IQube: a cube for learning

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***Abstract*-- This paper introduces a relatively new concept to be used mainly in primary education to improve the overall quality of education: a learning cube, tangible, interactive and playing platform for children. Our cube is very different from other educational cubes because it has a colored display on each of its sides, making it very customizable. The cube can either be used as a standalone learning tool or it can be associated with other cubes in games like word matching, picture association or any other games that require multiple matching. Another aspect that makes the cubes attractive is the fact that they have accelerometer sensors creating new possibilities for user interaction, very attractive, especially to children.**

I. INTRODUCTION

It is known that the development of knowledge has a direct bearing on a person's individuality. Every person should be able to attain education. It is a fundamental human right that all people must have, but this is nowhere near accomplished for some people. Some of the barriers that prevent this may include its cost, making it unaffordable for some people, or its decreasing quality. Considering that recent studies from UNESCO present some alarming facts related to literacy [1], we present a new concept to be used, mainly, in primary education to address this problem: a learning cube, tangible, interactive and playing platform for children.

Our solution to address this problem is to try and make education more accessible and fun for children from ages 2 to 10. Children prefer to challenge the world: explore, talk aloud, move around and manipulate different objects instead of interacting with the virtual world shaped by computers [2].

The design and development of an IQube relies on two main considerations which make our proposed solution stand out when compared to other conventional learning methods: in the real world children learn better by playing [3] and building representational mappings is facilitated by performing physical activities [4]. The IQube platform is based on Mind Lab's learning process [5] which begins with children engaging in game-playing activities and ultimately empowers them with skills and knowledge relevant to real-life situations.

The main advantage of our system is the flexibility of applying it into many areas. Besides its main functionality, as a learning tool, our cube can be used for browsing many kinds of contents such as Blogs, Web news, Movies, Music Videos and so on. In this way, the IQube may be used by various users. Moreover, progression through play reflects the observation and assessment of children's knowledge, skills and attitudes in order to provide developmentally appropriate experiences. Children will go to school already as skilled learners. Through observations on how every child plays with the IQube and solves different puzzles, we gain valuable insights into how each one learns best. This kind of information may help the teachers and the parents learn more about the children's needs and can better understand that child's abilities, interests and potential.

II. CURRENT EDUCATIONAL TECHNOLOGIES

We have conceived the IQube, to be a low cost and flexible hardware/software edutainment platform. Its flexible structure allows it to be reutilized for many years, decreasing the overall cost of implementing the solution.

Also another crucial aspect is the user interface, our team concluded after research that the children must interact naturally with the educational device, without any forehand training. So we excluded classical PC interfaces such as mouse, keyboard, etc. and came up with the idea of creating cube shaped devices.

There is no need for instructions how to use it. There are no special rules for how to play with it. It is simple, colored, plays different sounds and vibrates.

As we spoke with kindergarten tutors, they told us that the children are not very excited about the current toys their kindergartens are equipped with and that after a few days, children get bored with almost any toy. The kindergarten managers and teachers are searching for new educational toys that can improve the educational quality and keep the children entertained.

For developing a large number of abilities the schools have to buy many different educational materials. This can be very expensive and not all institutions can afford to buy everything.

We designed the IQube in order to cover very different fields: literacy, mathematics, logical games and even music. For the number of games that can be developed for the IQube, imagination is the limit. For creation of a wide portfolio of games and educational application to be uploaded on an IQube website in order to be accessed by the IQube educational community worldwide, a wide volunteering effort could be triggered, with people crowd-sourcing new valuable community-rated materials, generating a real IQube revolution.

After some research, we found many different products in this niche market of education. Some of them are traditional; others make use of different technologies. In order to identify the major strengths and drawbacks of our proposal, a competitor analysis contemplating more than 20 competitors was carried out. A summary of such an analysis is presented in this subsection.

