TRANSFICTION

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Introduction

At the crossroads of art and technology, of virtual and real spaces, of real-time and diegetic time, *transfiction* allows one to explore narrative concepts which demonstrate the its capabilities to engage audiences. With this aim in view, it uses tools that are widespread in cyberculture: computers, web-cameras and screens. Internet and its protocol ensure that the information is carried in a ubiquitous manner from one device to another.

Contrary to many approaches to virtuality or mixed reality, the *transfiction* system does not need any dedicated hardware, either for computation or for tracking of real objects/persons. It runs on standard Pentium PCs and video cameras are the only sensors used. This vision-based interface approach allows freedom for the user, no more tied to hardware devices such as helmets and gloves.

Various research projects have already adopted such a user-centric approach towards mixed reality. It ranges from the animation/command of purely virtual worlds only, as in the *KidsRoom* (Bobick & al., 1999), to a more mixed kind of worlds where the users can see a virtually reproduced part of themselves, as in *N.I.C.E.* (Roussos & al., 1997), and goes on to the inclusion of the user image within the virtual space in order to fully exploit the potential of mixed reality. In *ALIVE* (Maes & al., 1997), ”Artificial Life Interactive Video Environment”, wireless full-body interaction between a human participant and a rich graphical world inhabited by autonomous agents is used: a single video camera is used to obtain a color image of a person, which is then composed into a 3D graphical world; the resulting image is projected onto a large screen that faces the user and acts as a ”magic mirror” as the user sees himself/herself surrounded by objects and agents. Another and quite different approach is the *HyperStories* (Sanchez & Lumbreras, 1997) one, which extends the ideas of ”branching games” and classic ”choose your own adventure” novels: it aims at exploring hypermediacy in the narrative structure.

When implemented only in a room where users stand in front of a big screen and a camera, the *transfiction* system has many similarities with *ALIVE*. *Transfiction*, however, usually combines this approach with hypermedia concepts like the ones employed in *HyperStories*, and aims at offering users the possibility to share story spaces throughout the Web. The Internet Protocol brings in a distributed pattern for this narrative collaboration (the sharing of communication and feelings/emotions) and, at the same time, develops the notion of ubiquity as the user image is simultaneously reproduced on many different screens.

The transfiction concept

Overall, by *transfiction*, we mean ”transportation in fictional spaces”. A taxonomy of spaces and ”fictional space” is provided in section ”Narrative spaces”: real, actual, virtual and diegetic spaces are defined there with precision. If the notion of actual space defines what is (actually) seen in front of the camera, ”fictional space” is conversely defined as one that contains elements not coming out of this actual space. The image of the interactor is reproduced in this fictional space, hence transporting him/her into the fictional space and giving birth to a *transfiction* experience.

Since it makes use of both real and graphical images, *transfiction* needs to be positioned in the real-virtual continuum and in the context of the ”mixed reality”. According to Milgram and Colquhoun (1999), mixed reality covers the whole continuum ranging from reality to virtuality. At the one end is the real environment, made of the real world and captured images of it. On the other end is the virtual environment, i.e. a world completely modeled in terms of shape, location, texture, motion… Mixed reality consists thus of any combination of these two worlds. According to the relative importance of real or virtual (modeled) elements, one has to deal with augmented reality or augmented virtuality as depicted in Figure 1.

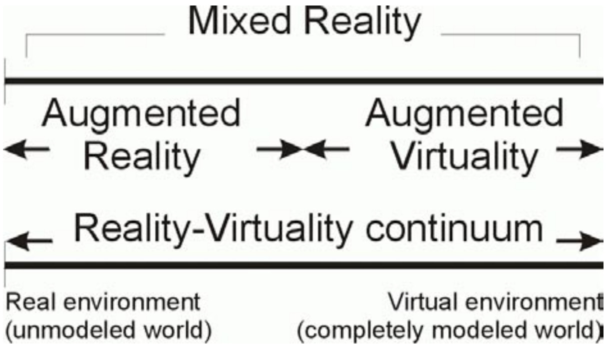

Figure 1. The mixed reality continuum.

