# Use of Augmented Reality in the furniture industry

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*Abstract*—**The architects conceive the interior visual aspect of a house based on sketches and drawings. These drawing schemes are perfectly understandable by technicians that are responsible for their implementation, but to the client, most of the time, they seem somewhat unrealistic and ungraspable in terms of visual model. This issue is especially sensitive when the inner components are actually pieces of different kinds of furniture and other decoration stuff. The ideal situation should be to offer the client a preview of what is designed to decorate his home and even better, to be able in real-time, to make changes in some of the design details and previewing the results. The VRINMOTION is a configurable and modular platform that has been developed to solve this gap between the designer's and the client's visual models. It offers an immersive preview of the interior decoration, customizable to the spatial real world visualization area having Augmented Reality (AR) as its technological background.**

***Keyword: Computer Graphics; Software Reusability***

## I. Introduction

The AR is an area of computer graphics [1] that allows the introduction of the concept of mixed reality in our daily lives [2]. It is obtained by simultaneous visualization of synthetic visual objects (which are generated with the aid of the computer) with the real ones. Thanks to this, the AR is a natural choice in terms of technology to support the visualization of interior [3] designs [4], allowing the development of differentiated and innovative products in the field of furniture industry.

Another relevant issue is the Human-Computer Interaction (HCI). The AR systems [5] are still under-evaluated in terms of HCI. The development of a RA solution, deployed in a portable device (such as an iPad) in order to assist furniture designer and customers in simulating and previewing different decoration scenarios may demand special HCI approaches.

The VRINMOTION is a configurable and modular platform that uses the augmented reality technology to visualize the objects (virtual 3D models) in real world environments, with or without marks. It is a portable system, composed by integrated pieces of software and hardware, to be used in a domestic, industrial or/and commercial context. The VRINMOTION aims to create a marketing tool that will allow the traditional furniture industry to show in 3D their products to the final client, simulating, positioning and visualizing them in loco via an augmented reality based approach.

## II. Scientific Background

The VRINMOTION was designed and is being developed taking into account two different approaches 1) AR with markers and 2) AR without markers.

Visual markers are widely used in existing AR [6] applications. Marker-based AR systems commonly use live video as input. As a result, the performance of a marker-based AR system strongly depends on the tracking system used for marker detection and pose estimation. AR with markers is already considered a well [7] established approach.

Another way less used to create AR visualizations is with a markless tracking approach. Techniques developed for Markerless Augmented Reality (MAR) [8] can be classified in two major types: model based and Structure from Motion (SfM) based. With model based techniques, knowledge about the real world is obtained before tracking occurs and is stored in a 3D model that is used for estimating camera pose. In SfM based approaches, camera movement throughout the frames is estimated without any previous knowledge about the scene, being acquired during tracking. The main aim in this case is to obtain a method to estimate the position, orientation and the three-dimensional movement of a camera from the captured images, using for it the only calibrated camera and without the need to add any type of markers to the scene. Figure 1 and 2 illustrate the use of AR with and without markers.

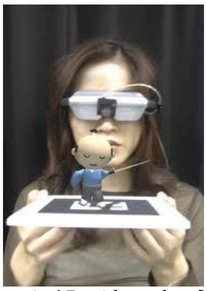

Figure 1. AR with markers[24]

Figure 2. AR without markers[33]

These two approaches were considered essential to achieve the main objective of VRINMOTION, which is to offer an immersive experience for the end user while previewing in real time the decoration of indoors space. This section summarizes the state of the art of two markerless approaches, the available technology and the main future challenges AR will have to face.

### A. Texture-based and SLAM

The texture-based techniques [9] take into account texture information presented in images. They can be subdivided into two major groups: template matching and interest point based.

The template matching technique has been proposed in order to apply a distortion model to a reference image to recover rigid object movement. The template matching approach is based on global information, unlike feature based techniques. The strength of this subcategory of texture-based techniques lies in its ability to treat complex patterns that would be difficult to model by local features. Figure 3 illustrates the template matching technique.

