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# Magic in Augmented Reality

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**Abstract**

*In this paper we suggest a new approach for playing the "Magic The Gathering" game. This approach allows the user to perform a set of game moves within this popular card game using a Tangible Augmented Reality (AR) environment. Each move represents a new interaction involving real and virtual worlds. We try to make the game more realistic and interactive, through the usage of a tangible user interface. Therefore, interaction with virtual objects is simple and natural. Magic in AR, consists of a camera, a computer, a video projection screen and a deck of cards to play the game. The original Magic card deck has been changed to include visual tags to be used within an AR system. However, the changes performed in this card deck don't modify the philosophy found within a common "Magic The Gathering" card deck. Consequently, we propose a new paradigm to play the game, keeping the traditional and known elements of the game that are now part of a system that frees our imagination. We describe the system requirements, its architecture, involving the integration of ArTooKit in the Virtools authoring environment, and finally extract conclusions of the system use and usefulness, drawn from usability evaluation.*

*Category and Subject Descriptors: 1.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism*

## 1. Introduction

The work presented in this paper has been largely influenced by the known "Magic The Gathering" (Magic The Gathering is a trademark of Wizards of the Coast, Inc) card game [MAGIC] and presents an innovative Tangible Augmented Reality approach to this game. Like the original game, our system is prepared for two users that manipulate physical game cards resembling the original, with an emphasis in the tangible aspect of the interface.
Each card is recognized by the application and, based on the configuration of the game, identified as a terrain, a warrior, a spell or any of the possible symbols found in the "Magic The Gathering" card game. The main game philosophy is centred in turns where each participant play is role. For that matter, cards received and the player's strategy draw up the path within the game.
In each movement, 3D animated virtual elements, registered on the cards or on the desktop were the game is taking place, will "fight" or "defend" themselves, following the rules found in the conventional version of the game. In our prototype, only subsets of the game rules were developed. However, we've set the basis for additional rules and even the implementation of the full Tangible AR version of the game.
In the next section, we provide an overview over related work that inspired our work covering interactive AR systems and their use in education and entertainment. In section 3, we present an overview of the Virtools 3D Authoring Platform used to develop the system. Section 4 covers system requirements and architecture details. We start by making a small introduction to the game "Magic the Gathering", analyse the need for our new approach for the game and define the system architecture. We cover the definition of game components, configuration, and the integration between Virtools and ArToolKit [ARTOOLKIT]. In Section 5, we presented some of the game rules and the way they were developed. Section 6 covers the Results and Usability Evaluation of the game. Finally, in section 7, we introduce the conclusions and future directions for this research.

## 2.Related work

Authoring of interactive systems using tangible augmented reality, enables interaction with 3D virtual elements through the manipulation of physical objects and artefacts. 3D virtual elements are registered over related physical objects by means of tracking, such as marker based tracking through computer vision techniques and computer graphics. Interest in this area of research has increased over the last years, which is proved by the increasing number of researchers building Tangible AR applications.
New requirements for the development of Tangible AR applications must be met, namely more efficient development tools. The solution has been to build high level programming systems and environments where the "virtual" elements can be manipulated by using physical objects and,

at the same time, making these interfaces extremely simple and easy to work. Several projects using this approach and type of interfaces have emerged, namely the Immersive Authoring of Tangible Augmented Reality Applications [LNBK04] and Directing Virtual Worlds [LGK04]. Both applications convey a new approach for authoring tangible AR applications, giving the ability to carry out some authoring tasks in a simple and very natural way to the user, which proves the increasing interest in this research area. The change from a pure education and authoring approach towards the development of entertainment applications in AR was an easy and short step taken towards the use of this approach.

The TankWar system [TJ05] provides an entertainment approach for the use of augmented reality applications. The authors of this work have built an augmented war game based on a table top approach and computer strategy games. All game elements (tanks, helicopters and artillery) are virtual objects working superimposed on top of real objects. The control of the elements within the game is made using a "magic lens" metaphor mounted on a wireless gamepad. The lens is used for selection while the buttons are used to issue different commands.

