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Abstract: Our research work deals with the development of a new type of game-based learning environment: (M)MORPG based on mixed reality, applied in the archaeological domain. In this paper, we propose a learning scenario that enhances players' motivation thanks to individual, collaborative and social activities and that offers a continuous experience between the virtual environment and real places (archaeological sites, museum). After describing the challenge to a rich multidisciplinary approach involving both computer scientists and archaeologists, we present two types of game: multiplayer online role-playing games and mixed reality games. We base on the specificities of these games to make the design choices described in the paper. The goal of the proposed approach is to raise awareness among people on the scientific approach in Archaeology, by providing them information in the virtual environment and inciting them to go on real sites. We finally discuss the issues raised by this work, such as the tensions between the perceived individual, team and community utilities, as well as the choice of the entering point in the learning scenario (real or virtual) for the players' involvement in the game.

Keywords: Game-Based Learning, Multiplayer Game, Mixed Reality, Learning Scenario, Archaeology

1. Introduction

We believe that Game-Based Learning (GBL) can significantly enhance learning, and do so in diverse application domains. In the last years, we have set up numbers of experiments using GBL environments. Immersing learners in such digital environments is a good way to enhance their learning, and especially their level of motivation. However, a well-known limitation of GBL learning is the difficulty for learners to apply the concepts they learn in the game into real life. Indeed, the objects manipulated in the game are a modelization of real life objects. To apply in real life the concepts acquired in game, learners need to become aware, to a certain extent, of the abstraction underlying the modelization. An operation, which we believe can be eased by manipulating directly the real life objects. We address this issue in this paper in a specific GBL environment: (M)MORPG, which rely on the collaboration and interactions amongst learners to increase their level of motivation. In 2012 computer scientists and archaeologists have launched a multidisciplinary project called JANUS, in order to design and experiment an educational MORPG. As explained in section 2, there is an immediate challenge to this rich multidisciplinary approach: the emergence of a shared vocabulary and the understanding of the research questions emphasized in each area.

Archaeology is a particularly appropriate domain to apply both this mixed (virtual/real) GBL approach and collaborative learning: it directly depends on physical artifacts as the seminal input to the various and complementary subsequent processes inherent to the several subdomains of Archaeology. The first result of our joint ideas is a learning scenario described in section 4 that explains how to integrate activities in a virtual world (the game and web sites) and activities on archaeological sites or in museums. The design of this scenario is based on two types of games that we study in section 3: multiplayer online role-playing games and mixed reality games.

In order to keep a strong motivation in the game, we have decided to organize a learning quest where students are grouped into guilds. We enhance the interrelationship of people inside their guilds, and the personal contributions of each student for the rest of the group (the community of learners). We also describe how we swap from activities in the virtual world to activities in the real world through a unique scenario. The idea here is to keep the same motivation and a continuous experience in the virtual game and at the museum or on the archaeological site. We finally conclude by drawing lessons about this work and by explaining generally the main research questions that have been raised and that we intend to address in the near future.

2. Designing new GBL activities

As explained earlier, we would like to propose a GBL approach for raising awareness among students on the scientific approach in Archaeology. That it why, in 2012, computer scientists and archaeologists have launched a multidisciplinary project called JANUS, in order to design and experiment an educational MMORPG.

Basically, this educational environment must allow individuals or groups of users to embark on a quest for discovering knowledge about archaeological items. However, a major goal of the project is also to create a community around archaeology. Peripheral aspects such as promoting the cultural heritage and make people discover it through their city walks are also to be considered.

These challenging objectives lead immediately to very complex questions: first of all, we believe that “learning by doing” is an interesting aspect to introduce in our learning sessions. This led us to consider how to take advantage of mixed (virtual/real) GBL features. In fact, even if general knowledge can be acquired in a virtual environment, more practical items must be studied on the archaeological site, in the museums or at the library. We can expect here that the motivation provided by a virtual game-based environment can be either improved with challenges in the real world. A side effect of having part of the activities on cultural sites is actually to promote the cultural heritage. Second, the learning process is not necessarily an individual process. Current trends on teaching tend to introduce collaborative learning, involving groups of pupils to gather knowledge, share it and use it to solve new problems. Collaborative learning features are thus also central in our research work. Third, some activities must be designed in order to generate collective debates, to produce new information, vital to the achievements of new social behaviours.

