Developing Educational Applications with a Non-Programming Augmented Reality Authoring Tool

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Developing Educational Applications with a Non-Programming Augmented Reality Authoring Tool

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Abstract: Nowadays, augmented reality application trends to place smart virtual objects into the real scene to react to user and environment condition. In this way, this article shows an application to teach polygon extrusion and revolution math concepts, using the authoring tool basAR to create a set of interactive educational applications based on Augmented Reality. This article presents the application design, the concepts involved and the evaluation results.

Introduction

Development of spatial skills is a critical understanding when students start learning three-dimensional objects. In order to help this achievement, usually the teachers use woodcraft objects and several orthographic and axonometric projections inside books (Martín-Gutiérrez, Saorín, Contero, Alcañiz, & Pérez-López, 2009).

A way to improve the learning of three-dimensional shapes is based on Augmented Reality (AR), whose definition by (Kirner C. , Prototipagem Rápida de Aplicações Interativas de Realidade Aumentada, 2011) is: "augmented reality is an interface based on computer generated information combination (static and dynamic images, spatial sounds and haptic sensations) with the real user environment, provided by a technological device and using natural interaction on the real world".

The main pointed advantages to use AR techniques for educational purposes are the following: (Cardoso & Lamonier Jr., 2009)

a) Students are more motivated, because they live an experience proposed by the application and the use of new technology;
b) AR, as Virtual Reality (VR), can illustrate processes and characteristics that aren´t usually viewed by the user;
c) AR allows detailed visualization and objects animation;
d) AR allows micro and macro visualizations that cannot be seen with naked eyes, and proposes different view angles to understand the subject, as atomic structures or planets and galaxies;
e) AR allows interactive virtual learning using virtual experiments;
f) AR allows the students to recreate the experiments out of the school;
g) The students become more active due to interactive application;
h) AR encourages creativity, improving the experience;
i) AR provides equal opportunities to different cultural students;
j) AR helps to teach computational and peripheral skills.

An example of application, which uses augmented reality interface, is the Construct3D Tool (Vienna University of Technology, 2011). This tool is designed to teach three-dimensional geometrical concepts, specifically projected to mathematics and geometry learning. The main goal, in this case, is that the students can visualize and interact with the objects, directly on a 3D space, with faster concept learning than the traditional methods.

Figure 1 shows two examples of the Construct3D application.

Figure 1: Construct3D examples (Vienna University of Technology, 2011).

basAR

The basAR (*Behavioral Authoring System for Augmented Reality*) (Cerqueira & Kirner, basAR: Ferramenta de Autoria de Realidade Aumentada com Comportamento, 2011) is an augmented reality authoring system to develop intelligent environments based on action points. Figure 2 shows the ARToolKit fiducial marker (Kato & Billinghurst, 1999) that has points (blue spheres) associated with it and the control marker (with its respective action point). Each action point has a reactive zone (transparent blue area), working as an area where the basAR understands that a collision between action points has carried out. When a collision between base and actuator action points happens, it activates a behavior.
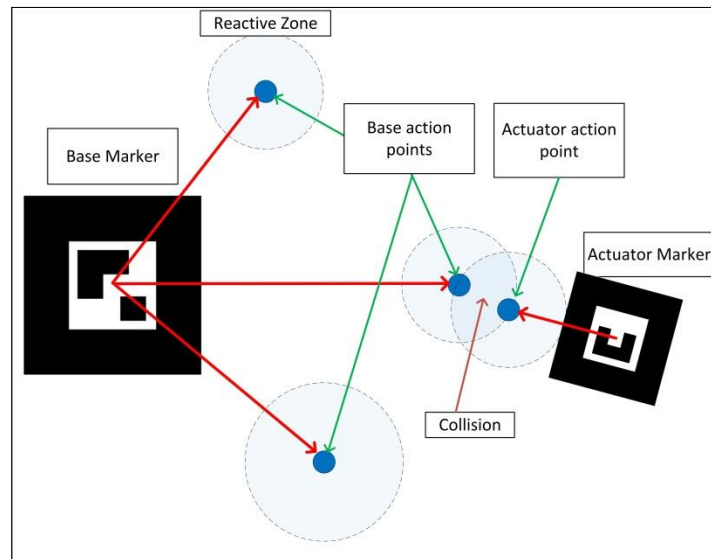

Figure 2: How basAR action point activation works.

