

The Design of an Augmented Reality Collaborative Game for Sustainable Development

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Abstract. In spite of recent efforts, there is still a demand for tools facilitating sustainability instruction. To this end, serious games offer remarkable possibilities to foster learning in this area. However, evidences suggest that these potentialities have not been fully leveraged yet. In particular, it is challenging to design games representing the different domains (ecology, economics, politics, and culture) and social structures (individuals, families and communities) involved by sustainability issues. This work explores the mix of augmented reality, collaborative gaming and theoretical guidelines in the design of Sustain, an educational game focused on raising awareness on sustainability topics. The paper details Sustain design decisions, highlighting their relation with the chosen methodology. Our aims are: (i) to exemplify the use of a not yet adopted theoretical background, and (ii) to present reflections concerning its use.

Keywords: Sustainability · Educational games · Augmented reality · Collaborative games

1 Introduction

The concept of *sustainable development*, or sustainability, was first introduced in 1987 in the report of World Commission on Environment and Development (Brundtland Commission) [2]. Sustainable development has been defined as the search of significant shifts in technologies, techniques or infrastructure, meeting today demands, without compromising future generations' needs. In order to improve people's capacity of addressing sustainability, it is critical to disseminate information towards environment and development issues [15]. Nevertheless, such task is not trivial. Sustainability has specific requirements, that can be summarized in two aspects: (i) the framing of issues contemplating individuals, families, communities and the society, and (ii) the representation of several interrelated domains, such as ecology, economics, politics and culture [14].

In this context, recent research [3,6] suggests that serious games, *i.e.* those that do not have entertainment as their primary purpose, offer unique possibilities for creating educational tools towards sustainability. Serious games allow experimentation in controlled environments, useful for instance for simulating future scarcity scenarios. They can be used as persuasive tools to influence players ideas and behaviors. They can provide compelling experiences helping to create engagement towards sustainability. However, at the same time, there are evidences that the approaches developed so far often fail to fully leverage such potentialities [6] and several research questions remain open. Which are the design models most suited to guarantee that these serious games can achieve their pedagogical goals? Since collaboration among users is a relevant dimension for learning, which are the design elements and the technological tools that can foster such cooperation? How innovative user interaction paradigms can be exploited to improve the expected outcomes of sustainability serious games?

This work tries to provide some preliminary answers to these questions through the description of *Sustain*, a collaborative game focused on raising awareness on sustainable development issues. The aim of *Sustain* is to engage the players in the management of a city, being responsible for creating and maintaining infrastructures towards environmental awareness. To ground the theoretical aspect of *Sustain*, the game design has been based on a model specifically proposed for driving the development of game-based sustainability learning by Fabricatore and Lopez in 2014 [7]. Immersion and collaboration among players are fostered by allowing co-located users to interact in augmented reality (AR) with a virtual scenario, which is also projected on a screen to facilitate result discussion and decision making.

Concerning the related works, the approaches most related to *Sustain* are the games *EnerCities* [10] and *Futura* [1], which aim to engage the players in city management mechanics. Qualitative and quantitative evaluation support the success of both games in offering enjoyable experiences and increasing awareness concerning sustainability issues [1,10]. In addition, some recent products coupled augmented reality with sustainable games. As an example, in 2013 McDonalds Germany released the mobile app *McMission*, in which visitors, by playing AR mini-games, receive information related to the societal and environmental projects in which the company is involved [11].

To the best of our knowledge, this work is the first to base its game design on the Fabricatore and Lopez model, and also the first to merge, in a sustainability serious game, multiplayer collaboration, augmented reality interaction and city management mechanics. Therefore, although the implementation is still in its early stage, we think this work exemplifies the use of the adopted tools and, thus, might allow to start a discussion about how to enhance their effectiveness.

2 Theoretical Background

The model proposed by Fabricatore and Lopez for game-based sustainability learning [7], on which the design of *Sustain* was based on, is grounded on theoretically solid research, *e.g.* [13,14], and is the result of a thorough analysis

of 30 sustainability games, which were used to offer practical examples of the framework's concepts. According to its authors, alongside the assimilation of domain-specific knowledge, sustainability requires promoting learning to deal with *complex systems* [7], whose main characteristics are:

- *Emergence*, *i.e.* changes in the system happen independently of external action, and their origins cannot be traced back entirely;
- *Uncertainty*, *i.e.* the impossibility of full predicting the outcomes of actions on the system, and;
- *Non-linearity*, *i.e.* depending on the actual context, the interactions among the various elements of the system can develop according to different patterns.

