instance, dedicated cognitive training plans seemed to be effective to improve reaction time, processing speed, working memory, executive function, visual spatial ability, and attention [19].

### 1.5.3. ActiveLifestyle Limitation

This thesis has several limitations. One of them is the rather small sample size in both physical intervention studies. This thesis, therefore, reveals in a first moment the feasibility to adopt a tablet application to support physical home interventions, followed by first estimates for gait speed measures and stages of behaviour change, and warrants further research in larger populations. However, both physical interventions served the purpose of Phase III trials [20], which is to provide preliminary evidence on the clinical efficacy of an intervention as discussed in the limitation section of our scientific contributions [14].

Regarding the physical intervention method, it would be preferable to have different group of researches to apply the final questionnaires and collect feedback, in order to avoid any biased results. However, due to the reduced number of researchers and collaborators, it was not possible.

Another limitation is the high fitness level of the participants of the Controlled Clinical Trial physical intervention. Such participants can be classified as normal walkers with a preferred gait speed between 1.0 and 1.4 $m.s^{-1}$. Future studies with community dwelling populations that exhibit mildly abnormal (0.6-1.0 $m.s^{-1}$) or seriously abnormal gait speed (below 0.6 $m.s^{-1}$) [18] should be performed to investigate whether similar or even better results in physical performance variables can be obtained.

About the ActiveLifestyle usability we are aware that elderly users without previous computer knowledge might face problems to complete the setup phase required by our application (e.g., create a Gmail e-mail account, create an apple-ID, and download the app from the Apple's App Store).

### 1.5.4. Looking ahead

ActiveLifestyle was a successful endeavor to support independently and healthy elderly users to follow dedicated balance and strength training plans autonomously at home. However, there are a variety of useful and interesting features that are good for elderly people and that can be easily implemented having ActiveLifestyle already in place. For instance, as future work we envision:

- To extend the set of training plans offered by ActiveLifestyle to include games or exercises to improve cognition, which is also an important factor to prolong independence by improving motor control and divided attention, which might reduce the risk of falls and further injures due to that;

- To make ActiveLifestyle more configurable to allow elderly users, healthcare experts, or caregivers to create dedicated training plans according the elderly user's needs and health conditions, transforming ActiveLifestyle into a real assistive technology device for physical home interventions, not only a prototype;

- To increase the customization of the user interface features of ActiveLifestyle according different tastes (e.g., music preferences, motivation instruments), computer skills (e.g., ability to interpret charts, navigation), and impairments (e.g., hearing and vision problems, shaking hands) of our target users. The current version of ActiveLifestyle successfully reaches its initial goal of being very simple to use for non computer experts, and at the same time being interesting and motiving for the expert ones. However, there is still place for improvements;

- To test ActiveLifestyle during a longer period in order to investigate its effectiveness to change physical behavior and prevent falls. Due to time constraints, we decided to initially evaluate gait speed that only requires minimum of 12 weeks physical intervention, instead of going directly for a large longitudinal study without knowing the actual physical benefits supported by ActiveLifestyle; and

- To investigate how elderly users from other countries react to the same motivation instruments, design and training structure supported by ActiveLifestyle, in order to discover whether well-known cultural idiosyncrasies are associated with different attrition rates and training plan compliance levels.

We used to think of old age as the frail line dividing the good times from those inactive last years of our lives, where we would depend on the care of others without contributing much more to society. However, these thoughts are falling behind, elderly individuals are progressively adopting a new way of living, enjoying as much as possible without ever stopping to size opportunities and contributing to society. Being old is no longer seen as ”the end of the road” and there is a new understanding of the process of ageing, with a focus on opportunities and how to fulfill them, which gives a lot of space for innovative ICT solutions, like ActiveLifestyle, aiming at making elderly’s life a little bit better.

# Chapter 2

# The road to ActiveLifestyle

## 2.1. Introduction

This Ph.D. research started by designing and developing solutions to measure, monitor and report on business process compliance (Section 2.2), which gave us the conceptual and technical knowhow to apply compliance governance in other fields e.g., healthcare. Our first endeavour in the healthcare field was a platform (Section 2.3) able to offer medical advice (i.e., physical training plan) to adults aiming at running a half marathon, based on their health condition and lifestyle habits. The platform also motivates and monitors the adults' compliance toward the plan aiming at promoting the adoption and maintenance of healthier lifestyles. Both background experiences were essential to assist the conceptualization, design, and development of ActiveLifestyle as discussed at the end of this section.

Before presenting the background experiences mentioned above, we offer a roadmap (Figure 2) of our scientific and peer-reviewed publications[20] describing the evolution of our work in chronological order from the backgrounds to ActiveLifestyle. All the papers illustrated in the figure are attached in the appendix section of this document.

## 2.2. Background: Compliance Governance

During the initial 30 months of my Ph.D. program, I actively participated in the COMPAS project (Compliance-driven Models, Languages, and Architectures for Services[21]), a 36 months project (from February 2008 to January 2011) composed of 11 partners (8 European research institutions and 3 industrial partners) and sponsored by the 7$^{th}$ Framework Programme of the European Commission. The objective of the COMPAS was to design and implement novel models, languages, and an architectural framework to enable organizations develop business compliance solutions in an easier and faster way.

*Compliance* generally refers to the conformance to a set of laws, regulations, policies, best practices, or service-level agreements. *Compliance governance* refers to the set of procedures, methodologies, and technologies put in place by a corporation to carry out, monitor, and manage compliance.

[20] The work [14] is not yet published, it was submitted to the Journal of Internet Medical Research

[21] COMPAS Project website: www.compas-ict.eu

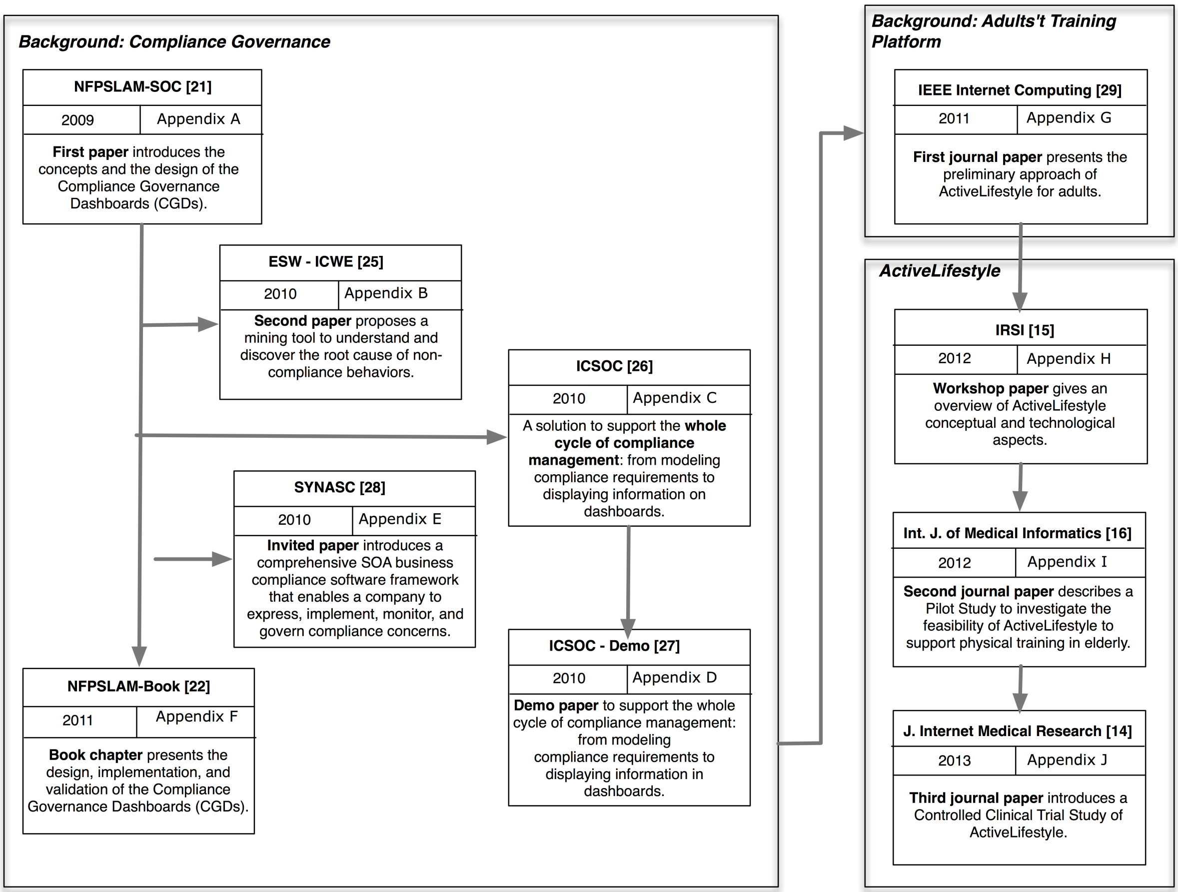



**Figure 2** Peer-reviewed publications[22] describing the evolution of our work in chronological order from the backgrounds to ActiveLifestyle.

Compliance governance is an important, expensive, and complex problem to deal with as we described in [21][22]. To deal with these challenges, COMPAS proposed a complete end-to-end framework that enables a company to express, implement, monitor, and govern compliance concerns, which are all well documented and described in many scientific contributions published along the project[23]. In this executive summary we concentrate on our contributions inside the COMPAS project.

Our work inside the COMPAS project concentrates on reporting on compliance through dashboards, which design and implementation are not trivial [23][24]. Reporting on compliance involves the following challenging tasks:

[22] The work documented in [14] is not yet published. It was submitted to the Journal of Internet Medical Research and is waiting for review.
[23] COMPAS Publications website: www.compas-ict.eu/compasPublications.php

- To identify what information to report on the compliance governance dashboard considering different users and their respective interests and expertise. For instance, CIOs and CFOs typically want to see key performance indicators and have few or no technical skills. Auditors usually have to investigate whether certain compliance concerns are met, which may vary according to the laws and policies that rule the company. In addition, external auditors are not used to the internal technical development details of a company, which might complicate their work of identifying noncompliant and even compliant behaviour. Finally, internal compliance experts try to discover possible non-compliant behaviours aiming at avoiding or, at least, reducing the risk of penalties and loss of reputation;

- To create a solution to report on compliance able to be applied in different business process scenarios controlled by different types of laws and regulations;

- To understand how large amounts of data can be visualized in an effective manner, and how such data can be meaningfully grouped and summarized according to i) different laws and regulations from which compliance concerns are derived, and ii) different phases and levels of business process development and execution;

- To identify the right level of abstraction for the information to be shown and how to structure it into multiple pages, that is, how to interactively and intuitively guide the user through the wealth of information. Each page of the dashboard should be concise and intuitive, yet complete and expressive;

- To find how to collect, process, and store raw business execution data in order to allow further business intelligence analyses, also taking into account possible changes in the business process, and on the compliance requirements;

- To deal with the data integration issues. To report on compliance is necessary to collect data from a variety of heterogeneous sources, which typically contain their own idiosyncrasies, e.g., data format and access requirements; and

- To choose which graphical components to report on compliance and how to dispose them on a web page in order to highlight the most important information to the user.

The following list summarizes our scientific contributions during the COMPAS project to deal with the challenges described above:

- The definition of a *conceptual model* for reporting on compliance using dashboards that covers a broad class of compliance issues and identifies the key abstractions and their relationships. Otherwise the dashboard loses its value of single entry point for compliance assessment. The description and illustration of this conceptual model are documented in [21][22];

- A *user interaction and navigation model* that captures the way the different kinds of users can interact with the dashboard, minimizing the access time spent in getting the information users need and making sure that key problems do not remain unnoticed. References [21][22] contain the conceptual and implementation description of such model, as well as its graphical representation with meaningful examples;

- The definition of *Key Compliance Indicators* (KCIs), which are metric values that can be used to quantify compliance performance in a pre-determined time interval compared to internal targets, in order to give evidence of the level of compliance performance. In addition, to the design of a graphical representation to abstract KCIs using taxonomies and colours able to report on compliance at-a-glance. The initial mock-up of the KCIs is illustrated in [21], their final implementation is documented in [22], and their adoption in two different compliance governance scenarios, in a drug reimbursement process and in telecom services, are respectively presented in [21][22][25] and [26][27][28];

- The design of the compliance governance dashboard i) to support different summarization levels and perspectives of analysis, ii) to enable compliance drill-down units (i.e., move through the different compliance units, from summary information to detailed data) and KCIs rendered according to the users' roles, e.g., violation details (low level) to internal auditors or IT personnel for root-cause analysis, and iii) to main KCIs to external auditors as a start point for the auditing process. The initial mock-ups of the compliance governance dashboards are introduced in [21], their implementation details are documented in [22], and their adoption are described in two different compliance governance scenario, in a drug reimbursement process and in telecom services. Both scenarios are respectively presented in [21][22][25] and

[26][27][28]. More details about the compliance governance dashboards are available online[24]; and

- The design and development of a data warehouse environment to collect business events generated by the execution of business processes and by the compliance monitoring components, to process and store them for further business intelligence analyses reported in the compliance governance dashboards. The following research works [21][22][25] introduce the conceptual and implementation details of the data warehouse environment, while references [26][27][28] show how such environment is embedded inside the COMPAS end-to-end framework.

The working experience in the COMPAS project was a fruitful period in my research career. During the project, we had the opportunity of:

- Understanding the importance of an automated ICT approach to monitor and report on compliance in order to support compliance governance. In addition to the reduction of the side effects associated to manual tasks (i.e., error prone, laborious and time consuming), an automated approach supports near to real time detection of non-compliant behaviours and, consequently, fast reaction time in order to avoid or, at least, reduce the risk of financial loss (i.e., lost of clients, payment of fees). Though, it is important to highlight that the reliability of an automated ICT approach like COMPAS to monitor and to report on compliance directly depends on the correct interpretations of the compliance regulations by the business analysts, and their ability and deep knowledge to model business processed and annotate them properly in order to allow the detection of non-compliant behaviours, as well as to transform high level and complex compliance rules into a programming language (i.e., designed to communicate instructions to a machine, particularly a computer); and

- Participating in the design and development of a research solution that may be adopted, with minor adaptations, in a real business process execution scenario to support compliance governance. The event driven, service oriented, and open source characteristics of the runtime monitoring and reporting components of COMPAS make the

[24] CGDs website: compas.disi.unitn.it/CGD/home.html

whole approach portable and easily replicable in different and heterogeneous compliance governance scenarios.

However, despite the vigorous conceptualization and prototyping of significant scientific contributions in the field of compliance governance, the COMPAS approach presented as limitation the lack of a final testing and evaluation phase in an auditing and industrial scenario with real users. Such test would be useful to estimate the amount of work required to reuse the approach, to improve and/or detected possible problems, and to give continuity to the work.

## 2.3. Background: a platform to support and motivate adults' compliance to a training plan

In a past collaboration effort, the Ospedale San Raffaele di Milano[25] and UNITN together with the Italian Cycling Federation developed a GPS-based monitoring application for cyclists called *Pinkr*[26], which is able to track live the position of individual cyclists, to compute their instant power output and overall energy consumption, to share those data with others in real-time, and to provide nutrition advices to bikers. From this experience we learned three key lessons: First, sports people – even amateurs – are incredibly competitive, and they like to monitor their performance. Second, training for competitions and sharing of performances with other people (e.g., friends or trainers) and obtaining feedback boosts motivation. Third, they are very open to advices and willing to follow them to improve their performance.

This pushed us to extend *Pinkr* to support a *personal health and lifestyle record* (PHLR), which is an extension of the traditional personal health records (PHRs) containing a set of habits that characterize the individual's lifestyle at a given time (e.g., being a beginning runner or a light smoker.). In addition, our new approach supports a *Personal Health and Lifestyle (PHL)* that monitors and assesses an individual's lifestyle and provides personalized advice on how to improve that lifestyle (or makes it easier for health professionals to provide such advice). The platform currently supports a physical training scenario, in which healthy adults are willing to train for a marathon.

---

[25] Ospedale San Raffaele di Milano website: www.sanraffaele.org

[26] Live broadcast in National television of *Pinkr* at work during the Maratona dles Dolomites, Italy's most important international competition for amateur cyclists: y2u.be/lzL_gcydjMc

Currently a variety of workout tracking self-monitoring solutions is available on the marker. For instance, solutions like NikePlus[27] and RunKeeper[28] to monitor running workouts sessions, or Vivago[29] to assess and monitor body signals. Similarly, a large variety of Personal Health Records (PHRs) to integrate, store, manage, and share personal health information from different sources are also available. Unfortunately, PHR solutions tend to benefit health professionals, such as doctors or therapists, more than the individual who must maintain the record. Both types of solutions are useful for their particular function, though none of these approaches integrates collected data in a wider vision, models or tracks a person's lifestyle, or provides automated, remote health suggestions.

Our research solution abstracts sensor data into life events in order to assess a person's lifestyle habits, and use such habits information to extend the traditional PHRs. Thus, based on the combination of heath and lifestyle data we aim at providing (of facilitating health professionals in proving) dedicated pieces of advice on how to improve one's lifestyles. In addition, we aim to motivate people to improve their lifestyles by making them aware about how they can manage and modify their lifestyles in order to preserve health and wellbeing.

Due to our fruitful experience with *Pinkr*, we investigate the context of physical training (i.e., a half marathon training) in which physical daily events of healthy adults are captured from a training watch instrumented with sensors. Supporting such context means taking over the role of the expert who advises the training plan and aiding runners in tracking their progress, which means solving a set of peculiar research challenges:

- We need to be able to provide (semi-)automated health advice (the training plan), starting from an individual's physical and health conditions. This also means that we need to be able to represent and match different kinds of advice;

- Doing so requires being able to store and maintain a Personal Health and Lifestyle Record (PHLR), which integrates health data, as can be found in traditional PHRs, with lifestyles and habits that may change over time;

[27] NikePlus website: www.nikerunning.nike.com
[28] RunKeeper website: runkeeper.com
[29] Vivago website: www.istsec.fi

- We need to be able to automatically identify lifestyles or habits from low-level events. For instance, identify if a person willing to train for a marathon is a runner beginner based on the workout logs obtained from a person's training watch, but more in general also identify drinking, sleeping, or smoking habits from daily events;

- Therefore, we need to be able to model habits and to express the necessary evaluation logic. Particularly challenging is to come up with a model that can easily be understood and operated also by non-IT people, e.g., a trainer or doctor, in order to facilitate knowledge transfer into the platform; and

- Finally, we need to be able to monitor the compliance, better known as adherence in the healthcare field, with the advice, in order to track progress, and to share this information with others, possibly allowing them to comment on a friend's performance and to provide feedback.

The scientific contributions in terms of concepts, designs, and prototypes to develop the *Personal Health and Lifestyle (PHL)* platform to solve the above challenges can be summarized as follows:

- *Conceptual Model for the PHL platform*: providing lifestyle-driven advice asks for features that go beyond conventional PHRs and, in particular, support multiple user roles, lifestyle data, habits, events, and active advice provisioning. The conceptual model underlies our PHL platform and addresses these issues. The description and graphical representation of the conceptual model is documented in [29];

- *PHL models*: proving medical advice based on lifestyle and health data requires the definition of three formal models, namely PHL models, and their operational semantics to enable the customization of the health monitoring features: *habit models*, *advice trigger models*, and *advice models*. These models express, respectively, how to aggregate daily events into habits (i.e., how to rank the running performance of a person: beginner, intermediate, or advanced runner), how to decide when to give an advice (i.e., how suggest a basic, intermediate, or advance training plan for a half marathon), and how to monitor the compliance to a given advice – all by looking at both the data we have in the PHLR and at the life events tracked for each individual person. All models, as well as their operational semantics are described with meaningful examples of our physical training scenario in [29];

- *Generic PHL platform*: for abstracting data from heterogeneous sources (e.g., on-line forms, training watches, mobile applications) into life events, use such information to assess and monitor a person's lifestyle habits, which are further used respectively to derive pieces of medical advice for this person and to report on the person's compliance to such advice. The complete version of the architecture and its components are introduced in [29]; and

- *PHL platform prototype*: supporting the half marathon training plan scenario, in which healthy adults willing to run a half marathon, inform their physical daily life events collected with a training watch, and inform their health conditions though on-line forms. Based on such information, the prototype provides pieces of health advice (i.e., a half marathon training plan) according to users' lifestyle and health conditions. In order to motivate its users, the prototype offers updated information about the user's physical performance and compliance to the training plan. The PHL prototype in available online[30].

The PHL platform monitors and assesses an individual's lifestyle and provides personalized advice on how to improve that lifestyle (or makes it easier for health professionals to provide such advice). We leverage on the data stored in a typical PHR and equip such with environmental and sensor data that enable us to monitor and analyse an individual's habits and compliance to the medical advice. Sharing habits and advices with doctors and friends allows them and the individual to become wellness co-producers and leads to a PHLR that is indeed useful to the individual maintaining it. The entirely details of the PHL platform are described in [29], which is attached at the end of this document as Appendix G as illustrated in Figure 2.

The development of the PHL was an excellent opportunity to learn:

- The high potential of the PHL platform to support self-monitoring in order to improve awareness of the improvements caused by a better lifestyle, which can be a stronger motivator to improve one's health and quality of life. Most of the on the shelf tracking solutions target a specific activity (e.g., diet, physical activity, or sleeping habits), but lack its correlation with health and wellness aspects. For instance, how does the practice of regu-

[30] Prototype of the PHL platform: compas.disi.unitn.it:8080/PHLEngine/lifestyle.jsp.

lar physical activities interfere in a person's blood pressure or sugar level? Can regular physical exercises improve a person's sleep patterns?;

- The large potential impact of both social interaction and of continuous monitoring as persuasive techniques in lifestyle management and improvement as showed in the *Pinkr* experience in the area of amateur cycling; and

- The large dissemination of sensors and mobile applications to track daily life habits can contribute to the creation of a rich source of data, which through large-scale data collection and mining can support the validation of the PHL models (which in essence derive from medical knowledge in a given health or wellness domain) as well as the discovery of new models from life events and of interesting correlations between lifestyles and non-communicable diseases.

PHL presents as a limitation the lack of further longitudinal studies with real users to better investigate the effectiveness of the PHLRs to motivate not only trainers, but people in general, to adopt a healthier lifestyle and how this can prevent the development of diseases.

Interestingly, reporting on whether a person adheres to a pre-defined medical advice is very similar to reporting on whether the execution of business processes is compliant with a set of laws, regulations, policies, best practices, or service-level agreements. However, instead of monitoring business events, it is necessary to monitor daily life events to check whether a person properly follows a medical advice recommended by healthcare experts to stay healthy and prevent diseases. And, in addition and even more important, in the healthcare scenario it is essential to find ways to motivate people to follow the medical advice, differently from the business scenario where the motivation is to prevent loss and reputation damage. Motivating people is far from easy and involves many subjective psychological and social aspects.

The PHL platform is our first endeavour to use ICT solutions to monitor and motivate people to adopted healthier lifestyles (i.e., train for a half marathon). The conceptual and prototype work developed behind such platform was important to give us the knowhow in creating, storing and modelling physical training plans, as well as in collecting raw data of training workout sessions to be further analysed in order to create meaning information to be used for reporting on a person's compliance to the half marathon training plan. Hence, both background experiences contributed to and manifested in ActiveLifestyle.

# Bibliography

[1] WW Spirduso and DL Cronin. Exercise dose-response effects on quality of life and independent living in older adults. *Medicine and Science in Sports and Exercise* 2001;33(6):598-608.

[2] RJ Johnson and FD Wolinsky. The structure of health status among older adults: disease, disability, functional limitation, and perceived health. *Journal of Health & Social Behavior* 1993;34(2):105-121.

[3] PT Katzmarzyk and I Janssen. The economic costs associated with physical inactivity and obesity in Canada: an update. *Canadian Journal of Applied Physiology* 2004;29(1):90-115.

[4] DN Proctor, MA Fiatarone Singh, CT Minson, CR Nigg, GJ Salem, and JS Skinner. American College of Sports Medicine position stand. Exercise and physical activity for older adults. *Medicine and Science in Sports and Exercise* 2009;41(7):1510-1530.

[5] M Stuart, S Chard, F Benvenuti, and S Steinwachs. Community exercise: a vital component to healthy aging. *Healthcare Papers* 2009;10(1):23-28.

[6] C Sherrington, JC Whitney, SR Lord, RD Herbert, RG Cumming, and JC Close. Effective exercise for the prevention of falls: a systematic review and meta-analysis. *Journal of the American Geriatrics Society* 2008;56(12):2234-2243.

[7] A Moschny, P Platen, R Klaaßen-Mielke, U Trampisch, and T Hinrichs. Barriers to physical activity in older adults in Germany: a cross-sectional study. *International Journal of Behavioral Nutrition and Physical Activity* 2011;8:121. Doi:10.1186/1479-5868-8-121.

[8] E Brox and J Hernandez. Exergames for elderly: Social exergames to persuade seniors to increase physical activity. In *Proceeding of the 5th International Conference on the Pervasive Computing Technologies for Healthcare* (PervasiveHealth), 2011, Dublin, Irland.

[9] Y Chen. Perceived barriers to physical activity among older adults residing in long-term care institutions. *Journal Clinical Nursing* 2010;19(3-4):432-9.

[10] ME Cress, D Buchner, T Prohaska, J Rimmer, M Brown, C Macera, L Dipietro, and W Chodzko-Zajko. Best practices for physical activity programs and behavior counseling in older adults populations. *Journal of Aging and Physical Activity* 2005;13(1):61-74.

[11] Anonymous. Physical Activity and Older Americans: Benefits and Strategies. Agency for Healthcare Research and Quality and the Centers for Disease Control. 2002. http://www.ahrq.gov/ppip/activity.htm.

[12] WC Mann, KJ Ottenbacher, L Fraas, M Tomita, and CV Granger. Effectiveness of assistive technology and environmental interventions in maintaining independence and reducing home care costs for the frail elderly. A randomized controlled trial. *Archives of Family Medicine* 1999;8(3):210-217.

[13] K Laver, J Ratcliffe, S George, L Brugess, and M Crotty. Is the Nintendo Wii Fit really acceptable to older people?: a discrete choice experiment. *BMC Geriatrics* 2011;11:64. DOI:10.1186/1471-2318-11-64.

[14] P Silveira, R van de Langenberg, E van het Reve, F Daniel, F Casati, and ED de Bruin. Tablet-based strength-balance training motivates and improves adherence to exercise in independently living elderly: a controlled clinical trial. *Journal of Medical Internet Research* (submitted).

[15] P Silveira, F Daniel, F Casati, E van het Reve, and ED de Bruin. ActiveLifestyle: an application to help elderly stay physically and socially active. *International Reports on Socio-Informatics - Designing for Inter/Generational Communities* 2012;9(1):39-44.

[16] P Silveira, E van het Reve, F Daniel, F Casati, and ED de Bruin. Motivating and Assisting Physical Exercise in Independently Living Older Adults: A Pilot Study. *International Journal of Medical Informatics* 2012, Dec 26. DOI:pii: S1386-5056(12)00239-0. 10.1016/j.ijmedinf.2012.11.015. (in print).

[17] JO Prochaska, S Butterworth, CA Redding, V Burden, N Perrin, M Leo M Flaherty-Robb, and JM Prochaska. Initial efficacy of MI, TTM tailoring and HRI's with multiple behaviors for employee health promotion. *Preventive Medicine* 2008;46(3):226–31.

[18] S Studenski, S Perera, K Patel, C Rosano, K Faulkner, M Inzitari, J Brach, J Chandler, P Cawthon, EB Connor, M Nevitt, M Visser, S Kritchevsky, S Badinelli, T Harris, AB Newman, J Cauley, L Ferrucci, and J Guralnik. Gait speed and survival in older adults. *Journal of the American Medical Association* 2011;305(1):50-8.

[19] AM Kueider, JM Parisi, AL Gross, and GW Rebok. Computerized cognitive training with older adults: a systematic review. *PLoS ONE* 2012; 7(7):e40588.

[20] L Thabane, J Ma, R Chu, J Cheng, A Ismaila, L Rios, R Robson, M Thabane, L Giangregorio, and CH Goldsmith. A tutorial on pilot studies: the what, why and how. *BMC Medical Research Methodology* 2010;10(1):1-10.

[21] P Silveira, C Rodríguez, F Casati, F Daniel, V D'Andrea, C Worledge, and Z Taheri. On the Design of Compliance Governance Dashboards for Effective Compliance and Audit Management. In *Proceedings of the Non Functional Properties and Service Level Agreements Management in Service Oriented Computing Workshop* (NFPSLAM-SOC2009), Stockholm, Sweden, 2009.

[22] P Silveira, C Rodríguez, F Casati, F Daniel, V D'Andrea, C Worledge, and Z Taheri. Aiding Compliance Governance in Service-Based Business Processes. *In Non-Functional Properties for Service-Oriented Systems: Future Directions* (NFPSLA-BOOK-2011), 2010.

[23] S. Few. Information Dashboard Design: The Effective Visual Communication of Data. *O'Reilly Media*, Inc., p. 223, 2006.

[24] A Read, A Tarrel, and A Fruhling. Exploring User Preference for the Dashboard Menu Design. *In Proceedings of the 42nd Hawaii International Conference on System Sciences*, pp.1-10, 2009.

[25] C Rodríguez, P Silveira, F Daniel, and F Casati. Analyzing Compliance of Service-Based Business Processes for Root-Cause Analysis and Prediction. In *Proceedings of the 1st Workshop on Engineering SOA and the Web* (ESW'10) in conjunction with ICWE'10, Springer, 2010.

[26] A Birukou, V D'Andrea, F Leymann, J Serafinski, P Silveira, S Strauch, and M Tluczek. An Integrated Solution for Runtime Compliance Governance in SOA. In *Proceedings of the 8th International Conference on Service-Oriented Computing* (ICSOC10), USA, 2010.

[27] A Birukou, A Betkowska Cavalcante, F Casati, SR Chowdhury, V D'Andrea, F Leymann, E Oberortner, J Serafinski, P Silveira, S Strauch, and M Tluczek. An Integrated Solution for Runtime Compliance Governance in SOA. Demo Paper. In *Proceedings of the 8th International Conference on Service-Oriented Computing* (ICSOC10), USA, 2010.

[28] H Tran, T Holmes, E Oberortner, E Mulo, A Betkowska Cavalcante, J Serafinski, M Tluczek, A Birukou, F Daniel, P Silveira, U Zdun, and S Dustdar. An End-to-End Frame-

work for Business Compliance in Process-Driven SOAs. *In Proceedings of SYNASC* 2010, September 2010, IEEE Press.

[29] F Daniel, F Casati, P Silveira, M Nalin, and M Verga. Beyond Health Tracking: A Personal Health and Lifestyle Platform. *IEEE Web Technology and Architecture for Personal Health Records* 2011;5(4):10-13, DOI: 10.1109/MIC.2011.99.

# Appendix A

## On the Design of Compliance Governance Dashboards for Effective Compliance and Audit Management[1]

Patrícia Silveira, Carlos Rodríguez, Fabio Casati, Florian Daniel,
Vincenzo D'Andrea, Claire Worledge, Zouhair Taheri

**Abstract.** Assessing whether a company's business practices conform to laws and regulations and follow standards, i.e., compliance governance, is a complex and costly task. Few software tools aiding compliance governance exist; however, they typically do not address the needs of who is in charge of assessing and controlling compliance, that is, compliance experts and auditors. We advocate the use of compliance governance dashboards, whose design and implementation is however challenging for these reasons: (i) it is fundamental to identify the right level of abstraction for the information to be shown; (ii) it is not trivial to visualize distinct analysis perspectives; and (iii) it is difficult to manage the large amount of involved concepts, instruments, and data. This paper shows how to address these issues, which concepts and models underlie the problem, and, how IT can effectively support compliance analysis in SOAs.

### 1 Introduction

*Compliance* is a term generally used to refer to the conformance to a set of laws, regulations, policies, or best practices. *Compliance governance* refers to the set of procedures, methodologies, and technologies put in place by a corporation to carry out, monitor, and manage compliance.

Compliance governance is an important, expensive, and complex problem to deal with: It is important because there is increasing regulatory pressure on companies to meet a variety of policies and laws (e.g., Basel II, SOX). This increase has been to a large extent fuelled by high-profile bankruptcy cases (Parmalat, WorldCom, the recent crisis) or safety mishaps (the April 2009 earthquake in Italy has already led to stricter rules and procedures for construction companies). Failing to meet these regulations means safety risks, hefty penalties, loss of reputation, or even bankruptcy [9].

[1] The original publication is available at www.springerlink.com, more specifically at dl.acm.org/citation.cfm?id=1926642

Managing and auditing/certifying compliance is a very *expensive* endeavour. A report by AMR Research [5] estimates that companies will spend US$32B only on governance, compliance, and risk in 2008 and more than US$33B in 2009. Audits are themselves expensive and invasive activities, costly not only in terms of auditors' salaries but also in terms of internal costs for preparing for and assisting the audit – not to mention the cost of non-compliance in terms of penalties and reputation.

Finally, the problem is *complex* because each corporation has to face a large set of compliance requirements in the various business segments, from how internal IT is managed to how personnel is trained, how product safety is ensured, or how (and how promptly) information is provided to shareholders. As a result, compliance governance requires understanding/interpreting requirements and implementing and managing a large number of control actions on a variety of procedures across the business units of a company. Each compliance regulation and procedure may require its own control mechanism and its own set of indicators to assess the compliance status of the procedure [1]. Today, compliance is to a large extent managed by the various business units in rather ad-hoc ways (each unit, line of business, or even each business process has its own methodology, policy, controls, and technology for managing compliance). Hence, it is very hard for any CFO or CIO to answer questions such as [16]: *Which rules does my company have to comply with? Which processes are following regulations? Where do violations occur? Which processes do we have under control?* Even more, it is hard to do so from a perspective that not only satisfies the company but also the company's auditors, since they are the ones that certify compliance.

This paper presents a conceptual model for compliance and for *compliance governance dashboards* (CGD), along with a dashboard architecture and a prototype implementation. The aim of our CGD is to report on compliance, to create an awareness of possible problems/ violations, and to facilitate the identification of root-causes for non-compliant situations. The dashboard is targeted at several classes of users: chief officers of a company, line of business managers, internal auditors, and external auditors (certification agencies). Typically, the two latter focus on a narrow set of processes and historical data to verify non-compliant situations and how they have been dealt with. Via the CGD, they also have access to *key compliance indicators* (KCIs). Managers are interested in a much broader set of compliance regulations and at quasi-real time compliance information that allows them to detect problems (unsatisfactory KCIs) as they happen and identify the causes (drill-down to the root of the problem), so that they can take decisions before they become (significant) violations. They have access and navigate through the entire set of regulations, business processes, and business units and also observe the overall compliance status (through KCIs).

Technically, building a dashboard that shows a bunch of indicators and allows drill-downs is easy. Indeed, the main challenges are *conceptual* more than technological [15] and constitute the contributions of this paper as follows:

1. Provide a *conceptual model for compliance and for compliance dashboards* that covers a broad class of compliance issues. It is important to identify the key abstractions and their relationships; otherwise the dashboard loses its value of single entry point for compliance assessment.

2. Combine the above *broadness with simplicity and effectiveness*. The challenge here is to derive a model that, despite being broad, remains simple and useful. If the abstractions are not carefully crafted and kept to a minimum, the dashboard will be too complex and remain unused. As we have experienced, this problem may seem easy but is instead rather complex, up to the point that discussions on the conceptual model in the projects took well over a year. There is no clarity in this area, and this is demonstrated by the fact that while everybody talks about compliance, there are no generic but simple compliance models available.

3. Define a *user interaction and navigation model* that captures the way the different kinds of users need to interact with the dashboard, to minimize the time to accesses spent in getting the information users need and to make sure that key problems do not remain unnoticed.

4. Derive a model aligned with the *criteria and approach that auditors* have to verify compliance. In this paper, this latter is achieved "by design", in that the model is derived via a joint effort of two of the major auditing companies and reflects the desired method of understanding of and navigation among compliance concerns.

## 2 The Problem of Compliance Management

Despite the increasing awareness of compliance issues in companies and the recognition that part of the compliance auditing task can be automated, i.e., assisted by software tools [9][12][13], there is still a lot of confusion around. This is especially true for the IT community, which would actually be in charge of aiding compliance governance with dedicated software. To help thinking in terms of auditing, in the following we aim to abstract a wide class of compliance problems into a few key concepts that are also the ones understood by auditors. The resulting model (see Fig. 1) does not cover all possible compliance problems, but our goal is to strike a balance between coverage and simplicity. So far, we didn't find any such model in literature.

At the top-left corner: The *Regulation* entity generalizes all documents that provide guidelines for the good conduct of business in a given domain. Examples of regulations are legislations (e.g., MiFID, The Electronic Commerce Directive), laws (e.g., SOX, HIPAA), standards (e.g., CoBIT, ISO-9001), and SLAs. Typically, a regulation defines a set of rules in natural language, which constrain or guide the way business is conducted. *Complying* with a regulation means satisfying its rules. The selection of the pertaining ones represents the *requirements* for compliance management, usually expressed in terms of control objectives and activities. A regulation expresses multiple requirements, and a requirement might relate to one or more regulations.
Assessing compliance demands for an interpretation and translation of the requirements provided in natural language in an actionable rule description (especially in the case of principle-based regulations) [7][8]. This is modelled by the *Rule* entity, which represents actionable rules expressed either in natural language (using the company's terminology and telling exactly how to perform work) or, as desirable in a formalism that facilitates its automated processing (e.g., Boolean expressions over events generated during business execution). Rules are then grouped into *policies*, which are the company-internal documents that operatively describe how the company intends achieving compliance with the selected requirements. Typically, policies group requirements into topics, e.g., security policies, QoS policies, and similar.

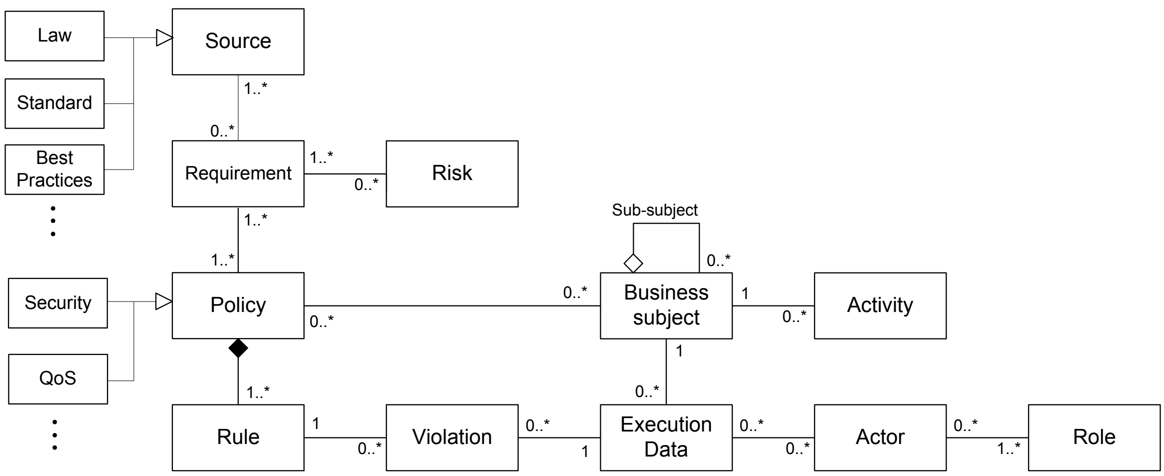



**Figure. 1** Conceptual model of the compliance management problem.

At a strategic level, compliance is related to the concept of risk. Non-compliant situations expose a company to risks that might be mitigated (e.g., a non-encrypted message that is sent through the network might violate a security compliance rule, which might put at risk sensitive information). Risk mitigation is the actual driver for internal compliance auditing. The *Risk* entity represents the risks a company wants to monitor; risks are associated with compliance requirements. For the evaluation of whether business execution is compliant, we must know which rules must be evaluated in which business context. We therefore assume that we can associate policies with specific *business processes*. Processes are composed of *activities*, which represent the atomic work items in a process.

The actual evaluation of compliance rules is not performed on business processes (that is, on their models) but on their concrete executions (their instances). Executing a business process means performing activities, invoking services, and produced business data (captured by the *Execution data* entity). In addition, e.g., separation of duties, it is necessary to track the *actors* and *roles* of execution of activities. When evaluation of a rule for a process/activity instance is negative, it corresponds to *violations*, which are the core for assessing compliance level and computing KCIs.

