# A cyber-physical educational game of Petanca. Petan-Camins.

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***Abstract*—This work-in progress (WIP) depicts the first edition of the educational game "Petan-Camins". This game is conceived as one of the many potential gap bridges between the physical and virtual realms among civil engineering students. Petan-Camins is based on the traditional Mediterranean game Petanca and players inherit identical rules. The difference between Petanca and Petan-Camins comes after the game. Once completed, a terrestrial laser scanner surveys the final scene of the physical game and generate a digital point cloud with the result. Then, players must use computational geometry tools for answering manifold geometrical questions. A physical-to-virtual journey of information is experienced by civil engineering students. The flow of information from the built-environment to building information models represents cornerstone knowledge for civil engineers in the verge of the digitization of the sector.**

***Keywords—terrestrial laser scanner, gamification, construction 4.0, computational geometry***

## I. Introduction

Continuously emerging technologies in Architecture, Engineering and Construction (AEC) are transforming the sector. In the Industry, the digitization of the built environment in manifold ways represents a pivotal moment in terms of increasing productivity, resource efficiency, safety and cost-benefit. As in other domains, this digitization comes with a profound cost in disruption. In Civil Engineering Education, there is a debate needed when it comes to embedding digitization within curricula in ways it fosters creativity and guarantees equal opportunities. Educators in Civil Engineering are increasingly making attempts for embedding digitization activities properly.

This innovative practice is aimed at providing one bridge between the physical and the virtual realms to civil engineering students. It aims at eliciting reflective thoughts on how information may flow in this physical-to-virtual journey. In particular, info coming from Terrestrial Laser Scanners, one tool that is claimed to contribute considerably in the digitization of the sector. For this purpose, a classical physical Mediterranean game *Petanca* is enriched with a terrestrial laser scanner (TLS) and with computational geometry tools to become a physical-to-virtual game.

This work in progress presents the tools, the methodology and some of the results obtained in initial editions of the activity at the School of Civil Engineering in Barcelona, Spain.

## II. The Games

### A. Petanca

In *Petanca* and all variations (petanque, pétanque, bocce balls, lawn balls, bolas criollas), the fundamental objective is to score points by having boules close to a target. This is achieved by throwing closer to the small target ball, colloquially known in many countries as cochonnet, mingo, bolig, pallino, boliche or nano. It requires a relatively small though flat and open surface, a set of equally sized and weighed balls and the smaller ball target.

### B. Petan-Camins

In *Petan-Camins*, hyphenated with the name of our School, the physical scene at the end of a given *Petanca* game represents the beginning of the experience. After players (in this case students) playfully share the physical ball-throwing game, the scene is scanned with a TLS. A TLS generates a text file with a list of individual points. The list includes a given identification of the point, its coordinates and other texture/color properties. This list is called a point cloud and it represents a useful type of information construct in civil engineering. Interestingly, students must use the resulting point cloud of the physical scene for developing basic computational geometry methods using snippets and simple codes. This represents for many of the students a first encounter with this type of files. The methods that require development are related to the extraction of information from the scene. It is required to perform an identification of planes, an identification of spheres (center and radii), measurement of distances between spheres, or obtaining the centroid of the system.

The game consists of answering a set of conundrums that require geometrical inspection of the scene. It represents an exercise of code development of tools that enable the geometrical interpretation of the scene. The activity blends the physical game with a thorough identification of its final scene in the virtual realm.

## III. Digitalization in Civil Engineering Education

The connection between the built- or natural environments (infrastructure, buildings, cities, industries, natural assets) and the virtual worlds (internet, information models and different sorts of verses) relentlessly brings new ecosystems at all levels of the AEC sector. Automation, the Internet of Things, Extended Realities or ubiquitous sensors in cities are only a fraction of those ecosystems that may be presently generating fertile economic growth. However, in the industry sector AEC, the physical (the built and the natural environment) and the virtual components (geometrical, numerical, information

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models) are mostly dealt with separately. There is still a huge margin of improvement when it comes to the development of live cyber-physical systems in which both realms are blended together using automated pipelines of information.