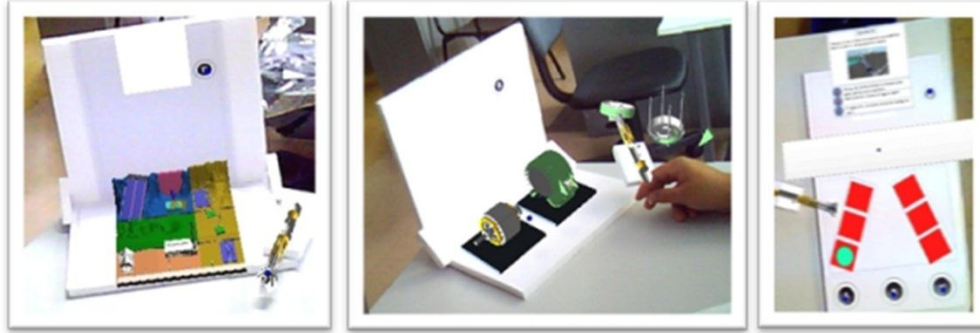Some basAR examples include: puzzles, assembly guides or interactive games as shown on Figure 3

Figure 3: basAR examples, from left to right: Puzzle, assembly guide and interactive game.

Authoring

The building steps to develop an augmented reality application using basAR have two approaches: top-down and bottom-up learning/development.

The top-down learning means that the author will start with progressive learning of the tool. On the bottom-up learning the author will learn the basAR structure and configuration files to create applications. In Figure 4, there is a learning/development cycle, based on software engineering development charts (Kirner & Martins, 1999).
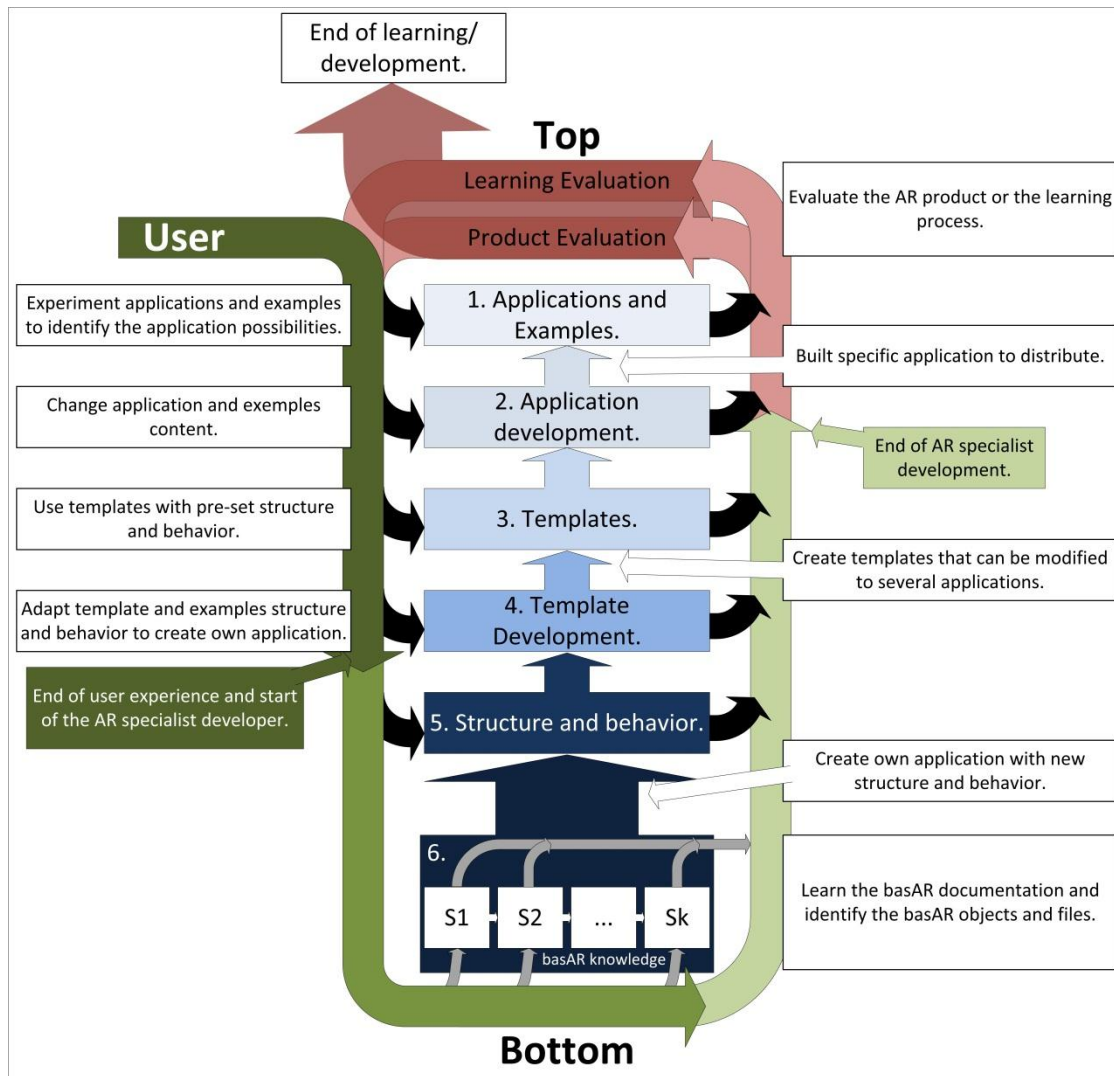
Figure 4: Learning/development basAR cycle.

