Design Methodology for Body Tracking Based Applications - A Kinect Case Study

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Abstract. Along with the popularization of new body tracking technologies such as Microsoft Kinect, and the increasing individual initiatives in order to design solutions for such platforms, it is necessary to improve and to adapt all the framework of methods and processes for developing new applications for this context. Just like that, this paper proposes a direction towards the formalization of an agile methodology for developing new applications on the background of body interaction, suitable for modest innovation projects with short schedules and small teams. To achieve that, we executed an experiment during a graduate course in Informatics, due to its similarities to the start-up context. The participating students followed a four-step methodology comprehending the stages of requirements identification, ideas generation, prototyping, and evaluation. The experiment outcomes are described in a way to enlighten the methodology techniques. As a conclusion, the students provided an extremely positive feedback regarding the adoption of the proposed methodology during the development of body interaction applications.

Keywords: Design methodology, body tracking, interaction applications.

1 Introduction

When it comes to small innovation projects, a quick development process suitable for each project's needs is essential in order to increase the odds of success. In such circumstances, it is common to have small development teams supported by one main idea and with short initial knowledge due to the use of recent technologies. Since these initiatives present high levels of uncertainty, a business model based on short development cycles and regular deliveries is desirable, once it is easier for the stakeholders to keep track. Summarizing, apart from the scarce human-resources and short schedule issues, innovation projects are also highly susceptible to severe budget limitations [12].

Regarding the interaction design context, these small initiatives generally make use of innovative platforms such as the Microsoft Kinect body tracking system in order to develop new applications. In addition to the great number of built-in features and

A. Marcus (Ed.): DUXU/HCII 2013, Part III, LNCS 8014, pp. 227–236, 2013.

sensors, this technology might be considered the first low-cost body tracking system, which provided designers and developers the opportunity to create a multitude of body interaction applications.

Distinct interaction approaches demand different functioning that must be considered when developing for this background. Errors in gesture recognition are highly likely to lead to frustration, requiring more robust solutions, and for reaching a high quality system, extensive testing is mandatory. On the other hand, prolonged usage of body tracking applications can overwhelm the tester, especially for the development team, causing too many interruptions during the implementation stage. These nuances bring new challenges in the development process, which are not equally found when developing for other devices.

In such way, this paper suggests an agile methodology for developing new applications in the context of body interaction, which is suitable for small innovation projects with short schedules and low budget. Accordingly, a methodological model for this reality should not hold back on documentation activities, but to aim at building functional disposable prototypes iteratively. It helps to keep regular productivity and the team members focused on validating the application concept.

2 Related Work

It is noticeable that a large majority of research about non-conventional body interaction applications are focused on developing software and describing the experiment for its validation. For instance, [9] presents important directions in order to formalize a methodology for the development and evaluation of interactive television applications (iTV), although his work did not formalize any recommendation yet.

In [14] is presented a solution to deal with the drawbacks of computer-mediated communication when compared to aspects of face-to-face communication like gestures and expressions. However, it is not one of its objectives to propose any design methodology or guidelines for developing similar applications.

Finally, [4] designed the MOWGLI system, in which the user interacts remotely and multimodally with large screen applications in real time. An ad hoc interface development methodology is presented and properly detailed, which, however, does not afford flexibility and does not focus on applications' development.

In such way, even though the interaction design field has in its theoretical body enough relevant studies towards the improvement of user interaction through movement and gesture, still few are the researches that propose general guidelines for the development of applications for this background. More critically, there is a lack of methodological uniformity that could direct the design of new body interaction systems.

Therefore, it is important to perform researches that aim to identify models in order to guide and facilitate other individual initiatives of development of new interfaces and applications for this field.

3 The Development Context

As it was commented previously, the start-up perspective presents some characteristics that demand many adjustments regarding its development process. Hence, a methodology suitable for this reality should emphasize agility along the procedure, especially in regard of testing activities.