Another example can be found in BattleBoard 3D [BATTLE]. BattleBoard is a game based in a sequence of the "Star Wars Episode IV" movie, where "virtual" pieces of the game seemed "alive", hence, able to "move" and "attack" each other in the chess table. Using this idea, the authors have built a battle board where users move physical chess pieces built with visual markers. Afterwards, 3D virtual objects are registered over visual markers. In this battle board, the pieces "fight" and "move" virtually based in chess movements performed by users. Other works can be found that use a Tangible Augmented Reality approach, as well as games that create a new and more natural approach to game play. In Collaborative Gamming in Augmented Reality [ZEM96], players, using a Head Mounted Display, can engage in board games like Mah-Jongg.

## 3. The Virtools 3D Authoring PlAtform

### 3.1 System Architecture

The Virtools 3D authoring and development platform [VIRTOOLS],[VIRTOOLSINTR], is the result of the integration of several technologies in a package, which is used to author 3D interactive environments. Virtools allows the user to create interactive 3D and multimedia content, in a simple, fast and effective way, using a drag and drop visual metaphor. It allows users without any programming knowledge to develop, in an extremely fast way, applications that create realistic visual representations and interactive scenarios, combining 3D art, sounds, animations and more.

The subsystems included in Virtools package are as follows (Figure 1): an authoring application, a behaviour engine, a rendering engine, a web player and a software development kit (SDK).

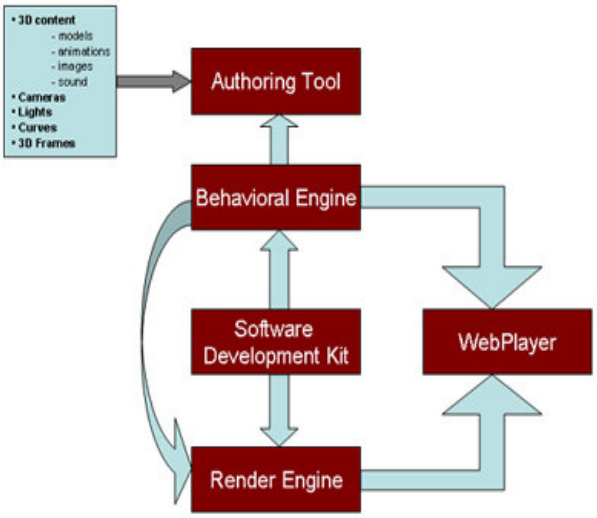


**Figure 1 – Virtools System Architecture [VIRTOOLS]**

The different resources that are used to author a 3D virtual world can't be created inside the Virtools system. Therefore, every graphical and multimedia resource has to be imported into Virtools. Applications such as 3dMax [3DSMAX] and Light Wave [LIGHTWAVE] are commonly used together with Virtools, when building interactive 3D applications.

The behaviour engine is responsible for the logical definition of the interactivity between objects and user, including the interaction behaviours. The system provides an interactive visual environment in the desktop where, with simple actions, the user can make the engine work. In the user's side, it isn't important how the function works, he or she just have to insert the boundary values and conditions, leaving the engine to perform all the work [VIRUSER].

The rendering engine is responsible to perform all the calculations, representing and presenting to the user, 3D and multimedia content, abstracting him/her from the lower details, namely DirectX or OpenGL rendering tasks. For a fast distribution of authored Virtools applications, a web-player is also available enabling content to be shown over the web.

### 3.2 An Overview of the Virtools Interface

Like most of the 3D authoring systems that are available in the market, Virtools provides a simple desktop interface (Figure 2). In its default settings, the top left viewport shows the 3D view where all the 3D elements are presented in a given scenario. This is where the render engine presents its results.

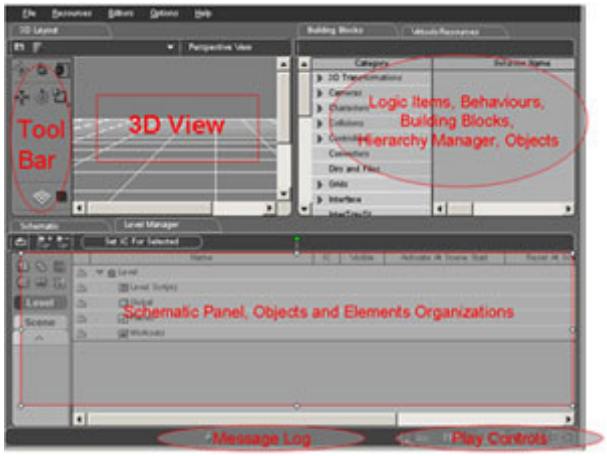


**Figure 2 – Virtools main desktop interface.**

The top right viewport is where we can find the behaviours and building blocks elements that correspond to pre-developed scripts that perform a series of pre-set actions. Using this elements, the user can apply behaviours and geometrical transformation to the objects presented in the 3D viewport that can occur during the life cycle of the application.