The model in Figure 1 puts into context the most important concepts auditors are interested in when auditing a company. Indeed, the typical auditing process looks at the company and decides which regulations are pertaining, how it implements its business processes, how it checks for violations, and so on. In short, the auditing process is embedded in a so-called compliance management life cycle [18].

## 3 Designing Compliance Governance Dashboards (CGD)

To aid the internal evaluation and to help a company pass external audits, a concise and intuitive visualization of its compliance state is paramount. To report on compliance, we advocate the use of a web-based CGD, whose good design is not trivial [4][14]. It is important to understand how: i) the information auditors expect to find look like; ii) large amounts of data can be visualized in an effective manner, and how data can be meaningfully grouped and summarized; and iii) to structure the available information into multiple pages, that is, how to intuitively guide the user through the wealth of information. Each page of the dashboard should be concise and intuitive, yet complete and expressive. It is important that users are immediately able to identify the key information in a page, but that there are also facilities to drill-down to details.

Designing a CGD requires mastering some new concepts in addition to those discussed above. Then, the new concepts must be equipped with a well-thought navigation structure to effectively convey the necessary information. Here, we do not focus on how data are stored and how rules are evaluated; several proposals and approaches have been conceived so far for that (see Section 4), and we build on top of them.

### 3.1 A Conceptual Model for CGD

In Figure 2 we extend the conceptual model (Figure 1) to capture the necessary constructs for the development of a CGD (bold lines represent new entities and their respective interrelations). The extensions aim at (i) providing different *analysis perspectives,* (ii) *summarizing* data at different levels of abstraction, and (iii) enabling drill-down/roll-up features (from aggregated data to detailed data, and vice versa).

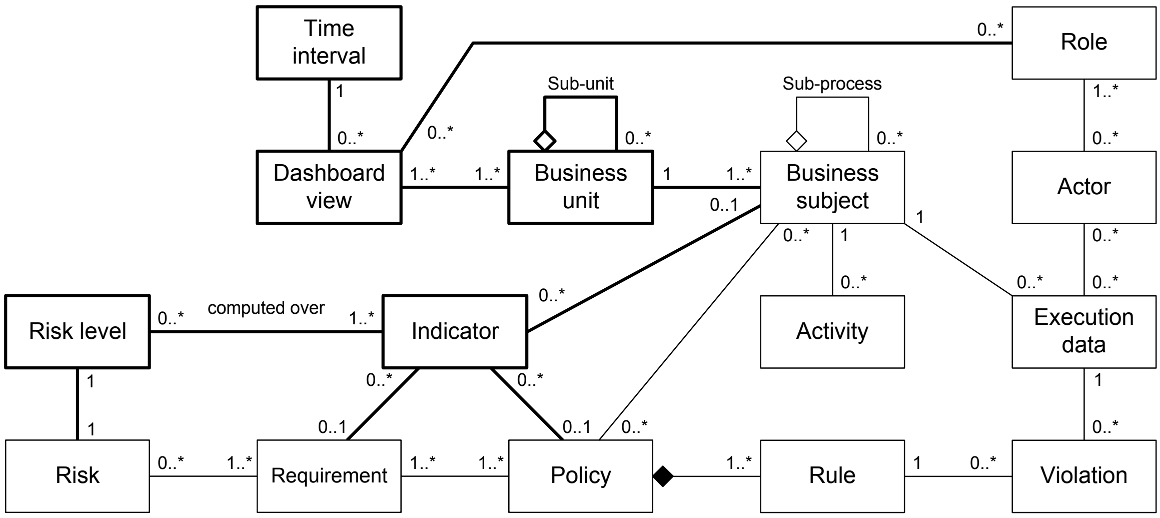



**Figure. 2** Conceptual model for CGD (dashboard-specific constructs are in bold).

The *Dashboard view* entity represents individual views over the compliance status of the company. A view is characterized by the user role that accesses it, e.g., IT specialists, compliance experts, or managers. Each of these roles has different needs and rights. For instance, managers are more interested in aggregated data, risk levels, and long time horizons (to take decisions); IT personnel are interested in instance-level data and short time spans (to fix violations). A view is further characterized by the *time interval* considered for showing data (e.g., day or year), also providing for the historical analysis (e.g., last year) and supporting different reporting purposes (operative, tactical, strategic). Finally, a view might be restricted to some of the company's *business units*, based on the role of the user. In summary, views support distinct summarization levels of the available data, ranging over multiple granularity levels.

Effective summarization of data is one of the most challenging aspects in the design of a CGD instrumented with indicators [11]. An *indicator* is a quantitative summarization of a particular aspect of interest in the business, i.e., a metric of how well an objective is being reached. Typically, KPIs (key performance indicators), are used to summarize the level at which business objectives are reached. In our context, we speak about KCIs, referring to the achievement of the stated compliance objectives (e.g., the number of unauthorized accesses to our payroll data).

In general, indicators are computed out of a variety of data and functions; in the context of compliance assessment, however, indicators can typically be related to the ratio of encountered violations vs. compliant instances of a process or activity. As an abstraction of indicator values, we can define taxonomies (e.g., low, medium, high) and use colours (e.g., red, yellow, green) for their intuitive visualization.

### 3.2 Navigation Design

After discussing the *static* aspects of the design of CGD, we now focus on the *dynamic* aspect, i.e., on how to structure the interaction of users with the dashboard, and on how users can explore the data underlying the dashboard application. Specifically, on top of the conceptual model for CGD we now describe how complex data can be organized into hypertext pages and which navigation paths are important.

For this purpose, we adopt the Web Modeling Language (WebML [2]), a conceptual modelling notation and methodology for the development of data-intensive web applications. We use the language for the purpose of illustration only (we show a simplified, not executable WebML schema) and intuitively introduce all the necessary constructs along with the description of the actual CGD navigation structure.

The WebML hypertext schema (Figure 3) describes the organization of our ideal CGD. It consists of five *pages* (the boxes with the name labels in the upper left corner), Compliance Home being the home page. Each page contains a number of *content units*, which represent the publication of contents from the data schema in Figure 2 (the *selector* condition below the units indicates the source data entity). Usually, there are many *hyperlinks* (the arrows) in a hypertext schema, representing the navigations a user might perform, but, for simplicity, we limit our explanation to only those links that represent the main navigation flow. Links carry *parameters*, which represent the selection done by the user when activating a link (e.g., the selection of a process from a list). For the purpose of reporting on compliance, we define a new content unit (not part of WebML), the *compliance drill-down* unit, which allows us to show compliance data in a table-like structure (see the screenshots in Figure 4).

Let's examine the CGD's structure (Figure 3): The home page of the CGD provides insight into the compliance state of the company at a glance. It shows the set of most important indicators (Main indicators *multidata* unit) and a set of indicators grouped by policy (IndByPolicy *hierarchical index* unit). Then, we show the (BUnits/Regul.) unit that allows the user to drill-down from business units to processes and from regulations to policies. A click on one of: i) the processes lead the user to the Regulations by Activity page; ii) regulations leads her to the Rules by BusinessUnits page; and iii) the cell of the table leads her to the Rules by Activity page. After the selection of a process, in the Regulations by Activity page the user can inspect the compliance state of each activity of the selected process with the given regulations and policies (Reg ByActivity), a set of related indicators (BPIndicators unit; the unit consumes the Process parameter), and the details of the selected process (Process *data* unit). Similar details are shown for policies in the Rules by BusinessUnits page, which allows the user to inspect the satisfaction of individual compliance rules at business unit or process level (RulesByBU).

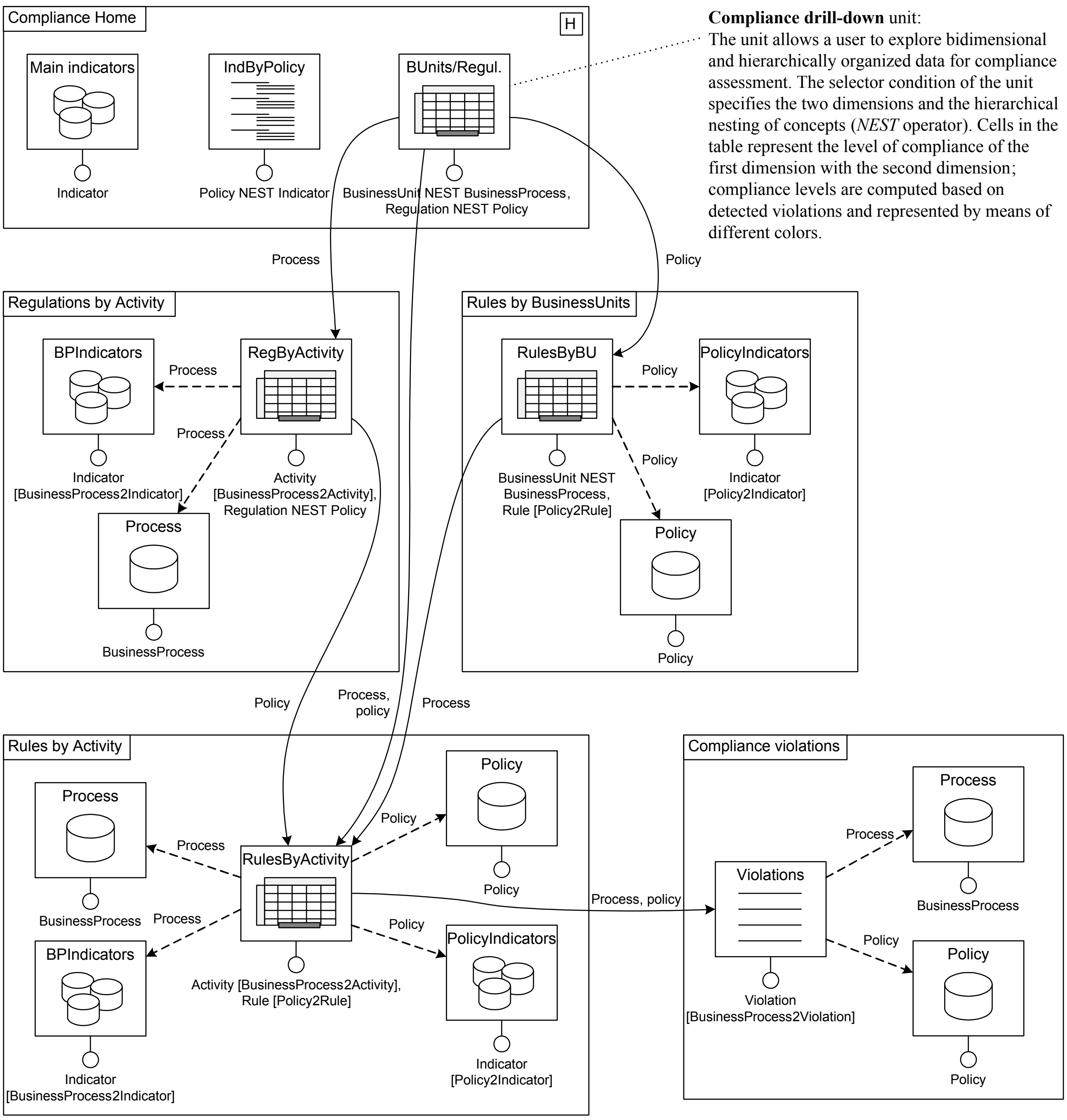



**Figure. 3** WebML hypertext schema structuring the navigation of CGD concepts and data.

A further selection in the compliance drill-down units in these last two pages or the selection of a cell in the BUnits/Regul. unit in the home page leads the user to the Rules by Activity page, which provides the user with the lowest level of aggregated information. It visualizes the satisfaction of the compliance rules of the chosen policy by the individual activities of the chosen process (RulesByActivity), along with the details of the chosen policy and process and their respective indicators. A further selection in this page leads the user to the Compliance violations page, which shows the details of the violations related to the chosen process/policy combination at an instance level in the Violations *index* unit.

The navigation structure in Figure 3 shows one of the possible views over the data in Figure 2, e.g., the one of the internal compliance expert. Other views can easily be added by restraining access to data and defining alternative navigation structures. Each page provides a distinct summarization level from high-level information to low-level details. The time interval for the visualization can be chosen in each of the pages.

### 3.3 CGD in Practice

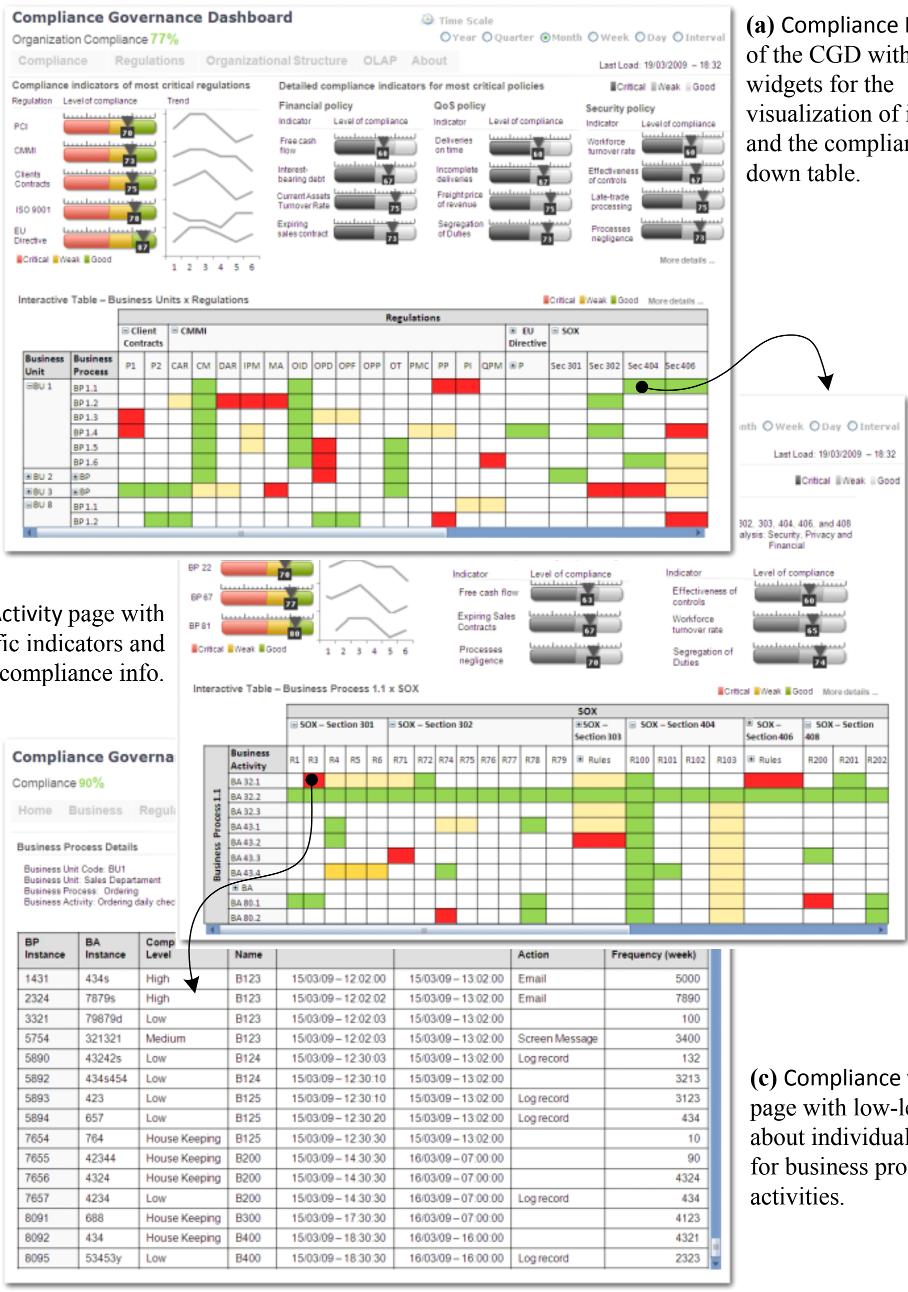
In Figure 4 we illustrate some screenshots from our prototype CGD, in order to illustrate its look and feel. The screenshots show views that consistently present our ideal CGD. Figure 4(a) shows the Compliance Home page, Figure 4(b) the Rules by Activity page, and Figure 4(c) the Compliance violations page.

Compliance Home concentrates on the most important information at a glance, condensed into just one page. The five coloured indicators (top left) are the most relevant, showing the most critical non-compliant regulations. The grey indicators (right) report on the compliance with the three main policies. In the bottom, there is the interactive compliance drill-down table containing the compliance performance of business units and processes (rows) in relation to regulations and policies (columns).

The user can easily reach lower levels of granularity by drilling down on the table. For instance, the Rules by Activity page condenses lower level information concerning a combination of Business Process 1.1 and the company's SOX policy. The colours of the cells represent the compliance performance of each combination (e.g., the Business activity 32.1 presents a critical situation regarding Rule 3 of SOX - Section 301 (red cell) and weak performance regarding Rule 5, and Rule 6 (yellow cells)).

A drill-down on the red cell, for instance, leads us to the Compliance violations page, which provides the lowest level of abstraction in form of a table of event violations of the selected rule. The page illustrates the main information that must be reported to assist internal and external auditors. The data in the particular page reports all violations of one activity in Business Process 1.1 of Business Unit 1, detected considering Rule 3 of SOX - Section 301. Each row of the table represents a distinct violation and the columns contain the typical information required by auditors, e.g., responsible of activity, timestamps, mitigation action, cause of violation.

The amount and position of the graphical widgets for indicators, tables, summaries, and so on are chosen in accordance with our short-term memory and the convention of most western languages that are read from left to right and from top to bottom [4].




**(a)** Compliance Home page of the CGD with graphical widgets for the visualization of indicators and the compliance drill-down table.

**(b)** Rules by Activity page with process-specific indicators and activity-level compliance info.

**(c)** Compliance violations page with low-level details about individual violations for business processes and activities.

**Figure. 4** Example CGD screenshots of our prototype implementation.

## 4 Relate Work

To the best of our knowledge, there are only few works that deal with the problem we address in this paper. For example, [1] studies the problem of designing visualizations (i.e., the representation of data through visual languages) for risk and compliance management. Such study focuses on capturing the information required by users and on providing visual metaphors for satisfying those requirements. In [3], the performance reporting is provided in a model-driven fashion. The framework provides four models: data, navigation, report template, and access control, which jointly help designing a business performance dashboard.

Business Activity Monitoring (BAM) has gained attention in the last decade, and many tools support it. BAM aims at providing aggregated information suitable for performing analysis on data obtained from the execution of business activities. For example, tools such as Oracle BAM, Nimbus and IBM Tivoli aim at providing its users with real-time visual information and alerts based on business events in a SOA. The information provided to users comes in the form of dashboards for reporting on KPIs and SLA violations. The compliance management part of these tools (if any) comes in the form of monitoring of SLA violations, which need the SLA formal specifications as one of its inputs. In our work, we take a more general view on compliance (beyond SLAs, which are a special case to us) and cover the whole lifecycle of compliance governance, including a suitable CGD for reporting purposes.

## 5 Conclusions

In this paper we discussed a relevant aspect in modern business software systems, i.e., compliance governance. Increasingly, industry and academia are investing money and efforts into the development of compliance governance solutions. Yet, we believe CGD in particular, probably the most effective means for visualizing and reporting on compliance, have mostly been neglected so far. It is important to implement sophisticated solutions to check compliance, but it is at least as important (if not even more) to effectively convey the results of the compliance checks to a variety of different actors, ranging from IT specialists to senior managers.

Our contribution is a conceptualization of the issues involved in the design of CGD in service- and process-centric systems, the definition of a navigation structure that supports drill-down/roll-up features at adequate levels of detail and complexity, and a set of examples that demonstrate the concepts at work. Our aim was to devise a solution with in mind the real needs of auditors and – more importantly – with the help of people who are indeed involved every day in the auditing.

**References**

1. R. Bellamy, T. Erickson, B. Fuller, W. Kellogg, R. Rosenbaum, J. Thomas, T. Vetting Wolf. Seeing is believing: Designing visualizations for managing risk and compliance. IBM Systems Journal, 46(2), pp. 205-218, 2007.
2. S. Ceri, P. Fraternali, A. Bongio, M. Brambilla, S. Comai, M. Matera. Designing Data-Intensive Web Applications. Morgan Kaufmann Publishers Inc., USA, 2002.
3. P. Chowdhary, T. Palpanas, F. Pinel, S.K. Chen, F.Y. Wu. Model-driven Dashboards for Business Performance Reporting. Proceedings of the 10th IEEE EDOC, pp. 374-386, 2006.
4. S. Few. Information Dashboard Design: The Effective Visual Communication of Data. O'Reilly Media, Inc., p. 223, 2006.
5. J. Hagerty, J. Hackbush, D. Gaughan, S. Jacobson. The Governance, Risk Management, and Compliance Spending Report, 2008-2009: Inside the $32B GRC Market. AMR Research, 2008.
6. S. Saqid, G. Governatori, K. Naimiri. Modeling Control Objectives for Business ProcessCompliance. Business Process Management, pp.149-164, 2007.
7. C. Giblin, S. Müller, B. Pfitzmann. From Regulatory Policies to Event Monitoring Rules: Towards Model-Driven Compliance Automation. IBM Research Report, Oct., 2006.
8. K. Namiri, N. Stojanovic. A Semantic-based Approach for Compliance Management of Internal Controls in Business Processes. CAISE'07, pp. 61-64, 2007.
9. H. Trent. Products for Managing Governance, Risk, and Compliance: Market Fluff or Relevant Stuff? In-Depth Research Report, Burton Group, 2008.
10. J. Lam. Operational Risk Management – Beyond Compliance to Value Creation. White Paper, Open Pages, 2007.
11. L. Imrey. CIO Dashboards: Flying by Instrumentation. Journal of Information Technology Management, 19(4), pp. 31-35, 2006.
12. G. Evans, S. Benton. The BT Risk Cockpit – a visual approach to ORM. BT Technology Journal, 25(1), 2007.
13. M.P. Papazoglou. Compliance Requirements for Business-process-driven SOAs. E-Gov. Ict Professionalism and Competences Service Science, July, V. 280/2008. pp. 183-194, 2008.
14. A. Read, A. Tarrel, A. Fruhling. Exploring User Preference for the Dashboard Menu Design. In Proceedings of the 42nd Hawaii Intern. Conf. on System Sciences, pp. 1-10, 2009.
15. E. Allman. Complying with Compliance. ACM Queue, 4(7), pp. 18-21, September, 2006.
16. J. Cannon, M. Byers. Compliance deconstructed. ACM Queue, 4(7), pp. 30-37, September, 2006.
17. E. Oberortner, U. Zdun, and S. Dustdar: Tailoring a Model-Driven Quality-of-Service DSL for Various Stakeholders. Workshop on Modeling in Software Engineering (MiSE), 2009.
18. F. Daniel, F. Casati, V. D'Andrea, S. Strauch, D. Schumm, F. Leymann, E. Mulo, U. Zdun, S. Dustdar, S. Sebahi, F. de Marchi, M. Hacid: Business Compliance Governance in Service-Oriented Architectures. Proceedings of AINA'09, IEEE Press, May 2009.

# Appendix B

## Analyzing Compliance of Service-Based Business Processes for Root-Cause Analysis and Prediction[1]

Carlos Rodríguez, Patrícia Silveira, Florian Daniel, Fabio Casati

**Abstract.** Automatically monitoring and enforcing compliance of service-based business processes with laws, regulations, standards, contracts, or policies is a hot issue in both industry and research. Little attention has however been paid to the problem of *understanding* non-compliance and *improving* business practices to prevent non-compliance in the future, a task that typically still requires human interpretation and intervention. Building upon work on automated detection of non-compliant situations, in this paper we propose a technique for the root-cause analysis of encountered problems and for the prediction of likely compliance states of running processes that leverages (i) on event-based service infrastructures, in order to collect execution evidence, and (ii) on the concept of key compliance indicator, in order to focus the analysis on the right data. We validate our ideas and algorithms on real data from an internal process of a hospital.

### 1 Introduction

*Compliance* means conformance with laws, regulations, standards, contracts, policies, or similar sources of requirements on how to run business. Effective *compliance management,* i.e., the practice of assuring compliance, is an increasingly more important concern in today's companies, since the set of compliance requirements a company has to implement grows fast and their effect on the "traditional" business practices in a company may be considerable. Despite its increasing importance, compliance is however to a large extent still managed in rather ad-hoc ways and with little or no IT support. As a result, today it is very hard for any CFO or CIO to answer questions like: Which requirements does my company have to comply with? Which processes should obey which requirements? Which processes are following a given regulation? Where do violations occur? Which processes do we have under control? And so on.

While IT has been supporting (in more or less automated fashions) the execution of business processes for long time now, in the past the adoption of ad-hoc and monolithic software solu-

[1] The original publication is available at www.springerlink.com, more specifically at link.springer.com/chapter/10.1007%2F978-3-642-16985-4_25

tions did not provide the necessary insight into how processes were executed and into their runtime state, preventing the adoption of IT also for compliance assessment. The advent of workflow management systems and, especially today, of web service-based business interactions and the service-oriented architecture (SOA) have changed this shortcoming, turning business processes into well-structured, modular, and distributed software artefacts that provide insight into their internals, e.g., in terms of execution events for tasks, service calls, exchanged SOAP messages, control flow decisions, or data flows. All these pieces of information can be used for online monitoring or enforcement of compliant process behaviours or they can be logged for later assessment. Unfortunately, however, the resulting amount of data may be huge (in large companies, hundreds of events may be generated per minute!), and – especially in terms of reporting and analysis – it is not trivial to understand which data to focus on and how to get useful information out of them.

Doing so is challenging and requires answering questions like how to collect and store evidence for compliance assessment in service-based business processes, how to report on the compliance state, and how to support the analysis of non-compliant situations. But more than these, the challenges this paper aims to solve are how to collect evidence in a way that is as less intrusive as possible, how to devise solutions that are as useful as possible, yet – at the same time – as generic as possible and independent of the particular IT system to be analyzed, and, finally, how to provide compliance experts with information that is as *useful and expressive as possible*. In light of these challenges, this paper provides the following contributions:

- A method for the definition and a dashboard for the visualization of so-called Key Compliance Indicators (KCIs) for at-a-glance reporting on compliance;
- An algorithm and a tool for the mining of decision trees from process execution logs that particularly look at data from the perspective of compliance;
- An application of the algorithm mining approach to real-world data stemming from a typical business process running in a large Italian hospital.

In the next section we provide the necessary details about this process and highlight its compliance requirements, so as to derive the requirements for this paper in Section 3. In Section 4 and 5, we then discuss how to report on compliance and how to analyze non-compliance, respectively. In Section 6 we discuss some related works, and in Section 7 we conclude the paper.

## 2 Scenario: Drug Reimbursement in Hospitals

Let us consider the case of a drug reimbursement process in the healthcare domain. The process is the case study in one of our EU projects, where we cooperate with Hospital San Raffaele (Milan, Italy), which runs the process shown in Figure 1. The overall purpose of this process, from the hospital's point of view, is to obtain reimbursements from the Italian Health Authority for the drugs dispensed to outpatients (i.e., patients that are not hospitalized). In order to obtain the reimbursement, there are many compliance requirements imposed by the Health Authority, among which we mention privacy preservation in personal information processing, separation of duties, and the adherence of standard template of dispensation reports.

The core process that generates the information that needs to be sent to the Health Authority occurs inside the Ward. The process starts when a patient visits the hospital's ward to consult a doctor. After diagnosing the patient, the doctor prepares a drug prescription that is delivered to a nurse, who is in charge of dispensing the prescribed drugs to the patient. If the amount of drugs is going below a certain threshold, the nurse issues a drug request to the central pharmacy of the hospital, which must replenish the ward's drug stock in no later than 48 hours. The execution of this process is fully supported by the ward's SOA-based information system, and all progress events generated during process executions are recorded in an event log for later inspection.

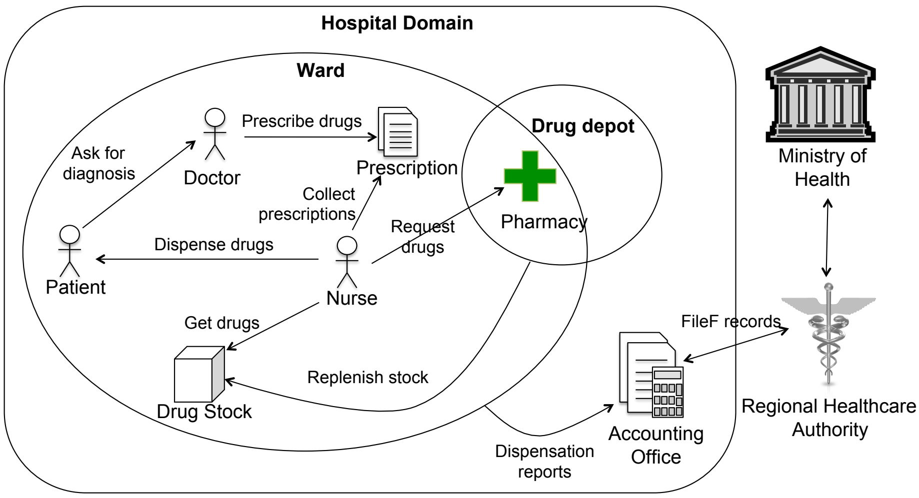



**Figure. 1** Summary of the direct drug reimbursement process.

While the process above is executed daily, the preparation of dispensation reports for drug reimbursement is a monthly task. That is, at the end of each month, the records of drug dispensations are collected from the various wards of the hospital and the corresponding dispensation reports to be sent to the Health Authority are created. These reports consist in simple text files (known as *FileF*) in which data about the dispensations are included. Examples of data included in these files are *hospital identification*, *patient, doctor, dispensed drug and quantity,* and *amount in Euros.* Whenever the report is ready it is sent to the Health Authority, which checks the quality of the report against some compliance requirements imposed on dispensation reports.

For instance, one compliance requirement that decides whether a dispensation can be reimbursed or not regards the completeness and correctness of records: no *null* or incorrect data are tolerated in any field. If there are such problems in the report, the Health Authority sends a feedback to the hospital indicating the number and type of errors found for each record of the file, and, in turn, the hospital must correct them so as to get the reimbursement.

The complete reimbursement process is complex, and not complying with the applicable requirements can be costly. Therefore, in order to better control the compliance of the reimbursement process, the hospital wants to implement an early warning system that allows the hospital's compliance expert to have updated information on daily compliance issues, e.g., in form of indicators, reports, or predictions on the compliance of its processes. In addition, in case of repeated problems, it is important to understand why they happen and how they can be solved for the future. However, manually analyzing the data in the event log is time consuming and also error-prone but, still, the hospital wants to improve its compliance in order not to lose money for not reimbursed drug dispensations.

## 3 Service-Oriented Compliance Management: Requirements

The above scenario describes a service-based business process that is distributed over the hospital's ward and the drug depot and that asks for proper compliance management, that is, compliance assessment, reporting, and analysis.

As this paper has its roots in two EU FP7 research projects, i.e., Compas and Master, that both assist **compliance assessment** in the SOA, here we do not propose a new assessment technique and rather rely on the techniques proposed there: Compas (www.compas-ict.eu) strongly focuses on model-driven development of compliant processes and proposes a compliance checking approach that is based on (i) compliance requirements expressed in logical rules or process fragments and (ii) complex event processing (CEP) and business protocol monitoring to detect non-compliance with requirements. *Master* (www.master-fp7.eu), instead, specifically focuses on the security domain and proposes a two-layered approach to compliance assessment: first, it supports the CEP-based monitoring of running processes and the enforcement of individual rules; then, offline, it checks compliance of executed processes by assessing their conformance to a so-called ideal process model. Both approaches have in common the use of an instrumented service orchestration engine for the execution of business processes and the generation/logging of suitable execution events, starting from a signaling policy that specifies which events are necessary for compliance assessment.

Building on this background, **reporting on the state of compliance** requires being able to *store process execution and compliance data* and to develop a *reporting dashboard* on top, a task that we partly approached in [1]. But we also need to devise a method for the *easy specification* and, then, automated computation of *key compliance indicators* (KCIs), in order to visualize them in the dashboard. Next, the **analysis of root-causes for non-compliance** requires selecting a suitable *analysis algorithm* and – more importantly – understanding *which data* to look at, out of the huge amount of data that is available for this task, and to validate the algorithm in the context of the described scenario.

## 4 Reporting on Compliance

In order report on the compliance of business processes, the common approach is to visualize the compliance status at a high-level of abstraction, for instance, by means of KCIs that are graphically rendered in a compliance governance dashboard (CGD) [1]. KCIs support compliance experts with an overview of the compliance performance of business processes and can be seen as particular type of KPIs (key performance indicators) that specifically measures how compliant a process is with given requirements. A typical KCI may, for example, measure how many process instances, out of all the executed ones, satisfy a separation of duties requirement; but also a traditional QoS indicator (e.g., the average process execution time) can be seen as KCI, if we are subject to a compliance requirement regarding QoS (e.g., deriving from a contract with the customer). As we will see, KCIs also provide a starting point for finding the root-causes of non-compliance. This section explains how we store process execution data, specify and compute KCIs, and visualize them through effective visual metaphors

### 4.1 Storing Process Execution and Compliance Data

The main sources of process execution and compliance data are the *event logs* generated by the execution of service-based business processes. Therefore, let us first conceptualize the key ingredients characterizing event logs, as we perceive them for our analysis. An *event* is a tuple $e = \langle t, s, ts, d, p_1, \ldots, p_n, B \rangle$, where $t$ is the type of the event (e.g., *ProcessStart*, *ActivityExecuted*, *Violation*), $s$ is the source that generates the event, $ts$ is a timestamp, $p_1, \ldots, p_n$ is a set of properties (e.g., event message header properties such as correlation data, process instance identifier or similar), and $B$ is the body of the event message (e.g., containing business data needed for the computation of an indicator). Using this data, events can be grouped together by their process instance and ordered by timestamp, forming this way traces. A *trace* is a sequence of events $T_i = \langle e_{i1}, e_{i2}, \ldots, e_{in} \rangle$, where $i$ refers to a process instance identifier and $n$ is the number of events that compose the process instance. This way, an *event log* can be expressed as a set of traces $L = \{T_1, T_2, \ldots, T_k\}$, where $k$ is the total number of traces.

The events in the log are processed by Extract-Transform-Load (ETL) flows, in order to store them into a data warehouse (DW), which is modeled using a compliance-oriented dimensional data model. The reason for doing this is that we aim at leveraging the capability of dimensional models for keeping a conciliated view on the process execution and compliance data, and for supporting further analysis, e.g., by means of root-cause analysis algorithms or Online Analytical Processing (OLAP) tools. Figure 2 shows an excerpt of the schema of the DW. The tables in white are the *dimensional tables* that allow us to slice and dice through the *fact tables* (shaded in gray). The fact table F_Event stores the events as they come from the event log, F_KCI stores the computed values of indicators, F_BPInstance, the instances of processes, and F_ComplianceEval, the compliance status of process instances as computed, for instance, by the compliance checking algorithms adopted in the context of the Compas or Master projects.

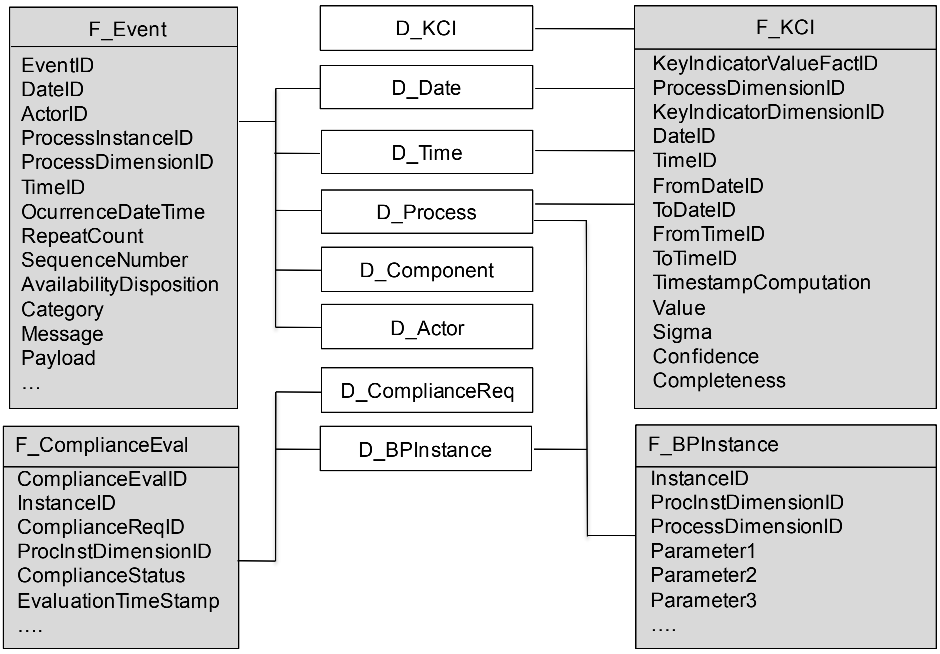



**Figure. 2** Simplified schema of the data warehouse model.

The F_BPInstance table deserves a further explanation, as it constitutes an *abstraction* of the process execution data, and the basis for computing indicators and performing root-cause analysis. In our DW model, each business process *BP* has its own F_BPInstance table, or, as we call it, *process instance table* (e.g., in our scenario we have a F_DrugDispensationInstance table). In these tables, each row corresponds to an instance of the associated process, while columns (i.e., parameters of the process instance table) correspond to business data that are of interest for the analysis of each process. Table 1 shows a conceptual view on the process instance table for the drug dispensation process, where each row corresponds to a single drug dispensation. The *DrugType* column refers to the type of drug, *ErrPerData* indicates whether there was an error in the information about the patient, *ErrCompData* tells us if there was an error in any other complementary data, and *Compliant* tells us whether the dispensation was free of error. These parameters are obtained from the attributes of the events that are part of the event trace. Sometimes, the parameter values can be directly extracted from events without modifications (e.g., the *DrugType* parameter), while in other cases the values are obtained by performing aggregation/computations over a set of events and attributes of process instances (e.g., the *Compliant* parameter).

**Table 1:** Example of a process instance table for the drug dispensation process.

| InstanceID | DrugType | ErrPerData | ErrCompData | … | Compliant |
|---|---|---|---|---|---|
| 38769 | 1 | False | False | … | True |
| 32537 | 6 | True | False | … | False |
| 27657 | 1 | False | False | … | True |
| 32547 | 2 | False | True | … | False |
| 35340 | 1 | False | False | … | True |
| …. | …. | …. | …. | … | …. |

Finally, it is worth to mention that in order to populate the DW, the ETL usually needs to access other sources of data such as user management systems and human task managers, which are the main data providers for dimension tables, as opposed to event logs, which provide mostly the evidences of process executions.

### 4.2 Specifying and Computing Key Compliance Indicators

Generally, indicators are computed out of a variety of data and by means of different functions, ranging from the lowest business data granularity to the highest business goals. In the context of compliance assessment, a KCI is a measure (i.e., a numeric value) that quantifies compliance performance against compliance targets in a pre-determined time interval. For instance, one of the compliance requirements imposed by the Healthcare Authority is that of sending drug dispensation reports without errors in the data about dispensed drugs and patients. Whenever there is an erroneous record of drug dispensation, the corresponding drug is not reimbursed to the hospital, and, thus, it is important for the hospital to keep an eye on the accomplishment of this compliance requirement. KCIs are therefore useful means to assist this task.

KCIs can be easily specified by using the available information in Table 1. For example, a KCI may be defined as the percentage of non-compliant process instances out of all instances in the DW (and the reporting time interval). More precisely, we can use the *Compliant* column of a process instance table to compute KCIs, and we can express their respective formulas using standard SQL queries. SQL has been designed also as a language for computing aggregates and is well known, understood, and supported, so there was no reason to come up with another language. Yet, the ease with which we are able to express KCIs stems from the abstraction we made on the process execution data by using the so called process instance tables.

## 4.3 Compliance Governance Dashboard

Finally, KCIs are rendered to the compliance experts by means of a CGD, such as the one depicted in Figure 3 [1]. The CGD features are a graphical representation of KCIs and serves as start point for further root-cause analysis. More specifically, the CGD creates an awareness of possible violations and concentrates the most important information to be evaluated at-a-glance. The interactive table (at the front in Figure 3) provides a drill-down and roll-up mechanism for the compliance status, for example, for the different drug dispensation locations controlled by the hospital (i.e., clinics, laboratories, dispensaries), according to two main analysis perspectives (compliance performance vs. process performance), down to the individual event level (e.g., the list of incomplete records associated to a drug (background of Figure 3).

