
AC 2011-1653: DESIGN AND EVALUATION OF A 3D CONSTRUCTION MOBILE GAME FOR THE IPHONE/IPOD TOUCH PLATFORM

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Design and evaluation of a 3D construction mobile game for the iPhone/iPod touch platform

Abstract

The work presented in this paper describes the design and user evaluation of a 3D construction mobile game. The game, iCube, works on iPhone and iPod touch devices consisting of an application where the student performs a set of exercises about building models with unit-sized cubes in a 3D environment. There are two game modes: training and competition. The training exercises are designed so that the user can get used to the game environment. The competitions are sets of tasks, created by the teacher or administrator, which the user has to download, by logging in to the system with a username and password. Competition results are sent to the server with data on times and scores. In this work, a trial version was brought out and evaluated by twenty two testers. Users were asked to complete the training tasks available in the device as well as two competitions. About positive tool's aspects they pointed out that game is useful for improvement of spatial ability being a fun application. However about negative aspects of it, some difficulties arose with use of tactile screen as the fingerprints caused problems while interacting with the game's 3D environment. The results revealed that it's necessary having in mind this item in games' design where screen action is continuous.

Introduction

Play, in its diverse forms, constitutes an important part of children's cognitive and social development^{1,2}. Several authors have analyzed the impact of games on education and there is wide empirical evidence supporting the positive effects of computer games as instructional tools³.

Spatial skills may be associated with success in scientific areas⁴. Non-academic activities, such as playing with construction toys as a young child and playing three dimensional computer games seem to have strong relationship with spatial visualization ability. The potential of video games or computer games for improving spatial skills have been analyzed by numerous researchs^{5,6}. Most recent research in the field of spatial abilities focuses on how these relate to new technologies^{7,8,9,10}.

Recent studies have brought attention to the educational potential of handheld devices. Some tools have been tested on these devices, indicating they strengthen and support learning in fields such as languages^{11,12,13}, science and natural history^{14,15,16,17}, and also provide an additional tool in common learning^{18,19,20,21}.

The game, iCube, is an iPhone game where users can perform a set of exercises about building models with unit-sized cubes in a 3D environment. This paper describes our experience from developing iCube and results from a user test followed by a questionnaire. This game could help middle and high school students to improve their understanding of the 2D-3D relationship in non formal educational format. Touchscreen handheld devices were selected for the implementation of the game, because they provide an intuitive, natural and flexible interface. In actual study, we have just evaluated the game with 22 undergraduate students with two targets: (1) improving user experience with application and (2) spotting bugs and troubles on application for future versions' improvement. The data obtained from the use of this application by the students, as described in this article, only constitute an initial

trial version of the mobile game and, therefore, cannot provide definitive conclusions. Although the idea that these applications are really useful for enhancing and practicing the students' spatial reasoning may be derived from the comments left by the students, they cannot be taken as the basis for a study of the students' spatial skills.

System Architecture Features

Figure 1 shows a summary of the system architecture and below is a brief description of how it works. The architecture we designed includes a mobile game (iCube) (1), a PC application to be used by the teacher or administrator (Building 3D Desktop) (2), a server application (3) and a database (4) to manage data about users, tasks, and results.

