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# ASSISTED NAVIGATION AND NATURAL INTERACTION FOR VIRTUAL ARCHAEOLOGICAL HERITAGE. IMPLEMENTATION OF AN ATTRACTOR-BASED APPROACH USING A GAME ENGINE

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## ABSTRACT

In this paper, the authors propose a new way to navigate inside virtual architectural environments such as those used in the field of Virtual Archaeology. This approach is based on the study of human movement inside real buildings. Authors describe the design of a computer aided navigation system that could facilitate visitors of virtual reconstructions in taking their journey inside digital 3D environments in a more human-like manner. This research considers aspects related to human attention and non-linear narratives in order to develop a new computer aided navigation paradigm using excellent capabilities of real-time visualisation, interaction and human-computer interfacing provided by a game engine. This system obtains information from the virtual environment, which is perceptually enriched by the presence of metainformation associated to the importance in terms of interest of every part, space or element present in the scene. Using this tool, the designer of the experience can influence the user walkthrough in the virtual archaeological environment to meet the expectations of the visit, follow thematic paths or adapt to different user profiles.

**KEYWORDS:** Virtual navigation, game engine, human movement, virtual archaeology, architectural walkthrough

## 1. INTRODUCTION

Videogames constitute one very important field of application of Computer Graphics since their very beginning and from more than a decade ago, they have fostered the advancement of graphic hardware more than any other computer related technology.

By means of the use of modern graphic cards, one can display three dimensional environments in real time with unprecedented realism. Simulations of virtual spaces and digital buildings now have a quality reserved to frame-by-frame animations.

Nowadays, game engines are becoming popular as a mean of developing high-end, real-time presentations of virtual environments not necessarily related to the game industry. The application of game engines in the field of architectural, urban and landscape visualisation has been broadly described (Engeli 2001;Uddin et al, 2002;Johns & Lowe 2005, Borries et al, 2007; Indraprastha&Shinozak 2008, De Kerckhove, D., &Tursi, A., 2009; Owen et Al, 2013). Actually, many important architectural visualisation studios effectively make use of this technology.

Consequently, virtual reconstruction of historical heritage using game engines has been the logical next step in the direction of their use in Virtual Archaeology.

The videogame industry itself has been a great motivator for the developers of virtual reconstructions with the release of games such as Assassin's Creed, which illustrate astonishing reconstructions of full cities such as Rome in the Renaissance or Acre in the time of the Crusades.

Professional 3D game engines, such as Unreal Engine, Unity3D or CryEngine, present the author of visual simulations very powerful tools to develop interactive presentations of 3D environments, including:

- Complex shaders for extreme realism in the appearance of the materials.
- A character system, both in first and third person view, in order to control the player/user interaction within the environment.
- An input system that can deal with all sorts of control devices, from mice to gamepads, touchscreens and depth cameras (i.e. Kinect system).
- A programming environment specially designed to produce exploratory and interactive experiences.
- High resolution display for a wide variety of device configurations, from monitors to smartphones, including HMD's such as Oculus Rift.

On the other hand, virtual simulations of historical reconstructions are not videogames, (or at least, not necessarily). Differences arise from many aspects ranging from narrative flow to depiction, user experience etc., derived of the pursuit of different objectives.

Many interesting examples can be found today that demonstrate visual recreations of archaeological reconstructions using game engines. They are mainly centred in achieving a high visual quality while offering the possibility to walk through the virtual recreation as well as the capability of interacting in different ways with the virtual replica, from the display of metadata to the activation of mechanisms and simulation of phenomena (Sheng et al., 2015; Lercari et al., 2015; Pietroni&Adami, 2014; Richards-Rissetto et al., 2014; Cappelletto et al., 2014; Huyzendveld et al., 2012).

Nevertheless, until today, little attention has been paid to the study of the walkthrough itself, crucial for the ease of exploration of the environment; in fact, the movement of a character representing the user (being an avatar or simply a first person camera) in a virtual space is far away from the manners of human exploration of the built space.

The general approach to character movement in a virtual visit is based on very simple actions: letting the user move forward or stop and turn and rotate the camera view in any desired direction, commonly using movements that are impossible to achieve by the movements of a human neck.