For instance, construction works advance mostly physically. In parallel, comparisons with previously made information models belonging to the virtual realm and models are undertaken. The process though, is not automated. The first generation of automated pipelines of information between both physical and digital realms is already disrupting the sector in unforeseen manners. Construction and fabrication are becoming digital [1-2]. Physical assets are becoming twinned with their digital counterparts [3-4]. Construction 4.0, as an instantiation of the vaster term Industry 4.0, is commonly referred as the framework in which all activities for digitization of the sector converge.

Educationally, civil engineering classrooms represents an ideal scenario for blending physical-virtual realms which may represent richer cognitive experiences.

Traditionally, all disciplines in civil engineering relate both built and natural environments with countless mathematical models and simulations. From simple geometrical depictions of assets to complex applications for asset monitoring, these models represent the core of practically all degrees on civil engineering worldwide. Seldom though, these models are blended with real-world data. Cost, technology readiness and lack of expertise undermined the systematic use of sensors in every single AEC classroom. Presently though, with all forms of digitalization, this becomes paramount.

Attempts and examples of infusing cyber-physical activities in AEC classrooms are increasingly found in the literature. A literature review performed within the frame of a vaster educational project [6] shows some of the examples categorized in three branches:

- Educational examples related to industrial production such as additive manufacturing, offsite manufacture and robotic assembly [7-10].
- Educational examples including cyber-physical systems (digital twins, smart infrastructure) [11-16].
- Educational examples focused on digital technologies (BIM, extended realities) [17-21].

## IV. DESIGN AND PRELIMINARY STRUCTURE OF PETAN-CAMINS

The educational game Petan-Camins has been conceived with slightly different characteristics for its potential application on four different scenarios. These scenarios correspond to the combination of two levels (Bachelor and Master) and two approaches (optional or compulsory). In the case of optional activity, no credits/points/scores are associated to any formal course. The activity is entirely optional. In the case of compulsory activity for the bachelor degree, Petan-Camins is presented in the formal course of Geomatics of the Bachelor in Civil Engineering. At Master levels, it is included in the formal course of Experimental Techniques at the Master of Structural Engineering and Construction. The first edition depicted in this WIP includes results on the Bachelor/Optional scenario.

In the first edition, the design of the activity included three legs.

- Organization and logistics. Open-call to students, dissemination and social networking, coordination with Campus Staff for the use of appropriate spaces, etc. This was entirely developed by DAEC, the civil engineering students' association at Universitat Politècnica de Catalunya.
- Development of short tutorials (30 minutes) on computational geometry tools. The chosen platform is Grasshopper and Rhinoceros. This was entirely developed by the instructors. The tutorial is developed under the assumption of no previous knowledge on those platforms.
- Application of the physical game (depiction of basic adapted rules as a function of the number of participants) and generation of the digital game (questions and challenges within the digital realm).

The first edition was planned to happen one week after the exam break (a potentially less hectic week for both students and instructors). The participation in this edition was rewarded in the physical game (extrinsic motivation) whereas in the virtual game, no reward was given (assuming intrinsic motivation among participants). The total duration of the activity was 2 hours and was scheduled according to the following steps.

1. Arrival to the pitch. 5 minutes to start.
2. Explanation of the activity to participants including basic comments on the physical-to-virtual journey of the data. 10 minutes.
3. Training of *Petanca*. 45 minutes. Social activity.
4. *Grand Finale* game. 10 minutes. Each participant has a different ball (color). It is worth pointing out that participants must take picture of the final scene for identification of each one's sphere.
5. The TLS scans the resulting final scene. 10 minutes.
6. Instructors process and filter the digital information required for the virtual game. Participants watch the tutorial. 40 minutes.

Participants are subsequently given a set of questions to complete the game in the virtual realm. These conundrums are related to manifold computational geometry methods. With the aid of tools that enable mathematical operations in virtual spaces such as Grasshoppper and Rhinoceros [23], it is possible to identify the best fitted spheres (centers and radii), calculating distances between them, finding centroids, planes, vectors, curves, surfaces and/or meshes. These calculations, which are necessary in any elementary course of Mathematics, are developed by participants within the context of the game. Calculating distances between spheres represents a straightforward *petanca*-related question. When solving the questions, participants are bridging naturally the gap between both physical and virtual realms using both mathematics and the mechanics of the game. Fig. 1 to 3 show some shots during the first edition.


