

Contextualised Design of African I-BLOCKS

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Abstract

We have designed and developed African I-BLOCKS based upon use amongst university students, secondary school pupils and hospitalized children in Tanzania. Using an initial prototype system, the Tanzanian users developed design guidelines for novel African I-BLOCKS to suit the local educational need and context, and these guidelines were used to develop the novel African I-BLOCKS to allow easier building in three dimensions and more reliable connection. The African I-BLOCKS are cubic with full-duplex connectors and magnetic connectors. They allow easy hands-on building of electronic artifacts by any user. The novel African I-BLOCKS were tested by Tanzanian university students (bachelor of education) in a rural hospital and orphanage with positive qualitative evaluation.

1. Introduction

Many well intentioned projects have tried to bring IT related systems and education to developing countries. Unfortunately, we find that such systems often allow little possibility for developing creativity and innovativeness amongst the recipients, but rather impose a user aspect on the recipients. Often, the IT systems and IT educational efforts aim at providing the users with skills for becoming users of such IT systems rather than developers of the IT systems. With this in mind, we wanted to create novel possibilities for African students, pupils and children to understand how to develop their own IT systems and electronic artifacts to suit their own living context. In our point of view, the promotion of such knowledge and creativity is best achieved through some initial hands-on experience that allows everybody to develop their own electronic prototypes within a very short time period, and with no demand for any a priori expert knowledge, i.e. we find it important to lower the barrier for entering into such development, so that any child, adult or elderly person can express her own creativity through the building of such artifact prototypes.

Therefore, we have engaged in the development of Intelligent building blocks (I-BLOCKS) that allows anybody to create his or her own IT artefact prototypes in a very simple, hands-on manner. In this paper, we will report on the technological development of a particular instance of such building blocks, namely the African I-BLOCKS, which were developed in close collaboration between African and Scandinavian students and researchers.

2. The Original I-BLOCKS

The original I-BLOCKS [1] are hardware building blocks, which are embedded in LEGO Duplo® bricks. The electronics and connectors have been designed so as to facilitate communication and power sharing between I-BLOCKS when these are physically connected. Each I-BLOCK contains a PIC 16F876 microcontroller, and metallic connectors for power sharing and communication. A 2x4 Duplo I-BLOCK contains 2 male communication connectors on the top surface, and 2 female connectors integrated in the PCB on the bottom (See Figure 1). The I-BLOCKS all have a programming connector on the main PCB inside, and this allows for easy reprogramming and/or updating of the I-BLOCKS software.



Figure 1 I-BLOCK top and bottom view

Power is supplied from special power I-BLOCKS that are either power adapter supplied or 9V battery supplied.

We developed a number of standard I-BLOCKS with the features mentioned above, as well as some that have actuators built-in, such as DC-motors, servos, light, LCD-displays, sound, etc. and some that include sensors such as LDR resistors, microphones, flex sensors, touch and sonar [2]. Additionally, we have experimented with and built communication I-

BLOCKS that use both IR and Radio communication to facilitate structure-structure communication [2].

As each I-BLOCK includes its own microcontroller, the processing in a connected structure is truly distributed, and therefore the activity of the structure that is built is directly dependent on the physical properties of the structure.

3. Original I-BLOCKS Issues

In collaboration with Sutinen, Vesisenaho and Duveskog (University of Joensuu), in April 2004, a toolset consisting of the different types of these original I-BLOCKS was tested at a workshop with students of Tumaini University, Iringa, Tanzania. Here we had pre-programmed all of the I-BLOCKS, and we wanted to test if they could be used as a tool for giving the students a hands-on introduction to IT and IT artefacts in an easy manner, and thereby making it easier for the students to gain the concepts of e.g. inputs and outputs and sensors and actuators. The students were at first quite hesitant to play with the I-BLOCKS, but after just 1-2 hours they started to find out what capabilities the different kind of I-BLOCKS had and how they could be combined to make small tools or robotic structures. Most of the first structures built by the students were direct connections of sensor and actuator I-BLOCKS, but after a presentation of our CPU I-BLOCKS, which we had pre-programmed with different functions, they started to realize that it was possible to process the input of one or more sensor I-BLOCKS before outputting it to an actuator I-BLOCK. As a final project, the students brainstormed, then designed and successfully built a wireless car burglar alarm that would tell the car-owner if somebody was touching his car while he was away from it.

