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A Task-Based Design Approach for Augmented Reality Systems

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Abstract**—**User interaction components of Augmented Reality (AR) systems have to be tested with users in order to find and fix usability problems as early as possible. In this paper we will report on a user-centered design approach for AR systems following the experience acquired during the design and evaluation of a software prototype for an AR-based educational platform. In this respect we will focus on the re-design of the user task based on the results from a formative usability evaluation. The basic idea of our approach is to describe task scenarios in a tabular format, to develop a task model in a task modeling environment and then to simulate the execution.

Keywords**—**AR-based educational systems, task-based design, usability evaluation.

I. Introduction

UNDERSTANDING the user tasks, how and why task modeling plays an important role in the design process is a pre-requisite to design a usable interactive system. Unfortunately, there are few techniques that support the design for usability of Augmented and Mixed Reality [7]. Task elicitation is more difficult for AR based systems than for traditional systems since real and virtual objects (computer generated) are integrated into a real environment.

According to Azuma [2], AR systems are featuring an integration of real and virtual (computer generated images) into real environments, real time 3D interaction and targeting all senses (visual, auditory and haptic). Augmented Reality is a variation of Virtual Reality (VE) that supplements reality, rather than completely replacing it.

AR technologies are expensive and require a lot of research and design effort to develop visualization and rendering software. On another hand, the mix of real and virtual requires appropriate interaction techniques. As pointed out by Hix et al. [4], the user interaction components of this kind of applications are often poorly designed and rarely tested with users. They proposed a design and evaluation framework having as central components user task analysis and formative evaluation.

Formative usability testing is performed in an iterative development cycle and aims at finding and fixing usability problems as early as possible by testing the software with a relatively small number of users. It is especially effective to support the development of novel systems as they are targeted at a specific part of the user interface design.

This paper aims at presenting a task-based approach undertaken in the framework of the ARiSE project. ARiSE (Augmented Reality in School Environments) is a research project that aims at creating an augmented reality technology for schools by adapting a virtual showcase used in museums. ARiSE will develop interaction scenarios for learning and associated software prototypes in order to assess the pedagogical effectiveness of the AR technology [1].

The 1st prototype has been tested with users during a summer school organized in Hamrun, Malta. The objectives of the test were to assess the pedagogical effectiveness and usability of the prototype. Several evaluation techniques have been used: observation, usability questionnaire and focus group.

In this paper we will elaborate on a user-centered design approach for AR systems based on the experience acquired during the design and evaluation of the 1st prototype. In this respect, we took into account the positive and negative aspects mentioned by students and teachers and decided to re-design the task model and to enrich the interaction scenario.

The rest of this paper is organized as follows. The evaluation context (platform, participants and tasks) and usability problems identified are briefly described in the next section. The design approach is presented in section 3. The paper ends with conclusion in section 4.

II. Results from a Formative Evaluation

A. The Evaluation Context

The AR platform consists of 4 independent modules organized around a table on which real objects are placed. The platform has been registered by Fraunhofer IAIS under the trade mark Spinnstube®. [3]

In Fig. 1, the photo of a module is presented.

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Fig. 1 A module of the ARiSE platform

The project will implement three prototypes based on three interaction scenarios. The 1st prototype is targeting Biology.

The real object is a flat torso of the human digestive system. A paddle has been used as interaction tool that serves for three types of interaction: (a) pointing on a real object, (b) selection of a virtual object and (c) selection of a menu item.

Five user teams from 4 countries (Germany, Lithuania, Malta and Romania) participated at the summer school with a total of 20 students from which 10 boys and 10 girls. None of the students was familiar with the AR technology. 16 students were from 7th form (13-14 years old) and 4 from 11th form (16-17 years old).

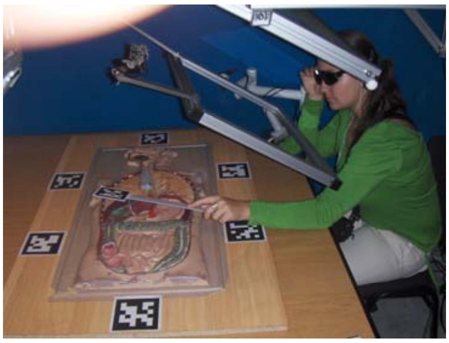

Fig. 2 User performing the 1st exercise

The participants have been assigned 4 tasks: a demo program and three exercises. The tasks have been presented via a vocal user interface in the national language of students. According to the test plan, each team should test the prototype in two working sessions: demo + 1st exercise and 2nd + 3rd exercise.

