ARBlocks: A Concept for a Dynamic Blocks Platform for Educational Activities

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***Abstract*—This paper describes the concept of a dynamic blocks platform, called ARBlocks, based on projective augmented reality and tangible user interfaces aiming educational activities. In it, the information is displayed by projectors, that exhibit the content only on the blocks using a projector calibration technique and the blocks are tracked through a frame marker. Despite the platform is still under development, some results regarding the frame marker tracking and the projection was achieved.**

***Keywords*-augmented reality; education; tangible user interface; design for children**

I. Introduction

For a long period of time, education was thought as transmission of knowledge. In this context, students were considered passive, being responsible only for the storage of the content transmitted by the teacher. Currently, however, these theories have been overturned in the sense that there is no teaching without learning and that knowledge is seen as a building process.

Thus, there are a lot of teaching materials that are facilitators of the learning process. From the perspective of Jean Piaget, we see how the activities carried out through these tools have become important and contribute to child development [1].

In this context, tangible user interfaces are a good instrument for the creation of a material that satisfies most of teacher's needs. They are able to create tangible tools that can help the students' development, contributing to motor aspects' improvement, collaborative activities and the understanding of the world around them.

Another area in computer science that has a great potential to contribute with early childhood education is augmented reality, given its enormous potential to improve information visualization quality, which is very important, especially when it comes to children.

For these materials be successful in facilitating learning, they must be designed so that, besides attracting the interest of children, visually and tactile, for instance, they must be very intuitive to use, in a way they have an enjoyable experience with these artifacts. For this, graphic, technical, ergonomic and educational factors should have a huge importance in the design process of these products [2].

This paper introduces the ARBlocks, a concept of a dynamic blocks platform for educational activities based on augmented reality and tangible user interfaces. It can be used as an educational resource for the process of knowledge construction in children. In order to explain the concept, this paper is organized as follows: Section 2 shows related work regarding the use of tangible user interfaces and augmented reality in early childhood education. Then, in Section 3, it is explained the main concepts that guide this work. Section 4 details how the product and an application for the platform were designed. In Section 5 the results achieved so far are presented. Finally, Section 6 presents conclusions and future directions for the tool's development.

II. Related Work

The use of interactive blocks is not new in education and this type of activity soon became a great ally of the teachers by the way it stimulated children's creativity, logical reasoning, language skills and other abilities [3].

Today they exist in several sizes, shapes and materials. For each proposed activity, there is a specific set of blocks. Thus, if the teacher wants to instruct mathematics, he/she uses a material made exclusively for this purpose, containing numbers, mathematical and geometric symbols [4], as shown in Figure 1. In another moment, when the activity has the objective to develop language skills, it will be used other blocks containing letters [5]. Thus, schools must have multiple sets of games, one for each purpose.

Figure 1. Example of mathematical game based on blocks.

When this type of resource can't be used, the authors observed that they attempt to use several multimedia fea-

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tures, like music, sound and video, in order to get children attention, since they like to be exposed to situations that stimulate many of their senses.

Recently computers have been used as a tool to simulate activities that children already perform in their daily life [6]. Despite holding their attention, those programs can't stimulate as well as tangible objects some important skills, because they work primarily as a digital finger on a flat screen.

With the cheapening and development of new technologies, solutions that use tangible objects to provide input or output for educational activities have began to emerge. They are called digital manipulatives. However, it is still evident the lack of interesting applications that can satisfy all child's educational needs [7].

A good example of digital manipulative is the Siftables [8], which are computers with approximately 3.5 centimeters of size that have an LCD screen and sensors to interact with other Siftables. Developed at MIT, it is a very good solution for educational use of digital tangible user interfaces, however its cost makes it impractical for many schools. They are not yet available for sale, but each Siftable is estimated to cost approximately US$ 200.00.

The same problem of obtaining good educational applications occurs with augmented reality, since it is a new field in computer science, where most of the initiatives are still being researched. Its use is almost null in classroom and one of the fewest initiatives is what is called of augmented reality books. They are similar to the usual ones, but the pages reveal a 3D content when are placed in front of a webcam [9].

III. Basic Knowledge

The platform designed by the authors is based on the use of augmented reality and tangible interfaces as a tool to help playfulness education, which is an educational proposal that is gaining a lot of attention nowadays for its ability to build solid knowledge in children. These concepts will be further detailed in the following subsections.

A. *Playfulness Education*

The concept of playfulness education consists in teaching a knowledge without the child to realize that he/she is learning. This can be accomplished through games that allow them to effectively participate in their knowledge's construction. From these activities, the learner establishes a positive relationship with knowledge. This aspect becomes very relevant when considering children with learning difficulties, which generally have a negative image crystallized in relation to knowledge. In addition, by playing, children are encouraged to develop their thinking, observe, question, discuss, interpret, analyze and solve problems, since these are skills needed to play well.

In addition, games and plays are present in children's lives outside the school. This fact corroborates with the idea that the playfulness' insertion in the classroom only contributes to increase the interest and participation of students in the learning process.

From this perspective, plays and games are some of the best ways of introducing to aesthetic pleasure, the discovery of individuality and individual meditation. The playfulness activities are also multidisciplinary, enabling a meaningful exploration of the content by the students while they are having fun with it, as can be illustrated in Figure 2.

