AgriVillage: a Game to Foster Awareness of the Environmental Impact of Agriculture

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Abstract

Agriculture, while of uttermost importance for society, may also have a strong negative impact on the environment. Hence we propose a game that offers players the opportunity to experience the effects of different styles of agriculture on the environment. The game was built with the purpose of promoting the awareness of agriculture issues, such as, (1) the impact of fertilizers in sources of fresh water, (2) the problems related to deforestation and impact on the weather, and (3) the importance of balancing the environmental and economic perspectives in order to produce food with good quality, with low impact on the environment and at the same time keep the activity sustainable. To make players care about these issues we added a direct impact of the players actions on a population of non player characters, the villagers, that have simple autonomous behaviour to resemble living entities. The game was implemented in the multi-user online three-dimensional (3D) virtual world platform OpenSimulator, which supports an immersive user experience and high accessibility. An experiment was performed and showed that the game improved players' knowledge about agriculture and their awareness of the environmental impact of agriculture.

Keywords: serious games, agriculture, environmental issues, 3D multi-user online virtual worlds
Categories and Subject Descriptors: D. Software D.2.Software Engineering. D.2.6 Programming Environments Subjects: Interactive environments; H. Information Systems H.5 Information Interfaces and Presentation (I.7) H.5.2 User Interfaces (D.2.2, H.1.2, I.3.6) Subjects: Evaluation/methodology

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General Terms: Design, Human Factors, Experimentation

1. Introduction

Agriculture is the basis for the existence and well-being of mankind and is often regarded as the basis for the development of human civilization. However, its activity does not come without costs. It was found that agriculture can have a major negative impact on the environment [17, 12, 4]. Hence any good program of sustainable development includes a discussion about this impact. This issue has also gained some relevance with the increasing concern regarding global warming and the Kyoto protocol, as agriculture is associated with deforestation, which has a direct impact on the levels of concentration of CO_2 in the atmosphere [18].

Although agriculture is highly relevant to society, it has rarely been explored in serious games. In the few examples found, the issues of the environmental impact of agriculture are not the main focus or are not present at all. Therefore, in this paper, we present a game designed with the purpose of increasing the sensibility of players to these issues. In the design of the game, we put special attention to mechanisms that may improve the experience of environmental impact.

The rapid growth of the Internet has promoted gaming to wider audiences that were not previously targeted. For example, many popular games at the moment run on *Facebook*.[1] For example *Farmville*[2] was launched on June 2009 by Zynga Inc.[3] and had more than 80 million active players by March 2010. Millions of people spend their time online using social networks such as *Facebook*, to seek social contact and new ways of expression and entertainment. Social networking websites are becoming the prime collaboration and advice-giving work spaces [21] and are being explored as media to support new learning styles [2].

However, the communication in current social networking sites still lacks the immediate nature of face-to-face communication or presence. This is handled more effectively in 3D virtual world communities (metaverse worlds), where users appear as 'avatars' (graphical self-representations) that may realistically interact with other user avatars or virtual objects. Examples of virtual worlds are *Activewords*[4], *Second Life*[5] or *OpenSimulator*.[6] Since the new generation of personal computers can bring good performance for 3D interfaces to common users at a reasonable price, 3D networked virtual worlds have been suggested as

[1] http://www.facebook.com
[2] http://www.farmville.com
[3] http://www.zynga.com
[4] http://www.activeworlds.com/
[5] http://secondlife.com/
[6] http://opensimulator.org/

promising and affordable collaborative platforms [1, 13, 11] that can be applied to gaming [6].

We opted for virtual world technology as the platform for our game (1) to explore the potential of integrating gaming with other aspects of the virtual community and (2) to make the game easily accessible to a wider population. We have in mind the integration of the game as a tool for the CyberBrain framework [8], developed in Thailand to support knowledge sharing and interconnecting communities of Thai farmers and experts of agriculture. Within this framework children of farmers, usually teenagers, have an important role as mediators of the interaction with new technologies (i.e. computers and the Internet). They facilitate knowledge sharing and dissemination to and from the farmers. For this reason, it is important that the game is particularly appealing to teenagers.

The rest of the paper is organized as follows. In the next section we will review some games about agriculture. Then we will discuss some environmental issues of agriculture and describe the ones we have decided to include in our game. In Section 4 we present the design of the game, *AgriVillage*, and discuss our choices to make players care about the ideas that the game is intended to teach. After that, we describe the architecture used to implement the game. In Section 6, we present an experiment that was performed with the purpose of evaluating the reaction of players to the game. The paper wraps up with conclusions and future work.

2. Agriculture Games

Agriculture has often been explored as a theme for entertainment. It has been the topic of many computer games and is even the theme of the currently most popular board games.[7]

Some examples are found in games for casual play. For instance, in games such as *FarmMania*[8], *VitualFarm*[9] or *The Farmer Game*[10] the main actions of the players are to sow, to fertilize and to water fields in order to grow vegetables. One of Facebook's most successful games, Zynga's Farmville, is based on similar mechanics and played by millions of people.

On the other hand, there are more complex games that aim to simulate more precisely different agricultural activities. Two classic examples are *SimFarm*[11] and *John Deere American Farmer*.[12] These games take into account weather, seasons, natural disasters and pests and have many different types of crops and include livestock. In addition, players have to manager a team or workers and buy equipment for farming.