The *transfiction* system takes place in this continuum because of the merging of natural and synthetic objects and backgrounds. While telepresence is usually considered to consist of the augmentation of a virtual world with some natural images of people (thus belonging to augmented virtuality), *transfiction* goes beyond since there is a narrative element included.

The will to explore new ways of storytelling with the help of technological devices using multimedia and (audio) visual elements as input and output channels has initiated the desire for *transfiction* systems. It therefore requires the combination of expertise coming out of the scientific and technical fields as well as from the artistic domains. More specifically, it combines: *The development of visual ambiences* (graphic-rich spaces, 2D and 3D) *and narrative concepts* (building on hypermediacy and audiovisual grammar) with *signal-processing and other processes of video surveillance* (including segmentation algorithms which allow us to track motion from materials provided by visual sensors).

Techno-narrative taxonomy

The word ”narrative” here refers to a set of events happening during a certain period of time and providing aesthetic, dramaturgical and emotional elements, objects and attitudes. In some ways, it is comparable to the script of a film. However, film scripts offer a linear reading where each piece is closely linked to the previous one: the meaning emerges from the whole story. In new media, one needs to have modules of scenarios/scripts, which maintain their own individual meaning. Moreover, modules can be interchanged, and the reader will have different experiences according to the paths of exposure through the set of modules.

Two levels of design have to be considered when extending modular narratives towards *transfiction* systems: the development process (author-centric orientation) and the reception process (user-centric orientation). The development process focuses on ”*techno-narrative fusion*”, where the aim is to optimize the dialogue between engineers and multimedia authors, in order to produce ”new media art objects” which are built upon the specific characteristics of the computing media and which imply both technical and narrative constraints. Narrative ambiences and algorithms need to be scripted, in order to install a system where the user can have real experiences, offering both narrative and interactive ”pleasure” (at emotional and/or aesthetic levels).

The user-centric orientation focuses on the mechanisms whereby a user accepts the system, and on how s/he acts with the designed apparatus. Two types of users are identified: the *interactor* who stands in front of the camera and ideally can see himself/herself on a screen next to the camera, and the ”classical” *viewer*. One can further distinguish two types of viewers: a viewer who sees the filmed/composed scene through a web browser (and can possibly click on it) and a viewer who stands next to the interactor but whose image is not captured by the camera; this second type of viewer remains a spectator in relation to the apparatus and has no interaction power. The real-time immersive experience is already different for these two types of viewers and interactors, and viewers obviously experience the concept of *transfiction* differently.

User-centric system

Interface

The starting point is the presence of cameras, screens and computing devices. The combination of these offers the basis for the narrative apparatus. This approach is also defined as ”vision-based interface” (Maes & al., 1997). The advantage of this interface technology is the fact that the user is not tied to any technological devices (gloves, helmet, etc.): his/her bodily movements and gesticulated attitudes are the only interface. The challenge is to ensure that the user understands the message/story that appears on the screen in an intuitive as well as effective manner (suggesting reaction or interaction). At this level, it is important to define the different types of users in the *transfiction* system.

User, viewer, interactor

Two types of screens coexist and get their information through two different channels. They implicitly define two types of users: the viewer and the interactor. The viewer basically receives the information through the Internet and views the streaming images on the web browser of his/her computer. The interactor directly sees his/her own image reflected in the screen in front of him/her and is therefore involved within the story: the mere fact of moving already offers him/her a basic and simple level of interactivity.

A subset of the *transfiction* system takes place in a room where interactors and viewers are in front of the same screen. The only difference is that the camera (visual sensor) does not capture the viewer image (representation), because the viewer is out of the shooting zone of the camera. Figure 2 positions the different types of users within the system for a simple case study. A complete system involves several cameras, screens and web browsers.

