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Reflections on Students' Projects with Motion Sensor Technologies in a Problem-Based Learning Environment

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Abstract: Game-based learning (GBL) has been applied in many fields to enhance learning motivations. In recent years, motion sensor technologies have been also introduced in GBL with the aim of using active, physical modalities to facilitate the learning process, while fostering social development and collaboration (when these activities involve more than one student at a time). The approaches described in literature, which used motion sensors in GBL, cover a broad spectrum of educational fields. These approaches investigated the effect of learning games using motion sensors on the development of specific skills or on the learning experience. This paper presents our experiences on the educational use of motion sensor technologies. Our research was conducted at the department of Medialogy in Aalborg University Copenhagen. Aalborg University applies a problem-based, project-organized model of teaching and learning in all its programs. Our approach differs from the aforementioned ones, since we did not develop learning games for students, but we provided students with motion sensors and asked them to use them for their semester projects. Since Medialogy is an interdisciplinary program that combines technology and creativity, our goal was to twofold: firstly, we wanted to observe if and how the introduction of such technologies facilitates the development of students' technical skills. Secondly, we wanted to investigate how this introduction affects the students' creativity. In order to answer these questions, we are presenting and discussing students' projects that used motor sensors. Our results show that the experimentation with motor sensor technologies boosted students' creativity. Students developed computer games, serious games, computer vision applications and investigated new ways of controlling games and applications. Nevertheless, the introduction of these technologies impeded development of technical skills, since such technologies come along with tools and interfaces that facilitate the development of applications to such extent that the students can produce sophisticated applications without much effort and deep understanding to the technical aspects. Therefore, we conclude that motion sensor technologies can be used to engage students (also in lower levels of education) in creative and research-based learning. However, if the development of technical skills is considered also important during learning, there should be strict requirements on how students should use such technologies.

Keywords: Motion sensor technologies, higher education, problem-based learning, creativity, technical skills.

1. Introduction

Game-based learning (GBL) has been applied in many educational fields to enhance learning motivation. GBL describes an instructional approach, where students are encouraged to learn through exploring games, which are designed by teachers or educational researchers (Prensky 2001). An effective game-based learning environment sets clear goals for students and provides them with different ways to react. Thus students are free to experiment and learn the right way to do things. Recently, game-based learning applications have been also developed that allow students to play in virtual environments, which implement aspects familiar to them (Ming et al. 2013).

As technology and creativity progress, gaming types and interfaces are facing great changes, from keyboard, mouse, and remote sensors, to motion sensors that facilitate natural user interfaces. Motion sensor technologies allow motion and gestures to control game functions, and thus physically involve the player in gameplay. In recent years, motion sensor technologies have been also introduced in GBL with the aim of using active, physical modalities to facilitate the learning process, while fostering social development and collaboration (when these activities involve more than one student at a time).

This paper presents a different perspective on the educational use of motion sensor technologies. Our research was conducted at the section of Medialogy in Aalborg University Copenhagen. Aalborg University applies a problem-based, project-organized model of teaching and learning in all its programs. In our research, we did not develop learning games for students, but we provided students with motion sensors and asked them to use them for their projects. For these projects, students design and implement applications related to their semester topic or courses (e.g. embodied

interaction, visual computing, and multimedia programming). Since Medialogy is an interdisciplinary program that combines technology and creativity, our goal was twofold: firstly, we wanted to observe if and how the introduction of such technologies facilitates the development of students' technical skills. Secondly, we wanted to investigate how this introduction affects the students' creativity. In order to answer these questions, we are presenting and discussing students' projects that used motion sensors.

2. Background

The studies in literature, which use motion sensors in GBL, cover a broad spectrum of educational fields (Kandroudi & Bratitsis 2013). Motion sensors have been used in physical education, mathematics, language learning, and biology to name a few. Moreover, many approaches targeted groups with special needs, such as autistic children, neurological patients, and children with vision disorders. These approaches investigated the effect of learning games using motion sensors on the development of specific skills or on the learning experience.

