A Semantic-Enabled Engine for Mobile Social Networks*

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Abstract. Social-related services like sharing, tagging or commenting are a mainstay of current web applications and platforms aimed at groups of users. These services not only enhance the purpose and main functionalities of their applications but also create a network of users and services that interconnects into a wider online ecosystem. Despite their success in general and recreational applications, these social networks also present a series of challenges like attracting user signups, keeping a healthy contribution level, user privacy concerns, etc. Furthermore, mobile social networks (i.e., social networks tailored for mobile devices) have to account for the additional immediacy and adaptability required from their services. This paper introduces the Social Core – a social network engine that adds semantic-based functionalities like semantic annotations, semantic search and semantic-enhanced access control; as a way to enhance and answer to the current challenges of social applications. The Social Core was integrated as part of the SmartCampus mobile platform, which is currently being live tested by around one hundred students.

Keywords: Social Networks, Semantic Search, Semantic Access Control, Mobile Services

1 Introduction

Online social networks are Internet-based services that people use for managing their social relations, for sharing their content and for having access to the content shared by others. According to [1], social networks are defined by having: i) public or semi-public profiles for their users, ii) a list of other users with whom they share a connection, and iii) a list of connections made by others within the system. Furthermore, messaging, tagging and/or commenting mechanisms are also normally provided (although under different names in each specific site) by most social networks. Beyond these most common features each social network also offers its own specific features like media sharing, blogging capabilities or document creation/edition.

The results of [2] go further suggesting that current social networks are successful because they offer the following user-gratifying services: social connection, shared identities, content access, status update, social search/navigation, and social investigation. Several general purpose Social Networks like Facebook[1] and Twitter[2]

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have been tremendously successful in attracting users and maintaining considerable activity levels of interaction.

However, despite the usefulness of their services and their general adoption, several studies (e.g. [1-6]) have exposed and discussed the concerns and issues related to more focused business and academia related and social networks. Some of these issues include:

- *Negative image*: due to the most popular social networks being recreational-centered, most of the people regard social networks as a “waste of time” [2][7]. Overcoming this prejudice is actually one of the main challenges of business/academia-oriented social networks;
- *Lack of contributions*: motivating users to actually contribute and keep the social network alive through their interactions is normally a key issue to consider when designing and managing social networks. A sometimes quite large percentage of users (referred as ‘lurkers’ [8]) may decide to only consume content without contributing or being active in the social network;
- *Privacy*: privacy is often cited as the main concern of social networks. Examples include revealing (by accident or misunderstanding of the social network rules) of sensitive data that can be used by third parties to harm users and the so called ‘right-to-be-forgotten’ arising from students and young users posting information that researchers suspect they will come to regret over time [9];
- *Registration resistance*: new users of a social network are normally asked to choose a user and password, fill forms with their personal information, upload a profile photo, identify relationships, and choose privacy options among other information. Even if this drawn out process is shortened to the last only until the first step of the previous list (through interconnectivity with other sites), users grow increasingly hesitant to register to “yet-another site”.

While these issues are deemed fairly complex, needing analysis from several fields of studies, the Social Core presented in this paper, introduces a framework for mobile social networks offering added value to the social interactions by enriching them with semantics (semantic annotations, semantic search and semantic-enhanced access control) and that aims to assist in ameliorating the presented issues.

The paper is structured as following; Section 2 will introduce and detail the key subsystems of Social Core, while Section 3 will describe the main services that Social Core offers. Section 4 will introduce the Smart Campus project, detail how Social Core contributes and end with some usage and testing information. Finally, Section 5 will enumerate how the Social Core addresses the presented issues and propose conclusions and future work.

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1 http://www.facebook.com/

2 http://twitter.com/

2 Social Core

The main objectives of Social Core are to provide metadata storage, user management, access control and semantic services to support semantic-enabled social networking. Fig. 1 shows a high-level architectural look at the inner components of Social Core.

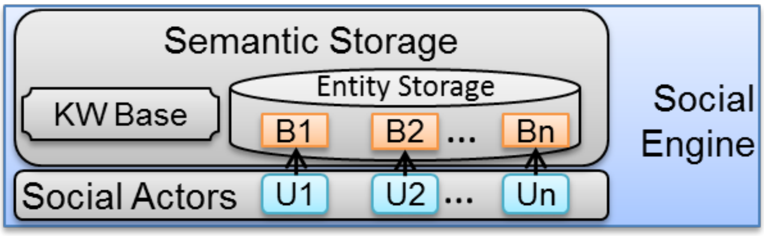

Fig. 1. Social Core internal architecture.