Thus, to cope with such complex systems, the game design should consider four main aspects. First, it is important to design for *contextualization* of the game activity. In order to facilitate the transfer of game-based learning to real-world contexts, the background story, gameplay and objectives should be coherent with the sustainability values to target. Second, the game should *empower* the players, who should be able to exert control on the game system by acting as freely as possible. The rationale is that empowered players are likely to be more easily engaged in the gameplay experience. Third, the game should foster *adaptivity*, *i.e.* force players to adapt to non-player-planned disruptions in system dynamics, which is an attitude that can help them better understanding the complexity involved in sustainability scenarios. Finally, the introduction of meaningful *social* interactions among players, and between players and artificial-intelligence-based agents, can (again) help engaging the players and harnessing their knowledge acquisition.

3 Sustain Game

Following the definitions of Fabricatore and Lopez model, the educational goal of Sustain is not to provide direct instruction to players, but to engage them in a complex system representing an urban area environment. The game aims at increasing awareness on both immediate and long-term consequences that policy-makers decisions' can generate.

Although the current version of Sustain is a prototype, it employs all the features that enable the discussion of the adopted theoretical framework, hardware platform, augmented reality interaction and collaborative gameplay. In the following subsections, we thoroughly discuss the design and implementation of Sustain. Section 4 relates the actual game design with the Fabricatore and Lopez model, and outlines future extensions of the game.

3.1 The Game Design

Sustain is a city management game for three players, whose goal is to expand the population of an urban area, exploiting a set of resources (coal, oil and money). The game rules aim at guaranteeing the relevance of sustainability practices,

since a non-sustainable city causes unsatisfied citizens to leave, thus leading players to defeat.

Players can take action in the scenario by assuming one of three roles: mayor, ministry of energy, and ministry of agriculture. Every role has a specific set of actions, which are progressively made available to the player as the game advances. These roles can be summarized as follows:

- The mayor can take decisions related to the construction of houses, factories, public transportation and leisure areas. He can also call for laws that influences the population energy consumption and food habits.
- The ministry of energy can decide for an energy matrix based on renewable sources (wind and solar) or not (coal, gas or nuclear fusion). He can also take action on the oil consumption of the urban area.
- The ministry of agriculture chooses mainly for the food production of the urban area, that can be turned to numbers increase, or to convince people to consume in a healthier way.

The roles are chosen by the players in the beginning of the game. They are balanced to be attractive to game audience, in order to foster game re-playability (thus players are hopefully willing to re-play with different characters). Sustain is intended for players of minimum 10 years old, who are able to understand the environmental impact of their decisions, and to handle the mechanics of managing diverse aspects in real time.

3.2 The Interaction Design

The game scenario is composed of two interrelated areas, the city and the farm. Each area is composed by a grid of 3×3 blocks. Players interact with these areas through a tablet, thus being free to move inside the physical game environment. By clicking on any block, the player sees the actions that he/she can take at that specific time, according with his/her role. In the farm area, the actions are related with the production of food and energy, and with resources collection. The city area actions deal with the consumption of the resources provided by the farm area, and also with offering housing, employment, developing public transportation and leisure activities for the population. Visualization and interaction with the game scenario exploit marker-based Augmented Reality (AR).

The rationale of leveraging on AR is that it allows the customization of players' view, according to their specific role. For example, when the ministry of energy focuses the city area, the rooftops of the buildings glow when it is possible to install solar panels on them. If the mayor points at the same area, the view highlights areas available for constructing houses and factories. Therefore, in Sustain, AR enhances the representation of different points of view over the same problem, a feature that is a concrete challenge to face in sustainability games [6].

The marker used to register the augmented view is a large image representing an urban area and its suburbs, printed on a A0 paper (84.1×118.9 cm), and fixed

on a table (80×160 cm). These dimensions intend to offer adequate physical space for three players, and to allow a consistent and stable marker tracking from various distances and view angles. Figure 1 shows an example of the 3D view of the game scenario and, in the background, the marker defining the game area.