[7] http://www.boardgamegeek.com/browse/boardgame
[8] http://www.realore.com/games/farmmania/
[9] http://www.alawar.com/game/virtual-farm/
[10] http://www.lsuagcenter.com/en/4H/Kids/agriculture/games/TheFarmerGame.htm
[11] http://en.wikipedia.org/wiki/SimFarm
[12] http://www.universalfarmer.com/

Some other games such as *SimAgri*[13] run online persistent worlds. *SimAgri* has similar game mechanics as the simulation games *SimFarm* and *John Deere American Farmer*, but it is played in a different time scale and involves competition among hundreds of players.

While agriculture is a topic for several games, most of these games were not developed for serious purposes. There are some exceptions though. For example, *NASA's BioBlast*[14] has been used in high schools to help students understand the processes that involve the growth of plants. The goal of the player is to produce food (biomass) and oxygen to sustain a crew of six in the space for three years. Players have control of a greenhouse where they grow different vegetables. They can change the temperature, CO_2 levels, light exposure and check how this affects the plants.

Another example is *Bet the Farm*[15] where the players start by defining polices for running a farm and then see the results of their choices in the course of a year. The choices provided are quite detailed, e.g. the player can choose to use precision farming, to give antibiotics to animals or to use genetic engineered seeds, and the player gets some advice/warning after making each decision. The goal is to have the most money in the end of the year. The game promotes re-playability to allow the player to explore different approaches.

One more example is the *3rd World Farmer*[16] where players manage a small virtual farm in a developing third world country and experience the hardships and dilemmas faced by a poor family. In addition to agriculture this game focuses on political, social and health issues. For example, the player is motivated to invest in the local development of the village and send children to school.

While not being an agricultural game, Design-A-Plant [9] is worth mentioning because it explores the use of animated pedagogical agents to foster knowledge-based learning in game-like scenarios. In Design-A-Plant, students learn about botanical anatomy and physiology by graphically assembling customized plants that can thrive in specified environmental conditions. The goal of the players is to find the characteristics that compose the plant that grow stronger in each environment.

None of the above games consider the environmental impact of agriculture, with the possible exception of some warnings in *Bet the Farm*. However, environmental issues should not be disregarded as they can be significant, as we will discuss in the next section. On the other hand, there are many games related to environmental issues (some can be found in the Games For Change website[17]), but none of them focuses on agriculture.

For the reasons mentioned above, we consider the development of a game that explores environmental concerns regarding agriculture as an important opportunity and promising direction. We believe that due to the popularity of

[13] http://www.simagri.com/
[14] http://www.cet.edu/?cat=online_learning&page=54
[15] http://www.cosi.org/visitors/on-line-activities/farm/
[16] http://www.3rdworldfarmer.com/
[17] http://www.gamesforchange.org/channels/environment

agricultural games, the theme of agriculture may constitute a good medium to introduce the environmental issues in general.

3. Environmental Impact of Agriculture

Agriculture is very important to society because it constitutes one of our main sources of food. The quality of the food produced by agriculture is, in fact, one of the major concerns with modern agriculture [16]. People care about the food they eat since what they eat has a direct impact on their health and well-being.

On the other hand, agriculture can have a strong impact on the environment. For example, the fertilizers used to foster plants' growth can have a negative impact on the soil [17], in particular due to high concentration of phosphorus and nitrates. These chemicals can damage the soil and often get infiltrated in water streams polluting important sources of fresh water [12].

Furthermore, agricultural cultivation is one of the causes of deforestation [5]. A large number of trees are chopped down to make space for agricultural fields. The problem is that such forests constitute the habitat for many species; thus the loss of forested areas have great impact on wild life and bio-diversity, which is often considered as the main richness of our planet [22, 4]. At the same time, reducing the area of forests can have impact on the climate. The presence of forests reduces the concentration of CO_2 in the atmosphere [7] and increases the levels of precipitation and rainfall [18]. These are two of the factors that can contribute to slow down global warming.

Our game was designed with the aim of increasing the sensitivity of people to the potentially negative impact of agriculture on the environment. Having in mind the issues we described above, we have defined a set of ideas that our game should teach:

1. The game should show that the fertilizers used in the soil may pollute the water streams.
2. The game should show that cutting too many trees negatively affects the environment.
3. The game should also show that agriculture is an important activity, notwithstanding the potential risks stressed by the previous two points. The game should show that it is important to produce food and that some impact on the environment is inevitable. For example, fertilizers are important for the economic sustainability of agriculture and quality of the food. The game should show that it is all a matter of balance. Not cutting trees at all or not fertilizing the soil is not an option. But, there are different options and the negative impact can be minimized.

4. Designing the Game

The AgriVillage game is intended to promote awareness and discussion about the impact of agriculture on the environment. To support accessibility and

Figure 1: AgriVillage paper prototype.

immersive experience, the game uses a networked 3D virtual world platform (*OpenSimulator*). The development of the game concept was iterated through several steps, the first ones using paper prototypes as shown in Fig. 1. The next sections summarize the resultant ideas.

4.1. Game World

The game world consists of an island with a small village and a river (see Fig. 2). Next to the village are small forests (one per player) that can be used for farming. While the main playing area is the forest, the player finds relevant information in various places in the world (e.g. the player can see the pollution levels reflected on the river). The forest is a cluster of fields, organized in a grid, that represent areas that can be cultivated by the player. At the beginning of the game, each field has a forest. The forest can be chopped by the player to create a field that can be fertilized and planted using seeds. In addition, each farm unit has a water pump that drains water from the river to the entire farm (i.e. waters all fields at the same time). The village is populated with some autonomous characters that serve two functions: (1) they are the recipients of the food produced in the farm and (2) they may help the player with some hints about the game.