From Fig. 1 the main 3 identifiable elements are the Semantic Storage where concepts and entities are defined (Section 2.1), the Social Actors (Section 2.2).

2.1 Entities and entity types

In order to describe and represent data of the users (potentially shared on the network), Social Core defines a set of commonly used (in social settings) entity types such as people, places, events, media and others. Each entity type provides a structured definition of the metadata used to describe entities of the entity type (e.g., people have name and age; places have coordinates; and so on). Entity types are then used by Social Core to help users to create entity instances. In principle, this approach is similar to the schema.org[3] initiative and continues the work from [10]. Differently from schema.org (which tries to provide a standard for web page annotations), entity types of Social Core are more tailored to be used in the social context and are more flexible in the sense that users can add personalized metadata to the instantiated entities. The entities in the Entity Storage from Fig. 1 are represented using an entity En, as described in (1):

$$En =< id; type; Attr; Rel > \quad \textbf{(0)}$$

Where:

- *id*: is a unique identifier (e.g., a URI);
- *type*: is the type of entity, that is, the category to which it belongs to (e.g., the entity John" is of type Person);

3 http://schema.org/

- *Attr*: is a set of attributes composed of pairs *attr* =< *attr_name; attr_value* > describing the properties (e.g. John’s date of birth is 02/01/88) of that particular entity;
- *Rel*: is a set of relational attributes composed of pairs *rel* =< *rel_name; rel_value* > describing the entity's relations (e.g., John is friendOf Paul") with other entities;

While a complete specification of each of these entity types is beyond the scope of this paper, it is important to note that these entity types are used to define the basic attributes a particular type of entity will have. For example, the document entity type defines that all instances of an entity representing a text document will have the 'title' attribute and the 'author' relation.

Finally, the entity storage defines different entity bases (*B1* to *Bn* in Fig. 1); these entity bases are used as separate containers of entities belonging to particular users or, more generally speaking, social actors (as defined in the next subsection).

2.2 Social Actors: Entities as Subjects

Besides the representation and management of content (i.e., objects) social networks also define the subjects that can create, own, modify and share this content. For this purpose we introduce the social actor structure, that is defined on top (i.e., as an extension) of the entities. The purpose of the separation between entity and social actor is twofold: the first and more immediate reason is that more than one social actor structure may be defined for the same entity (as shown in Fig. 1); the second reason refers to the fact that the type of information that each is aimed to manage is very different, as information in the entity represents the real-world or agreed properties of the object (e.g., name, height), while the information contained in the social actor refers to the online activity (e.g., commented or tagged another entity, sent a message to another user) of the one representing that object.

More specifically, (2) shows the definition of the Social Actor structure:

Sa =<id; target; name; base; Group> **(2)**

Where:

- *id*: is unique identifier of the social actor, this used to identify the subject or subjects of all the social interactions on the system;
- *target*: is the id of the entity that is extended by the current social actor. In the case of a user, this target attribute contains the id of its corresponding person entity;
- *name*: is an unique human-readable identifier of the social actor, this is analogous to the ‘username’ found commonly on existing social networks. To provide additional security, and in line with the common authorization requirements of the social network, the social actor structure can be extended with password and email attributes (that for simplicity are omitted in this definition);
- *base*: specifies the entity base that is assigned and owned by the social actor. This base is used to store all the entities created by this social actor and that can be

accessed by others (provided the owner social actor grants them permission to do so);

- *Group*: a set of user-defined and named sets of other users. The most common applications of this is the creation of user-specific groups like 'friends' or 'family'.

Fig. 1 shows a representation of how a social actor extends an entity:

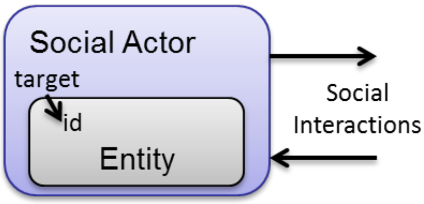

Fig. 1. The social actor extends an entity.