Top-down authoring

The top-down author, usually characterized as the content author, designs and inserts 3D models and audio in the application, examples and templates, changing the behavior and structure, sometimes helped by an auxiliary interface to meet the desired application.

In the learning process, the top-down author start using the products (applications and examples) created by the authoring tool, followed by the educational potentials evaluation to think about the universe of possibilities that the tool provides to the application designer.

After the applications and examples evaluation, the top-down author tries to change only the virtual objects and the audio, without changes in the structure and behavior. (Kirner C. , 2011) presents this type of activity.

The second step of this approach is the use of Templates. Templates are collections of pre-made scenario with defined behaviors and structure. The author can insert his content and organize the structure creating new applications. Templates are usually available at the developer site with user procedures, allowing changes in configuration files directly or by a visual interface hiding details about folders and names. This characteristic turns the basAR into a meta-tool because it is possible to create an upper application above the basAR to control or to easy the development process (Figure 5). The basAR layer covers the programming layer, so the basAR user can be a non-programming user. On the other hand, the structure and behavior layer, where is the AR application implementation, cover the basAR layer. The top-down author can create his/her application handling folders and files or using an interface that hides these details. As the author is going to work in the layers from top to down, the development complexity increases while the application abstraction decreases.
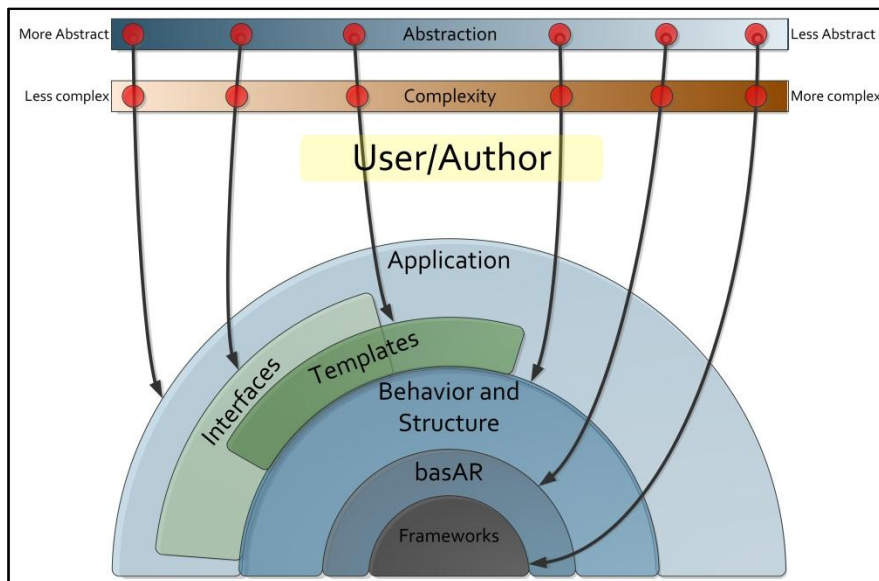
Figure 5: Concept layers and complexity x abstraction development.