The project involves researchers in very different domains ranging from computer science to archaeology. There is another challenge to this rich multidisciplinary approach: the emergence of a shared vocabulary and the understanding of the research questions emphasized in each area. We therefore entered a first step to list the different project requirements. We therefore hold several meetings that were dedicated to exchanging knowledge and approaches to problems. As the domains were quite large to cover, we decided to design a learning scenario that explains how to integrate activities in a virtual world (the game and web sites) and activities on archaeological sites or in museums.

To sum up, we were faced to the problem of designing a scenario where collaborative aspects are considered, where mix (real/virtual) aspects are included, while respecting strong domain constraints (precise tasks to be taught). Furthermore, we wanted to integrate particular activities facilitating the emergence of an archaeological community. In order to understand well the domain constraints and because the requirements were somewhat vague, we decided to adopt an Agile software development process, following a Scrum approach (ref scrum). We have therefore divided our projects into sprints (3 weeks periods) to build our scenario. As recommended in the Scrum methodology, we have gathered all the ideas of functionalities to be included in the scenario in a file called the “backlog product”. At the beginning of each sprint, both the archaeologists and the computer scientists meet and discuss the new version of the scenario. Relevant changes can be performed as well as new ideas added in the backlog product. The team then decides what features have the highest priority to be included in the scenario for the next sprint.

Since collaborative and community aspects are concerned, we must clearly rely on multiplayer games and also consider the work carried out in mixed reality games. We now present a state of the art for these domains and give more concrete examples on the scenario that is currently implemented in the project.

3. State of the art

3.1 Multiplayer games

Game-Based Learning (GBL) has the potential of improving training activities and initiatives thanks to its engagement, motivation, role-playing, and repeatability (failed strategies can be modified and tried again). These games have proven to be useful to provide learners with pedagogical content in a ludic or/and realistic way (Flynn et al., 2011). However most of LG are played individually and learners evolve in the game without interaction with “real” learners. One way to enhance learning and engagement in the game is to allow collaboration by proposing a multiplayer environment.

Currently, we observe the emergence and success of online multiplayer games in the world (Rosenbloom, 2004) and even in education (Purdy, 2007). Multiplayer Learning Games (MLG) usually immerse the players in a virtual 2D or 3D environment (Marty &Carron, 2011) and propose collaborative activities. This type of games can support development of a number of various skills: strategic thinking, planning, communication, collaboration, group decision-making and negotiating skills (Squire & Jenkins, 2003). Players learn not only from the game, but also from each others (Purdy, 2007). Unfortunately, these games usually allow collaboration only among a limited number of students inside the virtual world. Furthermore, collaboration occurs according to a predefined learning scenario, often regulated by a teacher. Learners have thus restricted possibilities of interaction with other learners. We believe that it is one of the main reasons why students tend to consider Computer-Based Learning Environments as unexciting.

Massively Multiplayer Online Games (MMOG) are nowadays predominantly played by digital natives. Educational MMOG often works as tournaments and are based on competition between groups of students like in (Araya et al., 2001). The most popular type of MMOG, and the sub-genre that pioneered the category, is the Massively Multiplayer Online Role-Playing Game (MMORPG). An MMORPG is "*an immersive 3D worlds where hundreds or thousands of players connect simultaneously from all over the world in order to meet each other in a simulated reality*" (Bennassi et al., 2011). Many MMORPGs offer support for in-game guilds or clans that are groups of players coming together to share knowledge, resources and manpower to reach common goals. For example, World of Warcraft is a MMORPG set in a fantasy world (like "The Lord of the Rings"). The aim of the game is to conduct a series of missions, so-called quests, with progressive levels of difficulty. We can see interaction in a MMORPG as a condition for social learning (Wenger, 1998). Players exchange ideas, solve problems and create relationships, through technologies like chat or forum. (Paraskeva et al., 2010) have considered the functioning of online multiplayer educational games to highlight the importance of developing a strong sense of community among players to highlight their motivation and engagement and the learning through a social experience. The sense of belonging in a community (game community or learning community) intrinsically motivates students to participate in the game and increase their performance. (Lavoué, 2012) defines Social Learning Games (SLG) as "*games that enhance learning by offering educational contents according to a learning scenario and by supporting a community that offers condition for social learning*". The author highlights the different ways to enhance learning in SLG: the engagement in the game through the community, the mutual help in the community to make decisions in the game, the educational contents to initiate discussions in the community, the freedom in the community and the control in the game. MMORPG therefore foster learners' engagement in the game and create dynamic learning opportunities due to the community. Role-playing incites players to help each other to solve problems, by using their own different knowledge and capabilities.

