Novel 3D Game-like Applications driven by body interactions for learning specific forms of Intangible Cultural Heritage

E. Yilmaz[1], D. Uğurca[1], C. Şahin[1], F.M.Dagnino[2], M. Ott[2], F. Pozzi[2], K. Dimitropoulos[3], F. Tsalakanidou[3], A. Kitsikidis[3], S. K. Al Kork[4,5], K. Xu[4,5], B. Denby[4,5],P. Roussel[4,5], P. Chawah[6,7], L. Buchman[6,7], M. Adda-Decker[6,7] , S. Dupont[8], B. Picart[8], J. Tilmanne[8], M. Alivizatou[9], L. Hadjileontiadis[10], V. Charisis[10], A. Glushkova[11], C. Volioti[11], A. Manitsaris[11], E. Hemery[12,13], F. Moutarde[12,13] and N. Grammalidis[3]

[1]*Argedor Information Technologies, Ankara, Turkey*
[2]*Institute for Educational Technology, National Research Council (ITD-CNR), Italy*
[3]*Information Technologies Institute, Centre for Research and Technology Hellas, Thessaloniki, Greece*
[4]*Universite Pierre et Marie Curie - Paris 6, Paris, France*
[5]*University Paris 3 Sorbonne Nouvelle, Paris, France*
[6]*Centre National de la Recherche Scientifique, Laboratoire de Phonétique et Phonologie UMR 7018, Paris, France*
[7]*Phonetics and Phonology Laboratory, LPP-CNRS, Paris, France*
[8]*Universite de Mons, Mons, Belgium*
[9]*University College London, London, UK*
[10]*Aristotle University of Thessaloniki, Thessaloniki, Greece*
[11]*MTCG Lab, Dep. Of Ap. Informatics, University of Macedonia, Thessaloniki, Greece*
[12]*Robotics Lab, Dep. Of Mathématiques et Systèmes, MINES ParisTech-ARMINES,Paris, France*
[13]*Signal Processing and Machine Learning Lab ESPCI, Paris, France*
erdal@gmail.com

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Abstract: The main objective of the EU FP7 ICT i-Treasures project is to build a public and expandable platform to enable learning and transmission of rare know-how of intangible cultural heritage. A core part of this platform consists of game-like applications able to support teaching and learning processes in the ICH field. We have designed and developed four game-like applications (for Human Beat Box singing, Tsamiko dancing, pottery making and contemporary music composition), each corresponding to one of the ICH use cases of i-Treasures project. A first preliminary version of these applications is currently available for further validation, evaluation and demonstration within the project. We have encountered a number of issues, most of which derive from the peculiarities of the ICH domains addressed by the project, and many have already been resolved/ The evaluation results are expected to lead to further optimization of these games. .

1. INTRODUCTION

Cultural expression is not limited to architecture, monuments or collections of artefacts, for which various systems have been developed for capturing, analysis and visualization (Kyriakaki, 2014), (Makantasis, 2014) and (Makantasis, 2013). Intangible Cultural Heritage" (ICH) is defined as a part of the cultural heritage of societies, groups or sometimes individuals and it includes practices, presentations, expressions, knowledge, skills and related tools to all of these such as equipment and cultural sites. This intangible heritage passes from generation to generation and gives people a sense of identity and continuity; it is the result of the continuous interaction of communities and groups with their nature and history and it promotes respect for cultural diversity and human creativity.

The main objective of the EU FP7 ICT i-Treasures project (Dimitropoulos, 2013) is to build a public and expandable platform to enable learning and transmission of rare know-how of intangible cultural heritage. The proposed platform combines lots of different technologies like multisensory technology, singing voice synthesis and sensorimotor learning to leave the beaten path in education and ICH knowledge transmission.

In i-Treasures project, four main ICH use cases are selected: i) rare traditional songs with the following sub use cases: a) Byzantine hymns, b) Corsican “cantu in paghjella”, c) Sardinian “canto a tenore” and d) beat box; ii) rare dance interactions with the following sub use cases: a) Calus dance, b) Tsamiko dance, c) Walloon dance and d) contemporary dance; iii) traditional craftsmanship focusing on the art of pottery making, and finally iv) contemporary music composition based on Beethoven, Haydn and Mozart musical pieces.