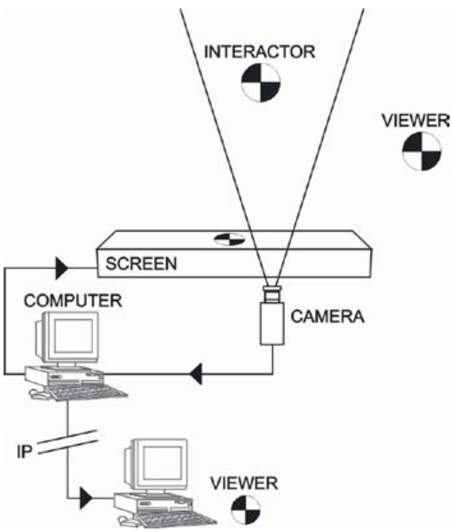

Figure 2. Classification of the different types of users according to their relation to the system.

Narrative system

Techno-narrative authoring

The techno-narrative authoring process takes into account several areas of expertise, namely the artistic ones (exploring narrative concepts at the intersection of film practice, visual grammar and literary paradigms) and the technical ones (focused on image segmentation and signal-processing).

The object-oriented paradigm introduced by Janet Murray (1997) offers an interesting scenario development methodology as it allows one to deconstruct the script development and, thus, to work with a modular methodology, not tied to the linearity of film for example.

The specifications in the scenario cover the specific aspects of a narrative system: procedural, participatory, spatial and encyclopedic. In other words, the multimedia scenario focuses on:

Scripting digital objects: objects of different media types (images, texts, animations…) are designed: background-related, non-moving objects, moving objects, random objects. Hence, it enables the constitution of the *encyclopedic* database of media elements.

Establishing rituals of participation for the users: the acting and relational possibilities allowed for the interactive user within the universe are defined and scripted. This contains the rules and grammar for moving in the universe as well as authorized attitudes and actions. It defines the *participatory* rules for the user and sets the *procedures* to be implemented (for interconnecting the different objects to users and to all the different spaces).

Structuring navigable spaces for the user: all the allowed/forbidden relations and paths ("flows") in and between the different types of spaces are translated into technical terms with the team of engineers. This allows the definition and circulation of flows amongst the *spatial* zones relevant to the *transfiction* system.

Segmenting and indexing information for multiform retrieval and assembly: the inventory of all media assets and all the computing and interactive processes are checked and stored. This ensures an optimal management of the database, i.e. the *encyclopedic* set of data.

In Figure 2, a systemic approach has been adopted: users are bound to a narrative apparatus which consists of cameras for image capturing, computers for image composition, signal processing and scene composition, and, screens for image rendering. For the sake of clarity, it is important to provide a praxis-based typology of the different spaces in which the bodies, objects and events may be situated. With this respect, it is interesting to quote Deleuze who already elaborated on such considerations about different types of spaces:

> We opposed the virtual and the real: although it could not have been more precise before now, this terminology must be corrected. The virtual is opposed not to the real but to the actual. The virtual is fully real in so far as it is virtual. Exactly what Proust said of states of resonance must be said of the virtual: 'Real without being actual; ideal without being abstract'; and symbolic without being fictional. (1994, 208)

Relying on such a point of view, the following definitions are used:

The *Actual Space* is the space in front of the camera. It is the space within which any person becomes an interactor.

The *Real Space* is the space in which the user is living, be it interactor or viewer. The viewer can look at the *transfiction* experience but is not part of it, while the interactor is.

The *Virtual Space* is the space which is rendered on the screens. It is composed of real-time images of the interactors or other real elements, as well as bodies and objects generated from a computer database.

The *Diegetic Space* (as defined regarding narrative films) refers to the world of a film story. The *diegesis* includes events that are presumed to have occurred as well as actions and spaces not shown onscreen. The concept of *diegesis* will be more accurate once we are able to offer the audience an extended narrative experience similar to viewing a film (Bordwell & Thompson, 1993).

It is clear that the combination of the actual and virtual spaces positions *transfiction* within the mixed-reality universe (Milgram and Colquhoun, 1999). The design and narrative challenges consist of articulating these spaces and formulating a set of events and potential actions which generate the basic dramaturgy. This obviously is closely tied to what is perceived by the user of the *transfictional* narrative system.