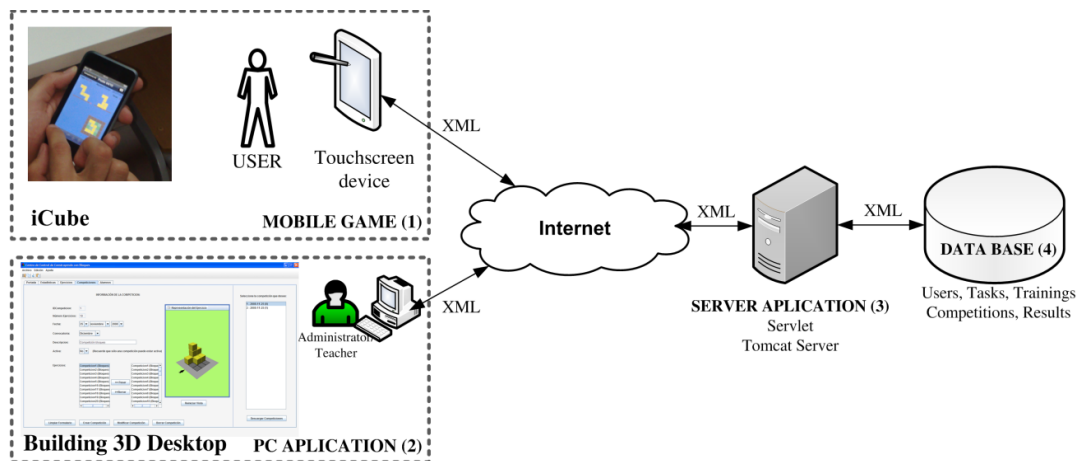


Figure 1. System Architecture

iCube (3D Mobile Game)

iCube mobile game is an application for iPhone and iTouch devices where user must solve a set of exercises about building models with unit-sized cubes in a 3D environment. Exercises are set on competitions which user can download once logged into the system. Desktop application (Building 3D Desktop) allows teacher registration of new users, creation of exercises, creation of competitions and activation once they are available for download. Figure 2 shows the mobile game interface. The mobile game consists of an application where the student performs a set of exercises created by the teacher. The exercises are about building models with unit-sized cubes in a 3D environment.

There are two game modes: training and competition. The training exercises are designed so that the user can get used to the game environment. They are available locally on the mobile device. The competitions are sets of tasks, created by the teacher or administrator, which the user has to download, by logging in to the system with a username and password. Users can only complete a competition once, and then go on to other competitions that the teacher or system administrator has activated. Competition results are sent to the server with data on times and scores. The application has a help function available for explaining how the game works. Each exercise has an overall score of one point if exercise is correct and zero if it's wrong as well as time used for completing it.



Figure 2. Mobile Game Interface: (a) Login (b) Menus (c) Training access (d) Exercises, (e) An example of a Type 1 exercise

Two types of exercises have been developed so far, which basically consist of building 3D models with cubes:

- Type 1: *Coping 3D Model*. This consists of copying the proposed 3D model (as seen on Figure 3).
- Type 2: *Three views*. This consists of building a 3D model using three orthogonal views, front, top and right. To develop this project we used the first angle projection, the ISO standard primarily used in Europe with three standard views: front view, top view and right view (see Figure 4).

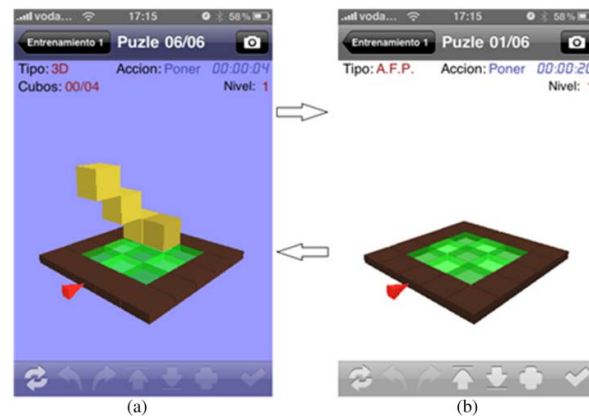


Figure 3. Type 1: (a) Screen 1: suggested task (b) Screen 2: 3D plan where the student solves the task

