PAPER • OPEN ACCESS

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To cite this article: T Rosi *et al* 2021 *J. Phys.: Conf. Ser.* **1929** 012036

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Learning motion concepts using Augmented Reality Active Learning (AnReAL) activities

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Abstract. Active learning and discovery-based laboratory curricula for the understanding of kinematics using motion sensors have extensively been studied in Physics Education Research for more than thirty years and provided strong evidence of their usefulness in terms of students learning and retention. More recently, activities based on video analysis software have also been developed and have become an important part of Physics Education Research. In this work we present a setup based on Virtual Reality (VR) headsets that may be used both for activities that are currently based on motion sensors and also for motion tracking. Our setup is based also on cameras that can be attached to the headsets in order to achieve an Augmented Reality experience. While VR headsets are mainly sold as gaming devices, they can be very interesting for Physics Education active learning activities: we called such an activity an Augmented Reality Active Learning (AnReAL) activity. As it will be shown, many curricula based on motion sensors or on video tracking can almost automatically be translated into AnReAL ones, while also being open for many new opportunities. In fact, following the emerging theory of Embodied Cognition, Virtual and Augmented Reality setups such as the presented one could prove to be very beneficial for information retention.

1. Introduction

Active learning and discovery-based laboratory curricula for the understanding of kinematics using motion sensors have extensively been studied in Physics Education Research for more than thirty years and provided strong evidence of their usefulness in terms of students learning and retention [1][2][3][4][5]. We ourselves have been using these curricula based on such sensors (such as PASPORT Motion Sensors [6]) for many years, and with good results and satisfaction. In figure 1, a student using a motion sensor is shown.

The roots of the advantages of relying on such an Active Learning curriculum, based on the motion of the students, can be found in the emerging theory of Embodied Cognition [7][8][9][10], for which "knowledge is grounded in sensorimotor systems, and that learning can be facilitated to the extent that lessons can be mapped to these systems" [11].

More recently, learning activities based on Video Analysis software have been developed and extensively been tested, becoming an important part of Physics Education Research [12][13][14][15][16].

We here present a setup based on Virtual Reality headsets which we believe features all the main pros regarding the use of both motion sensors and video analysis software, while also opening for many new opportunities.

Figure 1. The traditional setup with an ultrasonic sensor.

In fact, in the last few years Virtual Reality headsets have become more and more accessible, while also being able to rely on better professional and free tools for software development and distribution. A simple extension to these headsets is the use of stereo cameras in order to achieve what is called a "pass-through" experience, meaning the user can see beyond the VR headsets using the cameras. This way, it is possible to mix a stereo visualization of the real world and of any kind of virtual object, therefore achieving a type of Augmented Reality (or Mixed Reality). In figure 2, a student using the VR headset with the stereo camera is shown.

While these headsets are mainly sold as gaming devices, they can be very interesting for Physics Education active learning activities: we called such an activity an Augmented Reality Active Learning (AnReAL) activity. In this following, we discuss the first findings about the use of our AnReAL setup with two different applications: using it instead of the motion sensors, and using it for experiments based on objects tracking.
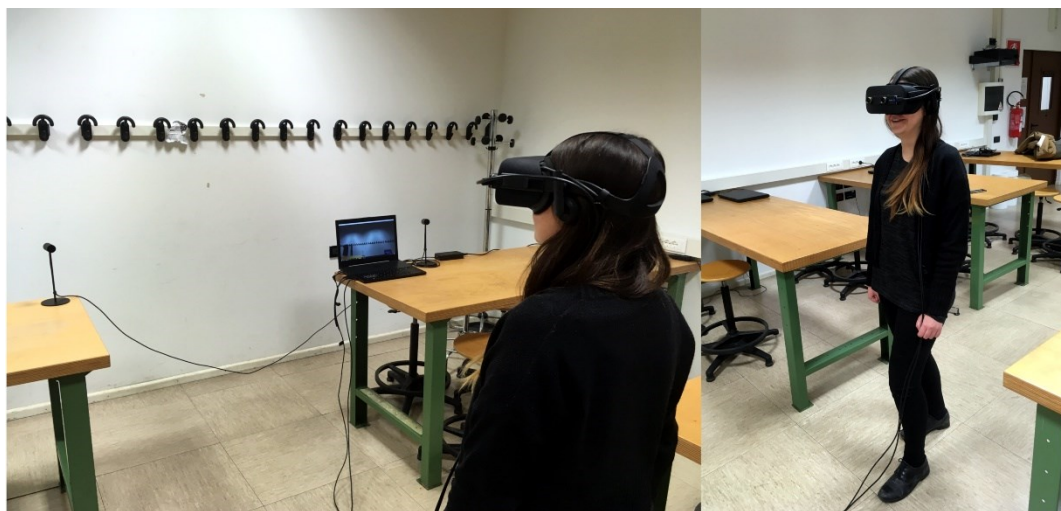

Figure 2. A student using our augmented reality setup.

2. The AnReAL Motion Curriculum

The aforementioned kinematics curricula based on motion sensors can almost automatically be translated into AnReAL ones. In fact, part of these *curricula* are based on the tracking of the position of a student using motion sensors, while she/he moves trying to obtain a certain graph regarding position/velocity/acceleration over time. In the AnReALversion of this experience, the student can do the same while wearing the headset, seeing where she/he is moving thanks to the cameras and visualizing all the motion data plotted in real time (figure 3). The position of the student is in fact given by the tracking of the headset itself.