We grouped the competitors in 5 categories labeled from A to E:

A) Traditional children books
B) Educative board games

C) Educative software/websites
D) External agents
E) Other educational gadgets e.g. Shiftables

Fig. 1. Some of the competitors

In order to compare these solutions we took into consideration following aspects:

- interaction (INT)
- interaction between children/team-game possibility (IBC)
- update capability (UC)
- cost (COS)
- personalization (PER)

TABLE I
COMPETITION ANALYSIS

Product	INT	IBC	UC	COS	PER	TOT
A (Traditional children books)	2	1	1	3	1	**8**
B (Educative board games)	2	5	1	2	1	**11**
C (Educative software/websites)	3	1	5	5	4	**18**
D (External agents)	3	3	2	2	2	**12**
E (other educational gadgets e.g. Shiftables)	4	3	5	4	4	**20**
IQube	5	4	5	3	5	**22**

It is clear that the IQube is not the winner in all the categories. However, overall the IQube presents competitive market advantages among its competitors.

III. GENERAL ARCHITECTURE

A. Hardware architecture

The IQube platform is based on a low-power microcontroller with wireless and infrared communication capabilities and several built-in sensors and actuators (e.g., an accelerometer and a vibrating motor). The hardware architecture of a single IQube has a 1.6' LCD on each side of the cube which is its defining feature, a buzzer for emitting sounds, a small vibrating motor and a RGB status led for indicating the status of that cube and position (relative to other cubes).

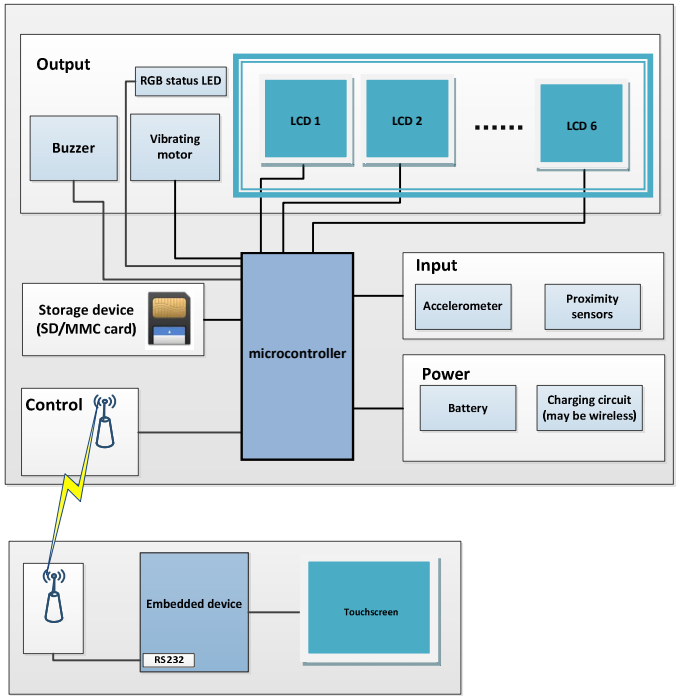

Fig. 2. Hardware architecture

The user interacts with the cube by means of an accelerometer sensor. Each tilt and rotation of the IQube corresponds to a certain change in its state. Also, the position relative to other cubes is constantly monitored using internal infrared sensors. The cube's state and position is sent to an embedded central node (C.E.N.) via wireless communication. The central node then processes the information received and, depending on the displayed images and the cube's position, it will send other images, change the color of the cube, announce a game completion or failure, depending on the running app.

Transmission and reception of information is done using a wireless connection between the IQube and the C.E.N. One way of accomplishing this is by using an XBee [6] wireless communication module. At the heart of the device lies a microcontroller which controls all above mentioned components. In addition, a storage component is added to store the received information and media (picture, sounds or

animations) from the C.E.N. The power supply consists of a rechargeable battery which is recharged wireless using inductive coupling.

As mentioned above, all the cubes communicate to one another as an ad-hoc network communication, as well as with the C.E.N. The next figure (Fig.3) shows one possibility of how this could be done.

