

SurveyingGame: Gamified Virtual Environment for Surveying Training

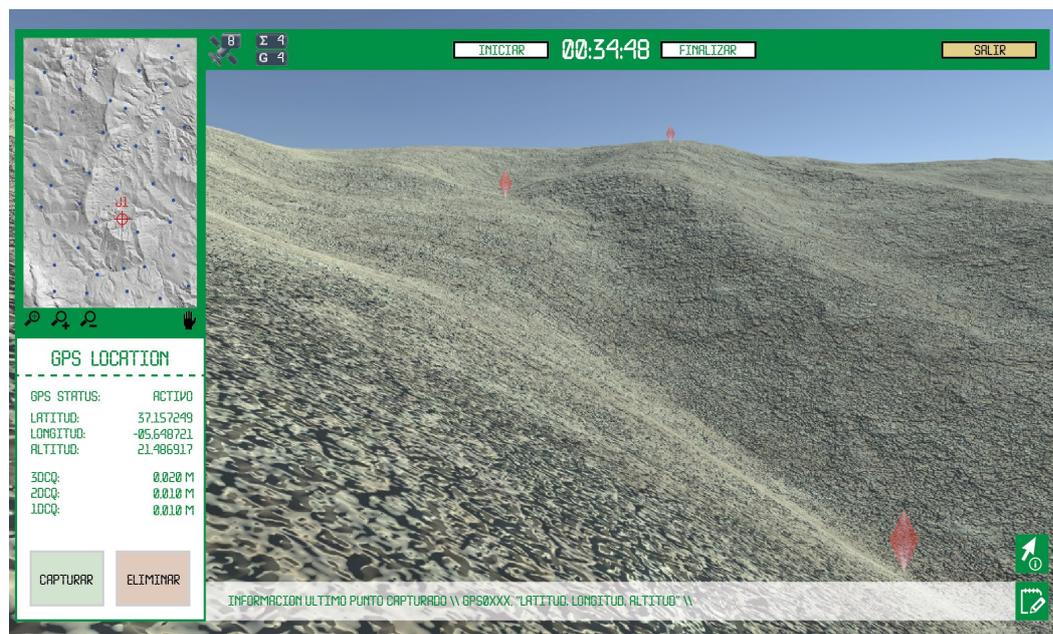
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Abstract

This contribution describes the first developing phases of a tool aimed to support field training sessions in topographic survey learning courses. After describing the issue that justifies the proposal of the research, a discussion of similar approaches carried out by researcher from different countries is shown. Thenceforth, the concept and description of the proposed gamified simulator are explained. Finally, the future features and scopes of the research are presented.

Keywords

surveying skills, virtual learning environment, gamification, educational innovation.



A Need of Innovation in Topographic Surveying Training

During the last decades, new technological instruments have been incorporated into the field of topographic survey, giving rise to different techniques and practices to be developed. Among these instruments it is worth highlighting the GPS and the Total Station, that are widely used in urban projects, roads, bridges, sewage systems, etc. The most relevant changes derived from these advances are evidenced in the process of capturing, storing, calculating, and transmitting the data obtained in the field work, as well as in their graphic representation. Obtaining a final product with greater precision and speed is allowed by using these tools.

The learning of these techniques is highly necessary along the training period of those students who will make use of topography for the performance of their professional activity. However, there are some operational limitations in the educational context of topographical subjects, mainly related to the economic aspect and the insufficient hours for practical training that usually are allocated in the subject programs. The high cost of surveying instruments sometimes implies the shortage of equipment to guarantee adequate learning ratios. On the other hand, environmental factors are decisive. Inclement weather can prevent the correct development of the educational practices necessary for the procedural learning of topographic devices, even delaying or making them impossible. In addition, sometimes the training of students is limited to the surroundings of the educational facilities for security and transportation reasons.

These factors keep down the actual learning performance for students, which is limited in relation to the operational handling of topographical techniques and instruments on-site field. Moreover, we should add the current social and health situation derived from the COVID-19 pandemic. The health protocols applied to educational contexts hinder the effective use of topographical instruments and force the reduction of student ratios, worsening the lack of devices.

The sum of all these factors has motivated the opening of this investigation. The development of a digital tool (simulator) can have a very positive impact on the topographical training of students. It could even replace traditional training sessions in topographic subjects, when environmental or socioeconomic contexts make their development impossible.