The top-down author usually does not go lower than adapt the template and create structure and behavior, once the templates and interfaces cover most of the application cases.

Bottom-up authoring

The bottom-up author, usually characterized as specialist author with programming skills, learns the tool specification by its documentation and courses to develop his/her applications.

The learning process of a bottom-up author begins in the same way as the top-down author, going to the top layer to test applications and examples, evaluate the potentials and identify the desired application characteristics.

After evaluate the application and examples, the bottom-up author goes to the bottom layer, searching for documentation and courses and getting consulting about the tool. This learning has steps that introduce parts of the basAR possibilities, where each part enables the author to produce a type of application. Other way to learn the basAR is to understand it as a whole, covering most of the possibilities of the basAR architecture and potentials. This way is suitable for some people depending on their learning styles.

After getting the basAR architecture knowledge, the author starts developing his/her own structure and behavior, creating applications without content. These applications are templates for top-down authors, who can manipulate his/her content or use an interface to do that (Flauzino, Kirner, Kirner, & Souza, 2011).

In the upper layer the author creates the final product to evaluate and use. The evaluation process of a basAR product can indicate changes and adjustments on it, as software re-evaluation procedures (Kirner & Martins, 1999).

Collaborative development between content and specialist author

The collaborative development between top-down and bottom-up author divides the application conception in two approaches: the content conception and creation and the augmented reality scenario creation. The content author may use tools as Autodesk 3D Studio Max, or download the models from the Google SketchUp Warehouse, use Microsoft PowerPoint to make textures, record audio or use sound repositories as SoundJay (www.soundjay.com), leaving the behavior and structure description to the specialist.

Application Development

Concept

The first step to create a smart augmented reality application is to understand the desired application working concept, creating a flowchart, Mind Map or a State Diagram. This step is necessary to organize the application working flow and build-up a list of necessary objects.

It is desirable to build a context guide, where, by choosing a specific path, the user achieves some result. This context guide has two levels. In the first level, the user chooses which polygon he wants to study: circle, square or a triangle. In the second level, with the polygon selected, the user chooses the action to apply to the polygon: extrusion or revolution. After the second choice, the application shows the polygon being transformed to a three-dimensional geometric polyhedron.