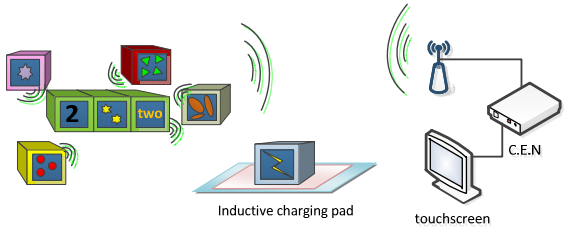

Fig. 3. IQube operations

B. *Software architecture*

At the highest level of abstraction, the software system is divided into three major components:

A. The web component runs in Windows Azure and provides two features: (a) User Statistics and Game Development Kit is the web application where users can see the statistics about the progress of children – information like: the games they played, the results, the time spent on each game, etc. It also provides an easy way to use game development kit: a Silverlight application that allows users to create and publish games in the Games Store. (b) The online Game Store is an application where customers can buy/rent games that can be installed on the IQube.

B. CEN application allows teachers to create teaching programs by choosing the games that children are going to play.

C. IQube framework environment - each cube provides a game environment and allows loading different games on it. It uses a local storage system to store images and game logic.

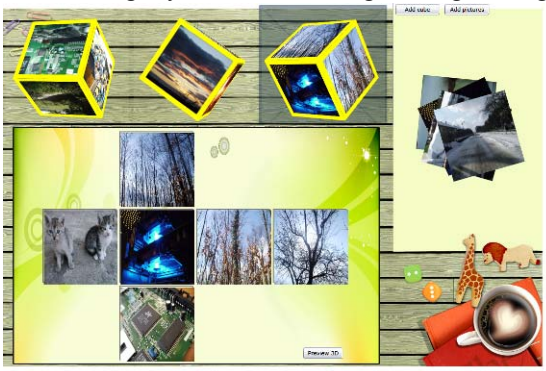

Fig. 4. Game development kit UI

IV. IQUBE GAMES

In the next few paragraphs we present a few games that could be implemented on the IQubes.

Game 1: Numbers, objects and words
Goal: Match the numbers with words and pictures
Number of IQubes: 3

Description: The child must match correctly a mathematical number and certain images that contain the same number of objects and with the word that spells that particular number. If you rotate the first IQube forward or backwards the number increases or decreases. (Number are shown as a mathematical symbol from 1-10). If you rotate the second IQube in any direction images appear with random number of objects (From 1 to 10 objects per image). If you rotate the third IQube in any direction a word will appear that spell a specific number (From 1 to 10). After obtaining the matching number-image-word on the three IQubes the child must then join them for verifying the result. If ok – the cube turns green. If not ok – the cube turns red.

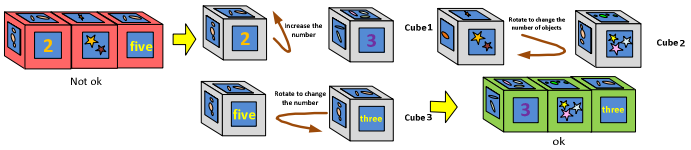

Fig. 5. Game example 1

Game 2: Numbers and colors
Goal: To build an existing image using counting abilities and color matching.
Number of IQubes: 2
Description: On one face of the IQube an image is shown (ex. 5 red flowers). Using the second IQube, the child must build the same image only by rotating the IQube. If the cube is rotated forward, the number of flowers increases. If he rotates the IQube backwards, the number of objects in the image decreases. If the IQube is rotated to the left or to the right, the color of the objects in the image changes. For checking if the image is correct, the child must join the two IQubes and the cube turns green if ok and red if not.

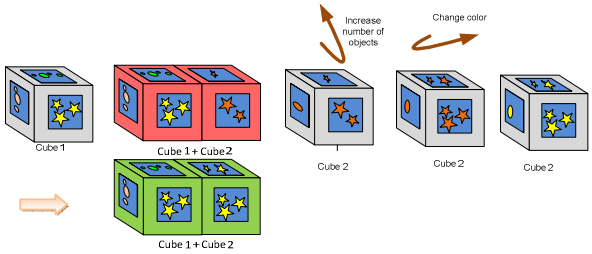

Fig. 6. Game example 2

Team games:

Every child has an IQube. Each of them is able to modify a certain characteristic of an animal; the first child can modify the head, the second - torso, the third – legs, fourth – color, etc. After joining all the cubes, final result is sent back to the eBox and the teacher evaluates the result on the screen. Other team games may include puzzle games.