Figure 2. Fun is an important factor for playfulness education.

Although with different emphases, all educational theories, from the classic to the latest ones, point to the importance of playfulness as a privileged means of expression and children's learning [10].

1) Collaborative Games: being sociocultural values and attitudes, competition and cooperation are likely to be taught and learned. In this context, many theorists have discussed the importance of collaborative games as a playfulness tool to convey these lessons to the children. A very important theoretical was Piaget [1], who in his theory of child development proposes the existence of three stages according to its age. In these, the game emerges in different manifestation forms of these processes, going through the child's thinking in the different stages of development.

Collaborative games are very important because through them the child has the need to cooperate and work with rules. The enforcement of rules is related with the fact of relate to other people who think, act and create strategies in different ways. Through the games, even if defeated, the child has the opportunity to know itselve, set its own limits and capacity as player, and evaluate what can be improved to avoid defeat in the coming times.

In collaborative games, players do not choose one side because they should be together. The content and dynamics of the game determine the child's relationship with the other, promoting the development of social relationship.

Through cooperative games, players can also work some important skills, like interaction, perception, relationships with empathy and self-esteem, be ethical and understand the other. These skills are called personal intelligences [3].

It is understood, therefore, that collaborative games provide thinking about their own actions and self-knowledge [11].

Other features of cooperative situations regarding the competitive situations are [11]: the perception that the goal's achievements are, in part, a consequence of the action of other members, sensitivity to the demands from others, high frequency of mutual help, equal amount of contribution and participation and greater activities' specialization.

2) Blocks Games: interactive blocks are famous toys, where letters, numbers and symbols are printed on their faces. Given its extreme simplicity and ease of manipulation, they became an important ally in children development.

These blocks are used as concrete tools to assist in the development of abstract concepts. With the freedom given by this toy, children are able to understand and solve problems by manipulating the blocks and grouping common elements.

Depending on the images present in the blocks, many skills can be developed, such as mathematical concepts and logical reasoning, besides evolve the language skills, increase vocabulary and the creative development of the children.

B. Tangible User Interfaces

We consider tangible any touchable utensil, so a tangible user interface can be defined as the one in which the person interacts with an activity, digital or not, through manageable physical devices.

In digital systems, these devices can provide a more realistic interaction between the user and the computer by giving life to metaphors used by the software to make its use friendlier.

Tangible devices provide three basic facilities [12]:

a) Interactivity: physical contact with the equipment is mapped to results in real time in the digital ambient;
b) Practicality: the user will interact as he uses the real equipment, as for example the use of a racket at a electronic tennis game;
c) Collaboration: more than one user may work with the equipment, in a collaborative way, as if they had it physically on their hands. As an example we have the use of musical instrument simulators for karaoke.

A successful example of tangible user interfaces is the Wii console, from Nintendo. In it, the user can control a car as if driving one, holding the joystick as a real steering wheel, or punch the air similarly to a boxing fighter.

1) Tangible Interfaces in Education: in education, tangible user interfaces are also a research subject as a way to improve the learning process, besides allowing a better knowledge absorption and student engagement. An example is the manipulatives, objects that represent abstract concepts in a concrete way [7], which are very common especially in mathematics. These objects are widely used in classrooms and have attractive colors and shapes for the children, beyond the capacity of being directly manipulated, as can be seen in Figure 3.

Figure 3. A tangram is a example of manipulatives used to teach mathematical concepts.

The use of tangible interfaces in education is not recent and precedes the use of computers. Among the first thinkers and designers, stand out Friedrich Froebel and Maria Montessori [13].

There are many advantages in using tangible interfaces in education [14], among them are:

a) Sensory Engagement: is related to how children learn, in their natural mode, using several of their senses in a constructive process;
b) Accessibility: increases the accessibility for younger kids, especially when they have learning difficulties;
c) Group Learning: allows that several hands can be used, i.e., several kids working as collaborators on the creation, facilitating the interaction and promoting group discussions.

More recent researches have focused on the intensive use of computers with tangible interfaces, especially in learning activities involving children. This development is natural because of the decrease of computer cost and the increasing access of these by the young.

C. Augmented Reality

Augmented reality has been very promising by its ability to make user interaction more natural and improve the information visualization quality. So, due to its enormous applicability, it has been extensively studied and there are some important classifications.

1) Marker Based Augmented Reality: a crucial step in augmented reality applications is scene registration, because that is where the information of the real world and the camera used to capture it are aligned with the virtual data generated by the computer so they can be displayed consistently.

The simplest way to accomplish this step is to use markers, which are elements with previously known information that serve as a reference to find those informations. This element revolutionized augmented reality by the way it assisted in obtaining the necessary registration data with a very low cost, since those codes usually are printed on a sheet of paper. Thus, it can be added to the scene as many as required.