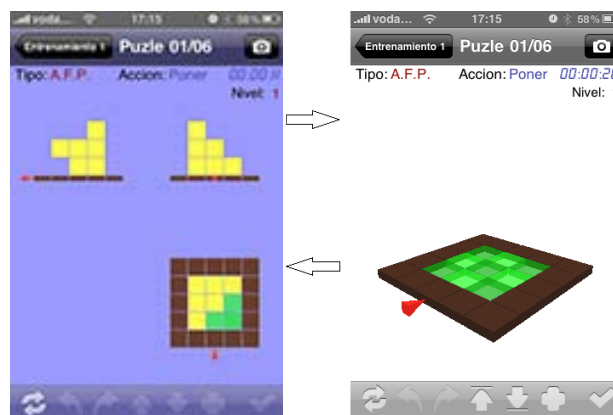


Figure 4. Type 1: (a) Screen 1: suggested task (b) Screen 2: 3D plan where the student solves the task

Building 3D Desktop (PC Application)

Desktop application allows system administrator managing the following operations:

- Users' management: Registering, revising and deleting users as well as consulting results of competitions made by participants (Figure 5).
- Consulting, creating, revising and deleting exercises (Figure 6). Exercises are created by teacher in a 3D interactive environment in the desktop application.
- Consulting, creating, revising and deleting competitions (Figure 7). Teacher will be able to manage information from competitions and exercises in a 3D environment.
- Viewing competition results graphics: Desktop application allows generation of graphics showing results of both scoring and times for certain competitions (Figure 8).
- Data export: Users' results from competitions (scores and times) can be exported in a .txt file for managing them later with any spreadsheet and data analysis software. Besides graphics can be saved in .jpg or .pdf format.
- Connection parameters configuration of both IP and port server in case it's necessary.

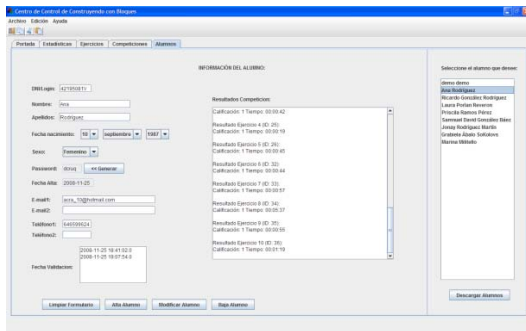


Figure 5. Users management in the PC application

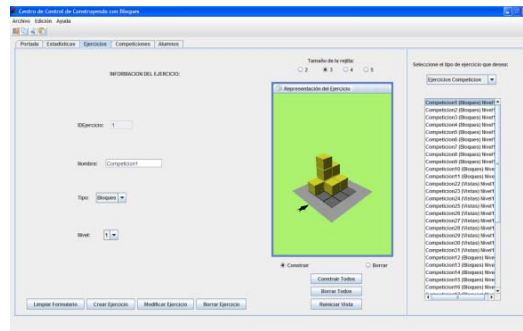


Figure 6. Creating exercises in the PC application

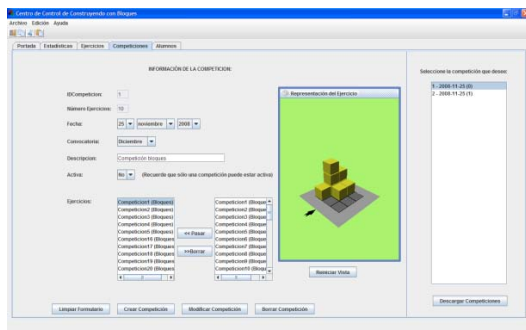


Figure 7. Creating competitions in the PC application

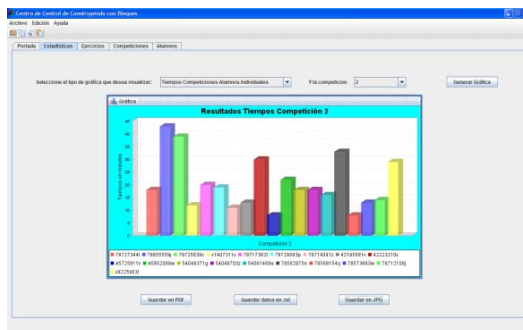


Figure 8. Users' statistics in the PC application

The specifications of the hardware and software are listed in Table 1. We used a iPod Touch device for testing the initial version of the mobile application.