Other types of games:

Besides these main game types described, standalone games are also a possibility. Taking full advantage of the accelerometer and the 6 LCD screens, games that involve fast and continuous rotation of the cube in a certain way are easily integrated on this platform. These types of games can be on a time based win condition and, when integrated with math and

logic skills can make the playing experience very educative, not just for young children, but also for teenagers.

V. Current Implementation

Currently, this project is a work in progress. We have achieved much but there is still a lot of work to be done. We succeeded in building one cube with some of the desired features: It has all the LCD screens functional, capable of displaying images and videos, wireless communication and data transfer, and a LED-colored plastic case.

Because it is difficult to work with small electronic components inside the cube, we made a test-bench in order to help us advance faster with the work. In this way, we managed to work with an SD card to make image displaying on the screens faster and easier (rather than sending one image at a time through wireless communication). Also, we started working with an accelerometer sensor. The test bench allows us to experiment with different types of hardware in order to maximize the efficiency of the overall embedded system keeping it all at lower costs.

For the power supply, we used a small 3.7V battery which can currently keep functional the cube for about 3 hours. Also we experimented with inductive electricity transfer and managed to light a LED wirelessly at a distance of about 3cm using two simple LC circuits. Inductive energy transfer will be integrated into the cube in order to charge its battery. This way the cube is symmetrical on all of its sides, not requiring any power sockets, making it more appealing for children.

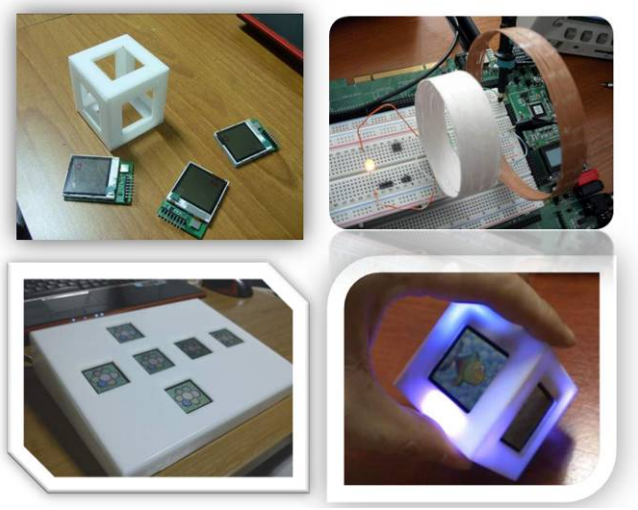

Fig. 7. Current hardware status

VI. Performance Analysis

The performance of the system is analyzed in relation with certain parameters:

Communication distances: the XBee sensors were able to communicate to a distance of up to 120m in the open field, but in indoor case up to 40m.

Consumption: The consumption of a cube, if the all LCDs are on, is about 230 mA. At this consumption rate the battery lasts for about 3 hours.

Image transfer duration: The transfer of the one image from C.E.N. to the cube has duration of 15s, but from memory to LCD the transfer is done in less than 100ms.

Charging the battery: Using wired energy transfer, the battery charging time is about 2.5 hours.

Number of cubes per C.E.N.: The maximum number of cubes per one C.E.N. is 24.

Supplying Voltage: The supply voltage for charging pad is 12V.

The functionality independence: The cubes are independent of each other and games can be configured to use any cubes from the set.

VII. Conclusions

Tangible user interfaces have received much enthusiasm and consideration. This is mainly because they take the next step into bringing the virtual world closer to the real world thus delivering us one step closer to a more pleasant and constructive interaction between the computer and the human. It also creates new opportunities for development and adaptability into other fields such as entertainment or advertisement.

Fig. 8. IQube impact on children

ACKNOWLEDGMENT

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