Actual and virtual events and actions

In order to enhance the user experience, an arrangement of *mise-en-scene* elements is needed when creating the set of narrative patterns. Mixing aesthetic ambiences and adding dramatic tension develops these patterns. One core element of the tension is generated by the ”mirror” effect: the interactor sees himself/herself in the virtual space and hence pays more attention to the potential events and actions. S/he is engaged in the narrative in relation to which the *transfiction* experience takes place. However, this ”mirror” effect has only a partial role in the web-based part of the *transfiction* system. To script and articulate the set of possible events and allowed actions, the notion of *narrative architecture* needs to be introduced.

Conceptual and technical architectures

Narrative architecture

With the emergence of new media offering computing power, all the processes of scripting and implementing story spaces are to be revised. The present article only focuses on the areas devoted to visual spaces and modalities of circulation within these spaces, although the same paradigm applies to audio elements and other instances of dramaturgy too. Web cameras are the tools chosen to capture the movement of ”actors” who are circulating in the visual spaces. The diegetic space (where the narrative is happening) is expressed through the screens. It is important to note that two spaces where events are happening coexist: actual space in front of the camera and virtual space, which can be seen through the screen(s).

The scenario offers an architecture in which the possible actions within the visual ambiences as well as the occurring events are defined according to a set of variables. The notion of architecture is associated with narrative because it expresses the modularity in the script development process and refers to the importance of writing scripts with embedded variables. Hence, narrative architecture combines both dramaturgy and information system approaches.

Contextual writing/scripting

Context refers to the background of the viewer's/reader's/spectator's life, including everything the user thinks, feels, and does (behaviour, needs, attitudes, perceptions, etc.) This context is mostly nonarticulated, and constantly changing. The challenge for the *transfiction* system is to design ambiences where the nonarticulated of the everyday life can fit together with what is provided as a potential interactive experience. The challenge is to ensure that some meaning comes out of the (narrative) experience, a concept we develop below.

Narrative experience

The notion of experience is largely explored in the design fields (Nielsen, 1994). But these are strongly focused and do not cover the emotional and perceptive layers that provide a deeper meaning for the notion of experience.

Experience here is related to the user time. During this period of user time (time the user spends in front of the camera), interactors continually register the quality of their experience with the apparatus (camera/screen). The apparatus must be reliable, creating a pleasurable framework that meets expectations, addresses concerns, solves problems, fits into the interactors' lives, and even gives them something extra.

The quality of the narrative experience will be different for the viewers and the interactors. The expectations also depend on the type of users and the place they occupy within the system.

Two types of experience, satisfying and rich, are identified in user-system interactions. A *satisfying* experience is a processdriven act that is performed in a successful manner. A *rich* experience implies immersive continuity and interaction, which may be made up of a series of satisfying experiences. One has to extract a set of principles for designing rich, immersive experiences. In order to better judge the quality of the narrative experience, a set of dimensions can be associated with it:

The social dimension, which relates to the values joining a collective group of people.

The inventive dimension, which relates to the needs of the user and to the utility of the experience.

The operational dimension, which refers to experience efficiency.

The aesthetic dimension, which relates to the individual values and how meaning is attached to the experience.

Transfiction

The concepts and the taxonomy developed so far allow a more specific positioning of the notion of *transfiction* - transportation within fictional spaces. As presented in Figure 3, the *transfiction* pulls the *interactors* out of their *context* when they enter the *actual space*. Their images are then integrated into a pre-existing *fictional narrative* in order to construct the *virtual scene* which is rendered on the screens. Moreover, the interactors' attitudes and behavior influence the *narrative*, with the explicit intent of making the immersion a rich *experience* for all users.