Figure 5 shows a simple flowchart, organizing the context guide as flow of actions, going from the polygon choice to the achieved polyhedron.
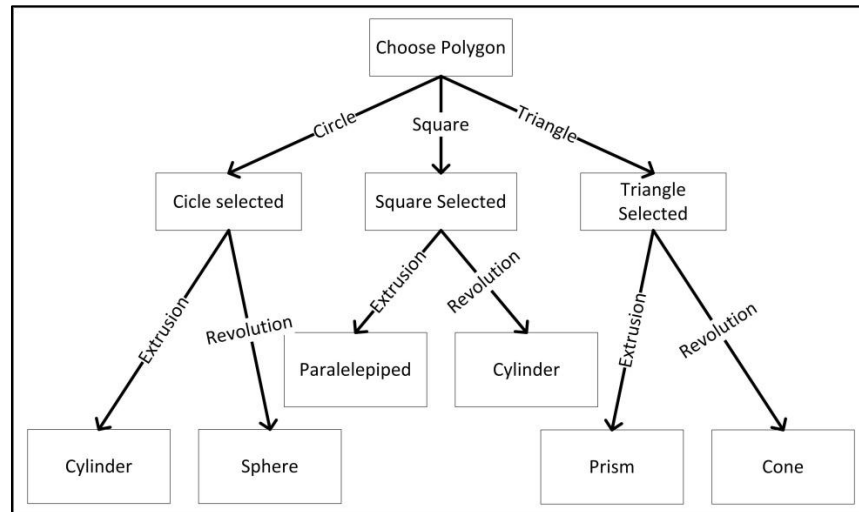

Figure 6: First flow chart to organize the application conception.

Defining infra-structure and structure

The application physical structure is the workspace where the user interacts with the application. To implement the context guide, a physical structure of a sheet of paper (Figure 6a) with a marker creates an AR infra-structure (object that defines real and virtual relation). Figure 6b shows the virtual action points, placed relatively to the infra-structure marker. Action points have behaviors and virtual objects to render (Figure 6c).
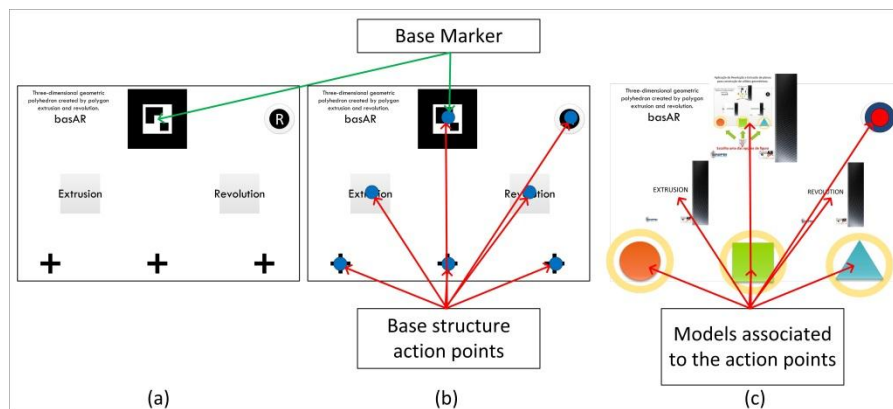

Figure 7: (a) Physical structure to be used as workspace; (b) Physical structure with the virtual structure; (c) Models on the virtual structure.

The base structure action points, which are numbered to create behavior, match to the printed workspace, according Figure 7 The action points are:
1. Place to select the circle;
2. Place to select the square;
3. Place to select the triangle;
4. Place to carry-out the extrusion action;
5. Place to carry-out the revolution action;

6. Place where will be shown the helping boards and action results;
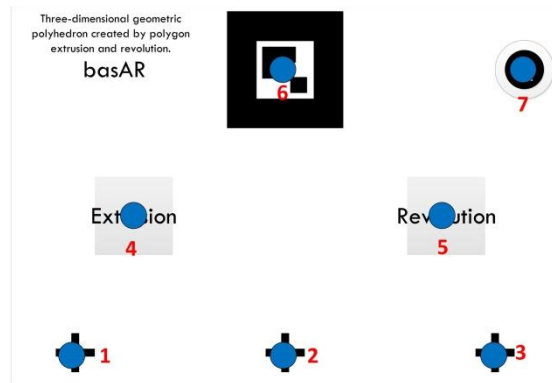7. Place to reset the application.