With its popularity, several types of markers were created to meet specific needs. The main ones are:

a) Template Based Markers: were the first to be created. On them, any image in black and white previously registered can be used as a marker [15]. Their tracking is done by comparing portions of the image taken by the camera with the marker database until one matches properly with a part of the captured frame. Because many comparisons are made during tracking, the scalability for this type of marker is a big issue;
b) ID Based Markers: developed to solve the scalability problem of template based markers [16]. Their principle is that the code is a matrix of black and white squares. Thus, the tracking is no longer done by matching of images, but by the direct reading of each matrix element. Due to the decrease in the processing, the number of markers tracked simultaneously increases significantly;
c) DataMatrix Markers: are quite similar to the previous type; the difference lies in the encoding because the DataMatrix follow a pattern similar to 2D bar codes, determined by the ISO [17], the International Organization for Standardization;
d) Split Markers: first developed by Sony [18], they are also ID based markers, but the code is on two of its edges, leaving the area between them free to insert any information;
e) Frame Marker: is similar to the Split Marker, being the main difference is that the code lies not just on two edges, but on all of them [19]. Thus, this marker gains more robustness and tracking simplicity without losing the free area to insert information.

Figure 4 illustrates those kinds of markers.

2) Projective Augmented Reality: other important step in augmented reality applications is the virtual elements visualization by the users. The most common way today is through monitors, where the person places a marker in front of the camera and observes through the computer screen the virtual object inserted. Other famous device is the Head-Mounted Display.

Another way to display the virtual information is to place these data directly into the environment, not only in the viewpoint of the observer, and is called spatial augmented reality [20]. This insertion can be done through simple screens attached to the environment or in a more complex ways, through the use of semi-translucent mirrors to create the effect of holograms. The most common form of exhibition in spatial augmented reality is held directly by projections on a surface, called the projective augmented reality.

Projective augmented reality has some peculiar features, starting with the tracking of the real environment. In the traditional visualization, the virtual elements are attached to portions of the environment that include only the user's point of view, unlike the projective where information is assigned to the entire ambient.

For some applications it is important that the projection changes as the viewer moves, which can be useful to provide the sense of depth or sensitivity to context. For this it is necessary to track not only the environment but also the direction of the user's point of view. It can be done using sensors attached to his/her head or through stereo projection and polarized glasses, as in many modern movie theaters.

Another peculiarity is related to occlusion, since in projective augmented reality virtual elements can always be occluded, but can never be fully superimposed onto the real world. The opposite occurs in the conventional viewing, where occluding virtual elements are quite complex, but they are superimposed very easily onto real objects. The colors of virtual objects also need a special attention, as this feature may be modified at the projection moment, depending on the colors of the surface where the display occurs.

The direct integration of the real environment with virtual objects heavily influences the way the user interacts with the application. The features of projective augmented reality impose a more natural interaction. Thus it is very common to use tangible user interfaces and tracking parts of the user's body so that they are used to provide input to the system.

Thus, a major benefit of projective augmented reality is the ability to provide the interaction between virtual and real elements in an immersive way to the user without the need for Head-Mounted Displays. Another advantage is to be able to control the environment in a relatively simple way in order to achieve a good projection quality.

On the other hand, projective augmented reality is very dependent both on the projection surface and on the environment. If the projection surface is not opaque, light-colored and uniform, the image quality will be significantly compromised. The sharpness of the colors is also directly related to the environment brightness. Another problem to be considered is shadowing, which can be basically solved by correctly position the projectors or using multiple projectors.

IV. Product Concept

The authors attempted to use all the concepts covered in previous sections to design a dynamic blocks platform, called ARBlocks, that can explore the playfulness activities' benefits for the creation of educational activities for children.

The platform conception process was divided into three stages. At first, the design of the product, where the authors need to know the context in which the product will be used to develop a device that fits the needs of early childhood education. Then, a technique's research, allowing the technology development to make this product possible. Finally, the design of an application to help educate children who

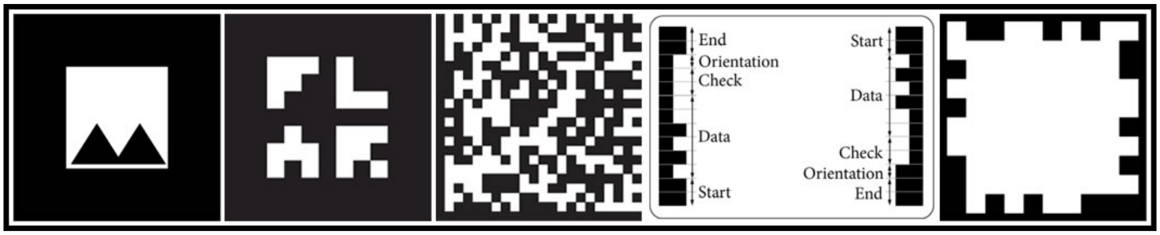

Figure 4. From left to right, template based marker, ID based marker, DataMatrix marker, split marker and frame marker.

use the proposed platform, in order to validate the authors' proposal.

A. Product Design

From the initial problem statement to the final product building, there are several steps to be taken in order to ensure the projects success for both the users and the market points of view [21]. With the product concept well defined, it was necessary to turn it into a product with aggregated usability and ergonomics qualities, having the kids necessities as guidelines. For this, in this project, main phases and methods from commonly used methodologies like Munari's and Bonsiepe's [22] were selected and applied, as described below.