Fig. 1. View of the augmented scenario on the tablet screen, from the city point of view.

Sustain features as well a projected virtual environment (Fig. 2). This screen shows the overview of the urban area, and the information regarding the game objective (population number), the available resources (money, coal and oil) and the sustainability status (energy level and environment friendliness). The projected screen aims at further enhancing players' collaboration by offering, during debriefing sessions after each game turn, a shared understanding of what has been achieved and how far they are from the objective, thus facilitating discussion and decision making processes.

3.3 The Gameplay

Sustain is played on 5 turns. Each turn corresponds to six months in the game time, thus a match spans 2,5 life years of the fictional urban area. During a turn, the players can take collectively 5 actions, with a maximum of two actions per player. This means that every round all the players are required to act, but one of the players has only one action. This intends to foster players reflection on which actions are the most important at every specific moment, highlighting the importance of the cooperation among different roles. The turns have no time limit, and the end of a turn is decided when the five actions are taken.

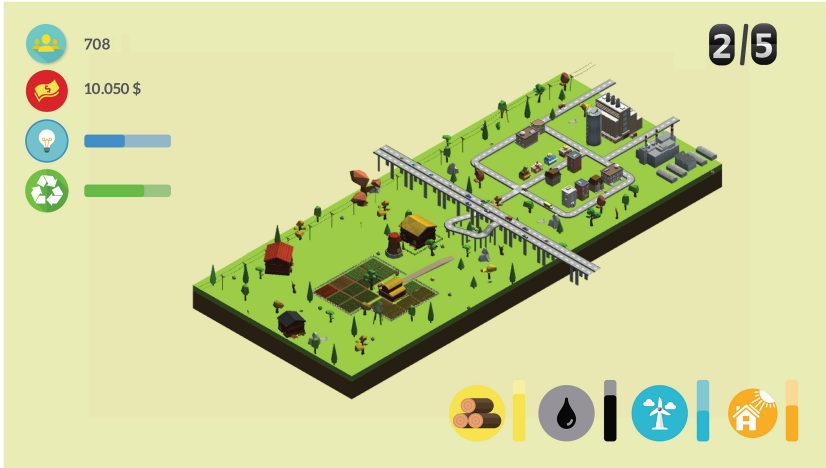


Fig. 2. An image of the projected scenario, displaying as well population number, available money, energy and environment friendliness levels (top left), the number of turns (top right) and coal and oil resources, and renewable energy production (bottom right).

Once that the turn is finished, each players' action is executed and its aftermath can be evaluated. This is the moment when players focus on the shared screen, which displays the influence of their actions on the three main game variables: (i) resources production and consumption, (ii) sustainability status (energy level and environment friendliness), and (iii) quantity of population of the city. The values of these variable are also reflected in the representation of game scenario. For example, the environment can get polluted (and displayed as such) when the environment friendliness level is low, or get darker due to the lack of public illumination when the energy level decreases.

After the second turn, the list of available actions per player starts to include what we called “critical” actions, *i.e.* actions introducing both relevant advantages and severe consequences. Examples of such actions are the construction of a nuclear plant (ministry of energy) or of an industrial park (mayor), and the alleviation of environmental policies in agriculture to increase the production and reduce costs (ministry of agriculture). Since these actions are critical for the environment, players willing to activate them must (mandatorily) find an agreement with their peers, who should grant explicit permission with their tablet. This game rule avoids any player to issue disruptive policies in a non-democratic way and is meant again to increase the in-game collaborative activities.

After the 5 game turns have been played, the win or lose conditions are related to the number of actual city dwellers. In case of defeat, a motivational message is displayed to encourage players to try again building a “better” city.

3.4 Implementation Details

Concerning the technical aspect, Sustain has been implemented into Unity 3D, a cross-platform game engine, which offers advanced lighting and rendering options, built-in support for spatialized audio, physics management, complex animations, multitasking, pipeline optimization and networking. Multiplayer collaborative interaction has been managed implementing a client-server architecture, in which the server handles the simulation state and controls the projected screen and the clients are the players' tablets. Finally, we used as AR engine Vuforia, a software library that can be integrated into Unity, thus supporting the game deployment on different mobile platforms (Android, iOS, Windows Phone and Tizen).