Figure 8: Base structure points.

To interact with the base structure action points, it is necessary an actuator artifact. This artifact also uses an ARToolKit marker, developed as an origami cube for easy distribution. The cube sheet has folding instructions, as Figure 8a. When fully folded, the actuator cube appears as shown in Figure 8b.
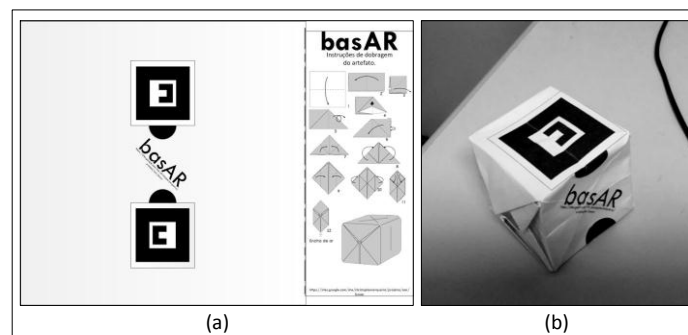

(a)   (b)

Figure 9: Actuator artifact: (a) folding instruction sheet; (b) folded artifact.

To each polygon type, there are two models: one showing a circulating arrow, indicating that the polygon can be selected, and other pulsing element to show that it is already selected.

To the extrusion and revolution informative boards, there are an explanation board and three other boards explaining the user action after the polygon choice, counting a total of eight models: extrusion explanation, circle extrusion, square extrusion, triangle extrusion, revolution explanation, circle revolution, square revolution and triangle revolution.

The major visualization board has explanations to help the user usability and to show the result of the extrusion or revolution: application introduction, a help to choose the circle action, a help to choose the square action, a help to choose the triangle action, the resulting cylinder one, the resulting sphere, the resulting parallelepiped, the resulting cylinder two, the resulting prism and the resulting cone.

Defining behavior

The application behavior follows the basAR behavior structure (Cerqueira & Kirner, 2011) and guided by the flowchart in the Figure 5, to define the behavior on each action point at each application instant. Figure 9 shows a simplified behavior map used to create this application. The arrows indicate where the actuator artifact has touched on the physical structure to go to the next level. Note that no programming skills as C/C++, Java or Flash is necessary.
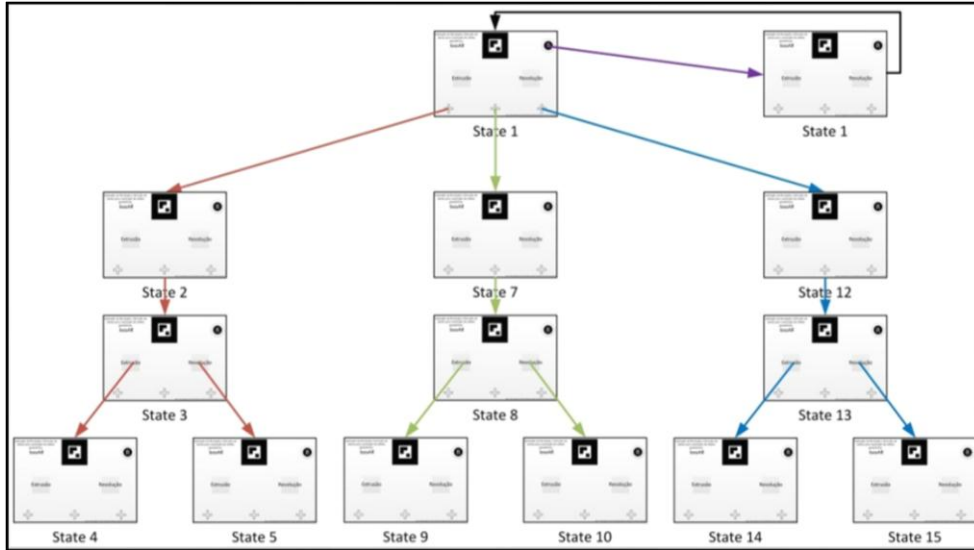
Figure 10: Simplified behavior map, showing where on the physical workspace, the user touches to interact with the application. The red arrows are the circle path, the green arrows are the square path and the blue arrows are the triangle path.