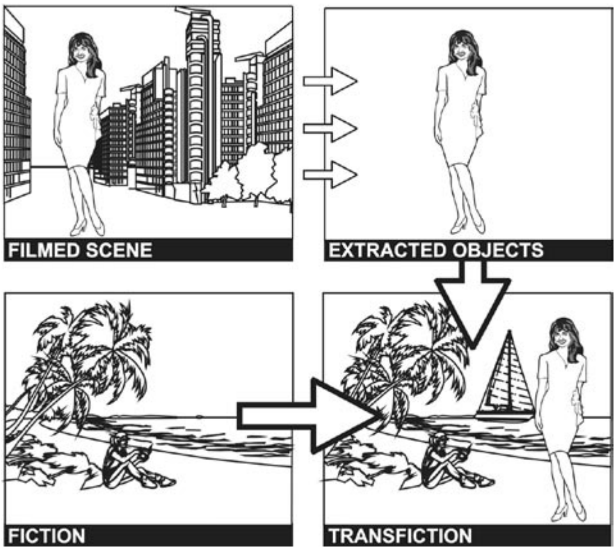

Figure 3. The principle of creating *transfiction*.

From the analytical viewpoint, this conceptual notion of *transfiction* is meaningful thanks to:

– the user experience,

– which is triggered off as a result of artistic exploration,

– and concretely provided by means of technological development.

The technical architecture described below sets down the first building blocks for turning *transfiction* into a ”reality”.

Technical architecture

In order to provide users with such an experience, the technological challenge is to gather all requirements and to issue a practical solution for it all. In order to compose all the visual objects (the ”real” ones moving in front of a camera as well as those generated from a computer database) within the final virtual scene, and to allow interactivity, the MPEG-4 standard (MPEG Video group, 1998) can be used as the transmission layer, especially if most visual pieces of information are images and not 3D models. This standard does indeed integrate all the appropriate functions.

In addition to the composition and transmission facilities, the following issues have to be addressed:

– how to achieve a real time segmentation of moving objects captured by a web camera

– how to associate these objects, extracted from the real world, with predefined synthetic objects in order to compose coherent virtual scenes

– how to perform the real-time encoding of these arbitrarily shaped objects with the help of various coding techniques that are available in the MPEG-4 framework

– how to establish an architecture based on the Internet Protocol that allows for ubiquity and composition of virtual scenes using elements from various sources

– how to design an interactive browser enabling the launch of events on the basis of user requests

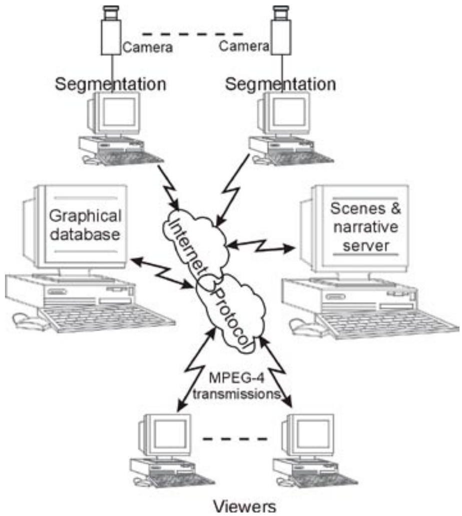

Figure 4. Technical architecture.

Solutions to these issues have then to be combined with each other in order to implement the architecture depicted in Figure 4: various graphical resources (segmented video material, graphics, virtual objects…) make their MPEG-4 encoded content available to the system. In parallel, a scene server makes various descriptions of virtual scenes available. Any screen can then connect to the scene server, select a scene and then compose it by drawing the relevant image streams from the cameras and/or image server(s) (graphical databases).

Thanks to the Internet Protocol, the system is very flexible and allows any screen to access any resource it needs. A phenomenon of ubiquity is therefore provided since two or more screens may simultaneously access the same camera stream. Moreover, the system is very open since the number of any elements can be increased according to the need.

Implementation issues

Scenario implementation

In addition to the structuration of the overall narrative, synthetic background(s) and several (moving) virtual objects have to be designed.

The appearance of these objects within the virtual space can be launched by events induced by the behavior of the real objects, or explicitly requested through user interaction, depending on the scene description used. All these graphical resources are pre-encoded in the graphical database so that the system can quickly refer to them.

It is important to keep in mind that ”the shape of the future at this point might not be found in looking more closely at the properties of silicon, but in paying attention to the ways people need to, fail to and try to communicate with one another” (Rheingold, 1996).