State of the Art

The bibliographic review carried out has brought back some experiences prior to this research aimed at the construction of virtual learning environments in the field of teaching topographic surveys. These contributions use virtual reality to enhance the user's immersive experience in different ways. Some are committed to a high-level immersive experience, using peripherals such as VR glasses, gloves, physical spaces set up for the use of the tool, etc. Other contributions are limited to the traditional display of the virtual environment on the screen of the devices. The main contributions studied are listed below, mentioning their main characteristics.

Corresponding to the first group, the "SurReal" simulator [Bolkas et al. 2021] recreates a highly realistic virtual environment for computers, modelled by capturing point clouds of real scenarios using drones (UAVs) and terrestrial laser scanners (TLS). At its current level of development, using the "Oculus Rift" hardware, students can perform pre-configured levelling exercises in different environments. However, the authors point out some limitations in the use of this hardware related to the virtual handling of instrumentation and the performance of certain tasks (tripod leveling, calibration or data recording), for which it has been necessary to enable some additional elements within the interface. In a similar approach, other authors propose a cyberlearning environment designed for smartphones based on virtual reality [Levin et al. 2020] that includes a digital elevation model (DEM), a total station and a virtual reflector. The VR implementation is done using the hardware "Samsung Gear VR". The students recreate the entire workflow of a surveying, emphasising the correct location

of the data collection points, that is, the proper interpretation of the terrain to be surveyed. The inclusion of various parameters for the evaluation of the survey is highlighted, taking into account the time spent and the root mean square error (RMSE) obtained by comparing the model obtained with the original. Despite the portability and ease of use offered by this tool designed for mobile devices, it incurs limitations regarding its power and functionalities. This is due to the limited data processing capacity of these devices, having to export the data to other devices.

In a different line to the eminently immersive experiences mentioned above, the Simusurvey tool [Lu et al. 2009] or Simusurvey X (in its latest version) [Kang et al. 2019] consists of a computer-based simulator focused on carrying out virtual surveying projects with a total station. This simulator includes several working modes: leveling surveying, horizontal angle surveying, vertical angle surveying, traverse closed surveying and free mode surveying. The tool is currently available for use on the XBOX 360 console and is compatible with "Kinect" technology, providing a distinctive user experience. However, its replicability within the teaching environment is limited precisely due to the use of such specific devices. Finally, the computer-based tool called "Virtual Environment for Learning Surveying (VELS)" [Dib, Adamo-Villani 2011] introduces some new features compared to the previous ones. It allows the import of digital elevation models (DEM), as well as the real-time generation of 3D terrains, considerably increasing the number of terrains on which to practise [Dib et al. 2013]. It also allows centralised monitoring of student performance, facilitating the later assessment task. The practical exercises that can be carried out with the simulator cover practically all the tasks that are considered minimum content for the training of this kind of professional (chaining, differential leveling, triangulations and coordinates calculations, etc.). It is worth noting that practically all the referenced contributions include a process of assessment of the tool and its impact on student learning, which is reported in the epistemology as very positive.

As a general conclusion of the literature review, it can be deduced that there are already several interesting attempts to create a surveying simulator, but the approaches of each of them differ in different aspects (use of virtual reality, type of fieldwork recreated, instrumentation included, operability of the tool, etc.). It is also surprising that none of the contributions studied has developed a module for the use of GPS equipment, all of them opting for the use of total stations, despite the high use of the former in professional practice. Although it is true that some of them have proposed it in their initial conception phases, none of them have developed it.

In this context, it is proposed to develop a new simulator that takes into consideration the most valuable features of these previous contributions, but which includes a series of distinctive factors. On the one hand, the use of GPS equipment to carry out the survey, in addition to the rest of the tools considered by other simulators. On the other hand, the approach as a learning tool that includes elements of gamification and creative learning (creative or Smart thinking). In this sense, it is also proposed that the simulator should be responsive to the decisions that the student makes during practice, modifying the contents shown and escaping from the idea of a single predefined roadmap. In this way, the aim is to encourage learner autonomy and initiative. Some of the references studied include elements of gamification, but in a secondary way. In this case, gamification occupies a vehicular role in the conceptualisation and development of the simulator. However, given the nature and length of this publication, this concept and its application are not presented in detail, and the interested reader can find more information about it in [Hidalgo-Sánchez 2021].