In order to prevent these ICH expressions from extinction, we aim to provide a tool that will allow their transmission to new people. Towards this goal, four novel game-like educational applications are currently developed, one for each of the four ICH use cases, to be studies within i-Treasures project: i) rare traditional songs with a contemporary singing style namely Human Beat Box (HBB); ii) rare dance interactions with a popular Greek dance (Tsamiko) iii) traditional craftsmanship focusing on the art of pottery making, and finally iv) contemporary music composition based on Beethoven, Haydn and Mozart musical pieces. In the current development phase, a first version of these game-like applications is available and is planned to be validated and evaluated for sensorimotor learning using educational scenarios that have been already been defined within the project. These applications will be continuously updated towards fulfilling satisfying the needs of the project and will also be extended to cover the needs of other sub-use cases (e.g. Walloon dance, Byzantine music, etc.).

The rest of this paper is organized in the following Sections: Section 2 provides an overview of the related work in similar game-like applications for learning purposes. Section 3 summarizes the system architecture and the design/development principles for these applications and Section 4 presents an overview of the four ICH games that were developed. Finally, Section 5 includes discussion in the lessons learnt, limitations and future work.

2. RELATED WORK IN GAME-LIKE APPLICATIONS FOR LEARNING PURPOSES

The adoption of game-like applications in i-Treasures follows a quite well consolidated trend in the Technology Enhanced Learning field. The educational potential of games has been widely explored and highlighted by researchers within the wider research area of Game Based Learning (de Freitas, 2012), (Gee, 2003), (Van Eck, 2006), (Hainey, 2010). A variety of games originally developed with entertainment purposes can be used for educational purposes (Djaouti, 2011); in addition we recently assisted to the taking off and to the fast increasing adoption of Serious Games (SGs), those games that are explicitly designed for educational purposes Michael, 2006), (Breuer & Bente, 2010), (Derryberry, 2007).

SGs are more and more employed to sustain learning and training in a variety of educational fields (formal and informal education as well as military, medical training etc.); this is done for a wide range of target populations, ranging from children to adults (Charlier, 2012).

The learning potential of Serious Games (SGs) has been extensively investigated in recent years. Despite some contrasting voices (Hays, 2005), their educational effectiveness has been widely recognized (Facer, 2007), (Mc Farlane, 2002), (Milovanović, 2009). When asserting the effectiveness of game-based learning, many authors focus on the nature of interaction with the game environment, citing aspects like motivation, flow and immersiveness (de Freitas, 2009), (Garris, 2002).

SGs, in fact, proved to support learning in a more active and engaging way (Gee, 2003) and, from the pedagogical viewpoint, they offer advanced interaction such as the possibility of customizing the learning paths (Bottino, 2009) and of keeping track of the learners’ behavior and successes/failures and are more adaptive to meet the specific users’ learning needs (de Freitas, 2013). Games seem to be able to support the learning a wide range of skills (spatial skills, decision-making, problem solving, etc.) (De Aguilera, 2003) and are also recognized as supporting the learning of procedures and gestures, reason why they are widely adopted in professional training (Martinez-Durà, 2011)

In the field of Cultural Heritage Education ICT technologies are increasingly being adopted (Ott, 2011), (Gaitatzes, 2001), (Veltman, 2005) and in particular, Virtual Worlds are often used to broaden the opportunity to appreciate cultural contents that are remote in space and or time. Even though they should be considered very helpful for widening access to cultural contents, these applications, for example Virtual Museums, often are not intrinsically engaging and sometimes fail in supporting active learning, just giving the opportunity to access information (Mortara, 2014).

This is why in the i- Treasures project it was decided to develop game-like educational applications (or, in other words, Serious Games, developed with the specific purpose of sustaining specific educational interventions)

As to the digital games available in the Cultural Heritage (CH) area, (Anderson, 2009) and afterwards (Mortara, 2014) carried out interesting State of the Art reviews. While the first one is more focused on technical aspects, the second sketches a panorama of the actual use of Serious Games in Cultural Heritage education. According to (Mortara, 2014) in the field of CH, SGs of different kind are adopted: from trivia, puzzle and mini-games to mobile applications for museums or touristic visits, (e.g. Muse-US[i] , Tidy City[ii]) to simulations (e.g. the battle of Waterloo[iii]) to adventures and role playing games (the Priory Undercroft[iv], Revolution[v]).

