Turning Augmented Reality into a Media: Design Exploration to Build a Dedicated Visual Language

Nicolas Henchoz[1] EPFL+ECAL Lab

Vincent Lepetit[2] EPFL CVLab

Pascal Fua[3] EPFL CVLab

John Miles[4] Space3D Solutions

ABSTRACT

This work collects the explorations conducted within the EPFL+ECAL Lab by several designers to interpret the various spheres of action of Augmented Reality in order to derive visual principles. These principles seek to contribute to developing a specific visual grammar, which is essential if Augmented Reality is to go beyond technological performance to acquire the status of a true media, like all other vision-based media. This visual grammar constitutes a reference based on which designers may then build projects whose narrative and/or emotional content captivates the end-user. The research presented starts from an artistic approach through design and derives generic principles. The starting-point is the development of actual AR installations and their presentation to the general public in the form of an evolving exhibition entitled Give Me More. Following two initial presentations in Lausanne and San Francisco, Give Me More was the winner of the DMY International Design Festival Berlin 2010. The designers' work relies on the software and research of the EPFL Computer Vision Laboratory (CVLab) and Dr Julien Pilet. The results have made it possible to define certain rules for visual links between the physical and virtual worlds, simple narrative principles for the animations and a global approach for the design of representation devices. The results also show that there is much work yet to be done in order to devise an initial global visual grammar for Augmented Reality – an absolute prerequisite to turn this into a fully-fledged media.

KEYWORDS: ART; AUGMENTED REALITY; COMPUTER VISION; INTERACTION DESIGN; IMAGE RECOGNITION; MEDIA DESIGN; OBJECT RECOGNITION; PERCEPTION; PERVASIVE COMPUTING

[1] nicolas.henchoz @epfl.ch
EPFL+ECAL Lab, Ecole polytechnique Fédéralde de lausanne
11, rue du 14-Janvier,
CH - 1020 Renens, Switzerland,

[2] vincent.lepetit@epfl.ch
CVLab, EPFL (Ecole polytechnique Fédéralde de lausanne)
Station 14
CH-1015 Lausanne, Switzerland

[3] pascal.fua@epfl.ch

[4] jm@space3d.ch
Space3D Solutions SA
Ch. des Larges Pièces B
CH - 1024 Ecublens

1 INTRODUCTION

For over a decade, scientific research, demonstrators and specialized conferences have turned Augmented Reality into a field in its own right (Behringer, Klinker, & Mizell, 1999)[1]. Several methods have gradually strengthened expectations. First, the liberalization and definition of standards for markers such as QR Codes, which make it possible to generate stable augmentations with restricted computing power under variable light conditions. Secondly, the development of effective markerless techniques, with applications such as the EPFL CVLab FERNS (Lepetit & Fua, 2006)[2], which do not interfere with the appearance of the physical world so as to make the relation to virtual augmentations more natural. Other principles are likened to Augmented Reality by the user, while moving away from computer vision techniques to be replaced with a combination of several positioning and movement parameters (Schall, et al., 2009)[3].

Various AR applications now target the general public – in the framework of theme parks such as the Futuroscope in Poitiers since 2008, in museums with approaches closer to Mixed Reality (Hayashi, Kasada, Narumi, Tanikawa, & Hirose, 2010)[4], but also on consumer goods such as the Chocapic cereal box which, in 2009, claimed to be the "3rd-generation games console". Finally, in the same year, several trend-setting magazines embarked on this adventure such as Esquire, followed by Wallpaper a few months later. However, this enthusiasm appears like a passing frenzy.

Initiated by artist Camille Scherrer's Souvenirs du Monde des Montagnes installation, based on the FERNS software, the EPFL+ECAL Lab developed a two-fold program to explore the prospects of Augmented Reality through design. The first line of this program looks at the various domains of application for the general public, while the second aims to contribute to develop a visual grammar, narrative principles and specific design methods. This exploration, conducted in cooperation with the CVLab and an industrial partner – the company Space 3D Solutions – in the framework of a project supported by the Swiss Commission for Technology and Innovation (CTI), aims to develop Augmented Reality from its current technological performance status to that of a media - where content takes precedence over technology for the end-user.