SurveyingGame. Description and Concept of the Simulator

The proposed gamified simulator, SurveyingGame, is conceived as a support tool, or even a substitute for field training sessions in topographic survey learning courses. Specifically, it simulates the use of GPS equipment for this purpose. The interface of the simulator has been conceived to make its use as easy as possible. It tries to emulate

student training procedures when using actual devices. As a result, the necessary data to post-process the office work is obtained, just as if it had been obtained in a conventional way.

Regarding the gamification process of training with the simulator, a diagram is included (Fig. 2) that represents the flow of operations that a player/student would carry out from start to finish in the simulator. The conceptual scheme of its development is shown, accompanied by some preliminary images of its subsequent computer development:

- As soon as the simulator is run, the student must enter the username provided by their teacher. This username is associated with a series of specific passwords for each player that they must enter as they obtain them to unlock the different levels.
- When starting to play, the student will appear with an avatar of free displacement within the "Device Room" (Fig. 1a). In it, each student will have to select the necessary device to carry out the land survey. Depending on the working procedure, the student will need different devices. Initially, "Real Time Kinematic (RTK)" and the "Differential GPS (DGPS)" work procedure will be included. Students must select the method of work and the necessary devices. After choosing the procedure, the fact that the student obtains each virtual device will be contingent on a correct answer to a series of related questions (Fig. 1b).
- Once students obtain the necessary surveying devices (inventory), they will need to select the difficulty level of the surveying task in the simulator. Initially, only "Difficulty Level 1" will be available. Several levels of difficulty are included. Each of them contains terrain with a different topography and degree of difficulty, which increases in complexity at each level. Level 1 is the simplest, and level 3 the most complex.
- Before starting the topographic survey training, the students will have to configure some parameters in the virtual device and check some key parameters on the work procedure. Once these steps have been completed, they will be able to start the training task, moving freely through the three-dimensional model of the selected terrain, visualizing it with a first-person camera and a top view little map (henceforth "minimap") to assist navigation (Fig. 1c).
- Once the work has started, the timer is activated, and the players can begin to collect those points on the virtual terrain model that they consider necessary. In addition, students will have to check a series of parameters related to the number of satellites captured by the device's receiver and the validity of the positional error obtained. Players will be able to see the points captured on the screen, both in the first-person camera and on the "minimap" (Fig. 1d). Likewise, they may eliminate those that they do not consider necessary.
- When each player completes the data collection, the timer stops. Previously, it is possible to check the data in the field notebook included in the simulator (Fig. 1e). When the work is finished, the simulator calculates the score obtained by the student, which will depend on the time spent and the number of points that the player has estimated necessary to complete the survey. The score obtained can range from 0 to 9999 points. More than 5000 points will be necessary to pass the level. Likewise, if the player passes the level, he will receive a badge, which will depend on the score achieved in the game (Fig. 1f). Having passed the level, the player receives the password to unlock the next one and he will move up to the following level.
- The data related to the captured points (ID, coordinates, positional error and a photograph of the point) are stored in the field notebook and can be exported to a directory on the personal computer. Data is exported in two forms: .csv format (point IDs and coordinates) and .pdf format (survey report with all collected data). The survey report will be delivered to the teacher for evaluation.

- With the password obtained, the students will be able to access the next level, repeating the same process, but in a three-dimensional model of the terrain with greater complexity. The same for level 3.

The overcoming of all the levels implies the overcoming of the complete training. However, the evaluation and final score of the training does not depend only on it. The evaluation of each student depends on several factors: game score, RMSE obtained, and assessment of the survey report carried out by the teacher. Likewise, even if the student has passed all the levels of the game, he can train again to get new badges. In addition, it is proposed that the student can import other three-dimensional terrain models to the simulator to train with. A comparator will also be incorporated to graphically check the adjustment between the original terrain and the terrain obtained by each student through the captured ground points. This comparison by means of the RMSE provided by the simulator itself will be a great indicator to evaluate the training activity of the student, having no necessity to use third party software.

