An Evaluation of Mobile 3D-Based Interaction with Complex Multimedia Environments

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Abstract. This paper describes the evaluation of an intuitive mobile environment controller. Through its 3D-based user interface, the PDA based controller provides the user with mobile access to her/his physical environment and ambient media. The goal of this usability evaluation is to test the performance and analyse the user acceptance of 3D-based interaction systems compared with traditional WIMP-based controllers. At first this paper describes the interaction model which has been evaluated. Then it explains the experiment and the approach of the evaluation. Finally we present and discuss our results.

1 A Novel 3D-Based Interaction Model for Human-Environment-Interaction

Ambient Intelligence (AmI) is the vision of a world where we are surrounded by a huge amount of intelligent and small things, which are seamlessly embedded in the user‘s environment [1]. They pro-actively support the user‘s everyday activities. In this world one major question is how to interact with all those devices? How to access physical devices in an unfamiliar environment without having knowledge about the technical infrastructure such as device addresses and IP-numbers?

Existing interaction systems for multimedia environments (like meeting or lecture rooms) are mostly based on complex menus and icon-based user interfaces (e.g., see fig. 1). In order to access a device, the user has to browse complex menu hierarchies and select a device based on its unique name or device address. Especially in unfamiliar environments, this is a challenging task (due to cognitive overload).

The Personal Environment Controller (PECo) provides a novel interaction metaphor to control intelligent environments. Its goal is to allow the user to easily access virtual and physical objects surrounding him. PECo uses an automatically created 3D visualization of the environment. Entering a room PECo discovers the infrastructure as well as available devices and constructs the integrated user interface. The user can easily identify a device within his environment based on its position, orientation, and form, and directly manipulate it within the 3D-scene. For example, he can simply click on a 3D object to turn on a light. The 3D-based user interface allows the user to access the infrastructure without having knowledge about specific device names,

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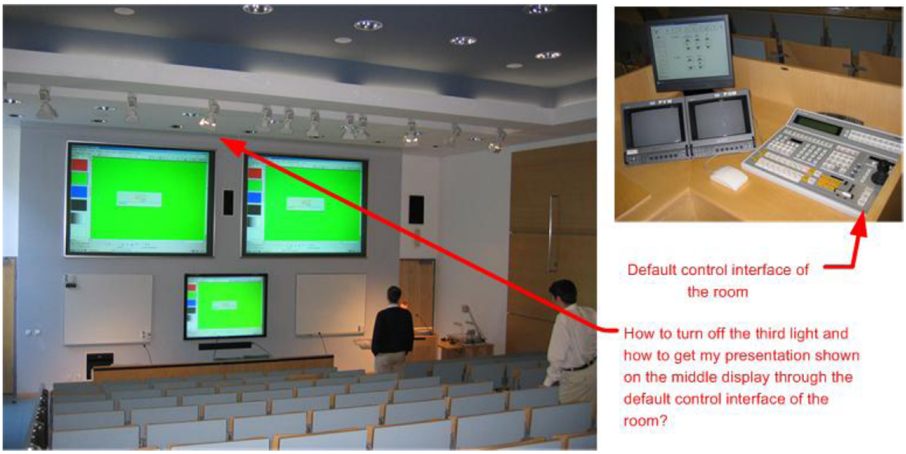


Fig. 1. Challenges of Human-Environment-Interaction and the complex structure of existing control systems (the control panel right)

IP-Numbers, URLs, etc. Figure 2 shows a complex meeting room and the corresponding user interface within the PECo system.

Furthermore PECo amalgamates the user‘s virtual media repository and the physical environment into a personal environment. By interconnecting these two worlds, the user can drag a presentation from her/his virtual media repository and drop it onto a representation of a real-world display with just one interaction step (drag&drop).

The interaction model has been discussed in detail in [2]. Some other aspects of the PECo user interface, the interaction concept, as well as the way how the 3D model is created dynamically for a new environment, are described in detail in [2, 3, 4, and 5].

2 The Evaluation

The evaluation of PECo has been done by a quantitative usability test and a complementary qualitative analysis of the software ergonomics based on ISO 9241/10 questionnaires [6].

Within the scope of a quantitative usability test, the task completion time and the rate of errors have been analysed. For this reason the subjects have used two interaction systems to perform activities within a meeting room. This allowed us to compare the usability of the mobile 3D-based PECo system against a stationary central control panel (CCP) which is based on traditional menus and icon-based metaphors.

The user evaluation has been performed in a traditional meeting room (see fig. 1). The usability test analysed most important activities of a presentation scenario. We selected the test situations and the activities involved with them from a situation-concept and a hierarchical task model for presentation scenarios see [7–9]).