As shown in Fig. 1, the target component of the social actor points to the id of an entity. The social actors thusly linked to an entity, are enabled to act as the ones representing that entity (e.g., a community manager representing an institution, a user representing a person online) and as such start or participate in social interactions as the represented entities. Some examples of these social interactions include sharing (e.g., a social actor granting access to another social actor), tagging, commenting and messaging (e.g., a social actor sending another a message). More details of services based on these social interactions are given on the next section.

Before presenting these functionalities to the end-users, Social Core further specializes the social actors into two structures:

- *Users*: currently the *target* attribute of the user is limited exclusively to a person type entity. As such, while the person entity contains all the information related to the physical person (e.g., first name, last name, address), the representing user is used to create and participate in social interactions.
- *Communities*: instead of being used as the "representing individual" of the target entity, the community social actor is used to create interest groups around a particular entity or topic. As such, a community represents a group of people coming together to discuss, create or share around a particular entity or concept.

Note that neither the definition of the social actor structure nor the additional limitation imposed on users prevents the definition of multiple users extending the same person. As such, a situation like the one exemplified in Fig. 1 is allowed.

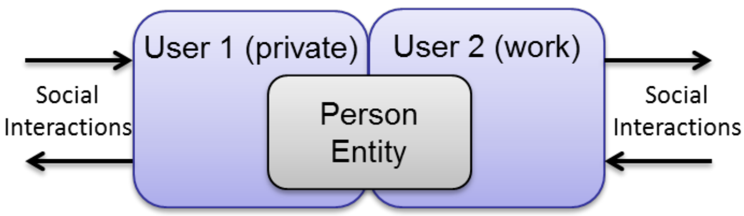

Fig. 1. Two or more users can be linked to the same person entity.

These multiple users can represent independent and different online facets of the same person. The example of Fig. 1 shows that that *User1* is a private user (that would, for example, share all the picture taken with its family) while *User2* is a work-related user (that would, for example, share work documents with its colleagues).

3 Services

3.1 Semantic Entity Sharing and Access Control

The Access Control component of Social Core (shown in Fig. 1) is based on the RelBAC (Relation Based Access Control) theory. RelBAC is a new model and a logic which has been introduced in [11] with the overall goal of dealing with the problem on access control in Web 2.0 applications. User groups (e.g., friend lists), tags/comments, event or photo collections; most of these systems have in common the tendency towards organizing their social relations and resources into tree-like structures; where the deeper a category is in the tree, the more specific is the resource it will contain.

This is also true in Social Core where, by exploiting the translation from classifications and web directories to lightweight ontologies (introduced in [12]) we can represent (as shown in [13] and [14]) both users networks (subjects) and entity organizations (objects) as lightweight ontologies. This enables us to comply with the main requirements of the RelBAC model that defines its main elements as:

- *Subjects*: a subject is user or a set of users that intends to access some entities. The 'IS-A' relations exist between sets of subjects, creating a hierarchy that goes from the largest and most general subjects group (i.e., the "all" group) to smaller and more particular ones (e.g., "work", "family").
- *Objects*: an object is an entity or a set of entities that subjects intend to access. Similarly to subjects, the 'IS-A' relations exist between sets of objects.
- *Permissions*: a permission is a triple <*Subject, Object, Operation*>, where *Operation* is the name of the operation (e.g., Read, Write, Delete). It is used to allow one or more subjects to perform a given operation on one or more objects.

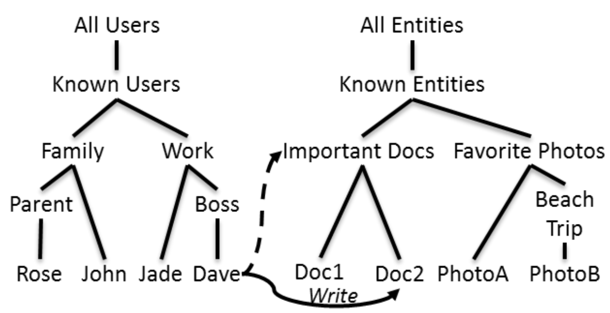

Fig. 1. RelBAC object and subject hierarchies

In RelBAC all the mentioned elements can be directly expressed in a Description Logic (DL). As explained in [13] Subjects, and objects are formalized as concepts and permissions are formalized DL roles (i.e., binary relations). As such, access control rules that express the kind of access rights the subjects have on objects based on the defined permissions are also formalized as 12 subsumption axioms presented in [11] and therefore computing access control and suggesting new rules can be carried out by applying off-the-shelf DL reasoners [15] on the structures of the model. This enables the following advantages of using RelBAC for access control in Social Core:

- In the conventional RBAC-based access control systems, a particular set of permissions is assigned to a particular role. When changes need to be introduced, it is sometimes is necessary to create new roles or to delete unused ones, which may leave the system in an inconsistent or unsafe configurations). In RelBAC the permissions are completely decoupled from subjects and objects and all changes must satisfy the underlying ontological semantics of the model, which enables the system to avoid entering a such conflicting states;
- The relational links across subjects and objects in the social network can be exploited to suggest candidate paths for permission propagation. For example, Fig. 1, if permission is granted to 'Work' usegroup, this means that both 'Jade' and 'Dave' will receive also that permission. Furthermore, by analyzing the defined subjects, objects and permission it becomes possible to infer and suggest additional permissions to the user. For example, if 'Dave' has access to several of the documents in the 'Important Docs' category then system may suggest that a more general permission (shown as a dotted line in Fig. 1). More work on inferring new rules from modal logics is found in [16] and [17].
- Each user is able to define its own personalized subject and object hierarchies that may have similar purposes and categories but ultimately give rise to the problem of semantic heterogeneity. This problem can be solved by applying semantic matching to the lightweight ontologies, thus allowing all these different hierarchies to be interoperable.
- Thanks to the pipeline for converting subject and object tree-like structures into lightweight ontologies, enabling RelBAC's to reason about them, we can add vast amounts of existing classifications of objects and subjects.

1.1 Semantic Annotations

Social Core allows its users to annotate their entities as well as entities of other users given that they are granted the necessary permission to do so. The engine supports the annotations of three kinds:

- **Free text annotations**: such annotation is an arbitrary sequence of characters provided by the user e.g., "java", "party", "xyz". This is probably the most commonly used annotation kind in social networks (e,g., Flickr[4]). The intended meaning of these annotations is defined by the user when s/he provides such annotations; however, no explicit machine processable semantics is assigned to these annotations in the system;

- **Semantic annotations**: such annotation is a tuple consisting of a string and a concept represented by the string, e.g. <“dog”, DOG>[5]. One advantage of semantic annotations is that they are represented in a formal language and, therefore, enable automated reasoning about them, e.g., searching with concept ANIMAL would find entities annotated with concepts DOG or CAT. Examples of this approach are Tagasarius[6]and L!NKs[7];
- **Entity annotations**: such annotation is a tuple consisting of a string and an entity represented by the string, e.g., <“Trento”, *Trento*>[8]. Such annotation can be used, for example, when an image entity is annotated with people in it or with the location where the image was taken. One advantage of entity annotations is that they allow interlinking related resources and enabling more search and navigation services, e.g., finding images from a particular location (or its part) or of a particular person.

For a more comprehensive overview of various annotation kinds, their relative cons and pros and related applications, interested readers are referred to [18].

1.2 Semantic Live Topics Following

Social Core provides a mechanism that allows its users to sign up and follow news and updates from what we call *live topics*, whereas each live topic consists of the following three components:

- **The source(s)**: single users, user groups, or all users and/or single communities, or all communities which created or updated some entity(ies) relevant for the given live topic;
- **The topic(s)**: a free text annotation, a semantic annotation, an entity annotation (see previous section), or a combination of them that defines what the life topic news should be about. For example, one could use concept ANIMAL as a topic and, therefore, an entity about concept CAT would be relevant for the given live topic;

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4 http://www.flickr.com/

5 For the sake of clarity concepts are written in capital letters.

6 http://www.tagasauris.com/

7 www.insemtives-links.net

8 For the sake of clarity entities are written in italic starting from a capitalized letter.

- **The type(s)**: one or more entity types that the computed live topic news entities should belong to (e.g., images, places, people). It is also possible to specify that entities of any type should be computed.

