Design Thinking Methodology for the Design of Interactive Real-Time Applications

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Abstract. In recent years, many interactive real-time applications that simulate real situations have appeared. As with every product, good design is an important aspect in meeting the needs of the majority of users. Interactive real-time applications are no exception; they too must fit users while at the same time simulating reality, creating as perfect a mirror of the real world as possible. Design Thinking establishes a methodology for the development of every project, whether a product or a service, based on the conjunction of user needs, the technologies available and the requirements of the entities that request the project. We in the Design Area at Tecnun, the University of Navarra's School of Engineering, asked ourselves how well Design Thinking would help in the design of interactive real-time applications.

Keywords: design thinking, interactive real-time applications, design process.

1 Introduction

Design Thinking is an approach to problem-solving and projects where we adopt the techniques that designers use, the way designers work and how they approach problem-solving [1-2] in order to re-think different models across a variety of fields (business, health, etc.) and modify them or create new ones that are suitable for users, taking advantage of available technology. In recent years, the number of fields in which Design Thinking is applied has greatly increased [3].

Designers usually develop their work in real environments. The design of different objects, spaces or even entire services almost always refers to everyday situations and spaces.

However, interactive real-time applications have become a tool of particular interest in many contexts. We can find them in recreational environments, work facilities and education centres, among other places. There are several reasons for designing and using interactive real-time applications: avoiding certain dangers, saving money, avoiding the need to transport people and equipment, etc. Regardless of the purpose of the tool, it has to be properly designed and fit the needs of all potential users.

For this reason, at Tecnun School of Engineering we created a methodology based on the Design Thinking process adapted to the design of Interactive Real-Time

A. Marcus (Ed.): DUXU/HCII 2013, Part I, LNCS 8012, pp. 583–592, 2013.

Applications. We supported the methodology by using several tools that designers use to help them obtain all the necessary information while the methodology moves forward. Once we had the methodology, we applied it to a concrete spraying simulator to validate it.

2 Tool Selection

In this section, we describe our process of selecting the tools that define our methodology.

The first step that needed to be taken in order to properly define a Design Thinking methodology for the design of an interactive real-time application was to select the design tools that were most suited to addressing the design requirements for designing these types of applications.

For this purpose, we needed to clearly define what the needs were when designing these kinds of applications. In order to correctly design an interactive real-time application, the most important requirements are that reality is properly mirrored and that the interaction with the application is as pleasant as and similar to the real activity as possible.

With this information in mind, we went through the 51 IDEO Method Cards [4] and selected the ones that provided the most useful information about those requirements.

We chose 11 tools, which shaped the core of the methodology. While choosing those 11 tools, 16 other tools were discarded because of their similarity to the ones selected in terms of the information they provided. Table 1 shows the 11 tools we chose and gives complementary tools, which come from the tools we discarded.

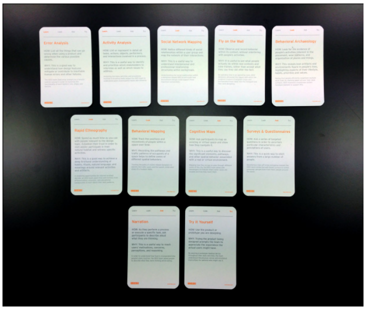

Fig. 1. Tools used in the methodology

Apart from those 11 tools, there were another 9 tools that we left outside the core of the methodology, though we felt they could be applied to any project were they become necessary or of particular interest.

Finally, 15 other tools were left out because they were inappropriate for the design of interactive real-time applications.

Table 1. Tools chosen in the methodology and complementary tools

Tool	**Information**	**Complementary Tools**
Error Analysis	This tool helps the team in charge of the design identify every possible error in the activity and in the simulator. When using 'Error Analysis' in the activity to be mirrored, errors that need to be simulated are found because trainees have to learn about them. Other times, errors are detected in order to prevent them from occurring in the application.	Scenario Testing
Activity Analysis	This helps designers identify all the tasks, all the steps to be taken, and all the objects in a process. This tool is very useful when used in conjunction with 'Error Analysis' since once every element of the process is identified and divided into smaller entities using 'Activity Analysis', it becomes much easier to identify every possible error and malfunction during each step.	Cognitive Task Analysis Flow Analysis Draw the Experience
Social Network Mapping	This technique allows designers to identify the different roles in the process; that is, the different jobs and responsibilities of each person involved.	Character Profiles Role-Playing Scenarios
Fly on the Wall	The information provided by this tool is related to how people behave while performing the activity that is being analysed. Designers gather the information through observation, though the people do not know they are being observed, thus avoiding expectancy effects [5].	A Day in the Life Still-Photo Survey
Behavioural Archaeology	Thanks to this tool, the design team gets to know how people organize the space where the activity takes place, what they have to wear, how they use and organize objects, and so on.	Personal Inventory
Rapid Ethnography	Similar to 'Fly on the Wall', with this tool information can be obtained directly from the people involved in the activity. The difference is that with 'Rapid Ethnography' a direct relationship is developed with the people in order to gain their trust, ask them about the activity, and participate in the activity with them.	Cross-Cultural Comparisons Shadowing A Day in the Life Still-Photo Survey Card Sort Foreign Correspondent
Behavioural Mapping	Thanks to this tool designers analyse how people use the space in which the activity takes place (how they position themselves, which areas are most used, and so on).	Guided Tours
Cognitive Maps	Similar to 'Behavioural Mapping', in this case designers ask the people involved in the activity to show them how they think of the space and how they navigate it.	Guided Tours