As a simple example that illustrates how to set a 3D walking character, the user has to do the following actions, in order:

1. Choose the 3D character presented in the top right tab "Virtools Resources" and drag it into the 3D View.
2. Select the correct building blocks and dropped those on top of the 3D character, in this case, the character controller.
3. A new window opens up and lets the user choose which animations are to be used for what actions. The user may add a keyboard Mapper and choose which keys will interact with the character. This allows the user to control the character with the keyboard.

Figure 3 presents the logical diagram of this example behaviour.

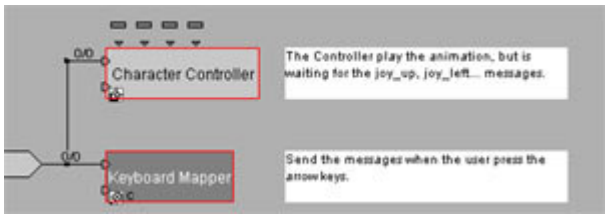


**Figure 3- Virtools schematic example of a behaviour.**

In the top right panel, we can find also predefined resources like sounds, 3D objects, 2D elements, textures, materials, etc., that can be dropped in the 3D view and used in the application. The bottom part of the interface is where the editing part occurs. All the objects presented in the 3D view are listed in this part and it is possible to change the attributes, materials and textures.

In the bottom part of the desktop interface (Figure 2), we can find the schematic panel presented before. It's where all the "*programming logic*" will happen. Each building block is represented as a box. The building block can receive input parameters and produce the output of other parameters. The types of these parameters are presented when the user superimposes the mouse over a given building block.

The flow of the application is represented with lines that connect the building blocks, where the dashed lines represent the flow of data (parameters) and, the solid lines represent the flow of the execution. The internal variables of the building blocks are not shown. Only the inputs and outputs to and from different building blocks are depicted. Watching these variables during execution time, simplifies the debugging of the application at any specific time. Therefore, ordinary users, not just skilled programmers, can easily understand and control a Virtools program's flow.

## 4. System requirements and architecture

### 4.1. Introduction to the Magic The Gathering game

Magic The Gathering is a simple game played using physical cards where two persons play imaginary battles using the cards. Each card represents an element of the game and all cards have special rules applied in the course of the game [MAGICRULE].

With the improvement of internet technology the physical limitation of imposing the face-to-face presence of the players, has ended and people could start to play the game in a virtual ambient, with virtual cards and with another remote person. Eventually, the opponent could be in the other side of the world [MAGICOFF].

Thus, to play a Magic The Gathering game with physical cards, you'll need a Magic deck, a friend with a deck, and something to keep track of your total life figure. The objective like, in any other strategy game, is to reduce your opponent's total life to 0 before the same happens to you.

The game starts with 20 points of life for each player. Afterwards, a coin is used to decide which one goes first and seven cards are taken of the shuffled deck. Once both players are satisfied with their starting hands, the game starts.

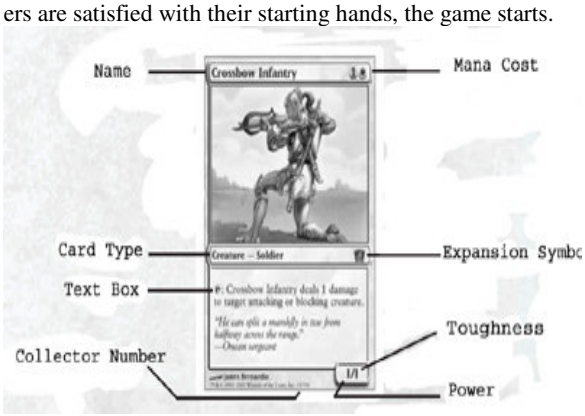


**Figure 4 – Magic the Gathering card example [MAGICOFF]**

Each "Magic The Gathering" card represents an element of the game. It has a name, a type, an information box, a *mana* cost or *mana* added, an attack power and/or a defense power. In figure 4, you can see this and other necessary attributes of a card.