Several authors have addressed the problem of assisting the user in the visit of virtual environments. Some of them focus on developing intelligent camera control systems based on specific constraints to calculate partial paths (Drucker&Zeltzer, 1994) or let the computer explore the environment and extract the path to follow prior to presenting the environment to the user (Elmqvist et al., 2007). Other cases focus on avoiding collisions and providing the user a path clear of obstacles (Andújar, 2004) or moving the user sequentially from one particular viewpoint of interest to another one on a virtual tour (Chittaro et al., 2010).

The aforementioned examples are based on influencing the user's location to reach predefined viewpoints located in landmarks and set camera view direction. Our approach is different. It is based on influencing the camera target only, independently from the user's location, to provide the user a clue regarding where to look at and to help him or her to point at this direction. The aid will be based on his or her location, orientation and interest of the near objects as well as the surrounding environment, including architectural elements and spaces.

This paper describes the design and development of this new aided navigation scheme. The approach will be based on the study of human movement inside real built environments trying to mimic the human attention process.

The system is implemented as an autonomous agent inside the character representing the user in a 3D virtual environment. This agent subtly modifies the view and movement direction based on the presence of attracting elements in the scene. The user is aware of this intrusion, which only happens under his or her consent during the simulation, taking place only when the input system does not detect any action from the human.

## 2. METHODOLOGY

In most part of the literature related to human exploration of the environment, the two concepts stand out: navigation and wayfinding, with the former considered to be a type of the latter. (Taylor et al., 2008). Wayfinding relates to the aptitude to develop mental complex models of the environment and it can present variations among different people depending on factors, such as the point of view, scale, complexity of the environment or the effects of previous experiences (Foo et al., 2005; Maguire et al., 2003). Navigation is more associated to the use of reference points, landmarks and even other aids such as maps. The importance of such reference points comes from visual, cognitive or structural factors (Sorrows &Hirtle, 1999) and its presence is crucial to attract the interest of the user to any given direction. Thus, appropriate management of these navigational aids may help in improving the wayfinding process.

On a given environment, the analysis of the presence of these key elements in a zone surrounding the user can be used to model the amount of attention of the area containing every single element arising from the user. Any environment may contain elements that are worth to be observed to some extent

The designer of the virtual experience can enrich the virtual environment by identifying the objects, places, spaces, etc. that make the visit interesting, especially considering that in many cases, the user does not know where to go or what to look for when he or she enters the virtual place for the first time.

This identification can be done in a way invisible to the user. We have implemented this by designing an element that can be placed anywhere in the virtual model called *attractor*. This element is defined by several parameters that comprise of interest, range of attraction, decay and other variables describing the willingness to look at it based on the distance to the user and its look-at direction in the scene related to the character's sight direction.

The presence of several attractors in the viewable area surrounding the user can be weighted using models from the field of Psychology of Perception, such as the one proposed by Karl Lewin (Lewin, 1938) that defines a *hodologic* space (the space surrounding the user containing zones, which push or pull his or her attention based on personal interest related to each one). In Lewin's model, every area has an associated magnitude named *valence* that quantifies the attractive effect to the user. The resultant of all forces of attraction describes the final intention of the subject to point his or her attention to a particular direction. Nevertheless, Lewin neither described a particular method to calculate the valence nor explained a procedure to weight the attracting forces.

The implementation of our system takes account of other theoretical references related to the attraction of visual attention. These are the Theory of Affordances (Gibson, 1979; Dalgarno,2010) that describes the potential capacity of any element of an environment to attract the attention and to be utilised by the perceiver; the Spotlight Model (Posner, 1980) that deals with issues related to act of focusing visual attention to an area, particularly when a shift of spatial attention occurs; and the Gradient Theory, which describes how attentional resources are given to a region in space rather than a spotlight, so these attentional resources are more concentrated at the centre of an attentional focus and then decrease the further stimuli from the centre (Colmenero et al., 2001).