Table 1. (*Continued.*)

Surveys & Questionnaires	These can be used in different stages of the methodology in order to obtain different kinds of information for designing or testing the activity. It is important to consider that a proper number of interviewees are necessary so that the results are valid [6-8] and that bias can appear while interviewing people. [9-12].	Five Whys?
Narration	Information about the validity of the project can be obtained through users' narrating their experience interacting with the tool in real-time.	-
Try it Yourself	Useful information can be obtained when the design team uses and interacts with the designed application.	-

3 Methodology

The process of Design Thinking is an iterative one with several stages. It starts with a briefing that yields a framework for the future work of the team. After defining the brief, the team starts exploring everything related to what is going to be designed. This provides a good starting point for the next stage, a divergent phase in which the team generates as many ideas as possible, which will be refined in a later selection stage. Prior to the selection stage, Design Thinking encourages a prototyping phase. After choosing the ideas and defining how the product will be, the team must define who is going to do what, in how much time and with what resources. Lastly, the team cannot consider the design as finished when it is developed and in use: they must review the product and check whether it actually fits the needs of the potential users.

In light of this, we can divide the process of Design Thinking into these stages:

Define►Explore►Ideate►Prototype►Select►Implement►Review

Following the above seven stages of Design Thinking, we assigned the selected tools to the stages where their use is necessary and created a proper methodology for the development of interactive real-time applications.

Experience with a simulator for training operators of concrete spraying machinery helped us tune the methodology.

3.1 Define

As explained above, in this stage the designers or the entities requesting the project set a proper framework for the work to be done. This framework can be seen as a series of constraints that guide the subsequent work.

In the case of interactive real-time tools, it is very important to define how faithfully the simulator must reflect reality. At a first glance, it would seem important to reflect reality perfectly, but in many cases only certain aspects need to be simulated rather than the entire activity. Other times, certain effects need to be exaggerated in order to make them noticeable.

3.2 Explore

The purpose of this second stage of the process is to gather information about everything that surrounds the project that is going to be tackled: potential users and their needs, previous solutions to the same issue, etc.

This stage will give the team very important information for the future generation of ideas, as it will help ensure that the ideas will be oriented toward the needs of the project.

The tools that are considered to be most suitable for this purpose are the following:

- Social Network Mapping
- Surveys & Questionnaires
- Rapid Ethnography
- Cognitive Maps & Behavioural Mapping
- Error Analysis

3.3 Ideate

During this stage, it is important to identify the things that are relevant to the people involved in the activity and to generate as many ideas as possible [13] for meeting those needs. Brainstorming is the core of this stage, but it is also important to consider other ways of getting insights for the future design. With that in mind, the appropriate tools for this stage are the following:

- Behavioural Archaeology
- Fly on the Wall
- Try it Yourself

3.4 Prototype

Design Thinking promotes prototyping from the beginning stages of the design process. Furthermore, early prototyping of software design is recommended in order to help users identify their needs in order to make them part of the process, among other reasons [14].

According to the Design Thinking methodology, the prototypes do not usually need to be detailed or working prototypes in the early stages of the process. However, when designing real-time applications, it is helpful to use an evolutionary approach

[15-17] to start developing the simulator so that it becomes the prototype itself. The tool selected for this stage is:

- Error Analysis

3.5 Choose and Implement

These two stages of the design process are merged since the tool that is most suitable for both stages is the same, and its application is based on the analysis of the reality that is being simulated.

- Activity Analysis

When this information becomes available, the development of the simulator can begin, using both the results of the activity analysis and the requirements from the briefing.

3.6 Review

Once the project is finished, the design team will have to keep track of how the product is introduced to the users whether it really fits the purposes it was conceived for, and identify possible areas of improvement and collect information from the people that benefit from the application.

In the case of real-time applications, three tools help the review process, two of which are used in prior stages.

- Fly on the Wall
- Narration
- Surveys & Questionnaires

4 Methodology Applied to a Real-Time Application

Once the methodology was defined, we applied it to a real project in order to validate it. The target was a real-time simulator for training operators in concrete spraying [18]. This application simulates the tasks involved in effectively and safely spraying shotcrete and was developed with the collaboration of the Santa Barbara Foundation (FSB), a training centre located in Spain.

FSB started the first stage, Define, by providing us with a brief with all the requirements of the project.