This work is conducted in a specific framework – so-called "natural" installations, i.e. as simple as possible for a wide audience. The set-ups refrain from confronting users with technological languages and actions and rely on a markerless computer vision technique which does not require visualization devices. Installations with complex visualization devices have been developed for several years; however, they have mainly professional objectives. Related applications have been produced e.g. in the military, maintenance and medical fields (Birkfellner,

et al., 2002)[5] due to their precision and reliability, but also to their complexity and high cost. In addition, the EPFL+ECAL Lab's artistic exploration focuses on a scenario whereby a physical action triggers a Digital Transformation (PDt, Physical World Action), i.e. one of four categories defined in the review of possibilities to couple real and virtual worlds (Carreras & Carles, 2009)[6].

2 THEORY

The EPFL+ECAL Lab's work involved several designers and the experience acquired through workshops with students and assistants of ECAL/University of art and design Lausanne. The designers were asked to define their own sphere of action and related specific issues. They were entrusted with exploring various augmentation contexts or scenarios, either narrative or non-narrative. From 2008 to 2010, eight concepts were the subject of a creative exploration which led to the development of an installation to be included in the Give Me More exhibition. This is a travelling and evolving EPFL+ECAL Lab exhibition aimed at museums, institutions and international design festivals. Its purpose is to confront the findings of explorations into AR with a wide audience in order to draw lessons and to validate or disprove related creative strategies. Beyond the initial exploration approach, the installations must meet credibility, intuitiveness and reliability requirements to be selected for the exhibition.

- Book and publication: Souvenirs du Monde des Montagnes.
- Alteration of an object's perceived values: Cashback.
- Perception of the body and its environment: Clouds
- Interaction with a physical object: Dots.
- Change in the user's identity: Inside Out
- Augmented architecture: Lively Light
- Flexible materials: Stitched Pixel by Pixel.
- Sound: Beatvox

These original set-ups focus on the relationship between the virtual and physical worlds at the heart of Augmented Reality. They leave aside the complex narrative processes of traditional interaction media, which have already been largely studied and documented (Cavazza & Pizzi, 2006)[7], in particular in the games industry, as these processes are generally used in an exclusively digital world with a holistic approach.

Interpretation of the findings draws on perception and narration theories, but is restricted to the results of a wide-scale artistic approach.

2.1 Souvenirs du Monde des Montagnes

Fig 1: The animations in Souvenirs du Monde des Montagnes play with collages and shadows to preserve the relationship to the initial paper-based object. Photo Camille Scherrer.

Produced by Camille Scherrer in the framework of her ECAL diploma in cooperation with the EPFL+ECAL Lab and CVLab, Souvenirs du Monde des Montagnes pictures bygone times in the Swiss mountain valley where the artist lives (Scherrer, Pilet, Lepetit, & Fua, 2009)[8]. Designed as a set of short stories with family photographs from 1910 to 1930, the book itself is a fully-fledged classical object. However, when placed on a device made up of a simple table, a desk lamp and a computer screen, the book will uncover hidden stories. Images come to life: the shadow of a bird flies over the paper, airplanes flap their wings across the sky, clouds fall on people's heads and turn into hats. The animations are a succession of images based on paper cutouts.

Technically, the set-up is an extension of an initial collaboration with the EPFL CVLab, "The Haunted Book" (Scherrer, Pilet, Fua, & Lepetit, 2008)[9]. It uses FERNS and its rapid markerless tracking system (Lepetit & Fua, 2006)[10]. The device includes a camera hidden in the desk lamp. It induces a geometry and lighting giving the set-up wide autonomy, provides great stability in the augmentations and offers the user a natural freedom of movement and interaction with the physical support. Presented in particular at the Maison Européenne de la Photographie in Paris and at the SantralIstanbul contemporary art museum, Souvenirs du Monde des Montagnes was awarded the Pierre Bergé prize for best European design diploma. It will be exhibited again at the New York Museum of Modern Art in New York in summer 2011, over three years after it was created. Conceptually, Souvenirs du Monde des Montagnes stands out through a complete narrative content in both the physical and virtual worlds. The narrative continuity is coupled with a wish for material continuity by using pieces of paper to create the animation.

