Chapter 16
Developments of Serious Games in Education

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ABSTRACT

As Human Computer Interaction technologies evolve, they are supporting the generation of innovative solutions in a broad range of domains. Among them, Serious Games are defined as new type of computer game that is capable of stimulating users to learn, by playing and competing against themselves, against other users or against a computer application. While it could be applied to a broad range of fields and ages, these games are becoming especially relevant in educational contexts and for the most recent generation of students that is growing in a new technological environment, very different from the one we had some years ago. However, in order to become fully accepted as a teaching/learning tool in both formal and informal contexts, this technology has still to overcome several challenges. Given these considerations, this chapter makes a state-of-the-art review of several works that were done in this field, followed by the description of two real world projects, helping to understand the applicability of this technology, but also its inherent challenges.

INTRODUCTION

The term "serious games" refers to the use of computer games for training and education with a purpose that extends beyond pure entertainment. They have been gaining popularity for some time now, to deal with real world problems by modeling and simulating them. While being used in a broad range of applications, including Military Training (Numrich, 2008), Humanitarian and Environmental Games, Health (Macedonia, 2009; Blackman, 2005; Sawyer, 2008) or Political Games (Democracy 2, 2015; President Forever, 2015) they perform an important role in education, branded as Educational Games (von Wangenheim & Shull, 2009; Mayo, 2007; Kelly et al., 2007; Zyda, 2007; Westera, Nadolski, Hummel

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& Wopereis, 2008). Moreover, they are starting to be applied to other innovative fields. For instance, they are seen as a way of instructing and motivating citizens to participate in energy management, as in the game 2020 Energy (2015).

But how do we broadly define "game"? Klopfer (2008) defines it as goal-oriented activity, based on specific rules that players perceive as enjoyable. In terms of Serious Games, Zyda (2007) define them as "a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives." In this definition the term entertainment may collide with the concept of a serious game. However, considering that "ludic" is not usually a priority in most activities of the educational context, a game may be the motivating factor that is needed in many learning resources.

In education, the research in innovative ICT solutions for Human Computer Interaction extends far beyond the conventional inclusion of multimedia contents, to include and recognize the role of new learning experiences. In this field, ludic learning models can cover various scientific fields, not only in formal educational contexts, but also in informal ones.

However, in order to become fully accepted as a teaching/learning tool in both formal and informal contexts, game technology has to overcome some challenges. One of the main issues is how to measure their actual learning effects. In this field some studies (Backlund & Hendrix, 2013) while evaluating the effectiveness of game-based learning concluded that, among the several studies analyzed, serious games had shown a positive effect on learning. The results of such studies are important to overcome a second difficulty related with the acceptance of these teaching tools by teachers, students and parents allowing it to be integrated in the curricula.

Given these considerations, in this chapter we analyze and describe current developments in serious games, with a special focus in education. This includes a state-of-the-art review of serious games applications, together with the description of two implementations aimed to help illustrate their applicability in real world scenarios. In one of these implementations we describe a solution that integrates the structure of a simple game in the last generation of ebooks. The idea is to create an electronic book that enables dynamic integration of text with images, audio, video and animations, but that may be used as a game. As serious games can be used in informal contexts, in the second implementation, we describe a solution that uses 3D electronic sensors in a wearable device (glove) to create a game capable of teaching sign language alphabet to any person who wants to learn it.

BACKGROUND

So far. serious Games have been used in several educational contexts that include natural sciences (Liu, Tan & Chu, 2009; Wang, 2008), mathematics (Chow, Woodford, & Maes, 2011; Kablan, 2010; Ke & Grabowski, 2007; Ke, 2008; Kordaki, 2011; Liao, Chen, Cheng, Chen & Chan, 2011; Main & O'Rourke, 2011; Panoutsopoulos, H. & Sampson, 2012; Sung, Chang, & Lee, 2008; Rosas et al., 2003; Wilson et al., 2006), problem solving (Huang, Yeh, Li & Chang, 2010; Yang, 2012), computing (Papastergiou, 2009; Sindre, Natvig & Jahre, 2009), software development (Gresse von Wangenheim, Thiry, & Kochanski, 2009), language learning (Connolly, Stansfield & Hainey, 2011), geography (Asaolu, 2012; Tüzün, Yılmaz-Soylu, Karakuş, İnal & Kızılkaya, 2009; Virvou, Katsionis & Manos, 2005), history (Huizenga, Admiraal, Akkerman & ten Dam, 2009; Kennedy-Clark & Thompson, 2011) and health (Tüzün, 2007;

Gomoll, O'Toole, Czarnecki & Warner, 2007; Gomoll, Pappas, Forsythe & Warner, 2008; Qin, Chui, Pang, Choi & Heng, 2010).

In terms of the natural sciences, serious games have been used in both outdoor and indoor education scenarios. As described by Liu, Tan and Chu (2009), by using mobile communication and wireless technologies, students can now move to any place, allowing scientific experimentation, augmented reality, image collection, resource sharing, and communication with colleagues. However, this solution can also be applied to more formal contexts, as described by Wang (2008), where Web-based quiz-games were developed for elementary school classes. Globally, the results of these studies have demonstrated an increase in the motivation and learning outcomes of students.

Mathematics is another of the application fields that have seen a large number of research studies and developments focusing in serious games. However, the effectiveness of these games is still far from reaching the desirable goals. As stated by Backlund and Hendrix (2013) the effect of serious games in mathematics varies significantly, with only nearly half of the studies demonstrating a positive result in the learning outcome.

Another important field of research concerns problem solving, with several projects trying to create serious games for this purpose. For instance, Huang, Yeh, Li and Chang (2010) developed a game called Idea Storming Cube (ISC), which aims to engage students in divergent thinking, applied to debris flow problems. According to Yang (2012) there is a quantitative improvement in problem-solving and learning motivation due to the introduction of digital game based learning, suggesting it can be exploited as a useful and productive tool to support students in effective learning while enhancing the classroom atmosphere.

In terms of computing and software development serious games are also becoming very popular with several studies giving positive results. For instance, in Papastergiou (2009), the author assessed the effectiveness and motivational appeal of a computer game for learning computer memory concepts in a high school Computer Science curriculum. Their results show that the gaming approach was at the same time more effective in promoting students' knowledge of computer memory concepts and more motivational than the non-gaming approach.

However, in this field the results of some studies are not as positive. In Sindre, Natvig, and Jahre (2009), a question/answer-based computer game called Age of Computers was introduced to replace traditional weekly paper exercises in a Computer Fundamentals' course at the university level. Their results have shown that with equal time being spent on the various learning activities, the effect of playing the game was not better than the other activities. According to Gresse von Wangenheim, Thiry, and Kochanski (2009) the results of an explorative study that investigates the learning effectiveness of a game prototype on software measurement was not very successful. While the results of the study reveal that the participants consider the content and structure of the game appropriate, no indication of a significant difference on learning effectiveness was shown.

In terms of language learning, serious games have the potential to increase the ability to listen, talk, read and write. This requires the creation of games that combine audio, video, driven by the language. In this area, Piirainen–Marsh and Tainio (2009) addressed additional language learning from the participation in the social activity of collaborative game-play. They describe how players engaged with the language resources offered by the game during collaborative play. Following a different perspective, Connolly, Stansfield, and Hainey (2011) describe the educational value of Alternate Reality Games (ARGs), for the teaching of modern European languages. ARGs are a form of narrative that often involves multiple media and gaming elements to tell a story that could be affected by the actions of the participant. The results of this study have shown that in general student attitudes towards the ARG were very positive, with the majority of students agreeing that they would be willing to play the game over a prolonged period of time as part of a foreign language course. In addition, through using the ARG, students believed they obtained skills relating to cooperation, collaboration and teamwork.

Geography is another field that has already seen the implementation of educational games. For instance, Asaolu (2012) experimented with the Lainos World software. The effect of this software on students' geographical knowledge was analyzed using online surveys, yielding a positive result. Tüzün, Yılmaz-Soylu, Karakuş, İnal, and Kızılkaya (2009) designed and developed a three-dimensional educational computer game for the learning about geography by primary school students. While testing it, they have verified that students demonstrated higher intrinsic motivations and lower extrinsic motivations learning within the game-based environment. Virvou, Katsionis, and Manos (2005) conducted an evaluation study on a virtual reality educational game that they had developed for teaching geography. While the results were positive, they revealed that students who were poor performers had benefited the most from the game environment, whereas the subgroup of good students had benefited the least from the game environment.