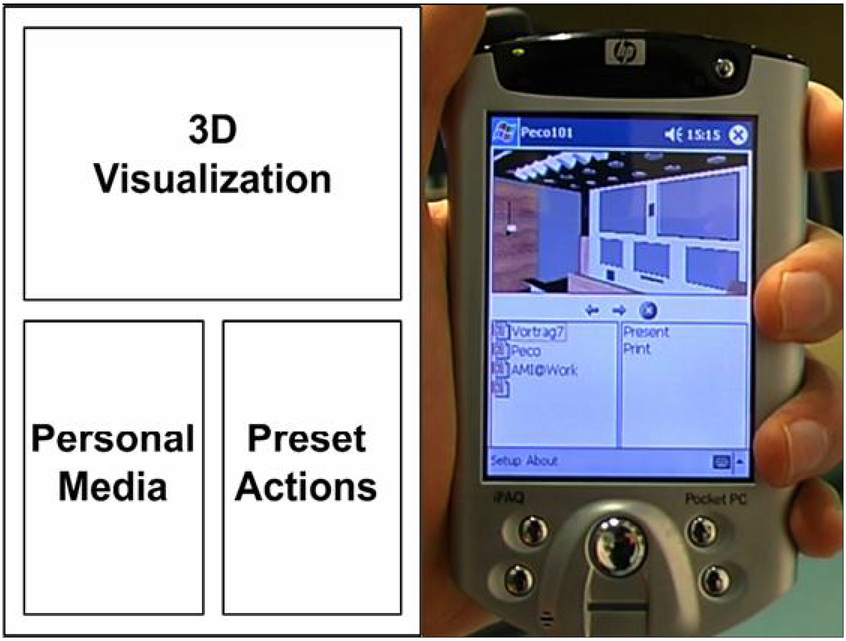


Fig. 2. The PECo-system uses a 3D-based interface to provide access to complex multimedia environments

A total of 46 subjects performed 41 different test cases (e.g., “set up the room for a presentation!” or “present your thesis-slides on the back-projection system!”); all cases included several activities within three different situations (Presentation, Setup, Explanation). Each activity has been performed three times with the PECo system and three times with the central control panel. By doing so we were able to analyse the learnability / the learning curve for each of the interaction system. Some activities have also been performed using manual controls (e.g. light switch). Before performing an activity, we prepared the room and re-started the interaction systems. Each subject has been introduced to both of the control systems. Two scientists observed them during their tasks. One of them measured task completion time. The other one counted the subject‘s error rate. We avoided having several test users in the room at the same time.

After performing the quantitative usability test (task completion time and error rate) we interviewed 38 of the subjects using the ISO-questionnaires to analyze the suitability of PECo, the self-descriptiveness of the user interface, controllability, conformity with user expectations, error tolerance, suitability for individualization and suitability for learning. The structure of those questionnaires is described in [6]. The interviews have been used to perform a qualitative analysis about the suitability of PECo. Minor modifications have been done in order to adopt the questionnaires to our system.

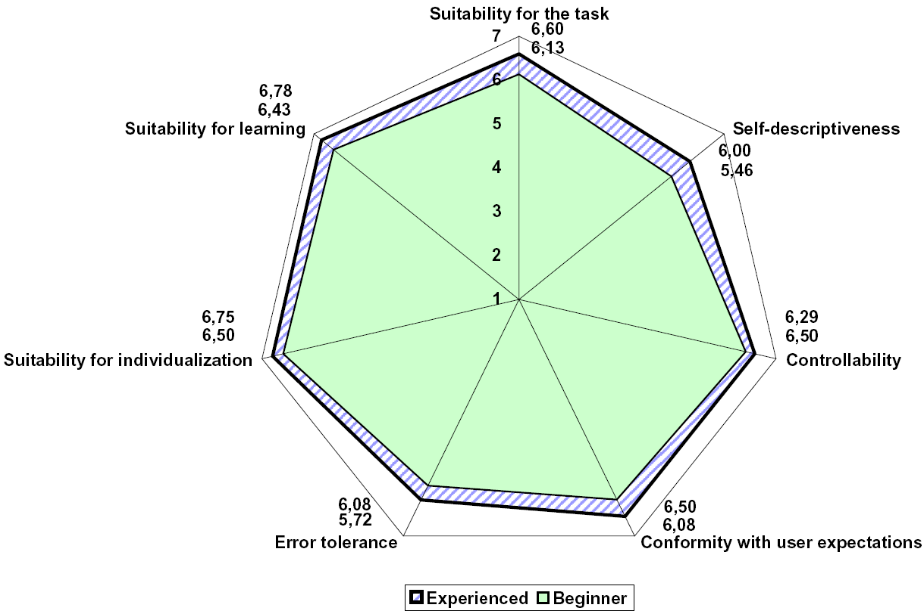


Fig. 3. Results of the ISO 9241/10 questionnaire showing the user interface "quality" of PECo. We show the results for two different user groups; a 3D-user interface beginners group and an experienced 3D-interface users group. All users have already worked before with PDA and touch-screens.