The live topic mechanism is access control aware in the sense that for any given user (and his/her live topic) it computes only those entities which are either public or explicitly shared with the user. The mechanism uses a semantics-enabled search (reported in [19]); more precisely, it matches concepts associated with a live topic with those used to annotate entities (and in this it reasons on the is-a hierarchy of concepts); moreover it matches location entities associated with a live topic with those used to annotate entities (and in this it reasons on the transitive part-of hierarchy of locations). For example, for the live topic defined as "follow images related to concept SPORT_EVENT and entity *Trentino*", the machinery is capable of finding shared images from a boat-racing event which took place in Caldonazzo (which is part of the Trentino province). Readers interested in knowing more about how the aforementioned semantics-based search works are referred to [19] for details.

The computed live topic news are then saved for each user with an indication whether the user has read the topic news; these topic news can be eventually archived or deleted by the user.

1.3 Social Actors Suggestion

Social Core provides a mechanism to compute social actors which are similar in interests to a given social actor. The mechanism is based on live topics (described in the previous section); namely, for two social actors it computes the number of live topic news shared by the live topics of the two social actors. The more live topic news the two social actors have in common, the closer their interests are assumed to be. The mechanism is based on the same semantic search machinery as used for the computation of live topic news and, therefore, it takes advantage of the automated reasoning. For example, if two social actors defined their live topics with concepts PROGRAMMING_LANGUAGE and JAVA respectively, then they can be considered close in their interests if they have live topic news entities in common and tagged with, for example, RMI, JNA, and possibly other concepts related to the Java programming language.

Note that this service is defined for both kinds of social actors, users and communities, and can be used, for example, to suggest users to join new communities, to suggest community actors to invite new members, or to build user-to-user contacts.

4 Usecase: SmartCampus Platform

SmartCampus is still running three-year project started on January of 2012 and that is funded and carried out by TrentoRise and specifically targeted to the students of the University of Trento.

4.1 Project description

The basic idea of the project is to harmonize the wide range of different system, infrastructures, services and devices that are related to university students, teachers and professors. In particular, the main focus is to help and support students moving into a new city (Trento in this case) by providing contextualized and personalized services through their mobile devices (e.g., smartphones, tablets).

Moreover, the students are not simply considered "consumers" of these services but also, through collaborative technologies, they are also considered providers and curators of the information in the system.

SmartCampus takes the "system of systems" approach as it offers services related to transport, student profiles, interesting places, and course information among others. All these services are offered as part of the services from the university to the students, so the students automatically have personalized access to them without having to register.

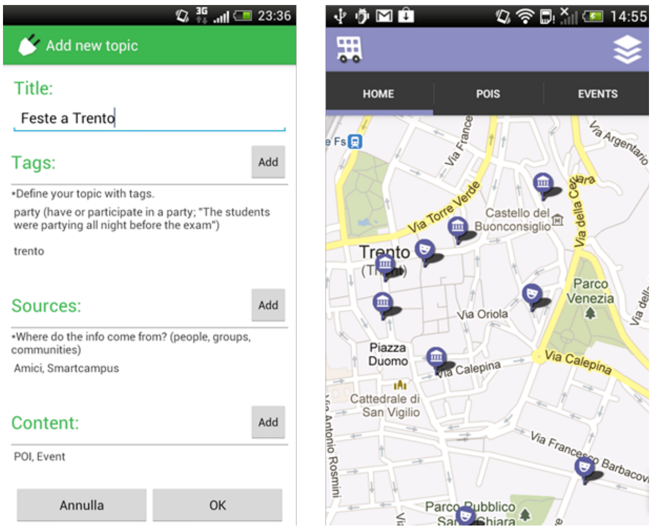

Fig. 1. SmartCampus Android app screens

In order to give a better idea of the type of services offered by the platform, the following are some of its main subsystems:

- *Community Manager*: it allows building and managing the social connections (i.e., subject lightweight ontology). This application provides services for discovering new users; organizing them into groups and sharing different entities with them (e.g., events, places, portfolios). Finally, through this app, it is possible to check what others are sharing and to 'follow' (i.e., by creating live topics) interesting events, places and more. The left picture of Fig. 1 shows an example screenshot of the creation of a live topic;

- *Discover Trento*: it provides information and virtual tours about top places and events from the city of Trento. The users are able to search by both public information and information added by other users and are also able to follow and receive notifications from places and events (via live topics) like for example "happy hours" from local establishments and attendance confirmations from friends. The right picture of Fig. 1 shows a search query result for proximity based on-going events;
- *Portfolio*: it allows the user to create and share multiple CVs and profiles using certified and updated information from the university and from their own additions. These profiles can then be shared (through the entity sharing and access control functionalities of Social Core) and users can subscribe to get notified on updates and changes (by using live topics);
- *Journey Planner*: provides maps and tools for the planning of walking, bicycle or public transportation trips around the city. Furthermore users can signal and comment and receive real-time notifications on the best routes and possible delays in public transportation.