1) Problem Definition: Löbach [23] says that is through the phase of problem definition that the formulation of the conditions of its resolution is possible. According to the cartesian method, to better understand a problem and solve it, we have to divide it at the maximum of sub-problems and solve them one by one, making the process more intuitive than trying to reach the solution directly [21].

The project could be divided in the resolution of three essential problems: shape, typography, and material. Being a project aiming a very specific public, data collection is a crucial task to find the optimal solutions to these sub-problems, becoming the base in which the other phases will stand on.

2) Data Collecting: this phase could be organized into a similar analysis and collecting information on two specific knowledge areas: typography and ergonomics, both focused on the infant public.

As the ARBlocks is a high-tech version of a well known object, the interactive blocks, the similar analysis was focused on objects that have formal, practical and symbolic functions [24] close to them. Most of the studied objects were low complexity, easily handled, educational, and reasonably small toys. Studying them allows the authors to know the market competitors of the product to analyze its features and also avoid possible reinventions [22].

It could be observed that the most commonly used material is wood, but plastic and foam were found too. The cubic shape allows the units to have 6 different kinds of information, one per face. This feature is widely explored, knowing that the same block set can have sequences formed by numbers, letters, colors, images and others. In some cases, the set forms a puzzle too.

Being all the investigated objects made for children, there are some fundamental features utilized to ensure users safety. Rounded corners avoid serious accidents to children, which doesnt have motor coordination completely developed. The size also follows some rules, not being so big that it gets hard to grab, or too small that the kid could try and succeed swallowing it.

Another characteristic verified is the necessity to have smooth and straight faces, so the graphic information can be printed easily and without deformations. An interesting differential found was the use of magnets on the blocks, so the kid can group them easier.

With the similar products found and analyzed, the next phase was to acquire knowledge about the typography to be used. It is common, when choosing fonts to assist children during alphabetization process, to think that fonts with "funny shapes", referring to the imaginary we have about infant themes, are appropriate. However, studies made by Watts and Nisbet [25], point to the opposite direction. They conclude that, being todays children in great contact with reading stimulating media — like signs, magazines, television shows and others —, they are well accustomed to the "adult typography". So, we should not create a separation from this reality with adaptations that dont aim exclusively to improve the readability and the legibility of letters, words and texts.

Following the same line of reasoning, some designers, typographers and pedagogues created typographies — some of them being used at national education programs — that have those improvements on its sizes, x-heights, terminals, brackets and other typography features.

For this project, two fonts were selected, as can be seen in Figure 5, both of them having typographic features similar to the researched fonts, being well accepted by the users. One of them is a printing style, the "National First Font"; the other, *"Mamãe que nos faz"*, is a cursive style, since children need to practice and learn both styles.

The third phase of data collection was about ergonomics. According to Itiro [26], ergonomics is the study of the relationship between man and its work, equipment and environment, and particularly the application of the knowledge

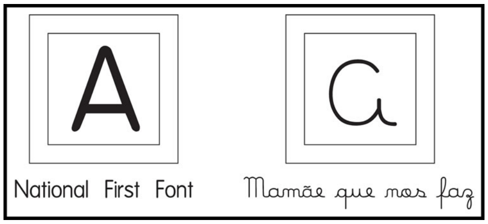

Figure 5. Fonts used to ensure good legibility and readability.

in anatomy, physiology and psychology, in the solution of the problems encountered in this relationship. The definition of the block measures was based on the ergonomic study defined as Strength Characteristics of U.S Children for Product Safety Design [27]. Aiming the blocks to be easily handled, they were designed to fit, approximately, at the palm of the kids hand. In technical terms, the maximum height of the blocks must measure the same size as the users third metacarpal bone, illustrated in Figure 6. According to the study, for 6 to 8 years old children, this size is about 5 centimeters.

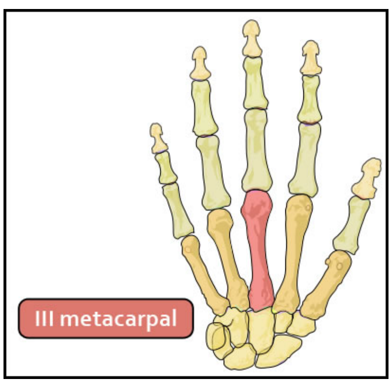

Figure 6. Hand and wrist bones with the Third Metacarpal in red.

Using the SCAMPER technique (Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, Reverse) [28], it was possible to create and study various combinations of the characteristics raised at the similar analysis phase. After producing several sketches for the product shape, two of them were selected and refined to reach the final solution. The other alternatives were discarded for presenting production high costs or use inadequacies like unsafe corners and inefficient storage. Durability and resistance were also requirements taken into account. Paper mock-ups were made to help studying and comparing shapes and proportions. This process is summarized in Figure 7.

The first solution selected is based on the most common shape, the cubic one, which allows 6 augmented reality markers per unit. Therefore, the application possibilities would increase, but with the drawback of higher complexity. As the system will project only on the top face, the user would have to memorize what information is on the other faces, causing a high difficulty level to the applications.