In the field of physical education, newer video gaming technologies (called exergaming) have been designed to take advantage of the reinforcing effects of video games to increase physical activity in children. Fogel et al. evaluated the effects of exergaming on physical activity among four inactive children in a physical education (PE) classroom (Fogel et al. 2010). Results showed that exergaming engaged children in substantially more minutes of physical activity and produced more minutes of opportunity to engage in physical activity than the standard PE program did. In addition, exergaming was socially acceptable to both students and the PE teacher.

In mathematics education, Thakkar et al. in their project "Learning Math Using Gesture" interfaced 3D animation software and gesture recognition hardware to create an interactive learning environment (Thakkar et al. 2012). They used a motion sensor (Microsoft Kinect) for capturing real time gestures of users in order to make teaching more visual, animated and lively. Lee et al. developed Xdigit, which is a motion based educational game (Lee et al. 2012). Xdigit uses a motion sensor as the interaction mechanism. The game situates the player in a spaceship and it requires the solving of simple arithmetical problems in order to advance. Lee et al. studied the suitability of motion sensors, in this case Kinect, in educational games, and at the same time aimed at improving mathematical skills in young children. Lee et al. found that using motion sensors for interaction in an educational game attracts the players because it is fun. Moreover, they concluded that the game is suitable as a teaching tool for learning mathematics at a young age.

In the field of education for people with special needs, Christinaki et al. developed an educational computer game for pre-schoolers with autism, designed to teach them facial emotion recognition in order to enhance their social interaction (Christinaki et al. 2013). The game uses Kinect as a game input controller and aims at supporting early intervention and at fostering emotion learning. Zafrulla et al. investigated the potential of the Kinect depth-mapping camera for sign language recognition and verification for educational games for deaf children (Zafrulla et al. 2011). They compared a prototype Kinect-based system to another system, which uses coloured gloves and embedded accelerometers to track children's hand movements. They collected a total of 1000 American Sign Language (ASL) phrases across both systems and they concluded that while the Kinect computer vision system required more tuning for seated use, it can be a viable option for sign verification.

All the aforementioned approaches use motion sensor technology in educational games created by teachers or educational researchers with the aim to improve learners' motivation, experience or specific skills. In our research, it was not the teachers or the researchers using motion sensor technologies. We chose rather to provide university students with motion sensor technologies and let them experiment with such technologies in order to create various applications. We hypothesized that this approach would improve students' technical skills, since they would learn to use motion sensor technologies, and at the same time would boost their creativity, since such technologies can be used in many directions. Students had the opportunity to work with various motion sensors for their projects in a problem- and project-based learning environment, which is described in the next section.

3. Problem Based Learning (PBL)

PBL is a student-centered instructional approach, in which learning begins with a problem to be solved (Kolmos, Fink & Krogh 2004). Students need to acquire new knowledge in order to solve the problem and therefore they learn both problem-solving skills and domain knowledge. The goals of PBL are to help the students "…develop flexible knowledge, effective problem solving skills, self-directed learning, effective collaboration skills and intrinsic motivation." (Hmelo-Silver 2004).