From the ethical point of view, the rules and rituals have to respect user's privacy and copyright laws. These are not elaborated in the present paper but are not neglected in the conceptual implementation.

Technological implementation

Because of the real-time constraints, only a subset of the MPEG-4 functionalities is implemented. This section of the paper will review the practical solutions to some specific subtasks of the technical architecture presented in Figure 4.

Segmentation

Although literature provides one with many techniques aiming at segmenting moving images (IEEE transactions on Circuits and Systems for Video Technology, 1998), the design of suitable and fully automatic algorhitms is still considered to be an unsolved problem as a whole. Moreover, the targeted application enforces the algorhitm to take into account two drastic requirements.

At first, the segmentation algorithm must run in real-time, which prevents the use of too sophisticated algorhitms. Secondly, since the algorhitm must run at any time, under any weather conditions, some special attention has to be paid to the variations in illumination variations. Although the camera does not move, the background changes! The two images in Figures 5 and 6 depict the same view from the *Urbicande-la-Neuve* demo. The first image is a typical view of the background at noon. The second image is the same view, about twelve hours later.

Figure 5. A real background, around noon.

Figure 6. The same background as on Figure 5, around midnight.

In order to comply with the real-time constraint, one clear point of departure has been pre-settled: the algorithm aims at segmenting only the moving objects. Therefore, to segment the image at time *t*, two change masks are generated by comparison with the previous and the next picture. Since each of these masks contains not only the moving object at its location at time *t* but also its location in the reference frame, both masks are combined with a logical AND operator. The resulting mask ($Mask_{temp}$) generally depicts correctly the object contours. However, the inside of the objects is not always correctly detected as a part of this change mask. That's the reason for using a reference image background. The change mask between this background image and the image to segment ($Mask_{bg}$) often allows detecting the inner part of objects. A logical OR operation applied to $Mask_{temp}$ and $Mask_{bg}$ provides the system with a reasonably good segmentation of the moving objects. Moreover, the objects that stop moving are also detected since they appear in $Mask_{bg}$. Figure 7 summarizes the functioning principle of the segmentation scheme.

Even if the use of a reference background image is crucial in enabling a complete and fast segmentation of objects, it does, on the other hand, require the automatic generation of this image. The problem is not trivial since the background illumination changes continuously in the case of outdoor scenes.

It is obvious that the background image cannot be extracted once and for all but needs to be constantly updated. The solution is to use a mobile median filter of size *b*. In order to further improve the quality of this background image, only pixels that do not belong to moving objects, i.e. which are not part of $Mask_{temp}$, are injected in the filter. Since it is a mobile filter of fixed size, a new pixel to be taken into account replaces the 'oldest' one among the *b* already in memory. Typically, *b* is set between 10 and 50.

One has to note that all change detection (- symbols on Figure 7) is not performed by mere comparison. Due to possible camera instabilities, the global illumination change between images is taken into account when comparing images: a histogram is built with the difference of the mean of paired *16x16* blocks, and the illumination change is estimated as the histogram peak. Moreover, change is not detected at a simple threshold *T* but with an adaptive threshold $T+\alpha.p$, where p represents the value of the reference pixel being compared. α is typically set to 10, while *T* equals 1 or 2 to compute $Mask_{prev}$ and $Mask_{next}$, and is equal to 5 or 6 for computing $Mask_{bg}$.

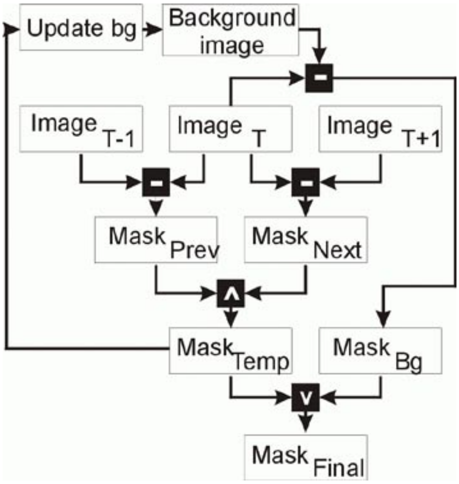

Figure 7. Segmentation scheme.