### 4.2. The need for something more: "Magic in AR"

"Magic The Gathering" is, in its basic definition, a card game, with specific rules, lots of elements involved, and with a strategy well defined by each player. All this together defines who wins and who loses the game. However, besides the standard elements, "Magic The Gathering" uses the imagination part of the human player. They are invited to imagine the soldiers, the terrains, the magic's, the wizards, the battles, all the magic elements of the game.

So the idea for this new approach is to free the player from this work, and keep him/her concentrated in the strategy, while proposing a visual approximation to his/her imagination, in real time and using Tangible AR. In our approach "Magic in Augmented Reality", the elements that where a part of imagination are now a virtual part of the game.

In "Magic in AR", the physical pieces are cards of the game. Each card represents an element of the game. It can be a soldier, terrain or a magic. Each card is associated with a virtual object showing the 3D virtual version of the element that the card represents. Through the integration of the Virtools and the ArToolKit [ARTOOLKIT] platforms, it became possible, using a simple web cam, to detect the pose (position and orientation) and identify visual markers on every card in play and to register associated virtual elements. Moreover, based on the card pose in the physical board game, properties (such as attack or defence) of each card can be determined. After the detection and identification is completed, the physical pose of the card is associated with the pose of the corresponding virtual element.

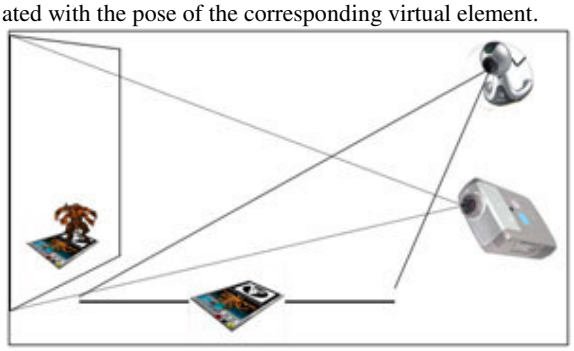

**Figure 5– Magic in AR conceptual architecture**

Using a monitor or a projector, players can see the result of their moves in an augmented reality representation, which, in an ordinary Magic game, they could only imagine (See Figure 5).

### 4.3. Component Definition and Configuration

Each card in the game has information associated. Consequently, after correct card pose and identification detection, a database is accessed in order to load related information. Through this procedure, a virtual element is selected and linked to the card. Moreover, a link is also established towards the type of card and the power of the card, in terms of attack and defence, in case of a warrior or the value of *mana*, in case of a terrain.

With this "load on demand" technique, it is very easy to include new cards without any need for new software development.

To make all this possible, there was a request to change the structure of the common Magic The Gathering Card. Namely, it was necessary to add a visual marker for ArToolKit identification. Without any space left, the decision was to replace the Text Box and the Collector Number and to change the Card Type, Power, Toughness and the Expansion Symbol. After all this changes, a completely different card has emerged (Figure 3).

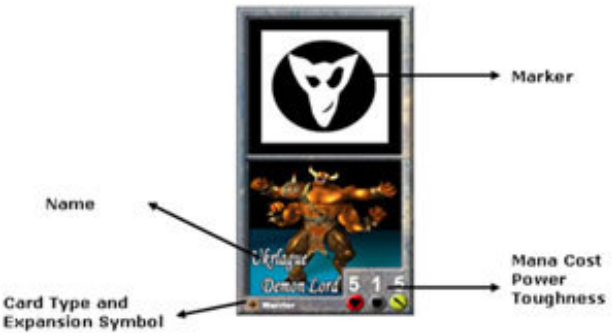


**Figure 6– Magic in AR card example**

During creation of this new card, considerations were taken to perform only minimal changes. The reason was to preserve the familiar way of the card to convey information and also to maintain a good relation between cards and the element they represent.

After creation of a new card, there's a request to add that card in a simple and rapid fashion to the "Magic in AR" game. In a similar fashion, cards already present in the game can be changed. Therefore, a configuration file was created with all information related to the newly inserted element. Namely, image files location of the markers created using the ArToolKit tools, the player id that the card belongs to, the type of card, the values for *mana*, attack and defence of the card and the 3D model associated to the card, are kept in one simple configuration file.