3 Results and Discussion

We present a study that evaluates conventional control systems and 3D- based user interface for accessing physical environments within presentation scenarios.

We are presenting results from two studies. The first study precisely demonstrates the performance of each interaction system for a given task. The second study shows the general usability aspects of the PECo system.

Our results show that the 3D-based interaction was significantly faster and required less mental effort than conventional interaction systems; this was true for all situations and for all performed activities. For example, the subjects performed the tasks for environment management – like light or projector control – just by clicking once into the 3D-scene. This step took 2.15 sec in average.

In order to perform the same activity with the CCP they needed more then 10 sec. We also analysed the learning curve for each interaction systems. The learnability for PECo is very good in comparison to the other systems.

Figure 4 shows the task completion time for 4 activities which have been performed under the situations "Setup" and "Presentation". For the required Human-Environment-Interaction manual control systems like switches, the central control panel (CCP), and the PECo system have been used. Figure 5 shows the task completion time for 8 different activities which have been performed using the different

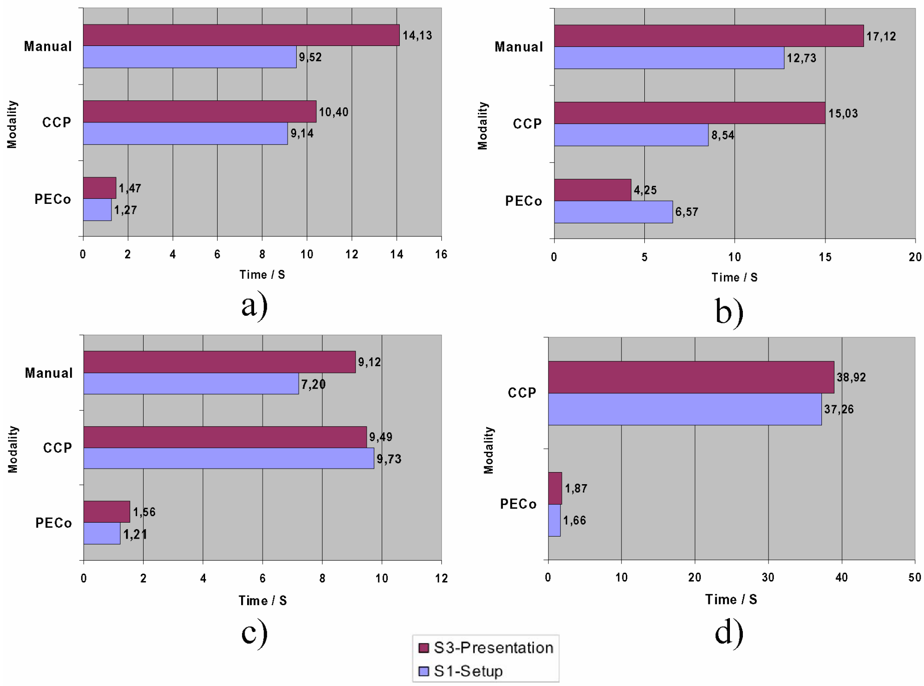


Fig. 4. The picture comprises the task completion time within the situations “Setup” and “Presentation” for 4 activities: a) Audience Light control, b) blind shutter control, c) Panel Light control, d) presentation control

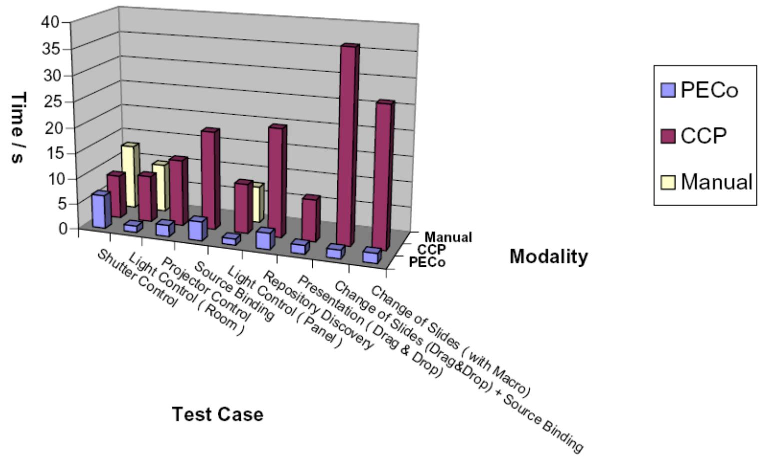
control systems under the “Setup” situation. The activity “presentation change” was performed using two different metaphors of the PECo system. These results show that the overall performance of the analyzed activities and situations is significantly higher for PECo compared to CCP or manual control.

Additionally the results of the questionnaires show (see fig. 3) that the interaction design of the PECo is easy to understand and easy to use.