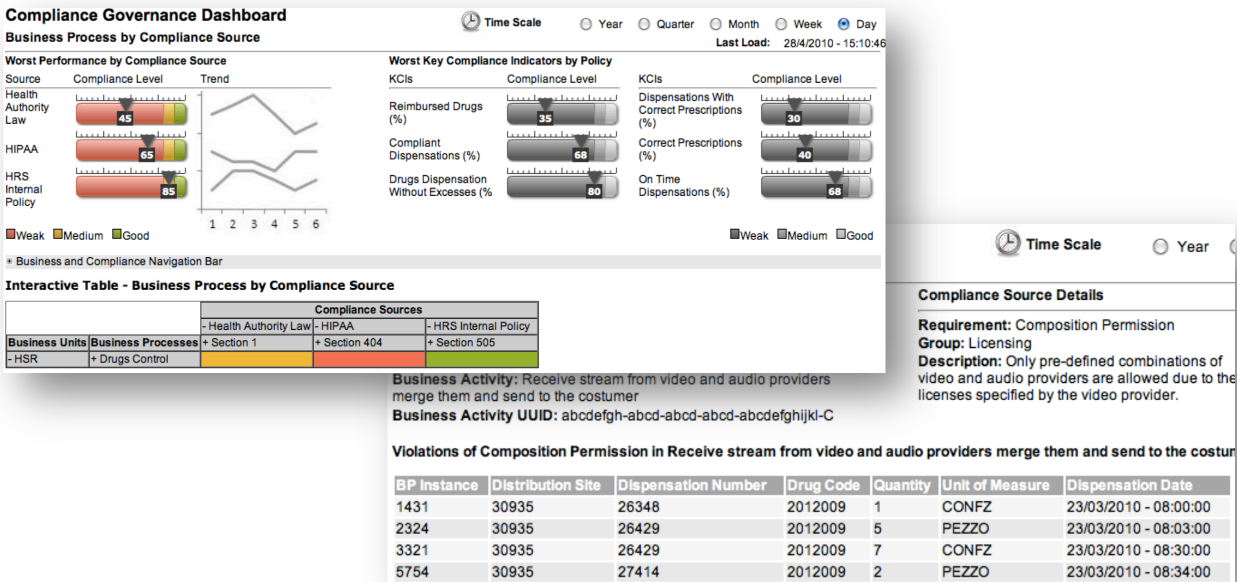



**Figure. 3** CGD with KCIs and the interactive table for drill-down and roll-up [1].

## 5 Analyzing Non-Compliance

While *checking* the compliance of business process instances means determining whether the process instances are compliant or not at the individual event trace level, *analyzing* non-compliance of business process executions, i.e., understanding and explaining the underlying reasons of non-compliance, needs to be performed over a set of traces in order to be able to derive meaningful knowledge that can be used to improve processes for future executions.

Incidentally, labeling event traces as compliant or non-compliant, which is the main goal of compliance checking, is very similar to *classifying* data tuples, a data mining practice that is well-studied in literature [20]. There are several algorithms that can help in performing this analysis, among which we choose decision trees, as they are good for knowledge discovery where neither complex settings nor assumptions are required [20], and they are easy to interpret and analyze. In this section, we discuss how we address the issue of compliance analysis through decision trees, going from data preparation to the actual building and interpretation of the decision tree.

### 5.1 Preparing the Analysis

In Section 4.1, we introduced our DW model, which constitutes the basis for our CGD and the root-cause analysis. Preparing the analysis therefore means selecting which data, out of the huge amount of events stored in the DW, are suitable for identifying root-causes for non-compliance. In the same section, we also introduced the idea of having process instance tables, one per process, in which we store those process parameters that are used for computing indicators. Recall that each tuple in a process instance table represents a particular instantiation of the process under consideration and that each instance comes with its compliance label. Now, considering that we are interested in analyzing non-compliance problems for process instances, it is interesting to note that the process instance tables initially conceived for the computation of indicators also contain the data we are searching for. In fact, by defining a set of indicators for each process (and the events and data attributes that are necessary to compute them), the compliance expert implicitly performs a pre-selection of the data that are most likely to be related with compliance issues. The availability of the compliance label for each instance indicates that the best choice for the root-cause analysis is to use the process instance tables to feed the decision tree-mining algorithm, as their data naturally fits the typical input format of these kinds of algorithms.

For instance, considering again the process instance table shown in Table 1, one way of building the training tuples for the decision tree is to use the *Compliant* column as the *class attribute* (leaf nodes) for the decision tree, while *ErrPerData* and *ErrCompData* can be used as the attributes on which the algorithm defines the split points (for internal nodes). This way, the training tuples can be represented as

<*ErrPerData, ErrCompData,* ***Compliant***>

The set of training tuples can be easily obtained through trivial SQL queries, and the retrieved result set can be used directly to feed the decision tree algorithm. Note that, as in the case of the specification and computation of the KCIs, the task of building the training tuples is great-ly facilitated by the abstraction provided by the process instance tables.

### 5.2 Understanding Key Factors

The algorithm we use in our prototype implementation for building decision trees extends the C4.5 algorithm to handle uncertain data [21]. In this paper we do not discuss the uncertainty aspect in mining data. However, our prototypes are equipped to handle uncertainty in the event logs we use for analyzing business process executions (for details on how uncertainty in event logs can be handled, see [6]). Instead, here we focus more on the aspect of discovering and understanding the key factors that affect the compliance of business executions.

As in any decision tree, the internal nodes contain the criteria used for classifying tuples. The leaf nodes, instead, contain the classes to which tuples are classified. For instance, if we choose the *Compliant* column of Table 1 as the class attribute, we will obtain a decision tree where the leaf nodes contain the *compliance outcomes* for the paths drawn from the root of the tree. However, nothing prevents us from choosing any other parameter of the process instance table as the class attribute when searching for the root-causes of non-compliant process executions.

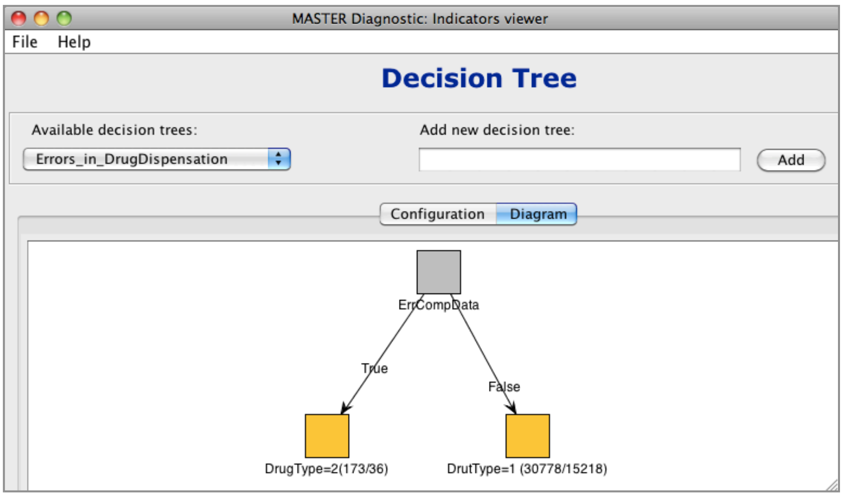



**Figure. 4** Decision tree computed over non-compliant instances of the drug dispensation process.

For instance, as part of the validation of this approach, we performed experiments on a dataset of more than 30000 drug dispensations performed between January and April of 2009 in the hospital described in the scenario (Section 2). To this end, a process instance table with around 25 relevant parameters was build for the drug dispensation process, among which the parameters shown in Table 1 were included. Since the dependence of the *Compliance* column on the *ErrPerData* and *ErrCompData* columns was fairly obvious (but still, proven with our tools), we narrowed our analysis by considering only those process instances that were not compliant. After exploring some combinations of parameters, we found out that there was a relation between the *ErrCompData* and *DrugType* parameters. More precisely, we found that 393 drugs dispensations out of around 30000 had some error, among which 173 had errors of the type *ErrCompData* and 220 errors of the type *ErrPerData*. While the decision tree was not able to tell us anything that was really significant about errors of the type *ErrPerData*, it was able to find something useful for the errors of the type *ErrCompData*, as shown in Figure 4. More precisely, the decision tree discovered that 137 out of 173 (79%) erroneous process instances corresponded to drugs of the type 2 (DrugType=2), which are drugs for ambulatory usage, while the rest (21%) corresponded to drugs of the type 6, 9 and 11.

Since the *ErrCompData* refers to error in the dispensation data (such as the drug code, quantity and unitary price), this may be an indication that, for example, this type of drugs is dispensed at ease, and thus, a better monitoring or compliance enforcement need to be carried out on the controls related to this compliance requirement.

### 5.3 Predicting Compliance States

While decision trees are generally perceived as simple classifiers, we however use them rather for discovering and understanding better the root-causes of undesirable behaviors. Furthermore, we advocate the use of decision trees also for predicting the potential outcomes of process instances that are still running. In fact, each decision point in a tree corresponds to an event (or better to an attribute of an event). So, if during process execution an event that corresponds to a decision point is generated, this allows performing predictions on the likely outcome (in terms of compliance) of the process instance: it suffices to inspect the path in the tree determined by the registered event to identify the instances' likely compliance label.

Thus, in the case of predictions of non-compliant behaviors, enforcement actions can be enacted in order to align process executions, whenever possible, to the corresponding compliance requirements. This is particularly useful in cases when the process has several tasks and long running times that span, e.g., over several hours. Also, the prediction is particularly useful in the case compliance is enforced manually, because it allows the compliance expert to better focus his effort on those process instances that are likely to be non-compliant, leaving out compliance ones.

## 6 Related Work

The major part of compliance management approaches focuses on the *business process modeling* aspect at design time [7-9]. Typically, they are based on formal languages to express compliance requirements (e.g., Business Property Specification Language, Linear Temporal Logic) and simulations to prevent errors at runtime (e.g., finite state machine, Petri nets). In this context, just few approaches address *compliance monitoring at runtime*. For instance, Trinh et. al. [10] monitor time constraints during the execution of process activities, using UML Timing Diagrams to specify constraints and Aspect Oriented Programming to control executions. Chung et. al. [11] check if the user-defined process is compliant to pre-defined ontology and a specific model, in which compliance requirements are described. An IBM research group [12] advocates the use of the REALM (Regulations Expressed As Logical Models) metamodel to define temporal compliance rules and the Active Correlation Technology to check them. That way, it can detect duplicate events or compute a user-definable function, which checks whether a function exceeds some threshold.

Concurrently, commercial *Business Activity Monitoring* (BAM) solutions have been developed to support compliance management (e.g., IBM Tivoli, HP Business Availability Center, Nimbus, Oracle Business Activity Monitoring). Although, such tools still do not have the capability to process and interpret *generic events* (e.g., user-defined business or compliance-related events). They only support the definition of thresholds for parameters or SLAs to be monitored. Also, the ability to *compare* monitored business process executions or, more in general, business patterns with expected execution behaviors is not supported.

Regarding reporting on compliance and KCIs, few works address this aspect and they do it partially. For example, [18] studies the representation of data through visual languages for risk and compliance management. In [19], the authors purpose a model-driven fashion approach to report on business performance and design dashboards.

To the best of our knowledge, no *mining approaches* have been specifically proposed to understand the root-cause of the compliance violations. However, few related approaches for the mining of business processes are in place [3-5][14-16]. Similar to our solution, they adopted log files and a consolidated warehouse containing business and process historical data, from where data subsets are extracted and used as input to mining algorithms in order to predict or understand the origin of undesired business process execution behaviors.

Finally, we can conclude that Compas and Master have been done significant contributions in all the fields mentioned in this section, since they provide solutions to manage, monitor and report on compliance based on generic events. For instance, [2][13] provide approaches to the management of the compliance monitoring at runtime, [17] states how to compute uncertain key indicators from uncertain data, [1] presents CGD to report on compliance and this paper presents root-cause analysis based on data mining techniques to understand non-compliant business processes.

## 7 Conclusions

In this paper, we leverage on automated compliance checking techniques and complement them with a tactical perspective that targets compliance experts, which are accountable for assuring and improving compliance. We assist them by automating the analysis of the huge amount of data that is produced during process execution and specifically provide (i) a reporting dashboard with KCIs and KPIs to assess the state of compliance, (ii) a root-cause analysis technique to understand non-compliance. Our experiments with real data from a major Italian hospital show that the developed dashboard is effective in highlighting encountered problems and that the proposed abstractions and selection of data indeed allow us to identify also unexpected causes for non-compliant situations out of a large amounts of data.

It is important to note that, although in this paper we focused on the case of compliance, the ideas and solutions we propose are of general nature and can, for instance, easily be applied to the computation and analysis of KPIs. Similarly, we are not limited to process engine event as only source of information; events may also stem from web services, human task managers, or similar – if suitably instrumented.

**Acknowledgements:** This work was supported by funds from the European Commission (contract N° 216917 / MASTER and contract N° 215175 / COMPAS).

## References

1. Silveira, P., Rodríguez, C., Casati, F., Daniel, F., D'Andrea, V., Worledge, C., Taheri, C.: On the Design of Compliance Governance Dashboards for Effective Compliance and Audit Management. In: NFPSLAM-SOC'09, Springer, Stockholm, Sweden (2009)
2. Daniel, F., D'Andrea, V., Strauch, S., Schumm, D., Leymann, F., Mulo, E., Zdun, U., Dustdar, S., Sebahi, S., de Marchi, F., Hacid, M.: Business Compliance Governance in Service-Oriented Architectures. In: AINA'09, IEEE Press (2009)
3. Rozinat, A., van der Aalst, W.M.P.: Decision Mining in Business Processes. BETA Working Paper Series, WP 164, Eindhoven University of Technology, Eindhoven (2006)
4. Grigori, D., Casati, F., Castellanos, M., Dayal, U., Sayal, M., Shan, M. Business Process Intelligence. Computers in Industry Journal, vol. 53/3, pp. 321-343 (2004)
5. Seol, H., Choi, J., Park, G., Park, Y.: A framework for benchmarking service process using data envelopment analysis and decision tree. ESA, vol. 32, pp. 432-440 (2007)
6. Rodríguez, C., Daniel, F., Casati, F., Cappiello, C.: Toward Uncertain Business Intelligence: the Case of Key Indicators. IEEE Internet Computing, vol. 14, no. 4 (2010)
7. Liu, Y., Mueller, S., Xu, K.: A Static Compliance Checking Framework for Business Process Models. IBM Systems Journal, vol. 46, no. 2, pp. 335-361 (2007)

8. Lu, R., Sadiq, S., Governatori, G.: Compliance Aware Business Process Design. In: BPM'05, pp. 120-131 (2007)
9. Awad, A., Weske, M.: Visualization of Compliance Violation in Business Process Models. In: BPI'09, LNCS, vol. 43, pp. 182-193 (2009)
10. Trinh, T., Do, T., Truong, N., Nguyen, V.: Checking the Compliance of Timing Constraints in Software Applications. In: KSE'09, pp. 220-225 (2009)
11. Chung, P., Cheung, L., Machin, C.: Compliance Flow - Managing the compliance of dynamic and complex processes. Knowledge-Based Systems, vol. 21 no. 4, pp. 332-354 (2008)
12. Giblin, C., Müller, S., Pfitzmann, B.: From Regulatory Policies to Event Monitoring Rules: Towards Model-Driven Compliance Automation. IBM Research Report RZ 3662 (2006)
13. Mulo, E., Zdun, U., Dustdar, S.: Monitoring Web Service Event Trails for Business Compliance. In: SOCA'09, IEEE Computer Society Press (2009)
14. Grigori, D., Casati, F., Dayal, U., Shan, M.: Improving business process quality through exception understanding, prediction, and prevention. In: VLDB'01, pp. 159-168 (2001)
15. Apte, C., Bibelnieks, E., Natarajan, R., Pednault, E., Tipu, F., Campbell, D., Nelson, B.: Segmentation-Based Modeling for Advanced Targeted Marketing. In: Knowledge Discovery in Databases and Data Mining. ACM, pp. 408-413 (2001)
16. Bibelnieks, E., Campbell, D.: Mail Stream Streamlining, Catalog Age, vol. 17, no. 12, pp. 118--120 (2000)
17. Rodríquez, C., Daniel, F., Casati, F., Cappiello, C.: Computing Uncertain Key Indicators From Uncertain Data. In: ICIQ'09 (2009)
18. Bellamy, R., Erickson, T., Fuller, B., Kellogg, W., Rosenbaum, R., Thomas, J., Wolf. T.: Seeing is believing: Designing visualizations for managing risk and compliance. IBM Systems Journal, vol. 46, no. 2, pp. 205-218 (2007)
19. Chowdhary, P., Palpanas, T., Pinel, F., Chen, S., Wu, F.: Model-driven Dashboards for Business Performance Reporting. In: EDOC'06, pp. 374-386 (2006)
20. Han, J., Kamber, M.: Data Mining: Concepts and Techniques. Morgan Kaufmann (2006)
21. Tsang, S., Kao, B., Yip, K., Ho, W., Lee, S.: Decision Trees for Uncertain Data. In: ICDE'09. IEEE pp. 441-444 (2009)

# Appendix C

## An integrated solution for runtime compliance governance in SOA[1]

Aliaksandr Birukou, Vincenzo D'Andrea, Frank Leymann, Jacek Serafinski, Patricia Silveira, Steve Strauch, and Marek Tluczek

**Abstract**: In response to recent financial scandals (e.g. those involving Enron, Fortis, Parmalat), new regulations for protecting the society from financial and operational risks of the companies have been introduced. Therefore, companies are required to assure compliance of their operations with those new regulations as well as those already in place. Regulations are only one example of compliance sources modern organizations deal with every day. Other sources of compliance include licenses of business partners and other contracts, internal policies, and international standards. The diversity of compliance sources introduces the problem of compliance governance in an organization. In this paper, we propose an integrated solution for runtime compliance governance in Service-Oriented Architectures (SOAs). We show how the proposed solution supports the whole cycle of compliance management: from modeling compliance requirements in domain-specific languages through monitoring them during process execution to displaying information about the current state of compliance in dashboards. We focus on the runtime part of the proposed solution and describe it in detail. We apply the developed framework in a real case study coming from EU FP7 project COMPAS and this case study is used through the paper to illustrate our solution.

### 1 Introduction

During the last decade several companies, such as Enron in US, Fortis and Parmalat in Europe, unexpectedly collapsed. In response to those events, new regulations for protecting society from financial and operational risks of companies have been introduced. The goal of those regulations is to avoid similar bankruptcies in the future, and companies must comply with them. Compliance becomes more and more important in modern organizations [12]. In this paper, we use the term \compliance" in the sense of the conformance of a company in fulfilling compliance requirements, i.e. constraints or assertions that are the results of the interpretation of the compliance sources. Modern organizations deal with three main types of compliance sources: legisla-

[1] The original publication is available at www.springerlink.com, more specifically at link.springer.com/chapter/10.1007%2F978-3-642-17358-5_9

ture and regulatory bodies (e.g., Sarbanes-Oxley Act, Basel II, Solvency II), standards and codes of practice (e.g., ISO9000, ISO/IEC 27002, internal regulations), and business partner contracts (e.g., licenses of service providers).

The diversity of compliance sources introduces the problem of compliance governance in an organization. Compliance governance refers to the overall management approach for controlling the state of compliance in the entire organization and, in general, consists of: (1) selecting the sources to be compliant with and designing corresponding compliance requirements; (2) (re-)designing business processes compliant with the selected requirements; (3) monitoring compliance of processes during their execution; (4) informing interested parties (managers, auditors) on the current state of compliance; (5) taking specific actions or changing the processes in cases of (predicted or happened) non-compliance.

There are solutions for automating one or several steps of the compliance governance, i.e. deriving requirements from sources (Global Information Rules Database[2]), modeling and automating design time compliance checks [10], monitoring [17] and informing interested parties [20]. However, the existing approaches rarely deal with different types of compliance sources and cover only a few steps of the compliance governance.

There are several research challenges arising when speaking about an integrated solution for compliance governance: (i) Is it possible to create a system dealing with the whole process of compliance management, from selecting compliance sources to dealing with cases of non-compliance? (ii) Is the service-oriented technology mature enough to be used as the basis for such a solution? (iii) Can we reuse the knowledge about achieving compliance within the company, or, even, across companies?

With the research challenges above in mind, we propose an integrated solution for runtime compliance governance in SOA. The framework is based on the service-oriented technology and includes tools for: modeling compliance requirements for different compliance sources; linking the requirements to the business processes; monitoring process execution using Complex Event Processing (CEP); displaying the current state of compliance in a Compliance Governance Dashboard (CGD) and analyzing cases of non-compliance in order to find what causes such situations. In the description of framework we focus on the runtime aspects, such as process execution and monitoring, but the design-time aspects (modeling processes and requirements) are also briefly described. For a number of issues (besides technical issues there are also organizational issues, legal responsibility, acceptance of an active role of the technology in the work practices), in this paper, we do not address the issue of taking specific actions for achieving compliance (al-

[2] http://www.grcroundtable.org/grc-grid.htm

so known as enforcement) and process re-design. This topic deserves dedicated research. Therefore, our framework covers selection and modeling compliance requirements and business processes, monitoring the compliance at runtime and informing interesting parties on the state of compliance. The framework and the prototypes of the licensing Domain-Specific Language (DSL) for expressing compliance requirements, the business process engine, CEP-based monitoring tool, the warehouse, the dashboard, etc. have been applied in a real case study in the context of the EU FP7 project COMPAS[3] (Compliance-driven Models, Languages, and Architectures for Services). The case study focuses on checking compliance of telecom service provider to licenses of its business patterns.

This paper is continuation of our work on the compliance governance. Previously, we introduced: compliance governance lifecycle and conceptual model [9], which we adapt in the presented framework; a model-aware repository and service environment (MORSE) [25], a licensing DSL [3], an approach for developing compliance governance dashboards [20], and algorithms for root-cause analysis [7], which are used within the proposed framework. This paper connects the proposed pieces within an integral runtime compliance governance framework and shows how the whole framework is applied in the case study scenario.

The paper has the following structure: in Section 2 we review existing approaches for compliance governance in SOA. Section 3 introduces the scenario we use through the paper to illustrate our solution. Section 4 presents the compliance governance lifecycle in an organization, while Section 5 presents our solution for runtime compliance governance, according to the considered lifecycle. We conclude the paper in Section 6.

## 2 Related Work

Our approach is different from related work as it enables the adaption to various domains of compliance by extending the conceptual model for compliance governance introduced in [9] and customizing the related components in the compliance governance architecture accordingly. We deal with the domains of Quality of Service (QoS), security, and licensing, while most of the existing approaches in the field of compliance governance in SOAs are focusing on one single specific compliance domain. For example, the approach presented by Kuster et al. [13] is limited to the compliance of business processes with respect to data object lifecycles. A data object lifecycle is specified as a model, which captures allowed states and state transitions for a particular data object. The generated process model complies to the object lifecycle based on automata theory.

[3] http://www.compas-ict.eu/

Most of the scientific publications regarding compliance involves annotation of business processes. For instance, Wolter and Schaad [27] investigated an extension for the Business Process Model And Notation (BPMN) [19], enabling the modeling of task-based authorization constraints and supporting resource allocation patterns such as separation of duties and role-task assignments. In contrast to our approach, this later focuses on task-based access control, which is a subtopic of the compliance domain regarding business process security. Sadiq [23] presents an approach based on a formal contract language to specify and describe compliance constraints, and to define compliance rules to annotate business processes. Namiri et al. [18] propose a semantic-based approach for modeling and implementation of internal controls in business processes, focusing on the separation of business and internal control processes. An approach focusing on the integration of semantic constraints in process management systems and its usage for the verification of the integrated semantic constraints is introduced in [14]. Those approaches only consider the modeling phase of compliance constrains or controls, lacking support for runtime compliance checking and monitoring.

The current studies involving policy-based frameworks are also restrict to the modeling phase and far from having a full and well defined framework to manage compliance. They have been extending and integrating semantic of business process and compliance policies in the form of ontologies in order to provide compliant business process [15], [16]. In fact, the same lack of completeness is also present when policy frameworks (e.g., IETF, Ponder, KAoS, Rei and WS-Policy) are adopted to manage compliance in SOA as describe in this survey [26]. Hence, a lot of open issues are still around in the compliance field.

The work of Governatori et al. [10] checks compliance of business process to regulations. They propose a framework for assessing if a given business process complies with a set of regulatory control objectives. The compliance governance framework proposed in this paper aims at an integral management of compliance of all business processes in an organization. Differently from Governatori et al., whose framework provides diagnostic support for business process design, our framework focuses on the aspect of compliance of process instances, with the current status of compliance being updated on dedicated CGDs.

Business Activity Monitoring (BAM) aims at providing aggregated information suitable for performing various types of analysis on data obtained from the execution of business activities. For example, tools such as Oracle BAM, Nimbus and IBM Tivoli aim at providing their users with real-time visual information and alerts based on business events in a SOA environment. The information provided to users comes in the form of dashboards for reporting on key performance indicators (KPIs) and violations of service level agreements (SLAs). The compliance management part of these tools, if any, comes in the form of monitoring of SLA violations, which need the SLA formal specifications as one of its inputs.

In the context of our research it is worth to mention event-based related work, since our framework checks compliance taking in consideration the content of the events produced during the execution of business processes or as a result of CEP. The following works present solutions to monitor and evaluate process events, but not taking into account their compliance. Michelson et al. [17] presented a complete report overview about event-driven architecture (EDA) in SOA environments. Their content is composed of many definitions and concepts involving events, as well as strategies to process them in a SOA. Additionally, they also describe event ows and the main components expected in an EDA. Many of those components are presented in our solution (e.g., repositories, events, process engine). However, even if with some similarities, the approaches are different, in the sense that Michelsons work does not focus on and mention compliance in its work. Sriraman et al. [24] also claim the business utility and agility provided by the union of SOA, EDA and model driven architecture (MDA). They present different perspectives containing SOA, EAD, and MDA together with different domains (e.g., user, development, business) and views (e.g., user centric view). They also show how to implement the proposed architectures in Java. However, also this work does not explicitly comment or focus on event-based compliance monitoring. Still, both paper are important to understand the role of events and how they can be useful in a business process environment.

Giblin et al. [6] propose a compliance meta-model for uniform description and management of compliance policies and show how subsets of compliance sources, expressed in terms of the meta-model, can be (semi-) automatically transformed into event monitoring rules. While the experience of authors in generation of rules from requirement is definitely useful for this step in our framework, we go beyond this, providing runtime monitoring and informing interested parties on the state of compliance.

Robinson [22] proposes a generic framework for defining, monitoring, and modifying (based on feedback) requirements in information systems. This work lies in the area of system verification, while our framework rather deals with compliance to requirements coming from different sources.

## 3 Motivating scenario: Advanced Telecom Service

In this section, we describe the Advanced Telecom Services scenario we use through the paper to illustrate our solution. This scenario is one of the case studies of the EU FP7 project COMPAS. The scenario deals with a service "WatchMe" that provides customers with on-demand aggregated audio and video streaming content. Service clients can use the service to see videos with soundtracks in different languages. This service is provided by a fictitious company called Mobile Virtual Network Operator (MVNO).

The case study focuses on particularly challenging environment: a provision of advanced telecom services by a mobile operator that does not have its own network, but uses existing networks of other operators to provide services. Therefore, network infrastructure and many applications that provide the MVNO service components are owned and managed by different enterprises, which include third party application providers, network carriers, and the MVNO company. We place the proposed architecture inside the MNVO company for managing and monitoring the compliance with the licenses of content providers.

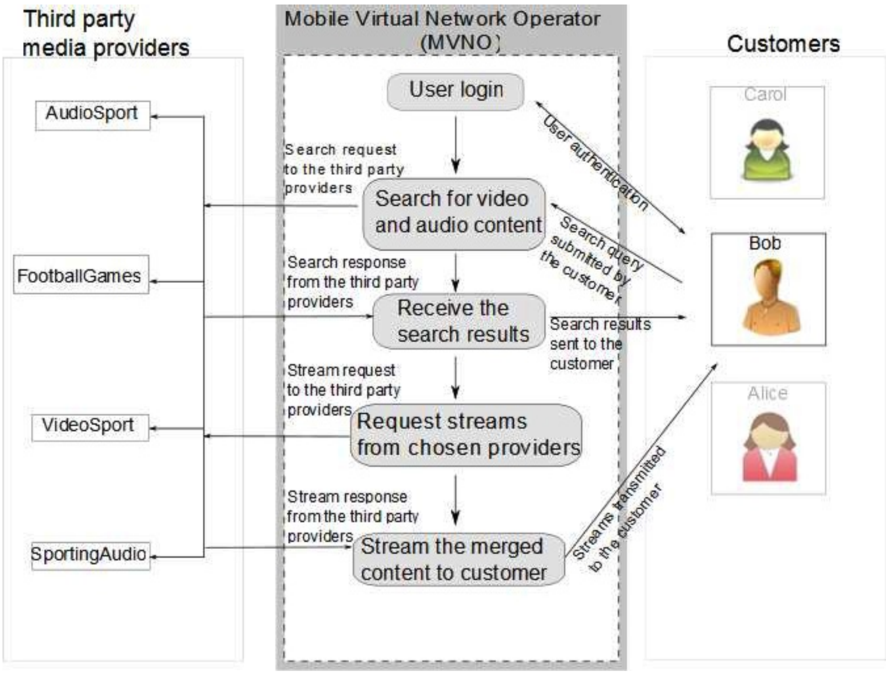



**Fig. 1**. The business process of the WatchMe service

In this scenario, the WatchMe service serves as a content aggregator placed between customers (cellphone owners) and the audio and video streaming third party providers. For example, customers access the WatchMe service to see sport events with audio comments in the language they prefer. The service processes customer requests and provides streaming of the selected audio and video content. In the scenario, we assume the MVNO company is providing synchronization between video and audio. The process describing the services offered by the company (presented in Figure 1) includes the following operations:

- authorization of a customer,

- processing search queries for audio and video streams received from customers and forwarding them to third party providers,
- collecting the results of the queries from the providers,
- merging all the results into a single list,
- sending the merged list of results to the customer,
- receiving requests for specific audio and video streaming content from the
- customer,
- acquiring requested video and audio endpoints from the selected providers,
- receiving streams from the acquired endpoints, merging them online and
- streaming the resulting content to the customer.

| **Compliance Requirement** | **Description of the Compliance Requirement** | **Control** |
|---|---|---|
| Pay-perview plan | When the WatchMe company subscribes for the Pay-per-view plan it acquires a limited number of streams based on the amount paid to the media supplier. | When the WatchMe company subscribes for the Pay-per-view plan it has to pay 29.90 euro first and then receive 300 streams from the media supplier. |
| Time-based plan | When the WatchMe company subscribes for the Time-based plan it acquires any number of times any possible streams in a certain period, based on the amount paid to the media supplier. | When the WatchMe company subscribes for the time-based plan it has to pay 89.90 euro first and then receive an unlimited number of times any available stream from the media suppler in a 30 days period starting from the contract start date. |
| Composition permission | Only pre-defined combinations of video and audio streams from providers are allowed due to the licenses specified by the video provider. | Video streams from Football Games can be assembled with audios streams from AudioSport or SportingAudio. Video from VideoSport can only be assembled with audio streams from AudioSport. |

**Table 1.** Licensing compliance requirements of the Advanced Telecom Services scenario.

The terms and conditions of using the WatchMe service are regulated by appropriate licenses between MVNO (the WatchMe service provider) and its customers, and between the third party providers and MVNO. In this scenario, we focus on the latter, which is the compliance of

MVNO to the licenses of third party providers. Licenses of audio and video providers specify conditions related to various payment plans, as well as to types of allowed compositions of audio and video streams. We consider two payment plans in this scenario. The Time-based plan allows MVNO to acquire and resell any stream for an unlimited number of times in a certain period, based on the amount paid to the media supplier. The Pay-per-view plan allows the company to acquire and resell a certain number of streams based on the amount paid to the supplier, without time constraints. In both plans, the composition permission specifies predefined combinations of video and audio providers, i.e., video streams from VideoSport can only be combined with audio streams from AudioSport, a company from the same media group.

All licensing compliance requirements for the business process of the WatchMe service are listed and described in Table 1. For each requirement we list the control, which describes what has to be done to realize the corresponding compliance requirement. The compliance sources from where requirements have been derived are licenses of the content providers. In order to model the requirements, we use Licensing DSL, developed in COMPAS [3]. For the sake of simplicity we focus on the composition permission compliance requirement throughout this paper and use it to show the application of our framework to the Advanced Telecom Services scenario.

## 4 Compliance governance lifecycle

Figure 2 shows the overall compliance governance lifecycle considered in the COMPAS project. The compliance governance lifecycle starts with the step of internalization of the external compliance sources, such as regulations, business contracts, standards. This step is performed by a compliance officer.

The next step is the design or modeling of business processes and compliance requirements that must be met by the processes. At this step, requirements are derived from internalized external sources and also from internal policies defined by the organization. This step involves a process analyst, a compliance officer and a technical specialist.

In COMPAS the compliance requirements are modeled in DSLs [1] using the corresponding DSL Editors. For instance, in the Advanced Telecom Services scenario we use the Licensing DSL [3], which is an extension of the Open Digital Rights Language (ODRL) [21], for modeling the composition permission compliance requirement. Other DSLs include QoS [1] and Security [4] DSLs. The processes are specified using the View-based Modeling Framework (VbMF) [11], which is a Model-driven Software Development (MDSD) software framework based on the Eclipse Modeling Framework (EMF). The EMF Models specifying the business process as well as the compliance requirements specified in the corresponding DSLs are the input for the Code Generator, a component integrated in VbMF to generate (semi-automatically) business processes defined in BPEL. In addition to the BPEL process the configuration artifacts, e.g., CEP rules for monitoring components are generated depending on the concrete compliance requirements the execution of the business process has to conform to. The framework currently does not deal with the problem of conflicts and redundancy among the selected requirements, introduced in [5], but, rather, aims at fulfilling all specified compliance requirements. Conflicts and redundancy can be detected at later stages, for instance, applying root-cause analysis.

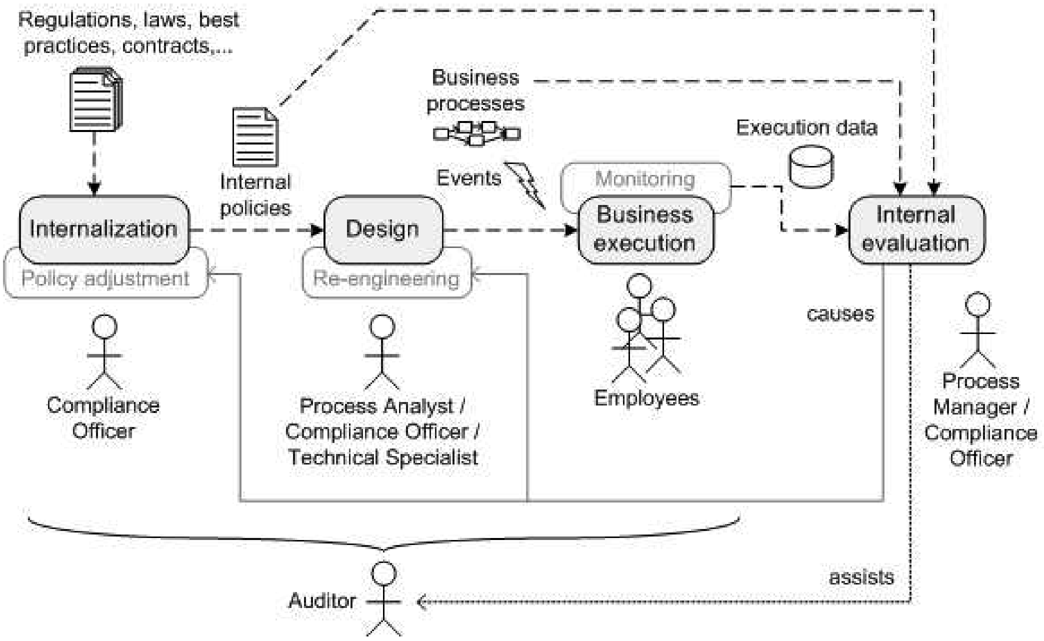



**Fig. 2.** The compliance governance lifecycle.

All artifacts used for the generation of the compliant business process and the configuration artifacts such as compliance requirements, the EMF models, and process models are stored in the Model Repository, which is part of the Model-Aware Service Environment (MORSE) [25]. For the unique identification of each artifact stored in the Model Repository we use Universal Unique Identifier (UUID). Thus this important information might be requested for finding the cause in case a compliance violation is detected during compliance monitoring, by querying the Web service interface of the Model Repository. Finally, the compliant BPEL process containing the UUIDs is deployed in the process engine and the configuration artifacts containing UUIDs are deployed to the corresponding compliance monitoring and checking components.

The third step of the lifecycle is business execution, where employees participate in execution of a business process. During such execution, the process emits events that are used for the monitoring, and also produces data about process execution. Such data, together with models of the business processes and compliance requirements is used by a process manager or a compliance officer at the fourth step: internal evaluation. During this step the compliance of the process is assessed and the data is analyzed in order to find what causes non-compliance. The results of the analysis assist an auditor and can be also used for process re-engineering and re-thinking of initial requirements. These two latter steps are out of the scope of this paper.

The reader can find the detailed definitions of terms and concepts of the compliance governance in COMPAS, stemming from an effort of the whole team of the COMPAS project at http://www.compas-ict.eu/terminology.php. An initial version of the compliance management lifecycle and of the terminology has been presented in [9].

## 5 Runtime compliance governance framework

In this section we describe the compliance governance framework for monitoring the compliance of business processes at runtime and show how to apply it in the Advanced Telecom Services scenario.

### 5.1 Runtime compliance governance architecture

Figure 3 shows the components of the runtime compliance governance architecture, described in the following. Runtime governance starts with deploying a BPEL business process that contains the UUIDs of the process model and those of the activities relevant for monitoring and checking of the compliance requirements to the Extended Process Engine Apache ODE. After the deployment a Process Deployed system-level event containing the BPEL file of the process including UUIDs is emitted and published to the Java Message Service Topic named Process Engine Output within the Enterprise Service Bus Apache ActiveMQ, used as messaging infrastructure. The Advanced Telecom Service Custom Controller (ATSCC) is subscribed to this JMS-Topic and therefore receives all events emitted by the Apache ODE. The purpose of the ATSCC is to select pre-defined events, e.g., Activity Completed system-level events, emitted by the engine that are related to the deployed process.

The system-level events augmented with the corresponding UUIDs passing the ATSCC internal event filter are published to the JMS-Topic named Compliance Governance Input. Both the Event Log and the CEP Engine Esper are subscribed to this topic to receive all system-level events relevant to runtime compliance monitoring and checking. The goal of CEP is to provide the possibility for finding complex event patterns within the low-level streams of events generated by the Business Process Engine or/and other Business Activity Monitoring tools. The CEP Engine Esper processes system-level events to create higher-level business-level events, for instance, subtracting timestamp of ActivityStarted event from the timestamp of ActivityFinished event for the calculation of the duration of an activity. The resulting business-level events also contain UUIDs, which are UUIDs of the CEP rules and generated semi-automatically during design phase using VbMF. Due to the fact that one business process may have to be compliant to several different compliance requirements affecting not necessarily a disjoint set of activities the UUIDs of the monitoring artifacts, e.g., CEP rules are additionally required for the sufficient querying of the Model Repository for drill-down. This enables a unique identification, because the relationship between a concrete compliance requirement and the corresponding CEP rule is always one-to-one as specified in the conceptual model [9]. The results of CEP are shown on the online tab of the Compliance Governance Dashboard, allowing for near real-time detection of violation patterns of events, which could lead to violation of any of the licenses signed with their contractors. Therefore, the runtime overhead of using CEP is required for the fast detection of patterns of events leading to violations. Such detection might prevent major financial losses for the company.