In terms of the istory subject, Huizenga, Admiraal, Akkerman, and ten Dam (2009) tested the effects of a game for the first year of secondary education, and evaluated student's achievements concerning the historical knowledge of medieval Amsterdam. Their results have shown that those pupils who played the game gained significantly more knowledge about medieval Amsterdam than those pupils who received regular instruction, while no significant differences were found with respect to motivation for History or the Middle Ages. Kennedy-Clark, and Thompson (2011) present the results of a study in which university students were asked to collaboratively solve inquiry-based problems related to historical disease epidemics using game-based learning. Their results indicated that students attended to visual information with more specificity than text-based information when using a virtual environment.

In terms of health, serious games have the potential to be used for behavior change, as is described by Munguba, Valdes, and da Silva (2008) where they were used a game as therapy for nutrition education, in a program for obese children. In another example, games were used for first aid classes in secondary school contexts as described by Tüzün (2007). In healthcare serious games have been used to teach surgery at medical university level, as described by Qin, Chui, Pang, Choi, and Heng (2010), supporting a reduction in the training costs, as well as in the associated risk for patients.

Still in the field of health, one important application of serious games lies in rehabilitation, which occurs after a disease or traumatic incident. In these scenarios, as stated by Rego, Moreira, and Reis (2010), the introduction of games has the potential to contribute to an increase in the motivation during rehabilitation sessions, which is a major problem in therapy due to the repetitive nature of such exercises.

In all the above-mentioned fields, the introduction of serious games in education creates new learning possibilities that were not available a few years ago. For each of them several technologies may be involved, targeting the development of learner skills and/or knowledge acquisition. To illustrate some of these solutions, in the next section we describe the implementation process and resulting structure of two projects that were undertaken to increase the game-like nature of real world learning applications.

APPLICATIONS OF SERIOUS GAMES IN EDUCATION

In this section two topics of serious games in education are explored. We start by describing the research involved in the implementation of a gamified book that merges an ebook with a game. Afterwards we showcase another concept that considers human 3D gesture recognition, using sensors, to support the creation of a learning tool that can be used by anyone who wants to learn sign language alphabets.

Development of Gamified Books

With the emergence of distributed learning technologies, students can now learn in a more informal setting using mobile devices, without being confined to a room full of computers. Furthermore, teachers and educators have emphasized the importance and need for "authentic learning activities", where students can work with real world problems (Brown, Collins, & Duguid, 1989). Therefore, the development of educational activities for students, that combine learning resources from the real world with those from the digital world, has become an important and challenging research topic. This may be accomplished, for example, through the use of mobile communication and wireless technologies, which can be moved to any place, allowing for scientific experimentation, augmented reality, image collection, resource sharing, and communication with colleagues.

The current context of mobility offers the possibility of integrating the typical structure of a game in a new type of electronic book - the gamebook (g-book) - to be used in tablets. The concept is, in essence, an interactive ebook, which enables the integration of text with images, audio, video and animations. There are clear pedagogical benefits in the development of an innovation that combines a book with a game with potential in various learning contexts (formal, informal or non-formal).

The mobile learning concept is part of a societal model that assumes digital skills as a valid stance. We refer, in particular, the ability to:

1. Analyze and produce digital information where and when the user wants,
2. Make decisions in the context of an information society,
3. Apply creative skills and innovation (technological and methodological),
4. Engage in collaborative work and
5. Master an operational knowledge about digital media and global communications.

In this context, this sub-section describes the creation of a gamebook that may be effective in various learning situations. Ongoing research involves the evaluation of three major components, clearly distinguishable:

1. Assess the potential of the current ebook technology,
2. Study the role of narratives in games, and
3. Determine the potential of gamebooks for certain educational applications.

Given these considerations in the following we explore the integration of the structure of a simple game in the last generation of ebooks. The idea is to create an electronic book that not only enables the dynamic integration of text with images, audio, video and animations, but also that may be used as a game, aligning ebooks with two learning scenarios: mobile learning and educational games.

Furthermore, it makes sense to consider the integration of mobile and educational games in a system managed by students, allowing them to set personal goals, manage content and communicate with each other. In practice, these Personal Learning Environments (PLEs) are made up of several components, which may include social networks, virtual worlds and authoring software, interconnecting various learning resources suitable to the pedagogical contexts and skills to be acquired by each learner. In this sense, due to their characteristics and potential for interactivity, ebooks (or gamebooks) can be a valued part of these PLEs.

Ebook Formats

At the most basic level, the ebook is an electronic book that can have a simple format, such as a text in PDF. However, there are currently more advanced standards, such as EPUB3 (universal) or iBooks 2 (Apple), that can integrate multimedia components. Ideally, an ebook should have sufficient quality for current devices with their high-resolution displays, and be compatible with a wide variety of reader apps, and if necessary allowing the conversion to other formats. In fact, however, there are more than a dozen formats not compatible with each other, and sometimes they do not adapt to higher resolution screens.

Over the years, teachers have often used multimedia encyclopedias and textbooks, on CD, DVD, or available online. But more recently a new generation of electronic books has emerged, that can offer more interactive and dynamic learning experiences. Students of the "PlayStation generation" tend to respond better to this dynamic and interactive content, with the ability to display not only text but also other media with hypertext links, search facilities, and connection to online databases. One benefit of these ebooks for students is for example the possibility of being able to select any word that they do not understand and find immediately its definition.

Another potential use refers to the capability to simultaneously have several students accessing the same book and thus share learning experiences. More specifically, they can communicate and share files, having opportunities to communicate in the context of group work, even if accessing from different locations. The ebook can also contain tests, allowing students to make their self-assessment.

An economic advantage refers to financial aspects; currently the cost of textbooks represents a high expense for students and their families. The introduction of electronic books contributes to reducing these costs effectively. Furthermore, it is also expected the emergence of cheaper mobile devices, which is happening in countries such as China and India. Altogether, the widespread use of ebooks will also benefit the environment by reducing paper consumption, bearing in mind that a device may store thousands of ebooks.

On a less positive note, despite huge advances with the technology, many applications used to read ebooks do not have really useful features such as the ability to highlight, mark text, bookmark or write notes. These are apparently trivial matters, but they are important for a student. In a paper book the student usually highlights the most important parts and adds annotations in the margins. In this way, when he reads the book again, he will focus mainly in these parts.

Although there are several standards for ebooks, not all reading applications and mobile devices use the same. Thus, to reach a wide audience, it is necessary to adopt some of the most commonly used formats for reading electronic books, for example, Adobe PDF in computers, Mobi for the Amazon Kindle, EPUB for the Barnes & Noble Nook, and iBook for Apple's iPad. The Portable Document Format (PDF) is the most popular format for creating digital books and can be read by the free Adobe Reader installed on most computers. It is an open standard that enables the creation of ebooks with support to the use of sound, images, video, notes and bookmarks. Its main advantage is to keep the layout of the printed book within original quality on any device. However, this benefit is a major disadvantage on mobile devices. The text is difficult to handle in a PDF file, when we visualize a page on a mobile device such as a smartphone, the characters become too small forcing the user to increase or decrease size in order to view the contents of the page. In other ebook formats, such as EPUB and iBook, there are no physical constraints to a fixed style and everything scales.

EPUB is a format based on open specifications, primarily written in XML and XHTML. The EPUB format is supported by a wide range of devices and platforms, including Android devices, Nook, iPhone, iPad, iPod, MobiPocket, Adobe Digital Editions, FBReader, Stanza, Sony Reader, and many other readers and applications. Of the most popular devices, the only one that does not support EPUB is the first Amazon Kindle. The EPUB specification is an open standard, allowing the creation of ebooks with sound, images and video (in its newest specification - EPUB3). This specification introduces innovative features to address structure limitations, such as: precise layouts specialized for comic books, support for MathML, support for multimedia, and introduction of notes.

The Amazon Kindle is an electronic book reader very popular in the US. Early versions used the Kindle proprietary format AZW. This is basically the Mobipocket format based on the Open eBook standard using XHTML. This specification supports images, notes and bookmarks. In late 2011, Amazon started selling the Kindle Fire along with the new file format Kindle Format 8 (KF8), which supports a subset of the features of HTML5 and CSS3. This is also a proprietary specification and expands the functionality of the earlier versions of the Kindle, in order for the Kindle Fire to support sound and video.

Ebook Authoring Tools

There are several ecosystems and tools that can be used to create ebooks and distribute them for personal computers and mobile devices. The simplest way to create digital books, for multiple mobile platforms, is to start with PDF or RTF files and use applications, like Calibre, that converts PDF files in multiple formats such as EPUB, or MOBI for the Kindle, among others. Calibre is a free application that runs on Windows, Mac OS X and Linux.