Each line represents a card. However, the information related to the owner of the card is still a constraint that will be worked in the future. Consequently, to update the current supported cards (e.g., with new 3D virtual representations) and to include new ones became an easy process.

Using the import tools of the Virtools authoring environment any 3D animation element made with any modelling software tool, could easily be imported into the Virtools format. Thus, it was straightforward to create a model (or use an old one) and import it, save it and add it to the configuration file.

### 4.4. Virtools and ArToolKit Integration

After the creation of the card structure and the configuration system, the next step was to find a way to use the simplicity of the Virtools, with some tracking system that provides the programmer and the user, with the pose of the game cards. This requirement was fulfilled by the ArToolKit system. Therefore, using the advantages of rapid development of Virtools and the capability of visual markers recognition and pose extraction of ArToolKit, the integration between this two elements would make possible the development of Tangible Augmented Reality applications

quickly, with rich interaction between real and virtual elements and available 3D models.
For this integration the following software versions were used:

- Virtools Dev v2.5;
- OpenCV vB4a – library for acquisition and image processing already integrated with Virtools. [OPENCV];
- ArToolKit v2.65.

The integration was made using the capabilities of the Virtools SDK.
Each of these software systems had its activity very well identified in a systemic framework. The OpenCV makes the streaming of the video possible to be used inside Virtools. After this step, ArToolKit could do is work, searching, identifying and tracking all the visual and updating the position and orientation information structures present in the Virtools environment. Virtools grabs these structures and use the information to establish the position and orientation of the virtual elements. Afterwards, it renders the objects in the video frame integrating the real and virtual elements.
This process is depicted in Figure 8.

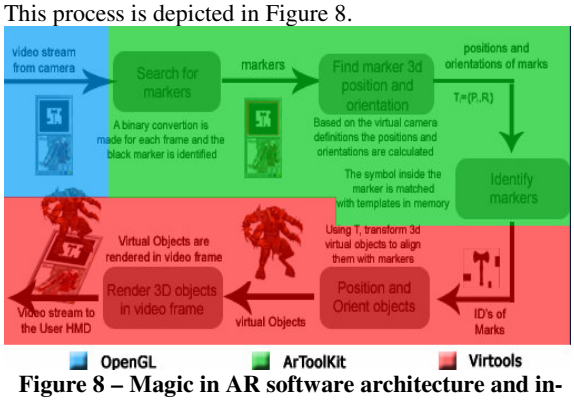


**Figure 8 – Magic in AR software architecture and information flow.**

With the development of an architecture that integrates Virtools and ArToolKit (Figure 9), the basic platform required to build Virtools applications, within an Augmented Reality framework, has been achieved. This was, effectively, the "hard" part of the system development.

## 5. Game Rules Development

For beginners, Magic the Gathering, seem to be a rather complicated game, but in fact, the game is governed by a set of simple and basic rules that apply to a restricted set of cards. After comprehending this first rules, all the others related to more specific and complex cards, became easier to understand [MAGICRULE]. Knowing this, it was decided that the first version of Magic in AR game, should only follow the basic rules and, in fact, not even all of them have been implemented.
The rules developed for the application described in this paper, were:

- Turn base game;
- The activation of cards happens only when the player has the necessary *mana* activated;
- The activation of the attack cards depends on its orientation relative to the camera.
- The combat card winner is defined by the attack and defence attributes of the specific cards.

In the next sections, we describe some of the developed rules.

### 5.1. Rule Implementation – Turn base game

Following the philosophy of the original game, Magic in AR role play is defined by turns, which will end when a given user interacts with a unique tangible element that represents the turn switch of the game. Any move made by a player out of his turn will be ignored until the next turn.


**Figure 9 – Demonstration of the turn base game rule.**

The important point in this rule was to distiguish from a turn demand to a failure in marker detection by ArToolKit. For that matter, we only decided for a turn demand when the marker was unseen for 3 seconds, in that case the state of the object is changed and a new turn is initiated. The system is then informed that a new player is active to play.

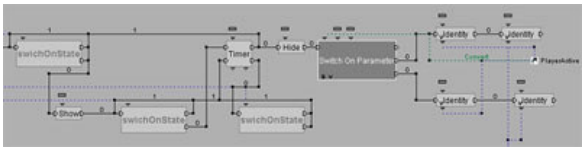

**Figure 10 – Turn base game rule implementation in Virtools**

### 5.2. Rule Implementation – Activation of cards depending on the active mana

A new soldier, monster or magician can only appear and be used by the player when the necessary mana is available and active. To active the necessary mana the player needs to have sufficient terrain cards and as to activate them. In such case, the action is accomplished by turning each card 90 degrees.