Fig. 1. Poster in Campus

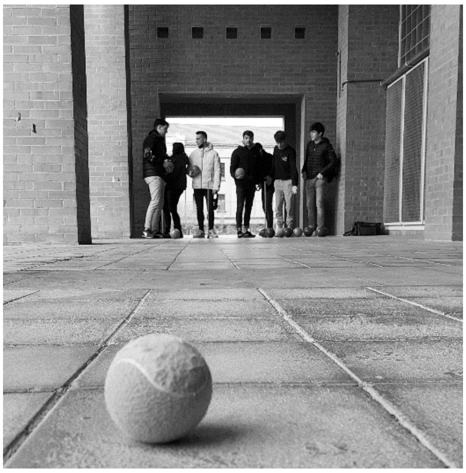

Fig. 2. Training. Social activity.

Fig. 3. LIDAR. scanning the scene with the TLS.

Recognizably, the virtual realm requires a thorough yet relatively short depiction. Assuming no prior knowledge on platforms that enable computational geometry tools and methods, a 30-minutes tutorial was designed. It consists of a sequential understanding of methods that allow representing geometry in a virtual space using snippets. The tutorial was kept simple and limited it to specific methods such as the use and identification of spheres given a point cloud, distances between points, use of vectors, definition of planes or definition of lines. Fig. 4 shows a screenshot of the video. Fig. 5 shows the result of the best sphere fitted to the point clouds within the virtual realm and Fig. 6 shows a screenshot of the visuals gathered by students when playing with computational geometry.

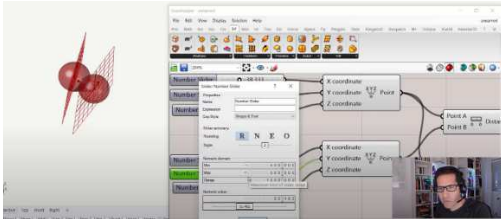

Fig. 4. Screenshot of the provided 30 minutes tutorial.

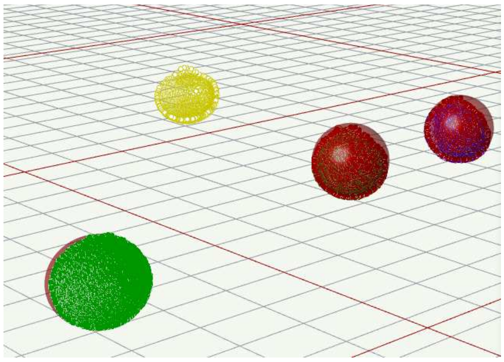

Fig. 5. Point cloud to spheres using Best Fit methods.

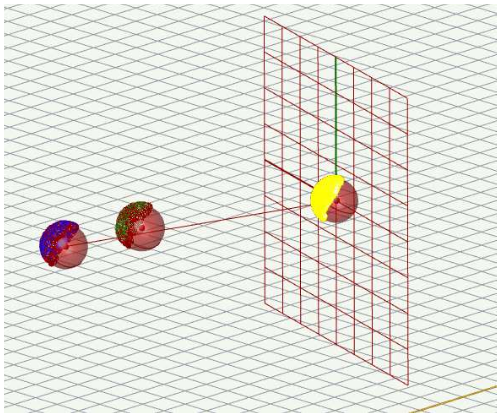

Fig. 6. Spheres, distances, planes, lines.

## V. RESULTS. FIRST EDITION

After launching an open call during one week, 16 students enrolled to the first edition of the activity. Instructors had set a maximum number of participants (20) but that limit was not reached. The reward for the participation (free lunch) did not generate an overreaction to participants. The group of 16 participants was split into two smaller groups which resulted into two finals and two scans of the *Grand Finale*. It was found that batches of 8 persons playing simultaneously (one sphere per person) represents a very good size for a given game. Social interaction is enabled and time is kept under control.

When it comes to the duration, time was kept adjusted to the schedule quite well. This was an indicator of the proportion of each step within the 2 hours can be replicated in future editions. However, in the post-game survey, students indicated that they would have preferred less training in the physical game and more training in the virtual realm (keeping 2 hours fixed).