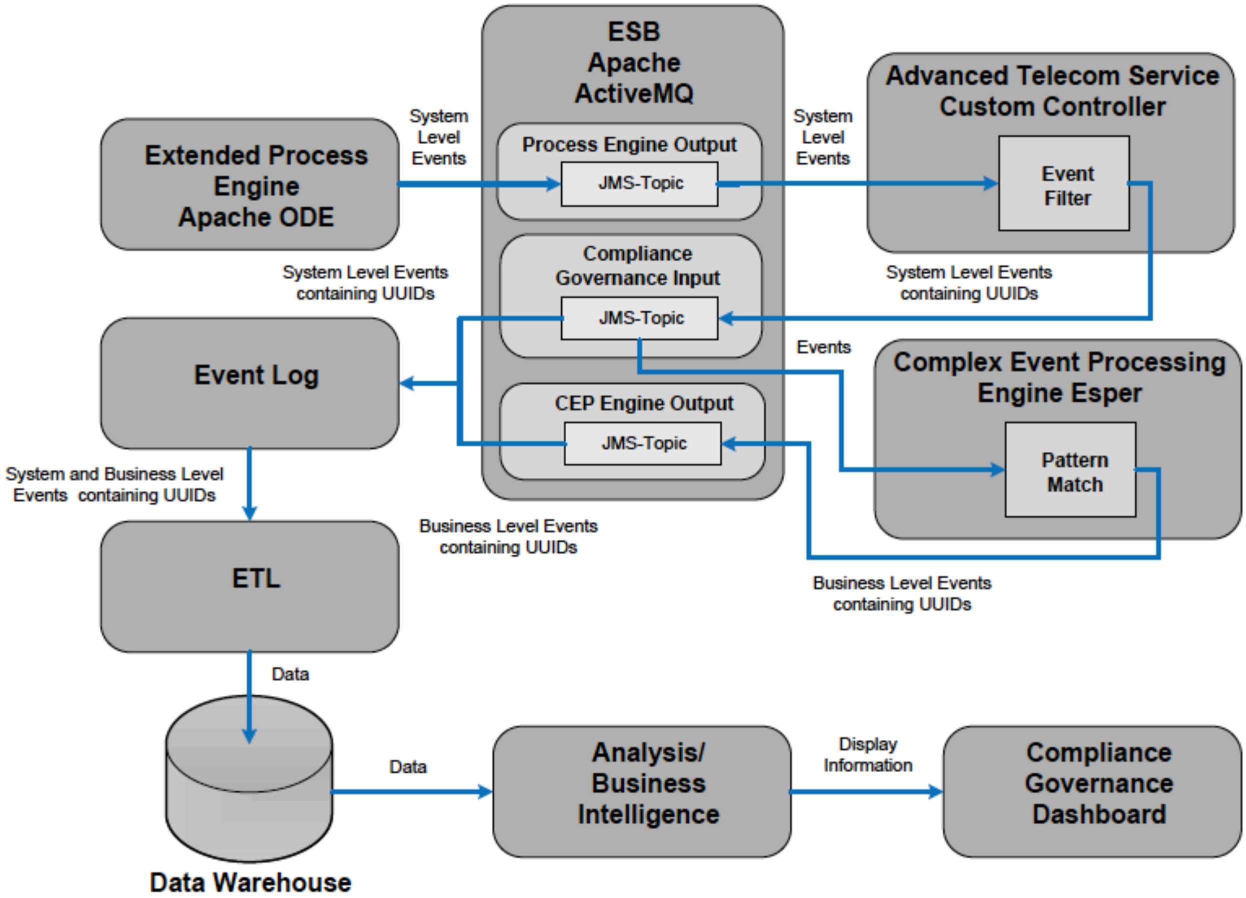



**Fig. 3.** Runtime compliance governance architecture

The Business Level Events augmented with UUIDs are published to the JMS-Topic named

CEP Engine Output. The Event Log storing the system-level events augmented with UUIDs and Business Level Events containing UUIDs is subscribed to both JMS-Topics Compliance Governance Input and CEP Engine Output. The ETL extracts, transforms and loads the data including UUIDs from the Event Log and stores it in the Data Warehouse. After this the Analysis/Business Intelligence component retrieves the data from the Data Warehouse and executes the analysis on the data. In case a compliance violation is detected the Model Repository might be queried for drill-down to retrieve the corresponding compliance requirements, EMF models, and CEP rules uniquely identified by the corresponding UUIDs. Finally, the results of the offline compliance monitoring and checking are displayed in the *Compliance Governance Dashboard*.

### 5.2 Compliance governance in the Advanced Telecom Services

In the following, we use the four steps of compliance governance to explain how our framework is applied in the Advanced Telecom Services scenario.

**Step 1. Selecting compliance sources and compliance requirements** Figure 4 shows how the composition permission requirement (selected for the running example, as we discussed in Section 3), is modeled in the Licensing DSL.

**Step 2. Designing business processes compliant with the selected requirements** The business process is modeled in EMF using the VbMF [1, 2]. This EMF model as well as the composition permission compliance requirement modeled in Licensing DSL, as shown in Figure 4, serves as input for the Code Generator component, which is integrated in VbMF.

This step is still under development in COMPAS, the goal is to have a process model annotated with events that will be emitted during the execution. Such events will be used during the execution to check compliance. Currently, attaching events and generating rules requiring to monitor the compliance requirements is done manually. The result of the semi-automatic generation is the business process in BPEL containing the UUIDs of the process model itself as well as of the activities relevant for compliance checking. Moreover the CEP rules will be generated for processing the corresponding system-level events for creation of business-level events. Additionally the configuration file for the ATSCC specifying the type of events not to be filtered out and the configuration artifacts for the Analysis/Business Intelligence component are generated.

```xml
<!-- the Scope of rights clause of the license -->
<o-ex:permission>
    <!-- allows composition under conditions listed below-->
    <sl:composition />
</o-ex:permission>
<!-- Financial terms license clause -->
<o-ex:permission>
    <!-- Allowed combinations of audio providers -->
    <o-dd:play>
        <o-ex:requirement>
            <wm:combinations>
                <wm:type>ApprovedAudioProviderOnly</wm:type>
            </wm:combinations>
        </o-ex:requirement>
        <o-ex:constraint>
            <o-ex:context>
            <o-dd:name>ApprovedAudioProviders</o-dd:name>
                <o-ex:constraint>
                <o-ex:context>
                    <o-dd:name>AudioSport</o-dd:name>
                    <o-dd:uid>ASport</o-dd:uid>
                </o-ex:context>
                </o-ex:constraint>
            </o-ex:context>
        </o-ex:constraint>
    </o-dd:play>
</o-ex:permission>
```

**Fig. 4.** The composition permission expressed in the Licensing DSL for the VideoSport provider.

**Step 3. Monitoring compliance of processes during their execution** In order to be able to quickly react to any compliance violation, it is essential to monitor business processes online. For this purpose we chose CEP as a perfect solution for efficient and fast detection of events that match violation patterns. Business process engine generates the events at every step of process execution, according to the annotations. A specialized CEP engine catches and uses them for the evaluation of predefined rules. The rules can be used to specify any complex patterns (including temporal logic), various operators (mathematical, logical) and operations for filtering and aggregation. Finally the configuration artifacts are deployed on the corresponding component involved in compliance monitoring and checking and the BPEL process is deployed on the extended Apache ODE.

The following rule for monitoring violations of composition permission is used to detect patterns of video and audio request events that are not compliant with a license.

```
select * from pattern [ every ( VidProvVideoSport = Event
(name = 'WatchMeGetVideoStreamEvent' AND VideoProviderID= 'VideoSport' )
AND ( AudProvAudioSport = Event ( name = 'WatchMeGetAudioStreamEvent'
AND NOT (AudioProviderID = 'AudioSport')))))]
where AudProvAudioSport.sessionID =VidProvVideoSport.sessionID
```

In this case, the pattern includes combinations of WatchMeGetAudioStream events from the audio stream of AudioSport and from the video stream of VideoSport for a given session. The query has to match only the events related to the same session (matching is done by “sessionID” property of the events). The system-level events emitted by the ATSCC as well as the Business Level Events generated and emitted by the CEP Engine are afterwards stored in the Event Log as described in Section 5.1. The ETL component extracts the data from the Event Log and loads it into the Data Warehouse. Then the Analysis/Business Intelligence component checks compliance based on the data. In case a compliance violation is detected the Model Repository may be queried in order to perform a drill-down.

**Step 4. Informing interested parties on the current state of compliance** The current state of compliance of the processes of the organization is shown in offline and online dashboards. Using the monitoring table in the online view, it is possible to verify event violations detected on the y and take actions to avoid violations in the future. Such view is mainly used by technical project resources that could change the business process implementation to correct wrong behaviors. Using the offline view, composed of Key Compliance Indicators (KCIs) widgets and an interactive table, it is possible to quickly check violations in different perspectives (e.g., business or compliance) and summarization levels (e.g., compliance source, requirement, or policies, which group related requirements, such as licensing requirements). In our example of monitoring the composition permission, ad-hoc KCIs can be defined and their values will be displayed in the dashboard. Having both business and compliance perspective and different summarization levels, it is possible to show high-level information (e.g., KCIs of compliance sources) useful for CEOs and CFOs and low-level information (e.g., list of events violations per compliance requirement) to technical experts. Figure 5 (a) illustrates the KCIs of the different compliance sources from the Advanced Telecom Services scenario in descendant order, where the first widget always contains the compliance source with the highest compliance performance (the worst case). CGD also provides indicators for the compliance requirements concerning licensing (Figure 5 (b)) and an interactive table (Figure 5 (c)). The later also allows users to drill-down KCIs from the highest level information until the lowest level. The values showed by the KCIs are calculated based on the data stored into the Data Warehouse (DW), which were previously temporally stored into the Event log. More details about the CGD design and implementation are available in [20] or at the CGD website[4].

[4] http://compas.disi.unitn.it/CGD/home.html

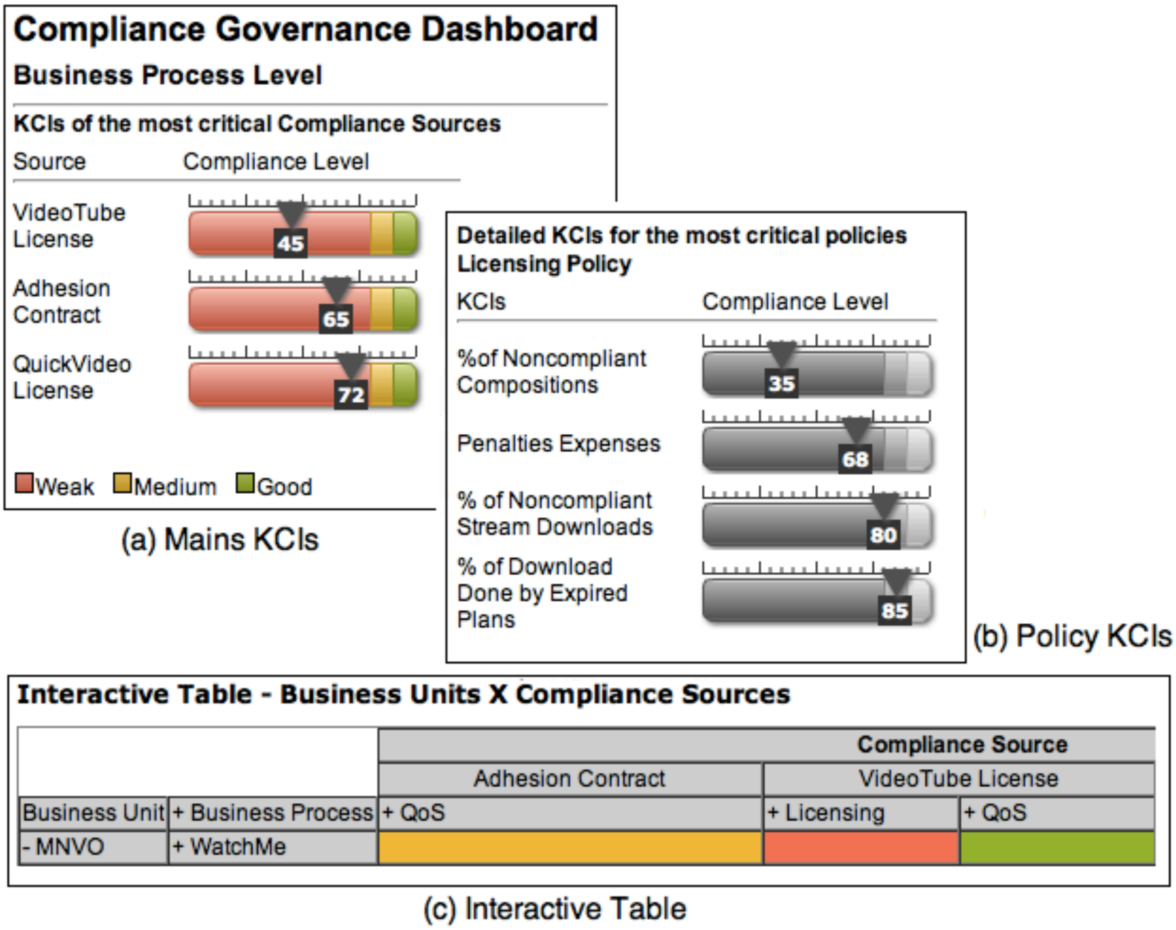



**Fig. 5.** The current state of compliance of the WatchMe Business Process displayed at the dashboard.

## 6 Conclusions and Future Work

We have presented an integral framework for runtime compliance governance supporting all the steps of the compliance governance lifecycle: from selecting compliance sources to runtime monitoring and reporting on violations. This ad- dresses the first research question posed in the introduction: (i) Is it possible to create a system dealing with the whole process of compliance management, from selecting compliance sources to dealing with cases of non-compliance? In this paper we presented runtime aspects of such a system, while design aspects have been presented in [1-2]. Since the solution is service-oriented, we also address the second question: (ii) Is the service-oriented technology is mature enough to be used as the basis for such a solution? The service-oriented technology seems to be capable of dealing with the matter, since the solution has been tested in a real case study and we are currently working on testing it in another real case study dealing with the loan approval scenario.

Future work includes support of other compliance domains, such as compliance to security or QoS requirements and addressing the third research question: (iii) Can we reuse the knowledge about achieving compliance within the company, or, even, across companies? In this regard, we are studying the application of business process fragments [8]. We are also planning applying the presented solution in different settings in order to evaluate its performance and feasibility for real-time business processes.

**References**

1. COMPAS Deliv. D1.2: Core Meta-models, Templates, and Languages, 2009.

2. COMPAS Deliv. D1.3: MDSD Software Framework for Business Compliance, 2009.

3. COMPAS Deliverable D5.3: Final Goal-oriented Data Model, 2009.

4. COMPAS Deliverable D5.4: Reasoning Mechanisms to Support the Identification and the Analysis of Problems Associated with User Requests, 2009.

5. A. Awad, M. Weidlich, and M. Weske. Consistency checking of compliance rules. In Business Information Systems, volume 47, chapter 10. Springer, 2010.

6. C. Giblin et al. From regulatory policies to event monitoring rules: Towards modeldriven compliance automation. Technical report, IBM Zurich, 2006.

7. C. Rodríguez et al. Analyzing compliance of service-based business processes for root-cause analysis and prediction. In Proceedings of ESW'10. Springer, 2010.

8. D. Schumm et al. Integrating Compliance into Business Processes: Process Fragments as Reusable Compliance Controls. In Proc. of the Multikonferenz Wirtschaftsinformatik (MKWI'10). Universit□atsverlag G□ottingen, 2010.

9. F. Daniel et al. Business compliance governance in service-oriented architectures. In Proceedings of the IEEE Twenty-Third International Conference on Advanced Information Networking and Applications (AINA'09), Bradford, UK, May 2009.

10. G. Governatori et al. Detecting regulatory compliance for business process models through semantic annotations. In D. Ardagna, M. Mecella, and J. Yang, editors, Business Process Management Workshops, volume 17, chapter 2. Springer, 2009.

11. H. Tran et al. Modeling Process-Driven SOAs { a View-Based Approach. In J. Cardoso and W. van der Aalst, editors, Information Science Reference. 2009.

12. T. Henry. Product for managing governance, risk, and compliance: Market u_ or relevant stuff? Report of Burton Group, March 2008.

13. J. Kuester, K. Ryndina, and H. Gall. Generation of business process models for object life cycle compliance. In Proceedings of the 5th International Conference on Business Process Management (BPM'07), 2007.

14. L. T. Ly et al. Integration and veri_cation of semantic constraints in adaptive process management systems. Data Knowl. Eng., 64(1):3{23, 2008.

15. M. El Kharbili et al. Policy-based semantic compliance checking for business process management. In Proceedings of the Workshops co-located with the Mo- bIS2008 Conference, volume 420 of CEUR Workshop Proceedings, pages 178{192, Saarbr□ucken, Germany, November 2008. CEUR-WS.org.

16. M. El Kharbili et al. Towards a framework for semantic business process compliance management, 2008.

17. B. M. Michelson. Event-driven architecture overview. Report of Patricia Seybold Group, 2006.

18. K. Namiri and N. Stojanovic. Pattern-based design and validation of business process compliance. In On the Move to Meaningful Internet Systems 2007: CoopIS, DOA, ODBASE, GADA, and IS, volume 4803 of LNCS, chapter 6. Springer, 2010.

19. Object Management Group (OMG). Business Process Model And Notation (BPMN). Version 1.2, OMG Speci_cation, January 2009.

20. P. Silveira et al. On the design of compliance governance dashboards for e_ective compliance and audit management. In Proc. of the 3rd Workshop on Non-Functional Properties and SLA Management in SOC (NFPSLAM-SOC'09).

21. R. Iannella. Open Digital Rights Language (ODRL). Version 1.1, Sept. 2002.

22. W. Robinson. A requirements monitoring framework for enterprise systems. Requirements Engineering, 11(1):17{41, March 2006.

23. S. W. Sadiq, G. Governatori, and K. Namiri. Modeling control objectives for business process compliance. In Proceedings of the 5th International Conference on Business Process Management (BPM'07), 2007.

24. B. Sriraman and R. Radhakrishnan. Event driven architecture augmenting service oriented architectures. Report of Unisys and Sun Microsystems, 2005.

25. T. Holmes et al. Monitoring and analyzing service-based internet systems through a model-aware service environment. In Proceedings of the 22nd International Conference on Advanced Information Systems Engineering. Springer, 2010.

26. T. Phan et al. A survey of policy-based management approaches for service oriented systems. In Proceedings of the 19th Australian Conference on Software Engineering (ASWEC '08), pages 392{401, Washington, DC, USA, 2008.

27. C. Wolter and A. Schaad. Modeling of task-based authorization constraints in BPMN. In Proc. of the 5th Int. Conf. on Business Process Management (BPM'07).

# Appendix D

## An integrated solution for runtime compliance governance in SOA[1]

Aliaksandr Birukou, Vincenzo D'Andrea, Frank Leymann, Jacek Serafinski, Patricia Silveira, Steve Strauch, and Marek Tluczek

**Abstract**: Compliance governance in organizations has been recently gaining importance because of new regulations and the diversity of compliance sources. In this demo we will show an integrated solution for runtime compliance governance in Service-Oriented Architectures (SOAs). The proposed solution supports the whole cycle of compliance management and has been tested in a real world case study.

### 1 Introduction

Compliance governance refers to the overall management approach for controlling the state of compliance in the entire organization and, in general, consists of: (1) selecting the sources to be compliant with and designing corresponding compliance requirements; (2) (re-)designing business processes compliant with the selected requirements; (3) monitoring compliance of processes during their execution; (4) informing interested parties (managers, auditors) on the current state of compliance; (5) taking specific actions or changing the processes in cases of (predicted or happened) non-compliance. Compliance governance has been gaining importance in organizations because of new regulations appeared recently (e.g., Sarbanes-Oxley Act, Basel III, Solvency II), non-compliance bringing money loss and reputation damage, and the diversity of compliance sources: business owners consider legislature and regulatory bodies, standards and codes of practice, business partner contracts. Existing approaches rarely deal with different types of compliance sources and cover only few steps of the compliance governance.

In this demo we will show how service-oriented technology can be used as the basis for an integrated solution for runtime compliance governance in a company.

The framework includes tools for: modeling compliance requirements for different compliance sources in domain-specific languages; linking the requirements to the business processes; monitoring process execution using Complex Event Processing (CEP); displaying the current state of compliance in dashboards, and analyzing cases of non-compliance to find what caused

[1] The original publication is available at www.springerlink.com, more specifically at link.springer.com/chapter/10.1007%2F978-3-642-17358-5_65

them. The framework is targeted at people dealing with compliance in an organization, ranging from people specifying compliance requirements (process analysts, compliance officers, technical specialists) to those controlling the compliance (managers, auditors) and it helps them to deal with various compliance aspects in a uniform and automated manner. The framework has been applied in a real case study in the context of the EU FP7 project COMPAS[2] (Compliance-driven Models, Languages, and Architectures for Services). The case study focuses on the compliance of telecom service provider to licenses of its business partners. The framework provides the following unique contributions:

– handling requirements from different source in a uniform manner within an integrated solution;
– covering whole compliance governance lifecycle;
– the model-driven approach reduces user inputs by transforming information defined in requirements to further steps - up to monitoring;
– supporting traceability and access to information during runtime execution, monitoring and mining, thus enabling drill-down in non-compliant cases.

## 2 Demonstration Storyboard

The live demonstration introduces the contributions of the compliance governance framework by means of a joint use of slides (for the conceptual aspects) and hands-on framework demos (for the practical aspects):

1. Advanced Telecom Services scenario: a company provides customers with on-demand aggregated audio/video streaming by combining services from different providers

3. Design aspects: identifying compliance sources and requirements, modeling business process, expressing compliance requirements in QoS and Licensing Domain-Specific Languages (DSLs), generating events and CEP rules for monitoring.

3. Runtime aspects: deployment of the process in the process engine, executing the process, showing the use of the online dashboard for monitoring and the offline dashboard for the historical analysis of the processes.

4. Runtime Compliance Governance architecture: explanation of the architecture and showing that framework in general is more than what is shown in the demo.

The video illustrating this demo is available at http://disi.unitn.it/~birukou/2010runtime-compas-demo.zip

[2] http://www.compas-ict.eu

# Appendix E

## An End-to-End Framework for Business Compliance in Process-Driven SOAs[1]

Huy Tran, Ta'id Holmes, Ernst Oberortner, Emmanuel Mulo, Agnieszka Betkowska Cavalcante, Jacek Serafinski Marek Tluczek, Aliaksandr Birukou, Florian Daniel, Patricia Silveira, Uwe Zdun, Schahram Dustdar

**Abstract:** It is significant for companies to ensure their businesses conforming to relevant policies, laws, and regulations as the consequences of infringement can be serious. Unfortunately, the divergence and frequent changes of different compliance sources make it hard to systematically and quickly accommodate new compliance requirements due to the lack of an adequate methodology for system and compliance engineering. In addition, the difference of perception and expertise of multiple stakeholders involving in system and compliance engineering further complicates the analyzing, implementing, and assessing of compliance. For these reasons, in many cases, business compliance today is reached on a per-case basis by using ad hoc, hand-crafted solutions for specific rules to which they must comply. This leads in the long run to problems regarding complexity, understandability, and maintainability of compliance concerns in a SOA. To address the aforementioned challenges, we present in this invited paper a comprehensive SOA business compliance software framework that enables a business to express, implement, monitor, and govern compliance concerns.

### 1 Introduction

A service is a distributed object that is accessible via the network and has certain characteristics: The service offers a public interface and is both platform- and protocol independent. Service-oriented Computing (SOC) is the paradigm in which services are used as the main constructs for composing distributed systems. Service-oriented Architecture (SOA) is the main architectural style for SOC. In this paper we focus on a particular kind of SOAs, which is *process-driven*. In a process-driven SOA, a process engine is used to orchestrate services in order to implement business processes.

This paper deals with issues of compliance in process driven SOAs. IT compliance means in general complying with laws and regulations applying to an IT system, such as the Basel II Ac-

[1] The final publication is available at dl.acm.org/citation.cfm?id=1957121

cord[2], the International Financial Reporting Standards[3], the French financial security law[4], and the Sarbanes-Oxley Act[5]. Laws and regulations are, however, just one example of compliance concerns that occur in process-driven SOAs. There are many other rules and constraints in a SOA that have similar characteristics. Some examples are service composition and deployment rules, service execution order rules, security policies, quality of services (QoS) rules, or licenses.

In the ideal case, a software framework for automatically dealing with all kinds of compliance would be provided. Unfortunately, there is the problem that it is almost impossible to formalize all details of a jurisdictional text, as they are usually subject to interpretation by domain experts or judicial experts and typically contain complex references to other (jurisdictional) texts. For this and other reasons, today, in many cases, compliance is reached on a per-case basis using hard-coded solutions that span diverse components of the SOA.

The consequence is that systems containing implementations of compliance concerns are hard to maintain, hard to evolve or change, hard to reuse, and hard to understand. It is difficult to ensure guaranteed compliance to a given set of rules and regulations, as well as to keep up with constant changes in regulations and laws. In many cases, domain experts are not involved enough in the system design, and hence often compliance implementations are missing important domain aspects.

In this paper, we propose an end-to-end approach to business compliance to overcome these issues in the domain of process-driven SOAs. In particular, our approach offers novel techniques for the whole software and compliance life cycle including modeling, implementing, monitoring, and governance. At design time, the view-based modeling framework, domain-specific languages tooling, and model repositories shall support the development and modeling of processes and compliance concerns. During run-time, the compliance governance framework shall provide mechanisms for monitoring compliance concerns, detecting compliance violations, and reporting to stakeholders.

The remainder of this paper is organized as follows. In Section 2, a Mobile Virtual Network Operator process extracted from a real industrial case study is exemplified to illustrate our approach and the realization of our approach. Section 3 describes the overall architecture of the proposed end-to-end business compliance framework. The view-based modeling framework, domain-specific languages tooling, and a model-aware service environment are presented in Section 4 whilst the compliance governance framework is elaborated in Section 5. Section 6 dis-

---

[2] http://bis.org/publ/bcbs107.htm
[3] http://www.ifrs.org/IFRSs
[4] http://senat.fr/leg/pjl02-166.html
[5] http://gpo.gov/fdsys/pkg/PLAW-107publ204/content-detail.html

cusses the relevant literature. Finally, we conclude the paper in Section 7.

## 2 Case Study

Modern mobile telecommunication infrastructures are rapidly expanding into SOAs. This is motivated by the need for delivery of advanced multimedia voice and video services to the users through new telecom service delivery platforms. It is crucial to provide real-time monitoring of such services (e.g. the services' QoS parameters and licensing clauses) and adaptability mechanisms to react to any compliance violations.

In this paper, we demonstrate our approach in a Mobile Virtual Network Operator (MVNO) process that provides advanced telecom services such as on-demand aggregated audio and video streaming content (see Figure 1). The MVNO process, which is offered by a fictitious company, namely, WatchMe, shall serve as a proxy between customers and audio and video streaming providers. As the MVNO process executes, a customer can log in and search for the audio and video content of his choice. As the search complete successfully, the customer is provided the requested media streams. In this way, the MVNO process enables the customers to watch, for example, a selected sport event with an audio commentary in the chosen language.

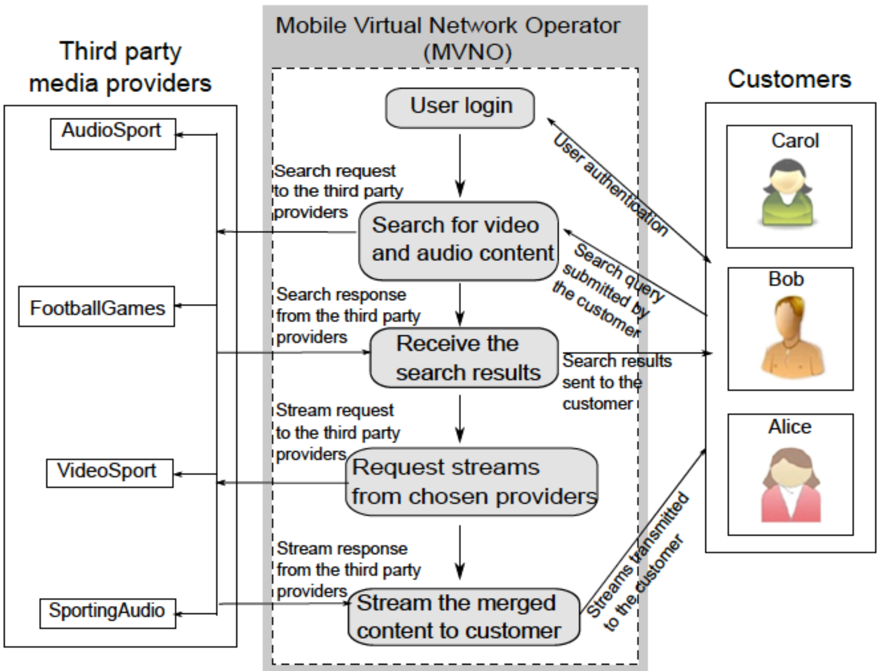



**Fig. 1.** The scenario of the MVNO case study.

There are several business compliance requirements that the MVNO process must comply with. For instance, the MVNO process must ensure particular quality levels of provided services, the protection of customer personal and payment data, the compliance with the licenses of content providers, and so forth. The terms and conditions of the offered services are regulated by appropriate Service Level Agreements (SLAs) that contain various compliance requirements. In this paper, we illustrate our approach with two compliance concerns that are quality of services (QoS) and licensing. Nevertheless, our approach is applicable to other compliance concerns as well.

As illustrated in Table 1, there are many QoS and licensing compliance requirements associated with the MVNO process and accompanying services to ensure that the process is compliant to the negotiated SLAs. It is crucial to monitor and avoid any potential compliance violations, which lower the services' quality offered to its customers. Monitoring any performance drops of the quality of the third parties' services is also important because these can impact the overall performance of the MVNO process. In addition, some licensing compliance requirements must be satisfied in order to ensure that the data streams are properly delivered to the customers according to the contract established between the WatchMe company and the content providers.

| **Compliance Concern** | **Example Compliance Requirements** |
|---|---|
| **QoS**: Availability | The availability of the Login and Search services must be more than 99%. |
| **QoS**: Processing-Time | The Search service must return useful searching results within less than 2 minutes. |
| **QoS**: Minimal-FrameRate | The minimal frame rate that the Stream service provides is at least 15 frames per second (fps). |
| **Licensing**: Composition permission | Only pre-defined combinations of video and audio providers are allowed due to the licenses specified by the video provider. |
| **Licensing**: Pay-perview plan | The WatchMe enterprise acquires a limited number of streams based on the amount paid to the media supplier. |
| **Licensing**: Timebased plan | The WatchMe enterprise acquires any number of times any possible streams in a certain period, based on the amount paid to the media supplier. |

**Table 1.** Excerpt of compliance requirement of the MVNO process.

## 3 Conceptual Architecture

Our end-to-end approach to business compliance is achieved through a conceptual architecture illustrated in Figure 2. This architecture covers the whole life cycle of business compliance at design time and runtime.

At design time, the View-based Modeling Framework (VbMF) along with the domain-specific language (DSL) tooling and model repository enable modeling and sharing process-driven SOAs and compliance concerns that we would like to address. The models capture a process driven SOA in form of architectural views, with each view providing a distinct perspective (concern) of the SOA [8, 11, 20, 21]. The domain-specific languages complement these view models with the specifications of compliance concerns. Finally, the design time components generate code that is deployed to the various platforms to be executed.

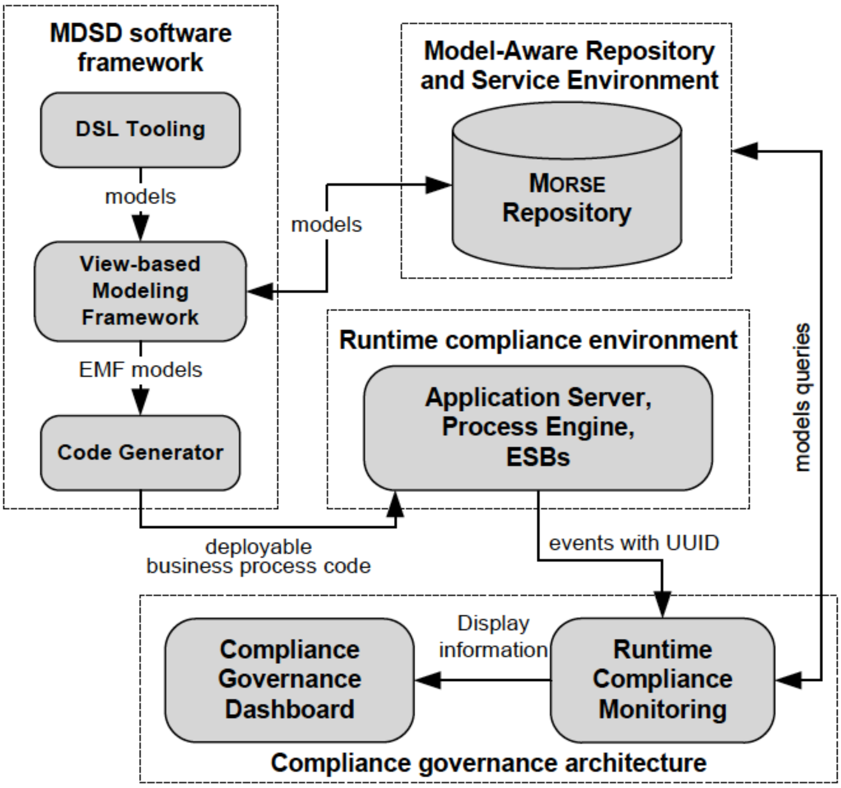



**Fig. 2.** Overview of the Architecture.

At runtime we have the execution environment to which code is deployed, for example, business processes are executed by a process engine. Dynamic verification and validation at run-time are performed by rule-based event-driven monitoring. The runtime compliance monitoring component can query the Model-Aware Repository and Service Environment (MORSE) to leverage models for runtime analysis and reasoning [9]. The monitoring results are assembled for comprehensive reporting on a compliance governance dashboard.

## 4 Process-driven SOAs development and compliance modeling

### 4.1 View-based Modeling Framework

The View-based Modeling Framework (VbMF) [20, 21] exploits the notion of architectural views [11] to reduce the complexity of software development in processdriven SOAs. In our approach, each view model is a (semi-)formalized representation of a particular processdriven SOA concern such as the control flow, service interactions, data handling, message exchange, or human interaction [8, 14, 20–23]. All VbMF view models are built up around a Core model as shown in Figure 3. The Core model plays an important role in our approach because it provides essential concepts for extending and integrating view models, and establishing and maintaining the dependencies between view models [20–23]. A new concern, for instance, a certain compliance concern, can be integrated into our approach by using a corresponding New-Concern-View model that extends the concepts of the Core model and defines additional (and/or domain-specific) concepts of that concern.

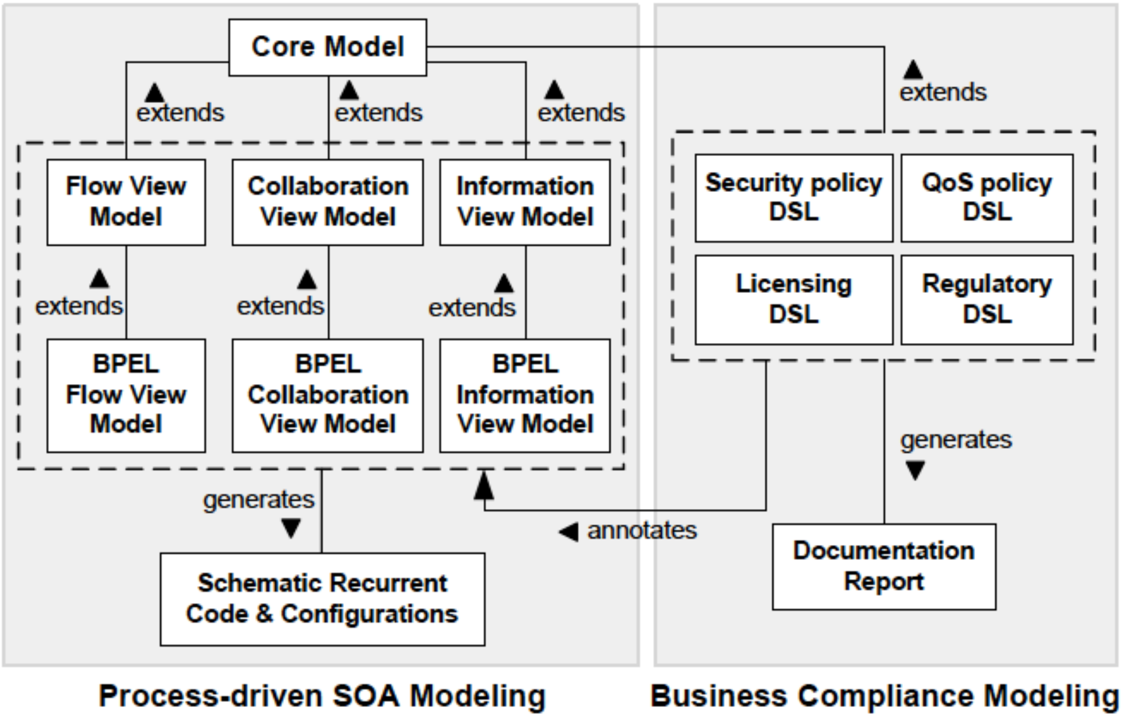



**Fig. 3.** Overview of the View-based Modeling Framework.

In addition, VbMF facilitates the model-driven development (MDD) paradigm to offer view models tailored to particular expertise and interests of the involving stakeholders at different abstraction levels. Views belonging to the abstract layer represent high-level or domain concepts that the business and domain experts can understand and manipulate. Then, the IT experts can refine or map these abstract concepts into the platform- and technology-specific views (see Figure 3) that enrich the abstract view models with more technology-specific details [20, 21]. Last but not least, VbMF provides code generations that take these views as inputs and generate process implementations and deployment configurations. In addition, VbMF code generators can also insert appropriate traceability meta-data in the generated process descriptions and/or configurations in order to enable the tracing from the running process to the corresponding process models. This will be elaborated in Section 4.3.

Figure 4 shows the MVNO process implemented using VbMF. The business and domain experts sketch out the fundamental behavior of the MVNO process to achieve the business goal using the Flow view as well as define high-level business objects such as customer requests using the abstract Information view. The IT experts will refine these concepts in the low-level views that are specific to the BPEL and Web services technology. The process implementation in form of Business Process Execution Language (BPEL)[6] and Web Services Description Language (WSDL)[7] code can be quickly generated out of the aforementioned views for deploying and testing.

### 4.2 QuaLa: A DSL for Specifying QoS Compliance Concerns

So far we have presented the development of process driven SOAs via the view-based modeling framework (i.e., the left part of Figure 3). Next, we elaborate the DSL tooling for modeling compliance requirements relating to process driven SOA concepts and elements along with a model repository for storing, sharing, and inquiring about process and compliance models.

To offer expressive and convenient languages for the different stakeholders, our approach provides a separation of DSLs into multiple sub-languages, where each sub-language is tailored for the appropriate stakeholders [17]. We divide our Quality of Service Language (QuaLa) into two sublanguages. The first language, the high-level QuaLa, is tailored for experts of the QoS domain and offers expressive notations for specifying the required QoS compliance concerns. Hence, the high-level QuaLa serves for specifying which QoS compliance concerns to monitor. In Figure 5(a) we illustrate an example of specifying one of service's QoS constraints presented in Table I using our high-level QuaLa.

The second language, the low-level QuaLa, extends the high-level QuaLa for specifying the required technological aspects that are needed for monitoring the QoS constraints during the runtime of the system. Hence, the low-level QuaLa serves for specifying how to monitor the corresponding QoS compliance concerns. In Figure 5(b) we present our low-level QuaLa and how to use it for specifying the technological aspects.

Based on the high- and low-level specifications, the QuaLa code generator generates interceptors for measuring the services' QoS properties at runtime. The interceptors send events to the runtime compliance governance components, which are responsible for checking the QoS compliance concerns.