The environment is characterized by four variables: two concerning the weather (temperature and rain fall) and two concerning pollution (level of nitrates in the river and concentration of CO_2 in the atmosphere).

The game was designed as a persistent world that does not require players' presence all the time, while players are supposed to check their farms from time to time. The game is processed in turns, each turn corresponding to one month in game time. Players do not control when the game goes to the next turn.

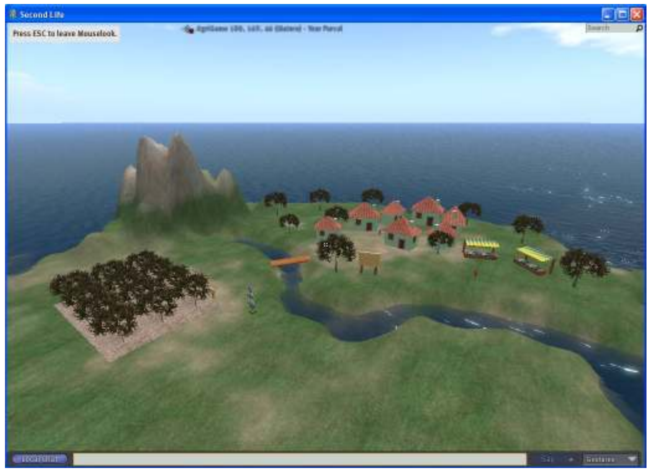

Figure 2: The game world: village to the right and forest to the left.

Turns are scheduled to be processed on regular time intervals. A typical game has 12 months (turns), from January to December and is processed once per day (i.e. the game takes 12 days to play). However, these parameters can be adjusted to create different scenarios, if desirable. For example, the full game may have 24 months and each month may be processed every 10 minutes.

4.2. Player Challenges

The main challenge of the player is to grow vegetables in order to sell them in the village's local market and make some profit. Accordingly, the player must cultivate the fields and plant seeds that will grow into vegetables (see Fig. 3). The quality of a vegetable depends on the conditions of the environment and the farm during its growth, which affect its value in the market.[18] Therefore, the challenge is to achieve good conditions for the vegetables growing in the fields. These conditions are defined in terms of range of water, temperature and fertilizer needed (Table 1 shows an example). The values for water and temperature should not be above or below the requirements and the field should have at least the amount of fertilizer needed by the vegetable.

The player must consider each month (1) what to sow given the current weather (and the forecast for the next month), (2) how much fertilizer to add in each field, and (3) how much water to add to the farm. The fertilizer in a field is consumed, each month, during the grow phase of a vegetable (depending on the

[18]The value of a vegetable is proportional to its quality. Villagers pay more for better vegetables and always prefer vegetables of better quality. The cost of the vegetable is not important for the villagers and does not have impact on their happiness. We use a very simplistic economic model of the market that assumes that money is not a problem for the villagers.

Name	Vegetable A
Temperature Range	10–25 °C
Water Range	10–40 mm
Fertilizer Consumption	2 kg/month

Table 1: A possible definition of a vegetable. This vegetable grows well if the temperature is between 10 °C and 25 °C, the water in the field is between 10 mm and 40 mm, and the field has at least 2 kg of fertilizer per month.

vegetable the growth can take a few months). For this reason, the player needs to keep good levels of fertilizer in the fields if s/he wants to grow vegetables of good quality. Each field is fertilized separately, therefore, the levels of fertilizer may differ from field to field. Fertilizers cost money and may pollute the river. When fertilizing, players may choose from a set of fertilizers. This choice takes into account the cost, the quality of the fertilization (i.e. amount of fertilizer added to the field) and the amount of pollution that will enter the river.

Vegetables also need water. The rainfall will automatically water all fields in the farm, but the player can add more water if s/he considers it necessary. The farm has a water pump that can be set to add water to the fields. This pump will add the same amount of water to all the fields and continue pumping (every month) until reset. Watering fields with the pump has a cost that is proportional to the amount of water requested.

Figure 3: A farm with some cultivated fields.

At the same time the player must decide if s/he cuts down another tree. Doing this opens one more field to grow vegetables and give players the opportunity to gain more money, but it will have impact on the CO_2 levels in the atmosphere. Each tree is responsible for "clearing" some CO_2 in the atmosphere and if the number of trees falls under a certain level the concentration of CO_2 in the atmosphere will rise. This will also depend on the CO_2 generated by the village (see Sect. 4.4 for more details). Given that trees contribute to the reduction of CO_2, they generate some carbon credits that represent money income for the player in the game.

Each action in the game costs money. The player will start with some money, but has to keep a good budget to perform well in the game. The quality of vegetables is proportional to the value they have in the market. Therefore, players must keep the quality of the food in mind when making decisions. This means, for example, that they should consider the positive and negative aspects of applying fertilizers.