We are actually researching in a formulation to reproduce this effect, obtaining interesting results by turning the continuous Lewin's space into a discrete one, populated with attractors with given interests, considering every attractor as the generator of a field of attractive force (Figure 1), being the geometry of this field as a function that involves distance (whose intensity decay is represented by the grey gradient around the attractor), direction ($\bar{A}$) related to user's sight ($\bar{V}$) and two values of willingness associated to distance and the viewing angle. Then, a vector of attention of this attractor ($\overline{F_A}$) is defined, being its valence, as the value of its module. Only attractors located inside the field of attraction (Ω) are considered. This field is delimited by the horizontal (HFOA) and vertical (VFOA) angles and view occluding elements.

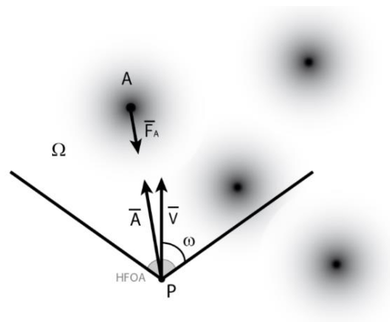


***Figure 1. Field of attention and elements involved in the calculation of the attention of an attractor***

The centre of attention is then calculated as a centre of force (C) and will be used to drive smoothly the user's sight towards it when no turning input is detected (Figure 2) and optionally when no moving input is detected, depending on the degree of navigation aid required. By placing attractors in every interesting point, the movement of the user can be controlled by the system based on the characteristics of field of attention that surrounds the user at every moment. Interest of attractors can also decay with maintained exposure to the user contemplation.

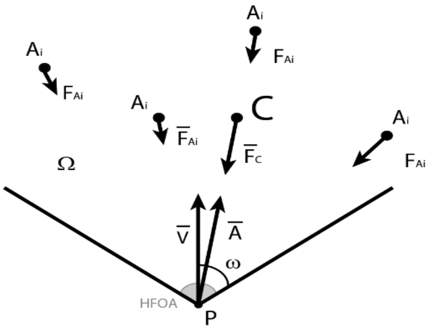


***Figure 2. Field of force and centre of attention***

The system described here is called *Paseante* (Spanish word for "Stroller"). It is implemented as an autonomous agent inside the character representing the user in the game environment.

This agent subtly modifies the view and movement direction based on the presence of attracting elements in the scene. The user is aware of this intrusion, which only takes place when the input system does not detect any action from the human to control view direction; hence it can be combined with human forward input.

The perceived effect of using the system is as follows: when the user releases the control of the turn and limits himself to the input when to go forward and when to stop, the system will lead his or her view to the most interesting point of its surroundings. By pressing forward, the system will take him or her towards that point. The centre of attention is being recalculated in every frame considering the change in location and orientation of the user.

If the user does not take any action, *Paseante* suggests a new point of interest to contemplate, or a direction to input motion, so that the user only has to touch a key to continue his or her walk. The stroll will then be carried on smoothly with more natural turns and camera pitches than those commonly found in the traditional navigation modes used in virtual environments.

