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Serious Game for Project Management applied to Large Constructions Plants in Africa

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Abstract

The high degree of complexity inherent to large construction plants demands skilled project managers able to take crucial decisions from planning phase to project commissioning. Stakeholders' interests must be attended without losing sight of project objectives, so a deep understanding of our reactions and the capacity to anticipate the outcomes of our actions are key to succeeding in this challenging venture. Under the umbrella of Modelling, Interoperable Simulation and Serious Games paradigm (M2SG), we have developed a serious game devoted to dealing with a large construction project in a complex environment, such as a water infrastructure in Africa. By considering, construction and project management aspects along with stakeholders' intelligent behaviour, user is asked to deal with stochastic events and tackle critical decisions that may put the project at stake. Their performance is eventually assessed by means of key performance indicators so they can restart the game over and over to improve their skills.

Keywords: Modelling; Simulation; Serious Games; Project Management; Construction Plants

1. Introduction

Sustainable use and responsible development of strategic resources are a crucial issue all around the world since they are a key element for any government to ensure stability and spot a promising future. Possession of resources such as oil, gas or water guarantees an advantageous position over competitor states. Hence, infrastructures to exploit and control them are subjected to all kind of conflict of interests among international and local partners, becoming their management a challenging matter to be addressed.

In the very middle of this complex scenario, we detect the need for an inclusive approach to model, study and assess all issues involved. The Modelling, Interoperable Simulation and Serious Games (MS2G) paradigm (Agostino G. Bruzzone et al., 2020) (A G Bruzzone et al., 2014) may be the means to tackle such an imposing endeavour. Within this umbrella, we have developed a discrete-event simulator based on the game engine Unity and object-oriented paradigm devoted to preparing experts from major international organisations on how to deal with strategic resources and operations in these environments. The simulator is presented in the shape of a serious game so as to combine an engaging experience with an intuitive

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approach while exposing users to a tough situation that request nimble decisions.

The simulator presented here acknowledges the user as the project manager of a major water infrastructure whose construction is to be undertaken. The player is also presented a set of Very Important Persons (VIP) and target variables such as key performance indexes. In the meanwhile, the simulator makes use of tangled chains of events that emerge stochastically as to their probability, the construction activity in process, or the season of the year (Agostino G. Bruzzone et al., 2018). These events pose questions to user whose response may have varied outcomes, from changes in stakeholders (VIPs) sympathies to unchaining of linked events. In this way, the user must take quick and smart decisions by foreseeing their possible consequences attending to her objective as well as her current situation in the game.

By combining cross-boundary stakeholders which include among others United Nations (UN) Deputies, Local Leaders or International Corporations and delicate topics such as climate change, diplomacy, bribery, or politics, we aim to teach and develop decision-making and project management skills in the field of large construction plants. Thus, we address a critical issue which is that of dealing with a key resource that is expected to explode in the upcoming years.

2. State-of-the-Art

Research interest on the use of serious games as a means to knowledge acquisition has been soaring in recent years (Hamari et al., 2014; Perrotta et al., 2013), and such is the case of those in the domain of Project Management (PM). According to (Rumeser & Emsley, 2018), most PM games are already digital-based, and half of them revolve around Procurement and Construction projects (EPC).

As stated by (Winter et al., 2006), the aim is to yield reflective practitioners with the ability to adapt to complex systems rather than technicians that follow predefined procedures.

In this sense, serious games based on simulation, let us complement the attributes of serious games like engagement, competitiveness and enjoyment with those of simulation, namely closeness to reality and the resulting immersion feeling (Karshenas & Haber, 2012)(Misfeldt, 2015).

By putting user in the shoes of a project manager and give him several ways to face a risky situation, he can better apprehend the possible outcomes and consequences of his actions (Taillandier & Adam, 2018).