4.3. Making Players Care

Given the focus on serious gaming we have created game elements specifically for making the player care for the issues discussed in Sect. 3. The general goal is to provide players with tangential learning, i.e. implicit learning. While the motivation of players is to win the game, the game mechanics induce practices that convey relevant environmental knowledge to the players. Importantly, the player has to achieve two possibly conflicting goals: producing (good) food and keeping the pollution levels low. To emphasize this aspect, we defined a 'population happiness' variable in the game. This variable reflects the population's level of happiness about the condition of the environment food quality. Population happiness decreases when the villagers see that the river is polluted or feel that the concentration of CO_2 is too high. It also decreases if the vegetables that villagers receive from the players are of bad quality. Vegetables are always sold independent of their quality; thus, players cannot throw them away to avoid this penalty. The villagers will also get unhappy if the farm is not producing any food (e.g. if the fields are empty). This type of penalty was introduced to motivate players to always grow some vegetables and often come back to check the state of their farm. So not to produce food at all is not an option.

If the villagers get too unhappy they will riot and expel the player from the farm and s/he loses the game. Hence, the challenge of the player is to both produce vegetables to gain the most profit and keep the population as happy as possible. The final score of the game is the sum of the points the player receives for the earned money and the points for the level of happiness of the population.

The dimension of the population happiness was added to take advantage of the 'people factor' that fosters enjoyment in gaming experiences. Playing with other people or game characters in a social setting is one of the factors that elicits fun [23]. The (computer-controlled) villagers convey a sense of social dimension in the game that can make players care more about the impact of their choices. The social experience is better if the characters are believable and able to achieve the suspension of disbelief [3]. Furthermore, the use of game characters may increase the motivation of players and improve their learning experience [9].

To improve the believability of the villagers, we gave them some (simple) conversational skills. The villagers will pro-actively complain when they are unhappy, referring to the source of their unhappiness, e.g. shouting that they are unhappy because the river is polluted (see Fig. 4). In turn, if they have a reason to be happy they will make positive comments to the players, e.g. telling them that the quality of the air is quite good.

Figure 4: Villager Ti Maria complains about the condition of the river, but is happy concerning the quality of the air.

Apart from giving life to the villagers and making their happiness part of the *gameplay*, we made some other specific design choices to stress the concepts we want to teach with the game. Concerning the impact of the deforestation, we made the decision to define the action to chop down trees irreversible (although in some tests with the paper prototypes players indicated that they would like to re-plant trees). As the effect is irreversible players need to consider more carefully if they cut a tree or not. In addition, the villagers inform players about bio-diversity and the use of forests to spend quality time, e.g. rest in the shade of a tree. They will become unhappy if the percentage of trees drops below a certain level. Concerning the choice of fertilizers we explicitly designed the ones that pollute less more expensive, so that the motivation to choose them is not monetary.

4.4. Gaming Scenarios

To support the adaptation of the game to different kinds of player's needs, the game offers some flexibility in the configuration of the scenarios that can be played. A scenario defines the flow of the environmental variables throughout the course of the game. It defines the initial values of temperature, rain fail,

	Initial (Jan)	**Feb**	**Mar**	**Apr**	**...**	**Dec**
Temp.	5 °C	+3	+5	+6	...	-5
Rain	50 mm	+20	+10	-20	...	+10
CO_2	400 ppm	+200	+200	+200	...	+200
River	20 N mg/L	+0	+0	+0	...	+0

Table 2: An example scenario. The table shows that the temperature starts at 5 °C in January and raises to 8 °C in February and that the CO_2 levels start at 400 ppm (parts per million) in January and that more 200 ppm are generated every month.

CO_2 in the atmosphere and nitrate levels in the river and the updates applied on these values each turn (e.g. monthly update). To enrich the context, a scenario is characterized by a place (corresponding to some geographical location in the world) and the update of each month is associated with a season. These are tags that are shown to the users to help them better understand the scenario. For example, this feature enables the person that configures the game to express the differences in seasons from the north and south of the globe (e.g. July is summer in Europe but winter in South America). Table 2 shows a possible scenario.

The scenario defines the typical weather fluctuations for the location and the pollution that is generated (by the population) in that location. This creates the possibility to present different situations to the players. For example, they can play in environments that they recognize and identify with, e.g. those similar to the place they live or where they spent their childhood, or experience completely new environments that correspond to distinct places on the globe. The challenges presented may also vary in difficulty. The player may face extreme weather conditions or face some situations where the control of the pollution must be tighter.

Villagers may also have different levels of sensibility for each of the issues that influence their happiness. For example, they may worry more about the water and not so much about the air or give no importance to the quality of the food. Some other minor definitions, such as the cost of water and the money the player has in the beginning of the game, may also influence the challenge and situation the players face. These definitions open up the possibility to adapt the game to different audiences and/or to give emphasis to different issues.

4.5. Multi-player Feature

To further explore the people factor [23] and to foster discussion about the environmental issues in agriculture, the game can be played by several different players at the same time. Each player controls a different farm and is competing with the others for profit. Since they all share the same environment, they all suffer from the negative effects in the environment even if they are not responsible for them.

For example, if one of the players is polluting the river the population will become unhappy and eventually riot and expel all the players. This game characteristic was built to encourage the users to collaborate in order to improve the environment; otherwise, they all lose the game. In this way the game may improve learning due to the discussion and argumentation it elicits [20].

Currently, the game does not support any mechanism to mediate the interaction of the players. They have to rely on the communication means available to users of the virtual world (e.g. Instant Messaging). We plan to develop specific mechanics in the game to improve player interaction in the future, e.g. if players are taking actions that damage the environment they would be vulnerable to others.