Compression and transmission

The various objects (MPEG-4 Video Object Planes) are encoded and stored into several buffers. Since MPEG-4 recognizes both H.263 (ITU Recommendations, 1995) and JPEG (Wallace, 1991) standards, these have been chosen as the compression algorithms because of their existing real-time implementations. However, it has to be noted that, for the purpose of random access from any new client (viewer) connecting to the any graphical resource (camera or database), only the intra-coding mode of H.263 is used.

Nevertheless, the use of video objects is more elaborated than a simple compression of rectangular images. Each frame is associated with a mask that allows defining the shape of the objects (*alpha channel*). This shape information is coded on 8 bits. It means that for each luminance pixel, a corresponding alpha pixel is set to 255 (full transparency) or 0 (opacity). The masks are used during the composition by the rendering system.

In this first implementation, only three basic types of MPEG-4 objects can be accessed:

- The objects moving in front of a camera are arbitrary shaped video objects coded with H.263 and associated with an alpha channel.
- Some backgrounds (still images) encoded with JPEG.

– Additional objects encoded with JPEG or H263 depending on whether they are moving or not, associated with an alpha channel.

Scene composition and interaction

The different objects described above will be displayed together on the viewing devices. They need to be coordinated and synchronized together. So, temporal information is needed, as well as spatial information. The scene description is transmitted in a separate bit stream, compliant with the MPEG-4 BIFS description.

The TCP-IP queries that navigate between the screens and the server emulate in a very simplified way the behavior of the flex-mux and DMIF parts of MPEG-4.

Preliminary results

So far, the technological solution implements a subset of the narrative architecture. Inspired by the comic strips albums of the *Obscure Cities* by Schuiten-Peeters and a web mise-en-scene directed by Alok Nandi with the collaboration of the multimedia team of Casterman Edition (see http://www.urbicande.be/), a first demo has been implemented. Http://urbicande.tele.ucl.ac.be/ gives an overview of this demo, which partly shows some of the concepts we are currently exploring in the *transfiction* body of work. This online demo consists of three cameras that have been placed in the city of Louvain-la-Neuve (Belgium). The background images of these cameras have been redrawn with the architectural style of the *Obscure Cities*. For example, Figure 8 depicts the virtual background that fits the street already shown in Figure 5.

All real objects (people, cars…) moving in front of the camera are then extracted and composed with the virtual background and additional virtual objects issued from the imaginary world. A typical view of the virtual scene is presented on Figure 9.

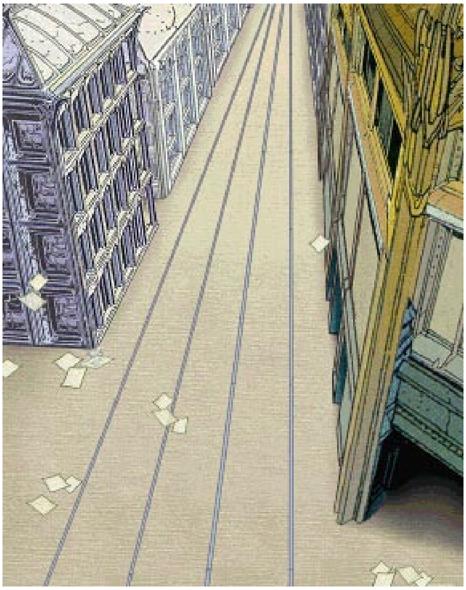

Figure 8. Virtual background for *Urbicande-la-Neuve* (Figure 5 depicts the actual scene).