Yet the best thing is that this would be otherwise inconceivable, at least at that degree of realism, if it were not for virtual simulations and games (Bruzzone, A.G., Gambardella, L.M., Giribone & Merkuryev, 2000) (Agostino G. Bruzzone et al., 2019).

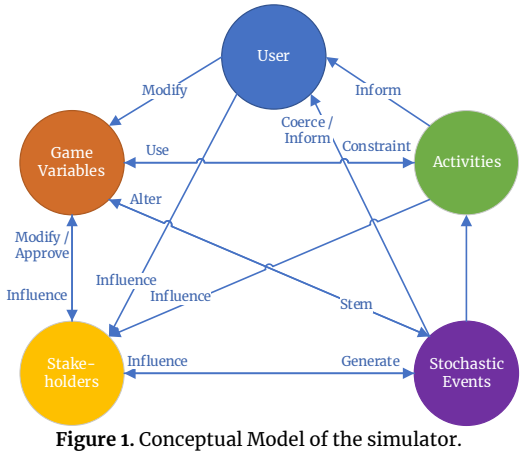

Figure 1. Conceptual Model of the simulator.

Among main examples found in the literature, (Misfeldt, 2015) presents a PM simulation game that centres on the link between the need for good planning and the successful of following project phases. The game Virtual Construction Simulator 4 (VCS4) developed by (Castronovo et al., 2017) simulates the planning and management phases of a construction project. Out of their results, they state that the game-based learning results engaging and stimulating yielding a positive experience both for students and researchers. (Taillandier & Adam, 2018) explain how by means of their serious game SPRITE trainees understand the complexity of decision-making within the field of territorial risk management, attending to the different actors involved. In close relation, (Galvão et al., 2012) propose a browser-based game focus on risk management in the context of software project management. Finally, (Karshenas & Haber, 2012),took designed a game engine from scratch to expose students to real-life project types and conditions in order to acquire planning and scheduling knowledge.

All in all, there are still some gaps to be filled like the communication with stakeholders, which play a relevant role to a successful PM (Karlsen, 2002). In most cases, their behaviour is not simulated, a lack that may lead to major problems like schedule or cost overrun (Rumeser & Emsley, 2018). Here we use intelligent agents to simulate their behaviour, becoming a crucial part of the game. Yet we expect to develop a multi-player function in the short term enhance the learning experience.

3. Conceptual Model

In order to address this problem, it is crucial to create simulation environment able to reproduce the EPC activities, but also all the other layers that influence the project and that represent usually the major contingency. In this case the authors suggest to adopt MS2G (Modelling, Interoperable Simulation and Serious Games) paradigm that combines the elements related to engaging and immersing the user into the virtual experience with the importance to integrate different models able to guarantee good fidelity levels

(Bruzzone et al., 2014). In this case the models to be used are expected to be agent driven by a discrete event logic that consider the stochastic factors affecting scenario evolution. Indeed, the conceptual model of the simulator considers four main elements around the user as depicted in Figure 1. They are game variables, activities, occurrences, and stakeholders. The relations and interactions among all of them makes up the mechanics of the game, generating on user's side the complex system that replicates the reality.

- Game variables: They include from inputs, outputs, and project resources. Inputs may be managed by user, being some of them resources used to carry out the activities. Outputs are outcomes of the game and are influenced by user's performance. Some of them define game target variables, whose value user must take care of.
- Activities: They form the construction project and shape the central and narrative thread of the simulator since the time goes on as long as there are uncompleted activities. Resources are needed to perform them in time and cost, although they can be affected by unforeseen occurrences thus posing serious dilemma to user.
- Occurrences: Stochastic by nature, their emerging behaviour is responsible for great part of the mechanics embedded in the serious game. They can be linked to time, game variables, activities, or other occurrences, and so can be their probability to occur. In this way, the simulator adopts a mutating behaviour during the same simulation, and a stochastic functioning among different runs.
- Stakeholders: They are the intelligent agents (IA) that simulate third parties prone to be affected by user's actions and objectives and who have any kind of interest whatever its nature. Accordingly, they will try to influence user's decisions by means of specific demands or by bringing about issues that could be eventually contrary to user's aims.