5. System Architecture

The game was built to run on a *OpenSimulator* server. *OpenSimulator* is a 3D Application Server that can be used to create persistent online 3D virtual worlds. These worlds can be accessed through a variety of visual clients, including the *Linden Lab's Second Life* viewer or *Hippo* viewer. *OpenSimulator* is an open source server version of *Second Life*.

To support the integration of the game with *OpenSimulator* we use the *OpenLibraryGrid*[19] developed at National Institute of Informatics. It consists of middleware and software that provide the capabilities to create and manipulate *OpenSimulator* entities through a socket connection.

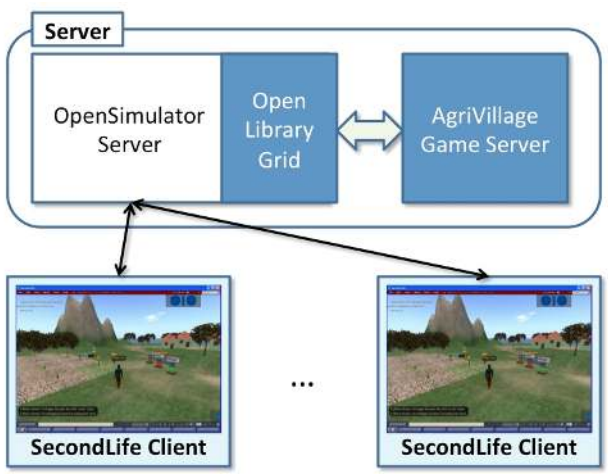

Figure 5: System architecture.

The overall architecture of the system is shown in Fig. 5. *OpenLibraryGrid* runs as a module of *OpenSimulator*, and the *AgriVillage* game server runs independently. The game server uses the connection with *OpenLibraryGrid* to create

[19] http://www.prendingerlab.net/globallab/technology/openscience/openlibrarygrid/

the game entities in the 3D world and to control their state as well as to receive information regarding the players' actions in the world. Game entities can easily be created with the the Environment Markup Language (EML3D) [10], whereas the villagers can be controlled by the Multimodal Presentation Markup Language (MPML3D) [15]. The game server runs a model of the game world and is responsible for running all the logic of the game while *OpenSimulator* is responsible for the visualization of the game state and user input. Thus, the state and dynamics of the game world, defined in the game server, have a corresponding representation in the *OpenSimulator*'s 3D world. The synchronization of this representation is performed by a component (the *OpenLibraryGrid* Bridge) that translates events in the game simulation into *OpenLibraryGrid* requests. For example, when the state of the game simulation specifies that it is raining in the game world, the *OpenLibraryGrid* Bridge requests the execution of a particle system that shows drops of rain in the 3D virtual world.

Users' input is achieved through the interaction of the users' avatars with objects in the 3D virtual world. For example, if the player wants to chop a tree s/he activates the specific object that represents the tree and a contextual menu, implemented as a message box, pops-up with the actions available. In the case of a tree the only option is to cut the tree (or cancel). Other objects that can be activated are the farm's water pump and the individual fields in the farm. We also use a simple HUD[20] to display the current season, information about the weather and the money the player has. In addition, players can use the chat facilities offered by *OpenSimulator* to talk to the villagers and to other players.

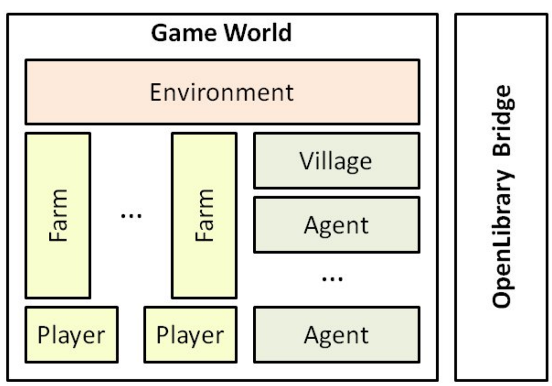

Figure 6: The core components in the *AgriVillage* game server.

The main components of the game world in the game server are (see Fig. 6):

- **Environment** – Stores the values that define the weather (rain and tem-

[20]Head-Up Display.

perature) and the levels of pollution (concentration of CO_2 in the atmosphere and nitrates in the river). Updates values of the weather according to the definition in the scenario when a monthly update is requested.

- **Farm** – Keeps track of the state of the fields (e.g. if they contain a tree, are fertilized or planted) and the state of the water pump. If a field is planted, the quality of the vegetables is tracked.
- **Player** – Stores information regarding players. Keeps track of the amount of their money and their score. A player is associated with a farm.
- **Village** – Defines the impact of the village on the levels of pollution defined in the environment. Updates the values of the concentration of CO_2 and river nitrates according to the definition of the scenario.
- **Agent** – Each villager is defined as an autonomous agent that senses the environment and acts accordingly. An agent's actions depend on its level of happiness.

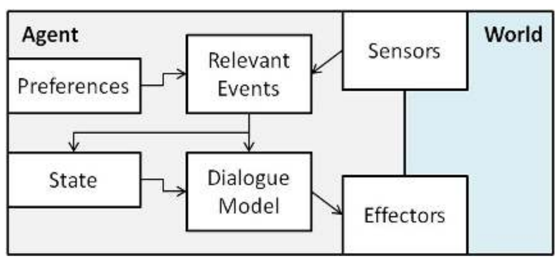

Figure 7: Agent architecture.