4.2 Integration Architecture

Social Core provides to the SmartCampus platform the services described in the previous section. These include entity/metadata storage, managing of users and their interactions, semantic services like search, creation of live topics and computation of live topic updates. Fig. 1 shows a high-level architectural representation of the SmartCampus platform and the Social Core inside it.

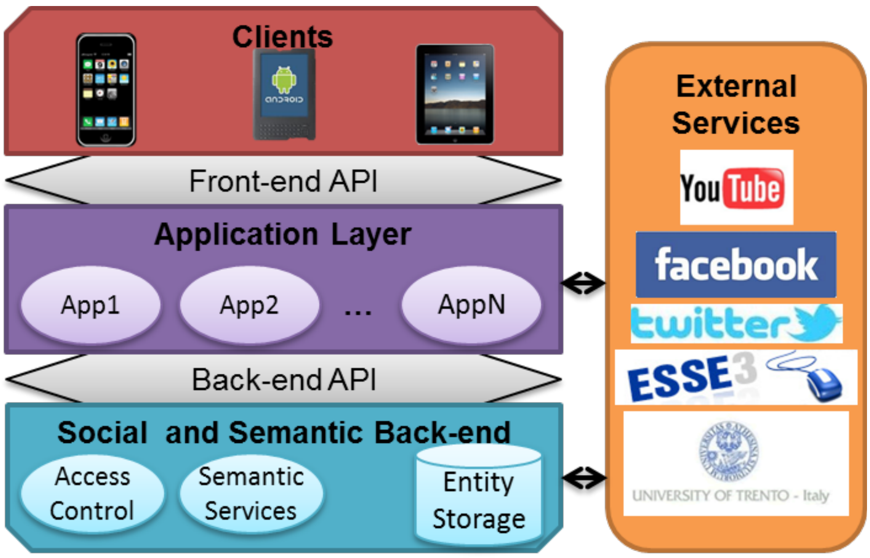

Fig. 1. Smart Campus Platform Architecture

As shown in Fig. 1 these functionalities are provided through (HTTP) APIs that are then used by the platform applications (e.g., community manager, discover Trento) and that offer their services by a front-end APIs allowing easy reuse and implementation of interfaces in native code for several mobile formats. The architecture further allows the integration and linking with external services at the backend or application levels.

4.3 First experiments

The live testing of the SmartCampus platform was started in October 2012 with a test population of almost one hundred students. Each student was given a smartphone with the SmartCampus applications installed on it and was briefly introduced to some of their features.

To the date of publishing this paper students have already provided over two months of feedback including usage statistics and as a result of this several improvements to the platform were planned and implemented. While a full-fledged user study is upcoming to future works Table 1 contains some relevant usage values from the users that could be used as a first hint of the final results.

Table 1. SmartCampus student usage statistics[9].

Users	98	Live topics	155
User groups	119	Live topic updates	6253
Entities	2309	Shared entities	203
Community entities	2056	Free Text annotations	145
User entities	253	Semantic Annotaitons	29

In more detail, the values in Table 1 represent:

- *Users*: this represents the number of students testing the platform. Note that test users and data are not included in these numbers;
- *User groups*: these represent user created subgroups of other users like ‘friend’, ‘following’ among others. Out of the 98 users, 59 added at least one friend.
- *Entities*: this includes the *person* entity for each of the users in addition to locations, events, and portfolio entities from the system.
  - *Community entities*: subgroup of entities that were created by the platform owners to bootstrap the system and also by the actual users (however, the provenance information is not currently recorded). These represent a large

9 Note that in the current implementation entity annotations are not supported; therefore, no statistics on this kind of annotations is provided.

percentage of the created entities, which is in line with the early testing stages of many systems;

  - *User entities*: subgroup of entities created by the users themselves. In the current implementation, these are only portfolio entities. Users are slowly learning how to participate and create new entities; this number is expected to increase as new facilities for contributing are added to the system.