One of the major issues of our work is to combine three levels of communication and learning: individual, team (guild) and community. The players will be able to collaborate within their team and consequently to benefit from collaborative learning. They will also exchange information with other players and thus facilitate the emergence of a community interested in archaeology so that they will benefit from social learning. To design such a game, we will base our work on the four lessons given in (Zagal et al., 2006) for the design of collaborative games: (1) a collaborative game should introduce a tension between perceived individual utility and team utility, (2) individual players should be allowed to make decisions and take actions without the consent of the team, (3) players must be able to trace payoffs back to their decisions, (4) a collaborative game should bestow different abilities or responsibilities upon the players. Meanwhile, we have to facilitate the emergence of a community of players interested in archaeology. In such a context, we will induce collaboration amongst the members of a same team, and competition between the players from different teams.

A game that is similar to our approach is described in (Wendel et al., 2010). The authors introduce methods and concepts of Woodment as a browser-based Serious Multiplayer Game to teach and explore a customizable learning content in a game-based and playful manner. The immersive environment sets the scene for a business simulation game in the field of logging: players can explore the island's 3D world, manage the company, react to unexpected events, fight for the victory of the team, communicate with others via in-game chat, level up and create learning content using the web interface. This game supports several levels of exchange (teams and global), but only by the way of a global chat and a team chat. In the course of the game, the players can take tests and answer quizzes individually or collectively. But there does not seem to be any connection between the educational content and the game itself, as the educational content can concern any topic. This can be considered a strength as it makes the game infinitely extendable — one question at a time — and repeatable, but it can also be perceived as a weakness as the conjunction of the business game and the quizzes can seem artificial to the learners. Here, we are developing a game under the form of a quest. It is scenarized to give the leaner a point of view on a precise field: archaeology. The form of the quest limits the repeatability of the game (in Woodment for instance the business game can be played many times) but integrates the learning activities in a consistent environment. Additionally, the quest mixes real and virtual activities, calling for a study of mixed reality games.

3.2 Mixed reality games

Learning Games have sometimes some limitations when it is necessary to transfer the knowledge learned in other situations. It could be useful to create situations closer to reality, especially for the acquisition of professional skills (e.g. technical gestures or procedures performed in complex environments). To achieve this, a solution is to go beyond the conventional use of computers and to use Mixed Reality techniques. The Mixed Reality (MR) refers to a continuum that connects the physical and digital worlds and it includes schematically two components (Milgram & Kishino, 1994):

- Augmented Reality (AR), where the real world is enriched by virtual information.
- Augmented Virtuality (AV) where, in contrast, a virtual world is enriched with real objects (e.g. by using tangible interfaces to manipulate virtual objects).

Several devices can be used for implementing MR, including see-through Head Mounted Displays (HMD), mobile devices such as digital tablets or smartphones, digital tabletops, or tangible interfaces that control or represent virtual information. Nilsen, Linton & Losser (2004) have shown that augmented reality kept both the benefits of real activities (especially communication between people) and the benefits of virtual environment, including the possibility of introducing virtual characters. Furthermore, adding information to real objects, information that is not perceptible naturally, is of great interest for educational situations. Some studies, such as Stedmon and Stone (2001), show that augmenting physical artifacts with associated information, facilitates the understanding of concepts. More recently, David et al. (2010) studied how physical artifacts (industrial machines or computers) could be augmented with digital data to promote just in time learning. Mixed Reality seems quite suitable for the learning of gestures, actions and operations, particularly in mobile and work situations.

Mobile devices give the opportunity to develop an active pedagogy, favoring learning in authentical context and allowing the use of the natural environment as a source of information. Some knowledge needs students to learn through observation and is not always easy to teach during a traditional classroom or with a web-based learning environment. Mobile application proves to be useful in this case. For instance, Explore! (Ardito et al., 2009) supports young students learning ancient history during a visit to archaeological parks. The game allows students to explore 3D reconstructions of historical buildings, objects, and places, and also contextual sounds are played in order to recreate the historical atmosphere and enhance the overall user experience.