Initial Development of the Tool

The application has been developed for PC Windows 10 operating system, but it can be directly used in Windows 7 SP1+, 8, 10, 64-bit versions only; Mac OS X 10.12+; Ubuntu 16.04, 18.04, and CentOS 7. When released it is aimed to be used by students at the “Higher Technical School of Building Engineering”, University of Seville in the subject “Topography”

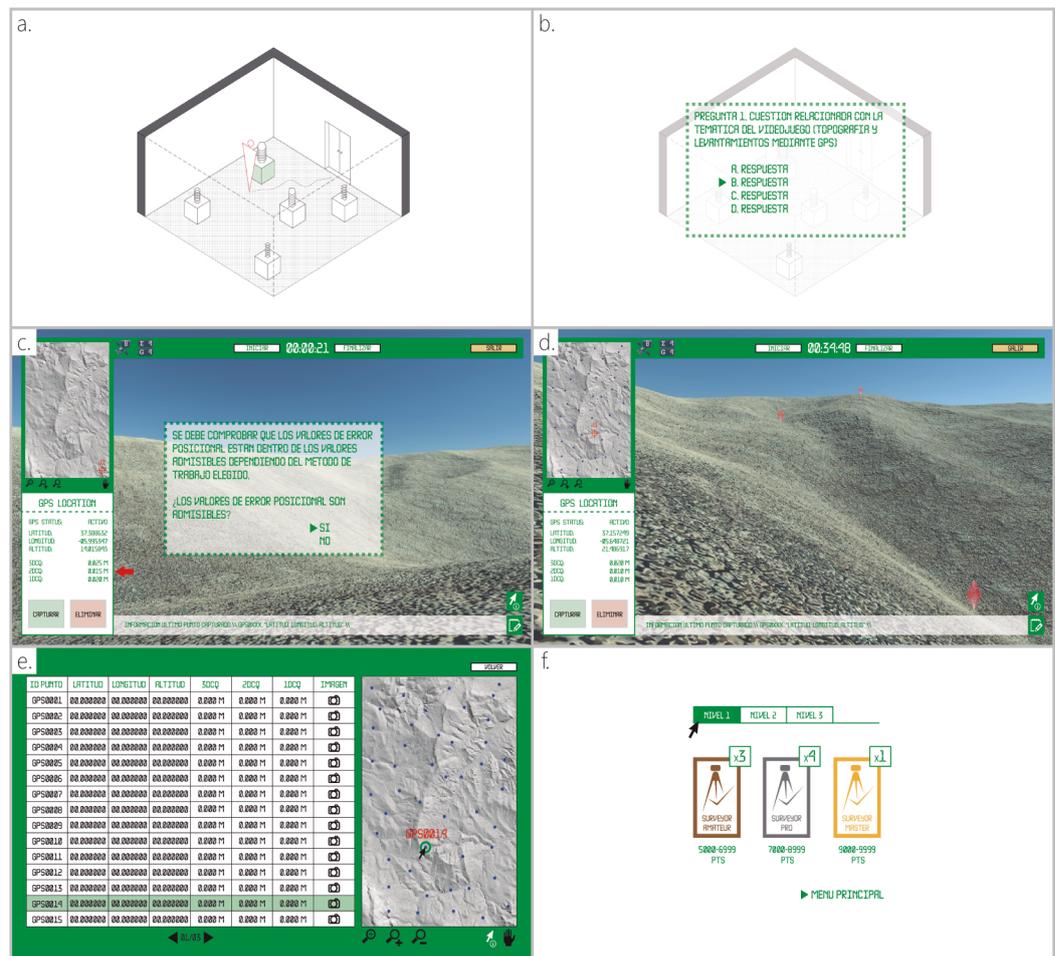


Fig. 1. Some examples of the screens that the student will face during the simulation.