- *Live topics*: live topics created explicitly by the users (by using the interface shown in Fig. 1) or generated by the system in response to user requests of 'following' or 'receiving updates' from certain places, events, portfolios, etc.
- *Live topic updates*: notifications generated by the system and sent to the users about their live topics news and followed entities;
- *Shared entities*: this number represents the number of access control directives created by users. The current version of the system only allows the sharing of the portfolio entities, so this number reports an interesting usage of that feature.
- *Free text annotations*: number of free text annotations added by the users to other entities. Recent improvements to the functionalities offered by tags and to the features that allow tagging are expected to further increase amount of user-created tags.
- *Semantic annotations*: number of semantic annotations added by the users to various entities. Feedback on this feature reported that the users were not sure of its usage and utility. This prompted for, currently in progress, redesign of the user interface and presentation that will be reported in future works.

Overall, despite the fact that testing and refining of the SmartCampus project is still just starting, students have demonstrated a good level of interest and participation that is bound to provide more feedback and insight for future work.

2 Related Work

The more business/academic-focused social networks like the work-oriented IBM's Beehive studied in [3] and the scientifically-aimed Academia.edu[10], ResearchGate[11] and IamResearcher[12] (analyzed in [4]) have been less successful in attracting users and maintaining their activity levels. As such, while the use of social networking in non-recreational environments is increasing dramatically, its influences and results (whether it increases productivity or not) are much less certain [6].
Ubiquity of mobile internet access through smartphones and or devices, has created the opportunity for new social networks offering mobile-based services like Dodgeball/Google Latitude, Google Now FourSquares and Instagram). Furthermore,

10 http://academia.edu/

11 http://www.researchgate.net/

12 http://www.iamresearcher.com/

conventional social networks have also moved into this space by releasing their own versions and services targeting mobile devices. Mobile social networks capitalize on the availability of user-location information and other features from the mobile device (e.g. the camera) to provide new services based on the current location and/or situation of its users that add convenience to people's everyday lives [3].

3 Conclusions and Future Work

Despite the recognized potential, successful examples of social networks and the observed tendency [20] that people have to ask questions to others even when they have access to the vast resources of information provided by the Internet, more focused social networks offering services for businesses and the academia have proven to have difficulties in attracting users and maintaining their activity levels consistently. This paper introduced Social Core, a mobile social network back-end infrastruc-ture, currently in-use as part of the SmartCampus platform that introduces semantic technologies to improve social network services like semantic annotation, semantic search and semantic-enhanced access control; while also aiming to help on the, admittedly complex and multidisciplinary, identified issues with service-oriented social networks. In particular, the following are the ways that in which Social Core and its integration in the SmartCampus platform address the previously identified issues of these social networks (see Section 1):

- *Negative image*: providing good utility with the combination of the semantic services and the location and context sensitive applications (thanks to use of the GPS and other tools available in smartphones) like done in the Journey Planner and Discover Trento applications, provides an immediate utility to users and reinforces the idea of the platform providing added value.
- *Lack of contributions*: establishing the utility of the platform and the sense of belonging to, participating and remaining constantly updated (through the live topic notifications) about a real community are powerful motivations for participation. To reinforce this, gamification tools like badges and achievements are also being planned.
- *Privacy concerns*: Social Core takes a "privacy by default" approach, giving each user its own private entity base and (through the implementation of the RelBAC theory) complete and clear control over sharing his personal information and entities.
- *Registration resistance*: leveraging public information and profiles already available to the institutions offering the service saves the users the added burden of registering and creating a profile from scratch. To avoid privacy issues, and as done in [10], all information that is not of public domain is set to private by default.

Future work includes expanding and testing some of the features from Social Core (community use and support and definition of user for non-person entities) along with a more in-depth exploration of multiple users for the same person and the privacy possibilities (i.e. full or partial anonymity) that this and a full implementation of the

RelBAC access control theory enables. Furthermore, a more wide-spread user study is already on planning stages, this would be used to gauge the interest level of users on each feature and also hopefully help improve the way of presenting semantic-based services to users and help addressing the more social and psychologically related issues that were mentioned in this paper.

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