As it could be expected, games are more widespread in the Tangible Cultural Heritage (TCH) area, where several different examples can be found (Ott, 2008). Among these, we can mention ThIATRO, a 3D virtual environment where the player acts as a museum curator (Froschauer, 2012), or other digital artifacts such as My Culture Quest[vi] , which aims at advertising real collections or even the History of a Place[vii], which is integral part of a museum experience at the Archaeological Museum of Messenia in Greece.

A number of games for smartphones also exist like Tate Trumps[viii] and YouTell and "G. Averof" (Cao, 2011) which, for instance, allow museum visitors to create and share through smart phones their own media and stories.

Many games also exist in the area of historical reconstruction for instance the Battle of Thermopylae (Christopoulos, 2011) or the Playing History[ix] , which are mainly based on 3D technology so to closely recreate the environment in which each single event happened.

A (smaller) number of games have also been developed in the field of Intangible Cultural Heritage transmission, where they are also considered very promising (Mortara, 2014). Some examples are:

- Icura (Froschauer, 2010), a 3D realistic environment in which the player learns about Japanese culture and etiquette, which can raise cultural interest and support a real pre-trip planning.
- Discover Babylon[x], Roma Nova[xi] and Remembering 7th Street[xii], that are aimed at raising awareness about ancient Mesopotamia's contribution to modern culture, ancient Rome and West Oakland in the time period post-World-War-II.
- Africa Trail[xiii] and Real Lives 2010[xiv] simulate a 12,000 mile travel by bicycle through Africa or a different life in any country of the world (e.g. a peasant farmer in Bangladesh, or a computer operator in Poland), respectively.
- Papakwaqa (Huang, 2013), a serious game about the Atayal minority in Taiwan, particularly focused on intangible cultural assets like tribal beliefs, customs, and ceremonies.

3. SYSTEM ARCHITECTURE

The general system architecture of the game-like applications that have been developed for the four ICH cases is shown in

Figure 1. As shown in this figure, there is bilateral communication between the game-like applications (i.e., the 3D Visualization Module for Sensorimotor Learning - 3DVMSL) and the ICH capture and analysis modules, which are different for each use case (e.g. Ultrasound and optical sensors and microphones for Rare singing, Kinect sensors for Rare Dancing, Kinect and/or Real Leap Motion[TMxv] sensors for Pottery and Contemporary Music Composition). This communication includes: a) data transfer from ICH capture sensor/s to the games, and b) control of ICH capture and analysis modules by the 3DVMSL module. The 3DVMSL module can start/stop sensor data capture and trigger the required data capture/analysis functions. 3DVMSL also has bilateral communication with a) a Content Management System ("i-Treasures Web Platform") that is responsible for different tasks such as user profile management, ICH expert recording management, etc. and b)

a Learning Management System, which contains additional educational courses and material regarding each use case.

Regarding the internal architecture of the 3DVMSL module, the initializer is responsible of activating sensor setups and starting the game-like application. This action is followed by login where the user credentials are taken from the Learning Management System (LMS). Thereafter, the game menu is shown and the user can either see the game tutorial or select one of the activities offered such as Activity 1, Activity 2,… or Final Challenge. The "Observe" screen currently displays pre-captured expert data (corresponding to the selected Activity) to the user. In the current version, we used expert data stored at the local game repository. However, in the final version of the games, this data will be obtained from the Content Management System (CMS). This is why the connection between CMS and 3DVMSL is displayed with dash lines. The "Practice" functions allow the user to try to replicate the expert moves and then receive feedback from the system regarding the evaluation of his/her performance. In order to capture the performance, a set of ICH capture modules are used and there is a bilateral communication between the 3DVMSL and the in order to transfer sensor data to the game.