While it is still too early to draw conclusions about the effectiveness of MR on learning (Anastassova & Burkhardt, 2008), learning outcomes seem to be rather short-term. In order to overcome these short-term limitations, more elaborate learning scenarios should be designed. By coupling Mixed Reality and Learning Games, it is possible to combine from one hand motivational and situated aspects of MR and on the other hand fun and scripted activity of LG. This point was the main goal of the SEGAREM project (George et al., 2013). During this project, an experimental study has been conducted to evaluate the impact of Mixed Reality interactions on learning. A Mixed Reality Learning Game (MRLG) was designed to teach Lean Management principles in an engineering school. Some actions are carried out with mixed reality, by using tangible interfaces over tabletops (e.g. a physical glue gun with an infrared light is used to stick virtual elements). The comparison between a learning session with the MRLG and an other without mixed reality interaction revealed a tendency for the MRLG situation to effectively have a positive impact on learning, particularly the understanding of theoretical concepts is favoured (George et al., 2013).

The work presented in this paper is clearly situated within the trend of mixed reality games described in this section. The originality of the Janus project lies in the exploration of the possibilities of an educational MORPG, which combines both real and virtual worlds.

4. A learning scenario for a MORPG based on mixed reality

Before entering the description of the scenario, we will describe the environment on which we build our game. We decided to reuse BrowserQuest[1], an open-source HTML5 retro-gaming styled MORPG. It had two main features at its core that decided us to reuse it:

- as a browser game both for PC and mobile devices, it can be used for MR applications;
- it provides ingame communication mechanisms required for collaborative learning.

Being totally open, we have here a highly customizable tool, but it was not designed as a game engine, which should be taken into account by developers.

4.1 An exploration game

Our game, like BrowserQuest, is an exploration game. The exploration will lead players to glean information and missions from NPC, to meet and talk with other players, including guild members. In Figure 1, we take into account the explorative nature of the game, one should therefore not perceive it as a linear timeline, but more as a spatial representation: the left being further away from the end of the quest than the right side. But the player is free to evolve in any direction (the dotted arrows display how new behaviours are unlocked) except in rare cases when an event triggers an activity (plain arrows).

In such a setting, the progress of the player(s) is based on events that affect the narrative and the tasks at hand. In the rest of this section, we will explain how we handle these events in order to play our scenario, especially from the standpoint of its mixed-reality and collaborative aspects.