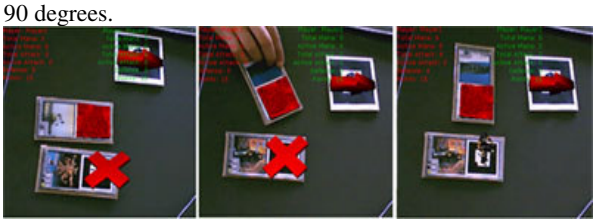

**Figure 11 – Demonstration of the activation of the cards depending on active *mana* rule**

Regarding the algorithmic development in Virtools, it was required, whenever a new soldier, monster or magician card is used, to check the active *mana* available. So the current player information has to be consulted and if possible, the element associated to the card shown. If not, a red cross appears instead of the registration of the associated virtual element.


**Figure 12 – Activation of the cards depending on *mana* active rule implementation**

## 6. Results and Usability Evaluation

New ideas for games and systems using Tangible AR interaction appear quickly in the community but, some of them, still lack usability evaluation studies [DJC*04], needed to assess the degree of its adoption by common players, the user perceived performance and the user satisfaction. In fact, the authors believe that usability evaluation is a critical and important phase for any interactive system development.

Usability can be 'measured' by studding at least the following user-oriented characteristics [GSH*02]:

- Easy of learning;
- Speed of user task performance;
- User error rate;
- Subjective user satisfaction;
- User retention over time.

Usability evaluation is the assessment of the combination of useful and usable system characteristics. If the users can perform certain tasks needed to be accomplished, by using this system, then we can claim it is useful. Additionally, if the use of this system to perform the given tasks can be done with low amounts of effort and training, then we can also claim that the system is usable.

This kind of situation, where the system is both useful and usable does not happen by accident or luck. There must be an engineering process that should exist from the very beginning of the engineering development of the system, providing usability evaluation. Usability engineering is considered to be a cost-effective, user-cantered development process that ensures a high development lifecycle [GSH*02].

For the Magic in AR game, we have designed a usability evaluation methodology, to assess the usefulness of the tangible AR interaction in the game, as a comparison to the traditional card game. Using a set of test cards, 10 unpaid subjects, with ages under 26 of both sexes, with prior knowledge of the "Magic The Gattering" game, were invited to do a set of test plays. The main goal was to make an attack with a soldier or monster and to use a Magic card to attack the opponent. With this specific set of game movements, we have tried to evaluate the way users would be able to perform these simple tasks.

For this specific test, we have used a "computer" player, whose only function was to put its cards on the table, in order for the real player to complete the predefined task.

The predefined basic tasks, which were shown to the subjects in separate turns and after a brief demo of the Magic in AR game, were the following:

- Making the turn switch;
- Putting a soldier in the game;
- Attacking the soldier of the other player;
- Attacking the soldier of the other player with a specific magic;

These tests were focused on the evaluation of the user satisfaction with the tangible interfaces, the easiness of comprehension and the use and impact of the registered virtual elements visualization

To test the easiness of comprehension, we have cheeked both the time a player took to perform the same specific task in a normal Magic the Gathering game and, afterwards, in our Magic in AR game. This would give us a measure of how understandable the Magic in AR cards, are for players.

To assess the satisfaction and the impact of the visualization, a little questionnaire was made to the subjects, right after they have performed the specified test tasks, and the answers were analysed.

### 6.1. Time Analysis

The observed task times were a little higher using our Magic in AR system compared to the Magic the Gathering original game. The difference was not very significant, as it can be seen in Figure 13, but we have realised that the small differences introduced by us in the cards, causes the subjects to pause and check what the card functionality was.