At the same time, even though Microsoft Kinect may be considered a device of easy acquisition, small teams with limited resources may find restrictive the need of purchasing several Kinects for programming tasks. Aiming to keep up with rapid prototyping cycles means to abstract the Kinect presence so programing and testing tasks must be fast.

Projects for Kinect may have both serious or entertainment characteristics, thus the proposed methodology should be flexible enough to guide the development for either situation. Due to the early prototypes' stage, methods to be incorporated in such a framework should let final users free to criticize the system as well as to allow rapid compilation of testing results.

Once the scenario described above is understood, it was possible to establish similarities with another context: classes in the academy, for both situations imply learning, preparing and presenting results in a short period. Considering this time issue, it was established that the final working prototype should be developed within a four-month deadline, which is the common period of a course during a student's graduation. The methodology was executed in a Computer Science course throughout the beginning of its professional cycle, in a way that all the students had already finished the basic theoretical cycle, at the same time that they did not have enough practical experience.

4 The Proposed Methodology

The proposed methodology in this work is inspired in the lifecycle model for interaction design presented by [11], which comprehends four iterative main stages: identify needs and establish requirements, design or redesign, build an interactive version, and evaluate it. For each stage a specific method was chosen as discussed and presented next.

4.1 Competitor Analysis

Among several possible methods for exploring the problem, the analysis of similar products or competitors presents multiple benefits: it has easy execution once it can be performed using the internet; it simultaneously provides the description of how existing products compete among themselves as well as how they would compete with the one under development; it identifies and evaluate innovation opportunities, and also establishes goals for the new product in order to improve its competitiveness. Once enough data about products were collected, a parametric analysis should be structured in order to organize the information. This analysis aims to compare the product under development with existing ones, based on relevant parameters for the project. These parameters can be categorized as quantitative, qualitative or for classification [2].

The positive aspects of using the competitor analysis guaranteed the choice of this the technique for execution in the initial step of the proposed methodology. This procedure, more than selecting products, detail their characteristics through a parametric analysis, and it should result on a summary containing all requisites and guidelines for designing the new product based on its similar.

4.2 Lessons Learned and Brainstorm

To understand design as a process of generating solutions means comprehending the synthesis stage as the core of it. In spite of some methodological models presented in the literature do not specify techniques for generating alternatives or reference it in the framework, every model has a mandatory stage of creation. Commonly, if tools are specified for this step, the brainstorm technique is very likely to be mentioned.

The brainstorm procedure is straightforward: team members suggest ideas spontaneously as they come to their minds, as inconsistent and random as they like to be. The ideas are said out loud while someone writes them down on a flipchart or board. The technique's objective is to produce the bigger load of possible ideas, whereas quality is not the focus at this stage [6].

Although it has its mechanics well defined, the brainstorm can take different executions according to the stages that precede it. The amount of previous information about the problem – or even the lack of it – may severely influence the idea generation in many ways. It may cause ideas to be either properly feasible or entirely unreal, for instance.

For the proposed methodology, the brainstorm was executed right after the problem exploration step. This way, it had as inspiration source the document of lessons learned conceived at the end of the competitor analysis, which was also useful to define constraints. Generation of ideas happened in groups with related stimuli and forced association, according to the classification proposed by [13].

The selection of the alternatives created, however, was later performed as an independent process of simple voting and involved all groups.

4.3 Design of Prototypes with the Kina Toolkit

The authors in [5] defend the use of prototypes for various purposes, such as for identifying inconsistencies on project requisites or clarifying the evaluation of critical and complex parts of the system. In order to guarantee coherence among its functions, an application must be frequently tested along the entire programming stage.

Due to the complexity of the data produced by all the Kinect sensors – color image, depth map, skeleton pose and sound stream – deterministic tests are almost unfeasible, considering that for each testing cycle the programmer should provide the same input into the system. While programmers could be able to do so, it would quickly become an exhausting activity. Finally, the Kinect SDK still requires its hardware to be continually connected to the computer in order to execute the system while programming, and as it was commented previously, the need of several devices for programming is likely to discourage the investment in such technology by a small design team.