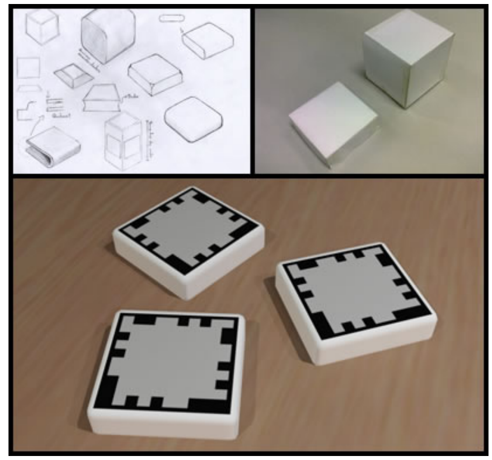

Figure 7. Initial sketches, paper mock-ups and final solution rendered with a 3D modeling software.

In order that the block has only two markers one at the top, the other at the bottom , the alternative two was developed with a height smaller than the first. The block must have the minimum height so that the user can move it without putting the hand on the top face, avoiding the marker to be occluded to the camera. Since the first solution has the difficulty of requiring a high spatial visualization and memorization effort, the second alternative was selected for better providing the needs of the project, analyzing technical viability and user restrictions.

3) Implementation and Tests: after achieving the objects shape solution, it is necessary to submit it to tests that prove its effectiveness. For this, mock-ups or prototypes depending on the complexity needed must be built and evaluated [24].

To perform the usability tests, a Styrofoam and paper prototype was made, using the real size defined, in order to study the necessity of adjustments on the product design as showed in Figure 8. Since at the moment the ARBlocks platform has only preliminary results regarding integration of tracker and projection technique and application, this test stage will be concluded after the results of the computational implementation.

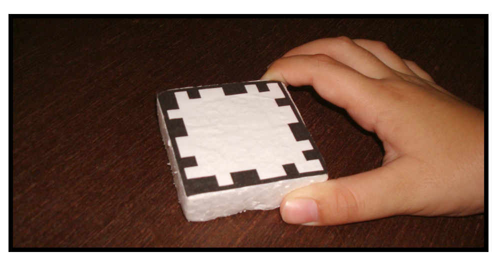

Figure 8. Prototype built to help making the usability tests.

B. Product Architecture

Once the main issues in product design have been defined, the technical development can start. For the information visualization and the interaction with them, the authors have concluded that augmented reality would be the best approach.

The first question to be addressed when developing an augmented reality system is how the tracking will occur. Since the proposed platform is a tangible user interface using projective augmented reality, the tracking, the information visualization and the input device involves the same cubic block object.

As the blocks are the projection surface, they cannot be textured so they do not harm image quality, should be uniform and white so that minimum interference occurs in the display of colors. However, it is not possible to track a surface with such characteristics. If all blocks are uniformly white, it is impossible to even distinguish one from another. To solve this problem, the first solution thought was to add a colored border to the blocks. However, this approach has some flaws, being the main one a limitation of the maximum number of markers tracked simultaneously, which would be only fifteen. This is due to the fact that color sensing is very susceptible to the ambient lighting condition and in order to have a reliable measure colors should differ from each other, as occurs in the CGA palette [29] which has only sixteen colors. Besides, the white color can't be used since it is the same as the block itself.

Therefore, the final solution uses a frame marker, with which it is possible to have all the benefits of a common marker and still get a large region of the block that does not have any information, totally free to display the projection. As far as the authors know, there is no free augmented reality library that supports this type of marker, thus a specific marker for the ARBlocks platform was created as well as a tracking solution.

The marker, shown in Figure 9, is wrapped by a continuous thin edge. Inside it is the code, a sequence of 10 squares, or bits, on each side. The code is the same for all edges so that redundancy gives more robustness to the identification process. The bits that change on each side are the first and the last one, which serve to indicate the orientation of the marker. Between those two squares on both ends are eight others that compose the code itself. This value allows the production of up to 256 different markers, which is sufficient for most applications.

The tracker for the proposed marker performs four steps. First the image is converted to grayscale and then segmented. In the next step, the Canny edge detector [30] was used to find all the edges in the image. Then, all edges that have four vertices and an area the size between two thresholds, calculated to have the most likely size of the marker , are selected. Finally, the code is read and those who possess a valid identifier are markers successfully tracked. This operation is done on every frame captured by the webcam.

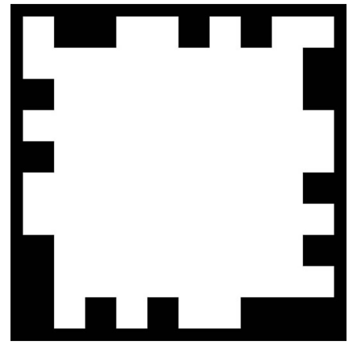

Figure 9. Frame marker designed for this project.

Another important aspect is the information visualization, which means projecting the information wanted only inside the marker area. For this, an adaptation of a technique proposed by Johnny Lee [31] was adopted in which a transformation is computed that modifies an image to be displayed in accordance to the dimension and orientation of the block tracked.