The agent architecture is shown in Fig. 7. The main components are:

- **Sensors** – These constitute the means of the agent (villager) to gather information from the world. Agents have sensors (1) to perceive if a player approaches or leaves their vicinity, (2) to listen to players' chat messages and (3) to recognize events in the game (e.g. a vegetable is sold, or changes in the level of pollution).
- **Effectors** – These constitute the means of the agent to act in the world. Agents have effectors to walk around and to speak.
- **Relevant Events** – This component analyzes the information gathered from the sensors and checks if an event that is relevant for the agent occurred, which depends on the preferences of the agent. A relevant event is, for example, the perception of high concentration of nitrates in the river. Such events may change the state of the agent and trigger a reaction that is handled by the dialogue model.

- **Preferences** – These define the sensibility of the agent to the issues regarding the environment and the agricultural activities of the players. The preferences define what are the accepted levels of CO_2 and nitrates in the river, the accepted percentage of trees, and the accepted quality of the food.

- **State** – This defines the level of happiness of the agent. The identification of relevant events may induce changes in the happiness of the agent. These changes depend on the agent's preferences and may increase (or decrease) happiness. If the happiness level reaches zero the agent riots and the players lose.

- **Dialogue Model** – Keeps a simple model of the dialogue the agent is having with a player. Stores patterns of conversations, e.g. to give hints/instructions to the player in a tutorial format, and conversation steps to avoid repetition in the dialogue. The occurrence of events that change the agent's happiness in a given turn may make the agent react to the player. The reaction is in the form of a comment that refers to the event that provoked the change, e.g. state a reason why the agent is unhappy.

6. Evaluation

We have conducted an experimental study to assess players' perception of the *AgriVillage* game regarding the following dimensions: (1) game flow experience and (2) learning about agriculture and its impact on the environment.

The experiment followed a pilot study previously performed at University X (unidentified for blind review) with five subjects. The results of the pilot study suggested that the game (1) was easy to understand, (2) its aim was clear and (3) it was able to maintain the concentration of the players. However, players stated that the game did not pose much challenge. Players suggested to improve the game scoring by giving more specific goals to the player, such as "earn more than *X*" (amount of money). We also found that the game seemingly does not teach much about agriculture. Nevertheless, most of the players stated that they have learned something regarding the impact of agriculture on the environment. In addition, we observed that the comments of the villagers have an impact on the players' decisions. It seems that complaints of villagers make the players worry more about their actions. A typical comment was: "She is complaining... Now she is mad at me!".

The results of the pilot study were promising, but we could not draw strong conclusions given that only very few participants were involved. Nevertheless, the pilot constituted a good preparation for our experiment. Specifically, we adjusted the difficulty of the game by changing some its configuration the parameters (see Sect. 4). The following sections present the design and results of the experiment.

6.1. Participants

The experiment was conducted with 20 subjects from University Y (unidentified for blind review), 21 to 50 years old (avrg = 30.95, $\sigma = 9.099$), 12 of the subjects were female and 8 were male. Most subjects (17 subjects) did not have prior experience with *Second Life* or similar virtual worlds. Subjects were students, researchers and professors at the university with different backgrounds (e.g. Computer Engineering, Linguistics, Education and Management). Eight subjects were working in projects related to agriculture. The game was in English, so we checked the subjects' skill with the English language. All subjects had some knowledge of English, but only 8 declared to have good English skills.

6.2. Procedure

Participants were asked to play a full year in the game (i.e. 12 turns). For practical reasons the time interval between turns was set to 120 seconds. Therefore, each game session took about 24 minutes. Before starting the game players could explore the world freely. To start the game players need to talk to one of the villagers that would instruct them on how to play the game. The village was inhabited by 3 villagers. Two of them were used to help players understand the game concepts. They are able to describe the main mechanics of the game through conversation with players. The third villager was used to comment on the environment state. She makes comments such as: *"I'm happy because I'm eating good food."*, *"I'm very happy because of the good quality of the air."* or *"I'm unhappy because the river smells bad."*.

The participants received very few external instructions regarding the game. They only received one sheet with instructions on how to connect to the game. Players should learn the game only with the in-game instructions given by the villagers. After the game session subjects were asked to fill out a small questionnaire.

6.3. Measures

To assess the quality of the game and the players' experience, we designed a questionnaire based on the 'Game Flow' criteria for player enjoyment in games [19]. We included questions regarding the players' concentration, the level of challenge, game understanding, clarity of the goals, player's sense of control and feeling of immersion. The questionnaire is shown in table 3. Each question was rated on a 5-point Likert scale as described in the table.

Furthermore, we included questions to assess whether the game had impact on the players' perception of their knowledge of agriculture and its environmental impact (see Table 4). In particular, question Q8 measures the awareness of the impact of agriculture on the environment, which was one of the main goals of the game.

The questionnaire was completed with two open questions that asked for suggestions for improvements of the game and general comments.

Question
Q.1. To what extent did you have a sense that the game kept you concentrated when you were playing? (1-Never ... 5-All the time)
Q.2. How challenging was the game for you? (1-No Challenge ... 5-Too Difficult)
Q.3. How difficult was to understand the game without any previous instructions? (1-Very Easy ... 5-Very Difficult)
Q.4. Did you feel that you were in control of what was happening in the game? (1-Never ... 5-All the time)
Q.5. The goal of the game was clear? (1-Never ... 5-All the time)
Q.6. When you were playing did you feel involved by the game, less aware of what was surrounding you and less worried about everyday life or self? (1-Never ... 5-All the time)

Table 3: Questionnaire to assess game flow experience.