2.2 Stitched Pixel by Pixel

Fig 2: Stitched Pixel by Pixel plays on the support's flexibility and takes into account occultation issues. Photo Michel Bonvin.

Also created by Camille Scherrer, this work reviews the use of Augmented Reality on deformable materials. This is the most technically sophisticated installation, using Julien Pilet's technique making it possible to solve occultation problems[11]. This set-up is the fruit of a lengthy creative process whose first stage was entitled Happy Wear (Scherrer & Pilet, Happy Wear, 2009)[12]. The artist developed her creative process based on one of the principles which made Souvenirs du Monde des Montagnes a success: the impression of material continuity between the physical object and virtual content. Stitched Pixel by Pixel combines a basic graphic element in embroidery - the cross-stitch - with the core of the digital world – the pixel. The installation is made up of a cushion expressing dreams. It also explores a way of moving away from the "Remote Control Syndrome", which considerably hampers Augmented Reality: the physical object is just a way of initiating or interrupting the animation. Here, each deformation of the cushion triggers a new image devised according to a principle inspired from the "exquisite corpse"

method. The image is generated by a random association of word and image blocs, where all 1200 possible combinations provide an impression of consistency thanks to their syntaxic operation. The display is inspired from that for Souvenirs du Monde des Montagnes, but without offering a specific context such as the office table.

2.3 Dots

Fig. 3 Dots requires the user to perform an initial physical augmentation before launching the virtual augmentation. Photo Michel Bonvin

The third installation based on a comparable typology to Souvenirs du Monde des Montagnes, Maria Laura Méndez-Martén's "Dots" is the result of specific research to make the physical element in Augmented Reality more interactive so as to escape the "Remote Control Syndrome". This is a tall order, as shown by a review of the Magic Show which considers that PDt-type interactions induce, at best, a medium grade of illusion (Carreras & Carles, 2009)[6]. Dots refers to the principles enabling children to learn to draw by following a series of numbered dots. The user may choose from various paper sheets, each offering a different drawing. By connecting the dots – a traditional physical gesture - the user makes an initial drawing appear. Animations emerge as soon as this drawing is completed. In one of the drawings, a boxer appears and starts to move when the drawing is complete. An adversary appears and knocks him out, scattering the numbers and dots which served to draw the picture. This type of scenario induces continuous play between physical and virtual elements. Many tests have shown that the presentation device, proximity between the screen and the drawing, the drawing's display on a 1:1 scale on the screen, lead to strong identification between the physical base and the virtual scenario development. A few hours later, the user no longer remembers whether the augmentation was projected on the drawing itself or on a nearby screen.

2.4 Cashback

Fig. 4 Cashback explores the possibility of altering values associated with an object – a field offering considerable marketing potential. Photo Michel Bonvin

Also based on the CVLab's FERNS software like Dots, Cashback, developed by ECAL designer Vincent Jacquier raises two fundamental issues: the object's authenticity and the possibility of altering associated values. By opting for a banknote, Cashback takes up a dual challenge: to alter perception of an object which everyone has in their pocket, and whose authenticity is subject to stringent controls. Deliberately provocative, the set-up aims to pervert Euro notes by turning their monuments and landscapes into a stage for a stripper. The show's audacity increases with the note's value. The graphic exploration focuses on appearance of the augmentation, which happens in two stages: first, an almost imperceptible movement of certain details of the note to make the idea of an animation credible. Secondly, the (male or female) stripper's entrance and motion designed to echo the notes' monuments and visual elements.

The display's strategy varies from that of Souvenirs du Monde des Montagnes: here the technology is fully integrated into a white, neutral terminal. The banknote is put down on a window just below the screen displaying the augmented note reproduced on a 1:1 scale.