PBL may also support group work (Kolmos 1996). While working in groups, students try to resolve the problem by defining what they need to know and how they will acquire this knowledge. This procedure fosters the development of communication, collaboration, and self-directed learning skills. Moreover, group work in PBL may enable students to experience a simulated real world working and professional environment, which involves process and communication problems and even conflicts, which all need to be resolved to achieve the desired outcome.
Additionally, PBL represents a paradigm shift from the traditional one way instructional methods. In PBL, the teacher is not an instructor but rather a tutor, who guides, supports and facilitates the learning process. The tutor has to encourage the students and increasing their understanding during the problem-solving process. Therefore, the PBL teacher facilitates and challenges the learning process rather than strictly transmitting domain knowledge.
PBL was first established in the medical school program at McMaster University in Hamilton, Ontario, Canada (Neville 2009). Since then, various educational institutes have adopted PBL as a model of teaching and learning. Since its establishment in 1974, Aalborg University, Denmark bases all its university programs on PBL, also referred to as “PBL - The Aalborg model” (Kjærsdam & Enemark 1994). The PBL-model is continuously developed and adapted as a learning model for students as well as teaching staff, in order to respond well to the demands and changes posed by the modern society and changes in the educational area.
The PBL – Aalborg Model shapes the institution’s program curricula. The program curriculum at Medialogy is mapped onto academic terms (semesters), which are characterized by a progression with regard to depth of content and to sophistication of project work. Each semester consists of an appropriate balance of courses, which accompany the students’ project work. In each semester, a theme is selected to serve as the context, which defines the learning objectives of this semester. Within this theme and the overall learning objectives, problems and project proposals are to be chosen (Barge 2011). Apart from their semester projects, students have often to work on projects for their semester courses.
For their semester and course projects, Medialogy students were offered the opportunity to work with motion sensors, which are described in the following section.

4. Motion sensor technologies

Motion sensor technology is the “discipline that processes, digitalizes, and detects the position and/or velocity of people and objects in order to interact with software systems” (Giori 2013). It is a technique widely used for designing and developing Natural User Interfaces (NUIs). NUIs are human-machine interfaces that enable the user to interact in a natural and intuitive way with intelligent systems (Giori 2013).
In this context, there are numerous devices that developed to act as motion sensors. The first breakthrough was the Wii Remote in 2006, which was the primary controller for Nintendo's Wii console. The main feature of the Wii Remote is its motion sensing capability, which allows the user to sense its position in 3D space via gesture recognition through the use of accelerometer and an infrared detector (Salah et al. 2011).
In a similar context, PlayStation Move was a motion-sensing game controller platform by Sony Computer Entertainment (SCE), released for the PlayStation 3 (PS3) video game console in 2009. PlayStation Move uses inertial sensors in a handheld motion controller wand to detect its motion, and the wand's position is tracked using a PlayStation webcam (Sinclair 2010).
The next breakthrough was Kinect, which is a series of motion sensing input devices by Microsoft initially for the video game console Xbox 360 and now also for Xbox One and PCs. It features a natural user interface for the human computer interaction, using gestures, body motion and spoken commands, by replacing the game controllers with a webcam-style add-on peripheral (Luos 2014). Kinect for Xbox was launched in November 2010 and its acceptance from the game and hacking community was wide. It also holds the Guinness World Record for being the "fastest selling consumer electronics device" ahead of the iPhone and the iPad (Giori 2013). The launch of OpenNI from PrimeSense and the Kinect SDK from Microsoft which both are a set of libraries and APIs, simplified the design and implementation of motion sensing applications.
The final addition to this list of the widely used motion sensing devices is the Leap Motion. Leap Motion is a sensor device that tracks and senses hand and finger motions as input, analogous to a normal mouse device, but requiring no hand contact or touching (Leap Motion 2014). The device started shipping in July 2013. Leap Motion is using two monochromatic IR cameras and three infrared LEDs (Leap Motion 2014). Its sensing space is a roughly hemispherical area, to a distance of about 1 meter. Leap Motion features a LED generator of a 3D pattern of IR light dots. Then two cameras generate about 300 frames per second of reflected data, which are analysed by the Leap Motion

controller software, producing the 3D position data by comparing the 2D frames generated by the two cameras.

5. Use of motion sensor technologies in students' projects

All the aforementioned motion-sensing devices were available to Medialogy students for use in their semester or course projects. We started following students' project work in fall 2011. We found that students used motion sensor technologies in projects for the following semesters/courses:

- 3rd semester (Semester theme: Human Senses – Digital Perception)
- 6th semester (Semester theme: Interactive Systems Design)
- Multimedia Programming Course (8th semester)
- Modelling Physical Systems Course (8th semester)
- Embodied Interaction Course (8th semester)

Our aim was to observe how students use motion sensor technologies in their projects and to evaluate the effect of the introduction of such technologies on their technical and creative skills. By analysing several projects from fall 2011 to spring 2014, we were able to separate the use of motion sensor technologies in student semester and course projects in three categories (Figure 1), which are described in the following sections. For each category, representative student projects are described.