There are other free or open applications that support the creation of electronic books. For example, the application eCub allows the creation of simple books in EPUB or MobiPocket, from text files or XHTML. However, eCub is very limited, with no WYSIWYG capabilities. It is suitable for the production of simple ebooks with front and back pages with an image, index, a title page and it can convert content to a sound file (WAV or MP3). The eCub is free and is available for Windows, Mac OS X, Linux, FreeBSD and Solaris.

Booktype is an open platform, available since 2012, which allows editing and writing of ebooks for different platforms by exporting in PDF, EPUB, MOBI, ODT and HTML. This application also exports the ebook directly to Amazon, Barnes & Noble and iBookstore online stores, as well as to online printing sites. Digital books written with this application are immediately available in any of these platforms. When writing the ebook, the author does not need to worry about formatting, since it will automatically be formatted to work in these different platforms. Booktype also provides a set of collaborative tools for reviewers, editors, translators, designers, and authors, enabling the different participants to work collaborative in the production of an ebook. Some of the features offered by this platform include: intuitive drag-and-drop tools, chat, messages, adding images and text formatting. Booktype also maintains a history of all changes, which allows the author to compare different editions and return to a previous edition. It is even possible to use snippets (pieces of computer code). One of the disadvantages of this platform is the need for installing on a server and accessing via web browser, which requires some additional expertise.

The Firedocs eLML editor can also be used to create ebooks (Weibel et al., 2009). The eLML framework (eLesson Markup Language) is an XML platform for creating online classes using XML. It exports produced materials in SCORM, HTML, PDF and EPUB format. The main objective is to ensure that classes are modeled according to the ECLASS reference, which defines five distinct sections: Entry, Clarify, Look, Act, Self-assess, Summary. Current implementation only supports JPG, PNG, GIF and SVG images. It does not allow Java scripts and forms, so some of the functionalities as the glossary, references to labels and self-assessment tests are not available in the EPUB format.

Sigil is an open WYSIWYG editor used by Google to create ebooks following the EPUB2 specification for Windows, OS X and Linux. This application imports, creates and edits XHTML documents and exports them into EPUB2 documents. Ebooks created with Sigil may contain text, pictures and links, but this standard does not support video or sound. It also provides multiple views of the work: book, code and a split mode. In the book view, it allows content edition in WYSIWYG mode.

Finally, we should mention the electronic books created in the iBook format from Apple. These ebooks are created with a free application - the iBooks Author tool. The format is proprietary, although based on the EPUB standard specification, with some differences in the CSS3 tags. This tool makes the process of creating ebooks very easy, by presenting a very complete set of integrated features, including: sound, image, video, dictionary, text underline, annotations, text-to-speech conversion, navigation and many widgets to enhance the interactive experience. The introduction of widgets in the iBook is an enriching experience for readers of an electronic book. iBook Author offers seven types of pre-defined widgets:

1. Photo gallery,
2. Video or audio media file,
3. Review questions,
4. Slide show;
5. Interactive tagged images, to give detailed information on specific parts of an image or graph,
6. 3D models, and
7. Objects created in HTML.

The ease of creating widgets allows users to add any object to an interactive iBook, and there are many possibilities, from calculators, puzzles, maps, YouTube videos, among many others. Table 1 summarizes the characteristics of the authoring applications surveyed.

Development of a Game-Book Prototype

This section outlines the implementation of a novel concept, the *gamebook* (or g-book) with a story that can be read sequentially or not. The main difference refers to the ability to choose different paths to the main characters or the unfolding of the history, as happens in games. The reader/player makes choices that affect how the story unfolds and his decisions have a significant impact on events and the final outcome.

Some choices may be as simple as turning right or left at the end of a road. Others may be much more difficult, requiring decisions about facts or occurrences, such as, problems arising in natural disasters, environmental pollution and climate change. In a particular story the student may be the main character - the hero of the story - or simply manipulate variables with consequences at the strategic level. Thus, not only decisions change the story, but also the sequence of choices can change the ending.

Table 1. Summary of free ebook authoring tools

Content	eCub	Booktype	Firedocs	Sigil	iBooks Author
Photos	√	√	√	√	√
Graphics					√
Sound					√
Videos					√
Hyperlinks	√	√	√	√	√
Animation					√
Search					√
Dictionary					√
Underline					√
Markers					√
Notes					√
Digital Speech					√
Collaboration		Messages			
Tests and self assessment					√
Widgets / programs / *apps*					√

A gamebook may follow typical genres and formats of electronic games, such as puzzle, RPG, adventure, strategy, among others, where the reader will face threats, adversaries, and discover the truth behind an intricate story. Ultimately, the objective of this project is to create a didactic narrative built on situations capable of providing expectation, suspense, challenge and other positive emotions. Based on the latter, it is theoretically possible to engage students in the study of a particular subject matter, and get more results in terms of attention, retention and understanding. In fact, the possibility and value of integrating game play in learning practices is indicated clearly by several researchers, who recognize its potential in making learning more meaningful and in assimilating new subject matter (Prensky, 2001; Gee, 2003; Kirriemur & McFarlane, 2004; Johnson, 2005).

The ongoing research involves three strategic components, clearly distinguishable:

1. Establish the potential of the technology: the most common formats and authoring tools that allow the creation of gamebooks that are effective in learning;
2. Identify the role of narratives and games: what kinds of narrative and game genres can be recreated as gamebooks for learning, and what learning activities can be prepared based on this typology.
3. Demonstrate real educational applications: according to a specific level of education, what pedagogical models can better integrate gamebooks, and in which subject areas are most effective.

After starting exploring the Apple iBook format (Bidarra *et al.*, 2012), essentially due to the vast potential for multimedia authoring with the iBooks Author tool, we built a model of a dynamic book considering all the multimedia features and widgets available. However, this was merely an interactive e-book, since using the features available we could not implement the desired g-book. Another question was that in this case the e-book becomes available only for the iOS mobile devices.

We also tested the EPUB3 standard with the creation of a dynamic book about a beautiful lagoon with a diversified fauna and flora in the middle of Portugal (Óbidos) (Bidarra, Figueiredo & Natálio, 2014). In the project we tried many different widgets and scripts that somehow emulated the effects achieved with the Apple format iBooks. Still, this implementation was not implemented like a g-book as we desired.

Since we were not able to implement the desired g-book with the traditional ebook authoring tools described previously, we decided to explore the Unity3D platform (Unity, 2015). Unity3D is a game development tool. It is an integrated authoring tool for creating video games or other interactive content such as architectural visualizations or real-time 3D animations. Unity's development environment runs on Microsoft Windows and Mac OS X, and the applications it produces can be run on Windows, Mac, Xbox 360, PlayStation 3, Wii, iPad, iPhone, as well as Android mobile devices. It can also run the developed prototype in a web browser using the Unity web player plugin, supported on Mac and Windows.

Supported by the Unity3D platform, we developed a novel educational g-book prototype for the curriculum of "Environmental Studies", fit for the children in the 4th grade program, with the title "Adventures in the Guadiana River" (Figure 1).

In addition to a story that can be followed by reading the text, consisting of a trip along the Guadiana River, there are several devices that make the development of the narrative more memorable. First of all, a basic text adapted to the target audience was illustrated with appealing images and galleries on various aspects of the river, emphasizing its environmental context. To ensure the engagement of readers, the narrative requires the fulfilment of certain tasks that are supported by interactive activities, in particular, the inclusion of thematic videos and their exploitation through multiple-choice questions (Figure 2).

The ultimate goal was to allow students the possibility to choose different paths to the unfolding of the story. The prototype already has a narrative based on a journey of discovery, with various unexpected situations to maintain interest. For now, the implemented g-book allows the student to progress to the next chapter of the book if the student answers half of the questions of a quiz correctly (Figure 3).