From the analysis of the issues discussed above as regards the development of body tracking applications, it was proposed the Kina toolkit with the objective of aiding and improving the creation of this kind of software. The Kina Toolkit is a group of tools that enhance the development process of applications that use the Microsoft Kinect SDK and makes the development not fully conditional to the existence of a sensor. Moreover, by providing playback capabilities together with an online movement database, it reduces the physical effort found while performing testing activities [10].

4.4 Questionnaire for Evaluation

Among several usability evaluation methods, [8] considers the questionnaires as indirect methods because they do not precisely evaluate the interface, but rather the users' opinion about it. Therefore, questionnaires are usually handled as post-evaluation methods in shape of quantitative forms presented to users once they have already interacted with the system. [15] point out as a positive aspect of this method the convenience of collecting data from users quickly as well as the fast tabulation and extraction of statistical information. It is common to make use of scales when preparing questionnaires, like a semantic differential scale or Likert. The latter was chosen for providing an easier way to formulate sentences to inspect specific issues, while semantic differential scales usually require more effort in order to employ the right terms for a very specific context.

The proposed questionnaire presented alternate positive and negative questions as suggested by [3]. According to the author, it demands more attention of the respondents and avoids a possible biased behavior. The final version of the questionnaire presented fourteen statements in order to evaluate user experience aspects. They were:

- I quickly understood what to do to interact with the system;
- I repeated the same movement several times consecutively;
- Movements are easy to be performed;
- It took me a while to perform the right movements in order to achieve a true interaction;
- The system recognized my movements properly;
- I felt tired after using the system;
- The proposed interaction with the system seemed more suitable than using traditional devices;
- I was too concerned about hitting close objects while using the system;
- the feedback for my movements were clear and quite satisfying;
- The feedback for my movements were delayed;
- I unintentionally activated features;
- I would feel uncomfortable to interact with the system in public;

- The interaction is compatible with the real world task, and
- It was not satisfying to use the system with interaction based on movements.

These statements comprehend, among other characteristics, user satisfaction, usability aspects and intuitiveness, as well as the learning curve. Users' physical welfare is also a constant concern when designing gesture-based applications, so it was analyzed fatigue and repetitive strain. Some other statements refer to the user's environment, regarding both spatial and social aspects. Another distinguished characteristic analyzed is the system robustness to gesture recognition, in order to avoid false positives and false negatives, since both situations are extremely likely to lead to frustration. These statements also respect some guidelines present in [7] published by Microsoft.

5 Methodology Results

5.1 Competitor Analysis

As commented previously, the first stage of the procedure was to perform a competitors' analysis, which was executed with an online collaborative tool. This way, students could insert the results of their investigation and observe contributions from other groups at the same time. This feature avoided equal data from different groups, guaranteeing a greater variety of analyzed applications. For each application, the following metadata were applied:

- title: it identifies the application among the others and allows fast searching;
- short description: application purpose, nature (entertainment, education, etc.), components and distinguishing features;
- positive and negative aspects: detailed review (the most relevant information is here), and
- images, videos and web links: all additional information.

A total of twenty applications were listed, among commercial, academic, and for productive or entertainment purposes. A brief example of entries of the final catalog is shown next. Only textual content is presented here due to page limitations.

Title: NAVI – Navigational Aids for the Visually Impaired – A student project in the course Blended Interaction [16].

Description: NAVI is a project developed by students with the objective of improving the navigation of visually impaired people. It makes use of a Kinect, a vibrotactile belt and ARToolKit makers.

Positive aspects: the NAVI system brings together on the same project powerful Kinect features, combined with the augmented reality provided by the ARToolKit. It gives tactile feedback by vibrating on users' waist, which supports orientation tasks when walking on a wide and populated environment.