[6] http://docs.oasis-open.org/wsbpel/2.0/wsbpel-v2.0.html
[7] http://www.w3.org/TR/wsdl

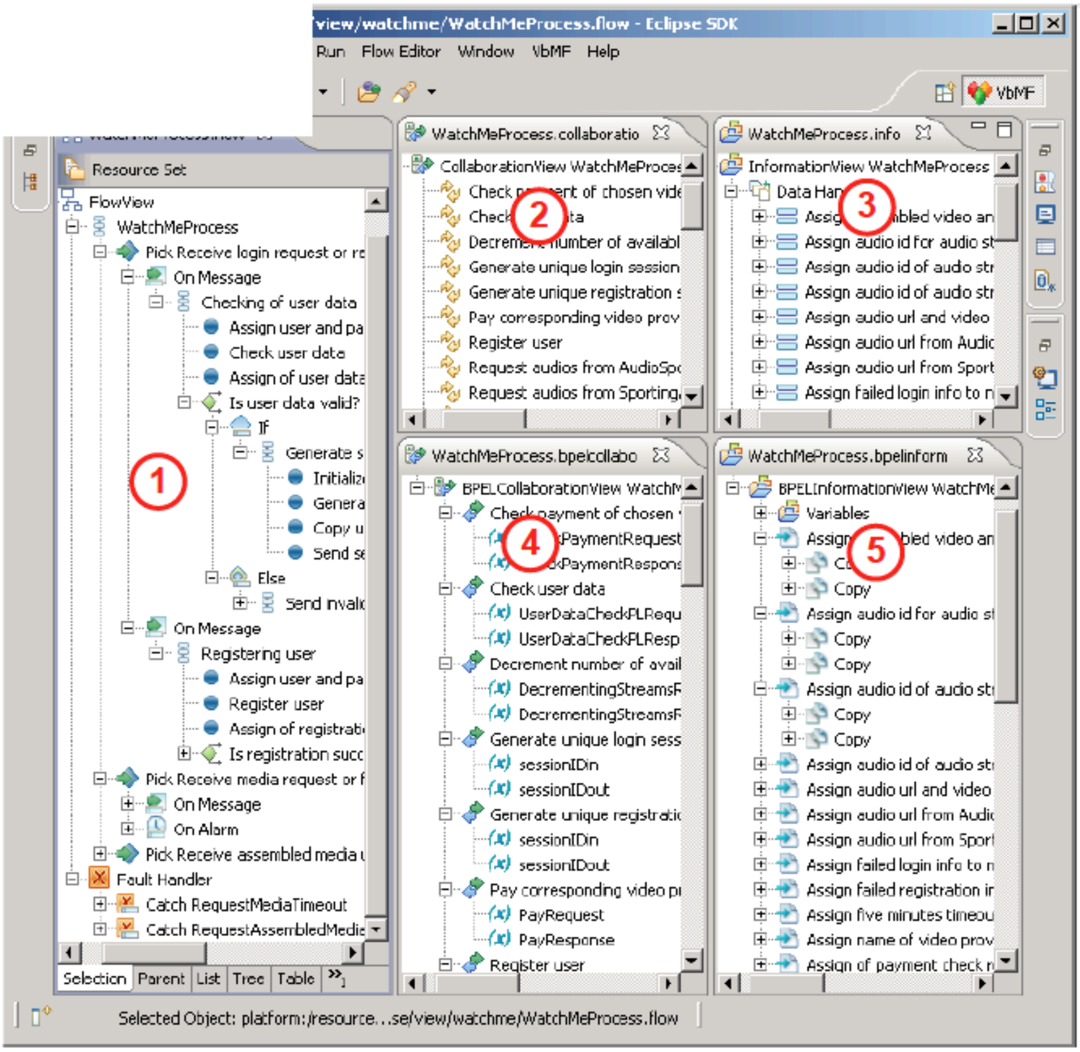



**Fig. 4.** MVNO process development in VbMF: (1) The FlowView, (2-3) The high-level CollaborationView and InformationView, and (4-5) The low-level, technology-specific BpelCollaborationView and BpelInformationView.

```
WatchmeSLA {
  Search {
    ProcessingTime<2min
    => mailto "abc@abc.at"
  }
}
```

(a) High-level QuaLa

```
#measuring the ProcessingTime
ProcessingTime chain ServerIn
ProcessingTime phases
     {InPreInvoke InInvoke}

#Location of WSDL file
Search wsdl "./search.wsdl"
```

(b) Low-level QuaLa

**Fig. 5.** Quality of service language (QuaLa).

### 4.3 Model-Aware Repository and Service-Environment

In our approach, all models (i.e., meta-models and conforming models (cf. [4]) are stored in a model repository. For this we have employed MORSE [9, 10] as a central component of the architecture as shown in Figure 2. For the compliance monitoring of the business processes, different services in the SOA reflect on models. Using MORSE they can look-up these models and related models dynamically and in a service-oriented fashion at runtime.

Our approach applies the MDD paradigm to generate service description, process code, deployment artifacts, and monitoring directives out of the VbMF view models. In a typical MDD approach, there are no backward or traceability links in the sense that the generated source code “knows” from which model it has been created. For correlating model instances or code at runtime with source models or model instances, respectively, traceability of model transformations is essential.

```
<process name="WatchMe">
 <extensions>
   <extension mustUnderstand="yes" namespace=
"http://xml.vitalab.tuwien.ac.at/ns/morse/traceability.xsd"
   />
 </extensions>
 <morse:traceability
     build="a3627172-38bc-4ff3-96d9-dc814d3a7ab2">
   <row query="/process[1]">
     <uuid>b0e5aad1-8aa1-406d-859c-324caf6044db</uuid>
   </row>
   <row query="/process[1]/sequence[1]/receive[1]">
     <uuid>1f56c377-7d12-436b-9760-349a0979df49</uuid>
   </row>
   <row query="/process[1]/sequence[1]/invoke[1]">
     <uuid>16a7749e-9560-4194-b9a8-ab04d6d8f2c9</uuid>
   </row>
   <row query="/process[1]/sequence[1]/invoke[2]">
     <uuid>16a7749e-9560-4194-b9a8-ab04d6d8f2c9</uuid>
   </row>
 </morse:traceability>
 <sequence>
   <!-- ... //-->
 </sequence>
</process>
```

**Listing 1.** MVNO BPEL process with extensions for MORSE traceability.

To overcome this limitation in order to achieve traceability, models (as the output of the generator) can hold a reference to their source models. As MDD artifacts in MORSE repositories are identifiable by Universally Unique Identifiers (UUIDs)[8], MORSE annotates the destination models with the UUIDs of the models. The VbMF code generators automatically insert references to these UUIDs into the generated source code or configuration directives, so that the correspond-

[8] http://itu.int/ITU-T/studygroups/com17/oid/X.667-E.pdf

ing models can be identified and accessed from the running system. The code in Listing 1 shows a generated BPEL process description that contains traceability information as a BPEL extension. The BPEL process engine shall emit events for, e.g., the process activities that contain matching UUIDs. Finally, the events will be processed by the monitoring and governance infrastructure.

## 5 Run-time compliance governance

In this section we present the compliance governance framework for monitoring the compliance of business processes at runtime. It is the bottom part of the architecture depicted in Figure 2, and its detailed view is provided in Figure 6. Runtime governance starts with deploying a BPEL business process to the Apache ODE process engine. The process contains the UUIDs of the process model and the UUIDs of the activities relevant for monitoring compliance requirements. After the deployment a Process Deployed system-level event is emitted in the Apache ActiveMQ Enterprise Service Bus (ESB).

Both the Event Log and the Complex Event Processing (CEP) engine are subscribed to the ESB to receive all system-level events relevant to runtime compliance monitoring. The goal of CEP is to detected violations (complex event patterns) within the low-level streams of events generated by the process engine. The results of CEP will be shown in the Compliance Governance Dashboard, allowing for near real-time detection of violation patterns of events, which could lead to violations of the licenses of the content providers. Hence, it is possible to verify event violations detected on the fly and take actions to avoid such violations in the future. In this way, the dashboard allows business process experts to react quickly and efficiently to violations.

The Event Log stores all low- and high-level events. The Extract, Transform, and Load (ETL) routines extract the data from the Event Log and load them into the Data Warehouse. The Analysis/Business Intelligence component is used to perform advanced off-line analysis of the historical data about compliance violations to raise awareness of the overall compliance status of the company. The MORSE repository may be queried in order to perform drill-down analysis to see in detail what at lower levels led to violations. The results of the off-line compliance monitoring of all compliance requirements (e.g., QoS and Licensing) are shown on the Compliance Governance Dashboard. Section V-B describes the use of the dashboard in the MVNO scenario. In the subsequent sections, we describe the major components of the runtime compliance governance framework including the Rule-based, Event-driven Compliance Monitoring component and the Compliance Governance Dashboard. For further details of the rest of the runtime compliance governance framework, please consult our previous work in [5].

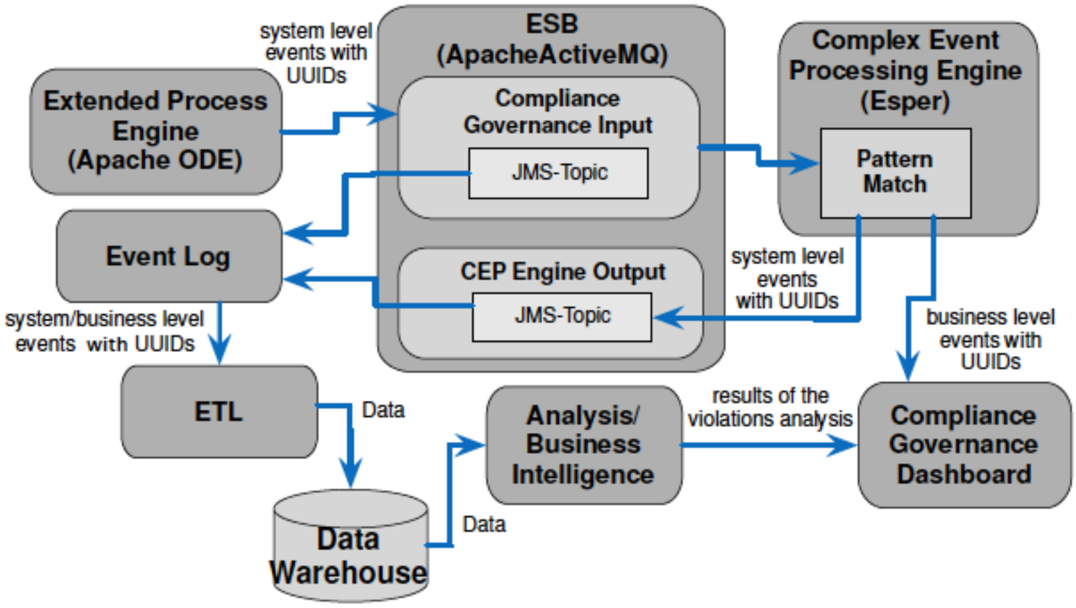



**Fig. 6.** Runtime compliance governance architecture.

### 5.1 Rule-based Event-driven Compliance Monitoring

In order to be able to quickly react to compliance violations, it is important to conduct the online monitoring of process execution. In our approach, we realize the runtime monitoring using complex event processing (CEP) for efficient and fast detection of events that match violation patterns. The process engine generates events during the course of process execution. The CEP engine aggregates the events and evaluates them according to a number of predefined rules. Listing 2 presents an excerpt of the event based rules for monitoring the violations of the composition permission licensing concern shown in Table 1. Those rules are used by the CEP engine to detect patterns of video and audio request events that are not compliant with a certain license.

In this case, the pattern includes combinations of Watch-MeGetAudioStream events from the audio stream of AudioSport and from the video stream of VideoSport in a certain session. The query has to match only the events related to the same session (matching is done by the "sessionID " property of the events). CEP allows for constant, real-time accumulation of events collected to evaluate the event patterns specified within the rules. Thus, any compliance violation specified by the CEP rule is evaluated in real-time, i.e., just in time when the last event required to match the event pattern arrives. When the rule is positively evaluated, the proper notification of compliance violation is immediately sent to run-time compliance dashboard. The notifications are also stored for off-line processing and analysis.

```
select * from pattern [ every (
VidProvVideoSport = Event
(name = 'WatchMeGetVideoStreamEvent'
AND VideoProviderID= 'VideoSport')
AND (AudProvAudioSport = Event
(name = 'WatchMeGetAudioStreamEvent'
AND NOT (AudioProviderID = 'AudioSport'))))]
where AudProvAudioSport.sessionID =
VidProvVideoSport.sessionID
```

**Listing 2.** An example of event monitoring rules in the MVNO process.

### 5.2 Compliance Governance Dashboard

The current state of compliance of the organization's business processes is shown in the Compliance Governance Dashboard (CGD) that comprises a number of Key Compliance Indicators (KCIs) widgets and interactive tables. It is possible to quickly check violations in different perspectives (e.g., business vs. compliance) and summarization levels (e.g., compliance source, requirement, or policies, which group related requirements, such as licensing requirements). In our approach, KCIs are defined and their values are displayed in the dashboard. Having both business and compliance perspective and different summarization levels, it is possible to show high-level information (e.g., KCIs of compliance sources) useful for CEOs and CFOs and low-level information (e.g., list of violations events per compliance requirement) useful to technical experts.

Figure 7 shows the monitoring of compliance requirements in the MVNO process. The top left part contains the KCIs of different business process activities in descendant order, where the first widget shows the compliance source or activities with the lowest compliance performance (the worst case). The results of monitoring QoS compliance requirements from Table I are reported in the top right part of the CGD. In addition, the CGD also offers interactive tables (the bottom part) that enable users to inspect the details of KCIs from the highest-level information to the lowest level. The values showed by the KCIs are calculated based on the compliance requirements and the data stored into the Data Warehouse. For example, looking at the interactive table the business and domain experts can see the high-level KCIs showing that the Composition permission concern is 100 % compliant whilst the monitoring of QoS concerns shows unexpected results that need to be investigated and addressed. Furthermore, the IT experts can click on these high-level KCIs to drill down and investigate the root causes and technical details of the compliance results. For more technical details about the CGD design and implementation, we recommend the readers to consult [18] and the CGD website[9].

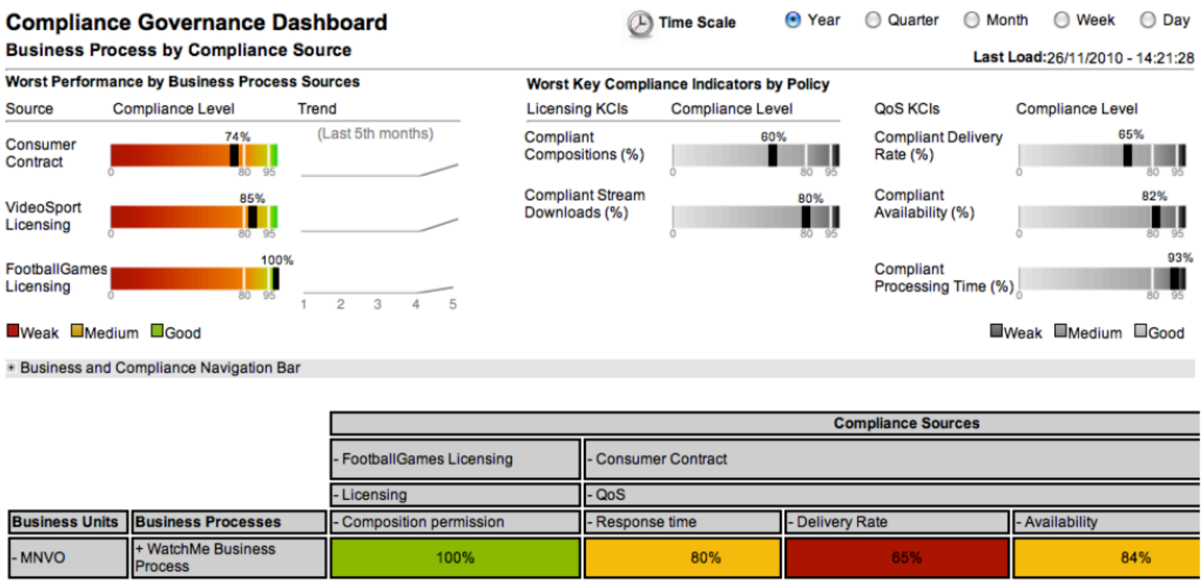



**Fig. 7.** Monitoring compliance using the Compliance Governance Dashboard.

## 6 Related work

In this section, we discuss the major related works in the area of an end-to-end framework for business compliance in general as well as model repositories and compliance runtime monitoring and governance. We categorize compliance into two main strategies: "compliance at design time", i.e., the implementation of compliance through designing it into a system, and "compliance at detection runtime ", i.e., the implementation of compliance by monitoring a system's compliance state.

For checking "compliance at design time", most of the existing approaches focus on one single specific compliance domain. For example, the European MASTER project [13] introduces a full life cycle for modeling, assessing, and monitoring security related business compliance concerns. We deal with multiple domains, especially in this work with QoS and licensing. Our approach enables the adaptation to various domains of compliance by extending the conceptual model for compliance governance. Daniel et al. [7] introduce the related components in the compliance governance architecture accordingly.

Namiri et al. [16] support compliance experts to add control patterns to the business process models to make the processes compliant. In our work, we concentrate to support the stakeholders with tailored model-driven DSLs that automatically transform the compliance requirements into rules that are checked during the system's runtime.

[9] http://compas.disi.unitn.it/CGD/home.html

AMOR [1], Odyssey-VCS 2 [15], and EMFStore [12] are model repositories that follow a similar approach to our MORSE approach. These repositories have a focus on the versioning aspect of model management (see also [2]). In contrast, MORSE abstracts from modeling technologies and its UUID-based implementation allows for a straightforward identification of models and model elements. None of the mentioned model repositories offers an integration scheme for runtime events, like our approach, or automated model generation and deployment capabilities.

For checking "compliance at runtime", Sriraman et al. [19] focus on business utility and agility provided by the union of SOA, event-driven architecture and model-driven architecture. The approach does not consider monitoring and reasoning business compliance. During the last decade Business Activity Monitoring has gained a lot of attention, and dedicated tools have been proposed to support it (e.g., Oracle Business Activity Monitoring, HP Business Availability Center, Nimbus IBM Tivoli, among others). The compliance management part of these tools, if any, comes in the form of monitoring of SLA violations, which need the SLA formal specifications as one of their inputs. In our research, we adopt a more general view on compliance (beyond SLAs, which are a special case to us) and cover the whole life cycle of compliance governance, including an appropriate dashboard for reporting purposes. Such tools still do not have the capability to process and interpret generic events. They only support the definition of thresholds for parameters or SLAs to be monitored. Also, the ability to compare monitored business process executions or, more in general, business patterns with expected execution behaviors is not supported.

To the best of our knowledge, there are no research approaches that specifically address the issue of visualizing compliance concerns using dashboards. Existing approaches, such as described in [3] or [6], do not provide suitable navigation models supporting different analysis perspectives, summarization levels, and user roles.

## 7 Conclusions

In this invited paper, we have presented an end-to-en approach and architecture for dealing with business compliance in process-driven SOAs. In summary, our approach supports stakeholders to deal with the variety of compliance requirements, including, but not limited to, QoS policies or license policies. The presented view-based, model-driven framework lays a solid foundation for modeling processdriven SOAs and compliance engineering. DSLs and view models together can be tailored to present compliance concerns to each stakeholder in an understandable form. During the course of process execution, a runtime governance infrastructure enacts the detection of compliance violations and compliance reporting according to the monitoring directives generated from the compliance DSL models. For this, traceability information emitted in process events is used and dynamic model look-up is supported through a model-aware service environment that consolidates design- and runtime use and management of models. Finally, the stakeholders, such as business analysts, IT experts, and end-users, can use the compliance governance dashboard to observe and analyze the current status of software systems' compliance, the root cause of any compliance violations, and so forth.

**Acknowledgements:** This work was supported by the European Union FP7 project COMPAS, grant no. 215175.

**References**

[1] K. Altmanninger, G. Kappel, A. Kusel, W. Retschitzegger, W. Schwinger, M. Seidl, and M. Wimmer, "AMOR – towards adaptable model versioning," in 1st International Workshop on Model Co-Evolution and Consistency Management, in conjunction with MODELS '08, 2008.

[2] K. Altmanninger, M. Seidl, and M. Wimmer, "A survey on model versioning approaches," International Journal of Web Information Systems (IJWIS), vol. 5, no. 3, pp. 271–304, 2009.

[3] R. Bellamy, T. Erickson, B. Fuller, W. Kellogg, R. Rosenbaum, J. C. Thomas, and T. V. Wolf, "Seeing is believing: Designing visualizations for managing risk and compliance," IBM Systems Journal, vol. 46, no. 2, pp. 205–218, 2007.

[4] J. B´ezivin, "On the unification power of models," Software and System Modeling, vol. 4, no. 2, pp. 171– 188, 2005.

[5] A. Birukou, V. D'Andrea, F. Leymann, J. Serafinski, P. Silveira, S. Strauch, and M. Tluczek, "An integrated solution for runtime compliance governance in SOA," in Proc. of the 8th International Conference on Service- Oriented Computing (ICSOC10), 2010.

[6] P. Chowdhary, T. Palpanas, F. Pinel, S.-K. Chen, and F. Y. Wu, "Model-driven dashboards for business performance reporting," in IEEE International Enterprise Distributed Object Computing Conference. IEEE Computer Society, 2006, pp. 374–386.

[7] F. Daniel, F. Casati, V. D'Andrea, S. Strauch, D. Schumm, F. Leymann, E. Mulo, U. Zdun, S. Dustdar, S. Sebahi, F. de Marchi, and M.-S. Hacid, "Business compliance governance in service-oriented architectures," in Proceedings of the IEEE Twenty-Third International Conference on Advanced Information Networking and Applications (AINA'09), May 2009.

[8] T. Holmes, H. Tran, U. Zdun, and S. Dustdar, "Modeling Human Aspects of Business Processes - A View-Based, Model-Driven Approach," in 4th European Conf. Model Driven Architecture Foundations and Applications (ECMDA-FA) 2008. Springer, 2008, pp. 246–261.

[9] T. Holmes, U. Zdun, F. Daniel, and S. Dustdar, "Monitoring and Analyzing Service-Based Internet Systems through a Model-Aware Service Environment," in The 22nd Int'l Conf. Advanced Information Systems Engineering, CAiSE, ser. LNCS, vol. 6051. Springer, Jun. 2010, pp. 98–112.

[10] T. Holmes, U. Zdun, and S. Dustdar, "MORSE: A Model-Aware Service Environment," in Proceedings of the 4th IEEE Asia-Pacific Services Computing Conference (APSCC). IEEE, Dec. 2009, pp. 470-477.

[11] IEEE, "Recommended Practice for Architectural Description of Software Intensive Systems," IEEE, Tech. Rep. IEEE-std-1471-2000, 2000.

[12] M. Koegel and J. Helming, “EMFStore: a model repository for EMF models,” in ICSE (2), J. Kramer, J. Bishop, P. T. Devanbu, and S. Uchitel, Eds. ACM, 2010, pp. 307–308.

[13] V. Lotz, E. Pigout, P. M. Fischer, D. Kossmann, F. Massacci, and A. Pretschner, “Towards systematic achievement of compliance in serviceoriented architectures: The MASTER approach,”

WIRTSCHAFTSINFORMATIK, vol. 50, no. 5, pp. 383–391, Oct. 2008. [Online]. Available: http://www.springerlink.com/content/lgr0v556845tt036/

[14] C. Mayr, U. Zdun, and S. Dustdar, “Model-Driven Integration and Management of Data Access Objects in Process-Driven SOAs,” in ServiceWave, 2008, pp.62–73.

[15] L. Murta, C. Corr^ea, ao Gustavo Prud^encio Jo and C. Werner, “Towards Odyssey-VCS 2: Improvements over a UML-based version control system,” in CVSM’08: Proceedings of the 2008 international workshop on Comparison and versioning of software models. New York, NY, USA: ACM, 2008, pp. 25–30.

[16] K. Namiri and N. Stojanovic, “Pattern-Based Design and Validation of Business Process Compliance,” in OTM Conferences (1), 2007, pp. 59–76.

[17] E. Oberortner, U. Zdun, and S. Dustdar, “Tailoring a model-driven quality-of-service DSL for various stakeholders,” in MISE ’09: Proceedings of the 2009 ICSE Workshop on Modeling in Software Engineering. Vancouver, BC, Canada: IEEE Computer Society, 2009, pp. 20–25.

[18] P. Silveira, C. Rodriguez, F. Casati, F. Daniel, V. D’Andrea, C. Worledge, and Z. Taheri, “On the design of compliance governance dashboards for effective compliance and audit management,” in Proc. Of the 3rd Workshop on Non-Functional Properties and SLA Management in SOC (NFPSLAM-SOC’09), 2009.

[19] B. Sriraman and R. Radhakrishnan, “Event driven architecture augmenting service oriented architectures,” Report of Unisys and Sun Microsystems, 2005.

[20] H. Tran, T. Holmes, U. Zdun, and S. Dustdar, Modeling Process-Driven SOAs – a View-Based Approach, Handbook of Research on Business Process Modeling ed. IGI Global, Apr. 2009, ch. 2.

[21] H. Tran, U. Zdun, and S. Dustdar, “View-based and Model-driven Approach for Reducing the Development Complexity in Process-Driven SOA,” in International Conference on Business Process and Services Computing, ser. LNI, vol. 116. GI, 2007, pp. 105–124.

[22] ——, “View-based integration of process-driven soa models at various abstraction levels,” in First International Workshop on Model-Based Software and Data Integration. Springer, Apr. 2008, pp. 55–66.

[23] ——, “View-based reverse engineering approach for enhancing model interoperability and reusability in process-driven SOAs,” in 10th International Conference on Software Reuse (ICSR), ser. Lecture Notes in Computer Science. Springer, 2008, pp. 233–244.

# Appendix F

## Aiding Compliance Governance in Service-Based Business Processes

Patrícia Silveira, Carlos Rodríguez, Aliaksandr Birukou, Fabio Casati, Florian Daniel, Vincenzo D'Andrea, Claire Worledge, Zouhair Taheri

**Abstract:** Assessing whether a company's business practices conform to laws and regulations and follow standards and SLAs, i.e., compliance management, is a complex and costly task. Few software tools aiding compliance management exist; yet, they typically do not address the needs of who is actually in charge of assessing and understanding compliance. We advocate the use of a compliance governance dashboard and suitable root cause analysis techniques that are specifically tailored to the needs of compliance experts and auditors. The design and implementation of these instruments are challenging for at least three reasons: (i) it is fundamental to identify the right level of abstraction for the information to be shown; (ii) it is not trivial to visualize different analysis perspectives; and (iii) it is difficult to manage and analyze the large amount of involved concepts, instruments, and data. This chapter shows how to address these issues, which concepts and models underlie the problem, and, eventually, how IT can effectively support compliance analysis in Service-Oriented Architectures (SOAs).

# Appendix G

## Improving Health, Not Just Tracking It: A Personal Health and Lifestyle Platform[1]

Florian Daniel, Fabio Casati, Patrícia Silveira, Monica Verga and Marco Nalin

**Abstract:** We propose a personal health and lifestyle platform, that is, an active, social instrument to maintain an own, Personal Health and Lifestyle Record (PHLR) and to obtain personalized, lifestyle-related advice to improve health by changing daily habits. We leverage on the data stored in a typical PHR and equip such with environmental and sensor data that enable us to monitor and analyze an individual's habits. Sharing habits and advices with doctors and friends allows them and the individual to become wellness co-producers and leads to a PHLR that is indeed useful to the individual maintaining it.

### 1 Introduction

Modern medical practices have long recognized the importance of prevention as a means to maintain the health of an aging modern society and to cope with the growing burden on public healthcare systems. Especially in the context of so-called non-communicable diseases (NCDs), such as cancer, depression, diabetes, or cardiovascular diseases, prevention specifically focuses on improving the way people live their daily life [1] e.g., in terms of diet, physical activity, smoking, alcohol consumption, sleep patterns, and stress. That is, prevention is a matter of lifestyle.

In the EU FP7 project *Preve*[2] we are studying how individuals can be empowered with personal IT solutions and services that motivate them to manage and modify their lifestyles, in order to preserve health and wellbeing. Results so far clearly show that changing and maintaining new habits requires guidance and support. Such help is most effective when it comes from a variety of actors (we call them co-producers), such as healthcare professionals, but also friends, family, employers, schools, restaurants, or food markets, which, by pursuing their own goals, implicitly also support the individual.

---

[1] The original publication is available at www.computer.org/csdl/mags/ic/2011/04/mic2011040014-abs.html

[2] http://www.preve-eu.org

One of the IT instruments available are Personal Health Records (PHRs), which allow individuals to integrate, store, manage, and share their personal health information coming from different sources. Given that the actual producers of the different pieces of information, e.g., the health institutions, would never actively share "their" information with anybody else, maintaining a PHR is typically a labor-intensive, manual burden on the individual. Interestingly, however, a PHR targets health professionals like doctors or therapists and provides only little benefit to the individual who actually maintains the data.

In order to motivate individuals to improve their lifestyle, in this paper we propose a Personal Health and Lifestyle Record (PHLR) and a corresponding Personal Health and Lifestyle (PHL) platform that monitors and assesses lifestyles and provides (or facilitates health professionals in providing) personalized advice on how to improve lifestyles. As for now, we investigate the context of physical activity, yet the final goal is to support NCD prevention.

## 2 Advising Health Improvements: Scenario and Challenges

The initial steps of this work started as a joint effort with the Italian Cycling Federation by developing a GPS-based monitoring application for cyclists called *Pinkr*[3], which is able to track live the position of individual cyclists, to compute their instant power output and overall energy consumption, to share those data with others in real-time, and to provide nutrition advices to bikers. From this experience we learned three key lessons: First, sports people – even amateurs – are incredibly competitive, and they like to *monitor* their performance. Second, training for *competitions and sharing* of performances with other people (e.g., friends or trainers) and obtaining feedback boosts motivation. Third, they are very open to *advices* and willing to follow them to improve their performance.

This pushed us to extend *Pinkr* to support the following scenario: Alice is a young woman who likes to run occasionally. However so far she has neither been constant in her training nor did she have a particular goal in mind when running. She is rather healthy but affected by high blood pressure. Lately, she has gained some weight, so she has decided to run more. For better motivation, she has bet with a friend that she will be able to run a half marathon within four months of training and she has bought a GPS-equipped training watch to track her workouts. Alice has never trained for an event like this, so she needs a personal training plan that tells her which kind of workout she should do on which day of the week and for how many weeks, also in consideration of her health conditions. Experts can derive such kind of training plan by taking

[3] Live broadcast in National television of *Pinkr* at work during the Maratona dles Dolomites, Italy's most important international competition for amateur cyclists: www.youtube.com/watch?v=lzL_gcydjMc

into account the training objective (running a half marathon), her current physical preparation (beginner), and her health conditions. In order to track progress, it is important that Alice keeps a logbook or diary of all her workouts, considering that she will not always be able to train or to train on the planned day. In order to show her friend how close she is to winning the bet, Alice would like to allow her friend to have access to her progress.

Supporting this scenario means taking over the role of the expert who advises the training plan and aiding Alice in tracking her progress, which means solving a set of peculiar research challenges:

- We need to be able to *provide (semi-)automated health advice* (the training plan), starting from an individual's physical and health conditions. This also means that we need to be able to represent and match different kinds of advice.
- Doing so requires being able to *store and maintain a Personal Health and Lifestyle Record* (PHLR), which integrates health data, as can be found in traditional PHRs, with lifestyles and habits that may change over time.
- We need to be able to *automatically identify lifestyles or habits* (in this scenario that Alice is a beginner, but more in general this can refer to drinking, sleeping, or smoking habits for example) from low-level events, such as the workout logs that can be obtained from Alice's training watch.
- Therefore, we need to be able to *model habits and to express the necessary evaluation logic*. Particularly challenging is to come up with a model that can easily be understood and operated also by non-IT people, e.g., a trainer or doctor, in order to facilitate knowledge transfer into the platform.
- Finally, we need to be able to *monitor adherence with the advice*, in order to track progress, and to share this information with others, possibly allowing them to comment on Alice's performance and to provide feedback.

The PHL platform introduced in this article provides answers to these challenges and lays the foundation for lifestyle-oriented wellness and prevention, at the same time fostering and extending the idea of PHR.

## 3 State of the Art

PHRs [2] or Health Portals have been growing in the last years. Typically, current solutions allow users to view common sense information about diseases, participate in chats/forums with other users, receive exams results, and perform quick illness diagnosis tests. Examples of generic

PHRs are WebMD (www. webmd.com), Google Health (www.google.com/health), and Microsoft HealthVault (www.healthvault. com), this latter, for instance, providing features like Lose Weight (captures weight directly from the balance, processes it, and produces charts); Get Fit (captures data on pulse and run distances from training watches and graphically shows the performance); or Manage Blood Pressure (reads metrics from a blood pressure monitor and shows diabetes indicators). Solutions like Vivago (www.istsec.fi) for body signal monitoring or Polar (www.polar.fi) and Nike Plus (nikerunning.nike.com) for workout monitoring, instead, specifically focus on individual aspects only. Telemedicine [3] mostly focuses on cardiovascular diseases, e.g., on ECG monitoring. None of these approaches integrates collected data in a wider vision, models or tracks a person's lifestyle, or provides automated, remote health suggestions.

Integrating health data is a hard and critical task. Traditionally, health data have been collected via questionnaires, whereas recently large amounts of data are also obtained via sensors [4-6]. Sensor data typically are streaming data, raising new issues regarding their processing and integration. While there are generic middleware solutions for data stream processing, such as Hermes, ARMADA, Echo, and IBM's Gryphon, in the healthcare domain there are dedicated solutions like ReMoteCare [7] HARMONI [8], and Health Care Monitoring of Mobile Patients [9] Going beyond the mere integration of data, we aim to abstract sensor data into life events, in order to simplify data integration and to enable domain experts to operate such data at the right level of abstraction.

## 4 The Personal Health and Lifestyle Platform

We have seen that providing lifestyle-driven advice asks for features that go beyond conventional PHRs and, in particular, support multiple user roles, lifestyle data, habits, events, and active advice provisioning. Figure 1 illustrates the conceptual model (an extended UML class diagram) that underlies our PHL platform and addresses these issues. In the model, we distinguish between common practice (solid black lines) and the novelties introduced by the PHL platform (dashed orange and dotted blue lines).

According to the model, we define the core concepts of the PHL platform as follows:

> A *Personal Health Record* (*PHR)* is a collection that contains a *profile* of the person maintaining the PHR (e.g., comprising weight, height, gender, age), a set of *medical facts* (e.g., results of *exams*, *surgeries*, and the like), and a set of *diagnoses* (e.g., *allergies*, *diseases*, etc.).

A *Lifestyle Record (LR)* is a collection that contains a set of *habits* (like being a beginner in running or a light smoker) that characterizes the person's lifestyle at a given point in time. That is, a lifestyle is defined by a set of habits (in practice, a set of text labels).

A *Personal Health and Lifestyle Record (PHLR)* is the integration of a person's PHR with its LR.

Habits may be associated to a person either automatically, by deriving them from a set of *life events* measured on a person depending on the sensors available (they can range from simple sensors like GPS devices to monitor physical activities to more complex ones such as sleep sensors) or by having the person filling information manually. Habits are derived based on *habit models*, that describe how to aggregate life events (e.g., Alice's workouts) into actionable knowledge, i.e., habits.

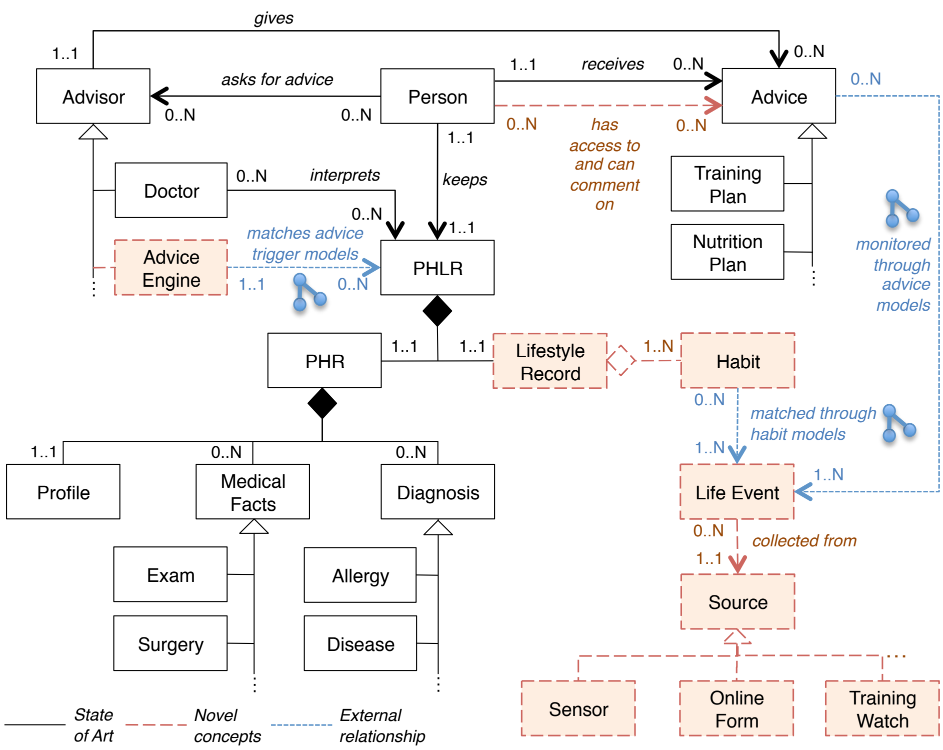



Figure 1 Concepts and features of the Personal Health and Lifestyle Platform.

The PHLR is used as input for providing lifestyle advices. Advices can be for the sake of prevention of NCDs that are strongly correlated with lifestyles may aim at achieving a certain physical goal in a manner that is mindful of health conditions. This is the case of Alice who wants to train for a half marathon, who is a beginner, and has high pressure. In this case the advice takes the form of a *training* or a *nutrition plan*. Advices can be given manually by *advisors* (a doctor or trainer) or automatically by an *advice engine*. The engine operates based on *advice trigger models* that are conceptually similar to sophisticated condition-action rules that monitor when a condition is verified on the PHLR (either a lifestyle condition or a lifestyle plus a goal as in the case of Alice) and trigger *advices*.

Once given, advices can be monitored via *advice models*, which are similar to habit models and allow the platform to correlate raw life events with the given advice. The goal is to automatically monitor how well the person is actually following a given advice or medical protocol or progressing toward a certain goal. For instance, we want to monitor Alice's progress toward her final goal, the half marathon.

Finally, each person may allow other people (e.g., friends, trainers, or doctors) to access their individual advices and possibly the related raw events (e.g., individual runs) and to comment on them, turning the PHL platform into a social instrument. It is here where the platform enables other people to become co-producers of health.

## 5 From Events to Habits to Giving and Monitoring Advice

While most of the concepts introduced above are either *data artifacts* (e.g., the PHR and the lifestyle record that jointly make up the PHLR) or *actors* (e.g., the advice engine and the doctor), the PHL platform also leverages three *models* that enable the customization of its health monitoring features: habit models, advice trigger models, and advice models. These models express, respectively, how to match habits, how to decide when to give an advice, and how to monitor a given advice – all by looking at both the data we have in the PHLR and at the life events tracked for each person. We collectively call these models *PHL models*. Via these models, the PHL platform becomes *extensible* toward different lifestyle-related concerns, spanning from sports to the prevention of NCDs.

In Figure 2 we illustrate two PHL models for the half marathon training scenario: one habit model (a) and one advice trigger model (b). The former expresses how to rank the running performance of a person; the latter decides which training plan is suitable for the person. The actual advice, e.g., the training plan, is modeled similarly, enabling the monitoring of progress or conformance with the advice.

The graphical formalism of PHL models is oriented toward *domain experts*, such as doctors, trainers, or dieticians, who have the actual knowledge necessary to characterize habits and advices, starting from a set of health conditions, habits, or life events. Yet, these are also people who do not have the knowledge to implement the pieces of software that are necessary to automatically evaluate such descriptions. This is a task that is performed by *IT experts*, who, by interacting with the domain experts, turn the non-executable, graphical representation into an automatically executable representation by implementing the necessary evaluation functions as web services or web pages and by binding the model to them through suitable model annotations.

Formally, PHL models are similar to *decision trees* and have a structure that can be described by the tuple $Model = <Name, ModelType, \{Node_i\}, \{Arc_j\}, \{Event_k\}>$, where *Name* is the unique name associated with the model, *ModelType* specifies whether the model is a "Habit", "Advice-Trigger", or "Advice" model, $\{Node_i\}$ is the set of nodes of the tree, $\{Arc_j\}$ is the set of arcs connecting the nodes in the tree, and $\{Event_k\}$ is the set of lifestyle events that may trigger the evaluation of the model.