Figure 1. The "Adventures in the Guadiana River" g-book prototype developed with Unity3D

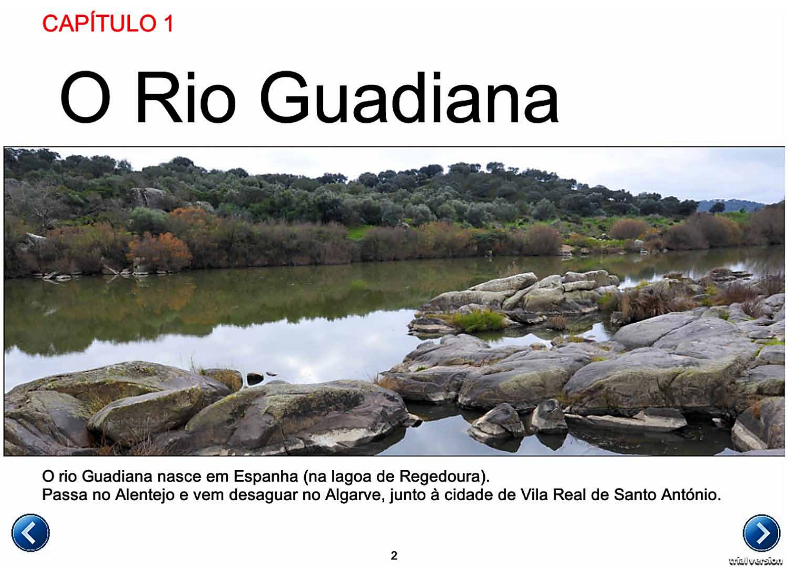


Figure 2. Quiz developed with Unity3D

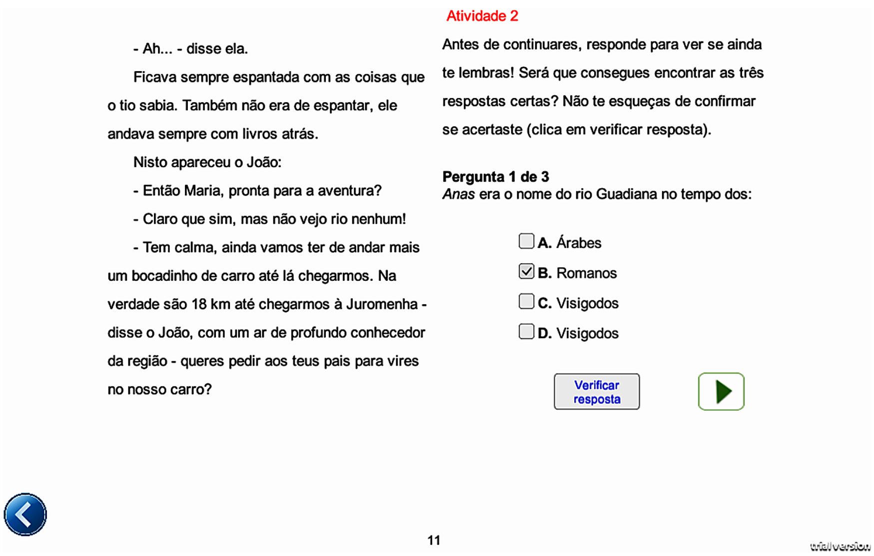
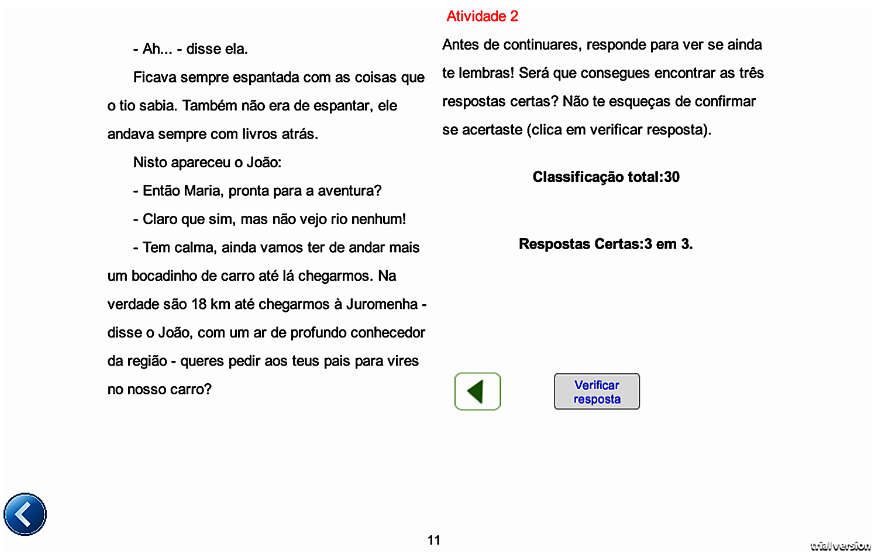


Figure 3. Scores enable the progress throughout the book



Development of a Serious Game for the Learning of Sign Language Alphabet

In this section we describe the implementation of a Serious Game that was created to help people in the process of learning a sign language. To do it, both, a computer game and a hardware device, called GyroGlove, were implemented. When interacting with the computer, the user is asked to represent alphabet letters by replicating the hand and fingers' positions, which are obtained using the GyroGlove module. The GyroGlove then sends that information to the computer using a wireless interface, which interprets the letter that is being done by the user and scores it.

In the following, we start by describing the implementation of the GyroGlove and afterwards the game that results from the combination of both modules.

Implementation of the Gyroglove

Currently, there are several sensors that are able to track and recognize body gestures such as Kinect (Microsoft, 2015), Leap Motion (Leap Motion, 2015), Structure Sensor (Occipital, 2015), Asus Xtion (Xtion, 2015), among others. All these sensors have a great importance to the industry of gaming and user-machine interaction tools. These sensors when complemented with appropriate software have the ability to detect the body posture and/or the user's hand, and accurately replicate that structure on a 3D mesh, to detect gestures.

All these sensors are based on color cameras (RGB) and/or depth (using infrared) and therefore have problems of spatial limitations, i.e. the user has to be located near the device, in the area where these cameras are oriented to, otherwise, they do not work properly. In addition to spatial limitations, in most cases, these devices do not work when they are close to an infrared source, for example on sunlight, or in a room with fluorescent lamps.

In order to overcome these limitations, in this subsection we adopt a different solution, based on a new tracking and gesture recognition system, supported by Inertial Measurement Units (IMUs) that detect the 3D rotation of the hand and fingers of a user. Afterwards, based on this system, a Serious Game for the learning of sign language gestures will be presented.

Inertial Measurement Unit

An Inertial Measurement Unit sensor is an electronic device capable of measuring various types of inertial forces. Depending on the composition of the entire device, it can be formed by several independent sensors comprising an gyroscope, an accelerometer, a magnetometer and, less commonly, an altitude sensor (using atmospheric pressure). In this work we opted to use an IMU in the electronic glove that contains both, an accelerometer and a gyroscope. The results of each of them are mapped to three axes, thus for each IMU sensor a total of 6 degrees of freedom will be obtained.

The accelerometer, such as its name suggests, measures the acceleration (m/s^2) applied to the device in relation to a specified axis. When stationary, i.e. static, the accelerometer only measures the gravitational force of the Earth (9.8 m/s^2) in the downward axis. Its exact value depends on the location and elevation where the device is placed. The accelerometer can measure static (gravity) or dynamic forces. One of its most common applications, on mobile phones and tablets, is the tilt-sensing. By measuring the force of gravity in all three axes, it is possible to know the direction of the device in relation to the gravity of the earth and so automatically rotate the screen to the user's benefit.

The costs of accelerometers depend on their capabilities, among which the most important ones are:

1. The maximum range;
2. Accuracy;
3. Number of measurement axes.

In terms of maximum range, it is measured in G-forces, with 1.0 G indicating an acceleration of 9.8 m/s^2. Typically, accelerations range from ±2 G to ±250 G, for the majority of available accelerometers.

In terms of accuracy, the higher the range of these values, the lower will be its accuracy, due to high granularity. The data obtained by the accelerometer are usually composed of integers of 16 bits, in 2's complement (from -32768 to + 32767). So, if a wide-ranging is used, i.e. ±16 G or more, a lower precision will be available.

Accelerometers can measure acceleration in one axis, or up to three axes. Although accelerometers are fairly accurate for long periods of time, they are unstable in short time, i.e. measured values are quite granular in short periods of time. When an accelerometer is placed in a device that moves or shakes significantly, is not possible to measure accurately all the acceleration data. These electronic components are rather more reliable when there are fewer changes in acceleration over time (measuring static forces).

The gyroscope is a sensor capable of measuring the angular speed, i.e. the speed at which an object rotates on a given axis. It is used when we need to know the direction of a moving object. The angular velocity is measured in degrees per second ($^{o}/s$).