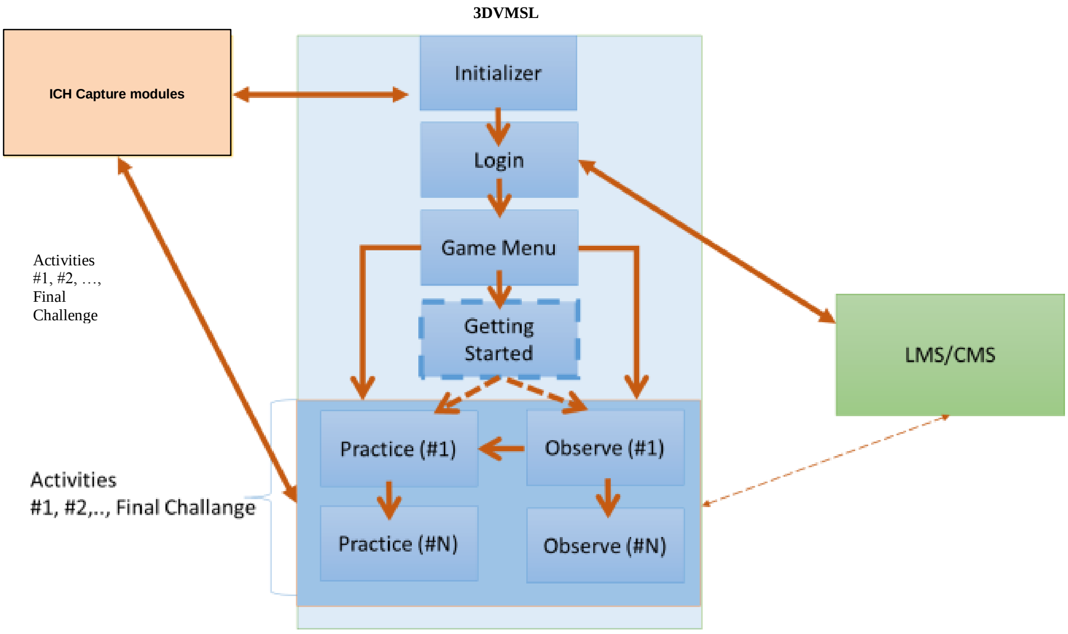

Figure 1: Detailed System Architecture of Game-like Applications

All four ICH games are incorporated in a single game-like application to ensure simplicity and integrity. Certain game characteristics, e.g. the splash screen, the authentication and game selection screen, the observe and practice phases are common in all ICH games. We used Unity 3D game engine to develop the games, due to the following reasons: a) Unity 3D is an industry proven game development environment, b) It is easy to deploy the games to various platforms ranging from Desktop PCs to mobile devices, c) The development team is highly experienced in Unity. We used 3DMax Studio and Maya to model the characters and game environments, namely 3D assets. Those 3D modelling tools are also very common in game development industry. We used Photoshop to prepare 2D assets of the games. All of the codes are written by using C# programming language.

4. GAME-LIKE APPLICATIONS FOR LEARNING FORMS OF ICH

4.1 Rare traditional singing: The Human Beatbox (HBB) game

The Human Beatbox (HBB) is an artistic form of human sound production in which the vocal organs are used to imitate percussion instruments, but also wind and string instruments. Therefore, facial and intra-oral movements of the tongue, lips and jaw are involved in sound production.

The game scenario for Human Beatbox (prepared by the sub-use case leader CNRS together with beat box expert) is as follows:

The learner will have at its disposal a portable helmet based system (Jaumard-Hakoun, 2013), (Chawah, 2014), (Al Kork, 2014). The latter provides vocal tract sensing techniques developed for speech production and recognition. It consists of a lightweight "hyper-helmet" containing an ultrasonic (US) transducer to capture tongue movement, a video camera for the lips, and a microphone.

The learner will be guided by some description of the sound to be produced and will be listening to the sounds to imitate them. These descriptions can be related to natural sounds such as imitating animal sounds or mouth noise.

The learner will also look at the mouth and tongue of the expert to try to produce different sounds. The rhythm is an important dimension in HBB and hand movement or a metronome can be added in the scenario in the updated future version.

The HBB game will consist initially of a single lesson, where each isolated sound will be described and will be demonstrated by the expert ("Observe mode") and then imitated by the learner("Practice mode"). Later on, the learner will go to the next step that will be to produce two sounds, then three in a row.