This amusing provocation around the guilty feelings associated with money also makes fun of the Euro note's very graphic design with its fake historical monuments. It also serves to illustrate a much more fundamental challenge: to make an object reveal hidden values, stories and information through Augmented Reality. Presented in Milan, Lausanne, San Francisco and Berlin, Cashback elicits many reactions from the users on the content, although few wonder about the technology. The content thus takes precedence over the technological demonstration. Note that the Euro banknotes are particularly well suited to this installation due to their complex and asymmetrical images. The FERNS computer vision software is thus able to provide an extremely stable tracking of the banknote, strengthened by the installation's in-built lighting system.

2.5 Clouds, Inside Out, Lively Light, BeatVox

Fig. 5: Technically very simple, Clouds plays on our relationship to the cloud symbol. Photo Daniela Droz

Fig. 6: Beatvox, by Japanese artist Yuri Suzuki, is a very open transposition of the idea of Augmented Reality into sound. Photo Michel Bonvin

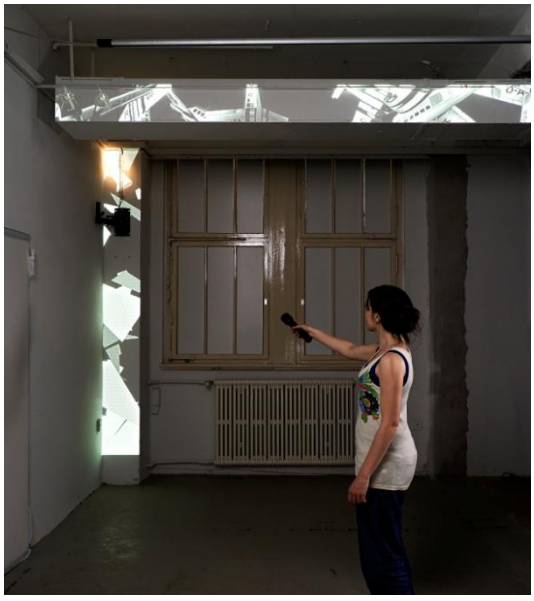

Fig. 7: The raw walls of Tempelhof Airport at the DMY Berlin festival were an ideal playing field for Eric Morzier's Lively Light set-up. Photo Michel Bonvin

This series of set-ups might be likened to Augmented Reality in the effect it has on the users, although they are based on simpler computer vision technologies. Clouds is designed on a principle associating animations with motion detection in the image taken by the camera. It stands out by placing the user's whole body in a central position and by acting on the latter in a symbolic way by attaching clouds to their head and limbs. In terms of simplicity and natural feeling of the experience, the installation takes the opposite direction to the Butterfly game (Norton & MacIntyre, 2005)[13]. Use of the simple motion flow rather than permanent body tracking heightens confusion as the clouds seem to have a degree of autonomy and to play with the user.

Focused on the users' upper body, Inside Out, designed by Audrey Richard-Laurent of ENSCI-Les Ateliers, explores the user's identity. The installation stands out by integrating the screen into a 19th century mirror whose look is consistent with the style of some of the animations tested: appearance of the heart in the biological sense, which then becomes metaphorical, as well as another scenario involving a coat of arms. Presentation at the DMY Berlin Festival served to confirm the principle of acting on the user's personality, but also highlighted a technical problem with the lighting. The very specific lighting required to guarantee tracking of the subject without interfering with the projection turns the display into a theater stage. It places the user in a context bringing forth specific cultural and behavioral references which condition the augmentation's impact. Inside Out operates by tracking the user's eyes thanks to an algorithm developed by Julien Pilet for this project.

Lively Light focuses on the idea of augmented architecture. A flashlight is used to light up a wall in a dark room. When the beam passes over certain physical details – angles, beams, asperities – the wall comes alive to tell virtual stories which blend into the physical building. The installation acts as a revelator. Presented at Tempelhof Airport, it interacted with the place's rich history.