Such as the accelerometer, the gyroscope has also some intrinsic characteristics, which include:

1. The maximum range;
2. Its Accuracy;
3. Number of measurement axes.

The maximum range is measured in degrees per second, and usually has a value that ranges between $\pm\frac{30°}{s}$ and $\pm\frac{2000°}{s}$. If a too low range is chosen, the device can be quite accurate but cannot exceed its maximum angular velocity. On the other hand, if the maximum value is too high, the accuracy is reduced. Thus it is necessary to adjust this value according to the desired application. Like the accelerometer, there are gyroscopes able to measure the angular speed using one, or up to three axes. While the gyroscopes are very accurate in measuring angular velocity, they suffer from drift problems when measuring low constant angular velocities, even when immobilized. This problem is due to intrinsic errors and noise production phase, with different drift values for each module. Unlike the accelerometer, the gyroscopes are very accurate in short periods of time, and inaccurate otherwise (due to the drift problems). Thus they can be combined, thus complementing each other.

GyroGlove Background

The glove developed in this work, called GyroGlove (GyG) uses several MPU-6000 sensors, that combine both and Inertial Measurement Unit with a Magnetic Pickup (MPU). As shown in Figure 4 (InvenSense, 2015) a central controller module is used to program and configure all the IMU sensors and to serve as interface between the glove and the computer. Each sensor has an accelerometer and a gyroscope. Both 3-axes are programmable with a maximum configurable range of ±2 G, ±4 G, ±8 G, ±16 G and $\pm\frac{250°}{s}$, $\pm\frac{500°}{s}$, $\pm\frac{1000°}{s}$, $\pm\frac{2000°}{s}$ respectively. As the sensors are placed in the hand and in the user's fingers, high values of G-forces or high angular velocities are not expected to occur. Thus to keep the values as much accurate as possible, a maximum range of ±2G and $\pm\frac{500°}{s}$, were respectively used for the accelerometer and gyroscope.

The sensors are strategically placed on the glove, in order to be able of extracting the three-dimensional rotation of each finger and also of the hand. To do it, sensors were positioned in the most critical and important locations of the hand, trying to minimize the number of sensors, without limiting the capturing capability of the device, when measuring the rotations of the whole hand.

The anatomical names of the hand bones, that were considered more important to capture the gesture, were the distal, intermediate and proximal phalanges (see Figure 5, left). Considering the above observations, it was decided to use eleven sensors on these locations, enabling the data retrieval of all the rotational data of the fingers and hand. Except for the thumb, in all the other fingers the distal bones are very short, making it very uncommon to fold this finger's part without moving its adjacent. Thus in all the fingers we decided to put two sensors. In the thumb, we decided to place them in the Distal Phalange and Proximal phalanges. In all the other fingers they were placed in the intermediate and proximal phalanges (see Figure 5, right). The last sensor (i.e. number 11) was placed on top of the hand, next to the main module, to extract the overall orientation of the hand. This latter sensor is the basis for the correlation of all the other sensors, as will be explained later. For easier identification, all modules were numbered from 1 to 11, as shown in (see Figure 5, right).

These sensors are integrated with a DMP (Digital Motion Processor) system that is used to process complex algorithms of a 6-axes motion fusion. These algorithms are proprietary, registered by InvenSense and the mode of operation is not of public knowledge.

Figure 4. MPU-6000 sensor module

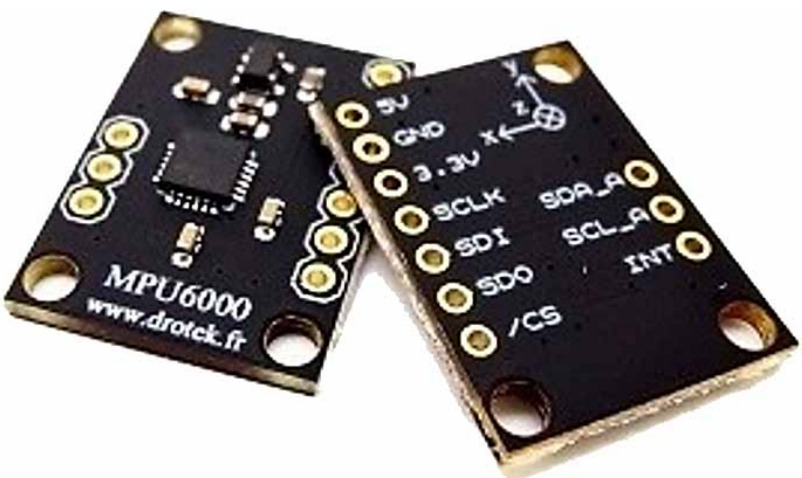
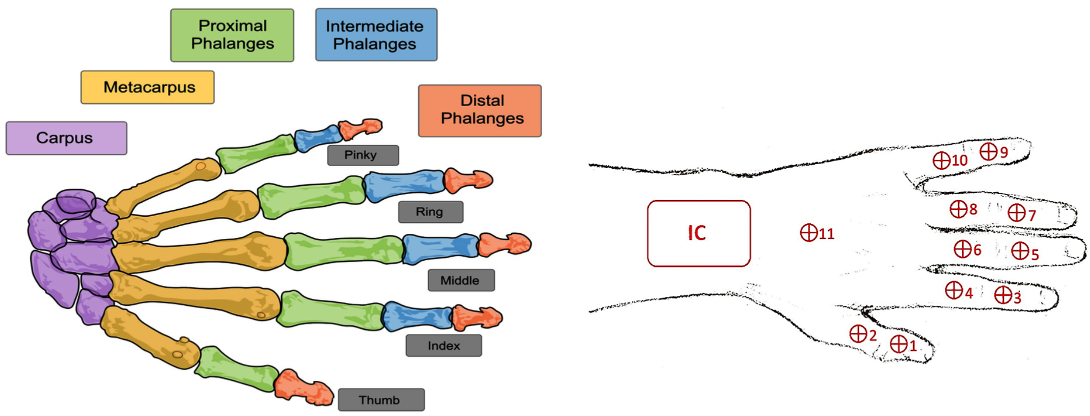


Figure 5. Left: anatomic names of bones in hand. Right: location and number identification of the sensors and main module



The computation supported by these algorithms, in the IMU modules, is useful for four reasons:

1. Support a reduction and even elimination of the problems associated with the inaccuracies of accelerometers and gyroscopes.
2. It is time saving for post-processing on the controller module or PC.
3. It eliminates the problems/limitations associated with the Euler angles.
4. They process angles in the form of quaternions.

In order to eliminate or reduce the problems of inaccuracies of the sensors, digital filters can be used. The accelerometer is very accurate over long periods of time but is inaccurate for short periods. The gyroscope is just the opposite. Thus, a very easy way to reduce both problems is to join the data from the two sensors, using a complementary filter. This filter combines in a single equation, a low pass filter for the gyroscope and a high pass filter for the accelerometer. Being *C*, the complement value which can range from 0.0 to 1.0 and dt the sample time, the final angle of each axis (An_{axis}^{t}) is computed using its previous value (An_{axis}^{t-1}) through $An_{axis}^{t} = C(An_{axis}^{t-1} + Ga_{axis}^{t} \times dt) + (1-C)Aa_{axis}^{t}$. In this equation, the value of Ga_{axis}^{t} represents the raw angle computed around each axis, which is obtained from the gyroscope data using $Ga_{axis}^{t} = \frac{Gd_{axis}}{G_{sen}}$. In this later expression, Gd_{axis} represents the raw data around each axis of the gyroscope and G_{sens} the gyroscope sensitivity, which is calculated using $G_{sens} = \frac{2^{16}}{G_{range}} = 131.072$, with $G_{range} = 500$ (which represents the range chosen for the gyroscope).

Regarding Aa_{axis}^{t} , it represents the raw accelerometer angle, that can be calculated around each axis (Aa_x and Aa_y) using $Aa_x = \tan^{-1}\frac{Ad_y}{Ad_z} * \frac{180}{\pi}$ and $\mathrm{Aa_y} = \tan^{-1}\frac{\mathrm{Ad_x}}{\mathrm{Ad_z}}$ *180 / À.

The angle around the z-axis cannot be calculated the same way as the y and x-axes, because the accelerometer computations rely on gravity, that points in the Z direction (i.e. in the z-axis). This is a phenomenon known as Gimbal Lock, a problem/limitation that occurs when working with Euler angles.

This means that the angle around the z-axis (An_z) can only be calculated with the gyroscope, therefore, this angle will suffer from a small drift along time.

The complementary filter algorithm has a simple implementation, is fast and enough efficient. For best results one may employ the Kalman filter (Ristic, Arulampalam, & Gordon, 2004). Though more complex and computationally expensive, it is more efficient. This algorithm relies on all observed values over a predetermined time and estimates the future state of the system based on the previous states.