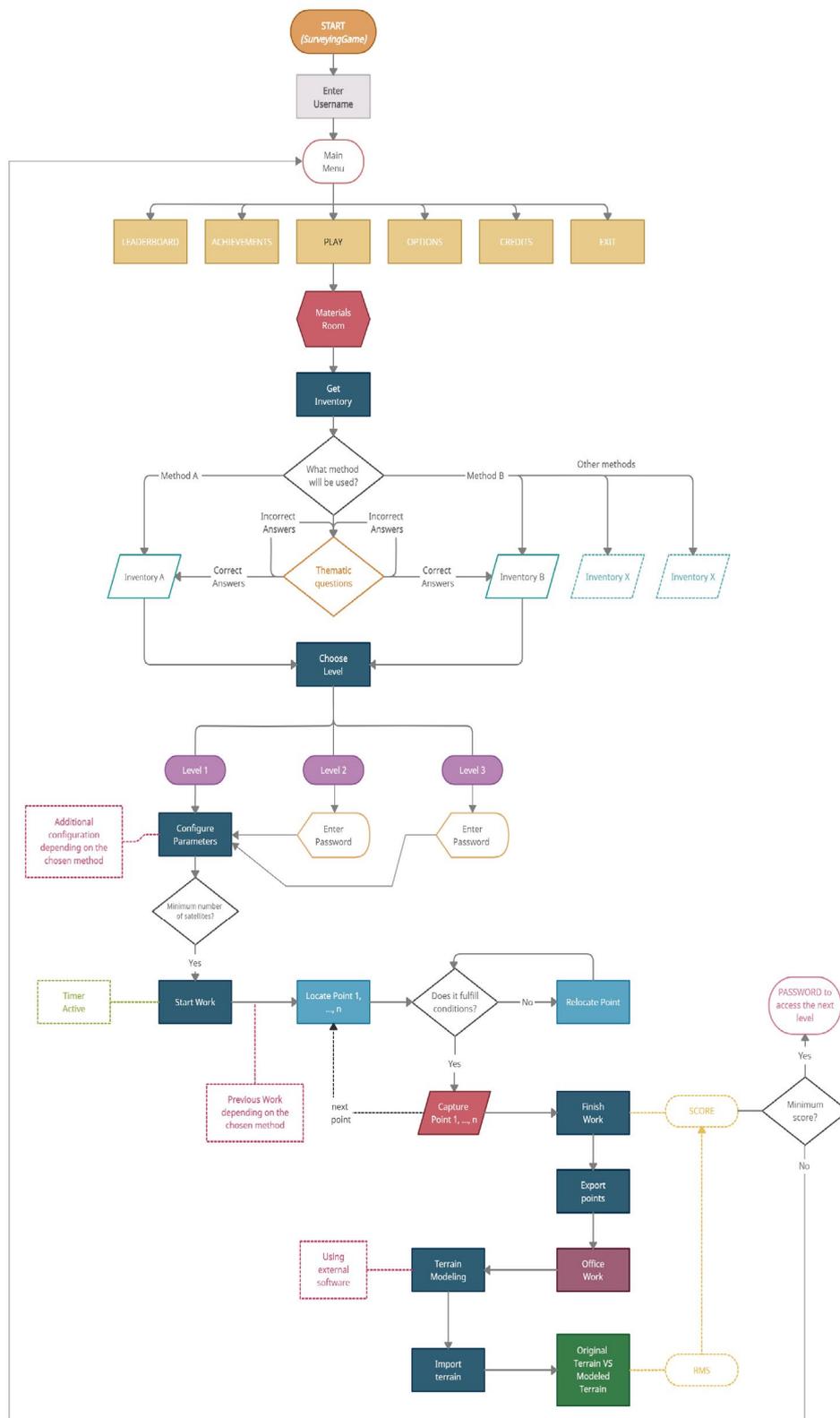


Fig. 2. Flowchart of actions performed by the student within the SurveyingGame simulator.

and stakeout survey" as a testing phase. The hardware requirements for the game are just a personal computer, and peripheral such as mouse, keyboard and speakers. In this way, every student can carry out the fieldwork surveying practice individually by means its own laptop either on screen or by using cardboard virtual reality glasses.

After a perusal review of the different engines for games development, Unity is the platform chosen to program the simulator. It is the most popular gaming engine, and it is the platform that has been used for most of the applications described above. Apart from the gaming engine a code editor is needed to configure the scripts for the interactivity between the different assets of the game. "Microsoft Visual Studio Community 2019" has been the editor used to operate in C# that is the native programming language of Unity.

The development of the simulator is still in progress (Fig. 3). So far, several tasks have been undertaken in this regard: development and operation of the simulator interface (UI); creation of environments and 3D objects with which the student will interact; user movement settings within the virtual environment; control of tracking and position of cameras/views. Each of these tasks has been programmed using specific scripts of different complexity.