These activities are traditionally carried out in groups, with students taking turns to move in front of the motion sensor while the rest of the group can look at the monitor of the computer displaying the corresponding motion-data graph in real time: in the AnReALversion, the experience for the rest of the group is not radically changed, but can be more effective and productive since on the monitor they can see exactly what the moving student is seeing, plots included, resulting in a more immersive and intuitive experience.
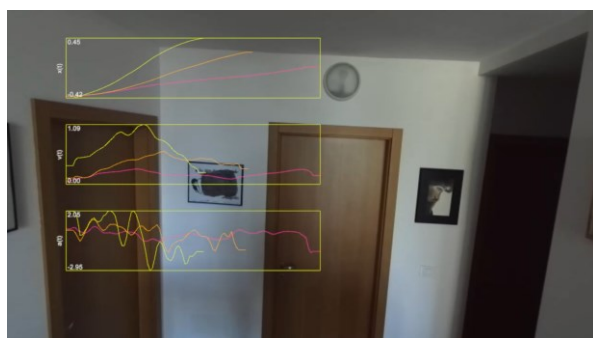

Figure 3. What the users sees using the VR headset: the image in front of him/her given by the stereo cameras and the graphs regarding his/her motion tracking such as x(t), v(t), a(t).

Figure 4. Motion tracking data can also be seen using a 3D visualization created in real-time. Here some acquired positions are visualized, together with the corresponding velocity and acceleration vectors.

3. The AnReAL 6 DOF motion tracking and 3D visualization

The position and the rotation of the VR controllers may also be tracked: for this reason, our setup is capable of obtaining a 6 degrees of freedom (DOF) tracking of multiple objects in real-time: the measurements of the positions of the controllers can be visualised in real-time, while also displaying additional information such as velocity or acceleration vectors (figure 4). The controllers may also be attached to any moving body (such as a pendulum, or a rotating platform) in order to track its movement. The tracking of these objects, which are often used in a physics laboratory, can therefore be obtained.

Any other information which can be derived by the measurements of the positions can be visualised, such as the angular momentum vector (figure 5). This particular vector, as it also happens for angular velocity or acceleration vectors, takes full advantage of the 3D visualization of the data, as the students can move around the displayed data and see for example that if the tracked object moves on a plane the direction of such vector is normal to the plane of motion. The visualization of these vectors can generally not be obtained by means of other traditional tracking methods such as video analysis software (such as Tracker [17]), while it still may be done in other 3D tracking setups, such as those based on 3D cameras (e.g. Microsoft Kinect [18][19]).

Different series of tracking data can be acquired and displayed at the same time for comparison: in figure 6 for example, three different series of data are acquired for a controller moved with an increasing speed for each series, and the corresponding data is visualized.
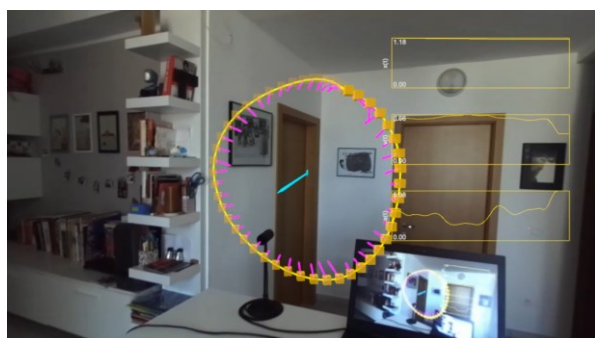
Figure 5. The angular momentum vector, normal to the plane in which the motion occured.
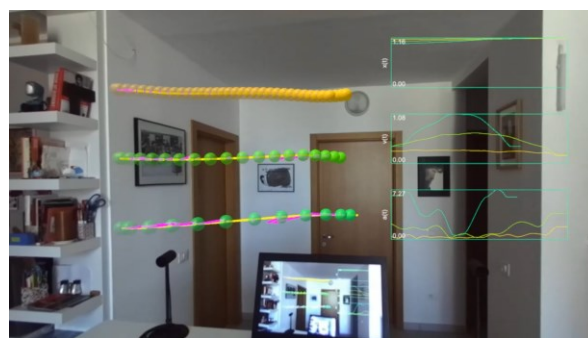

Figure 6. Multiple data series can be acquired and compared.

4. Conclusions

In this work we commented how an Augmented Reality setup based on a VR headset and a stereo camera can be used in the laboratory of physics to discuss motion. We showed how traditional curricula based on active learning activities using ultrasonic motion sensors or on video analysis software can almost automatically be translated into this new Augmented Reality version, which we called an AnReAL version. Of course, because of the high degree of flexibility of this Augmented Reality setup, much more can be done, starting from a 6 degrees of freedom, real-time tracking of multiple objects and the corresponding data visualization; multiple series of data can also be acquired and displayed at the same time, and vectors such as those regarding angular velocities, angular accelerations and angular momentum take full advantage of such a 3D visualization environment.

Virtual Reality experiences are truly immersive because of the intuitive way the user-software interaction occurs: the user is free to rotate his/her head and also to move around, and can even use controllers to reach out for objects. This degree of interaction is achieved for a very simple reason, which is that these VR setups are first of all (from a physicist point of view) low-cost and high-quality tracking devices. For this very reason, we think that they cannot be overlooked by the Physics Education Research Community and need more attention and further investigations.

5. References

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