Finally, Beatvox is a very personal attempt by Japanese artist Yuri Suzuki, a graduate of the London Royal College of Art, to use Augmented Reality in the world of sound. Users express a sound into a microphone. A few meters ahead, the sound impulsions trigger a beat on an actual drum kit. The installation starts with a physical action to turn into an augmentation – which is also physical. This is the only set-up in Give Me More which provides another type of interaction (PPt). Tested in public at the DMY Berlin Festival, this is primarily a source of reflection on the very nature of Augmented Reality, usually restricted to the field of vision.

3 Discussion

The discussion is based on observations made during presentation of these set-ups, collected to make up the Give Me More exhibition. Parts of the exhibition were shown in Lausanne (EPFL+ECAL Lab, October 2009), San Francisco (Swissnex, November 2009), and the whole exhibition was presented at the DMY International Design Festival Berlin 2010, where some 4000 people interacted with the installations.

The Festival Jury, made up of Hella Jongerius, Jürgen Bey, Werner Aisslinger, Jerszy Seymour and Patrick Reymond, awarded Give Me More the festival prize.

3.1 Languages and Limitations of Physical Devices

All the works developed in the framework of this exploration make up three categories of physical visualization devices:

"Super Normal" devices, with reference to this trend in object design (Fukasawa & Morrison, 2007)[14]. Rather than hiding all technological elements, the idea is to integrate them as users would in everyday life. Therefore, the set-up initially appears as a

natural environment, as in Souvenirs du Monde des Montagnes or Dots, made up of a desk, lamp and computer. This elicits fewer reactions than a set-up where objects would be partly integrated and hidden but confronting users with new object typologies, as discreet as they might be. The presence of a special screen for Dots, which varies from the global approach as the artist wished, confirms this observation: it pointlessly leads users to question the display technology, contrary to Souvenirs du Monde des Montagnes.

Hidden devices: in this category, the design takes every possible measure to hide technological components. Projection installations such as Clouds or Lively Light rely on existing building walls, avoiding the need for a projection screen, while Cashback integrates all its technology in an almost monolithic box, including the lighting. Although highly convincing, this type of device raises major design and technical challenges. Imperfections reveal a technological dimension which may become pervasive to the point that the content loses credibility. Indeed, the public tests of Lively Light at the Berlin Festival highlighted the importance taken by a slight difference between the colors of the flashlight held by the user and that of the projector, thus introducing a break between the object of the action and the augmented animation. In that case, the defect may be easily remedied with a filter on the flashlight. However, many other exploration ideas were abandoned due to design difficulties in this type of device.

"Diversion" devices: the third installation category seeks to divert the user's attention by using strong style and typology references. Inside Out, for instance, uses a 19th-century style mirror. This principle shows convincing results provided that it is consistent with the augmented content. Of the various animations developed, only those using visual codes consistent with the mirror were retained.

Experiments partly corroborate the systematic analysis of Perceptual Issues (Kruijff, Swan II, & Feiner, 2010)[15]. However, our research findings stress that technology is not the only way to overcome problems with a device. By playing on the user's perceptions, taking into account technical limitations in the device's very design, one may still achieve consistency between the physical and virtual worlds. The latency problem, which is extremely obvious when an augmentation is projected on the object itself, might not be seen if one displays the augmentation on a separate screen. This is not perceived as a break in the space continuum provided that the right distance and scale ratio are used, as indicated by Dots, Souvenirs du Monde des Montagnes or Cashback. Using visual gimmicks may prove highly efficient, as shown by the "vice category. In this respect, studying Augmented Reality in the field of magic (Carreras & Carles, 2009) is particularly enlightening.