However, only applying a transformation that takes the data in the blocks' orientation and position is not enough for an accurate projection. This occurs because the camera and projector have different coordinate systems. Thus, it is necessary to align the camera-projector system in order to find the correlation between the coordinate systems of each device. This step is still under development, so the authors have not yet reached to a definitive alignment solution. Because the camera and the projector will remain motionless, the authors' initial idea is to use a calibration stage at the system's initialization. Thus, the four corners of the projection area would be selected, finding a match with the camera coordinates. In possession of four pairs of correspondent points that relate the systems, a homography between all positions of both devices can be applied.

Figure 10 illustrates the concept of ARBlocks, showing the complete setup of the system.

C. Application Development

From the moment the platform is concluded, an application should be developed that makes use of its characteristics. As a first application, the authors created a game to help teachers in early childhood literacy.

In order to develop an educational application that could assist the teachers and young needs, the conception of this game was centered on them, being necessary constant interaction with the educators and the children.

The starting point was the definition of a clear goal for the application. As this study case aims to create an educational activity, which uses the proposed tool, the main goal is the development of a game based on the dynamic

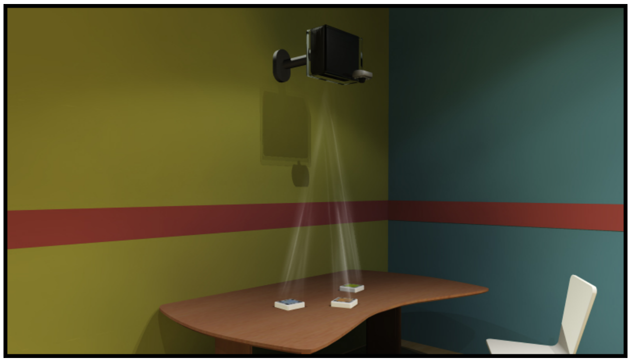

Figure 10. Platform's conceptual illustration, with the information on the blocks being displayed through its projection.

blocks platform that can be used as a support tool on early childhood literacy and that is capable to contribute with the creativity stimulation and with children development.

This objective clearly sets that the application must assist the teacher, contributing in the most natural way to the learning process, without removing the student's focus from the main goal, which is to learn through playfulness. To this goal be achieved is important to comprehend the classroom field, that brings up some questions that must be answered. Among them, there are:

a) How is the children literacy nowadays?
b) How children literacy may become more attractive to the young using tangible user interfaces?
c) What the current tangible user interfaces can provide regarding the interaction and teaching for the children?

The answer to these questions came up through a two phase research:

a) Competitor analysis: a detailed research about what has been developed, both in education as we know today as in tangible user interfaces and its use in the games context. Virtually all the results from this stage came from an intense bibliographic research in both areas;
b) Context comprehension: at this stage, a classroom observation was made, aiming to understand its operation, dynamics, rules, routine and difficulties, and also a semi structured interview was done with the teachers to obtain information, valuable contributions, and also the application's generic requirements. The obtained results show that the traditional literacy make a small use of manipulatives. It was possible, as well, to observe the way teachers minister their activities and test their students; that was of a great importance in the creation of the educational game dynamics.

With the research results, the authors were able to create a game, afterwards evaluated by the teachers in two prototyping sessions. The first one on paper and the second one on Styrofoam, with the block shape, as seen in Figure 11. From these two prototyping phases it was possible to refine with the educators the initial game idea, in a way that it could better attend the classroom necessities.

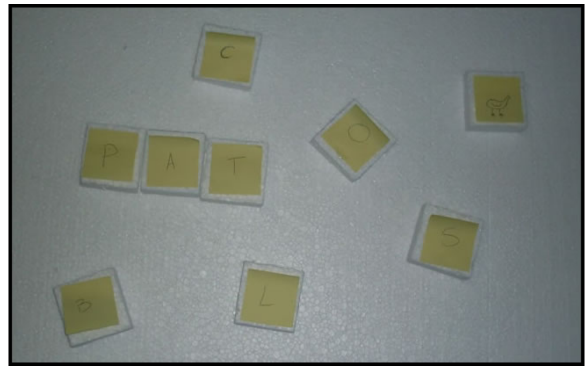

Figure 11. Styrofoam prototype tested with the teachers.

V. Preliminary Results

The steps already researched were implemented according to the descriptions found in the previous section. Thus, it was written a tracker to the frame marker described and a code to project information in a specific area.

Both were developed in C++ using Microsoft's Visual Studio 2010 C++ Express as the development tool. In order to help in the development, it was used the data structures for image, point, vector, line and other found in the OpenCV (Open Source Computer Vision) library [32] version 2.1, as well as some simple functions such as converting color image to grayscale.

The implementation and execution was performed on a Windows 7 virtual machine on a MacBook with an Intel Core2Duo 2.4 GHz, 2GB RAM and Intel X3100 video card. For the frame marker tracker it was used the iSight webcam, integrated with the notebook, with 640 x 480 pixels resolution. The information projection was done using an Epson projector, model S577C, which has a resolution of 800 x 600 pixels.

To validate the tracker the authors developed a simple application that, according to the code, draws blue, red or green lines over the marker. Thus, it is possible to assess whether the identification code is correct. It is also possible to validate its rotation, since the lines originate and terminate in the same vertices. Figure 12 shows the detection of a marker.

With just one marker the algorithm execution, along with the lines drawing occurred in an average time of 30.97 milliseconds, giving an average FPS of 32.2851 frames per second. This is sufficient time for real time applications, a basic requirement for augmented reality.