Conclusions and Future Research

The SurveyingGame simulator is still at an early stage in terms of its operational capacity. In this contribution, the approach of the tool, its design and some details about the development process have been exposed.

Beyond the necessary computer development to enable the actions defined above, there are some lines of future work that would be interesting to research in order to achieve an implementation. We are working specially in increasing the immersiveness of the application, augmented reality and the automation of the evaluation process by means of artificial intelligence.

This simulator aims to imitate the field work procedure in a real context, but in a virtual way. Therefore, any addition that helps to achieve a more immersive environment in pursuit of a more realistic experience would enrich the project. Beyond that possibility, the inclusion of augmented reality and beacons technology (electronic beacons) seems to be quite appropriate for this proposal. Eventually, this would allow the use of real instruments in a virtual field and vice versa: virtual instruments in actual terrains. In fact, another of the key reasons for

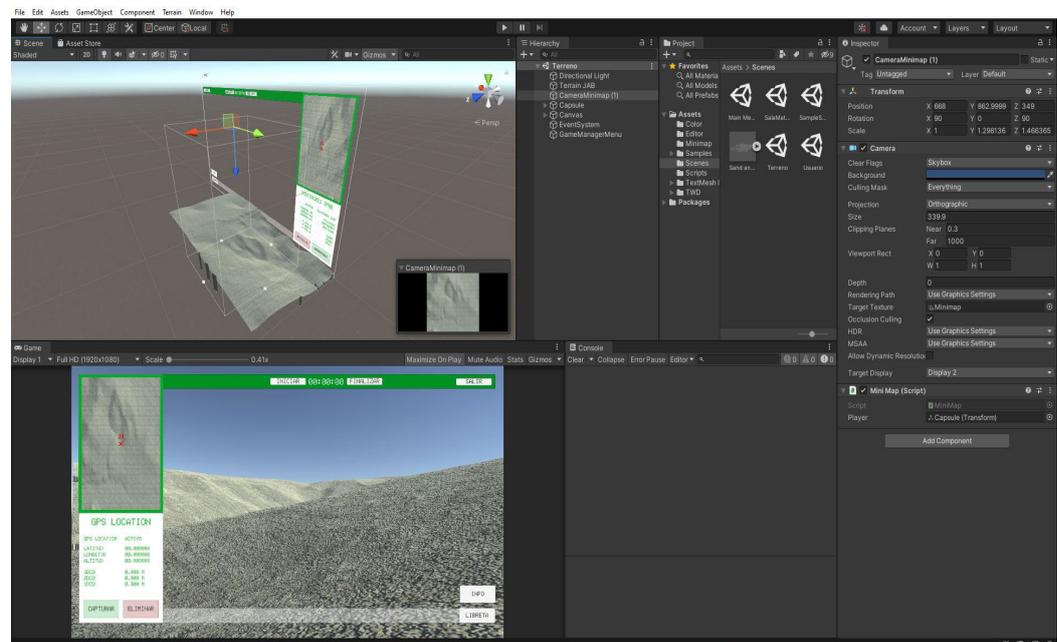


Fig. 3. Development and configuration of the simulator in Unity.

the choice of Unity as the used game engine is that it offers powerful tools to create rich and highly attractive augmented reality experiences that intelligently interact with the real world. It should be noted that its implementation would not imply a very significant cost increase in terms of necessary hardware requirements, since nowadays there are quite affordable solutions, both for beacons and for augmented reality glasses.

As artificial intelligence is concerned, it would automatize the assessment process of virtual land surveying carried out depending on several factors. A database that registers both solutions and given scores would be created. A machine learning algorithm would determine whether the solutions of incoming practices match with found values in the database within a predetermined threshold, and in that case, it would assign the matched score. Otherwise, the solution would be assessed by the teacher, and it will feed the database. In this way the database will be continuously growing and improving the automatic assessment capability of the algorithm.

Another example of the application of this type of algorithm would be its use to evaluate the suitability of the points captured. For example, an algorithm that detects the terrain break lines (significant points that should be captured) could be implemented in order to evaluate the proximity to the points captured by the student. The shorter the distance from these break lines, the better the assessment.

Just some of the possibilities offered by this proposal are shown above. The mixture of software and hardware under a unified criterion oriented to the virtualization and gamification can greatly enhance the learning process of practical land surveying.

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