3.2 Composition of Physical Objects and Virtual Animations

The design of physical objects and of their augmentation also plays a central role in the process to focus the user's attention on the relationship between the real and virtual worlds. We observed that the size ratio between an object and its augmentation is a major issue. Several Give Me More installations finally adopt a 1:1 ratio, or at least such a perception. Another token of consistency is the impression of material continuity. Thus in Souvenirs du Monde des Montagnes, the images of the paper book are enriched with paper cutout animations. Physical perception of the materiality of an object handled by the user is echoed in its virtual representation. In the case of the Monde des Montagnes, this idea is further justified by a specific artistic context, as cutouts are part of popular culture in this mountain area. With Stitched Pixel by Pixel, the material link was a starting-point to the creative process by identifying the relationship between the cross-stitch and pixel. This continuous reference to the physical world, which can also be expressed on a purely graphic, or even cinematographic level, considerably strengthens the set-up's credibility and its narrative content. Although Cashback represents a very direct implementation of this principle, Souvenirs du Monde des Montagnes introduces well-controlled breaks: for instance, the paper cutout animations temporarily yield to the shadow of a bird. In Dots, the dots which enabled the user to complete the initial physical drawing are taken to task in the animation.

3.3 Appearance and Disappearance

The animations' appearance defines when the real and virtual worlds meet. It is a key instant which defines how credible the user will find this relationship. Most Give Me More installations control this appearance: the augmentation does not merely appear on the screen as soon as the computer recognizes the object - a scenario triggers a sequence to make the animation appear in a controlled fashion. Failing this, the physical object often gives rise to uncertain recognition for a time. The augmentation's instability during this time makes the set-up less credible as it highlights its artificial nature. Moreover, a controlled appearance serves to establish an effective graphic continuum. In Cashback, the animation starts with small movements of almost invisible details in the banknote – e.g. small circles – followed by larger elements, before the main actors come in. Thus there seems to be no break between the inert state of the physical object and its ultimate animated character.

3.4 Interactivity

In a vast majority of Augmented Reality installations, interaction remains very limited: the image of the physical object is either ON or OFF, what we already called the "Remote Control Syndrome". Interactivity is restricted to moving the object over a limited space. However, this motion is usually used to validate the link between the object and its augmentation. The games industry recently started to develop interactivity and a narrative strategy for the virtual component (Nintendo 3DS: AR Games and Face Raiders, 2011).

The creative work conducted at the EPFL+ECAL Lab mainly explored interaction with the physical world. This issue is central to the development of Maria Laura Méndez Martén's Dots: the initial object is just a series of dots, and the user has to create the image to trigger off the animation. The first augmentation is thus performed physically by the user before the virtual element takes over. If kept here simple and linear, this principle may become part of more complex scenarios involving relations between several physical objects (multitracking) or resorting to techniques to increase the user's freedom (character recognition, gesture library, etc.). Interactivity with the physical object also appears in Stitched Pixel by Pixel, where the material's physical deformation actually alters the augmentation.

Can the user's position influence this impression of interactivity? The principle of Radiating Centers (Pedersen, 2009)[16] aims to conceptually place the user at the center of the installation to be immersed in the interface. This principle operates astonishingly well with Clouds, which was acclaimed to the point of being invited as one of the main attractions of the 2011 "Maison & Objet" show in Paris. With Clouds, this immersion is not of a technological nature. Although the user's position is immersive, the installation does not resort to tricks such as a Head Mounted Display, 3D game or to additional senses such as hearing. However, the clouds which gradually eclipse the user's head and limbs in Clouds add a strong symbolic dimension. Therefore, installations should not be thought merely in terms of

the relationship between the real and virtual worlds, but also in terms of reality and symbolic expression. This observation confirms the statement that users act not only physically, but also mentally and existentially (Pedersen, 2009)[16].

4 CONCLUSION

Creating a specific visual grammar to give Augmented Reality media status still requires much effort. It calls for considerable artistic exploration work in an open, diversified, yet coordinated fashion so as to derive general principles for this media. Specific skills are needed such as interaction design, but also graphic design and object design, animations, etc. Setting up a team of designers complementing each other's approaches can be a major asset. This exploration must imperatively be tested with the target audience, which we were able to do with the evolving Give Me More exhibition. However, it should go through an additional stage of external assessment through the humanities and social sciences in order to study perception mechanisms and to enshrine the principles developed into global narrative theories. This artistic exploration requires ongoing dialogue with the engineers and scientists offering advanced technology solutions, in particular in the field of computer vision. As shown by some of the installations in this work, problems apparently technical in nature may also be solved by visual responses developed by the designers based on the user's perception. In this close cooperation, designers may also put forward new challenges by defining stakes and opening new avenues with strong potential for Augmented Reality. The work conducted by the EPFL+ECAL LAB contributes to this endeavor. It has now embarked on a new research stage with a strengthened team of designers and engineers to present, in June 2011, a new version of Give Me More in the framework of the Designer's Days in Paris.