The learner should practice each activity a number of times, and finally perform all the activities at once. The practice screen of the HBB game is illustrated in Figure 2.

Figure 2 Practice Screen HBB Game.

4.2 Rare Dancing: The Tsamiko game

Four different sub use cases are examined in the project: (a) Calus dance (Romania), (b) Tsamiko dance (Greece), (c) Walloon dance (Belgium) and (d) contemporary dance. In this first version of the application, a game for Tsamiko dance learning was implemented. Tsamiko is a popular traditional folk dance of Greece, done to music of ¾ meter. The game focuses on teaching the basic steps of Tsamiko to learners with minimal or no prior dancing experience. The game scenario was prepared in close cooperation with Tsamiko dance experts in Thessaloniki and was the basis for designing the game.

In order to simplify the learning process of Tsamiko dance, the experts have defined two activities comprised of several exercises. The first activity focuses on the simple single step Tsamiko style (10 steps) and includes five exercises while the second activity focuses on the more advanced double step style (16 steps) and includes four exercises.

The learner has to repeat all of the exercises to complete the activity objective. Each exercise consists of several dance steps, which are presented to the learner one by one. In order to proceed to the next exercise, the learner must repeat the current exercise at least 3 to 5 times correctly. Some exercises of the second activity are more challenging and must be repeated at least 8 times.

At the beginning of each exercise, a video with the 3D expert virtual avatar performing the specific moves is shown to the learner. Afterwards, the learner is expected to try to imitate the same moves correctly.

The system starts the data capture and gets fused animation data from an Body motion capture module that acquires animation data via multiple Kinect v1 sensors, fuses the information properly and provides to the game a single sequence of animation data corresponding to the user body movements.

If the imitation is completed properly, the learner can proceed to the next exercise. Otherwise, the learner is expected to repeat the same exercise till s/he does the moves correctly. Although the exercises progress sequentially, in some cases the learner has to repeat not only the previous exercise but also some more. A screenshot from the Practice Screen is shown in Figure 3.

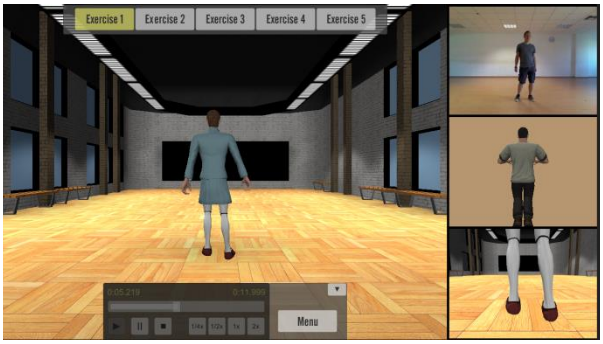

Figure 3 Practice Screen: Backward View of 3D Expert Avatar (Big Central Window), Animation Controller (Bottom Center), Exercise Indicator (Top Center), Expert Video (Top Right), 3D Learner Avatar (Center Right), Backward View of Close-up Expert Legs (Bottom Right).

One of the most important aspects of the game is to evaluate the performance of the learner. In order to achieve this challenging task, moves of the learner avatar and expert avatar are compared using a Fuzzy Inference based algorithm (Kitsikidis, 2014). This approach uses fuzzy inference to not just compare absolute joint positions, but to evaluate more meaningful features.

4.3 Traditional Craftsmanship

The traditional craftsmanship use case focuses on pottery, which is an art of crafting ceramic. The main objective of this game is to let the learner observe and practice the basic moves of wheel-throwing earthenware pottery by using various sensors and gaming interface.

The following game scenario, prepared with the close cooperation of pottery experts in Thessaloniki, is taken as a basis while designing the traditional craftsmanship application. There are four activities, which are different from each other and have different levels of complexity. The expert demonstrates the pottery making procedure and it is expected from the learner to imitate the expert to form an object (Figure 4). The first activity focuses on throwing and centering the clay on the wheel, the second on how to make the bottom of the object, the third activity shows how to shape formation with a tool and the forth how to cut and remove the final object from the wheel. In the “Final challenge” activity, the learner tries to perform all activities in a row in order to make an object. There is a performance evaluation threshold value for each activity that allows the user to proceed to the next activity.