Despite regarding filters as a good way to obtain a better reliability of the orientation of the sensor over both short and long time periods, their implementation, especially the Kalman filter, may require excessive computational capability, typically unavailable in a simple micro-controller.

Using Euler angles, also induces a negative effect, a problematic phenomenon, known as Gimbal Lock, with a loss of a degree of freedom on a 3-axes system. Gimbal Lock is a mathematical problem associated with Euler angles, impossible to solve. Without introducing too much detail into this phenomenon, this is a real problem that many 3D programs such as games and animation editors try to solve. While Euler angles are the easiest way to get the orientation of the sensor, which are easy to understand and implement, they have limitations and therefore must be avoided.

At this level, the DMP system is of the highest importance. This proprietary system uses the quaternary system, that does not suffer from the same problem as the Euler angles. The quaternion is an alternative way to represent an angle on a 3D space and is represented by $Q = q_w + q_x i + q_y j + q_z k$, where q_x , q_y and q_z translate the values of the position direction vectors and q_w the rotation about this axis, formed by the direction vector. Alternatively, the quaternion Q can also be expressed in a matrix form by:

$$Q = \begin{bmatrix} 1 - 2q_y^2 - 2q_z^2 & 2(q_x q_y - q_z q_w) & 2(q_x q_z - q_y q_w) \\ 2(q_x q_y - q_z q_w) & 1 - 2q_x^2 - 2q_z^2 & 2(q_y q_z - q_x q_w) \\ 2(q_x q_z - q_y q_w) & 2(q_y q_z - q_x q_w) & 1 - 2q_x^2 - 2q_y^2 \end{bmatrix}$$

Hardware

The hardware component of the GyroGlove consists of three major blocks, comprising:

1. Eleven MPU-6000 sensors;
2. Main controller module;
3. Receiver module connected to the PC.

Each IMU sensor has a size of 17 x 23 mm (see Figure 4). The main controller acts as the intermediary interface between the sensors and the application on the PC. It is responsible for programming and configuring all the sensors and to send the data via Bluetooth to the receiver on the PC. It consists of:

1. A Microcontroller, ATMega Atmel 328p (Atmel, 2015), with a 8MHz oscillator.
2. A USB to/from UART converter (FT232RL) that converts the Micro USB port data to the microcontroller and vice versa.

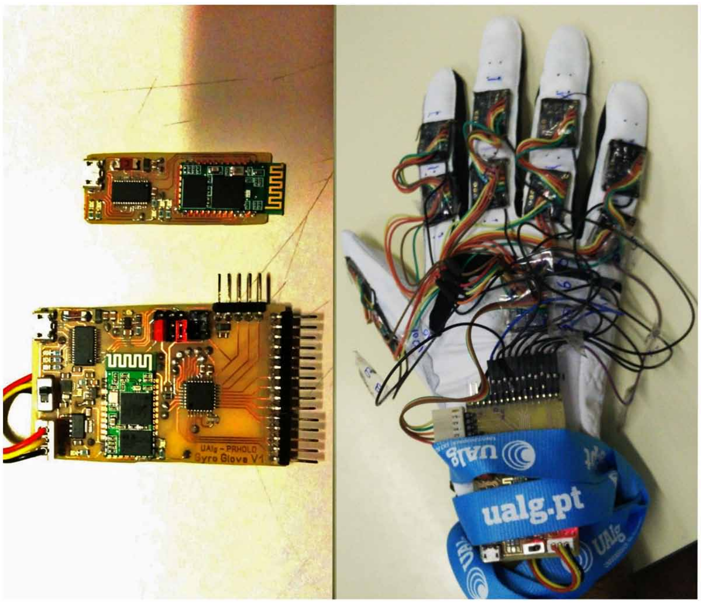
3. One Battery Charger LiPo (MCP73831).
4. A voltage supervisor circuit (BD523G).
5. A LED that emits a warning (to the user) if the battery is low.
6. A Voltage Regulator (TPS13733), that regulates the 5V tension from the USB or battery voltage to the main 3.3V of the circuit.
7. A charge distributor (LTC4413) that provides an automatic way of selecting the power source. When only the battery is connected, only this power source is used in the circuit. When the USB is connected, it becomes the main source power, regardless of how many sources are connected (USB and / or battery).
8. A Bluetooth Module (HC-06).

The receiver is a Bluetooth module similar to that used in the controller, but with the ability to be used as a master device, i.e. it has the initiative to bind to other Bluetooth modules. Similar to the controller circuit, the circuit of the receiver has:

1. A USB to/from UART converter (FT232RL) that converts the USB Micro port data to Bluetooth;
2. A Bluetooth Module.

All modules, PCB controller and receiver, were produced by handmade methods and its description is out of the scope of this article. In figure 6, on the left, the final result of the PCBs are shown and on the right the entire system is shown attached to the glove.

Figure 6. PCB prototypes on left. Assembled prototype glove on the right.



Interface between the GyroGlove and PC Application

The transmission of data to the PC has to be done quickly, to avoid delays between finger's rotations and their representation in the screen (lag). For this reason, as represented in Figure 7, the microcontroller and Bluetooth modules are programmed to use a 115200 bps transmission rate. This is the maximum possible rate allowed by the devices. The limitation is due to the fact that the oscillator (8 MHz) on the micro-controller does not allow higher speeds. For the same reason, the interface between the micro-controller and the sensors communicates at a top speed of 2 MHz SPI. The maximum frequency of the ATMega328P on the SPI interface is 1/4 of the oscillator frequency. These transmission speeds allow the system to update all data on the PC at a frequency of 33.3 Hz, confirmed by various tests.

Similarly to the Game-Book described in the previous section, the PC version of the developed application for the PC was made using Unity3D (Unity, 2015) which, by processing angles in the quaternions form, constitutes an ideal tool to work directly with the data obtained from the IMU sensors. The communication between the PC and the glove is made using an ASCII character oriented data packet, with the format shown in Table 2.

The packet starts with the ASCII character $, followed by the quaternion data *X, Y, Z* and *W*. This data is transmitted using four 16-bit fields (i.e. each one with two 8 bit parts, represented by (X_m, X_l), (Y_m, Y_l), (Z_m, Z_l), and (W_m, W_l), where *m* and *l* respectively represent the most and less significant parts). They are followed by the index/number of the associated sensor *i* (as identified in Figure 5 right). Finally, *CR* and *LF* respectively represent the Carriage Return and Line Feed codes, signaling the end of the packet.

Figure 7. Communications scheme between the GyroGlove and PC

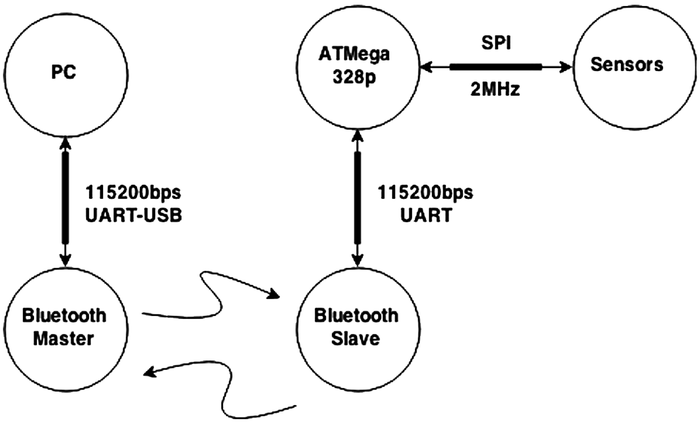


Table 2. Structure of the transmitted packet between the GyroGlove and PC

1 Byte	1 Byte	1 Byte	1 Byte	1 Byte	1 Byte	1 Byte	1 Byte	1 Byte	1 Byte	1 Byte	1 Byte
$	X_m	X_l	Y_m	Y_l	Z_m	Z_l	W_m	W_l	*i*	*CR*	*LF*
	X		*Y*		*Z*		*W*				

The DMP system can compute the exact rotation of each sensor by itself but needs an initial and self-controlled set up configuration. This auto-configuration aims to reduce and possibly eliminate the drift problem caused by the gyroscope, as previously presented. Thus, after the power up of the system, all the sensors enter into an auto-configuration phase that can last between 10 and 20 seconds. When finished, all sensors will be stable, but before that, the extracted rotational data is not usable since it suffers from extreme drift, even if stabilized in the correct orientation.