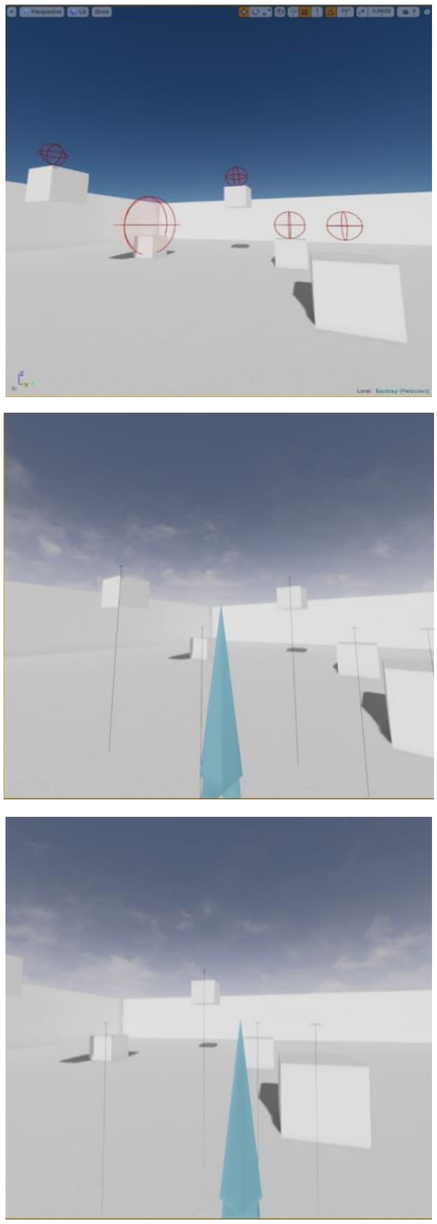

***Figure 3. Movement of the view direction in a field of attractors Top image: Location of attractors. Centre: When the simulation begins, the view direction points to somewhere among the attractors. Low image: In the following moments, the view direction shifts owing to the effect of attraction towards the centre of attention, turning both in azimuth and height. If the user then moves on, Paseante will lead him to a new point of interest.***

Since the user can always retake the full control of the input and move and turn as he or she wants, every situation in the virtual model is different, as every location and view direction provokes a different suggestion of what to look at.

By placing attractors and calibrating them adequately, it is possible to design walkthrough experiences suited to different kinds of users based on their particular interests.

The design of the virtual walkthrough experience might then focus, on one hand, on a balance between the freedom of movement of the user inside the space and on the other hand, on the intention to take him to the most important places and make him view the most relevant things. Therefore, the application combines both forms of navigation: when the user indicates an action, the system helps to navigate naturally with auto adjustable points of view, whereas when the user does not perform any action, the system behaves as a "tourist guide", helping to point the camera to the most distinguished aspects of the environment, as they are defined by the designer so that the user can observe them adequately.

*Paseante* can be considered a new and different approach for aided navigation on virtual models, which presents the following features:

1. It is based on the emulation of human attention.
2. Designers of 3D models can use it to design the corresponding assisted walkthroughs as well.
3. This system is of general application to digital architectural reconstructions.
4. It is especially suitable for museum applications.
5. It is well suited to facilitate natural Kinect based interaction.

## 3. SYSTEM'S DESIGN

The implementation of *Paseante* follows the workflow commonly used in the design and interaction programming of experiential videogames; played in first or third person view, in a world composed of both static and interactive elements that are experienced by means of a character. It is called, in videogames terminology, a map or level.

*Paseante* is implemented together with a series of elements that comprise of a kit for the designer to be uses in the map as he or she designs the walkthrough experience in the game engine editor. The effects produced by the elements of this kit in relation to the map can be classified in three different layers.

1. Active environment layer: Comprise of those elements that perform some type of function or activity in order to influence the behaviour of the character or can be influenced by its actions. They are invisible to the user although they have an associated geometry for the designer to place and manipulate. Their shape, size and colour provide the designer a visual feedback regarding their future effect in the simulation during the process of the edition of the scene. Some of these elements are:

   a. Attractors: They are the base of the design of the simulation. They allow catching the attention of the user towards them using several configurable features. The kit contains several types of attractors with different characteristics.
   b. FOV (Field of View) Volumes: Enclosing elements that adapt the FOV of the character's camera to the dimensions of the space where the character is located. They are used to adapt the aperture of the view to different degrees of width or narrowness of the architectural space.
   c. Turners: Elements placed in the map that help the user to perform turns of some difficulty along the way, such as 180 degrees turns in stairways or abrupt 90 degrees turns in doorways.
   d. Lookers: Elements that concentrate on the viewing direction and close the FOV, zooming to a single point. They help to concentrate the attention very closely to a given object or place. They are used for in depth examination of things.
   e. Interactive objects: Visible objects present in the scene that respond to actions in a manner that they are expected, such as doors that can be opened or lamps that can be turned on and off.

2. Character's layer: This includes all functionalities inserted in the player's character to analyse the environment, evaluating the aforementioned elements, to calculate the instantaneous location of the centre of attention as well as to take the necessary actions to lead the user towards it. They constitute the core of *Paseante.*

3. Passive environment layer: It comprises of all visible, non-interactive parts of the map, from objects to lighting. They play their role in the immersion of the player inside the scene and need to be as realistic as possible in order to avoid losing attention on noticing lack of realism in the appearance of things.