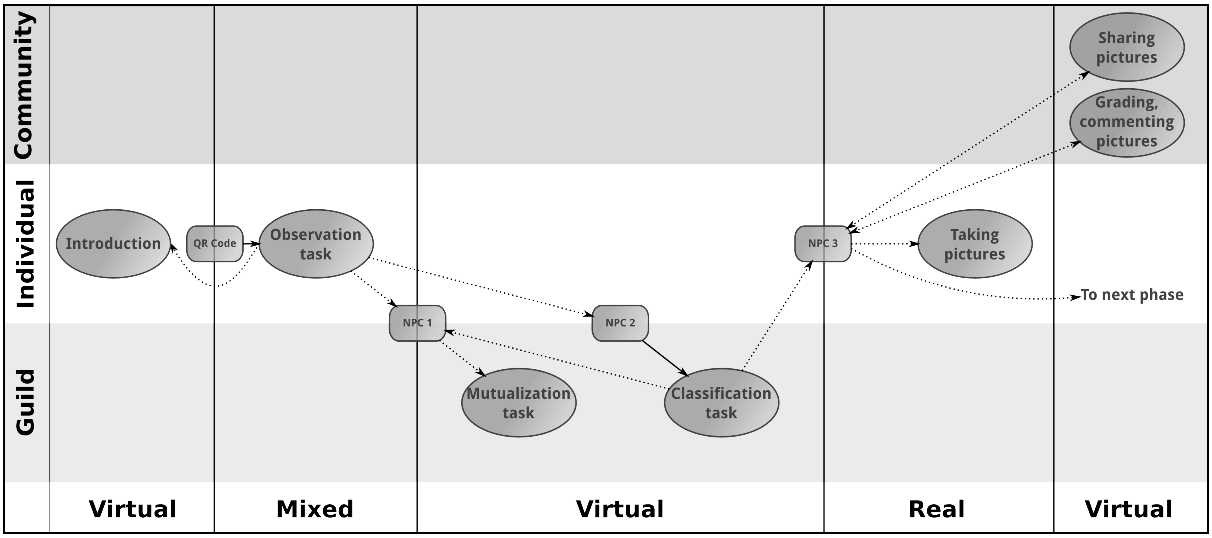

Figure 1: A technical point of view on the first phases of the scenario

4.2 A mixed approach: real and virtual experiences

In the portion of scenario described above, we isolate three modalities respective to the role of the real world in the activity (virtual, mixed and real world experiences).

Some actions take place exclusively in the virtual environment. This is the case of the introduction of the game, where the players learn about the storyline and their global role in the scenario.
This is also the case of the exploration of BrowserQuest, which is of course solely virtual. All the same, being virtual does not mean it is disconnected from the real world: the underlying map contains representations of real places. These places act as landmarks of the real world. When visiting archaeological sites, the learners can access this map from any place thanks to mobile devices, and so access information on that place and linked quests. Indeed aids provided for real world tasks come from the virtual environment. With this respect

[1] https://github.com/browserquest/BrowserQuest (repository maintained by the community) / http://www.littleworkshop.fr/browserquest.html (description by the developers)

the learners need to be able to recognize in the virtual environment, the places they have visited in real life. Likewise, geolocalization is a means for the environment to provide contextual aid.

For instance, the “taking pictures” activity is dedicated to allowing the learners to realize that various gallo-roman monuments exist in their city. They are therefore asked to photograph some of them. This allows explaining some of the standards of pictures used in archaeology archives. Learners are also asked to notice monuments that will later be at the center of other activities. To help players to find all the expected monuments, aid can be provided by NPCs (Non Playing Characters) depending on where the user is, giving more precise information if the user is close to the concerned location.
Yet we do not consider this activity as mixed, as a player having studied well the task description and knowing very well the city, could finish it without any connection to the system, and with no other device than a camera.

On the other hand, certain activities require the user to be in a specific location both in the virtual world (place on the map/url) and in the real world (artifact). In this case, the real artifact is contextualized by its representation in the system. For such an issue, geolocalization is inadequate in that it describes the players or their device, more than it describes the environment. In this case, we resorted to QR codes that both allow ensuring that the players are in contact with the considered artifact and that they will load the appropriate url to perform the task at hand.
In the “observation task” in Figure 1, the players are asked to observe a monument and need to answer questions on site using a mobile device. The execution of such activities being highly circumstantial the QR code triggers the task and does not just unlock it.

4.3 A combination of individual, team and community experiences
In order to keep a strong motivation in the game, we have decided to organize a learning quest where students are grouped into guilds and can also carry out social activities involving the whole community of learners. We describe in this part how the proposed scenario in meant to enhance collaboration into the teams and social interactions into the global community.

The “observation task” (see Figure 1) is an example of a task we consider as individual: the players can play right after entering the game without waiting for others. Such a task is also meant to help them learn the specialization associated to their role[2]. This is the object of an individual progression, associated to an indicator, to be presented to the user as recommended in (Zagal et al., 2006).

Individual activities also serve the group goal: players of different roles constitute guilds. The information gathered by players in individual tasks are meant to be reused for the progress of the team. All teams have the same goal that is to build a virtual notice for an archaeological site. The virtual notice constitutes a virtual representation of the team progress. It is accessible at any moment, so that each member can see the progress of the team. We use an etherpad[3] to implement it. Each quest aims to provide information to the team to fill the notice. There is a competition between the teams, since at the end of the game the best virtual notice will be printed to be put in the real site.

An example of such group progress is provided in the scenario. When all players in a guild have completed the “observation task”, a flag is lifted so that the NPC1 adapts its message to the task outcome. It reminds each player of the most important facts s/he has gathered in the tasks and suggests them to go on a mutualization task, *i.e.* to write them down in the etherpad, which allows both synchronous and asynchronous edition and also provides chat facilities.

Other tasks that take place later in the game require the guild members to collaborate in order to achieve completion. For example, in the “classification task” all players of a same guild have to be online at the same time: depending again on their role, the players are provided with different pieces of information. All are necessary to solve the puzzle. The circumstantial conditions required to perform this task make it necessary to

[2] So far we have implemented two roles: epigraphist and art historian, 2 other roles are to be included in the game (documentalist and architect).