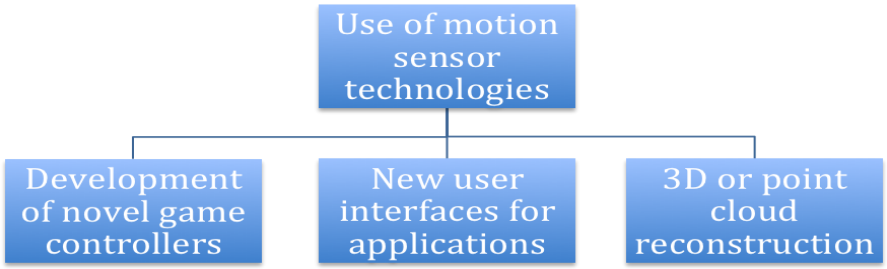

Figure 1: Applications of motion sensor technologies in students' projects

5.1 Development of novel game controllers

The first category of students' projects includes efforts to develop novel and innovative controllers for games. Students used motion sensors in order to improve controllers in computer games, which in most cases they developed themselves.

An example of such a project is a 3rd semester project by Boye et al. (Boye et al. 2011). The aim of this project was to investigate if users of a game are more immersed when they wear a wing suit that utilizes gesture-based controls compared to standard PC controls. Boye et al. concluded that this novel game controller using gestures (wing suit) might provide easier controls since it felt more natural to users. Nevertheless, students found immersion level hard to measure during the tests.

Another 3rd semester project explored how to achieve visual dominance in a motion-controlled game (Paludan et al. 2011). More specifically, the project investigated to what extent visual dominance can prevail over one's kinesthesis in a game that utilized Kinect technology. To this aim, a motion-controlled game was developed, where users utilized their whole body to play the game. The goal of the game was for the user to mimic certain poses at the right time. A graphical representation of the body was provided on the screen, as a help to the user. During the game this graphical representation was being slightly rotated. By doing this, Paludan et al. wanted to test whether it is possible to influence people's kinesthesis sense by manipulating their sense vision (the rotated representation of their bodies). During the tests of this project, it was found that people were actually tricked and thought that their body position was as seen on the rotated graphical representation.

5.2 New user interfaces for applications

Apart from novel game controllers, students used motion sensor technologies in order to develop new NUIs for applications (Câmara 2011). A representative project where motion sensor technologies were used for the development of NUIs is "Kinesonica" (Watanabe 2012). This 9th semester project attempted to explore the affordance of movement-gesture based NUIs for play pedagogy of preschool children. A prototype game was created using Kinect, which enabled children to produce sound and visuals by body movements and gestures. Using the tools, children explored their body movements by

producing sound and images alone and with a partner under an adult's. The results suggested that this game can be used for creative kinaesthetic learning activities among pre-schoolers.
Another project that also belongs to this category is a project for the Physical Systems Modelling course by Aabern et al. (Aabern et al. 2012). The aim of this course is the as accurate as possible simulation of real-life physics phenomena. In this project, students tried to use a game physics engine, namely Unity 3D, connected with Kinect to develop a simulator of a hang glider. The idea was to use arm and shoulder movements in order to control a simulator of a hang glider in a mountain terrain in presence of variable wind and thermals. However, the students needed to program some wind simulation and stability control of the glider as plugins for Unity. This is the step where students' lack of experience with mathematics and physics showed off, as they were not able to figure out how to implement that code correctly, and therefore the majority of their "flights" ended up as clashes to mountains.