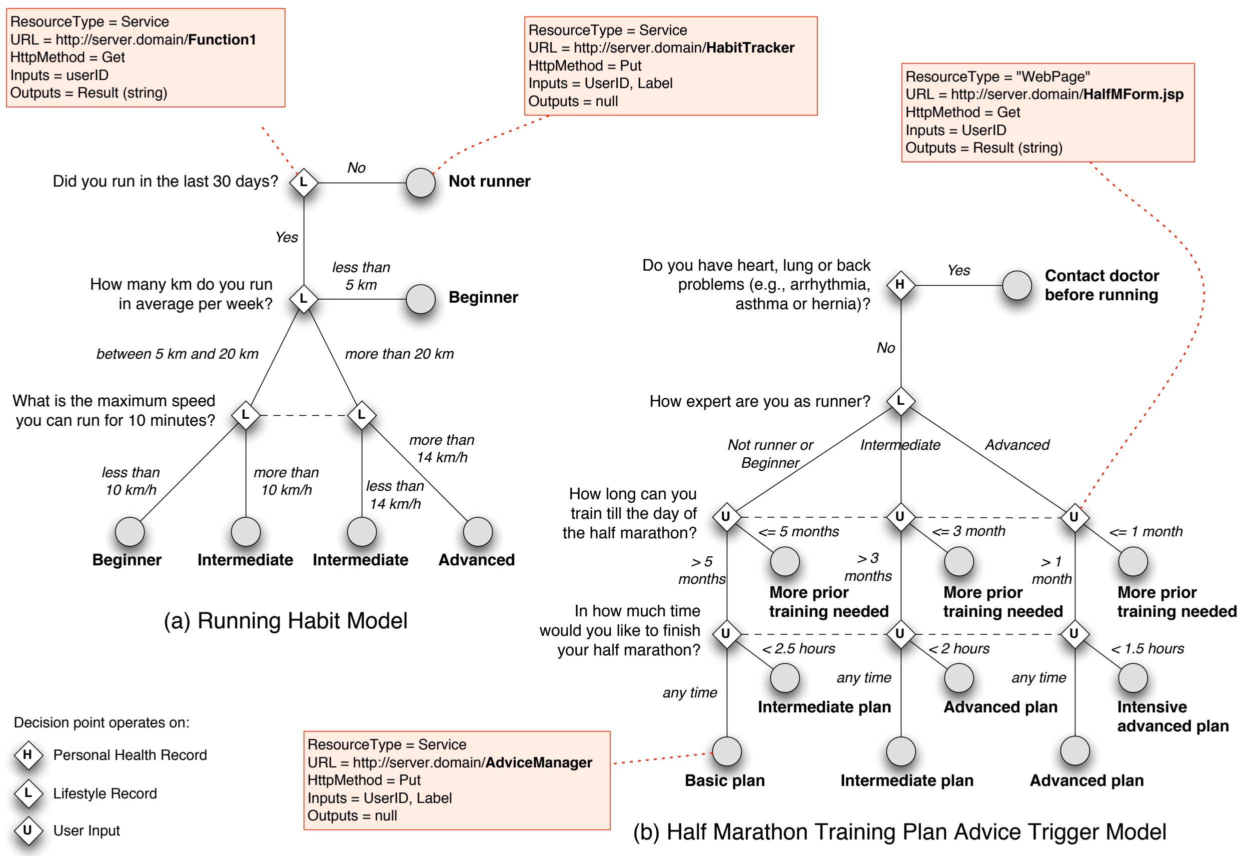



Figure 2 A habit and a trigger advice model. Dashed lines relate nodes with the same decision to be taken, i.e., the same service to be invoked. The text boxes exemplify how to annotate nodes in the tree.

A node is defined as $Node = <Label, NodeType, ResourceType, URL, HttpMethod, \{Input_m\}, \{Output_n\}>$, where *Label* contains the text label associated with the node (e.g., "Did you run in the last 30 days?"), *NodeType* is either "InternalNode" or "LeafNode", *ResourceType* is either "Service" (to invoke an evaluation function) or "WebPage" (to ask the user for explicit input via the PHL portal), the *URL* points to the respective web service implementing the decision logic or the web page allowing the user to input the necessary data, *HttpMethod* specifies whether the service/page needs to be invoked via a "Get", "Post", or "Put" operation (we use models only to create or update facts in the PHLR, so we do not support delete operations), $\{Input_m\}$ represents the set of input parameters of the service or page, and $\{Output_n\}$ represents the set of output parameters. Intermediate nodes always have at least one input parameter, i.e., the unique *UserID* of the user to be evaluated, and one output parameter, i.e., the *Result* of the evaluation.

In order to clarify which data each of the internal nodes operates on and to show how the evaluation of a PHL model may leverage on the integration of three types of data, i.e., PHR data, lifestyle data, and user input, in Figure 2 we explicitly label each node (see the legend in the lower-left corner of the figure). We use the labels only for presentation purpose, since in practice each service knows which data to look at, while web pages always represent user inputs.

Arcs are of the form *Arc = <Parent,Child,Condition>*, where *Parent* is the parent node in the tree, *Child* the child node, and *Condition* (label of the arch in the tree) allows the definition of a condition over the arc's parent's evaluation output. Conditions can be composed of basic comparison operators (<, <=, =, >=, >) for numbers and of = or <> for strings. For instance, the label "yes" after the first node in Figure 2(a) is to be interpreted as "Parent.Result = 'yes'?"

The *operational semantics* of such a PHL model is as follows: The evaluation of the model starts upon user request or in response to a triggering event. Then, starting from the root node, for each internal node we invoke the respective web service or page and evaluate the node's arcs against the result. Only arcs whose conditions are true are followed. A correct definition of a tree, therefore, requires the specification of mutually exclusive conditions for each arc. If a leaf node is reached, its web service is invoked, and the processing of the tree terminates.

In the next section, we provide some insights into the technicalities of PHL models, while from the domain expert's point of view it is important to recognize that modeling habits and advices is far from being easy, since it is an innovative, subjective, and not ICT-exclusive theme. A habit definition strongly depends on the doctor's personal interpretation and specialization and requires the cooperation of both the doctor and the IT expert. To carefully take into account each individual's needs and medical conditions, it might also be necessary to tailor PHL models to individuals.

To the best of our knowledge, there is no well-defined literature on this, and the platform, once multiple habit models are deployed, will allow us not only to monitor habits but also to validate the suitability of the deployed models. Experience will show which is the right level of granularity to adequately model habits, advice triggers and advices, and whether dependencies among models (e.g., between an advice and an advice trigger model of another advice) or more complex evaluation logics (e.g., non-exclusive conditions) need to be taken into account. In the training scenario considered so far this was not the case.

## 6 Architecture and Implementation

The PHLR and the PHL models are the core ingredients of our PHL platform, which enables individuals to keep their own PHR, to store lifestyle events, to have an automatically updated lifestyle record, to obtain and monitor health improvement advice, and to share their advices and monitoring pages with their health co-producers. Figure 3(a) details the functional architecture of the platform.

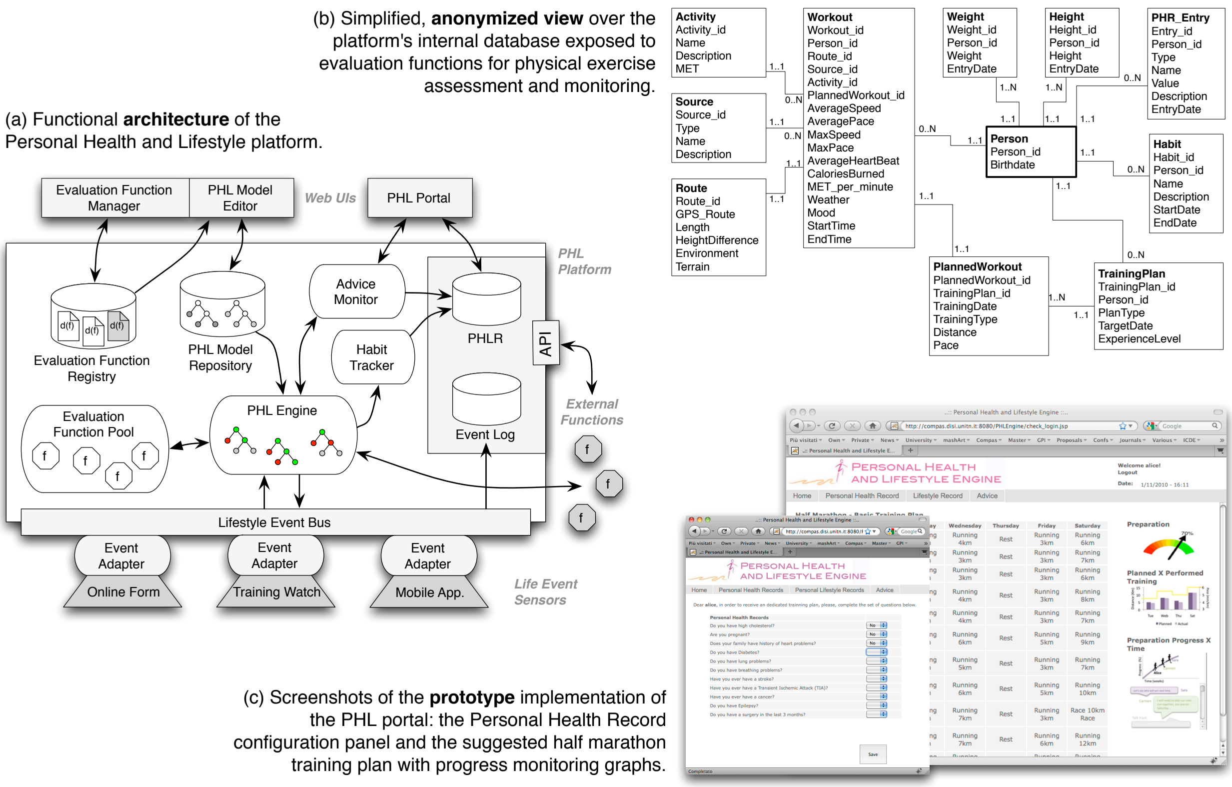



Figure 3 Architecture of the PHL platform, integration with evaluation functions, and screenshots of the PHL portal at work.

The core element of the platform is the *PHL engine*, i.e., the automated evaluator of PHL models. For a model to be monitored and evaluated it must be deployed in the engine and bound to its set of triggering life events. The engine constantly listens to the life events flowing through the *lifestyle event bus* and starts the evaluation of a model upon reception of a respective triggering event or user request. Life events may come from a variety of sources, such as online forms, training watches, mobile applications, electronic scales or glucometers, and similar, each of which requiring a suitable *event adapter* (in our prototype, so far we support the first three sources; for instance, a workout event is composed of its date, time, activity type, and the set of GPS coordinates of the running track). The deployment or termination of a new model in the engine causes the generation of a life event that can be used to trigger other models. For instance, Alice's training plan is paired with a nutrition plan that considers her high-pressure condition.

Once instantiated, a model's internal nodes are evaluated until a leaf node is reached. Each node causes the engine to interact with either a web service or a web page, depending on their annotation. Leaf nodes are associated only with services, i.e., either the *habit tracker* or the *advice monitor*. The former is in charge of adding and updating identified habits (e.g., if Alice advances from beginner to intermediate status). The latter is in charge of giving and monitoring advice.

Internal nodes may be associated with a web page to collect user input or they may be associated with an *evaluation function*, i.e., either a built-in or an external RESTful web service. Built-in services (e.g., the ones to assist the training scenario) are stored in the platform's *evaluation function pool*, while external functions can run remotely. In order for a service to perform its evaluation task, services have access to both the *PHLR* and the *event log*, providing a historical view over past events. In order to perform their evaluation, evaluation functions can securely access a restricted view over. The two repositories can be accessed securely via a dedicated *API*, which provides the evaluation functions with a restricted and anonymized view over them.

For instance, Figure 3(b) shows the read-only view that we use in the implementation of our prototype. The core entity is the person, which does not unveil any private information and only provides anonymous identifiers plus basic data that may be needed in the implementation of the functions. The PHR comprises the entities *Person*, *Weight*, *Height*, and *PHR_Entry* (e.g., the diagnoses); the lifestyle record the entity *Habit*. The event log is represented by the entities *Workout* (e.g., a run), *Activity* (e.g., running or cycling), *Source* (e.g., human input or sensor), and *Route* (the GPS tracks of the workout). The advice is instead represented by the *TrainingPlan* and *PlannedWorkout* entities. Answering the question "Did you run in the last 30 days" in

Figure 2(a), for instance, implies issuing to the view a query for workouts that have been registered in the last 30 days.

Once implemented, functions and PHL models are managed by the IT expert (via the *evaluation function manager* web application), who can store descriptors of the various evaluation functions, both built-in and external ones, so as to make them available for model design in the *PHL model editor*. Models are stored in an internal *PHL model repository*, which also supports the deployment of models in the PHL engine. The actual users of the PHL platform interact with the *PHL portal*, which is a web application providing access to all the platform's features. For instance, here Alice can manage her own PHR and upload her workouts, and she can inspect her progress and share her training plan with her friends (Figure 3(c)).

As noted earlier, unlike habits, which are tracked in the lifestyle record, advices and advice triggers may also require suitable web pages to gather user input and to communicate the advice and support monitoring and sharing. As for now, the UIs in Figure 3 are still hardcoded, yet it is our goal to enable the users themselves to visualize advice progress/conformance data via simple graphical widgets and to compose them, leveraging on our research done in [10]. This will allow us to fully decouple advice monitoring from its visualization.

Besides the PHL models themselves, the platform comes with three main *extensibility* points: First, implementing custom evaluation functions allows the plugging in of custom decision logic. Second, abstracting raw sensor data into life events enables the addition of new sensors and data sources, given a respective event adapter. Third, it is possible to extend the platform's internal database structure, e.g., to accommodate new PHR data or new types of life events. While this represents a more intrusive evolution, the sensible use of views to expose data limits the impact of these kinds of changes to a minimum.

As a first step toward the prevention of generic diseases, we fully support the training scenario described in this paper, also going beyond current training software (e.g., with automated progress monitoring). The implementation of the PHR is based on our former work on digital socio-sanitary records in the Province of Trento [11]. A continuously updated prototype of the PHL platform is accessible at http://compas.disi.unitn.it:8080/PHLEngine/lifestyle.jsp.

## 7 Conclusion

The initial findings for this work, both in the *Pinkr* deployment and then in the context of the EU projects *Preve* and *Cilmi* point to a very high potential for PHLRs and lifestyle engines. The *Pinkr* experience in the area of amateur cycling has shown the large potential impact of both social interaction and of continuous monitoring as persuasive techniques in lifestyle management and improvement. These experiences also point at the habit and advice models as viable techniques for defining how to derive lifestyles and analyze progress toward advices. Yet, we recognize that collecting lifestyle events and integration health data is far from being easy in general, from all the IT, the medical, and the legal perspectives, and that the prototype developed so far is not be able to scale up to thousands of users (which is also not yet needed).

What comes next is the validation of the approach in the NCD domain. The most exciting aspect of all this, which will drive our work as more users and sensors are added, lies however in enabling, through large-scale data collection and mining, the validation of the models (which in essence derive from medical knowledge in a given health or wellness domain) and the discovery of new models from life events and of interesting correlations between lifestyles and NCDs, as well as between models themselves.

**Acknowledgment**. This work has been partially supported by the EU Projects PREVE (FP7-ICT-248197) and CILMI (FP7-IRSES-247620).

**References**

1. World Health Organization. World health statistics 2010. ISBN 978 92 4 156398 7.

2. M. Ball, C. Smith, R. Bakalar. Personal Health Records: Empowering Consumers. Journal of Health¬¬care Inf. Management, 21(1), 2007, pp. 76-86.

3. T. L. Huston and J. L. Huston. Is telemedicine a practical reality? Commun. ACM, 43(6), 2000, pp. 91-95.

4. A. Yamaguchi, M. Ogawa, T. Tamura, T. Togawa. Monitoring behavior in the home using positioning sensors. Proceedings of EMBS’98, pp. 1977-1979.

5. M. van Gils, J. Pärkkä, R. Lappalainen, A. Ahonen, A. Maukonen, T. Tuomisto, J. Lötjönen, L. Cluitmans, I. Korhonen. Feasibility and User Acceptance of a Personal Weight Management Based on Ubiquitous Computing. Proceedings of IEEE EMBS’01, pp. 3650-3653.

6. J. Pärkkä, M. Van Gils, T. Tuomistol, R. Lappalainen, I. Korhonen. A wireless wellness monitor for personal weight management. Proceedings of IEEE EMBS’00, pp. 83-88.

7. M. Fischer, Yen Yang Lim, E. Lawrence, L. Ganguli. ReMoteCare: Health Monitoring with Streaming Video. Proceedings of ICMB’08, pp. 280-286.

8. I. Mohomed, M. Ebling, W. Jerome, A. Misra. HARMONI: Motivation for a health-oriented adaptive remote monitoring middleware. Proceedings of UbiHealth’06.

9. G. Amato, S. Chessa, F. Conforti, A. Macerata, C. Marchesi. Health Care Monitoring of Mobile Patients. ERCIM News, 60, 2005.

10. F. Daniel, F. Casati, B. Benatallah, M.-C. Shan. Hosted Universal Composition: Models, Languages and Infrastructure in mashArt. Proceedings of ER'09, pp. 428-443.

11. J. Stevovic, A. Chiasera, G. Armellin, T. J. Toai, D. Betti, F. Casati, G. Martinez. Event-driven privacy aware infrastructure for social and health systems interoperability: CSS platform. Proceedings of ICSOC'10, pp. 708-710.

# Appendix H

## ActiveLifestyle: an application to help elders stay physically and socially active[1]

Patrícia Silveira, Florian Daniel, Fabio Casati, Eva van het Reve, Eling D. de Bruin

**Abstract:** Age typically brings motor control impairments and loss of the lower body muscle strength, which can lead to falls, injuries and, in the worst case, death. It is well know that the practice of simple daily physical exercises can reduce the likelihood of falls, however, it is also known that it is far from easy to motivate elders to exercise, especially autonomously at home. To address this challenge, we have designed an app that not only makes it feasible and easier to follow a training plan for physical exercises, but that also introduces individual and social motivational instruments to increase the adherence to a plan – everything inside a virtual community composed of training partners, healthcare experts, and family members.

### 1 Introduction

The incidence of falls among older adults is high. Approximately 33% of the community-living elders fall at least once a year in developed countries (Deandrea et al. 2010). This percentage increases to 50%-70% for elders over 85 years old living in the same conditions (Iinattiniemi et al. 2009; Yeom et al. 2011). Falls can lead to injures, fractures, dependency to perform daily living activities, and, in the worst cases, to the elders' premature death.

As an attempt to decrease these numbers and promote elders' health, wellbeing, and independence, the Healthcare Community (i.e., physicians, gerontologists, and human movement scientists) strongly recommends a routine of physical exercises, more specifically strength and balance (Sherrington et al, 2008).

It is well known that being physically and mentally active implies many benefits to a person's health, while inactivity is at the origin of several chronic diseases (Katzmarzyk & Janssen 2004). However, people, and especially elders, typically don't know how to include even simple exercises in their routines, and they lack motivation. E.g., in Korea, even with strong support from the government and the healthcare system, only 9% of the elders practice vigorous physical ac-

[1] The final publication is available at www.iisi.de/fileadmin/IISI/upload/IRSI/IRSI-Vol9-Iss1-2012-finale.pdf

tivity, 10% practice moderate, and 48% practice walking (Yeom et al. 2011). Hence, the sole availability of money and training plans is not enough and the need for further studies to discover how to motivate elders to follow physical activities remains.

We introduce an IT-based solution for active and healthy ageing, named ActiveLifestyle app, that aims to improve elders' balance and strength and specifically aims to keep them motivated. For that, we propose a pro-active software for physical training that assists and monitors elders. The software comes with individual and social motivation features that aim to persuade elders to keep a routine of training exercises. The software was specifically designed for elders and runs on an iPad. The trainings and the design of the app were developed together with human movement scientists of the Institute of Human Movement Sciences and Sport at IBWS at ETH Zürich.

## 2 Example Scenario

As a fictitious scenario, let’s take Albertina (80), a healthy and alone living woman that has been presenting some difficulties to stand up quickly and has fallen some times in the last year. In order to prolong her independence and avoid serious injuries, her doctor prescribes an 8 weeks plan of balance and strength exercises.

According to the plan, the strength workout sessions must be done twice a week, starting with 6 warming-up, followed by 9 strength, and finalized by 3 stretching exercises. For each, she has to do a minimum number of sets (1-3) and repetitions (10-15). In some exercises weights are required (2-6kgs). In practical terms, Albertina needs to know which exercises she has to do every day and how (i.e., sets, repetitions or seconds, as well as the amount of weights). As Albertina is not used with the exercises, she might have an easy way to learn/remember them[2,3].

Albertina spends more than half an hour exercising the days she has to perform both sessions. Sometimes, following the rather repetitive, mechanical exercises is boring, and only her goal to remain independent is not always enough to maintain her motivation high. Supporting her to follow a plan of exercises autonomously at home therefore also means doing the work of a personal trainer and taking over planning of exercises, but also helping her track her progress and motivate her

[2] E.g. of balance exercise (Heel-to-toe walk) www.youtube.com/watch?v=krxw-1mfrDc
[3] E.g. of strength exercise (Chair stand) www.youtube.com/watch?v=RTXDWiCpSZQ

## 3 Requirements and Principles

The aforementioned barriers pushed us to extend our previous work (Daniel et al. 2011), developed to remotely assist and monitor runners during a marathon training plan, to support elders' strength and balance training plans. For that, we need to:

- design an interactive and friendly UI to be easily understood and managed by elderly users with no or only few computer skills;
- offer support for balance and strength training plans, informing the user when, what, and how to do each exercise;
- collect, process, store and report information to allow healthcare experts to remotely monitor the users' performance and compliance with the plan, their mood, and also detect eventual problems;
- allow remote communication between elders and healthcare experts;
- support motivation instruments to persuade elders to follow a plan.

Motivation is a very broad, multifaceted and complex topic that has been researched for ages by psychologists and sociologists without reaching an agreement about the real factors that motivate someone. Though, it is common to find research where motivation instruments have been successfully applied. In the IT field, we can mention the well-known work lead by Fogg (captolgy.stanford.edu) to motivate people to follow a certain behavior. As a first attempt we decided to follow his intrinsic and extrinsic motivation strategies (Fogg 2008):

*Intrinsic motivation* strategies are based on trigging someone to do something because it is inherently enjoyable for this person, independently of any external pressure. For example, by means of:

- goal-setting: establishing specific, measurable, achievable, realistic and time-targeted goals;
- self-monitoring: allowing people to monitor themselves to modify their attitudes and behaviors to achieve a predefined goal or outcome;
- creating awareness: showing the benefits of following a determined behavior or the progress toward a plan;
- conditioning though positive and negative reinforcement: immediately offering a reward/praise for someone after an expected behavior to encourage it and as a result increase the probability that it happens again, or the opposite, reprimanding whenever undesired behavior happened aiming to decrease the probability of a relapse.

*Extrinsic motivation* strategies are build on social psychology, in which other people can be the source of motivation. For example, by means of:

- competition: proposing a goal that can be shared and at least two parties strive to reach it;
- collaboration: offering a beneficial outcome that the involved parties con only achieve collaboratively;
- comparison: allowing a person to compare similarities and differences between two or more parties, people tend to keep equity in their relationships.

Another important requirement is to facilitate human computer interaction, since our elderly users not necessarily have computer and high cognition skills. Previous works pointed to the mouse as the main barrier to computer adoption among such class of users (Loureiro et al. 2011; Tsai & Shang 2009). To facilitate the adoption of our system, we have seen that the iPad as mobile device – if equipped with suitable, easy-to-use software – is very promising in the context of elderly people (e.g., relatively robust, and using fingers instead of a mouse makes the iPad much more intuitive and easy to use compared with smartphones, notebooks, or desktops).

## 4 Architecture and Implementation

Figure 1 shows the architecture of the ActiveLifestyle platform, and its main components are described in the paragraphs below.

The iPad ***ActiveLifestyle app*** is the core of the platform. It is responsible for the communication with the elder. The app supports the elder during the workout sessions (e.g., via videos and written details about the correct movements), collects their feedback (e.g., the number of performed sets, repetitions, and used weights, as well as mood and additional comments) to be further remotely monitored by the expert and used as input to compute metrics and set the motivation instruments. Using this app, the elder can also send/receive messages to/from his/her healthcare experts and friends. For more details watch our video available on the Web: youtu.be/Akvs13UMvfc and youtu.be/ MT0UCQD5Odo.

The ***ActiveLifestyle web portal*** (test.lifeparticipation.org/ActiveLifestyleWebPortal) allows healthcare experts to create training plans, associate them to users, manage communities, and remotely monitor the users' performance, as well as communicate to them whenever necessary to send motivational feedbacks.

Finally, the iPhone ***ActiveLifestyle Friend app*** allows the elder's friends to send and receive messages. In addition, the app can show the elder's performance, allowing the friends to monitor the elder and to provide feedback.

The applications and web portal invoke REST services and exchange JSON messages with the IT4LifeParticipation APIs. The UM API deals with authentication and user management issues. The What'sUp API controls the communication and social aspects (e.g., communities, messages exchange). Finally, the AL API manages the training plans, the motivation instruments, and the feedbacks of the users sessions. The event feeder consumes raw events (JSON messages) containing the details of the performed activities, parses them according to an event model, and transforms them into application events to be finally stored on the database.

The ActiveLifestyle platform makes part of the LifeParticipation project, which not only aims to help elders to stay physically fit, but also to feel useful to society and be socially involved. More information about it and a complete state of the art is available on our website site at lifeparticipation.org.

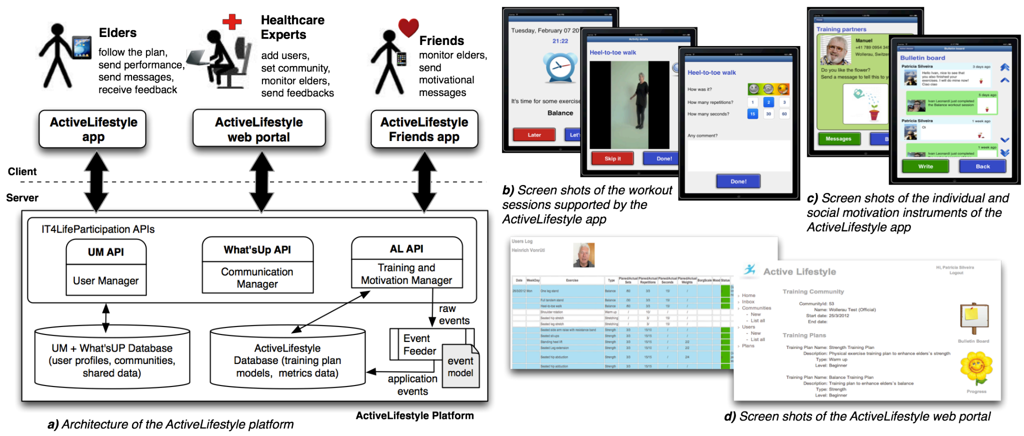



**Fig. 1. a)** Architecture of the ActiveLifestyle platform; **b-c)** Screen shots of the ActiveLifestyle app; and **d)** Screen shots of the ActiveLifestyle web portal.

## 5 Evaluation and Conclusion

To evaluate the ActiveLifestyle app, two tests are planned. At the moment we started the Feasibility Test, in which 15 Swiss elders (76-84 year old) are using the app during two weeks[4,5]. The test aims to evaluate the feasibility of the app and the iPad adoption by elders. To collect the results and evaluate our hypothesis we adopted three questionnaires (i.e., health, technology familiarity, and feasibility). The test is ongoing, but we are already very satisfied with the preliminary results. Most of the participants have been doing the exercises and sending enthusiastic comments. For example: *"I feel fine thanks to your help*; *"I have age. I did the exercises more bad than good. Hope you all do it better"*, *"The right leg is much stronger than the left leg! I feel*

[4] Teaser of the Feasibility Test: www.youtube.com/watch?v=pgyYSjAR6h4
[5] Höfner Volksblatt newspaper note: lifeparticipation.org/IT4LifeParticipation/news.pdf

*that the training is necessary"*; *"I'm glad my legs are not always so hard!"*). Apart of that, the participants already asked how to continue the exercises after the study, and one of them already bought an own iPad. So far, our participants seem very enthusiast. If this paper gets accepted, we will be able to present the complete results of our study in the final version and during the presentation.

In the second round, Physical Test, 30 elders will follow the physical plans for 12 weeks. At the first 6 weeks one sample will be supported by the app and the other not, and at the last 6 weeks we will switch this configuration to obtain a cross validated results. Apart from questionnaires, this second round includes a physical evaluation before and after the plan to measure their fitness and improvements.

We are strongly confident about the possible physical and social improvements that can be achieved with the ActiveLifestyle app. In the near feature, we will be working to add the missing motivation instruments and to fix the eventual issues raised during the on-going study to have a complete app for the second round of tests.

**Acknowledgments** Maria Messmer-Capaul of the Spitex Zürich and Corinne Heck of the Verenahof Informationsstelle für Altersfragem in Wollerau. At last, but not least, all the participants of the feasibility test for their great enthusiasm and support.

## References

Sherrington C, Whitney J, Lord S, Herbert R, Cumming R, Close J (2008) Effective exercise for the prevention of falls: a systematic review and meta-analysis. J Am Geriatr Soc 56(12):2234-43

Deandrea S, Lucenteforte E, Bravi F, Foschi R, Vecchia C, Negri E (2010) Risk Factors for Falls in Community-dwelling Older People: A Systematic Review and Meta-analysis. Epidemiology 21(5):658-668

Iinattiniemi S, Jokelainen J, Luukinen H (2009) Falls risk among a very old home-dwelling population. Scandinavian Journal of Primary Health Care 27(1):25-30

Yeom H, Jung D, Choi M (2011) Adherence to Physical Activity Among Older Adults Using a Geographic Information System: Korean National Health and Nutrition Examinations Survey IV. Asian Nursing Research 5(2):118-127

Daniel F, Casati F, Silveira P, Verga M, Nalin M (2011) Beyond Health Tracking: A Personal Health and Lifestyle Platform. Internet Computing, IEEE 15(4):14-22

Fogg B. (2008) Persuasive Technology: Using Computers to Change What We Think and Do. Boston (USA)

Katzmarzyk P, Janssen I (2004) The economic costs associated with physical inactivity and obesity in Canada: an update. Canadian journal of applied physiology (1):90-115

Tsai T, Chang H (2009) Sharetouch: a multi-touch social platform for the elderly. In the 11th IEEE Int. Conference on Computer-Aided Design and Computer Graphics, 557-560

# Appendix I

## Motivating and Assisting Physical Exercise in Independently Living Older Adults: A Pilot Study[1]

Patrícia Silveira, Eva van het Reve, Florian Daniel, Fabio Casati, Eling D. de Bruin

**Abstract:**

**Background:** With age, people tend to reduce their reaction time, coordination and cognition power, which may lead to gait impairments, falls and injuries. To reduce this problem in elderly and to improve health, wellbeing and independence, regular balance and strength exercises are recommended. However, elderly face strong barriers to exercise.

**Objective:** We developed ActiveLifestyle, an IT-based system for active and healthy ageing aiming to improve elderly's' balance and strength. ActiveLifestyle is a proactive training application, running on a tablet, which assists, monitors and motivates elderly to follow personalized training plans autonomously at home, while integrating them socially. The objective is to run a pilot study to investigate i) the feasibility of the ActiveLifestyle system for assisting the autonomous, physical training of independently living elderly, ii) the adherence of the participants to the training plans, and iii) the effectiveness of the motivation instruments built into the system.

**Methods:** After three introductory meetings, 13 elderly adults followed personalized two-weeks strength and balance training plans using the ActiveLifestyle app autonomously at home. Questionnaires were used to assess the technological familiarity of the participants, feasibility aspects of the app, and the effectiveness of the motivation instruments. Adherence to the exercise plan was evaluated using the performance data collected by the app during the study.

**Results:** A total of 13 participants were enrolled, of whom 11 (85%) completed the study (mean age 77 ± 7 years); predominantly females (55%), vocational educated (64%), and their past profession requiring moderate physical activity (64%). The ActiveLifestyle app facilitated autonomous physical training at home (median=7 on a 7-point Likert scale), and participants expressed a high intention to use the app also after the end of the study (median=7). Adherence with the training plans was 73% (89% on the balance exercises and 60% on the strength exercises). Without the app, the participants did not feel motivated to perform exercises; with the support of the app they felt more motivated (median=6). Participants were especially motivated by being part

[1] The final publication is available at www.sciencedirect.com/science/article/pii/S1386505612002390

of a virtual exercise group and by the capability to automatically monitor their performance (median=6 for both).

**Conclusions:** This study shows that the ActiveLifestyle app prototype has valuable potential to support physical exercise practice at home and it is worthwhile to further develop it into a more mature system. Furthermore, the results add to the knowledgebase into mobile-based applications for elderly, in that it shows that elderly users can learn to work with mobile-based systems. The ActiveLifestyle app proved viable to support and motivate independently living elderly to autonomously perform balance and strength exercises

## 1 Introduction

Health status is an important indicator of quality of life among older persons [1,2]. Especially functional performance, chronic conditions, and diseases, which directly influence fitness, are related to the perceived health among middle-aged and older adults [2-4]. Chronic diseases are, furthermore, leading causes of death and disability in both developed and developing countries [5,6]. Inactivity is at the origin of several chronic diseases [7]. Regular physical activity or exercise substantially prevents the development and progression of most chronic degenerative diseases [8, 9, 10], is of benefit to frail and older persons, and is the only therapy found to consistently improve sarcopenia, physical function, cognitive performance and mood in both frail and non-frail older adults [11]. For older people, a sedentary lifestyle also increases the risk of falls, whereas physically active older people have a clear reduced risk of falls with injuries [12]. In summary, it is evident that to increase older adults quality of life and fitness, we need to encourage the elderly to become more physically active [13].

There are, however, a variety of barriers that make it hard for elderly to maintain or increase their physical activity level. Neighborhoods and communities may be poorly designed or perceived as being unsafe, thus preventing elderly from leaving home [14-15]. Older adults may also have trouble getting to specialized facilities (e.g., community center for the aged) and physical training programs offered in such institutions [14-15]. General health care professionals (e.g., nurses, family physicians) may lack the time or expertise to address problems of physical inactivity among their older patients, and often lack information about quality programs, training materials, and how to make referrals to community resources [16]. Furthermore, elderly often express the desire for training support at home [17].

To promote health, wellbeing, and functional independence of the elderly, the specialized healthcare professionals (i.e., sport medicine, gerontologists, physiotherapists and human movement scientists) strongly recommends physical training programs that especially focus on traditional components of exercise such as muscle strength and balance [18]. Home environmental interventions that are based on different forms of assistive technology devices have, in this context, the potential to overcome some of the barriers to start training and maintain physical independence for independent living elderly [19]. However, the effectiveness of such an approach has not yet been demonstrated to a large extent. Modern exercise equipment may not always be suitable for elderly individuals, who might be concerned about the intensity of training sessions and may rather express to have a preference for more traditional therapy approaches [20]. New treatments usually have to go through a series of phases to test whether they are feasible, safe and effective [21]. It seems, therefore, necessary to perform a pilot study to assess the feasibility of applying assistive technology devices in an elderly population with the aim to encourage performance of targeted physical exercise. Findings of such a study can inform a larger scale main Phase III study [21].

The objective of this study is to run a Phase II pilot study according the model for complex interventions advocated by the British Medical Research Council [22] with an iPad-based app (short for *application*) called ActiveLifestyle, a software for the autonomous physical training of strength and balance for independently living elderly. We specifically aim to investigate i) the feasibility of the ActiveLifestyle system ii) the adherence of the participants to the pre-defined training plans, and iii) the effectiveness of the motivation instruments built into the system.

## 2 Methods

### 2.1 The ActiveLifestyle app

The ActiveLifestyle app is pro-active software for *active and healthy ageing* that assists and monitors elderly during autonomous physical workout sessions at home [23][24]. The software has been designed taking into account usability aspects to avoid frustration of non IT elderly experts users, and persuasive strategies to motivate elderly users to keep a routine of physical exercises.

Strength and Balance training plans are supported by the app. The *Strength* training should be done twice a week; it starts with 6 warm-up exercises, and is followed by 9 strength and 3 stretching exercises. There is a minimum number of sets (1-3) and repetitions (15-30) for each exercise. Some exercises also require the use of weights (2-6 kg). The *Balance* training should be done five days per week. Each session is composed of 3 exercises, in which the elderly repeatedly (1-3 times) holds a certain position for the duration of several seconds (15-30 sec). The training program follows best practices recommendations [25] and important training principles (e.g.

is progressive in nature) [26]. The training procedure is illustrated in Figure 2 and in a video [27].

**(a)** **(b)** **(c)**

**Figure 1**. **(a)** and **(b)** illustrate the *Chair stand* exercise (Strength); **(c)** shows the O*ne leg stand* exercise (Balance).

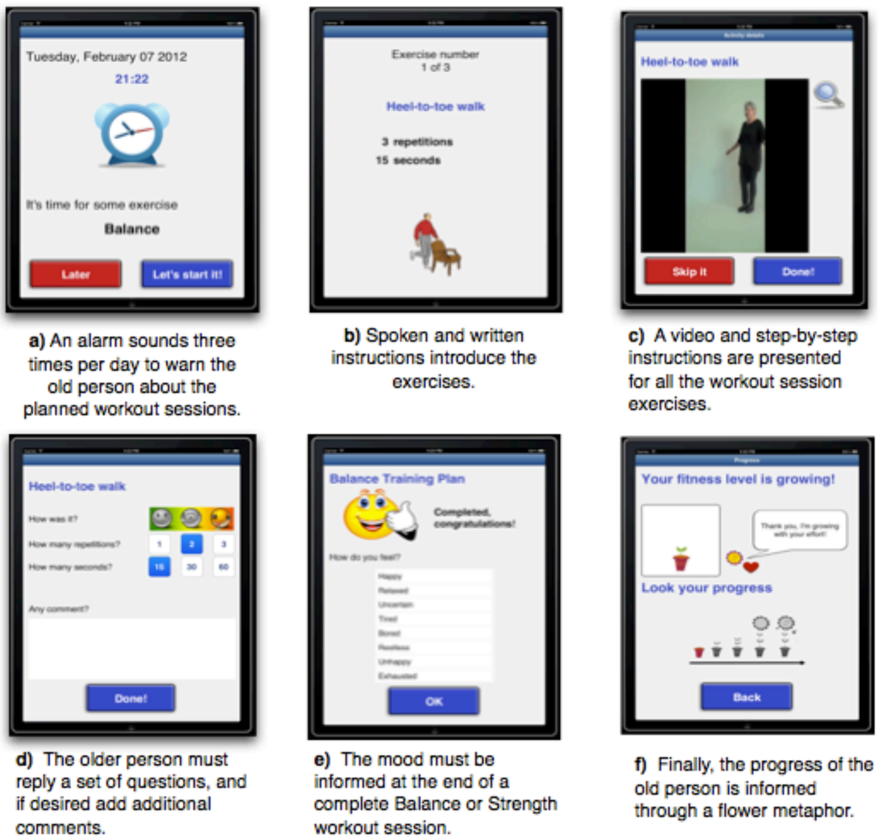



**Figure 2**. Main screenshots of the training plan procedure.

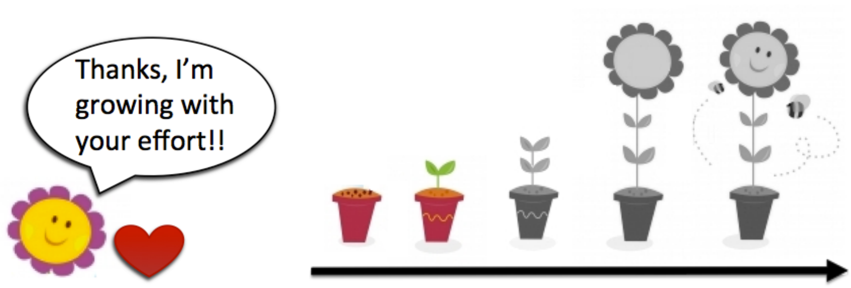
To motivate the elderly, the app supports *individual* and *social* motivation instruments [28].

*Individual* motivation strategies aim to convince someone to do something because it is inherently enjoyable for this person, independently of any social pressure. The app specifically supports:

- *Conditioning through positive and negative reinforcement*: that is, immediately offering a reward/praise after an expected behavior to encourage the behavior and to increase the probability that it happens again, or reprimanding whenever undesired behavior happened aiming to decrease the probability of a reoccurrence of the behavior. We use metaphors for positive and negative reinforcement, i.e., a flower that grows whenever a session is completed and that has a *mood status* that varies according to the person's daily compliance to the plan (see Figure 3.a), but the flower does not die or become ugly to avoid possible negative reactions on the users;

- *Goal-setting*: establishing specific, measurable, achievable, and time-targeted goals. In our case, we communicate the goal by anticipating the best achievable growth of the flower metaphor (see Figure 3.b);

- *Self-monitoring*: allowing people to monitor themselves and to modify their attitudes and behaviors. We show progress toward the goal by coloring the respective growth stage of the flower (Figure 3.b)




**a)** **b)**

**Figure 3**. Individual motivation instruments based on a flower metaphor.

*Social motivation* strategies are built on social psychology, in which an individual's social network (other trainees) is the source of motivation. For example, ActiveLifestyle uses:

• *Comparison*: allowing a person to compare similarities and differences between two or more parties, people tend to keep equality in their relationships. Whenever an old person completes a workout session, an automatic message is posted on a *Bulletin Board* to inform the training plan community (i.e., other users following the same training plans). The message also shows the status of the individual's flower metaphor.