Figure 3. 3D tracking with template matching [8]

The template matching techniques are also called sum-of-square-difference or SSD, as they consist in minimizing the difference between a region of the image and a reference template. Basically, such techniques search for the parameters of a function that warps a template into the target image, so that tracking can be done. However, there are some problems with variations in illumination and partial occlusions.

Simultaneous Localisation and Mapping (SLAM) [10] is a popular map building approach in autonomous mobile robotics. Because users demand faster and more effective algorithms, SLAM remains an active area of research. On the other hand, most work in visual AR employs predefined markers or models that simplify the algorithms needed for sensor positioning and augmentation but at the cost of imposing restrictions on the areas of operation and on interactivity. For a variety of AR applications, the aim is to be able to use previously unseen physical objects as the basis for the augmentations. This of course demands accurate, robust and interactive systems that can jointly position sensor and scene with little prior knowledge. SLAM [11] techniques can help a lot to handle or even solve this drawback.

While core problems of SLAM [12] have been intensively researched in terms of computational complexity, map representation and data association, many challenges still remain. The most important [13] remaining challenge is the development of algorithms for increasingly larger and more unstructured environments. Concerns here include linearization errors and sensing difficulties due to unstructured environments.

Muhammad, Fofi, and Ainouz [14] introduced an extensive classification of the state-of-the-art vision based on SLAM techniques in terms of (i) imaging systems used for performing SLAM which include single cameras, stereo pairs, multiple camera rigs and catadioptric sensors, (ii) features extracted from the environment in order to perform SLAM which include point features and line/edge features, (iii) initialization of landmarks which can either be delayed or undelayed, (iv) SLAM techniques [15] used which include Extended Kalman Filtering, Particle Filtering, biologically inspired techniques like RatSLAM, and other techniques like Local Bundle Adjustment, and (v) use of wheel odometry information.

An extensive tutorial about SLAM method and related research is presented in by Durrant and Bailey [16] [17]. They described the essential SLAM problem and the recent advances in computational methods and in new formulations of the SLAM problem for large scale and complex environments.

### B. *Augmented reality challenges*

Some of the main challenges rely on the realism the rendered objects mixed with the real world. Because in the surrounding real world the light cannot be fully controlled or predicted, the synthetic model is rendered according a lighting model that might not match the one that actually exists in the real world (light position, intensity, color, etc.). Other sensitive issue is in what scale factor the synthetic model must be rendered according end-user's viewpoint position and the size of surrounding real objects. It should be properly controlled. Occlusion of markers can cause very annoying effects and hardware processing capacity might impact severely in the overall system performance (image flickering and unsteadiness) especially when the synthetic object has a high degree of detail.

Another challenging issue is still the markerless approach. As discussed in section A, most of the solutions proposed till now have still several constraints and are not fully stable. The texture-based solution is the most well-established so far and is being exploited by commercial software packages.

### C. *Augmented reality available technology*

Throughout last years it is increasing the interest and the results reached in the technologies of AR on desktop PC environments. Several platforms have been developed with different architectures; including AMIRE [18], ARVIKA [19], StudierStube, DWARF [20], DART [21], etc. Quite a lot of open source software tools for development are also available: NyARToolkit [22], ARToolkitPlus [23] [24], SLARToolkit [25], ATOMIC [26], IrrAR [27], OSGART [28], etc. Most of them are marker based.

Besides these, there are also emerging many commercial ones, such as: Metaio [29], SARI, Total Immersion [30] or Junaio [31], based on a texture approach and Layar [32] which considers also GPS information. Finally, in terms of markerless platforms, there are already some available, although in a significant smaller number in comparison to those marker based. Most of them are actually libraries that can be included in the code. Some examples are: PTAM [33] SceneLib [34], Bayes++ or FastSLAM 2.0 [35] for MatLAB.

## III. VRINMOTION ARCHITECTURE

The VRINMOTION architecture is basically composed of an AR content editor (back office) and an AR player. Because it is considered both AR marker and markerless approaches, the player and the editor present very distinct functionalities in each case. The figure 4 illustrates the system architecture.