5.3 3D or point cloud reconstruction

The third category contains projects that exploited the depth sensing abilities, which come along with some motion sensing devices (i.e. Kinect, Leap Motion). These projects used depth sensing for 3D or point cloud reconstruction. 3D reconstruction is a term in computer vision that refers to the process of capturing the shape of real objects (Izadi et al. 2011), while a point cloud is a set of points in a three-dimensional coordinate system, which are often intended to represent the external surface of an object. An example of a motion-sensing device that has the potential to perform 3D reconstruction by using depth information (where accuracy requirements are less strict) is the Kinect sensor. The Kinect sensor captures depth and colour images at the same time and the integration of this depth and colour data results in a coloured point cloud.
An example of a project that used motion sensor technologies for 3D reconstruction is a project for the Multimedia Programming Course (Kastbjerg 2014). This project aimed at creating a projection mapping on non-flat areas. Projection mapping is a projection technology, in which real life objects are turned into projection surfaces. Video projectors display usually images on flat, white screens (e.g. watching a movie). Projection mapping is used for the challenging task of displaying images on non-flat, (possibly non-white) arbitrarily complex surfaces. For the projection on non-flat areas, a reconstruction of the 3D surface is needed. In this project, Kastbjerg used Kinect as a depth-sensing device in order to reconstruct the 3D surface and concluded that Kinect can be used for projection mapping applications.

6. Discussion

In this section we reflect on the introduction of motion sensor technologies for students' projects in a PBL environment. Our reflections target two directions: effect on students' technical skills and effect on students' creative skills.
For the projects that we included in our analysis, one of the research team was either project supervisor, lecturer of the course, or censor during project examination. Therefore, we were able to evaluate if students who experimented with motion sensor technologies were able to improve their technical skills. Our experience shows that the introduction of these technologies impeded development of technical skills. Motion sensor technologies come along with tools and interfaces that support the development of applications using these technologies. These tools and interfaces facilitate the development of applications to such extent, that students can produce sophisticated applications without much effort and deep understanding on the technical aspects. In many cases students could not explain why their applications functioned the way they did or how they could alter some aspects of them in order to change their functionality. Moreover, we experienced that many students failed in explaining the operating principles of motion sensor technologies and they could not apply knowledge from mathematics or physics in order to do so.
However, our results regarding students' creative skills are more positive. Students who chose to use motion sensor technologies for their semester or course projects have been quite creative. Students developed computer games, serious games, computer vision applications and simulators, and investigated new ways of controlling games and applications, as described in the previous section. Moreover, they explored new ways of using motion sensors, namely using them as depth sensors. Students reported also that they felt very enthusiastic during these projects, since these technologies provide many possibilities to their users. Finally, they welcomed the idea to provide students with novel and high-end technologies and let them develop their own ideas into concrete applications.

7. Conclusions

In this paper, we have presented our experience with the use of motion sensor technologies in student projects. In a problem- and project-based environment, we gave the opportunity to students to use such technologies in their projects, with the aim to improve both their technical and creative skills. Our results showed that students used motion sensors in various creative ways and developed interesting applications. However, according to our observations, the use of motion sensor technologies in student projects did not contribute to further development of students' technical skills.

Based on these results, we conclude that the introduction of motion sensor technologies in students' project work engaged students in creative and research-based learning, which is an important aspect of PBL. However, developing applications with such technologies does not require high technical skills, since these technologies are accompanied by advanced interfaces. Therefore, if the development of technical skills is considered important during learning, we suggest that there should be strict requirements on how students should use such technologies. In this way, students will be able to improve their technical along with their creative skills. We also suggest that motion sensor technologies are introduced to younger students, since they do not require advanced technical skills. Younger students could experiment with such technologies and use them in combination with single-board computers (e.g. Raspberry Pi) or single-board microcontrollers (e.g. Arduino) for the development of low-cost embedded systems. We argue that such projects have the potential to be both fruitful and fun for these ages.

The research presented in this paper will guide our future work, which will focus on addressing the question of how to guide or supervise the use of motion sensor technologies in student projects in order for it to lead to further development of students' technical skills, while preserving students' creativity and enthusiasm.

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