• *External-Monitoring*: allowing one party to monitor the behavior of another party to modify behavior in a specific way. In ActiveLifestyle, healthcare and IT experts have access to data about the persons' performance and compliance toward the plan. The elderly users have access to their own flowers; however, they can also monitor the other flowers and consequently can monitor their progress toward the plan.

**2.2 Sample**

Participants were 70 years or older; able to walk independently with or without walking aids; able to follow instructions spoken in German, English, or Italian; and with no severe illness, cognitive impairment, progressive neurological diseases, stroke, severe cardiac failure, or high blood pressure.

**2.3 Settings**

Participants were recruited by convenience sampling from the "Informationsstelle fuer Altersfragen" in Wollerau, Switzerland. This institution, dedicated to deliver services and information related to ageing to the elderly population, issued 220 invitation letters, together with an information sheet outlining the research, inviting independently living elderly of the region to participate. Ethical approval for the study was obtained from the ETH Ethics Committee (EK 2011-N-64).

**2.4 Interventions**

During an initial meeting, all potential participants received information about the ActiveLifestyle app and about the study. Interested people filled a form and provided their personal contact data.

During a second meeting, participants were taught how to use the iPad and the app. To ease learning, user guides with written content, illustrations about the app and the iPad were provided.

During a third meeting, participants were taught how to perform the balance and strength exercises supported by the app. The same day, they also signed the consent form and replied health and technology familiarity questions. At the end of this meeting, participants received one resistance band, one Pilate's ball, and one pair of ankle weights (2kg). iPads with 3G SIM-card were borrowed to the participants.

After these three meetings, the participants started a two-weeks balance and strength training autonomously at home. To settle possible remaining obscurities, an additional meeting was scheduled on the second day of the training period. Contact information of our team members was provided to all participants in case of further obscurities or problems.

At the end of the two-weeks training period, a final meeting was held to conclude the study and collect the material previously borrowed. At this time, the participants replied questions regarding the feasibility, perceived usefulness, usability, visual attractiveness, and the effectiveness of the motivation instruments of the app.

### 2.5 Outcome Measures

The criteria for success, an important part of a pilot study [21], were based on the primary feasibility objective and focused on recruitment, attrition and adherence to the exercise. Values for these parameters were compared with median rates in falls prevention interventions in community settings for clinical trials [29], in which recruitment of 70% of the residents that are eligible for the training session, a 10% attrition rate, and 50% adherence to the individually targeted exercises were deemed acceptable.

For recruitment, data for the total sampling for inclusion in the trials were taken to assess generalizability to all elderly individuals within the community. We measured the inclusion rate — i.e. the proportion of participants invited to participate that enrolled into the study — and distinguished between those who refused, did not respond or who were willing but excluded (volunteered but did not meet the study inclusion criteria).

For attrition, we measured the number of participants lost at final follow-up.

For adherence to the intervention we recorded engagement with the intervention, e.g., compliance with all 4 strength and 10 balance training sessions. The adherence was computed by ActiveLifestyle during the intervention and stored into a central database.

The effectiveness of the motivation instruments built into the system were determined on the basis of the participants' feedback, collected with a 7-Point Likert Scale questionnaire at the end of the intervention (Table 1).

| Statement | Median (range) | Percentage Agreed |
|---|---|---|
| The ActiveLifestyle app facilitates the performance of strength and balance exercises autonomously at home. | 7(6-7) | 100 |
| **Use intention** | | |
| I would use the app again. | 7(6-7) | 100 |
| I would recommend the app to my friends and family. | 6(6-7) | 100 |
| **Perceived usefulness** | | |
| The videos assisted to properly perform the exercises. | 7(6-7) | 100 |
| The sound alarm helped to remind me about the planned workout sessions. | 4(3-7) | 45.4 |
| The calendar was useful to make me aware about which kind of workout session I need to perform every day. | 7(6-7) | 100 |
| **Motivation** | | |
| I usually don't feel motivated to perform physical exercises, the app helped me. | 6(3-7) | 63.6 |
| It was funny to me to carry out the strength and balance exercises. | 6(3-7) | 90.9 |
| I like the pictures of the flower. | 7(6-7) | 100 |
| I would prefer another picture instead of a flower. | 5(2-7) | 54.5 |
| **Individual Motivation Instruments** | | |
| I felt motivated when I saw the plant growing due to my performance. | 6(4-7) | 90.9 |
| I felt motivated when I saw my progress on the bar. | 6(4-7) | 90.9 |
| I felt motivated when I saw the emotional status of the flower. | 6(4-7) | 63.6 |
| **Social Motivation Instruments** | | |
| It motivated me to be part of a training group and to know that other people did the same exercises. | 6(4-7) | 90.9 |
| I usually compared my flower with others on the Bulletin Board. | 5(2-7) | 63.6 |
| I felt motivated to perform the plan because I knew that I was being monitored. | 6(2-7) | 63.6 |
| **Usability** | | |
| The operation of the application was easy. | 6(5-7) | 100 |
| I was able to use the app. | 7(6-7) | 100 |
| I was able to write messages on the Bulletin Board. | 4(2-7) | 45.4 |
| I was able to read messages from the Bulletin Board. | 6(6-7) | 100 |
| I was able to send messages to a person (InBox). | 6(4-7) | 63.3 |
| I was able to receive messages from a person (InBox) | 6(4-7) | 72.7 |
| I was able to navigate through the messages posted on the Bulletin Board using the scroll. | 7(4-7) | 90.9 |
| I felt nervous to use the app. | 3(1-7) | 18.1 |
| The application worked without any problems. | 6(2-7) | 72.7 |

**Table 1**. Characteristics of the participants.

*†A fall was defined as unintentionally coming to the ground or some lower level, excluding the consequence of sustaining a violent blow, loss of consciousness, or sudden onset of paralysis, such as during a stroke or epileptic seizure* [30].

### 2.5 Statistical Analyses

Descriptive statistics (Mann-Whitney U test) were used to assess baseline characteristics and analyze the questionnaires. All analyses were conducted using SPSS Version 18.0 (SPSS Inc., Chicago, IL, USA). Recommendations of items to include when reporting a pilot study [20] were followed for describing the results of this pilot.

| | Intervention (n=11) |
|---|---|
| Female gender, n (%) | 6/11(54.5) |
| Mean/Median age [range] (years) | 77.2/76 [70-85] |
| Vocational education, n (%) | 7/11(63.6) |
| Moderately physical activity past profession, n(%) | 7/11(63.6) |
| **Health Questions, n (%)** | |
| Estimated good health | 7/11(63.6) |
| Estimated middle balance | 5/11(45.5) |
| Feeling daily pain | 5/11(45.5) |
| Fell in the last six months† | 0/11(0) |
| Leisure time walking at least twice a week | 11/11(100) |
| Practiced some sport in the past | 7/11(63.6) |
| Never practiced strength exercises | 9/11(81.8) |
| Wanted to improve fitness | 7/11(63.6) |
| **Technology Familiarity, n (%)** | |
| Frequently use ATMs | 9/11(81.8) |
| Don't use books on tape or CD | 5/11(45.4) |
| Sometimes use cellphones | 6/11(54.5) |
| Don't use digital photography | 5/11(45.5) |
| Don't use electronic book readers | 5/11(45.5) |
| Don't use GPS | 5/11(45.5) |
| Don't use automatic kiosks | 6/11(54.5) |
| Use a computer | 9/11(81.1) |
| Between 1-5 hours per week | 4/11(36.3) |
| Use the Internet | 9/11(81.1) |
| Between 1-5 hours per week | 5/11(45.5) |

**Table 2**. Characteristics of the participants.

*†A fall was defined as unintentionally coming to the ground or some lower level, excluding the consequence of sustaining a violent blow, loss of consciousness, or sudden onset of paralysis, such as during a stroke or epileptic seizure* [30].

## 3 Results

### 3.1 Participant Demographics

Detailed information about the participant demographics is summarized in Table 2.

### 3.2 Feasibility of the ActiveLifestyle app

A total of 220 information letters were send. The first information session was held and visited by fourteen residents, who were all eligible and invited to participate. Thirteen residents consented to join the study. This resulted in a recruitment rate of 7% for the total sample frame. The inclusion rate — fourteen invited to participate; thirteen enrolled — was 93%.

Eleven elderly individuals participated during two-weeks training plan, which resulted in a 16% attrition rate. Two individuals were lost; one was disappointed for not receiving the iPad after the second meeting and the other because Wi-Fi connection problems. For adherence to the intervention we had 73% compliance with all 14 trainings (89% for balance and 60% for the strength exercises). There were no reports on adverse events during the training.

### 3.3 Effectiveness of the ActiveLifestyle app

All participants affirmed that the *ActiveLifestyle app facilitates the performance of balance and strength exercises autonomously at home*. This outcome is attested by their high *intention to use* the app again or to *recommend* it to friends or family members (100%, range 6-7). Some of the participants verbally expressed their disappointment with the end of the training period and the impossibility to continue it in the near future (at the moment the app is not yet available on the market).

The participants expressed a high-*perceived usefulness* of the training plan videos. According to some feedbacks, the videos are "…absolutely great" and "…very helpful", while others stated "I adjusted my posture based on them" or "the exercises were easy with the videos". One explanation for such high approval can be derived from the fact that most of the participants had never performed strength exercises before (82%).

Differently from the *Weekly Exercises Calendar* — a menu option in which the user can check the planned workout sessions on a weekly basis — considered useful by all users, the *sound alarm* was useful only to a few users (46%).

### 3.4 Effectiveness of the motivation instruments

Most of the participants generally do not feel *motivated* to perform physical exercises, but they felt motivated with the ActiveLifestyle app (64%). According to the participants, it was fun to follow the exercises with the app (91%). Their mood after doing the exercises was mostly relaxed (41%) or happy (25%).

The individual motivation instruments were very effective. Most of the participants *felt motivated when they saw the flower growing* or *could monitor their progress toward the plan* (91%

for both). At the end of the study, we noticed that the participants really appreciated the flower metaphor. When filling the questionnaires, most of them made spontaneous comments saying that it was lovely, “tender and cheerful”, or “a sunflower is funny, it makes you happy”. However, one woman suggested a racing car instead of the flower. According to her, the car is a perfect metaphor, since it also needs to get warm to work properly. The same high motivation was not achieved with the *mood status of the flower* (64%).

The social motivation instruments also achieved good results. The majority of the participants *felt motivated by being part of a training plan group* (91%). “I'm happy to see others doing the same exercises, I'm not a single athlete”. The monitoring and the flower comparison were similarly effective (64%). One woman said “I need someone to push me!”. Two participants checked their friends' flowers on the Bulletin Board every day and whether they did the exercises. However, another woman said “Of course not, I'm not nosy!” but she also told us “my husband and I always looked at the Bulletin Board to see if there was something interesting to read”. The same participants also reported “…after two days I could reach the same level of my husband, it made me happy”. From such results, we understood that our participants felt motivated by being part of a social group and by knowing that other people are doing the same exercises and facing the same kind of problems (e.g., pain, difficulties to wear the ankle weights). It was however possible to notice their interest to know how others were doing and to compare their performance with themselves, which can be explained by the human tendency to keep equality (Herzberg's equity theory [31]).

### 3.5 Usability

All participants were *able to use the ActiveLifestyle app* and agreed that *it is easy to use*. The scrolling and reading activities were performed by most of the participants. For instance, *navigate through the messages posted on the Bulletin Board using the scroll* (91%); *read the posts from the Bulletin Board* (100%); and *receive messages on the InBox* (73%, some participants never received a message, so they were not able to express their option about it). Although, the writing activities showed the same high usage, not all were *able to write private messages on the Bulletin Board* (64%) and *public* messages on *the InBox* (46%). Both messages are written following the same approach and appearance, the only difference is that the public messages can be read by all the elderly participants, as opposed to the private messages that are only available for selected persons.

Few participants *felt anxious to use the app* (19%). With further questions we discovered the reasons: One woman had problems to use the app alone the first day; after the extra meeting she, however, learned the use and was comfortable with it. Another woman performed the exercises very early in the morning when she usually has very cold fingers. Due to that, the tablet was not very effective to react to her touches.

**4 Discussion**

The aim of the current study was to investigate i) the feasibility of the ActiveLifestyle system ii) the adherence of the participants to the pre-defined training plans, and iii) the effectiveness of the motivation instruments built into the system.

We demonstrated the feasibility of acquiring acceptable attrition and adherence rates for independent living elderly to the experimental training. Our target of about 70% recruitment rate for the total sample frame was by far not met. Those individuals that responded and visited an information session, however, showed a large inclusion and adherence rate. These findings indicate the importance of recruitment strategies and information sessions for elderly individuals. The differing adherence for the strength and balance training components should be addressed in a revised version of our app. It might be that the balance part required less effort and was easier to perform in contrast to the strength exercises. Many participants made remarks about the load and the side effect of the strength exercises, e.g. some participants had difficulties to walk or had had surgery on the knee or hip and, therefore, could not perform the recommended number of sets.

The ankle weights were a stronger barrier to the adherence to the strength exercises. Apart from the effort required to lift the weights, most participants reported difficulties to wear and close them around their ankles. One man bought a new pair of weights that were easier to wear and close. Another woman mentioned “tie the weights is almost the hardest!”

Compliance with the intervention was excellent. Eleven of initially thirteen included elderly individuals completed the training. This is far more than the rate that could have been expected. It should be noted, however, that the mean compliance rate for interventions in independent living elderly that was determined for several studies summarized in a systematic review [26] mainly focused on studies with far longer time periods. Our data should, therefore, be replicated in another study where the intervention is applied during several training sessions over several weeks. It can be expected that because of such a longitudinal design less favorable compliance and retention rates are to be expected. Our findings warrant, however, such follow-up studies based on these first results.

Regarding motivation, we noticed that all participants felt motivated by making something grow with their effort and by receiving a simple reward (e.g., a new picture of the flower metaphor). We infer that positive reinforcement using the growing flower metaphor worked successfully, even if approximately half of the participants (55%) would prefer another metaphors. The selection of a metaphor is indeed very subjective and depends on the individual preferences of each participant.

About the low rate of writing activities we hypothesize two possible reasons. Firstly, participants did not know each other, so they did not feel very comfortable to write. Secondly, a minor part of them did not have good typing skills. For instance, one woman wrote once on the board but the message was impossible to understand, since it was not correctly written. When she was asked about the sending messages option, she said "I would write more, but for that I need to learn how to do it better", which is understandable, she is 81 years old and never used the Internet or a computer before.

### 4.1 Lessons learned

We conclude that the participants enjoyed and felt motivated to follow the training plans using the ActiveLifestyle app and an iPad. At the final meeting we received encouraging and motivating comments from the participants, e.g. their desire to continue using the app, their disappointment for not being able to perform the exercises in the last days (the training plan finished on Friday, and they tried to perform after that). One woman, used to perform exercises with a book ("Fit after 40"), commented, "the app is much better". For her the study was a motivating way to exercise. She and her husband took notes to continue the exercises even after the study. Another woman said that her doctor was impressed with the result of her cholesterol exam. The oldest man sustained a heart attack two years ago and stopped doing sports. According to him, "this was a great opportunity to reactivate" "…it was perfect. I noticed progress, especially on my balance". One person bought a tablet after the third meeting, and two expressed their intention to buy one soon and to install the app.

We learned that the motivations instruments worked. However, the social motivation instruments were not as effective as we expected. Most of our participants were not familiar with social networks and virtual friends. Due to that, they were initially not willing to share their thoughts and life with strangers. However, we assume that if they learn how to use the app to make friends, receive feedback from people experiencing the same aging effects, and find a way to keep close and share their thoughts and life with old friends and family members, they might change their attitude. For that we need to build additional motivation and encouragement (i.e., dedicated mechanisms or features, in which the elderly users have to reply questions, participate in a collaborative activity or comment on a specific topic). Another important aspect is to enable communication and sharing of information between the elderly and their younger family members. During the intervention, we had only six comments on the Bulletin Board, of which three were addressed to our IT expert. We received sixteen private messages with suggestions and general comments about the exercises/app (e.g., “I'm glad, my legs are not always so hard!” “The right leg is much stronger than the left leg! I feel that the training is necessary.”).

We also noticed that some of the participants felt very proud about using the tablet and shared this experience with their families. One woman showed the tablet and the app to her grandchildren, who were impressed: “our grandma has an iPad, wow!!!” The oldest woman received hints from her daughter about how to perform the heel-to-walk exercise; she had difficulties to walk along a straight line. Finally, another participant invited her sister to perform the exercises together. These results reinforce our intention to allow family members to interact with the elderly and to monitor their performance. We strongly believe that social and emotional support is a strong motivation instrument. This is a point of attention for the revised version of our app.

### 4.2 Limitations

This study had several limitations that should be mentioned. This work is a pilot study to assess the feasibility of our approach in a rather small sample, due to that we did not focus on recruitment strategies. For our experience we can conclude that sending letters to potentially qualifying elderly was apparently not a good strategy.

We also decided to start with a short training period to avoid risks (e.g., late detection of bugs that can cause a higher participants withdrawal, high investment to provide the tablets and 3G SIM-card Internet connections) and to collect novel requirements. In the next study we will also perform medical assessments of the physical conditions of participants before and after the study.

## 5. Conclusions

We conclude that pilot studies with explicit feasibility objectives are important foundation steps in preparing for large trials. On-going formal review of the multifaceted issues inherent in the design and conduct of pilot studies can provide invaluable feasibility and scientific data for IT developers and rehabilitation specialists alike, and may be highly relevant for furthering the development of theory driven mobile-based rehabilitation. This study shows that ActiveLifestyle has valuable potential to support physical exercise at home and it is worthwhile to further develop it into a more mature system. Furthermore, the results add to the knowledgebase into mobile-based applications for elderly, in that it shows that elderly users can learn to work with mobile-based systems. The ActiveLifestyle app proves feasible to support and motivate independently living elderly adults to autonomously perform balance and strength exercises at home. The app in a main study is deemed feasible with some need for protocol modifications regarding recruitment strategies, motivational instruments and information on strength exercises. In our further work we should more specifically examine the effectiveness of ActiveLifestyle on measures of physical functioning, with a longer training period, and a larger set of participants.

**Acknowledgements:** This work was carried out with the support of Maria Messmer-Capaul of the Spitex Zürich and Corinne Heck of the "Informationsstelle für Altersfragem". We would also like to thanks all the participants to the study for their great enthusiasm and support.

**References**

1. Spirduso WW, Cronin DL. Exercise dose-response effects on quality of life and independent living in older adults. Med Sci Sports Exerc 2001;33(6):598-608. PMID:11427784.

2. Johnson RJ, Wolinsky FD. The structure of health status among older adults: disease, disability, functional limitation, and perceived health. J Health Soc Behav 1993;34(2):105-121. PMID:8277124.

3. Malmberg JJ, Miilunpalo SI, Vuori IM, et al. A health-related fitness and functional performance test battery for middle-aged and older adults: feasibility and health-related content validity. Arch Phys Med Rehabil 2002;83(5):666-677. PMID:11994806.

4. Malmberg J, Miilunpalo S, Pasanen M, et al. Characteristics of leisure time physical activity associated with risk of decline in perceived health — a 10-year follow-up of middle-aged and elderly men and women. Prev Med 2005;41(1):141-150. PMID:15917005.

5. Beaglehole R., Ebrahim S, Reddy S, et al. Prevention of chronic diseases: a call to action. Lancet 2007;370(9605):2152-2157. PMID:18063026.

6. Yach D, Hawkes C, Gould C, et al. The global burden of chronic diseases: overcoming impediments to prevention and control. JAMA 2004;291(21):2616-2622. PMID:15173153.

7. Katzmarzyk PT, Janssen I. The economic costs associated with physical inactivity and obesity in Canada: an update. Can J Appl Physiol 2004;29(1):90-115. PMID:15001807.

8. Chodzko-Zajko WJ, Fiatarone SM, Monson CT, et al. American College of Sports Medicine position stand. Exercise and physical activity for older adults. Med Sci Sports Exerc 2009;41(7):1510-1530. PMID:19516148.

9. Stuart M, Chard S, Benvenuti F, et al. Community exercise: a vital component to healthy aging. Healthc Pap 2009;10(1):23-28. PMID:20057213.

10. Anonymous, Physical Activity Fundamental To Preventing Disease, U.S.D.o.H.H. Ser-vices, Editor. 2002, U.S. Department of Health & Human Services: Washington.

11. Landi F, Abbatecola AM, Provinciali M, et al. Moving against frailty: does physical activity matter? Biogerontology 2010;11(5):537-45. PMID:20697813.

12. Thibaud M, Bloch F, Tournoux-Facon C, et al. Impact of physical activity and sedentary behaviour on fall risks in older people: a systematic review and meta-analysis of observational studies. Eur Rev Aging Phys Act 2011;8(1). DOI:10.1007/s11556-011-0081-1.

13. Ferrucci L, Baldasseroni S, Bandinelli S, et al. Disease severity and health-related quality of life across different chronic conditions. J Am Geriatr Soc 2000;48(11):1490-1495. PMID:11083330.

14. Zunft HJ, Friebe D, Seppelt B, et al. Perceived benefits and barriers to physical activity in a nationally representative sample in the European Union. Public Health Nutr. 1999;2(1A):153-60. PMID:10933635.

15. Schutzer KA, Graves BS. Barriers and motivations to exercise in older adults. Prev Med. 2004;39(5):1056-1061. PMID:15475041.

16. Anonymous. Physical Activity and Older Americans: Benefits and Strategies. Agency for Healthcare Research and Quality and the Centers for Disease Control. 2002. http://www.ahrq.gov/ppip/activity.htm.

17. Eckert JK, Morgan LA, Swamy N. Preferences for Receipt of Care Among Community-Dwelling Adults. Journal of Aging and Social Policy 2008;16(2):49-65. PMID:15148044.

18. Sherrington C, Whitney JC, Lord SR, et al. Effective exercise for the prevention of falls: a systematic review and meta-analysis. J Am Geriatr Soc 2008;56(12):2234-2243. PMID:19093923.

19. Mann WC, Ottenbacher KJ, Fraas L, et al. Effectiveness of assistive technology and environmental interventions in maintaining independence and reducing home care costs for the frail elderly. A randomized controlled trial. Arch Fam Med. 1999;8(3):210-217. PMID:10333815.

20. Laver K, Ratcliffe J, George S, et al. Is the Nintendo Wii Fit really acceptable to older people?: a discrete choice experiment. BMC Geriatr; 2011;11:64. DOI:10.1186/1471-2318-11-64.

21. Thabane L, Ma J, Chu R, et al. A tutorial on pilot studies: the what, why and how. BMC Medical Research Methodology 2010;10(1):1-10. PMID:20053272.

22. Craig P, Dieppe P, Macintyre S, et al. Developing and evaluating complex interventions: the new Medical Research Council guidance. Brit Med J. 2008;25:337(7676). DOI:10.1136/bmj.a1655.

23. Silveira P, Daniel F, Casati F, et al. ActiveLifestyle: an application to help elderly stay physically and socially active. FoSIBLE Workshop at COOP2012 (in press).

24. LifeParticipation Project. 2012. http://www.lifeparticipation.org/active.html.

25. Cress ME, Buchner D, Prohaska T, et al. Best practices for physical activity programs and behavior counseling in older adults populations. J Aging Phys Act 2005;13(1):61-74. PMID:15677836.

26. Kraemer WJ, Ratamess NA. Fundamentals of resistance training: progression and exercise prescription. Med Sci Sports Exerc 2004;36(4):674-688. PMID:15064596.

27. ActiveLifestyle app. 2012. http://www.youtube.com/watch?v=Akvs13UMvfc.

28. Fogg BJ. Persuasive Technology: Using Computers to Change What We Think and Do. Boston USA: Morgan Kaufmann Series in Interactive Technologies 2008. ISBN:1-55860-643-2.

29. Nyman SR, Victor CR. Older people's participation in and engagement with falls prevention interventions in community settings: an augment to the Cochrane systematic review. Age and Ageing 2012;41(1):16–23. PMID:21875865.

30. Gibson MJ, Andres RO, Isaacs B, et al. The Prevention of Falls in Later Life — a Report of the Kellogg International Work Group on the Prevention of Falls by the Elderly. Dan Med Bull;1987;34:1-24. PMID:3595217.

31. Herzberg F, Mausner B, Snyderman BB. The Motivation to Work. John Wiley. New York, USA: Transaction Publishers; 1959. ISBN:978-1560006343.

# Appendix J

## Tablet-based strength-balance training motivates and improves adherence to exercise in independently living elderly: a controlled clinical trial[1]

Patrícia Silveira, Rolf van de Langenberg, Eva van het Reve, Florian Daniel, Fabio Casati, Eling D. de Bruin

**Abstract:**

**Background:** Reaction time, coordination and cognition power typically diminish when we grow old, which may lead to gait impairments, falls and injuries. Regular strength-balance exercises are highly recommended to reduce this problem and to improve health, well-being, and independence at old age. However, many elderly face lack of motivation, in addition to other strong barriers to exercise. We developed ActiveLifestyle, an IT-based system for active and healthy ageing aiming at improving balance and strength. ActiveLifestyle is a training application that runs on a tablet and assists, monitors, and motivates elderly to follow personalized training plans autonomously at home.

**Objectives:** Run a 12-weeks study to investigate i) which IT-mediated motivation strategies increase adherence to physical exercise training plans in elderly; ii) whether ActiveLifestyle induces physical activity behaviour change; and iii) the effectiveness of the ActiveLifestyle training to improve gait speed.

**Methods:** 44 elderly adults followed personalized 12-weeks strength and balance training plans. All participants performed the exercises autonomously at home. Questionnaires were used to assess the technological familiarity, stage of behaviour change, as well as the effectiveness of the motivation instruments. Adherence to the exercise plan was evaluated using performance data collected by the application and through information given by the participants during the study. Pre- and post-tests were performed to evaluate gait speed of the participants before and after the study.

**Results:** Participants were 75 ± 6 years; predominantly females (64%), vocational educated (54%), and their past profession was in a sitting position (43%). A total of 44 participants were enrolled, of which 33 (75%) completed the study. The application proved to assist and motivate

[1] This work was submitted to the Journal of Medical Internet Research and it under review at the moment - http://www.jmir.org

independently living and healthy elderly adults to autonomously perform strength-balance exercises (median=6 on a 7-point Likert scale). The social motivation strategies were more effective to motivate the participants to comply with the training plan, as well as to change their behaviour in order to be more physically active. The exercises were effective to improve preferred and fast gait speed.

**Conclusions:** ActiveLifestyle assisted and motivated independently living and healthy elderly to autonomously perform strength-balance exercises during 12 weeks and had low dropout rates. The social motivation strategies were more effective to stimulate the participants to comply with the training plan and remain on the intervention. The adoption of assistive technology devices for physical intervention tends to motivate and retain elderly people exercising for longer periods of time.

## 1 Introduction

The primary public health goal is to increase the number of years of good health and, therefore, to maintain independence and quality of life as long as possible. Healthy ageing is characterized by the avoidance of disease and disability, the maintenance of high physical and cognitive function, and sustained engagement in social and productive activities. These three components together define *successful ageing* [1].

An important part of successful ageing, hence, is maximization of physical performance. The ability to fully participate in productive and recreational activities of daily life may be affected when the capacity to easily perform common physical functions decreases [1]. Health status, thus, is an important indicator of quality of life among older persons [2-3]. It appears that especially components of health-related fitness and functional performance, or serious, chronic conditions and diseases that directly influence the components of fitness and performance are related to perceived health among middle-aged and older adults [3-5].

Regular physical activity or exercise substantially prevents the development and progression of most chronic degenerative diseases [6-8], is of benefit to frail and older persons, and is the only therapy found to simultaneously improve sarcopenia, physical function, cognitive performance, and mood in older adults [9]. For older people, a sedentary lifestyle also increases the risk of falls, whereas physically active elderly have a reduced risk of falls with injuries [10-12]. An important marker for improvements in physical function that influences health status and survival is gait speed [13]. In summary, it is evident that to increase older adults' quality of life and fitness, we need to encourage the elderly to become more physically active [14-15] and increase their fitness through training.

Home environmental interventions to prevent functional decline seem to be effective [16] and are, furthermore, preferred by elderly [17]. Such interventions with integrated assistive technology devices have, in this context, the potential to further help in overcoming some of the barriers to start training [18] and, thereby, maintain physical independence for independently living elderly [19]. Recently developed innovative ideas designed to alter clinical practice in sports involved the creation of tablet applications for prevention purposes [20]. However, the effectiveness of such an approach has not yet been demonstrated in elderly. From a pilot study, run using the ActiveLifestyle tablet application, we know that it is feasible to apply assistive technology devices in an elderly population with the aim of encouraging performance of physical exercise [18]. However, this short duration pilot did not focus on aspects of physical functioning, and indicated that the application could be improved by explicitly considering additional motivational strategies. Only few solutions explore different motivation techniques to stimulate regular physical activity [21-22], however, these solutions have the drawback that they do not specifically focus on elderly. Albaina et al. [23] presented a user-friendly software interface running on a small touch screen display to motivate elderly to walk. They used a graphical representation of flower to motivate and assist elderly to monitor their daily amount of steps collected by pedometers. To the best of our knowledge there is no such software application applied to dedicated strength-balance training plans for elderly.

The objective of this research is to run a Phase III study [24] with a tablet application called ActiveLifestyle, a software for the autonomous strength-balance physical training for independently living elderly. We aim to investigate i) which IT-mediated motivation strategies increase adherence to physical exercise training plans in elderly; ii) whether ActiveLifestyle induces physical activity behaviour change; and iii) the effectiveness of ActiveLifestyle training to improve gait speed.

## 2 Methods

### 2.1 ActiveLifestyle

ActiveLifestyle is a software for active ageing, aiming at assisting, monitoring and motivating elderly during autonomous home-based physical workouts [18, 25-26]. The software takes usability aspects into account, to ensure that users can use it independently and adopts motivation strategies to stimulate elderly users to exercise regularly. A video of the application is shown in [27], and the application can be directly downloaded from Apple’s App Store [28].

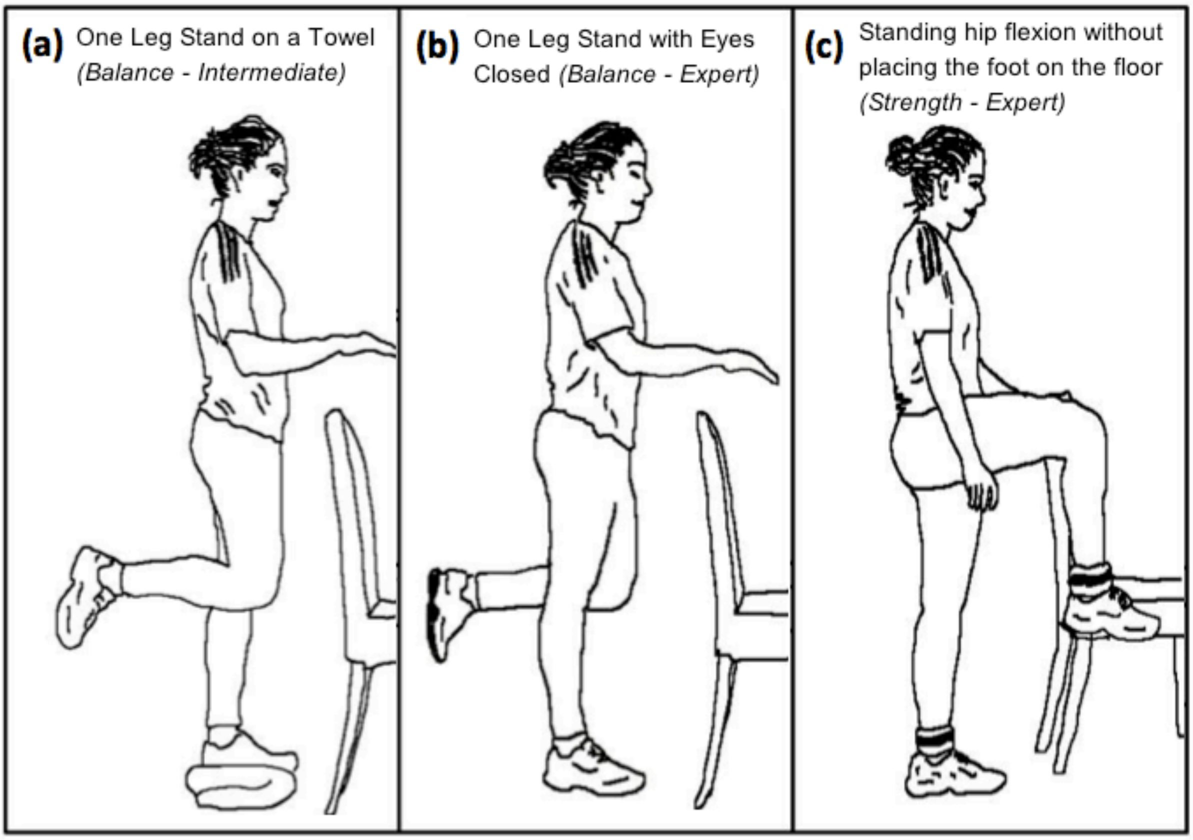



Figure 1. Exercise examples.

Three levels of Strength-Balance training plans are supported: Beginner, Intermediate, and Expert. In all levels, the Balance training should be done five days per week. Sessions are composed of 3 exercises, in which the trainees repeatedly (1-3 times) hold a certain position for several seconds (15-30 sec). Each level has different exercises, allowing progression as the elderly advance through the levels (e.g., at the intermediate level the elderly must do the exercises while standing on a towel; at the expert level the exercise must be performed with the eyes closed). Strength training has three levels and should be done twice a week; starting with 6 warm-up exercises, then 10 strength and 2 stretching exercises. A minimum number of sets (1-3) and repetitions (12-30) are available for each exercise. Some exercises require the use of weights (2-6 kg). The required effort of the exercises increases ac-cording to the level (e.g., beginner level does not require weights; intermediate level requires ankle weights and performance in sitting position; expert level requires weights and exercises performed in standing position).

The Strength-Balance training follows best practices recommendations and training principles (e.g., it is progressive in nature) [29-30]. The training procedure is visualized at [27] and all exercises are available on YouTube [31].

Next to the actual physical training, ActiveLifestyle features have a set of individual and social motivation instruments. *Individual motivation* strategies aim to convince someone to do something because it is inherently enjoyable for this person, independently of any social pressure. ActiveLifestyle supports:

- *Conditioning through positive and negative reinforcement*: immediately offering a reward/praise after an expected behaviour to encourage the behaviour and increase the probability that it happens again, or reprimanding undesired behaviour to decrease the probability of a reoccurrence of that behaviour. Metaphors for reinforcement include a flower that grows whenever a session is completed (i.e., positive reinforcement) and a gnome who takes care of the flower. The gnome's mood status varies according to the person's daily compliance to the plan (i.e., positive and negative reinforcement, if the person performs the exercise the gnome is happy, otherwise he is sad) (see Figure 2.a).

- *Goal-setting*: establishing specific, measurable, achievable, and time-targeted goals. The goal is anticipated through the achievable growth of the flower (Figure 2.b).

- *Self-monitoring:* allowing people to monitor themselves and to modify their attitudes and behaviours. Colouring the respective flower growth stages reflects progress to-ward the goal (Figure 2.b).

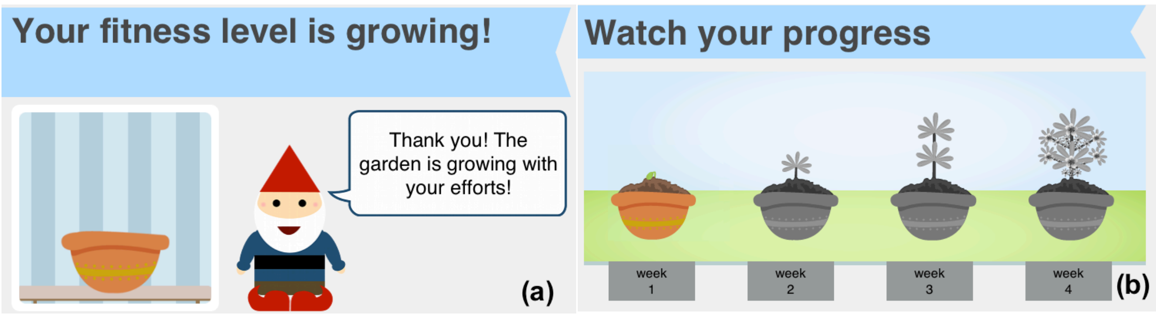



Figure 2. Metaphors to motivate elderly through conditioning, goal-setting, and self-monitoring.

- *Awareness*: improving awareness about the benefits of being physically active by providing written content on a Bulletin board and by showing inspiring stories (e.g., link to newspapers, videos, or websites) (Figure 3).

*Social motivation* strategies are built on social psychology. An individual's social network (other train-ees) may act as source of motivation. ActiveLifestyle uses:

- *Comparison*: allowing a person to compare similarities and differences between two or more parties, people tend to keep equality in their relationships. Whenever a person completes a workout session, an automatic message is posted on a Bulletin board in-forming the training community (i.e., other users following the same training plans). The message also shows the status of the individual's flower.

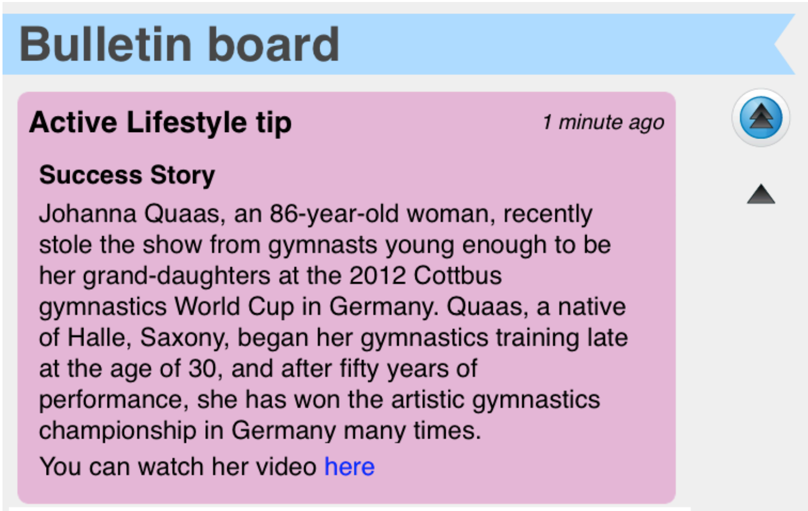



Figure 3. ActiveLifestyle tips to improve awareness about the benefits of being physically active.

• *External Monitoring*: allowing one party to monitor the behaviour of another party to modify behaviour. ActiveLifestyle enables healthcare experts to access data on performance and compliance toward the plan. The elderly have access to their own flower and to that of their training partners, enabling monitoring progress of peers toward the plan.

• *Emotional Support*: encouraging exchange of written messages between trainees and experts to motivate and assist. ActiveLifestyle uses the Bulletin board and the inBox. The first is a public channel where all members of the training community have ac-cess. The second is a bidirectional private channel for contact with professionals capable of giving advice and feedback on trainings.

• *Collaboration*: offering a collaborative activity set out as a game, in which a predefined amount of trainees from a training group needs to be compliant with the training in order to progress in the game. The To-the-Top-game is a trekking trail with 24 predefined points (2/week). The aim of the game is to reach the top of the mountain as a group of successful trainings end. Compliance with the training plan is evaluated twice weekly on group level. 65% of members or more of a group have to perform the scheduled workout to be awarded a new flag on the trail (representing progress toward the mountain top). Each flag uncovered a story with trivia about the Matterhorn and what is needed to "conquer" the mountain as a parable for the information explaining benefits associated with being physically active (Figure 4).