B. *Findings*

The usability questionnaire had 12 closed items and 2 open questions, asking the user to describe the most positive and negative aspects. In Table I, most mentioned positive aspects are summarized in a decreasing order of their frequency.

Educational support includes aspects like: easy to understand the lesson, stimulating to learn, easy to learn the lesson, usefulness of the demo program, flexibility (potential to do other things) and possibility to repeat the exercise.

TABLE I
SUMMARY OF MOST POSITIVE ASPECTS

Category	Frequency
Educational support	29
Funny, alike games	19
Attractiveness and comfort	11
Novel, original and interesting	10
Interaction 3D and animation	10
Easy to understand and use	8
Vocal interface and clear explanation	8

The fact that students liked the similarity with a computer game (learning by doing) shows the intrinsic motivation created by the AR technology (“the system makes me to want to work with it” or “big stimulation of trying to understand the topic”). The 3D interaction and animation are other positive aspects of the AR technology (“the 3D animation raise the interest” or “it is well animated what happens with the food”).

Several usability problems have been identified by analyzing the most negative aspects mentioned by students. A summary is presented in Table II.

Most frequent was the difficulty to reach each organ with the interaction tool. (“some areas for my position were very unreachable”, “I’m not always able to reach everything” or “not every organ is to be reached”). This category of usability problems are related to the selection technique.

TABLE II
SUMMARY OF USABILITY PROBLEMS

Category	Frequency
Selection	31
Interaction tool (paddle)	14
Feedback	14
Discomfort	12
Clarity of sound and writing	7

Second category of negative aspects was the difficulty to use the interaction tool (paddle) which sometimes blocked (“sometimes the cursor isn't moving” or “the program doesn’t reacts to my actions sometimes”). Other negative aspects are related to the discomfort provoked by the stereo glasses and the position of the screens.

III. THE TASK-BASED DESIGN APPROACH

A. *The Concur Task Tree Notation*

Task modeling in HCI is an important concern for developers aiming at producing usable systems. The ISO 9241-11:1994 standard defines usability as the extent to which a product can be used by specified users to achieve specified goals effectively, efficiently and with satisfaction in a specified context of use. In this standard, the context of use has four main components: user, tasks, platform and environment.

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Several notations and tools exist for task modeling. Concurrent Task Trees (CTT) [6] is a notation that is using constructors, termed as operators, to link sibling tasks, on the same level of decomposition. This is different from other notations where operators are describing parent-children relationship thus scoping over all sub-tasks in a task.

CTT uses a tool for editing the task model used to specify tasks, roles, and objects as well as the task hierarchy with temporal operators. Another feature of CTT is its graphical facility providing means to describe different task types like abstract, co-operative, user, interactive, and application. The Concur Task Tree Notation has been implemented in the CTT Environment (CTTE) which is providing with a graphical notation for task representation (see Table III) and temporal operators (see Table IV).

TABLE III
TASK CATEGORIES IN CTT

Abstract	Interaction	Application	User	Cooperative
				

There are some restrictions in combining binary and unary operators. For example, the combination T1*>>T2 is not allowed, since T2 will be never performed. Also, optional tasks are not allowed in the left and right side of the operators |>, [> and [ ].

CTTE enables the designer to create task trees and to specify task properties such as task type, frequency, and estimated execution time. An important feature is the XML output capability that makes CTTE a useful tool for the handling of mappings between the task model and other models.

TABLE IV
TEMPORAL OPERATORS IN CTT

Binary operators	
Choice	T1 [ ] T2
Order independency	T1 |=| T2
Interleaving	T1 ||| T2
Synchronization	T1 |[ ]| T2
Enabling	T1 >> T2
Enabling with info passing	T1 [ ]>> T2
Disabling	T1 [> T2
Suspend / resume	T1 |> T2
Unary operators	
Optional	[T1]
Iteration	T1*

The temporal priority (from higher to lower) is given below:

[ ], |=|, |||, |[ ]|, [> and |>, >>, [ ]>>.

CTT provides us with means to describe co-operative tasks: a task model will be composed of different task trees: one for the co-operative part and one for each role that is involved in the task. Tasks are further decomposed up to the level of basic tasks defined as tasks that could not be further decomposed. Actions and objects could be specified for each basic task. Application objects could be mapped onto perceivable objects in order to be presented to the user.

CTTE is publicly available and could be downloaded from the following web address: http://giove.cnuce.cnr.it/ctte.html

B. *The Task Model for the 1st Exercise*

After evaluation we realized that many usability problems are due to a lack of understanding of user tasks. Although the initial interaction scenario has been specified in detail by using a PowerPoint presentation, many requirements which were not explicitly represented had been lost at implementation time.