The relations among all previously described elements and different game systems that control the character are shown in the following figure (Figure 4).

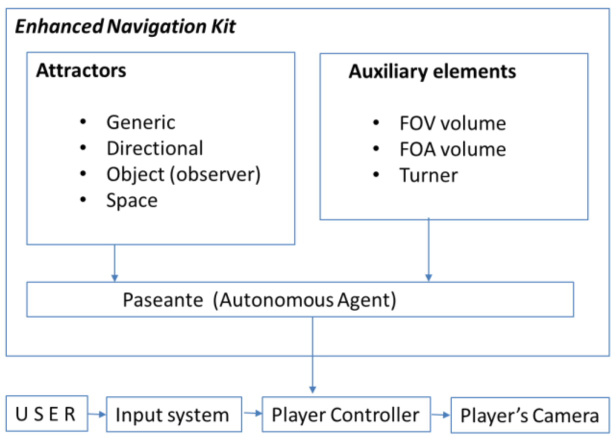


*Figure 4. Enhanced Navigation Kit*

## 4. IMPLEMENTATION

The system is implemented on a game engine as a toolkit for designers of virtual environments. In this working environment, any 3D model can be imported, so the designer can place attractors to influence the way that the model has to be travelled.

In this research, Unreal Engine 4 (Epic Games, 2015) turns out to be the most suitable engine considering the following aspects:

a. Very high level of realism. This criteria has been one of the most important in the selection of this game engine, because it offers a visual quality without precedents. The set of features of the visual quality of this engine includes real time global illumination, use of adaptive adjustment to different conditions of light, HDRI (High Dynamic Range Imaging) and a programmable shader system capable of emulating extremely complex materials.
b. Visual Programming using Blueprint Visual Scripting.
c. Access to a vast library of assets that include geometries, materials, textures, animations, characters, sounds, particle systems, etc.
d. Capability of producing contents for all platforms and operating systems, including game consoles and smart-phones. It also exports code to HTML5 by means of asm.js and Mozilla Emscripten.
e. Complete documentation, tutorials and on line forums populated by a community of very active developers that assures constant improvement in this technology.
f. Free of charge for non-profit projects.

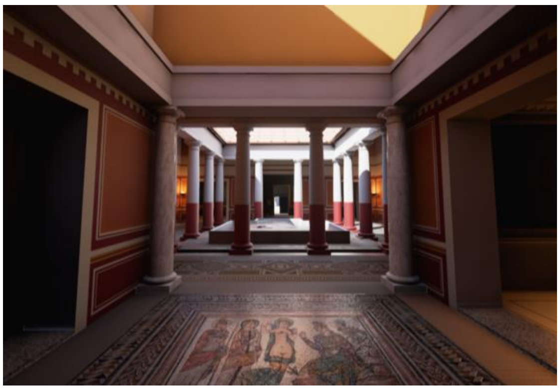

*Figure 5. Atrium 1 with" The Judgment of Paris" mosaic.*

The system is being tested, for demonstration purposes, on a model of a 4th century roman villa named "El Alcaparral"(BlázquezMartínez, 1985; De la Sierra, 1985; De la Hoz et al., 1987), made as a virtual installation for an interpretation centre near Seville (Spain). The virtual model was intended to accomplish two objectives. On the one hand, it should display a complete recreation of the mosaics found in the nearby excavation, allowing the visitors to contemplate the appearance of the pavements in their full size instead of just fragments. On the other hand, the villa model was designed to act as built-in environment that could provide context for the interpretation of the mosaics (as shown in Figure 5).

Several elements of the different kinds composing the kit, such as attractors, FOV volumes, turners, etc. were placed in the 3D model of the building for *Paseante* for using them to help the user navigate the villa. All the parameters that adjust their effect were then established to define their behaviour and fine-tuned progressively by successive tests until they got close to the expected effect.