The scenes of the finales were scanned by the TLS in due time. Fig. 7 and Fig. 8 display the result. These images were given to the students as references for making sure all spheres are under control (linked to a given individual in the physical game).

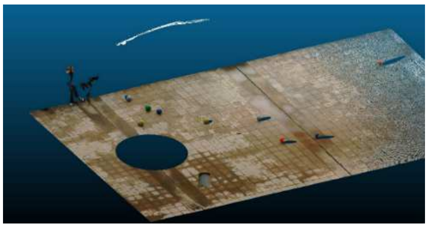

Fig. 7. Finale 1. Scene

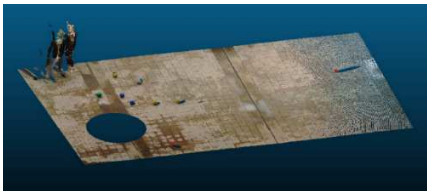

Fig. 8. Finale 2. Scene

Communication with participants was established in a Moodle course created for the activity. Information was uploaded in the course (tutorial, point cloud, pictures) and tasks and polls were submitted within the system (non-anonymous profiles).

Questions asked included:

- Identification of personal spheres (center and radius).
- Calculation of distances between the personal spheres and the rest of spheres.
- Identification of the plane passing through the personal sphere which is perpendicular to the line between this sphere and the target ball.
- Identification of centroids between given spheres.
- Identification of spheres with varying center and radii (inscribed, circumscribed to others, etc).

When it comes to participation in the virtual realm, results were unexpectedly low. 33% of participants completed the virtual game. However, 12 single users watched the tutorial (75%). Among those who completed the game, answers were 100% correct. It was thus found that the objective of the activity is achieved (bridging the gap between realms) but motivation was not intrinsic enough to the majority of students in this edition. In future editions, this aspect must be revisited for improving the proportion of completion. In the other scenarios (Master levels, or for the cases of compulsory activity), the rate of completion is expected to be higher.

The activity was evaluated using a Moodle poll. As an example, among comments and feedback provided by students to the question “How useful do you find playing with Maths using computational geometry tools”

- A1: *I think it is a very visual way of applying mathematics, it is less abstract and more intuitive. It is a tool that has the potential to make future generations lose the "fear" of mathematics.*

- A2: *I find it very interesting, since in school there are no subjects of this type, and in the end it is what is more similar to what we will have to do during our professional career.*

- A3: *It facilitates the work of studying areas. I will take it into account in my professional future*

Fig. 9 displays the graphics related to distances between spheres and Fig. 10 displays the computational geometry platform with spheres, planes and circles from those asked in the task.

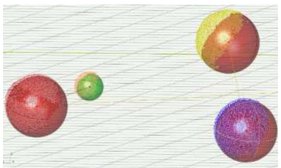

Fig. 9. Distances between spheres and target ball

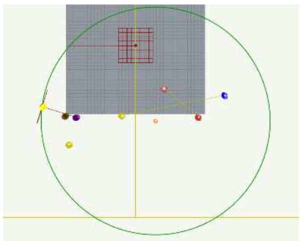

Fig. 10. Circle whose center is the target ball containing all spheres.

## VI. CONCLUSIONS

Petan-Camins represents a game in which the traditional Mediterranean game *Petanca* is played in the physical realm and thus, the final scene is taken to the virtual realm using a Terrestrial Laser Scanner. The game is conceived as one of the many gap bridges one may include in civil engineering classrooms. The bridge helps understanding and overpassing the flow of information from the physical to the virtual realm in a single gamified experience. A physical-to-virtual journey of the information from the physical scene to the virtual realm contribute to understanding how information models are increasingly developed in the AEC sector. This particular example deals with the use of point clouds gathered by scanners and embedded into BIM-enabled computational geometry tools. The design and application of the activity were also gamified. The First Edition depicted in this WIP is related to its application at Bachelor level with an optional nature. In order to motivate students for participation, rewards were offered for attending the physical game but no rewards were offered for developing the virtual game. After the game, only a third of participants completed the virtual part. Those who completed the activity provided excellent results with a high score in the evaluation. When it comes to logistics, duration, size and accessibility of the tutorials were positively scored in the post-activity toll. Students who participated in the poll suggested that it would be better to keep the location of the activity in Campus without autonomous work from home.

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