In order to present our task-based approach we will take as example the first exercise preformed by students. The task model represented with the CTT notation is given in Fig. 2.

The task goal is to identify the organs of the digestive system. First, the student is given a vocal explanation on how to perform the task. Then, the list of organs is displayed and the organ to be identified by the student is highlighted in the

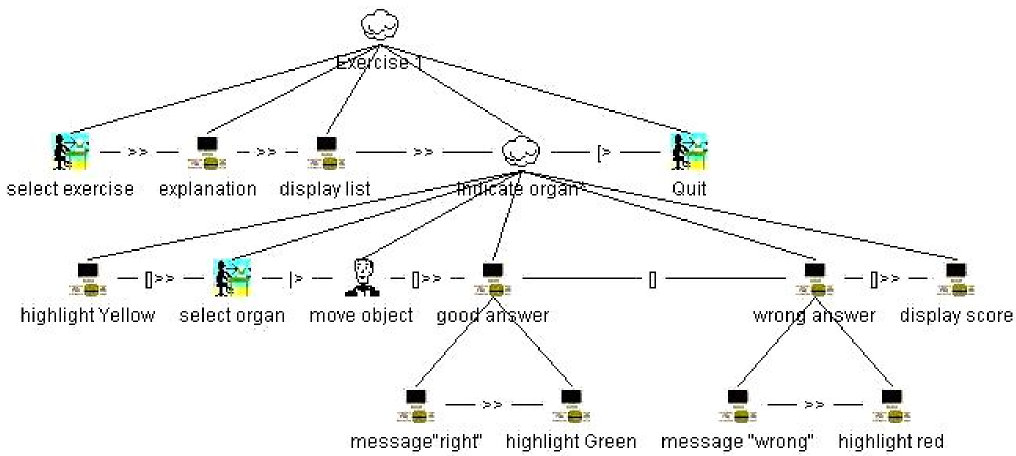

Fig. 2 The task model for the 1st exercise

list. The student has to point to the organ on the real object by using the paddle. If the answer is good, (s)he receives a positive audio feedback and the object is highlighted in green. If not, the student receives a negative audio feedback ('the answer is wrong'). Then a new organ is highlighted in the list and so on. The time elapsed and the number of right / wrong answers is displayed on the screen.

Our approach is to model each task by using the CTT (Concur Task Tree) notation and to link the graphical representation with a tabular description for each task scenario, close to User Action Notation.

The scenario for the first exercise is described in Table V.

TABLE V
SCENARIO FOR THE TASK "EXERCISE 1"

Task name	**User input**	**System output**	**Description / observations**
Select exercise	Select "Exercise 1" from the menu	The menu is displayed	Select the exercise with the paddle
Explanation		Vocal explanation	[text to be recorded]
Display list		The list of organs is displayed in the left part of the screen	[list with the names of the organs]
Indicate organ			Iterative abstract task, to be performed until no more organs to be indicated and the student quits the exercise
Highlight Yellow		The name of the organ from the list is highlighted in yellow	
Select organ	Select the organ		Select the organ with the paddle
Move object	Move real object		Bring the organ in the selection area
Message "right"		Vocal message	[message to be recorded]
Highlight Green		The name of the organ from the list is highlighted in green	
Message "wrong"		Vocal message	[message to be recorded]
Highlight Red		The name of the organ from the list is highlighted in red	
Display score		Written text	Update and display the results (good / wrong answers) and execution time
Quit	Select "Quit" from the menu	Return to the main menu	Select "Quit" with the paddle

The specification is completed with an appendix containing the images of the organs (the developer should be provided with the mapping image-name) and the text messages to be recorded and loaded into the system. This way we benefit from the graphical notation and temporal constraints provided by CTTE without losing the detailed specification of each task. Moreover, the execution could be easily simulated with the CTTE tool.

A usability problem was related to the size of real object that exceeded the selection area. In order to reach all organs, the student has to move the real object and / or adjust the screen position. The task "move object" has been modeled with the suspend / resume operator (|>).

IV. CONCLUSION AND FUTURE WORK

In this paper, we presented some results from a formative usability testing that have been further used for the re-design of a software prototype. The main conclusions could be summarized as follows:

- Usability of AR systems depends mainly on the design of the interaction components. Formative usability testing is useful and cost-effective since it helps to find usability problems early in the development cycle.
- A task-based approach is supporting developers in understanding both the user tasks and the interaction space integrating real and virtual objects. In this respect, CTT representation together with a tabular description of the scenario is a useful design aid.

This work is a first step in the task-based design of the ARiSE platform. The next step is the testing of the second version (currently under implementation). Future work will address task modeling for the second prototype.

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