Moreover, the relationship between user experience and efficiency can be expressed by learning curve. As individuals get more experienced at a task, they usually become more efficient at them. The learning curve states that the more times a task have been performed, the less time will be required on each subsequent iteration.

Figure 6 shows, the learning curve of performing four tasks using two interaction systems, PECo, and CCP. The user performed three times the specific activity (1^{st} – 3^{rd} iteration) within the “setup” situation. The rest of the test case (iterations 4^{th} – 6^{th}) have been performed and measured under the “presentation” situation. As you can see the required time for performing the test number 4 increases in all diagrams, since there is a time gap (~ 30 minutes) between running test 3 and 4.

Figure 6.a, shows the learning curve of presentation rendering task. The average time of performing this task in test2 is rapidly decreased. Actually, the “presentation rendering” task is a set of seven tasks; projection selection, projector on/off, source



	Shutter Control	Light Control (Room)	Projector Control	Source Binding	Light Control (Panel)	Repository Discovery	Presentation (Drag & Drop)	Change of Slides (Drag&Drop)	Change of Slides (with Macro)
PECo	6,57	1,27	2,24	3,74	1,21	3,19	1,70	1,66	1,92
CCP	8,54	9,14	13,02	19,29	9,73	21,20	8,20	37,26	27,50
Manual	12,73	9,52			7,20				

Fig. 5. This diagram shows the task completion time for the "Setup" situation whereby PECo-based control is compared to CCP and manual control

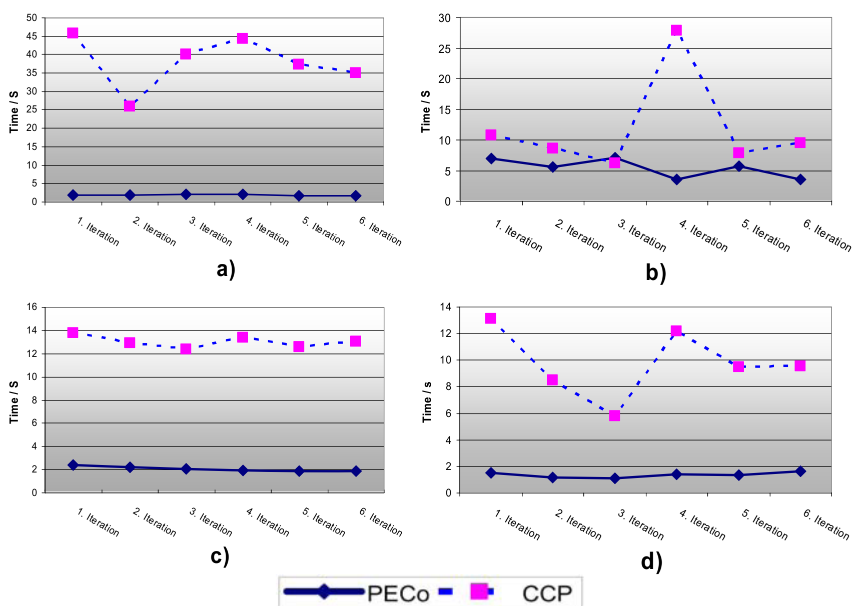


Fig. 6. The learning curve of the PECo interaction system compared to the CCP interaction systems for performing four typical tasks; a) Presentation rendering, b) Shutter movement, c) Projector control, and d) Audience light adjustment

browsing & selection, source binding, media browsing & selection, media opening, and media rendering. In test1/ test3, the user has been asked to choose notebook/camera as source and show its output on the display. It was very complicated and time consuming task to find notebook/camera source option within the CCP interaction system. But in test2, the users have asked to choose “Room PC” as source which was an easy task using the CCP interaction system. Hence required time for performing “presentation rendering” task making use of CCP in test 2 was very low, since most users were able to find the “Room PC” quite easily.

Figure 6.b, belongs to “shutter movement” task. The average time of performing this task for the test 4 is too much (~ 27 seconds). The reason for that lies in the complicated shutter control of the CCP interaction system. Some users have found the shutter interaction menu too late, while some users could not find the shutter interaction menu on the CCP at all.

The percentage of learning could also be calculated by the learning percentage formula (1) [10],

$$Y_x = Kx^{\log_2 b} \tag{1}$$

where K is the time of performing the desired task for the first test, Y_x is the time of performing the desired task for the x-th test, x is the test number, b is the learning percentage.

Making use of this formula, we have realized that the learning percentage of all aforementioned tasks using PECo is higher compared to CCP. As an example, the learning percentage (b) for performing projector control task using PECo system is 9% whereas it is just 2% for the CCP system.

Future research will focus on providing new metaphors and icons as well as improving the user interface look&feel. An extended usability evaluation will be conducted to investigate and compare different metaphors to perform a certain interaction step.

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