When more markers are inserted, the runtime virtually does not decrease. This is due to the fact that the steps occur in almost constant time regarding the number of markers tracked simultaneously, as it is always done a search by

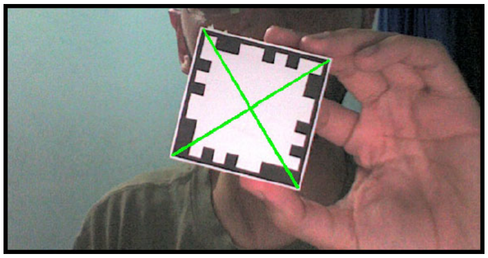

Figure 12. Tracking a frame marker using the proposed algorithm.

squares on the entire image, regardless of how many they are, and the access to the code information is performed directly. Thus, for the case illustrated in Figure 13, where three markers are being tracked simultaneously, the average running time for each frame was 32 milliseconds, giving an FPS of 31.25 frames per second.

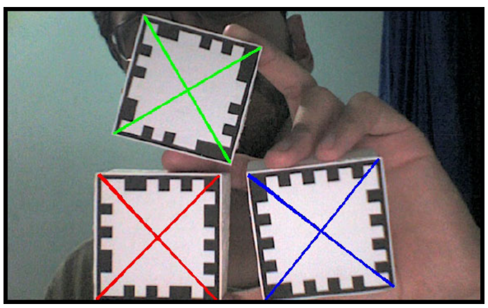

Figure 13. Tracking three frame markers simultaneously.

For the projection technique to be fully integrated with the frame marker tracker in a way that the marker vertices can be identified and used as the limits of projection, it is necessary that the camera projector alignment system is implemented. Thus, for evaluating the controlled area projection, the marker vertices' location is manually provided.

The projector used was positioned at a distance of one meter of the block, which is roughly the distance between both that the authors estimate to be ideal. The four corners of the marker were assigned and projection was properly done inside the marked area, a five centimeters side square, as shown in Figure 14. The time for the homography calculation and display of the content lasted more than necessary for a real time application, with an average FPS of one frame per second. This is due the fact that the implementation had prioritized accuracy, without having any optimization in the implementation.

VI. Conclusions

This paper presented a concept for a dynamic blocks platform. It was based in projective augmented reality, with the tracking made by using a frame marker and the data visualization by a projection only inside the bock area. By being a tangible user interface to be used for educational

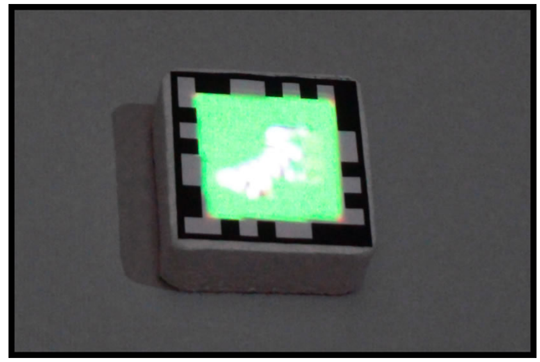

Figure 14. Projection occurring only inside the marker's free area.

activities its design required careful attention, especially because they are aimed for children.

The data collected in the design process proved very helpful for the development of ARBlocks. Through them, the result of a parallelepiped with rounded corners, measuring 5 x 2 x 5 centimeters of width, height and depth, respectively, was achieved and guaranteed as ergonomically efficient. The typeface was also chosen ensuring that users can interact with the product naturally.

The computational implementations were quite satisfactory, even running on a virtual machine. When executed on a native system the speed tends to increase. Although precise, the projection needs to be optimized by at least 30 times to be used in a real time application.

The authors believe that this work will have an important contribution both to the subareas of computer science that encompasses this work and for society as a whole.

A. *Future Works*

Regarding computation, as future work, the authors intend to solve first the bottleneck found in the restricted area projection. Initially it will be done an optimization on the code and how the homography is calculated.

Later it will be performed a research regarding the camera-projector calibration system, as well as its implementation. Finally, with all modules integrated the application can be developed.

In order to complete the project of graphic and formal aspects of user interaction, usability testing will be done with the prototype built. From the tests, it will be verified the design decisions made, like measures, shapes and typography, and the blocks material will be defined.

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References

[1] J. Piaget, *A formaçãoo do símbolo na criana: imitação, jogo e sonho, imagem e representação*, 3rd ed. LTC, 1971.

[2] C. A. W. Torrezzan and P. A. Behar, "Design pedagógico de materiais educacionais digitais," in *Anais do V Congresso Nacional de Educação Superior a Distância*, 2008.

[3] G. M. Schwartz, *Dinâmica lúdica: novos olhares*, 1st ed. Manole, 2003.

[4] Holgatetoy, "Hickory dickory dock clock nursery rhyme wooden mouse ran time learning shapes colors classroom teaching aid."