For this purpose, there is a test mode that has been implemented in the game engine. The designer of the experience can make visible the elements placed in the scene as well as their controlling parameters and their changing effect on the user's view direction as he or she moves along the scene.

The following images (Figures 6 and7) correspond to captures of screen taken along the same navigation, this time with the presence of visible cues to monitor the functioning of all elements.

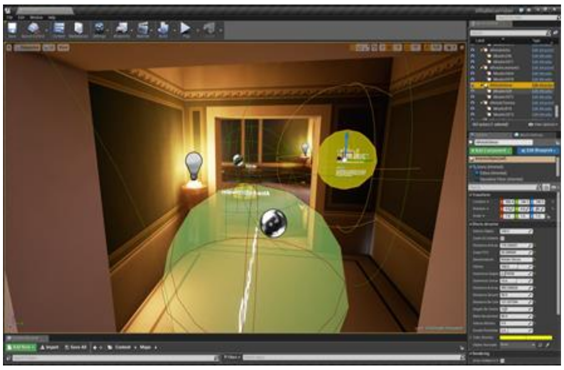

*Figure 6.Enhanced navigation kit being used in the Unreal Engine 4 editor in the model of the villa. The spheres represent attractors put in place whose geometrical elements represent their values of interest and other behavioural parameters*


*Figure 7. Attractors operating in Atrium 1*

All elements of the kit present in the scene display their name for quick identification. Yellow spheres represent attractors with variable interest. The beginning of the decay of the interest is represented by a sparkle in the corresponding sphere and the decrease in the value with an increase in its transparency until it gets invisible or remains semi-transparent if the attractor is configured to always retain a minimum interest. The wireframe spheres that surround the attractor provide information regarding other parameters, such as ranges of activation or decay triggering.

In order to monitor the movement of the centre of attention, the designer can activate the presence of thin violet lines that come up to the attractors and are active at any given time for the character location as well as orientation. The blue arrow indicates the instantaneous location of the centre of attention.

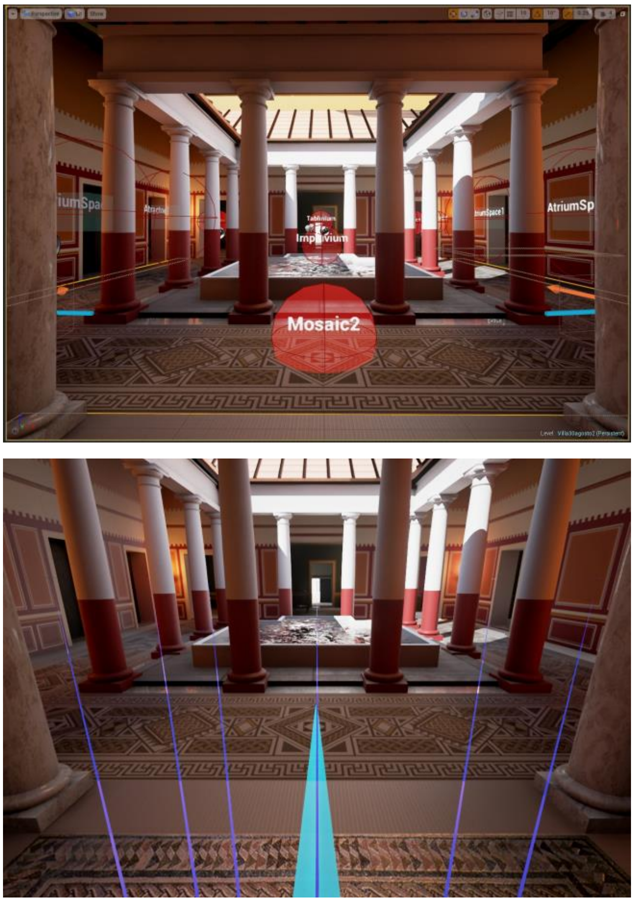


***Figure 8.Establishment of the view direction in a field of attractors. Top: Attractors being displayed on test mode. Bottom: Display of direction lines to active attractors and centre of attention on test mode***