The user experiments that have been carried out in this project and previous, similar workshops in Tanzania showed us that there are some limitations with the current version of the I-BLOCKS. First of all, the LEGO Duplo® housing does not allow for connections that are stable enough for e.g. robotic walking structures. In the current version, the I-BLOCKS structure simply disassembles when exposed to even light shakes.

The I-BLOCKS are in the current version all hand-made, and therefore we have experienced some problems with especially the metallic connectors. Assembling and disassembling the I-BLOCKS several times results in loose connections and this problem should be solved in a new version.

Another issue is that the user until recently has been unable to alter the content of i.e. the CPU I-BLOCK. This limits the user to only be able to experiment with pre-programmed I-BLOCKS, and we might therefore

be missing out on general functionalities that would enhance the entire system.

Finally, the current version of the I-BLOCKS is limited to the way one can build with the standard LEGO Duplo® I-BLOCK. The Duplo only has connectors on the bottom and the top, and therefore the direction of building almost always bottom-up. This problem will be investigated further in a section below.

In order to address the challenges, a simple graphical user interface was developed that allows users to author the contents of the individual I-BLOCKS, and 3D I-BLOCKS were designed with neighbourhood information. These two developments are described below.

4. Programming Interface

The I-BLOCK Application is a Java application that provides the user with a simple graphical interface to change the behaviour of an I-BLOCK. This application has been made to make it easy for the user to test her ideas, without having to ask a skilled programmer to write the programs. The user does not need to have any previous knowledge of traditional programming languages to use this interface and she needs only to have a concept of what inputs and outputs are, and what kinds of sensors and actuators the different I-BLOCKS contain (which a user normally obtains simply by playing with the I-BLOCKS, as exemplified with the Tanzanian project mentioned above). The user also needs to know how to connect the programming interface from a PC to an I-BLOCK.

Together with Sutinen, Vesisenaho, and Duveskog (University of Joensuu), the I-BLOCK application was tested October 2004 in an ICT course in Tumaini University, Iringa, Tanzania, where the students have successfully been using this interface together with the I-BLOCKS to gain the basic concepts of programming, before continuing on learning the Java programming language. The course started with an intensive two-day workshop playing and developing with I-BLOCKS, and then continued as a normal course with lectures and practical exercises each week, until a final project was performed by the university students, e.g. by teaching with I-BLOCKS at a secondary school in the rural area. Some of the objects constructed during the first workshop included a tool that measures the height of people, an earthquake alarm, a burglar alarm and a vehicle that avoids walls. To verify the university students' gain of knowledge about IT and technology, the students taught secondary school children using I-BLOCKS (Figure 2).

During the Tanzanian workshop that initiated the full course, questionnaires were handed out, and two questions give a good understanding of their gaining of

the general I-BLOCK concept and what they have actually learnt. The answers were given as free text, but the two tables below (Table 1) describe the number of answers that fit within each mentioned category. The students were allowed to give several answers to each question.



Figure 2. Some pupils from the Pommern Secondary School in Tanzania working with the I-BLOCKS

A) What have you done for learning?

General answers	#
I have been connecting I-BLOCKS to see and observe their individual and connected functionalities and how/what they sense, actuate or process.	19
I have used I-BLOCKS and supplied software to download both pre-fabricated and self-created programs.	8
I have been taught about computer programming through the use of I-BLOCKS	7
I have tried to relate to what we have been doing in the workshop and how that can be used in our daily life.	3
I have built structures that allowed for arithmetic calculations.	1

B) What have you learnt?