Figure 4 Practice Screen: Angled View of 3D Learner Avatar (Big Central Window), Animation Controller (Bottom Center), Expert Video (Top Right), Close-up on Expert Hands (Center Right).

The application communicates with the Body and Gesture Data Capture and Analysis Module that is responsible for capturing the hand and upper body motions of an expert potter. Specifically, the module can read, process and capture hands animation data from a single Leap Motion sensor (multiple Leap Motion sensors will be supported in the near future) and combine this information with body movement from multiple Kinect sensors. In addition, synchronization and fusion of hand and body animation streams are performed in order to output a single animation stream containing skeletal information of both hands and the body of a person. Also, there is an optional mode available for accurately tracking wrist positions in space, based on blob tracking. This mode significantly improves the quality of captured data but requires the user to wear round coloured markers around the wrists.

4.4 Contemporary Music Composition

The Contemporary music composition use case aims to develop a novel Intangible Musical Instrument (IMI), which is supposed to map natural gestures performed in a real-world environment to music/voice segments. Besides, the emotional status of the performer is also planned to be part of this multimodal human interface. Thus, the game-like application is designed in a way to map not only gestures but also the emotions of the learner.

The Intangible Musical Instrument aims at capturing piano-like gestures, which means that the gestures of the performer resemble piano player gestures. The new gestures are inspired by piano-like performances and are transformed into sounds via a “mapping” phase. Another objective, made possible with the technology used here, is to create a powerful pedagogical tool. The player then becomes a learner and interacts with the system in order to master piano-like techniques.

The current IMI sensor setup (Figure 5) includes: a) a “stand” made of wood and Plexiglas under which a Leap motion sensor is placed. b) Two inertial sensors for wrists (Animazoo motion capture suit) and c) an Emotiv sensor for capturing emotions.

Figure 5: Detailed description of IMI sensor setup

This prototype setup is integrated into a game framework where the user/learner is assessed by the system. There are two phases: the first one is the observing phase, in which the learner observes the expert’s gesture and listens to the corresponding sound. The second phase is the practice phase, in which the learner experiments with the expert’s gestures. The practice phase of gestures involved in the contemporary music case could be depicted as follows (Figure 6): a simple table stands in the middle of a room. This room looks like a recording studio with several musical instruments dispatched around. The user can also see the avatar of the learner/expert player inside the 3D environment and s/he is able to manipulate both the studio environment and the avatar so as to get an “objective view” where s/he sees his/her own hands plus additional views (perspective, top view). One main idea conveyed in this first prototype is the use of the table as a reference plane.

The main approach concerning the learning phase is “learn by doing”. The learner should basically attempt to perform the gestures introduced by a virtual expert on a (real) table. The expert gestures are driven offline from previously recorded gesture data. In this first prototype, only the effective gestures were considered (gestures for Ascending/descending scales and ascending/ descending arpeggios).

The musical game activities include observe and practice phases. In the observe phase, the learner can observe the video of an expert performing a musical gesture.

Figure 6 Practice Screen: Isometric View of 3D Learner Avatar (Big Central Window), Animation Controller (Bottom Center), Expert Video (Top Right), Close-up Expert Hands (Center Right).

4.4.1 EmoActivity Scenario

A special activity (EmoActivity) of IMI is basically designed to prompt the user to reach and sustain certain affective states via a gamified process involving affective images. The activity is also based on the characterization of affective states by the valence-arousal model of affect (Russel, 1980). Valence denotes whether an emotion is positive or negative, while arousal constitutes a measure of the excitation that accompanies the emotion. Thus, each affective state can be modeled as a point on the plane defined by the orthogonal axes of valence and arousal. The EmoActivity will be part of the novel intangible musical instrument where the user's affective state will influence the produced musical content.

The game consists of three levels with each level having three difficulty levels. In Level 1 the user is asked to reach a certain affective state and sustain it, while in Levels 2 and 3 the user is asked to reach two and three consecutive states, respectively. The difficulty in each level (easy, medium, hard) lies in the target affective states that the user is asked to reach based on his/her current emotional status, e.g., if difficulty level is set to easy and the user is calm, he/she will be asked to reach a target affective state of excitement as this transition is more easy than a state of sadness or anger/fear.