[3] http://etherpad.org/

trigger it at once when the players meet in the virtual environment (cf. NPC2). After each task, the last information gathered is reminded to the player by an NPC (cf. NPC1).

The part played by the guild in the quests is both meant to support players' involvement and the co-construction and appropriation of knowledge by learners. We so aim at enhancing collaboration into the teams and social activities into the global community. Indeed, some tasks involve the players at community level. For example, the "taking picture" task (see Figure 1), linked to NPC3, can be carried out individually by players, but its outcome is meant to be shared with the community. The other teams' members can rate these photographs and comment them. We incite players to participate by making their social indicator evolve according to their level of participation in this quest (posting photos, rating and commenting them). The evaluation provided is in term used to compute individual and guild successes.

5. Discussion and perspectives

The JANUS project is a feasibility study leading to a prototype. It examines the possibility to provide a social, mixed reality, serious game to raise awareness about archaeology as well as to promote the city's monuments. We described in this paper the design choices we have made in the implementation process and especially in the learning scenario. We performed the connection between the virtual and the real world, by representing real places in the virtual map, by contextualizing information in the game using geolocalization and by identifying artifacts using QR codes. To complete the quests the players evolve as individuals and members of teams and of the community.

This social component adds a layer to the problem of collaboration as described in (Zagal et al., 2006). While recommendation (4) — players with different abilities — does not require adaptation to our context, the decisions we took provide a lead for an extension of recommendation (1) to a social context. With the team final goal (creating a notice board for a monument), by allowing players to choose among all team productions an actual notice board, we introduce a tension between perceived individual and team utility (voting to favor one's own team) and the perceived community interest (sharing valuable resources with outside the community, here the people visiting the archaeological site). To this tension, one has to add the tension between the different social consequences for individuals of the behaviors used to favor individual or team utility.

All the same, this does not deny the possibility to apply the recommendation at the level described in Zagal *et al.*'s study. We could extend our scoring mechanisms by computing the team and the individual indicators according to different criteria: the individual score favoring the quickness of responses, the team score penalizing errors harsher. Given a choice, the learners would be able to choose between taking the risk of an error (individual utility) or involving others' knowledge to eliminate as much uncertainty as possible through discussion (group utility).

This leads directly to another recommendation: (3) — tracing payoff back to one's decision. In the case of a closed output activity (such as the classification task), providing feedback on a user action can easily be computed. But the regulation role of the community seems noteworthy. Indeed the community can be instrumental to providing feedback on actions performed in more open tasks in terms of outcome (a set of photos or writing a text) than a fully computational solution. Additionally the social actions of the users (sharing pictures for instance) can be traced to influence the progress of the game (e.g. after sharing five photos among its members a flag allows a guild to unlock the next phase of the game, cf. NPC3 in Figure 1). If successful in practice, this would further anchor the game in the social web paradigm by "harnessing collective intelligence" (Musser et al., 2007). In the long term, this feature could be taken further by performing real community tasks. After evaluating photos and notices, the various outcomes could serve as a base for a community written article about city monuments, for instance in a wiki.

The mixed reality aspect of the game is not without social consequences either. By bringing players to actual real life artifacts, the environment relinquishes control over user interactions. Players are free to communicate in the real world or to perform tasks together with team members or other players. These untraced interactions should not be neglected in later analyses nor ignored in the game design. Let's follow on the example we gave for computing individual task scores: computing team work solely by counting chat interactions during the task would negate the possibility for players to interact in the real world. This would be problematic in that the task actually creates the possibility for players to be physically able to communicate.

This makes the actual city locations part of the environment of the game in exactly the same way as BrowserQuest. The location of the "observation task" initiating our scenario is in effect an entry point to our game through the presence of a QR code that can be scanned by any passer-by or bystander curious about players present in the premises. This calls for general thoughts on how to favor entering a mixed reality game such as this one and the consequences of design decisions in term of guild constitution and community engagement. In our future works, we plan to conduct several experiments with people with different backgrounds to study the implications of these decisions on their progress in the learning scenario and on their level of knowledge acquired in the archaeological domain at the achievement of the game.

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