As previously mentioned, interaction between elements come to be the fifth component of the game mechanics. These interactions may appear in many different shapes and forms, being all these links predefined by the modelled. Some of them are the connection between a stakeholder's sympathy to user's performance and the events the former can originate, as well as the increase in probability of some occurrence to happen which is bound to the coming of summer, like a drought. Other interactions are straighter, such us the lack of resources to undertake the next activity. In this case, the user's is asked whether she was to accept the consequent delay in the project or pay extra cost to compensate it. All in all, the fact that the user can restart the simulation over and over helps him anticipate the events, either by prevented them from occurring or by offsetting their consequences beforehand.

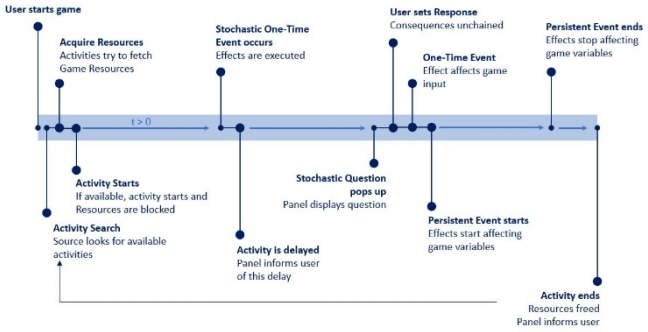

Figure 2. Sequence example of game logic.

In this way the game achieves its objective of improving user's ability to take tough decisions.

4. Game Sequence Example

As an illustrative example of the game mechanics, Figure 2 shows how the simulator works once the user starts it. As follows:

1. The simulation core looks for the first activity or activities, that is, those which do not have any predecessor.
2. Once selected, it tries to fetch game resources from user, who has previously decided their quantity based on a reference value provided by the game.
3. In case of successful, resources are temporary blocked, and the noticed activity starts by informing the user by means of a pop-up (Figure 3). Otherwise, the game would bring on the mechanics beforementioned.
4. In the meantime, some random event may occur. The event may be just one-time, so effects are immediately executed. An example help could be provided by a stakeholder as a sign of good relationship, however, it could also work the other way around, thus having a negative impact on the activity performance as an additional delay.
5. Another occurrence may emerge in the form of a question posed to user by a stakeholder. The available reactions are limited, and the user must visualise the possible outcomes of each one. To make it more demanding, questions may have timers (Figure 4) which puts pressure on user and require quick response.
6. Once selected, the reaction may have consequences on game variables and stakeholders, or may it unchain other events. As a matter of clarity, here we include a persistent event, which remains for a specific period of time, having a continuous effect. Some examples are the filling of a basing, or the increase in population consensus while some activity is underway.
7. Finally, when an activity comes to end, resources are freed again a may be available to start the following one.

Figure 3. Activity Start pop up panel.

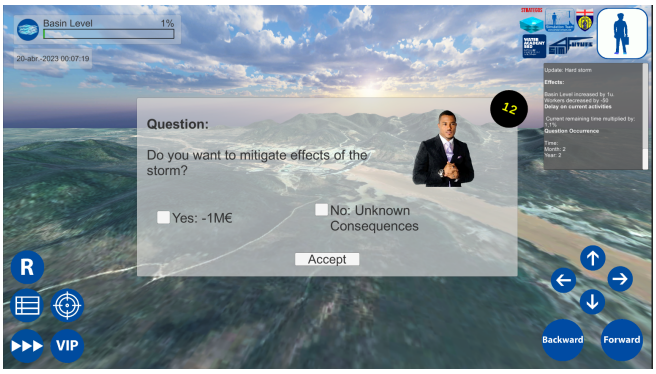

Figure 4. Stochastic question pop up panel during game run.