General answers	#
I have learnt how to use and program I-BLOCKS. (Both physical and computational programming!)	24
I have learnt how I-BLOCKS can be used many places in our daily life.	9
I have learnt how the different I-BLOCKS can be used as teaching aids.	6
I have practiced simple learning.	1
I have learnt how to translate binary numbers into decimals through the I-BLOCKS	1
I have learnt, through I-BLOCKS that a computer program is an integration of small parts each with different functions. And when combined you are able to perform more complex tasks.	1

Table 1: A) and B) Student Answers

5. 3D Challenges

As mentioned above, one of the important feedbacks from the Tanzanian end-users was that the I-BLOCKS should allow for better building opportunities in three dimensions, and that connections should be made more reliable. This is an important lesson learned for the technological development from the Tanzanian experience. Therefore, in order to

accommodate “real” 3D structures we have decided upon a cubic shape of the new I-BLOCKS. This shape is much more modular, and gives us the possibility of connecting up to 6 other I-BLOCKS to one I-BLOCK. However, when constructing this way, then one has to take gravity into account, and we will definitely experience problems such as bend-down and eventually self-disassembly when building perpendicular to the gravity vector without supporting the structure. This is, however, the case in all building kits on the market, and it just adds an extra challenge to the user of the system. When talking about self-disassembly we have to take into account that it will eventually occur and we need to design the connectors so that they will not break by such an incident.

Another challenge when building with cubes is that it might not be possible to connect cubes in e.g. corners if the connectors are outside the cube borders. So therefore we either have to design special integrated connectors, or the user will have to take this into account when building.

When building in 3D we would often like to know the 3D structure that has been built, because this information can directly be used to determine the functionality of sub-parts of the entire structure. The challenge here is to find ways to record this structural information, and likewise use this information in a clever way.

When designing connectors, there are both physical aspects and electrical aspects to take into account. In this section we will mention the different results we reached during this process.

Starting with the electrical aspects of the connectors, we should make sure that the following features are included in each connector side of the cube:

- 1- Power transfer. Power should be able to be supplied from one I-BLOCK to another, so that it is possible to have only few special power bricks in the structure.
- 2- Communication connectors. Each side should include one or two connectors for half or full duplex serial communication.
- 3- Possible rotational information. This can be used to record the exact 3D structure if needed.

Also, when transferring power between the bricks, the electric connectors need to be able to transfer the sufficient amount of power, so that every I-BLOCK will work as intended.

After having worked with several different designs in 3D CAD software [3], two new prototypes were made.

5.1 Rejected Prototype

This first design that was chosen is quite feasible both for implementing the electrical connectors and

also because of the great unisex features that improve the construction possibilities to a large degree. We have currently produced 2 cubic I-BLOCKS of this type (Figure 3), and have tried to find a stable way to join the individual sides of the cube as well as develop electronics and metallic connectors. However, the solutions were cumbersome and did not seem feasible for production. Therefore, for the time being, this design has been rejected.



Figure 3. New I-BLOCKS – Single and Connected

6. The African I-BLOCK Prototype 1

The African I-BLOCK prototype design shown below has proven feasible for production, and although it does not implement unisex connectors or any rotational information, this solution still offers more stable electrical connections, full duplex serial connections and power sharing capabilities.

The design of the African I-BLOCKS is based on a classic cubic building-block shape. The cube side length is 8cm. The shell has been machined in a cross-like shape as shown in Figure 4.

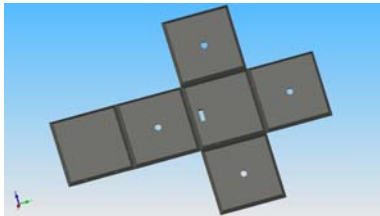


Figure 4: Rendered CAD-drawing of machined African I-BLOCK shell

Four of the six sides on each cube have communication connectors, whereof 2 are male 4-pole jack connectors and 2 are 4-pole jack female connectors. Besides the connectors each side of the cube also has 4 Neodymium (NdFeB) magnets to stabilize the connection at right angles. The neodymium magnets are polarized so that sides with male jack connectors have north-pole magnetic connections and sides with female jack connectors have south-pole magnetic connections. This makes the

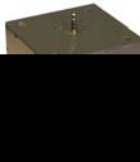


assembly very easy for the user, as the blocks will automatically rotate into the right angles.