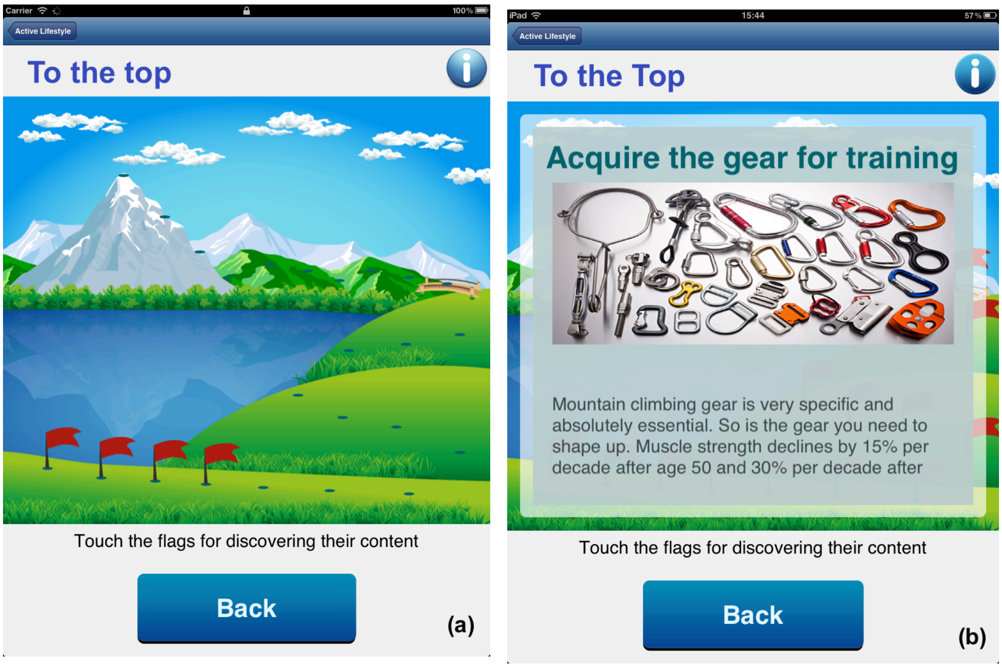



Figure 4. The To-the-top collaboration game.

ActiveLifestyle has two versions. The Individual version contains only the above mentioned individual motivations strategies. The Social version supports the aforementioned individual and social motivation strategies, and, in addition, a virtual training plan community and communication features.

### 2.2 Eligibility Criteria

Participants were independently living elderly 65 years or older; able to walk independently with or without walking aids; able to follow instructions spoken in German, English, or Italian; and with no severe illness, cognitive impairment, progressive neurological diseases, stroke, severe cardiac failure, or high blood pressure. Ethical approval for the study was obtained from the ETH Ethics Committee (EK 2011-N-64).

### 2.3 Setting

Participants were recruited by convenience sampling from two institutions for the elderly and one organization responsible for coordinating and providing at-home-nursing-care for elderly. “Senioren Begegnungszentrum Baumgärtlihof”, a day centre dedicated to deliver services and information related to ageing to the elderly population (Horgen, Switzerland), advised potential participants through its mailing list and by notes in the local newspaper [a]. "Alterswohnungen Turm-Matt", a cooperative offering housing and daily living facilities to elderly (Wollerau, Switzerland), informed and advised potential participants in person or by phone and distributed flyers to advertise the study. “Fachstelle für präventive Beratung Spitex-Zürich”, a home-care nursing organization (Spitex-Zürich), promoted the study sending letters and calling patients in need of improving their physical performance level. Spitex nurses selected potential participants on the basis of clinical judgment.

## 2.4 Intervention

To investigate the effects of different motivation strategies a pre-test post-test clinical trial was performed. For convenience, the ActiveLifestyle groups were randomly composed of participants from Baumgärtlihof and Spitex-Zürich in: i) an Individual Group that followed training using the Individual version of ActiveLifestyle; ii) a Social Group that followed training using the Social version of the application, iii) a Control Group that followed exercises with printed information without additional motivation strategy (this group was composed of participants from Turm-Matt only). Figure 5 shows the recruitment process and the flow of participants through the study. Some parts of the interventions can be watched in [32].

## 2.5 Outcome Measures

### 2.5.1 Adherence and Attrition

Adherence was computed by ActiveLifestyle during the intervention and stored into a central database. The control group adherence was assessed with training logs. In order to calculate adherence, the total number of workout sessions for each participant was divided by 81, which was the total number of possible training sessions for the 12-weeks period (due to technical issues the training was suspended for three days and the trainees were aware of the 81 training sessions in advance). Adherence of participants lost because they dropped out was calculated by dividing the number of workout sessions attended up to the point of dropout from the study by 81 [33]. Values were compared between groups and with median rates in community-based fall prevention interventions [34]. For attrition, we measured the number of participants retained and lost at final follow-up.

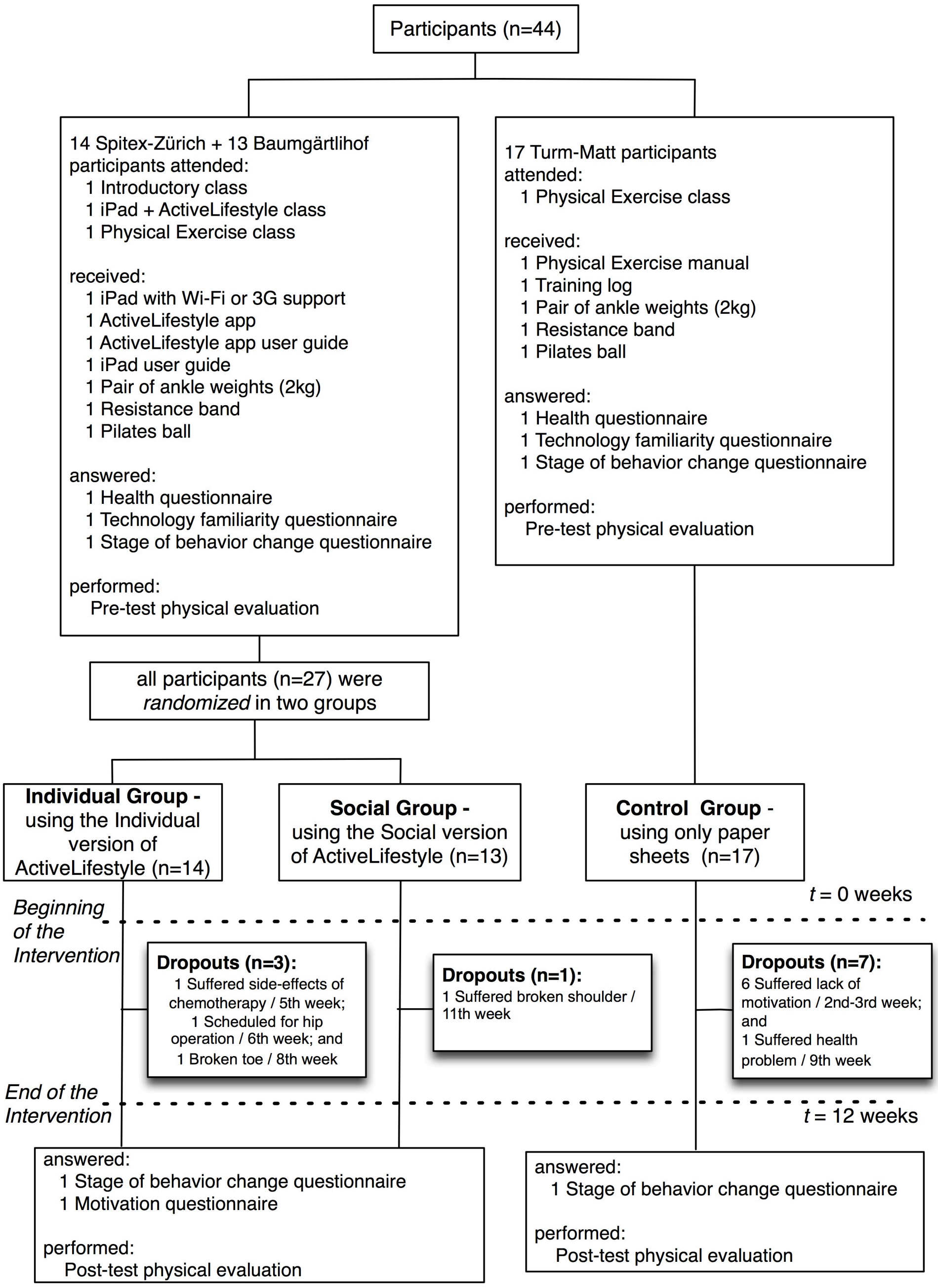



Figure 5. Illustrates the intervention details.

### 2.5.2 Gait Speed

The effect of the training on physical performance was assessed by measuring preferred and fast walking speed [35] with the GAITRite® walkway, a valid and reliable tool for measuring gait in elderly [36-37].

### 2.5.3 Motivation Instruments

The effectiveness of the motivation instruments built into the system was assessed based on the participants' feedback, collected with a 7-Point Likert Scale questionnaire at the end of the intervention (Table 2) [b-c], and on the performance (adherence, attrition, and gait speed) comparison among the three groups of participants.

### 2.5.4 Change Behaviours

The level of exercise adoption was evaluated according to the Trans-Theoretical Model (TTM) [38], which describes how people modify or acquire behaviour [39-40]. A TTM questionnaire [d] was applied before and after the training period. Participants were classified in four groups: Contemplation (e.g., thinking about (physical) behaviour change), Preparation (e.g., already being somewhat physically active), Action (e.g., doing enough physical activity) and Maintenance (e.g., making physical activity a habit).

### 2.5.5 Statistical Analyses

Analysis of variance (ANOVA) was used to test for differences in adherence to the training program between groups, as well as gait speed over time and between groups. Significant main effects were followed up by post-hoc *t*-tests with correction for multiple comparisons. Between-group differences in attrition were analysed using a $\chi^2$ test. Questionnaires on enjoyment, motivation and change of behaviour were analysed using Kruskal-Wallis ANOVA and Wilcoxon signed rank tests. In all analyses, the level of significance was set at $p \leq 0.05$. For effect size, we used $\eta^2$ in all ANOVA analyses, Cohen's *d* for all post-hoc analyses, $\varphi$ for $\chi^2$ tests and *r* for Kruskal-Wallis ANOVA and Wilcoxon signed rank tests. *r* is calculated as $r = Z/\sqrt{\boldsymbol{N}}$, where Z is the standardised difference and *N* is the total number of samples. Suggested norms for interpreting $\eta^2$ are: .01=small, .06=moderate and .14=large effect [41]. These norms are [.2 .5 .8] for Cohen's *d* and [.1 .3 .5] for both $\varphi$ and *r* [41]. All tests were conducted using SPSS Version 21.0.

## 3. Results

### 3.1 Demographics

Detailed information about participant demographics, based on the Health and Technology Familiarity questionnaires [e-f], is summarized in Table 1.

| | Individual (n=14) | Social (n=13) | Control (n=17) |
|---|---|---|---|
| Female gender, n(%) | 10(71) | 8(62) | 10(59) |
| Age mean/SD | 74/5 | 75/6 | 76/15 |
| Vocational education, n(%) | 7(50) | 7(54) | 10(59) |
| In a sitting position past profession, n(%) | 7(57) | 6(46) | 6(35) |
| **Health Questions, n(%)** | | | |
| Estimated good health | 5(36) | 8(61) | 8(47) |
| Estimated average balance | 7(50) | 5(38) | 9(53) |
| Feel pain but not every day | 9(64) | 7(54) | 7(41) |
| **Flexibility Questions, n(%)** | | | |
| Fell in the last six months[a] | 2(14) | 5(38) | 4(23) |
| Walk at least twice a week | 5(36) | 8(61) | 9(53) |
| Practiced some sport in the past | 10(71) | 8(61) | 5(29) |
| Never practiced strength exercises | 11(79) | 7(54) | 14(82) |
| **Technology Familiarity, n(%)** | | | |
| Frequently use ATMs | 7(50) | 9(69) | 7(41) |
| Frequently use cellphones | 7(50) | 10(77) | 6(35) |
| Frequently use digital photography | 8(57) | 4(31) | 4(23) |
| Don't use GPS | 7(50) | 8(61) | 6(35) |
| Don't use automatic kiosks | 9(64) | 6(46) | 12(71) |
| Don't know what an e-book is | 7(50) | 5(38) | 11(65) |
| Use a computer | 12(86) | 10(77) | 8(47) |
| Between 1-5 hours per week | 6(43) | 4(31) | 3(18) |
| Use the Internet | 12(86) | 9(69) | 5(29) |
| Between 1-5 hours per week | 7(50) | 6(46) | 2(12) |

**Table 1.** Participants' demographics.

[a]*A fall was defined as unintentionally coming to the ground or some lower level, excluding the consequence of sustaining a violent blow, loss of consciousness, or sudden onset of paralysis, such as during a stroke or epileptic seizure* [42].

### 3.2 Adherence and Attrition

Table 2 presents the adherence to ActiveLifestyle strength-balance training plans. Adherence across training plans differed significantly between groups, $F(2,41)=4.8$, $p=.014$, $\eta^2=.19$. Post-hoc *t*-tests with Benjamini-Hochberg correction revealed a large and significant difference between the Social group (*M*=81.9%, *SD*=1.6%) and the Control group (*M*=48.1%, *SD*=41.5%), $t(19.2)=3.1$, $p=.015$, $d=.91$. The difference between the Individual group (*M* = 71.1%, *SD* = 25.2%) and the Control group was moderate to large and approached a trend, $t(26.9)=1.9$, $p=.10$, $d=.63$. The difference between the Individual and Social groups was moderate yet non-significant, $t(18.6)=1.4$, $p=.19$, $d=.50$.

Thirty-three elderly completed the 12-weeks of training, resulting in a 25% attrition rate in total, 21% in the Individual group (3 of 14), 8% in the Social group (1 of 13), and 41% in the Control group (7 of 17). Figure 6 illustrates the number of remaining participants of each group per week after the enrolment. More details about dropout reasons are described in Figure 5. A $\chi^2$ test revealed that attrition rate was significantly higher in the Control group (41.2%) than in the combined ActiveLifestyle groups (14.2%), $\chi^2$=3.9, *p*=.049, φ=.30.

| | Individual Group visited/planned(%) | Social Group visited/planned(%) | Control Group visited/planned(%) |
|---|---|---|---|
| **Balance Training Plan** | 547/812(67) | 549/754(73) | 451/986(46) |
| **Strength Training Plan** | 221/322(69) | 217/299(73) | 291/391(74) |
| **Across Training Plans** | 768/1134(68) | 766/1053(73) | 742/1377(54) |

**Table 2.** Adherence to ActiveLifestyle strength-balance training plans.

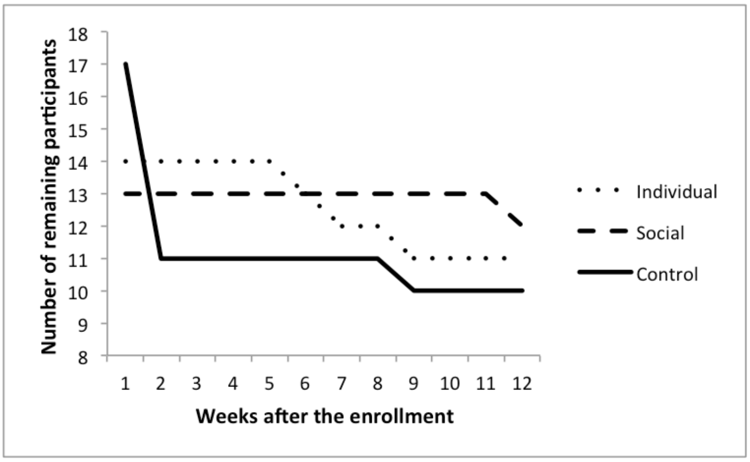



Figure 6. Illustrates the number of remaining participants of each group per week.

### 3.3 Gait Speed

Table 3 shows participants' preferred and fast gait speed during the pre- and post-test evaluations. With respect to preferred gait speed, the three groups were very similar. We used two mixed 2-way ANOVA's (one for preferred and one for fast gait) with within-subject factor Pre-Post (2 levels) and between-subject factor Group (3 levels). For preferred gait speed, there was a large and highly significant difference between pre-test and post-test, $F(1,29)=29.6$, $p<.001$, $\eta^2=.51$: Participants walked significantly faster in the post-test (1.276 $m \cdot s^{-1}$) than they did in the pre-test (1.141 $m \cdot s^{-1}$). There was no significant main effect of Group (*p*=.072) and no significant interaction effect (*p*=.63), suggesting that preferred gait speeds and their improvements were similar in all groups.

The results for fast gait speed were similar to those for preferred gait speed. Again, there was a large difference between pre-test and post-test: Participants walked significantly faster in the post-test (1.716 $m \cdot s^{-1}$) than in the pre-test (1.564 $m \cdot s^{-1}$), $F(1,29)=20.1$, p<.001, $\eta^2=.41$. The main effect of Group was significant as well, $F(2,29)=5.3$, $p=.011$, $\eta^2=.27$. Post-hoc tests revealed that the Individual group (1.891 $m \cdot s^{-1}$) was significantly faster than the Control group (1.448 $m \cdot s^{-1}$), $t(19)=3.935$, $p=.003$, $d=1.31$, and tended to be faster than the Social group (1.581 $m \cdot s^{-1}$), $t(20)=2.050$, $p=.081$, $d=.89$. The Individual group by chance was the fasted since the beginning. Fast gait speed was not significantly different between the Control group and the Social group ($p=.39$).

| Condition | Pre-test mean±SD | Post-test mean±SD |
|---|---|---|
| **Individual Group** | | |
| Preferred speed [$m.s^{-1}$] | 1.260±0.178 | 1.417±0.208 |
| Fast speed [$m.s^{-1}$] | 1.805±0.268 | 1.977±0.312 |
| **Social Group** | | |
| Preferred speed [$m.s^{-1}$] | 1.096±0.252 | 1.244±0.315 |
| Fast speed [$m.s^{-1}$] | 1.499±0.346 | 1.662±0.502 |
| **Control Group** | | |
| Preferred speed [$m.s^{-1}$] | 1.066±0.192 | 1.167±0.218 |
| Fast speed [$m.s^{-1}$] | 1.389±0.220 | 1.507±0.272 |

**Table 3.** Participants' gait speed during the pre- and post-tests.

### 3.4 Motivation Instruments

Detailed information about the effectiveness of ActiveLifestyle's motivation instruments and user intention aspects are summarized in Table 4. The questionnaires used to collect the content of the table are available at [b-c].

Most participants affirmed that ActiveLifestyle facilitates autonomous performance of strength-balance exercises. This is confirmed by a high intention to use the application again or to recommend it to friends or family members. All participants enjoyed the strength-balance exercises. Few participants (less than 25%) felt frustrated, worried or nervous during the study. A majority of participants reported that they will miss ActiveLifestyle.

Mann-Whitney U tests comparing the Likert scores for all questions presented in Table 4 did not detect any significant differences between the groups (all $p$'s>.05).

| Statement | Ind. Median (range) | Ind. % Agreed | Social Median (range) | Social % Agreed |
|---|---|---|---|---|
| ActiveLifestyle facilitates the performance of strength-balance exercises autonomously at home. | 7(6-7) | 100 | 7(4-7) | 92 |
| **Use intention** | | | | |
| I would use the application again. | 6(5-7) | 100 | 6(4-7) | 83 |
| I would recommend the application to my friends and family. | 6(6-7) | 100 | 6(3-7) | 67 |
| **Enjoyment** | | | | |
| It was fun to carry out the strength and balance exercises. | 6(6-7) | 100 | 6(5-7) | 100 |
| I felt frustrated during the study. | 2(1-5) | 9 | 2(1-6) | 8 |
| I felt worried during the study. | 2(1-6) | 18 | 2(1-7) | 25 |
| I felt nervous during the study. | 1(1-6) | 9 | 1(1-4) | 0 |
| I will miss the exercises and the ActiveLifestyle application | 5(2-7) | 54 | 6(3-7) | 67 |
| **Motivation** | | | | |
| I usually do not feel motivated to perform physical exercises, ActiveLifestyle helped me. | 6(1-7) | 54 | 6(2-7) | 83 |
| **Individual Motivation Instruments** | | | | |
| I felt motivated when I saw my progress on the bar (*Goal-setting* and *Self-monitoring*). | 6(4-7) | 91 | 6(1-7) | 67 |
| I felt motivated for being aware about the benefits of being physically active (*Awareness*). | 6(3-7) | 82 | 6(3-7) | 82 |
| I felt motivated when I saw the plant growing due to my performance (*Conditioning*). | 6(4-7) | 64 | 6(1-7) | 83 |
| I felt motivated when I saw the emotional status of the gnome (*Conditioning*). | 5(2-7) | 55 | 4(1-6) | 50 |
| I would feel more motivated using the social version of ActiveLifestyle, in which I could interact with other training partners. | 5(1-7) | 64 | - | - |
| **Social Motivation Instruments** | | | | |
| I felt motivated for being part of a training group and to know that other people did the same exercises. | - | - | 6(2-7) | 83 |
| I felt motivated to perform the plan because I knew I was being monitored (*External monitoring*). | - | - | 6(2-7) | 83 |
| I felt motivated for being emotionally supported by the other training plan partners and by the ActiveLifestyle experts (*Emotional support*). | - | - | 6(2-7) | 75 |
| I felt motivated with the collaboration activity to reach the top of the mountain (*Collaboration*). | - | - | 6(3-7) | 58 |
| I usually compared my flower with others on the *Bulletin board* (*Comparison*). | - | - | 4(1-6) | 42 |
| I would feel more motivated using the individual version of ActiveLifestyle, which does not require interaction with other training partners. | - | - | 4(1-6) | 8 |

**Table 4**. Outcome data expressed by the participants on a 7-Point Likert Scale (range, 1-7; 1=Completely disagree - 7=Completely agree) at the end of the intervention period (n=14 for the Individual group and n=13 for the Social group).

### 3.5 Change Behaviour

Table 5 shows the stage of behaviour change of the participants at the beginning ($t_0$=0 weeks) and at the end ($t_1$=12 weeks) of the intervention.

Wilcoxon signed rank tests comparing pre- and post-test behavioural scores in each group revealed a trend – with large effect size – in the Social group, $Z$=1.79, $p$=0.074, $r$=0.52. Hence, the Social group tended to change their behaviour towards integration of ActiveLifestyle into their daily routine. No behavioural changes were detected in the Control group ($p$=0.28) and the Individual group ($p$=0.50). Although this suggests between-group differences with respect to behavioural change, no such differences could be shown statistically: A Kruskal-Wallis ANOVA directly comparing change of behaviour between the three groups was clearly non-significant ($p$ = 0.75).

| Change Behavior Stage | $t_0$ = 0 weeks | $t_1$ = 12 weeks |
|---|---|---|
| **Individual Group** | | |
| Contemplation | 3 | 0 |
| Preparation | 1 | 4 |
| Action | 1 | 1 |
| Maintenance | 6 | 6 |
| **Social Group** | | |
| Contemplation | 5 | 3 |
| Preparation | 2 | 0 |
| Action | 0 | 0 |
| Maintenance | 5 | 9 |
| **Control Group** | | |
| Contemplation | 5 | 3 |
| Preparation | 1 | 2 |
| Action | 0 | 0 |
| Maintenance | 4 | 5 |

**Table 5**. Stage of Behaviour change of the participants according to the TTM.

### 4 Discussion

The aim of this study was to investigate i) which motivation IT-mediated strategies increase adherence to physical exercise training plans in elderly; ii) whether ActiveLifestyle induces physical activity behaviour change; and iii) the effectiveness of the ActiveLifestyle training to improve gait speed. The main focus was to evaluate the ability to retain elderly in the exercise program. Based on findings from a systematic review [34], we could expect a 10% attrition rate and 50% attendance rate for the individually targeted exercise training. Where the Control group showed 41% attrition mainly due to lack of exercise motivation both tablet-based training groups showed far lower values, 21% and 8% respectively for the Individual and Social ActiveLifestyle groups. Furthermore, these last two lower numbers are explained by morbidities not related to the motivation to train. We saw that especially in the Control group subjects were lost due to a lack of motivation to continue training. The degree of engagement with the intervention was well above 50% for both groups using the ActiveLifestyle application and 42% for the Control group. Compared with median rates for attrition and adherence in fall prevention interventions in community settings we achieved better or similar rates for the tablet-based training groups. From previous research we know that the intention to undertake strength-balance training in elderly is closely related to all elements of coping appraisal [43]. Elements of coping appraisal include the belief that strength-balance training has multiple benefits and is associated with a positive social identity, and the feeling that family, friends, and doctors would approve of taking part in such training [43]. It can be hypothesized that ActiveLifestyle is effective in influencing attrition and adherence because it explicitly supported individual and individual & social motivation instruments.

The reason to use a tablet solution is related to the numerous potential advantages attributed to such a tool (e.g., tablets are relatively robust, and using fingers instead of a mouse or a touch pad make them much more intuitive and easy to use compared with smartphones, note-books, and desktops). A tablet-based intervention as ActiveLifestyle constitutes a powerful tool to provide feedback about performance, and motivation to endure practice because of social inclusion. Interventions that use frequent, non-frequent, or direct remote feedback are to be favoured against treatments without feedback, because they seem to be more effective and, furthermore, equally effective as supervised exercise interventions [44]. The second most mentioned barrier to physical exercise for subjectively insufficiently active older adults is lack of company. Direct remote contact seems a good alternative to supervised onsite exercising [45]. In addition, this feedback can be adapted based on the individual participant's baseline motor performance and be progressively augmented in task difficulty. Further, ActiveLifestyle has the potential to engage people who otherwise would lack interest to participate in a physical exercise regimen. Especially in the older population it is difficult to maintain high adherence to training programs [43]. The participants of the present study allocated to the tablet groups showed good compliance rates. The losses related to low exercise compliance (n=6) in the Control training group were caused by a lack of motivation. The reasons for discontinuation of training in the tablet groups were not because of rejection of the application per se. In a future Phase III trial the follow-up period for the assessment of adherence and attrition should, therefore, preferably be extended to 12 months to facilitate comparability of this future study with reference values of previous physical interventions [34]. Our findings, however, are very encouraging because they seem to indicate the effectiveness of a tablet-based training approach in elderly. This encourages further exploration of this training approach in elderly.

Analysing the participants' answers to the motivation instruments of ActiveLifestyle, it is possible to notice that the Individual participants (64%) would feel more motivated using the Social version of the application, while the opposite is not true (8%) – both tablet groups were aware of the different versions of ActiveLifestyle. Regarding the physical activity habits, the training group using the Social version of ActiveLifestyle was the only one showing a tendency to change behaviour. At the end of the intervention, 50% of the Social group participants changed their behaviour according to the TTM. At the beginning these participants were at the Contemplation or Preparation stages (thinking about or already being somewhat physically active), and they were classified as being on the Maintenance stage (making physical activity a habit) by the end. However, a further longitudinal study with a bigger sample, and counting with evaluation after the end of the intervention is required to ensure change of physical behaviour.

Gait speed is a clinically relevant indicator of functional status associated with important geriatric health outcomes (i.e., impact healthcare activities have on people) [46]. Slowing down has been recognized as an indicator of failing health and vulnerable old age [47]. Some researchers hypothesize that gait speed may act as a "vital sign" giving indications of the health status of elderly. Mortality, for example, is substantially reduced when gait speed is improved through interventions [48]. Large epidemiological studies reveal that significant increments of 0.1 m.s-1 in walking speed are related to a 12% decrease in mortality [13]. In this context, it seems encouraging that all elderly in our training groups that adhere to their training plan, independently of their group allocation, show an increase in both preferred and fast walking speed.

In addition to the high level of adherence caused by the social motivation instruments, the training community created by the study served to improve the connectedness of the participants. Two women, who did not know each other before, started to perform the exercises together in order to check if they were following the correct posture. Moreover, some participants contacted other training partners using the application, via email or phone when they faced problems. The same support was also requested from our team of experts, who frequently, especially at the beginning of the study, received phone calls due to technical problems or doubts with the exercises.

As learned from our previous study [18], some of the participants felt proud of being able to use new technology. One of our oldest participants (83 years-old) installed Skype to call his daughter living in Central America. He confessed us that his daughter was very surprised. He even wanted to know details about iCloud. Another woman, at the beginning, was afraid of not being able to deal with the tablet, since she had never used a computer before. After the study she bought a tablet to play with her grandchild and installed Wi-Fi at home to be more connected with them. Another woman expressed a similar concern at the beginning of the training, but finished the study with a new tablet and a Gmail account: “I’m proud to be in possession of the iPad and to be able to write to my friends. The whole matter was a change for me”.

### 4.1 Limitations

The study has several limitations. One of them is the rather small sample size. This study, therefore, reveals first estimates for gait speed measures and stages of behaviour change, and warrants further research in larger populations. However, the purpose of Phase III trials is to provide preliminary evidence on the clinical efficacy of an intervention [24]. When evaluating the validity of a study, it is important to consider both the clinical and statistical significance of the findings [49]. Studies that claim clinical relevance may lack sufficient statistical significance to make meaningful statements or, conversely, may lack practicality despite showing a statistically significant difference in treatment options. Researchers and clinicians should not focus on small p-values alone to decide whether a treatment is clinically useful; it is necessary to also consider the magnitude(s) of treatment differences and the power of the study [49]. Encouraging in this context is the observation that the majority of the between groups comparisons for adherence show medium or medium-to-high magnitude(s) of treatment differences in favour of the tablet groups. This in mind, the relationship between tablet-based physical training research and its effect on adherence and fitness in elderly individuals requires further exploration. Future adequately powered studies with similar or frailer populations should, therefore, be performed to substantiate or refute our findings.

The participants of this study can be classified as normal walkers with a preferred gait speed between 1.0 and 1.4 m.s-1. Future studies with community dwelling populations that exhibit mildly abnormal (0.6-1.0 m.s-1) or seriously abnormal gait speed (below 0.6 m.s-1) [47] should be performed to investigate whether similar or even better results in physical performance variables can be obtained.

## 5 Conclusions

The finding of this study supports the notion that it is advantageous to combine physical training with specifically targeted IT motivation instruments that offer the possibility to socialize in a group in clinical practice. The combination seems to have a positive influence on older adults’ training adherence in comparison to more traditional exercise. ActiveLifestyle proved to assist and motivate independently living and healthy elderly adults to autonomously perform strength-balance exercises. The social motivation strategies seemed to be more effective to stimulate the participants to comply with the training plan and remain on the intervention. The adoption of assistive technology devices for physical intervention tends to motivate and retain elderly people exercising for longer periods of time.

**Acknowledgements:** This work was carried out with the support of Maria Messmer-Capaul and her team of the “Fachstelle für präventive Beratung Spitex-Zürich”, of Claudia Nüesch of the “Senioren Begegnungszentrum Baumgärtlihof” and Data Quest, who provided tablets for the study. We would also like to thank all the participants for their great enthusiasm and support. This work is partially sponsored by the Trento Legge 6 project Anchise and EIT project Virtual Social Gym.

References

1. Rowe JW, Kahn RL. Successful aging. Gerontologist 1997;37(4):433-440.

2. Spirduso WW, Cronin DL. Exercise dose-response effects on quality of life and independent living in older adults. Med Sci Sports Exerc 2001;33(6 Suppl):S598-608; discussion S609-510. PMID:11427784.

3. Johnson RJ, Wolinsky FD. The structure of health status among older adults: disease, disability, functional limitation, and perceived health. J Health Soc Behav 1993;34(2):105-121. PMID:8277124.

4. Malmberg JJ, Miilunpalo SI, Vuori IM, Pasanen ME, Oja P, Haapanen-Niemi NA. A health-related fitness and functional performance test battery for middle-aged and older adults: feasibility and health-related content validity. Arch Phys Med Rehabil 2002;83(5):666-677. PMID:11994806.

5. Malmberg J, Miilunpalo S, Pasanen M, Vuori I, Oja P. Characteristics of leisure time physical activity associated with risk of decline in perceived health − a 10-year follow-up of middle-aged and elderly men and women. Prev Med 2005;41(1):141-150. PMID:15917005.

6. American College of Sports Medicine position stand. Exercise and physical activity for older adults. Med Sci Sports Exerc 2009;41(7):1510-1530. PMID:19516148.

7. Stuart M, Chard S, Benvenuti F, Steinwachs S. Community exercise: a vital component to healthy aging. Healthc Pap 2009;10(1):23-28. PMID:20057213.

8. Anonymous, Physical Activity Fundamental To Preventing Disease, U.S.D.o.H.H. Services, Editor. 2002, U.S. Department of Health & Human Services: Washington.

9. Landi F, Abbatecola AM, Provinciali M, Corsonello A, Bustacchini S, Manigrasso L, Cherubini A, Bernabei R, Lattanzio F. Moving against frailty: does physical activity matter? Biogerontology 2010;11(5):537-45. PMID:20697813.

10. Thibaud M, Bloch F, Tournoux-Facon C, Brèque C, Rigaud AS, Dugué B, Kemoun G. Impact of physical activity and sedentary behaviour on fall risks in older people: a systematic review and me-ta-analysis of observational studies. Eur Rev Aging Phys Act 2011;8(1).

11. Hilbe J, Schulc E, Linder B, Them C. Development and alarm threshold evaluation of a side rail integrated sensor technology for the prevention of falls. International Journal of Medical Informatics 2010;79(3):173-180. PMID:20083427.

12. Mei Y, Marquard J, Jacelon C, Defeo AL. Designing and evaluating an electronic patient falls re-porting system: Perspectives for the implementation of health information technology in long-term residential care facilities. Int J Med Inform 2011. PMID:21482183 (in print).

13. Studenski S, Perera S, Patel K, Rosano C, Faulkner K, Inzitari M, Brach J, Chandler J, Cawthon P, Connor EB, Nevitt M, Visser M, Kritchevsky S, Badinelli S, Harris T, Newman AB, Cauley J, Fer-rucci L, Guralnik J. Gait speed and survival in older adults. JAMA 2011;305(1):50-8. PMID:21205966.

14. Ferrucci L, Baldasseroni S, Bandinelli S, et al. Disease severity and health-related quality of life across different chronic conditions. J Am Geriatr Soc 2000;48(11):1490-1495. PMID:11083330.

15. Obi T, Ishmatova D, Iwasaki N. Promoting ICT innovations for the ageing population in Japan. International Journal of Medical Informatics 2012. PMID:22727612 (in print).

16. Stuck AE, Egger M, Hammer A, Minder CE, Beck JC. Home Visits to Prevent Nursing Home Ad-mission and Functional Decline in Elderly People. JAMA 2002;27;287(8):1022-8. PMID:11866651.

17. Eckert JK, Morgan LA, Swamy N. Preferences for receipt of care among community-dwelling adults, J. Aging Soc. Policy 2008(2):49–65. PMID:15148044.

18. Silveira P, van het Reve E, Daniel F, Casati F, de Bruin ED. Motivating and Assisting Physical Exercise in Independently Living Older Adults: A Pilot Study. International Journal of Medical Informatics 2012, Dec 26. doi:pii: S1386-5056(12)00239-0. 10.1016/j.ijmedinf.2012.11.015. (in print).

19. Mann WC, Ottenbacher KJ, Fraas L, Tomita M, Granger CV. Effectiveness of assistive technology and environmental interventions in maintaining independence and reducing home care costs for the frail elderly. A randomized controlled trial. Arch Fam Med 1999;8(3):210-217. PMID:10333815.

20. Zwerver J, A Weir, Tol J. What's app? sports medicine physicians should not talk double Dutch. Br J Sports Med 2012;46(12):833-834. PMID:23130364.

21. Consolvo S, Klasnja P, McDonald DW, Landay JA. Goal-setting considerations for persuasive technologies that encourage physical activity. 4th international Conference on Persuasive Technology 2009.

22. Lin JJ, Mamykina L, Lindtner S, et al. Fish'n'steps: Encouraging physical activity with an interactive computer game. Ubiquitous Computing 2006 (261-278). New York: Springer.

23. Albaina IM, Visser T, van der Mast C, et al. Flowie: A persuasive virtual coach to motivate elderly individuals to walk. 3rd International Conference on Pervasive Computing Technologies for Healthcare 2009,1-7.

24. Thabane L, Ma J, Chu R, et al. A tutorial on pilot studies: the what, why and how. BMC Medical Research Methodology 2010;10(1):1-10. PMID:20053272.

25. Silveira P, Daniel F, Casati F, et al. ActiveLifestyle: an application to help elderly stay physically and socially active. International Reports on Socio-Informatics - Designing for Inter/Generational Communities 2012;9(1):39-44.

26. LifeParticipation Project. 2012. Achieved at: http://www.lifeparticipation.org/active.html.

27. ActiveLifestyle app video. 2012. Achieved at: http://youtu.be/XSFjHcUtt_A.

28. ActiveLifestyle App Store. 2012. Achieved at: https://itunes.apple.com/us/app/it4life-activelifestyle/id465295073?mt=8.

29. Cress ME, Buchner D, Prohaska T, et al. Best practices for physical activity programs and behavior counseling in older adults populations. J Aging Phys Act 2005;13(1):61-74. PMID:15677836.

30. Kraemer WJ, Ratamess NA. Fundamentals of resistance training: progression and exercise pre-scription. Med Sci Sports Exerc 2004;36(4):674-688. PMID:15064596.

31.ActiveLifestyle videos. 2012. Achieved at: http:// youtube.com/user/psilvieraf81?feature=results_main.

32. Longer study of the ActiveLifestyle in Switzerland. 2012. Achieved at: http://youtu.be/mNaIOYqN6tU.

33. Arikawa AY, O'Dougherty M, Schmitz KH. Adherence to a strength training intervention in adult women. J Phys Act Health 2011;8(1):111-118. PMID:21297191.

34. Nyman SR, Victor CR. Older people's participation in and engagement with falls prevention interventions in community settings: an augment to the Cochrane systematic review. Age and Ageing 2012;41(1):16–23. PMID:21875865.

35. de Bruin ED, Schmidt A. Walking behaviour of healthy elderly: Attention should be paid. Behavioral and Brain Functions 2010;6:59. PMID:20939911.

36. McDonough AL, Batavia M, Chen FC, et al. The validity and reliability of the GAITRite system's measurements: A preliminary evaluation. Archives of Physical Medicine and Rehabilitation 2001;82(3):41-425. PMID:11245768.

37. Hartmann A, Luzi S, de Bie RA, et al. Concurrent validity of a trunk tri-axial accelerometer system for gait analysis in older adults. Gait Posture 2009;29(3):444-448. PMID:19070494.

38. Prochaska JO, Butterworth S, Redding CA, et al. Initial efficacy of MI, TTM tailoring and HRI's with multiple behaviors for employee health promotion. Prev Med 2008;46(3):226–31. PMID:18155287.

39. Kirk A, MacMillan F, Webster N. Application of the Transtheoretical model to physical activity in older adults with Type 2 diabetes and/or cardiovascular disease. Psychology of Sport and Exercise 2010;11(4):320-324.

40. Dishman RK, Vandenberg RJ, Motl RW, et al. Using Constructs of the Transtheoretical Model to Predict Classes of Change in Regular Physical Activity: A Multi-Ethnic Longitudinal Cohort Study. Behavioral Medicine 2010;40(2):150-163. PMID:20552417.

41. Cohen J. Statistical Power Analysis for the Behavioural Sciences. 2nd Edition. Lawrence Erlbaum Associates. ISBN-13: 978-0805802832.

42. Gibson MJ, Andres RO, Isaacs B, et al. The Prevention of Falls in Later Life — a Report of the Kellogg International Work Group on the Prevention of Falls by the Elderly. Dan Med Bull 1987;34:1-24. PMID:3595217.

43. Yardley L, Donovan-Hall M, Francis K, et al. Attitudes and beliefs that predict older people's intention to undertake strength and balance training. J Gerontol B Psychol Sci Soc Sci 2007;62(2):119-125. PMID:17379672.

44. Geraedts H, Zijlstra A, Bulstra SK, et al. Effects of remote feedback in home-based physical activity interventions for older adults: A systematic review. Patient Educ Couns 2012. PMID:23194823.

45. Moschny A, Platen P, Klaassen-Mielke R, et al. Barriers to physical activity in older adults in Germany: a cross-sectional study. Int J Behav Nutr Phys Act 2011;8:121. PMID:22047024.

46. Ostir GV, Berges I, Kuo YF, et al. Assessing gait speed in acutely ill older patients admitted to an acute care for elders hospital unit. Arch Intern Med 2012;172(4):353-358. PMID:22371922.

47. Studenski S. Bradypedia: is gait speed ready for clinical use? J Nutr Health Aging 2009;13(10):878-880. PMID:19924347.

48. Hardy SE, Perera S, Roumani YF, et al. Improvement in usual gait speed predicts better survival in older adults. J Am Geriatr Soc 2007;55(11):1727-1734. PMID:17916121.

49. Bhardwaj SS, Camacho F, Derrow A, et al. Statistical significance and clinical relevance: the importance of power in clinical trials in dermatology. Arch Dermatol 2004;140(12):1520-1523.