Table 1. Hardware and Software Specifications

Mobile Device	iPod Touch iPhone
PC Application	Windows XP; 2.00GHz; 1 GB RAM Java Virtual Machine / Java 3D virtual machine Libraries: iText-2.1.3, jcommon-1.0.13, jdom, jfreechart-1.0.10
Server and Database	MySQL and Apache Tomcat

Evaluating iCube

Usability study allows obtaining both objective and subjective information from user as well as checking application's usability. In this stage of development it's interesting knowing users' experiences with the game for targeting further investment necessary for application's improvement.

Tests were performed by users and questionnaires were used as rating method for the mobile application. Targets approached are mainly two:

- Improving user experience with application.
- Spotting bugs and troubles on application for future versions' improvement.

Participants and Devices

A study was conducted on 22 undergraduate students from La Laguna University (Spain). Of the 22 participants, 16 were males and 6 females, with ages ranging from 22 to 28, and an average age of 23.8. All of them are students from technical engineering degrees and are taking part in a seminar named 'New tools in teaching and learning of Graphic Engineering I'. Following figures shows snapshots from users undertaking tests (Figure 9). The game works on iPhone and iPod Touch devices.



Figure 9. Users testing iCube application

Methodology

The study was conducted in a lab setting and began with an introduction to the objectives of iCube and the study itself. Participants were then given a demonstration of the device in which they were shown how to use a iPod Touch for given a set of tasks (e.g. internet navigation, wireless internet access, etc.).

Study with users in this project has been developed in several stages (see below). A first trial version of the mobile game was brought out and evaluated by 22 users. A second trial version was then released based on the correction of detected bugs and suggestions made on the first version.

STAGE 1: Establishing project targets, getting lab ready and choosing tasks that users should perform.

STAGE 2: Users' evaluation: performed by users on laboratory, collecting data through questionnaires.

STAGE 3: Collect data: Summarizing bugs found and proposing solutions.

STAGE 4: Application improvement: Programming and implementing suggested enhancements.

STAGE 5: Application final version.

The user was asked to complete the four training tasks available on the device and two competitions: 10 type 1 tasks and 10 type 2 tasks. There are photos and videos of the user test sessions available in the image gallery of our research group website (Figure 9)²².

At the end of the evaluation, participants were given a questionnaire to complete. The questionnaire comprised items that rated six categories of usability (See Table 2) of iCube's various features on a scale of 1 to 5. Participants were also asked to provide qualitative comments that they felt were not raised during the evaluation.

Results and Analysis

Figure 10 shows global rating of application made by 22 users over different aspects of the game. All items are rated between 1 and 5 in a Likert scale where lowest rating is given to the worst consideration (left) while highest belongs to the best considered (right).