After that, the rest of the methodology described in the previous section was applied to obtain the necessary information for the development of the application (Table 2).

Table 2. Methodology and tools applied to the concrete-spraying project

Stage	Tool	Information obtained
Explore	Social Network Mapping	Different levels were not identified in the activity. Nonetheless, we found it necessary to set different levels of learning in the application for the operators to gain different skills step by step.
	Surveys & Questionnaires	Several interviews were conducted with different operators to learn about how they use the machine, their work and the environment.
	Rapid Ethnography	Operators in FSB were open to explaining how the machine works and how it is handled. The information was recorded and analysed.
	Cognitive Maps & Behavioural Mapping	Thanks to these two tools, we learned about the possible scenarios in concrete spraying and about how the operators position themselves to perform their activity.
	Error Analysis	This work was facilitated by FSB based on their experience. They gave us a complete dossier with all the possible breakdowns and incidences.
Ideate	Behavioural Archaeology	Thanks to behavioural archaeology we learned that, due to the difficult, dirty and dusty environment while spraying, special protection must be worn and that other objects, apart from the machine controls, are difficult to use.
	Fly on the Wall	Our team took the opportunity to observe the operators in real situation to obtain additional information about the activity.
	Try it Yourself	People on our team were able to test the machines that FSB uses. Thus, we learned first-hand how to operate them and how to use them to obtain perfect results while spraying.
Prototype	Error Analysis	Following the evolutionary approach for prototyping, different betas of the application were shown to FSB and tested to identify all the possible errors within it. In addition, these tests helped FSB find things that were missing in the application.
Choose & Implement	Activity Analysis	With the help of FSB and the observation, our team divided the activity into smaller tasks and steps. We also identified the devices involved in each step and thoroughly analysed their functioning.
Review	Fly on the Wall	After the application was developed, thirty-five people (trainers and trainees from FSB) tested the application. Not everyone did all the exercises but all the exercises were performed at least once.
	Narration	During the tests, people were encouraged to narrate their experience. The information was recorded and subsequently analysed.
	Surveys & Questionnaires	The last tool used in the post-development stage was a questionnaire prepared by our team. The thirty-five people completed the questionnaire and the information was subsequently analysed.

5 Results

After applying the methodology described above, a shotcrete machine simulator [19] was developed that fit the requirements and the results of the entire Design Thinking process.

5.1 Simulator Description

The goal of the simulator was to offer a detailed course for learning to spray concrete. For this purpose, all the possible scenarios where the concrete spraying machine is used and all the possible ways to use it were simulated.

The visual environment of the simulator took into account multiple factors such as shadows, light refraction, water effects, and so on. The sounds that accompany the activity were also simulated to enhance the experience.

To accurately reproduce the interaction with the machine in real life, a device with two joysticks and eight buttons controlled the simulator, thus emulating the real controls of the machine.

Three levels of training were established: basic, intermediate and advanced. This addresses what we observed during the Explore stage using the social network mapping technique.

The computer automatically evaluated the exercise. For those aspects that the computer could not evaluate, an instructor needed to be present to take notes on those aspects.

5.2 Review Stage Questionnaires

As we stated in the Review stage, questionnaires were given out to evaluate:

- Interaction with the simulator
- Realism of the simulator
- Teaching capacities

Table 3. Results of the questionnaire

Question	Median	Mean	SD
To what extent do you feel that the interaction with the virtual environment is natural?	4	3.77	0.57
How similar are both experiences: spraying with the simulator and spraying with real machinery?	3.5	3.55	0.74
How realistic is the way that shotcrete adheres to the surface?	4	3.58	0.82
How realistic is the modelling of the rebound effect?	4	3.69	0.69
How realistic is the modelling of cohesion failures?	4	3.8	0.69
To what extent is training with the simulator more comfortable than training on-the-job?	4	3.95	0.87
How would you rate your motivation while performing the training exercises?	4	3.95	0.84
How would you rate the training capacity of the shotcrete model?	4	3.9	0.74

There were ten questions that respondents rated on a five-point Likert scale. Thirty-five people were given the questionnaire, and the results of the questionnaire were subsequently analysed to obtain the data in Table 3.

6 Conclusions

Design Thinking has shown itself to be an effective methodology for the design of interactive real-time applications.

Following a specific methodology and choosing the correct and most suitable techniques for this kind of project, we balanced the needs of the users, the requirements of the project, the needs of the company developing it (FSB in our particular case) and the technologies available for this tool.

Currently, we are working on applying this methodology to new projects. Many of these projects are related to virtual reality applications.

Furthermore, according to the questionnaire results listed above, we see that the tool has been validated and enjoys wide acceptance among users.

We also validated that the prototyping method we used was correct and suitable for these kinds of projects. The prototype gave us valuable information at every iteration, until the final product was released.

Again, Design Thinking proves that its creativity-based methodology can be of use for any kind of project. Design Thinking also makes it clear that creativity is not only an isolated spark but also a whole system that can bring important results.

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