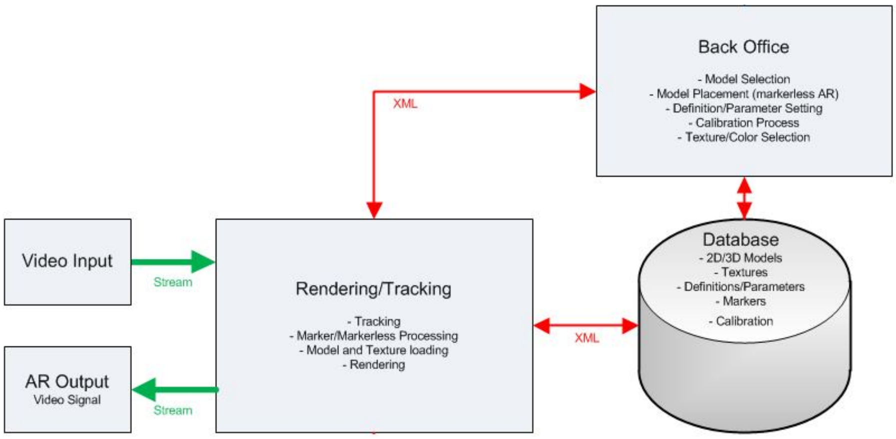


Figure 4. VRINMOTION Architecture

The back office module is responsible for the loading of 3D models, selection and association between the AR approach to be used (with or without markers), visual customization of the 3D models (color, texture, scale, etc.), definition of configurations and parameters to be used by the player while rendering the AR visualization, besides the preview of 3D simulation of the real environment. This last functionality enables the interactive positioning of 3D furniture models on a perspective view of the room (based on snapshots of it).

The back office module is also responsible for the generation of a XML file that is further read by the AR player while running. This file contains the configurations and parameters defined to the player and the 3D models associations (depending on the AR approach to be used).

The AR player has two different versions: with markers and without markers. The AR player includes both tracking and rendering capabilities. It is the visualization module where the end-user can see *in loco* an AR visual representation of the furniture. The player includes functionalities that allow an easy interaction with the AR final visualization.

Finally, the architecture includes also a database where 2D and 3D models, textures, markers, texture templates, besides the XML files relevant to the functioning of the AR player are stored and retrieved.

## *A. Usability*

The AR, due to the complexity in creating an immersive environment, presents new challenges to HCI (Human-Computer Interaction) with regards to handling, and selection techniques suitable for AR deployed in portable devices. It is assumed, thus a new paradigm in the design of the interaction, which becomes evident by the exploitation of the whole human body to perform interaction actions with a system, either through moving the body, either through the touch and even gestures [36]. The interaction design [37] thus aims to provide a support to the activities of people, whether at home or at work, and create experiences that enhance and extend the way people work, communicate and interact [38].

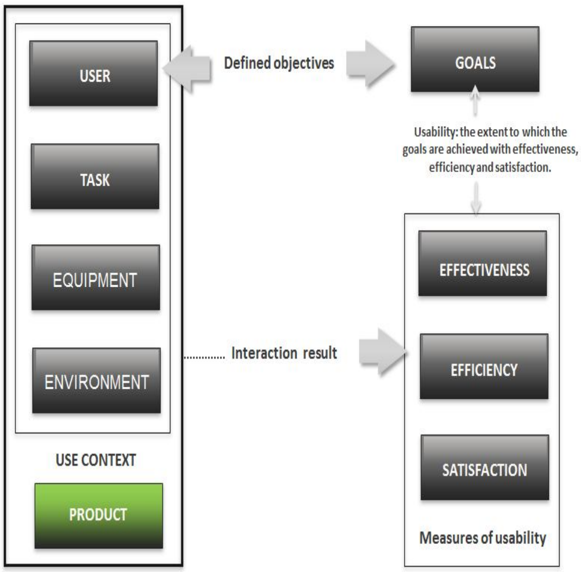


Figure 5. Usability structure

It is in this context that the usability as a major component of IHC study was one aspect considered in the project VRINMOTION, since it aims to offer the furniture industry a product that integrates virtual objects with the real world, using handheld devices and providing a high level of immersion and realism.