The system is designed to be able to use a Kinect2 depth camera in order to get the input from the user, for instance, by means of slight movements of his or her arm (Figure 11). Other sets of user's gestures have also been tested, both for moving (step ahead, lean forward, swing arms) and for turning (swing upper body, tilt upper body, pointing at places). The combination of natural interaction and enhanced navigation using *Paseante* makes the walkthrough on this model extremely easy and intuitive. Another advantage comes from the difficulty to control the camera pitch to look at places under or over the horizon (i.e. mosaics, ceiling structure, etc). Adding another gesture based control for the camera pitch in the Kinect interaction scheme makes interaction more complex. *Paseante* is especially useful in this sense, since it automatically takes control of the pitch as well.

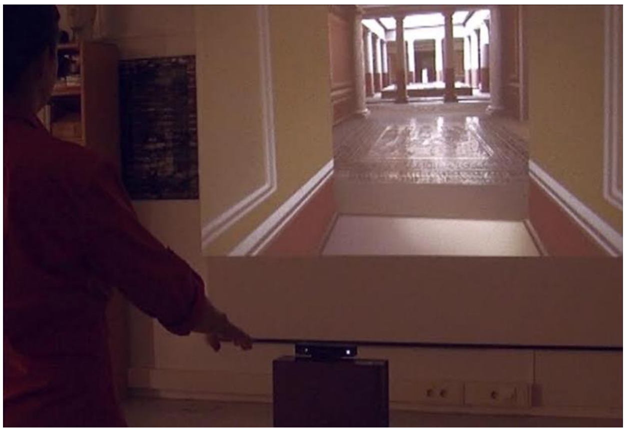

***Figure 9.Kinect interaction combined with Paseante***

This is worth considering that the visitor of a museum is expected to drive a virtual walkthrough like this with zero previous training.

Several UX tests have been performed with user groups ranging from 7 to 25 people aged 12 to 61. The results obtained helped to establish the values of many of the parameters that influence the behaviour of the system. Some of them are associated to *Paseante* itself, such as time of activation upon user inactivity, camera turn ratios towards the centre of attention, preferences regarding deactivation on turn only, on move only, or on both etc. Other results reflect the pros and cons of different gesture sets for Kinect based installations to get a better outcome from the use of *Paseante.* The user experience analysis stage is still under development and will be subject of future publication.

As a resume, the response of users to the question regarding the usefulness of the system provided a value of 4.21 over 5 ($\sigma$ =0.39) (1.- not useful at all / 5.- Extremely useful).

The tests related to the use of Kinect unveiled special problems. Due to the fact that this kind of natural interaction does not have a physical feedback of the action performed by the user, (unlike pressing a key or moving a mouse), several users commented that at some occasions, they were not sure if the camera turn movement was caused by *Paseante* or it was unintentionally done by themselves. To mitigate this problem, we introduced a visual clue of the activation of *Paseante*, by adding horizontal black bands in the upper and lower part of the screen when *Paseante* had the control of the view. These bands can be used to print information on screen related to the attractor being contemplated.

## 5. CONCLUSIONS

This paper describes the design and implementation of an authoring tool that facilitates the design of architectural walkthroughs and its use on archaeological reconstructions to be placed in a museum environment.

This system obtains a new form of assisted navigation on virtual architectural models very different from traditional approaches based on paths. The proposed approach considers the application of theories from the field of the study of the human attention and applies concepts of the Psychology of human behaviour related to the processes of navigation and way-finding. Architectural walkthroughs on digital models may be enhanced by means of this scheme of assisted navigation.

The flexibility in the configuration of different elements that encompass the aided navigation design kit, from *Paseante* itself to attractors, FOV volumes, etc. makes possible to set up very different kinds of strolls, adapting the walkthrough experience to different user profiles and varied thematic explorations.

The emulation of the behaviour of human attention makes the walkthrough experience more familiar and close to the real explorative stroll, especially when it is combined with the use of natural interfaces such as Kinect.

The use of game engines provides extremely adequate environment for the implementation of this approach. The possibilities of this technology go far beyond visualisation, offering a frame for development that can foster new and interesting ways to show an archaeological model.

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