5. Project Management Aspects

The serious game presented here deals with project management skills on large construction plants. Therefore, most common project management aspects have been inserted to the simulator for the player to assess the course of construction. As key Performance Indexes (KPIs), the Schedule Performance Index (SPI) and the Cost Performance Index (CPI) allow user to monitor project progress and identify possible budget or time overruns. Equations (1) and (2) show the values calculated by the simulator.

$$SPI = \frac{BCWP}{BCWS} \quad (1)$$

$$CPI = \frac{BCWP}{ACWP} \quad (2)$$

As illustrated, they are based on the right calculation of the Budget Cost of Work Scheduled (BCWS), the Actual Cost of Work Scheduled (ACWS) and Budget Cost of Work Performed (BCWP). These values are being event-based updated by the simulator, so user has a constant view of them.

$$Budget\ Respect = \frac{BAC}{CBAC} \quad (3)$$

$$Time\ Respect = \frac{EAC}{CEAT} \quad (4)$$

Furthermore, we included the Budget Respect (BR) and Time Respect (TR) values (Equations (3) and (4)). The first one displays the ratio of Budget At Completion (BAC) which is calculated once and for all, to the Current Budget At Completion (CBAC), calculated based on the costs of activities at the moment. As for the TR, it is the ratio of Estimate At Completion (EAC), calculated once for all, to the Current Estimate At Completion. The latter is calculated based on the critical path at any moment, so it is updated every time there is any kind of change in activities duration.

6. Case Study in Africa

As case study, we were inspired on the New Renaissance Dam in Ethiopia, a crucial infrastructure to be constructed in an area that presents geopolitical conflicts of interests and around water as key resource (Timmerman et al., 2011). Regarding the stakeholders, we introduce Local Police, Local Authority, Local Leader, Local Healthcare Chief and Diplomatic Depute as VIP. As target variables, there is the Power Generation and Basing Filling Level of the dam. As inputs, we have personnel, labourers, and budget. Finally, we introduce a set of event chains based on Acute Watery Diarrhoea as it is one of the major causes of death each year (WHO & Unicef, 2000) and some stochastic events linked to introduced VIPs. Figure 5 illustrates a general view of the game scene with the dam constructed and Basin Level at 65.5%.

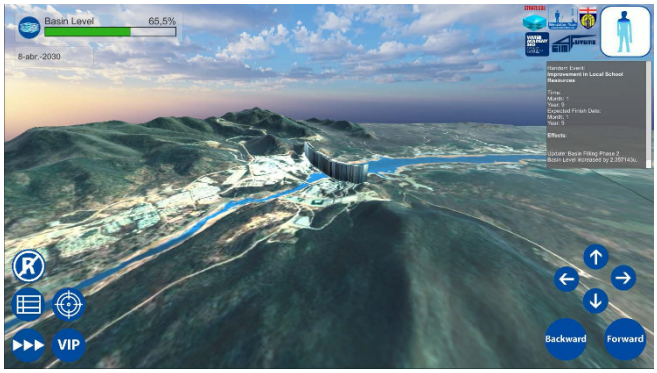

Figure 5. General view of the game scene for the case study in Africa.

7. Conclusions

The cruciality of water as strategic resource along with the myriad aspects involved in decisions on large construction plants put forward the need for developing necessary skills to deal with those complex systems. In this context, Modelling, Interoperable Simulation and Serious Games (MS2G) provides the means to face this challenge by combining immersive and engaging environments with realistic simulations where user is introduced and plays a main role.

In our simulator, the player acts as project manager of a large construction project and must attend stakeholders' demands without losing sight of project objectives. The simulator uses a 3D environment as

immersive experience, which executed in a computer or smartphone, as well as in a Virtual Reality environment. Regarding future work, we are currently focusing on improving intelligent agents functioning and introducing new elements to make the simulator more engaging.

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