Negative aspects: high cost in order to buy the entire system. The need to carry a wooden box attached to a backpack with a notebook, as well as the implications of wearing a Kinect on the user's head, may be considered bad ergonomic aspects.

5.2 Lessons Learned and Brainstorm

The second step started with a session of lessons learned, in which the participants presented their observation based on the previously acquired experiences from the competitor analysis technique. All students should compose a brief list of concepts in order to be employed as a related stimulus for a later stage, in which creative techniques could take place. This list also leveled everyone's knowledge about the main issues on developing body tracking interaction systems. At the end of it, the list of lessons learned was composed by nine topics as following:

- a multi-user system is more likely to be more entertaining;
- a system may undergo some delay depending on its complexity;
- the extended use of gestures inevitably tires players;
- the system must provide constant feedback to its users;
- to perform the same movements is boring; movements must constantly change;
- an application must have easy tasks;
- gesture-based applications demand considerable floor space;
- Kinect-like systems have a restricted tracking area; lateral movements should be avoided, and
- speech recognition features are generally underutilized by the analyzed applications.

Given that this research was performed along with Computer Science graduate students, it is necessary to emphasize that while the topics of the lessons learned list may seem obvious to an expert at a first sight, the formalization and sedimentation of the knowledge are fundamental for the creative process [1].

After finished the session of lessons learned, the students were asked to form groups and to start the creative process. This way, the class was divided into three groups (two with three members and one with four members), but all of them took part of the brainstorm session and cooperated among groups in order to define three scopes for all teams. As a result for this step, three main concepts were conceived and should be developed as described in the next session.

5.3 Prototyping with the Kina Toolkit

The BugClapper (Figure 1A) is a game in which the players must kill flying mosquitos by clapping their hands to achieve higher scores. Each match has a predetermined duration, although it can be extended by killing lots of mosquitos. The Kinect is used to capture users' movement and keep track of their hands, mapped into the virtual world as two white gloves. Power-ups were used as means to diversify the interaction movements, like the power of an insecticide, which requires the user to pretend to be holding a spray can.

The Functional Training project consists of a system capable of supporting users in functional training tasks (Figure 1B). This activity, first applied in rehabilitation, is based on performing fundamental movements and staying in specific positions for a given period in order to improve one's physical conditioning. The posture they should keep was classified according to three difficulty levels. Each level demand different physical preparation considering: balance, strength, flexibility, resistance, motor coordination and speed. The Kinect identifies if a posture is correct or not and informs the player. The system also has a general performance evaluation system that rates users from zero to ten according to the time spent on right positions.

The Paint.iNEct (Figure 1C) is a digital painting system that presents as a main characteristic the fact that users can paint with their body and use any part of it as a brush. It features the possibility of painting several different patterns on the screen, as well as an eraser and color pick tools. Another option given was to choose the distance to the painting screen. To do so, users should perform specific gestures that could not be misunderstood by the tracking system, avoiding possible false positives.

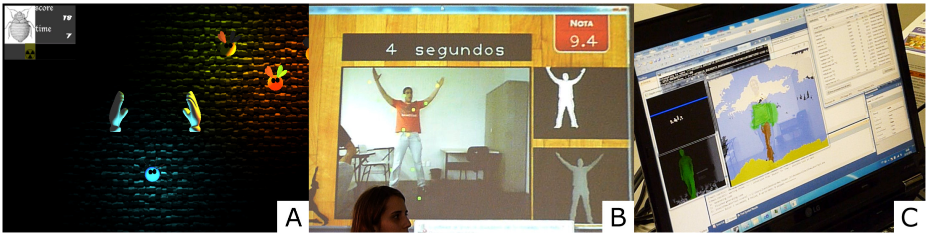

Fig. 1. BugClapper (A), Functional Training (B) Paint.iNEct (C)