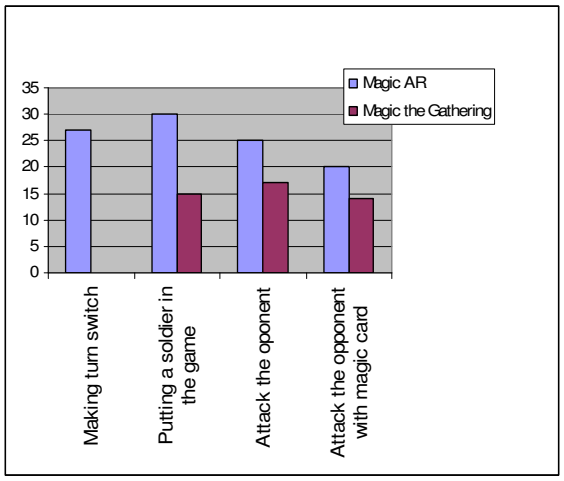


**Figure 13 – Time spent performing designated task in the two approaches**

As it can be seen in Figure 13, the first specified test task couldn't be compared, because there is no task to switch turns on the original game. In the following tasks, the observed time difference between each of the games, was decreasing from one task to the other. By observing this and based on these tests, we can conclude that at first, the new proposed Tangible AR philosophy, is initially strange for the user and increases the time to accomplished the designated tasks. However, when the subjects start to understand this philosophy, this time decreases, which is encouraging for our plans of future developments.

### 6.2. Questionnaire Results

After the test was completed we have presented the subjects with a 5-questions questionnaire. Since the purpose of this questionnaire was to measure the level of satisfaction and, the impact of the visualization of the 3D elements

registered on top of real cards, the questions were directed to the subject's feelings and suggestions.
First questions were directed to the game usage compared with the original card game. For each one it was asked the rate of the game in terms of:

- changing the game turn (not applied to the card game)
- adding a new card to the game
- attack a opponent element using a soldier
- attack a opponent element using a magic spell

Then a question was made to check the preference of the user between the two approaches in terms of:

- adding a new card to the game
- attack a opponent element using a soldier
- attack a opponent element using a magic spell

After this question to compare the two approaches it was asked the user to classify the Magic AR in terms of:

- easy to use
- funny and interesting
- understand the rules

In the end there were a request for comments and suggestions from the user to see new ideas and to check the major aspects i
In our results observation, we have concluded that, in terms of difficulty, the results were not very high, which tells us that still we must do more research and development, to decrease this feeling of difficulty of the Magic in AR approach.
The easiness of use aspect brought us interesting results. Subjects that made the test and were real fans of Magic the Gathering, have ranked the Tangible AR application usage as "good", but the ones that didn't like the original game also think that this new approach as also a "low" usage ranking.
Comparing the two approaches, Magic in AR and Magic The Gathering, subjects clearly rank the easiness of the task higher when playing the Magic The Gathering. However, when comes to classifying the approaches, in terms of use and visualization impact, our approach shows a more consistently higher ranking.
In terms of suggestions, some players refer that, "the system to change turns can be more explored. In an innovative application like this one, you can create also other innovative technique to change the turns". Other subject wrote: "I never enjoyed Magic The Gathering, but the 3D models are very cool. Maybe they could be bigger and the tracking should be better". Finally a comment was made that brings a new issue for further developments in future: "the application is nice but it's strange that, to see everything in the game, we have to look to two places (e.g. the cards and a monitor) at the same time". This brings the need to create some different type of demonstration infrastructure (using head mount displays or other approaches), to improve game experience and resolve this kind of problems.

## 7. Conclusions and Future Directions

In this paper we have presented a new approach for playing the "Magic The Gathering" game. This approach allows the user to play this popular card game using cards as a Tangible Interface in Augmented Reality. From the architectural point of view, Magic in AR, consists of a camera, a computer, a video projection screen and a deck of cards to play the game. The system development highlighted the need to integrate a 3D authoring platform, Virtools, with a well known marker-base tracking system, ArToolkit. After the development of the system, we have performed usability evaluation. The comments received showed that, although some more R&D work has yet to be made, the approach improves the traditional use of the game and improves the visual impact of its action. Test subjects still take more time to play the Magic in AR version of the game, in simple tasks, but this difference attenuates, when the subjects get more acquainted with the new approach. The majority of the subjects that made the usability test, concluded that the new approach is "very impressive and fun". Most of the subjects agreed that the Tangible AR version brings new interest to the game.
We plan to integrate Virtools with more robust techniques for marker tracking, being developed in our group [DB05] or even texture tracking, which is able to handle the partial occlusion of textured cards [BDS05]. We plan also to develop a larger number game rules and design a new display philosophy, in order to improve the Magic in AR user adoption.

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