Figure 10 shows a storyboard with print screens of the application. Note that not all the states have associated screen, once those are configuration states that only change properties and automatically passes through. To know more about basAR behavior, look to basAR manual. (Cerqueira C. S., 2011)
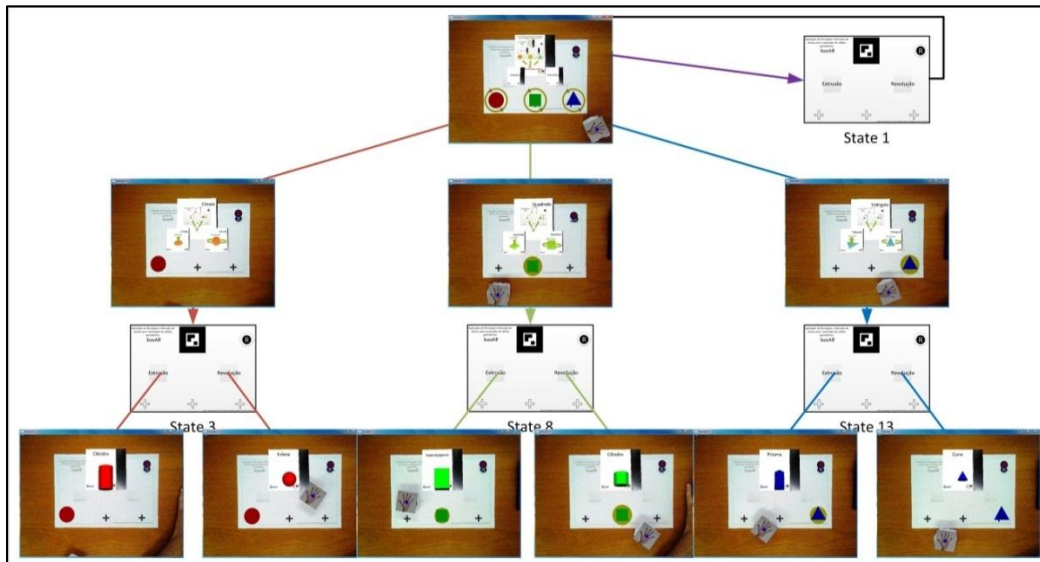

Figure 11: Storyboard showing print screens of the application to each possible choice.

Figure 12 has an example of how the states describe the basAR behavior file, showing the States 1 through 4.

```
BEGIN_STATE 1
        1 CHGST ONLY_OBJECT 2 Audio/Colisao1.mp3
        2 CHGST ONLY_OBJECT 7 Audio/Colisao1.mp3
```

```
        3 CHGST ONLY_OBJECT 12 Audio/Colisao1.mp3
        4 STAT  ONLY_OBJECT
        5 STAT  ONLY_OBJECT
        6 STAT  ONLY_OBJECT
        7 CHGST ONLY_OBJECT 17 Audio/Colisao1.mp3
END_STATE

BEGIN_STATE 2
        1 CHGM 2
        2 CHGM 3
        3 CHGM 3
        4 CHGM 2
        5 CHGM 2
END_STATE GO_TO 3

BEGIN_STATE 3
        1 STAT ONLY_OBJECT
        2 STAT HIDE
        3 STAT HIDE
        4 CHGST ONLY_OBJECT 4 Audio/Colisao1.mp3
        5 CHGST ONLY_OBJECT 5 Audio/Colisao1.mp3
        6 CHGM 2
END_STATE

BEGIN_STATE 4
        6 CHGM 5
END_STATE
```

Figure 12: Example of how behavior is described on basAR.