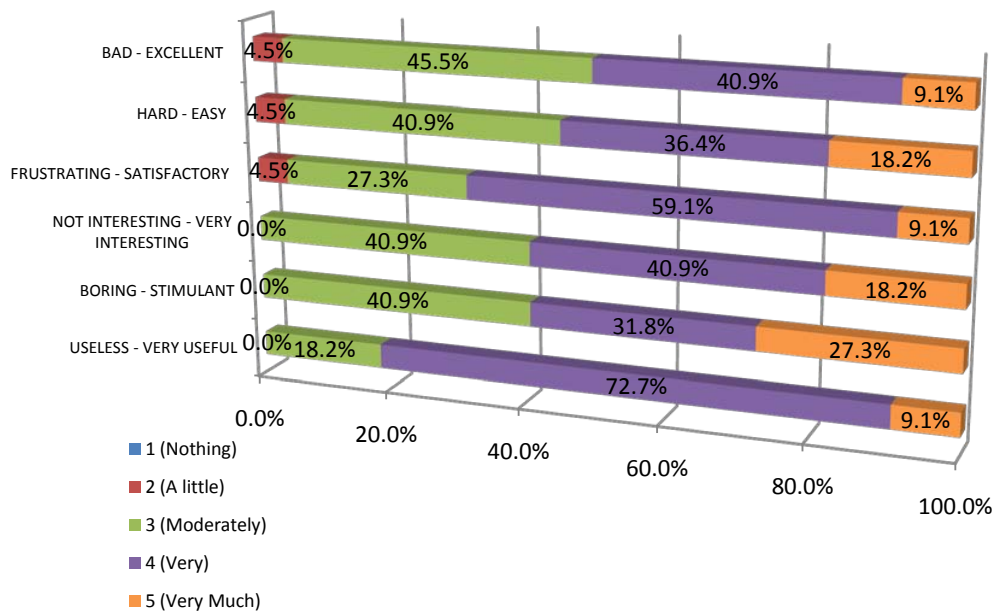


Figure 10. Application's overall scores

Figure 10 shows overall rating that users have made of several iCube aspects. All items have been rated by more than 50% of users with scores of 4 (very) and 5 (very much) with an 81.8% regarding it as very useful and extremely useful.

When asked about the positive and negative aspects of the application and their suggestions for its improvement, their answers have been summarized in the following table belonging to open questions which users wrote in free text.

About positive tool's aspects they pointed out that game is useful for improvement of spatial ability being a fun application. However about negative aspects of it, some difficulties arose with use of tactile screen as the fingerprints caused problems while interacting with the game's 3D environment. It's necessary having in mind this item in games' design where screen action is continuous. That's why 13 users report 'trouble while adding/erasing cubes'.

Suggestions as well as improvement proposals are related to detection of dust on screen caused by intensive use. This problem causes some users have a troublesome feeling when trying to add or delete cubes in the 3D environment.

Table 2. Students' answers to attitude questionnaire regarding the game experience

Ítem	Times reported
iCube app positive aspects	
Useful for spatial ability improvement	14
Nice help supplied. Easy to learn	6
Fun app	7
Good interface app	4
iCube app negative aspects	
Trouble when adding/erasing cubes	13
Confusing interface for exercise access. Not enough help	5
Landscape screen format not suitable for app	2
3D surfing on environment	7
Interface: Cubes color, weariness by screen size, buttons	3
Suggestions, improvement proposals	
Help/system info improvement	6
Results' sending improvement	4
Interface improvement: Cubes, colours, audio, button, surfing on 3D environment	12
New exercises added, exercises time assignment	4

Discussion and Conclusion

Some limitations of actual research must be taken into account. In actual study, we have just evaluated users experience with this mobile application, not measuring improvement of this game in spatial visualization.

Data obtained from questionnaires allows us stating that this interactive mobile game done on handheld touch screen devices motivated the students that took part in it, generating a high degree of satisfaction.

It is important emphasizing that this course offers a new context for developing spatial abilities: in first place it offers the use of a new hardware device, the handheld touch screen devices, while it also offers mobility for the teaching-learning process and a distance learning course which can be used on the subway, bus, tram or any place where a wireless internet access is available (Wi-Fi, 3G, GPRS, etc.). There are many studies and developments done for spatial training, but it is the first one specifically targeting development of spatial abilities with mobile devices.

This work has been led by interest in developing material that includes development of spatial visualization related skills, promulgated by the EHEA (European Higher Education Area) and included in the new Engineering degree courses offered by the Spanish Ministry of Education. We believe it is necessary keeping development of material of this kind that provides students with mobility opening up new teaching and learning possibilities according to actual students habits and lifestyle.

We continue to work towards improving and complementing the developed application in different aspects, which will form our future lines of research in order to:

- Create new types of exercises.
- Verify the effectiveness of the mobile game through spatial visualization enhancement.
- Assess users' work overload with respect to the number of exercises and level of difficulty in each competition.
- Test our tool among middle and secondary school students.
- Develop an English version of the application, considering the third angle projection system.
- Test and port the mobile game in other devices (such as iPad and other tablets).

Acknowledgements

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