A real assembled working prototype of an African I-BLOCK can be seen from Figure 5. This I-BLOCK also implement an RGB-LED actuator in the passive side facing the reader, and the black connector in the lower half of this side is a JTAG connector for programming and debugging the Atmel mega128 microcontroller, which is embedded in the electronic module.



Figure 5: Working prototype African I-BLOCK with RGB-LED

The 2 sides without connectors are used for implementing different sensors, such as flex, light, microphones etc. or actuators such as RGB-LEDs, sound, displays, motors etc. Different African I-BLOCKS types are shown in Table 2.

	<p>Battery BLOCK: This block contains a battery pack for supplying a group of connected I-BLOCKS. It has an on-off switch on one of the sides, and only one male jack connector side with neodymium magnets. The 5V supply is shared through the jack connector to other I-BLOCKS.</p>
	<p>Flex sensor BLOCK: This block implements a resistive flex-sensor which will change input-voltage to the microcontrollers A/D-port when bent. This type of block can be used directly for user interaction or as a sort of bumper/whisker if implemented in a robot walker or vehicle.</p>
	<p>FSR sensor BLOCK: This sensor block implements a force sensitive resistor, which will change resistance when force is exerted directly on the sensor. In this way this block can be made to react to user interaction by touch.</p>




	<p>Light sensor BLOCK: This sensor block is sensitive to light through the implementation of an LDR sensor. This block can e.g. be used in monitoring ambient conditions.</p>
	<p>RGB-LED actuator BLOCK: This actuator block can emit light of all colours through a built-in RGB-LED. This sort of actuation can be used for e.g. displaying right or wrong behaviours, high or low sensor inputs or sensor ranges translated into light ranges etc.</p>
	<p>Sound actuator BLOCK: This actuator block implements a speaker, which can output audible frequencies and thereby also play tunes etc.</p>

Table 2: Different African I-BLOCKS types

7. African I-BLOCK Experiments and Conclusions

The African I-BLOCKS prototype was tested at Ilembula Hospital in Tanzania with hospitalised children (e.g. children with leg fractures who are normally bedridden for 6-8 weeks) in June 2005 (see Figure 6), and was evaluated by the Tanzanian instructors and nurses to be very effective. Indeed, parents and nurses commented that the I-BLOCKS had therapeutic benefits including their children becoming more cheerful and making a faster recovery. For instance, one nurse expressed about one child's use of the cubic I-BLOCKS: "She concentrates on this play. If she has other feelings such as a bad feeling, she may forget this", and another nurse that "it gives happiness for the children – in what they have seen and done. Even if they are at home, they will tell the others that at the hospital we did this and this. So the information goes through to others at home."

In general, the whole I-BLOCKS project was highly recommended by the Tanzanian instructors and the concerned community, especially the children wards of the Ilembula hospital. Quoting one mother "... Mkiendelea kuwepo hapa watoto watapona haraka, kwa sababu wanapata cha kufanya, wanashinda wanacheza na vitu hivi vinavyowavutia..." meaning;

"...Your presence speeds recovery of our children because they have something interesting to do rather than staying in bed..."

Compared with the experiments with the initial technological prototype, the novel African I-BLOCK system allowed for a much easier use by the end users, in this case hospitalised children and children at an orphanage in a rural area of Tanzania. There were no power and communication problems, and it was easy to build 3D structures. This meant that the hospitalised children could use the new manipulative technology immediately without need for instruction or training.



Figure 6: Hospitalised boy playing with the novel African I-BLOCKS

8. Acknowledgement

The African I-BLOCKS experiments and development was done in collaboration with Sutinen, Vesisenaho, and Duveskog, University of Joensuu, and students from Tumaini University in Tanzania. Some initial I-BLOCKS applications were developed with Prof. Marti, University of Siena. The authors are grateful for the fruitful collaboration with Ilembula Hospital and orphanage in Tanzania.

9. References

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