Experiments

The geometry application was tested by a group of students and teachers at *Universidade Federal de Itajubá* (UNIFEI), after an introductory speech about the basAR authoring tool; the tested group presented some knowledge about augmented reality applications. A quiz about interaction, usability, learning, behavior, graphics and functionality measured some characteristics of the application. A histogram graph (Figure 12) created by a Likert scale presents the evaluation results.
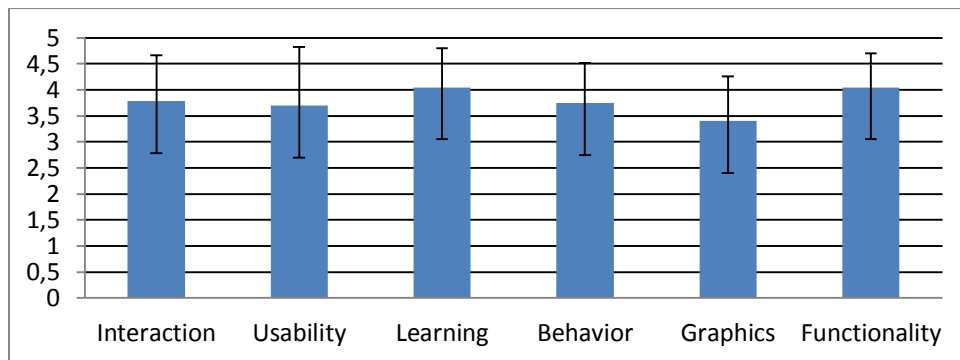

Figure 13: Evaluation results.

Some students suggested the use of a plane marker with a pointing ball, instead of the cube, as the test group uses this other type or actuator artifact in other projects(Figure 13a), developed by (Kirner & Kirner, 2011). The difference is that the pointing plane marker needs others materials than the cube marker, as in Figure 13b, which needs only to fold the sheet of paper.

Observations about usability suggested the increasing of the text font size, to be more readable.
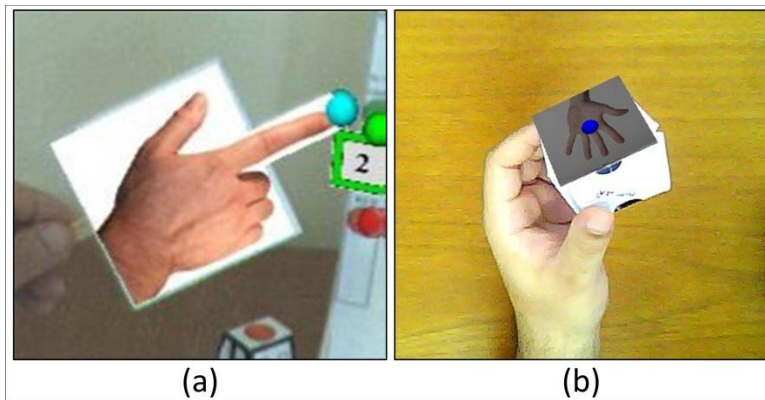
Figure 14: (a) Plane actuator artifact; (b) Cube actuator artifact.

Conclusions

Augmented Reality based on monitor is a powerful tool to improve educational activities, turning it more creative and interactive, motivating the student learning. This approach is inexpensive rather than other experiences, as the Construct3D, which makes this type of augmented reality usable on most of school environments.

The basAR tool allows to easily create smart augmented reality environment, without programming skills. It is only desired to know the concept of Mind Maps or flowcharts creation. The basAR development team and some students, involved in similar projects, are developing a repository of templates which will make even easier and faster to build-up the application.

This geometry application, using extrusion and revolution concepts, is a first attempt of a series of future application which will be developed and published online, involving content manipulation on augmented reality environments. A future version of basAR will provide a graphic interface to build the augmented reality scene and behavior.

This application is available to download at:

- http://www.ckirner.com/basar
- https://sites.google.com/site/christophercerqueira/projetos/ear/basar.

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