In this project, the level of usability measures mentioned above, seeks to answer the following questions: i) can users perform tasks and actions in the real environment, which are reproduced in the virtual environment in order to achieve the objectives established? (Effectiveness: the accuracy and completeness with which users achieve specified objectives.) ii) What effort do users need to achieve the objectives defined? (Efficiency: resources expended in relation to the accuracy and completeness with which users meet the targets), iii) what do users think about the easiness of the product use? (Satisfaction: The comfort acceptability of use). Figure 5 illustrates the structure of usability of ISO 9241[39] framed this project.

The integration of the usability component in this project puts users at the center of the design (user-centered design) and product lifecycle development, presenting themselves as active participants in the development process. The design process for interactive systems, based on the ISO 13407 standard [40], has five phases: 1) Analysis: Understand and specify context of use and users and individual and organizational needs, 2) Design: Develop conceptual design and prototyping of low and high-fidelity, 3) Implementation; Implement a heuristic [41] evaluation and / or empirical tests of usability and interaction design run to fix problems, 5) Evaluation: Get feedback and standards use by end users, as well as monitor and control use in the context of real use.

These usability aspects, although not being a concrete part of the system architecture, were considered relevant in terms of designing both the AR player and back office end-user interfaces.

## IV. IMPLEMENTATION

Besides the basic goals of the VRINMOTION, it was also relevant to identify potential end-users requirements. The first phase of analysis of the project had a total of 35 participants (potential users) have been prepared three types of scripts, directed to each of the types: (1) Vendors / distributors, (2) Influencers, (3) User / consumer. The scripts presented semi-structured, open-ended responses, allowing a systematic way to decompose the problems, needs and expectations of respondents, and reflected the definition of the product requirements. It was obtained in this way a list of 19 requirements, and then subjected to analysis of the Kano model [34]. In fact, the questionnaire was developed (Kano), to obtain a proper categorization of the requirements selected. In this sense, respondents were asked to rate each of the requirements in a qualitative scale (1. Like 2. It has to be 3. Neutral 4. I can tolerate 5. I do not like), later revealing how they would feel in the face of absence and presence of each of these requirements (functional analysis and dysfunctional). The questionnaire results allowed the classification of each of the requirements within one of the following five possible categories: Mandatory, One-dimensional, attractive, Indifferent or Questionable.

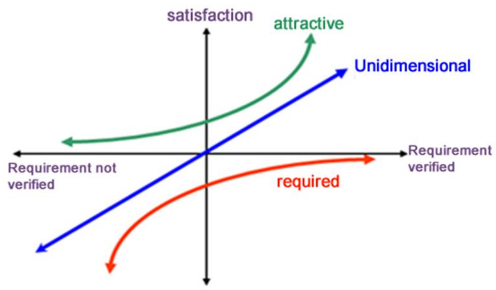


Figure 6. Requirements categories

The results of the assessment requirements structured by categories (Figure 6) contributed to the coordination of design, particularly for structuring the basic concept of the interface and the identification of useful functionalities.