Afterwards to correct the offset problem it is necessary to know, a priori the state of the rotation of all the sensors, i.e. to position all sensors in a known orientation. Given Q quaternion with an unknown direction, applying $K = Q^{-1} \times Q$, we obtain a quaternion with no rotation, stabilized. In an application on the PC where there are objects that replicate the users' hand orientation, an initialization is required to associate both. Thus, in a process guided by the application, the user places his hand with a certain orientation, before powering up the system. Being i the sensor number and $t1$ the time in which the initial configuration is finished, all rotations of the sensors in time $t1$ are stored in the quaternion U_{it1}. For all subsequent time instants, the user's hand rotation is obtained using $K_i\left[t\right] = U_{it1}^{-1} \times S_i\left[t\right]$, where $S_i\left[t\right]$ represent the data from the sensors, after the initial setup configuration (after $t1$). If the user's hand is not placed with all the sensors stabilized, $K_i\left[t\right]$ must be obtained from $K_i\left[t\right] = \left(U_{it1}^{-1} \times D_i\right)^{-1} \times S_i\left[t\right]$ with D_i being the quaternion with the offset rotation of each sensor that we had before powering up the system.

Thus, at startup, the user should keep his hand as straight as possible on a table or horizontal plane during initial setup configuration. Afterwards $K_i\left[t\right] = U_{it1}^{-1} \times S_i\left[t\right]$ is applied, avoiding the offset rotations of the sensors, with the exception of the ones positioned on the thumb. In fact, as can be easily seen from Figure 6, right side, when the hand is positioned horizontally on a table, all sensors are straight (without rotation), with the exception of the two sensors in the thumb. In this particular case, it is necessary to estimate the associated rotation of these two sensors and apply $K_i\left[t\right] = \left(U_{it1}^{-1} \times D_i\right)^{-1} \times S_i\left[t\right]$ to each of them. In this particular case, we opted to apply an initial rotation of $-45°$ to both x and y axis. These values were obtained empirically.

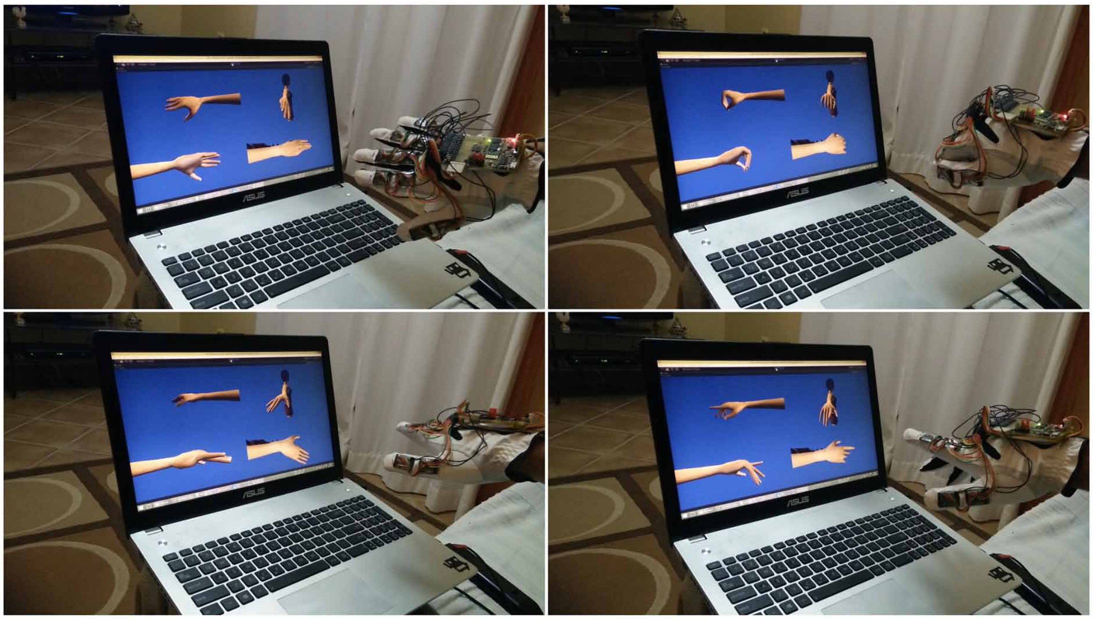
For testing and calibrating purposes, an application was made with the Unity 3D software. This application replicates the position of the user's hand, using a 3D model of a human hand, as shown on figure 8. Examples of four different situations of the user's hand position are shown.

Learning Application of Portuguese Sign Language Alphabet

After testing the GyroGlove with the application described in the last section, a game was developed to help and encourage the learning of a sign language using the GyroGlove. Gestural language is known to be difficult to learn and thus a game intended to help in its learning process could be considered an advantage.

As the GyroGlove only allows the detection of the rotations of all fingers and hand, it cannot be used to learn sign language words, phrases or sentences, but only the sign language alphabet where each letter possess a direct relationship with the hand position and fingers.

Figure 8. Four examples of the user's hand replication on a human 3D model. From left to right and top to bottom. Hand tilted to the left, hand closed, hand straight with index finger pointing.



As the GyroGlove system was developed in Portugal, an alphabet of the Portuguese Sign Language (PSL) was used as the first sign language that this system can recognize. The hand's position of the PSL can be seen in Figure 9, that contains both, the sign language of the alphabet and of the numbers.

Recognition of Sign Language

In order to recognize each of the hand's positions shown in Figure 9, it is necessary to compare all the rotations of the sensors with all rotations associated with a particular letter of the alphabet.

Instead of comparing the quaternion of each sensor, a comparison is made between the quaternion of each two adjacent sensors, pre-defined, as well as the relation of the hand sensor quaternion (number 11 on the glove) with the vertical axis. This last one is used to determine the overall direction of the hand (face up, or down, left etc.).

There are 11 distinct relations identified by R_j (with j ranging from 1 to 11). To determine the relations between each other, it is necessary to compute the angle between each rotation, between all sets of two sensors.

As illustrated by Table 3 and Figure 10, each sensor is associated with another one. For example, sensor nº 8 (Ring Proximal finger) is related to sensor nº 7 and nº 11, which in the following will be identified as relation R_8 and R_7 respectively.

Figure 9. Portuguese Sign Language Alphabet
Adapted from (Vivendo em Silêncio, 2015)