Question
Q.7. This game improved your knowledge about agriculture? (1-Not at all ... 5-Very Much)
Q.8. This game made you more aware of the impact of agriculture in the environment? (1-Not at all ... 5-Very Much)
Q.9. In your opinion what is the main factor that affected the environment? (1- Deforestation; 2-Fertilizers; 3 - Other)

Table 4: Questionnaire to assess improvement in the knowledge about agriculture and its impact on the environment.

6.4. Results

The descriptive statistics of the results of the questionnaire are summarized in Table 5 and Table 6. The experiment confirmed some of the results of the pilot study. As we can see in Table 5, the game's goals are clear (Q5 = 3.5), the game is able to maintain the players' concentration (Q1 = 3.65) and the players had an appropriate sense of control on the game (Q4 = 3.4). The level of challenge was considered neutral (Q2 = 3.05), neither too easy nor too difficult. This is an improvement over the results of the pilot study.

The feeling of immersion (Q6 = 3.1) was ranked close to neutral. The immersion might be decreased due to the nature of the game, as players need to wait for the vegetables to grow and do not have much to do meanwhile. We might consider adding activities for the player while s/he waits for the vegetables to grow. Another method is to increase the amount of interaction with the villagers.

Regarding the players' agricultural knowledge and awareness of its environmental impact, results were different from the pilot study. Players reported that the game improved their knowledge about agriculture (Q7 = 3.95) and their awareness about the impact that agriculture can have in the environment (Q8 = 3.95). Next we asked subjects what they considered was the main factor that affected the environment in the game. The results are shown in Table 6: 65% of the players think that it was deforestation, while 30% attributed the main impact to fertilizers.

Item	N	Mean	Std. Dev.
Q1. Concentration	20	3.65	.813
Q2. Level of Challenge	20	3.05	.887
Q3. Game Understanding	20	3.55	.945
Q4. Sense of Control	20	3.4	.883
Q5. Clarity of the Goals	20	3.5	1.192
Q6. Feeling of Immersion	20	3.1	1.119
Q7. Knowledge of Agriculture	20	3.95	1.146
Q8. Impact of Agriculture	20	3.95	1.146

Table 5: Results for questions Q1 to Q8.

Factor	Frequency	Percentage
Deforestation	13	65
Fertilizers	6	30
Other	1	5

Table 6: Results for Q9: *"Main factor that affected the environment"*.

With the results of the pilot study as a baseline, the surprising finding was that players reported that the game taught them something about agriculture. To further analyze this we divided the subjects into 2 different groups, using the fact that some have worked on agriculture related projects while others have not, and compared their results.[21] The comparison is summarized in Table 7.

Item	Work Agri.	N	Mean	Std. Dev.
Q1. Concentration	Y	8	3.5	1.069
	N	12	3.75	.866
Q2. Level of Challenge	Y	8	2.63	.774
	N	12	3.33	.888
Q3. Game Understanding	Y	8	3.5	1.138
	N	12	3.58	1.069
Q4. Sense of Control	Y	8	3.5	1.073
	N	12	3.33	1.061
Q5. Clarity of the Goals	Y	8	3.63	1.083
	N	12	3.42	1.188
Q6. Feeling of Immersion	Y	8	3.38	1.165
	N	12	2.92	1.302
Q7. Knowledge of Agriculture	Y	8	3.38	.888
	N	12	4.33	.926
Q8. Impact of Agriculture	Y	8	3.5	.900
	N	12	4.25	1.069

Table 7: Comparing the attitudes of subjects depending on whether they worked in agriculture related projects or not.

The first result from the comparison is that there is no difference in the understanding of the game, the clarity of the goals, the sense of control and the level of concentration. This suggests that players do not need to have prior

[21] In the pilot study we did not check the subjects' experience in agriculture related projects, therefore this comparison was not possible.

knowledge of agriculture to be able to understand and play the game. This result is good as we did not want to target the game to specialists only.

However, the other two variables related to the flow experience of the game showed some differences. The feeling of immersion was a bit higher if the player worked in agriculture related projects, but, at the same time, the challenge was lower for those players. Not surprisingly, players with some experience in agriculture found the game easier and could identify themselves better with the situation that the game depicted.

The report on the level of knowledge that the game transmitted was also different in the two groups. In this case, the players with less experience in agriculture found that the game taught them more about agriculture and its impact on the environment. Note that, although the descriptive statistics presented in Table 7 suggest these differences, performing a t-test did not show statistical significance ($p < .05$).[22] Nevertheless, in the case of the level of challenge of the game and the improvement of the knowledge about agriculture, the results are close to statistical significance: ($p = .071$) and ($p = .067$), respectively.

Furthermore, we grouped the players according to the factor they identified as the one that affected the environment the most in the game (Q9), in order to investigate how this judgement affected their game experience. The results are shown in Table 8. Surprisingly, we found some differences. The results suggest that players who chose deforestation as the main factor concentrated more on the game, had a better feeling of immersion and found the game more challenging. Those players also felt that the goals of the game are less clear.