5.4 Questionnaire for Evaluation

The three groups evaluated their applications with twenty subjects each. The prepared questionnaire was used in this phase, in which each subject should place his/her level of agreement according to each statement on a five-point Likert scale. Since it was known the applications had distinct purposes, it was defined an expectation control regarding the possible answers. For example, one of the final solutions was supposed to aid users while they executed physical exercises, thus if inquired about "feeling tired after using the system", to strongly agree with that would be considered a positive feedback. On the other hand, as for the Paint.iNEct application, which was designed for productive purposes, the expected answer to the same topic should be the opposite, which means that feeling too tired is obviously bad.

In order to analyze the questionnaires' information, it was taken the mean of each statement and this value was compared to the previously defined expectations for each group, as it can be observed in Figure 2. The evaluation can be observed by comparing both curves: the expected one, as an optimal outcome, and the real result, presented by the mean curve.

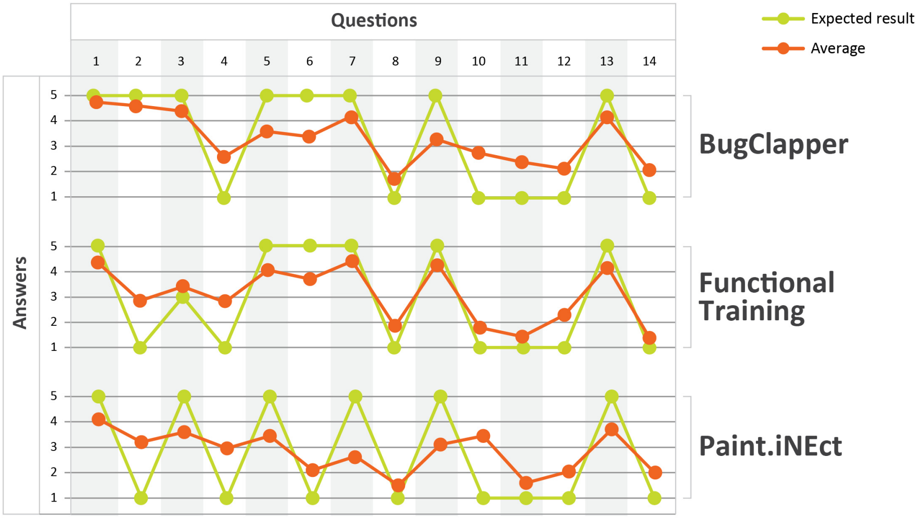

Fig. 2. Evaluation results for each application

6 Conclusions and Future Work

Even though more case studies are needed to validate this methodology, it presented a very satisfactory level of adequacy considering the proposed scenario. According to the participant students, the competitor analysis had a key role in order to formalize their knowledge and to specify the scope for body tracking systems as a possibility for interaction. Likewise, the concatenated session of lessons learned and brainstorm received excellent feedback.

The ease-of-use and convenience provided by the Kina Toolkit during the prototyping steps and functional tests was emphasized as a positive aspect, especially regarding the gain in time in programming tasks and the effort reduction when performing tests. Another advantage was mentioned, which is the possibility of easy interchanging for the execution of the prototype either in the Kinect or connected to a computer.

The questionnaire for evaluation has also shown itself very appropriate to this experiment due to the fast data tabulation and interpretation. Moreover, it rapidly suggested what to improve on each prototype precisely.

Overall, all students agreed that the adoption of a collaborative and structured design process during the development of body interaction applications with short schedule was imperative as a way of building their body of knowledge. Finally, the solution each group conceived achieved its objective of validating the application concepts that were initially proposed.

Future works indicate the need of more iterations aiming to verify the outcomes of using this methodology in more complex and longer projects. Considering the developed applications, a few flaws must be solved regarding its use. The BugClapper game presented some issues affecting the action recognition when users clap their hands, while for Paint.iNEct, users reported difficulties when trying to find a proper distance from the paint screen.

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