4 Results and Discussion

Being in its development stage, a systematic evaluation of Sustain is not possible at the moment. However, to obtain some preliminary indications, we can comment some of the feedbacks received by our alpha testers, which seem to suggest the appreciation of a gameplay combining both multiplayer collaboration and augmented reality interaction. Players readily understood the need to collaborate, which means that the game mechanics and platform were successful in promoting collaborative behaviors. Players also expressed overall enjoyment in playing the game, specially towards the use of augmented reality to display the interactive areas.

One aspect we deemed interesting to analyze is how the four keypoints of the Fabricatore and Lopez model described in Sect. 2 influenced the game design. In the following, we analyze separately each of these keypoints.

Contextualization. Three main design elements have been introduced to contextualize the game thematic with environmental issues: (i) the Sustain virtual scenario, which resembles real-life ones and where players perform real-life roles; (ii) the gameplay and game rules, which guarantee that the adoption of non-sustainable practices leads to player (collective) defeat; (iii) the game platform, where the shared screen and the tablets have been introduced with the purpose of adequately representing the interrelations of elements in a complex urban environment.

Empowerment. The possibility to differentiate the players' role is the fundamental feature related with empowerment. Every player has a unique skill-set, which requires her/him to negotiate with peers and to explore alternative ways to fulfill their common tasks. Players also freely decide which action to take, driving the non-linearity of the gameplay. Indeed, although the game main objective is clearly defined, the possible paths that lead to a positive conclusion are numerous and cannot be shaped as an algorithm. Finally, visually displaying in the shared environment the aftermath of players' actions aims to deliver what Sweetser [13] calls third order emergence, *i.e.* changes on a global scale rising from dynamics happening at a local scale.

Social. The social dimension highlighted by Fabricatore and Lopez and the verbal interaction among players are stimulated by several design elements: (i) players sharing the same physical space, (ii) the possibility to debrief each game turn sharing a common view, through the projected screen, (iii) the game-play rules that require synchronized coordination, and (iv) the voting system, for enabling critical actions, which requires reaching an agreement over relevant development policies.

Adaptivity. Players' adaptivity is fostered by the division in turns of a game. After having performed their actions, players have to adapt to the new situation created. Furthermore the introduction of novel actions that can be performed in each new turn, force the player to mentally adapt to the new features available. Despite that, we believe that the adaptivity aspect has not been fully developed in Sustain, as also partially confirmed by our testers.

4.1 Further Extensions

Since Sustain is in its development stage, there is still plenty room for introducing improvements to its design. The first is related to reviewing and enhancing the features related with the adaptivity dimension. One possibility we are considering is the introduction of *crisis*, events related to players action (for example, cities with high dependence of fossil fuels, can face a depletion of the resources) or independent from them (a natural disaster). The players will be offered novel sets of actions to deal with the crisis, which should be activated in a short time. Inadequate response to the crisis would lead to a massive escape from the city and defeat in the game.

In addition, we are planning to (i) extend the number of blocks in the interactive scenario in order to provide a higher diversification of the game areas and, thus, more challenges for the players, and (ii) introduce novel problems to deal with, such as trash recycling and water management.

Another point we are planning to investigate in further details is related to a question arose during the development process: *how to guarantee the transfer of game-based learning to real-world contexts?*

Fabricatore and Lopez link game-based learning transfer to the contextualization aspect. Although there are scientific evidences supporting this statement [5], we found hard to assess whether the contextualization features of Sustain effectively improved the players' understanding of real-life sustainability issues. We think that a deeper game evaluation with players is needed to enlighten this question.

5 Conclusions

In this work we presented the design and (initial) development of Sustain, a collaborative AR-based multiplayer game aimed at supporting sustainability learning. The game design is based on a sound theoretical model, which helped us to identify the main elements for improving the expected educational outcomes of

the game. Preliminary evaluation sessions indicate the game success in immersing the players in a collaborative experience.

As future work, we are planning to complete the implementation of Sustain, introducing as well some improvements to the current design (as detailed in Sect. 4.1). We are also planning to perform a thorough evaluation of the game, exploiting both quantitative and qualitative approaches. Such evaluation would allow assessing the efficacy of the chosen reference framework in guiding the design of sustainability educational games.

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