TABLE I. EVALUATION RESULTS OF THE VRINMOTION REQUIREMENTS

| Requirement | Requirements categories/ Number of responses | | | | | Predominant category |
|---|---|---|---|---|---|---|
| | Attractive | Required | Unidimensional | Questionable | Indifferent | |
| Allow customize/manipulate objects/furniture at the time of presentation to the client (eg run/move objects, change color/material) | 5 | 9 | 20 | | 1 | Unidimensional |
| Allow simulate lighting (type, location, etc.), shadows and reflections | 14 | 4 | 11 | 1 | 5 | Attractive |
| Having as Interface a tactile device (eg iPad tablet or similar) | 10 | 2 | 10 | | 13 | Indifferent |
| Ease of use | 3 | 7 | 18 | | 7 | Unidimensional |
| Being lightweight and portable | 8 | 3 | 13 | 2 | 9 | Unidimensional |
| Able to transmit the details of finishing | 6 | 4 | 16 | 1 | 8 | Unidimensional |
| Be compatible with the most used software in the area (Autodesk, Solidworks, Adobe) | 5 | 5 | 17 | | 8 | Unidimensional |
| Simulate the functionality of objects and interior/furniture | 15 | 1 | 16 | | 3 | Unidimen. Attractive |
| Having high quality viewing - photorealism | 7 | 4 | 19 | | 5 | Unidimensional |
| Not having wires | 13 | 3 | 9 | 1 | 9 | Attractive |
| Be operated immediately | 10 | 4 | 13 | | 8 | Unidimensional |
| Allow to view an object on 360° | 10 | 6 | 16 | | 3 | Unidimensional |
| Being fast processing | 8 | 6 | 16 | | 5 | Unidimensional |
| Storing historical views of each user (the products displayed) | 8 | 1 | 11 | | 15 | Indiferente |
| Submit technical and additional information (eg product description, color, price, type material) | 13 | 2 | 9 | | 11 | Attractive Indifer. |
| Present the scale of the objects/furniture and spaces | 5 | | 18 | 8 | 4 | Unidimensional |
| Allow simultaneous viewing by user and technical supporter | 12 | 4 | 10 | | 9 | Attractive Unidim. |
| Designing catalogs virtually (sequential presentation of full-scale products in 3D) | 16 | 4 | 10 | | 5 | Attractive |
| Allow change some dimensions of furniture / objects in real (time (height, width, depth) | 10 | 9 | 12 | 1 | 3 | Unidim. Attractive |

The results indicated that the VRINMOTION should predominantly: (1) be competitive in Unidimensional requirements (requirements that as much as more available, generate greater satisfaction to customers) (2) "Delight" of the customers, attending some of the "attractive" requirements Attractive (those that will achieve differentiation of the new product on the market).

Crossing the classification of the requirements with their assessment of importance, it was possible to reach a set of priority requirements, listed in table 1.

Priority requirements were considered: 1) Be easy to use, 2) Allow to customize / manipulate objects / furniture at the time of presentation to the customer, 3) Being lightweight and portable, 4) Allow prompt some dimensions of furniture / objects in real time , 5) Getting convey the details of finishing, 6) Be compatible with the software more in the field, 7) have high-quality viewing - photorealism, 8) present the scale of objects and spaces, and 9) Designing catalogs virtually , 10) allow simultaneous viewing by the user and technical support;11) Allow simulate lighting, shadows and reflections; 12) Not having wires.

The first prototype version was implemented in C + + and IrrAR, an open source library. The editor was developed with Microsoft Visual Studio 2010, with the C # programming language and XNA Framework 4.0. The models are in OBJ format, but may use others. Some of the models were improved (textures included) in Maya 8.0. The textures must have the same resolution (number of pixels) for the width and height, being large ones avoided. This detail is relevant since the application should be able to run on machines with less processing power and memory.

Figure 7. Back office interface – Preview of the scene in AR through the use of images captured on the spot

The application is being tested on a Toshiba Satellite laptop 500, Intel Core i5-430M (Turbo 2.26GHz/2.53 GHz), TFT TB 13.3 "WXGA, 4GB 1,066 MHz DDR3, 500GB, NVidia GeForce 310M GT. The iWear920 from Vuzzix was used as AR goggles.

The present version of the editor (figures 7 and 8) allows the insertion or deletion of 3D models and markers, the association between them and even the assembly of interactive 3D models on a photo of the space in the building. The functionalities that are already available to the end user of the prototypes of the editor and the AR player are the following: (1) Import and display of an image of the interior of the space, (2) Interactive association between markers and 3D models of furniture and decoration elements, (3) Database for 3D models and their visualization and management, (4) Database for markers and their visualization and management, (5) Setting the scene in interactive AR: location identification, number of models for mapping, etc., (6) Preview of the scene in AR through the use of images captured on the spot.