REFERENCES

[1] Behringer, R., Klinker, G., & Mizell, D. (1999). Summary of the Discussions at IWAR 98. *IWAR98* (pp. 18-20). San Francisco: VR News.

[2] Lepetit, V., & Fua, P. (2006). Keypoint Recognition using Randomized Trees. *Transactions on Pattern Analysis and Machine Intelligence* , 1465 - 1479.

[3] Schall, G., Wagner, D., Reitmayr, G., Taichmann, E., Wieser, M., Schmalstieg, D., et al. (2009). Global Pose Estimation using Multi-Sensor Fusion. *IEEE International Symposium on Mixed and Augmented Reality* (pp. 153-162). Orlando: IEEE.

[4] Hayashi, O., Kasada, K., Narumi, T., Tanikawa, T., & Hirose, M. (2010). Digital Diorama System for Museum Exhibition. *IEEE International Symposium on Mixed and Augmented Reality* (pp. 231-232). Seoul: IEEE.

[5] Birkfellner, W., Figl, M., Huber, K., Watzinger, F., Wanschitz, F., Hummel, J., et al. (2002, octobre). A Head-Mounted Operating Binocular for Augmented Reality Visualization in Medicine—Design and Initial Evaluation. *IEEE TRANSACTIONS ON MEDICAL IMAGING* , pp. 991-997.

[6] Carreras, A., & Carles, S. (2009). Coupling Digital and Physical Worlds in an AR magic Show Performance: lesson learned. *IEEE International Symposium on Mixed and Augmented Reality* (pp. 25-28). Orlando: IEEE.

[7] Cavazza, M., & Pizzi, D. (2006). Narratology for Interactive Storytelling: A Critical Introduction. *TIDSE* (pp. 72-83). Springer-Verlag Berlin Heidelberg.

[8] Scherrer, C., Pilet, J., Lepetit, V., & Fua, P. (2009, Vol. 42, No. 4). Souvenirs du Monde des montagnes. *Leonardo* , pp. 350-355.

[9] Scherrer, C., Pilet, J., Fua, P., & Lepetit, V. (2008). The Haunted Book. *IEEE International Symposium on Mixed and Augmented Reality* (pp. 163-164). Cambridge: IEEE.

[10] Lepetit, Vincent et Fua, Pascal. Keypoint Recognition using Randomized Trees. *Transactions on Pattern Analysis and Machine Intelligence.* 2006, Vol. 28, 9, pp. 1465-1479.

[11] Pilet J., Lepetit V., and Fua P. (2007). *Retexturing in the Presence of Complex Illumination and Occlusions*. IEEE International Symposium on Mixed and Augmented Reality.

[12]Scherrer, C., & Pilet, J. (2009). Happy Wear. *ACM SIGGRAPH ASIA 2009* (p. 44). Yokohama: ACM.

[13] Norton, M., & MacIntyre, B. (2005). Butterfly Effect: An Augmented Reality Puzzle Game. *International Symposium on Mixed and Augmented Reality* (pp. 212-213). Vienna: IEEE.

[14] Fukasawa, N., & Morrison, J. (2007). *Super Normal, Sensations of the Ordinary.* Baden: Lars Müller Publishers.

[15] Kruijff, E., Swan II, J. E., & Feiner, S. (2010). Perceptual Issues in Augmented Reality Revisited. *IEEE International Symposium on Mixed And Augmented Reality, Arts, Media and Humanities Proceedings*, (pp. 3-12). Seoul.

[16] Pedersen, I. (2009). Radiation Centers: Augmented Reality and Human_Centric Design. *IEEE, International Symposium on Mixed and Augmented Reality* (pp. 11-15). Orlando: IEEE.