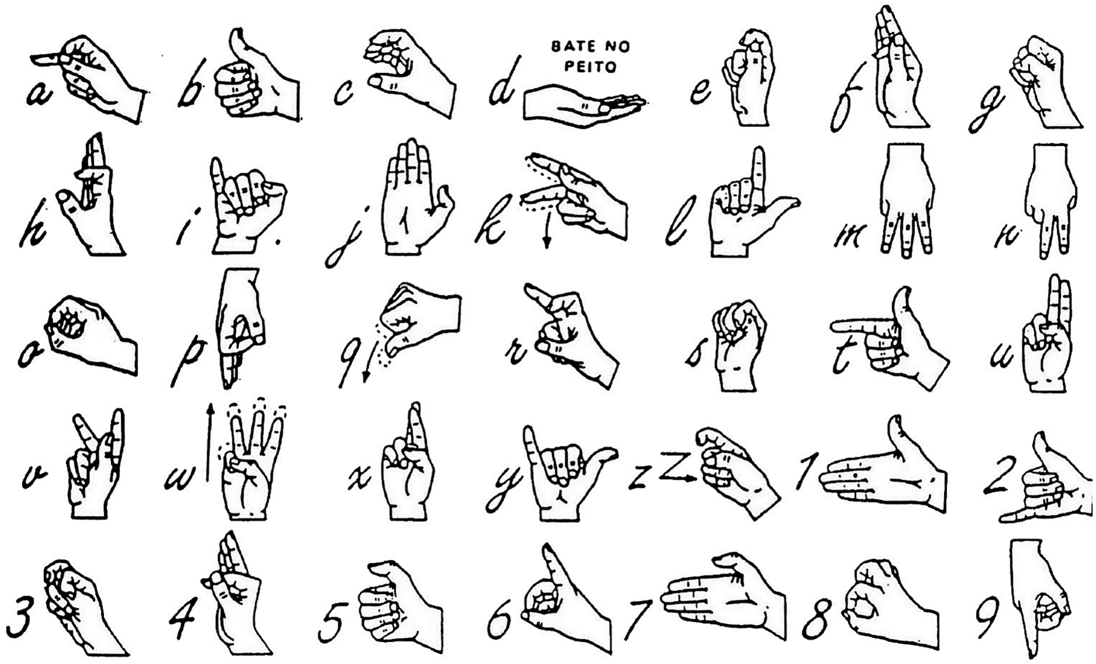


Figure 10. Association between adjacent sensors and vertical axis

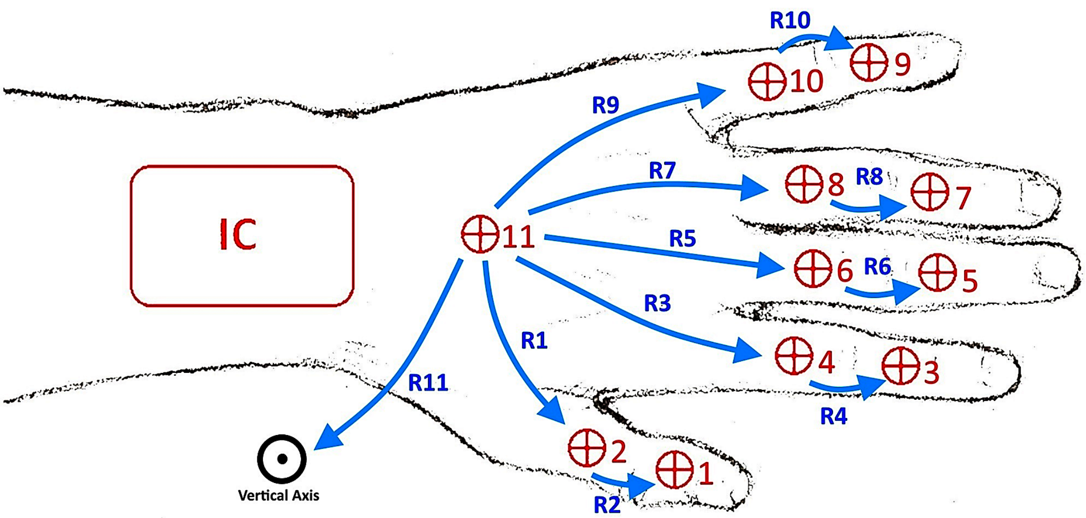


Table 3. Association between sensors for gesture recognition

Sensor	Relation with Sensor ID nº x (R_j)
ID: 1 – Thumb Distal	2 (R_2)
ID: 2 – Thumb Intermediate	1 (R_2) 11 (R_1)
ID: 3 – Index Intermediate	4 (R_4)
ID: 4 – Index Proximal	3 (R_4) 11 (R_3)
ID: 5 – Middle Intermediate	6 (R_6)
ID: 6 – Middle Proximal	5 (R_6) 11 (R_5)
ID: 7 – Ring Intermediate	8 (R_8)
ID: 8 – Ring Proximal	7 (R_8) 11 (R_7)
ID: 9 – Pinky Intermediate	10 (R_{10})
ID: 10 – Pinky Proximal	9 (R_{10}) 11 (R_9)
ID: 11 – Hand	2 (R_3) 4 (R_3) 6 (R_5) 8 (R_7) 10 (R_9) Vertical Vector (R_{11})

As a quaternion defines a rotation and not a vector in space, it is necessary to apply the rotation of each quaternion to a known vector $\vec{V}_{front} = (0,0,1)$. Applying $\vec{V}_i = K_i \times \vec{V}_{front}$, results in $\vec{V}_i$, which is a vector with the rotation of K_i (raw quaternion data obtained from the sensors).

After obtaining $\overrightarrow{V_i}$, the vector defining the orientation in 3D space of each sensor, it is necessary to calculate the absolute, shorter angle between each two orientation vectors. This angle is computed using the relation between each sensor pair, applying $A_j = \left| \arccos \frac{\overrightarrow{V_n} . \overrightarrow{V_m}}{\left\| \overrightarrow{V_n} \right\| . \left\| \overrightarrow{V_m} \right\|} \times \frac{180}{\pi} \right|$ for each set of two sensors (shown in Table 3 and Figure 10). A_j represents the angle in degrees formed between each set of sensors n and m (with $n, m = \{1, \ldots, 11\}$) and also between the main hand sensor (sensor nº11) and the vertical vector $\vec{V}_{up} = (0,1,0)$. Angles A_j can range from $0°$ o $180°$.

To identify the hand's position, it is firstly necessary to record these positions, calculating the angles between each sensor A_j and its reference. To do it, for each letter of the alphabet, $l = \{a, \ldots, z\}$, both the maximum angle $S_{max_{j,l}} = \max_{t-\Delta_{sample} \leq w \leq 0} A_j[w]$ and minimum angle $S_{min_{j,l}} = \min_{t-\Delta_{sample} \leq w \leq 0} A_j[w]$ are computed. In order to be validated, the hand's position needs to hold a certain association with a letter for Δ_{sample} seconds.

Whenever new hand data is available, in K_i, all current vector angles, A_j, are calculated. Then for each letter *l* and during a minimum period of time ($\Delta ts = 1s$, defined empirically) it is verified if every angle falls between $S_{min_{j,l}}$ and $S_{\max_{j,l}}$. In order to allow an adjustment of the detection sensitivity a margin value was introduced. Thus, after analyzing all the data A_j a positive gesture detection is considered if $S_{min_{j,l}} - \Delta_m \leq A_j \leq S_{max_{j,l}} + \Delta_m$ is verified during a Δts period of time (Δ_m set to 20).

Implemented Game for the Learning of Sign Language Alphabets

Figure 11 presents the Serious Game that was developed for the learning of the sign language alphabet. The interface consists of 4 parts: (1) the letter and hand's position of the corresponding image, (2) a visual input of the hand's position replicated in a 3D human model, (3) a scoring system and (4) a level bar to indicate how close the user is standing next to the goal.

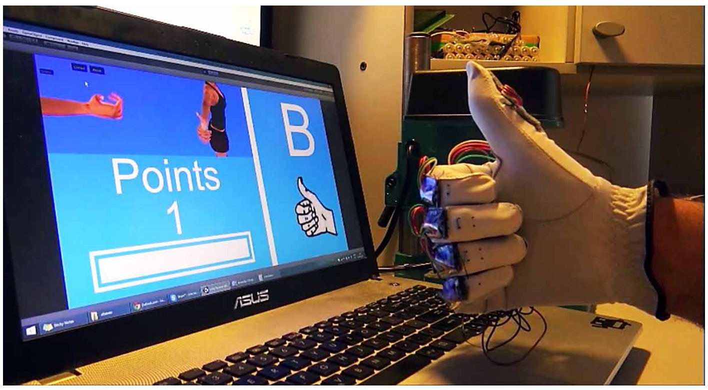
When the users play with the application, random letters are dynamically shown. The user then has to replicate the image shown in the right side. Eventually when he is well succeeded, the system scores the associated result, according with the time spent to do the associated letter and the correctness of the hand's position.

CONCLUSION

In this chapter we made a review of the current trends and developments in Serious Games, with a special focus in Education. The details of two real implementations help illustrate the technologies that could be involved in the creation of these games and its applicability to very distinct and innovative fields.

In the first of these examples we showcase the educational g-book prototype for the curriculum of "Environmental Studies", created for children in a 4th grade program. This g-book concept has the potential to challenge students to become actively involved in the educational process, as it allows students to try different routes and distinguish what is important from what is secondary, enabling them to create and

Figure 11. Game for learning stimulation of alphabet sign language. The user is encouraged to replicate the hand position.



annotate material from various sources, while also encourages the exploration of new issues. These are, however, aspects that need to be investigated and validated by future research in the educational context.

In the second example a serious game was developed for learning the sign language alphabet, combining hardware and software. The game prototype was tested, demonstrating a high level of accuracy in the recognition of the letters inserted by users.

FUTURE RESEARCH DIRECTIONS

There is an enormous potential in integrating games with the solutions that already support collaboration and interactivity, not only to make them become more engaging, but also behavior-changing. Serious Games can be used to help people think differently, in a more integrated, holistic way, as required in complex solutions.

In order to achieve it, more research needs to be done into how Serious Games can develop better students and professionals, make teams more productive and make applications become more collaborative.

The solutions presented in this chapter highlight the potential of Serious Games, in education. In future these solutions need to be tested, to verify their effectiveness.

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KEY TERMS AND DEFINITIONS

Augmented Reality: Real time integration between digital information, with live video and the user's environment.

Body Gesture Sensors: A sensor that is used to acquire the position of body gestures.

eBook: An electronic book that integrates text, images or video.

Educational Game: A computer game used for education purposes.

Gamified Books: An electronic book that integrates text, images or video, with a computer game.

Inertial Measurement Unit (IMU) Sensor: An electronic device capable of measuring various types of inertial forces.

Sign Language Alphabet Learning: The process of learning a visually perceived language that is based on a naturally evolved system of articulated hand gestures which translate alphabet letters.