5. DISCUSSION: LESSONS LEARNT, LIMITATIONS, FUTURE WORK

Four novel 3D game-like applications driven by body interactions have been developed of four ICH types within i-Treasures project. In this first version, we have encountered a number of problems, most of which derive from the peculiarities of the ICH domains addressed by the project. Each ICH has its own specificities and knowledge domains that need to be made explicit and formalized, but also there are no consolidated teaching/learning practices, as the transmission of these cultural expressions relies on informal situations based on imitation. Thus, the task of designing and developing games able to support teaching and learning processes in the ICH field, is thus per se a huge challenge.

Starting from the definition of the learning objectives and the contents to be included in the games, down to the definition of the game dynamics and the interface, the whole process was the result of a complex interaction among many variables, some of them predictable, others completely unforeseen.

More specifically, a first issue to discuss is the multi-disciplinary structure of the development (project) team. The i-Treasures consortium is comprised of partners with different backgrounds ranging from commercial video game development to audio research. Thus, this first version of visualization module harmonizes not only technical research and 3D game development, but also educational aspects. Probably blending technical research and educational targets under a game design pipeline at the same time was the toughest challenge, since the expectations differ significantly. This has led to accept some compromise, especially from the educational' and game dynamics' point of view.

On the other hand, when we look at it from the technical perspective, communication of sensors and the visualization module and conversion of the sensor output into 3D animation were very challenging issues. However, any of these technical issues have no meaning to the end users of the i-Treasures project, unless it is presented in a coherent way in respect to the learning objectives and educational design. Therefore, significant amount of time and resources have been assigned to blending technical work and educational aspects and parallelization of development efforts. At the end of this first version, the development team has reached a common understanding and raised the required know-how, thus facilitating future work.

Regarding to the communication between the sensors and the visualization module, we encountered many issues, such as different OSs, different types of same OS (such as Windows 32 bit, Windows 64 bit) due to variety of sensors, 3rd party controllers, limitations of research tools etc. At the beginning, we have tried to define a single data transfer framework based on TCP. However, at later development phases many modifications have been made and even some data transfer is shifted from TCP to UDP considering the data size, data transfer frequency and even the limitations of the 3rd party controllers. Besides, web services have also been assigned for low-frequency communications between remote systems. In order to minimize the workload, we transferred fused data when we used different sensors. Besides, we defined a common structure to visualize both the offline and online version with same software functions. Thus, the same data template is used to keep expert data and to transfer learner data in real-time. Even though we spent additional resources, this approach will save additional development time for the future versions.

One last issue regarding the communication between sensors and visualization module is the bilateral communication. In typical games, game controllers and sensors are all controlled by the game in order to ensure full control. However, in this research project we have to use more experimental setups, which have no built-in functionality to be controlled by a game. Thus, the game must be ensure that everything is OK and calibrated. Besides, the game should trigger many events, such as starting a record, data transfer or even request an evaluation result. For this first version, this issue was quite challenging. Even though we achieved some sort of control, there are still significant issues to be solved for the next versions.

Another lesson learnt is to have more flexibility for modifications of the games. Although an initial design was available, when it came to the realization, there were many modification requests. In a typical commercial game or educational application most of the requirements are determined earlier and the design is realized by following the initial plan. However, in this work, there are external participants, such as domain experts, who have no expertise in software development and games. Thus, we followed a more iterative approach to get their feedback during intermediate development steps and update the design to reflect their contributions and feedback. Considering the rich variety of ICH content, the games started to show more diversity. Many things have been changed, ranging from activity captions to practice modes. In order to overcome this issue, the only way is to design an external entity, which is capable of changing almost every visual aspect of the game. Therefore, we designed a configuration XML that can help us define almost everything about the games. At the beginning, this took significant time and caused some delays in the planned work. However, in the next versions and development cycles this XML will be a life-saving jacket for us, allowing everything will be fully configurable without compiling the games.

In conclusion, many of the issues have been resolved and four solid game-like applications have been, able to be integrated in the i-Treasures platform and further updated and extended in the future. Besides, the latter outputs will be more robust, since most of the resources will be used for research and development rather than trying to solve the technical problems.

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