[5] Hape, "Alphabet abacus," fev 2011. [Online]. Available: http://www.hape-international.com/products/det/5/18/523/alphabet-abacus

[6] R. Cuca, "Tangram - racha cuca," mar 2006. [Online]. Available: http://rachacuca.com.br/jogos/tangram/

[7] T. P. Falcão and A. S. Gomes, "Design de interfaces tangíveis educacionais: uma metodologia baseada em contexto," in *Proceedings of VII Brazilian symposium on Human factors in computing systems*. ACM, 2006, pp. 13–16.

[8] D. Merrill, "Siftables: towards sensor network user interfaces," in *In Proceedings of the 1st international Conference on Tangible and Embedded interaction. TEI '07*. ACM Press, 2007, pp. 75–78.

[9] T. Ha, W. Woo, Y. Lee, J. Lee, J. Ryu, H. Choi, and K. Lee, "Artalet: Tangible user interface based immersive augmented reality authoring tool for digilog book," in *Proceedings of the 2010 International Symposium on Ubiquitous Virtual Reality*. IEEE Computer Society, 2010, pp. 40–43.

[10] R. Rodulfo, *O Brincar e o Significante: um estudo psicanaltico sobre a constituição precoce*, 4th ed. ArtMed, 1990.

[11] F. O. Brotto, *Jogos cooperativos: o jogo e o esporte como um exercício de convivência*, 3rd ed. Projeto Cooperao, 1999.

[12] B. Ullmer and H. Ishii, "Emerging frameworks for tangible user interfaces," 2001.

[13] D. Africano, S. Berg, K. Lindbergh, P. Lundholm, F. Nilbrink, and A. Persson, "Designing tangible interfaces for children's collaboration," in *CHI '04 extended abstracts on Human factors in computing systems*. ACM, 2004, pp. 853–868.

[14] O. Zuckerman, S. Arida, and M. Resnick, "Extending tangible interfaces for education: Digital montessori-inspired manipulatives," in *Proceedings of CHI 2005*. Press, 2005, pp. 859–868.

[15] H. Kato and M. Billinghurst, "Marker tracking and hmd calibration for a video-based augmented reality conferencing system," in *Proceedings of the 2nd IEEE and ACM International Workshop on Augmented Reality*. IEEE Computer Society, 1999, pp. 85–.

[16] M. Fiala, "Artag, a fiducial marker system using digital techniques," in *Proceedings of the 2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'05) - Volume 2 - Volume 02*, ser. CVPR '05. IEEE Computer Society, 2005, pp. 590–596.

[17] D. Wagner, "Handheld augmented reality," Ph.D. dissertation, IInstitute for Computer Graphics and Vision, Graz University of Technology, Graz, Austria, 2010. [Online]. Available: http://studierstube.icg.tu-graz.ac.at/thesis/Wagner_PhDthesis_final.pdf

[18] H. Nishino, "A split-marker tracking method based on topological region adjacency & geometrical information for interactive card games," in *SIGGRAPH ASIA Posters*, 2009.

[19] D. Wagner, T. Langlotz, and D. Schmalstieg, "Robust and unobtrusive marker tracking on mobile phones," in *Proceedings of the 7th IEEE/ACM International Symposium on Mixed and Augmented Reality*, ser. ISMAR '08. IEEE Computer Society, 2008, pp. 121–124.

[20] R. Raskar, G. Welch, and H. Fuchs, "Spatially augmented reality," in *In First IEEE Workshop on Augmented Reality (IWAR98*, 1998, pp. 11–20.

[21] B. Munari, *Das Coisas Nascem Coisas*, 1st ed. Martins Fontes, 1998.

[22] G. Bonsiepe, P. Kellner, and H. Poessnecker, *Metodologia experimental; desenho industrial*. CNPq, 1984.

[23] B. Löbach, *Design Industrial - Bases para Configuração dos Produtos Industriais*, 1st ed. Blucher, 2001.

[24] N. Baxter, *Projeto de Produto: Guia Prático para o Design de Novos Produtos*, 2nd ed. Brochura, 2003.

[25] M. C. Ponte, "Reflexões sobre design gráfico de livros para crianas em processo de alfabetização," Centro Universitrio Senac de São Paulo. [Online]. Available: http://www.praxisdesign.com.br/mais/img/monografiadesigngraficoealfabetizacao.pdf

[26] I. Lida, *Ergonomia: Projeto e Produção*, 2nd ed. Edgar Blucher, 2005.

[27] C. Owings, D. Chaffin, R. Snyder, and R. Norcutt, "Strength characteristics of u.s children for product safety design," Tech. Rep., 1975.

[28] D. Silverstein, P. Samuel, and N. DeCarlo, *The Innovator's Toolkit: 50 Techniques for Predictable and Sustainable Organic Growth*, 1st ed. Wiley, 2008.

[29] I. B. M. C. IBM, "Color/graphics adapter," Tech. Rep., 1981.

[30] J. Canny, "Finding edges and lines in images," Cambridge, MA, USA, Tech. Rep., 1983.

[31] J. Lee, P. Dietz, D. Maynes-Aminzade, R. Raskar, and S. Hudson, "Automatic projector calibration with embedded light sensors," in *Proceedings of the 17th annual ACM symposium on User interface software and technology*. ACM, 2004, pp. 123–126.

[32] G. Bradski, "The opencv library," *Dr. Dobb's Journal of Software Tools*, 2000.