Item	**Main Factor**	**N**	**Mean**	**Std. Dev.**
Q1. Concentration	Deforestation	13	3.92	.760
	Fertilizers	6	3.17	.753
Q2. Level of Challenge	Deforestation	13	3.31	.855
	Fertilizers	6	2.67	.817
Q3. Game Understanding	Deforestation	13	3.54	.776
	Fertilizers	6	3.33	1.211
Q4. Sense of Control	Deforestation	13	3.38	.768
	Fertilizers	6	3.40	1.224
Q5. Clarity of the Goals	Deforestation	13	3.46	1.127
	Fertilizers	6	4.00	.894
Q6. Feeling of Immersion	Deforestation	13	3.38	1.121
	Fertilizers	6	2.50	1.049
Q7. Knowledge of Agriculture	Deforestation	13	4.31	1.032
	Fertilizers	6	3.50	1.049
Q8. Impact of Agriculture	Deforestation	13	3.85	1.345
	Fertilizers	6	4.17	.753

Table 8: Comparing subjects according to the factor they identified as the one that affected the environment the most in the game.

This observation is intriguing. Apparently, the players, who found the game more challenging, more easily realized that cutting too many trees damaged the environment. Their higher levels of immersion and concentration may be

[22] This might be due to the fact that we only have 20 subjects in the experiment.

explained by a better adjustment to the difficulty of the game. On the other hand, the players who chose fertilizers as the main determinant of environmental impact, perceived the game as too easy. While easy game play might add to the general fun of the game, it may distract players from noticing the influence of fertilizers on the environment, also given that the mechanics involving fertilizers are somewhat complex. However, the players that perceived the game as to too easy had a less rewarding experience. Given these observations, we speculate that different gaming skills may affect the type of learning from the game.

In addition, we checked the correlations between the measured variables. First of all, we found that the difficulty in the game understanding correlates negatively with the clarity of goals of the game (r= -.678, sig = .001) and the levels of immersion it elicits (r= -.533, sig. = .012). To understand the game players need to understand their goals and if they do not understand the game, their feeling of immersion decreases. Interestingly, the level of immersion and perceived clarity of goals are not correlated. In addition, we found that the improvement in the knowledge of agriculture is positively correlated with the level of challenge of the game (r= .572, sig = .008) and the level of concentration of the player (r= .715, sig = .000), but no correlations were found with the improvement in the awareness of the impact of agriculture on the environment.

To convey knowledge to the player, the level of challenge (and consequent concentration) has to be considered carefully. However, in our study those factors did not influence awareness of the environmental impact of agriculture. Furthermore, we need to develop more sophisticated measures to assess the knowledge players gain from the game, rather than relying on simple self reports.

Finally, we received some interesting comments on how to improve the game from the open questions section of the questionnaire. Some suggestions concern improvements in the user interface and the addition of some more elements to the game, such as pests, diseases and soil characteristics. Some players suggested that the village should have more villagers and that their behavior should be richer. Some of these ideas are on our agenda, but we have to be careful with the inclusion of additional features as they may distract the player from the environmental issues. Nevertheless, new features can contribute to more attractive challenges and a better gaming experience that eventually leads to a deeper understanding of environmental issues.

7. Conclusions

Agriculture can have negative impact on the environment, in particular, on water quality and climate change. Since agriculture is a basis of the development (and existence) of modern societies, it is important to also increase the sensitivity of people regarding negative effects of agriculture.

For this purpose, we developed a serious game that addresses the issue of environmental impact of agriculture. The game places a user in a virtual environment where s/he has the responsibility of running a farm that produces food for a small village. The game mechanics were designed in a way to make the players think carefully about the impact of their actions as farmers on the environment. In particular, we have enhanced the role of the villagers in the game and turned them into active elements. The villagers reinforce good behaviors by encouraging players if the environment is in a good condition and penalize their bad decisions by complaining if the actions of players damage the environment. To foster the impact of the game, we exploited the 'people factor' by having 'people' (the autonomous villagers) comment on player actions, rather than a faceless system.

The game was initially tested in a small pilot study with a few subjects in Portugal, and then the experiment was run again with more people in Thailand. The results are promising regarding the gaming experience.

We believe that, with a few simple extensions, other issues can be explored with the *AgriVillage* game. One is the exhaustion of the soil: the game can promote crop rotation in the fields and periods of rest. Another issue is the usage of water: the game score can reflect how much water players used in their farms and can penalize players that wasted more water.

Another avenue for future work is to increase the "life-likeness" of the villagers to achieve a higher level of suspension of disbelief [14]. We already found some evidence that even with the limited life-likeness of our agents, players seem to care about their comments. In particular, we will try to promote attachment between villagers and the players. Attachment might be achieved by enabling more (and deeper) interactions between the players and the villagers. This can be a challenge if we aim to provide long turn-intervals without requiring the presence of players all the time.

Furthermore, we plan to explore advanced multi-player modes of the game, since multi-player situations might lead to more reflection of the players about the impact of their actions. In addition, competition and collaboration among players can be a source of motivation for playing the game, and contribute to a better understanding of the environmental impact of agriculture.

Finally, we would like to refer that the economic model of the village's market is very simplistic and ignores economic pressure in the villagers' choice when buying vegetables (e.g. villagers have no concern for the price of a vegetable only consider its quality). The game could be extended with a demand model and a better decision model in the agents that takes into account both quality and cost. This extension would increase the economic realism of the game, which can be good factor to stress the difficulty in keeping the balance between the sustainability of agriculture and its impact on the environment.

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