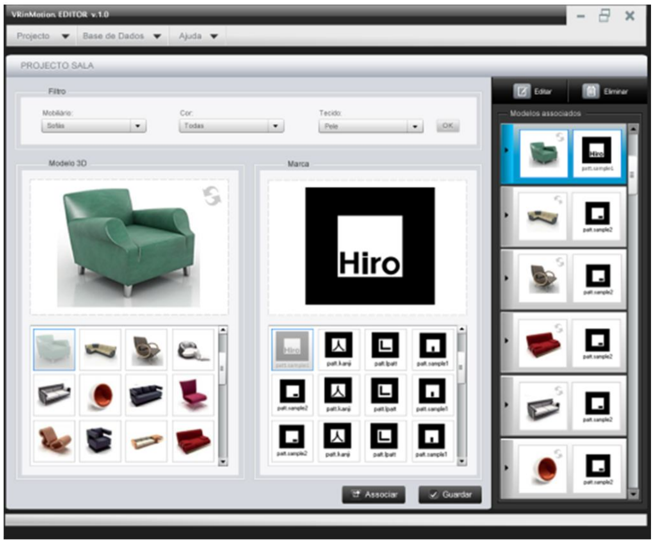


Figure 8. Back office interface – association between markers and 3D models

Another important aspect is the visual realism. The visualization in AR should represent the objects as much as real as possible. Initially we used shaders to make objects appear more realistic. However, other solutions are also being evaluated, which includes real-time adjustment of the light model interactively by the user or automatically by the system. The use of light sensors would be an asset in terms of accuracy and thus a more realistic calibration of shaders, lighting and shadows. Figure 9 illustrates the use of an experimental phase of VRINMOTION (with markers) by an end user. The end-user puts on the floor or the wall a marker which is consisted of a specific figure printed on paper or on a plate built for that purpose. Through the camcorder, the application recognizes the marker, and determines the position and orientation of it in relation to the user. From this information, and the object selection by the user, the application generates a virtual model of that object with hyper-realistic rendering. The 3D model is seen through AR glasses positioned on the marker. The user can move around, and the point of view is automatically updated. If you want to move the virtual object, you simply move the mark.

Figure 9. VRINMOTION. Marker based AR.

The present version of the AR player also includes a coarse mixed reality approach. The end-user can interactive choose 3D models and position it (resizing and rotating) somewhere in the image being seen through the AR glasses. It is also starting to be implemented a markerless approach based on template matching.

## V. Main Conclusions and Future Work

We highlight some aspects relevant to the expectations of potential users, particularly the ease and simplicity of the system VRINMOTION, interaction with the objects of synthetic furniture. Another important aspect is the need for ergonomics of the system, since according to participants, it should be compact, lightweight and portable and does not necessarily, therefore, its performance. The first prototype has been developed and implemented taking into account theses aspects.

Future work includes the enhancement of the AR visualization without markers (template based), the implementation of other outstanding features in the editor and the improvement of the interfaces with the end-user, as a whole. This improvement will be based on results from the assessment of the usability study, included in all phases of product development.

At this stage of the project, after evaluating the results of the first stage of analysis, which reflected the conceptual development and creation of early prototypes, was executed the implementation of a heuristic evaluation (inspection of the interface with specialist area) and empirical tests of usability (with potential end users) in order to proceed with the execution of interaction design to correct any problems identified.

At technological level, we intend to evaluate the use of VRINMOTION on platforms with very different technical features – other brand of AR glasses and AR Pads.

Some of the main challenges ahead include the graphic representation with reasonable realism, of the objects to be inserted in the image captured from the real world. Because the lighting in the real world cannot be completely controlled or predicted, the synthetic model is processed according to a fixed model of light, which may not match what actually exists in the real world (position of light sources, intensity, orientation, color, etc.). Another sensitive issue is that the scale factor of the synthetic model must be processed in accordance with the position and distance from the viewpoint of the end user and proportional to the size of real objects that are nearby. These aspects should be properly controlled. The occlusion of the markers can cause side effects and processing capabilities of the hardware can have serious impacts on overall system performance (image flicker and instability), especially when the display of a high degree of detail synthetic object.

In terms of AR markerless, many other challenges can still be added. As the recognition of shapes and / or positions should occur automatically, algorithmic complexity and the requirement is still a major technical limitation.

## Acknowledgment

The VRINMOTION project is co-financed by QREN – I&D, under the number 13709. It has as leader the Meticube – Sistemas de Informação, Comunicação e Multimédia Lda. and the SPI – Sociedade Portuguesa de Inovação S.A and the CCG – Centro de Computação Gráfica as partners.

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