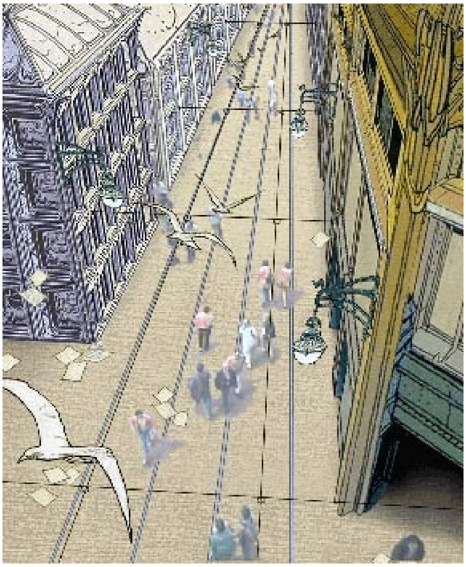

Figure 9. Typical transfictional scene from *Urbicande-la-Neuve*.

Any pedestrian crossing the Grand-Rue or any of the University of Sciences squares in Louvain-la-Neuve takes instantaneously part in a *transfiction* experiment. The challenge now is to truly make it an experience offering a narrative pattern.

From the technological point of view, the performance is mainly limited by the compromise in segmentation between quality and speed. The segmentation algorithm presented above behaves relatively well but has difficulties to tackle very fast illumination changes that are interpreted as moving objects. Its speed is limited to 6 frames per second for 360x288 images and 2 images per second for 720x576 images.

Conclusion

Extensive use of virtual reality for industrial as well as entertainment purposes is nowadays a strong trend. However, the interface modalities of such technologies (helmets and gloves, or expensive CAVEs™) may hamper the development of creative and artistic projects. Looking for interface devices that are not a constraint for the user is very important for exploring new modalities of story telling and story sharing.

The choice of vision-based interfaces (like web cameras) allows one to give freedom to the user with respect to the technology. It obviously requires exploring image-segmentation and signal-transmission technologies. It does also lead towards the emerging area of Mixed Reality, and requires the development of a taxonomy that explores this new praxis defined at the edges of the scientific and artistic practices. This techno-narrative fusion is visible both on the authoring level where the teams of engineers and artists collaborate in more complex ways, and on the reception level which involves the user who is experiencing the result of the fusion, the *transfiction*. The challenge of offering rich emotional and cognitive experiences to an audience requires one to address the complexity of the underlying system which needs to respect the constraints of intuitive and effective usage.

Therefore, in addition to some insights concerning the taxonomy, the present paper pragmatically introduces the early implementation of the *transfiction* system, focused on the user as a viewer, but not especially as an interactor. A praxis-based approach, built on modularity, has dominated the implementation strategy. A distributed architecture has been chosen on the technological and narrative levels. This architecture is IP-compliant and allows the management of streams of data coming out of multiple cameras. The work-in-progress is now exploring the different aspects of the techno-narrative taxonomy developed above.

The good reception of the *Urbicande-la-Neuve* demo by a large audience has confirmed the importance of proposing an attempt at techno-narrative taxonomy and motivates the effort of further developing the implementation of new modules in the *transfiction* system.

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REFERENCES

Bobick, Aaron & Intille, Stephen & Davis, Jim & Baird, Freedom & Pinhanez, Claudio & Campbell, Lee & Ivanov, Yuri & Schütte, Arjan & Wilson, Andy (1999) ”The KidsRoom: A Perceptually-Based Interactive and Immersive Story Environment”, *PRESENCE: Teleoperators and Virtual Environments* 8:4, 367–391.

Bordwell, David & Thompson, Kristin (1993) *Film Art, an Introduction*. McGraw-Hill.

Deleuze, Gilles (1994) *Difference and Repetition.* New York: Columbia University Press.

IEEE Transactions (1998) *Special Issue on Segmentation, Description, and Retrieval of Video Content*, IEEE transactions on Circuits and Systems for Video Technology 8:5.

ITU Recommendations (1995) ”Draft ITU-T Recommendation H.263”, ITU Recommendations, Telecommunication Standardization Sector of ITU.

Maes, Pattie & Darrell, Trevor & Blumberg, Bruce & Pentland, Alex (1997) ”The ALIVE system: Wireless, full-body interaction with autonomous agents”, *Multimedia Systems* 5:2, 105–112.

Milgram, Paul & Colquhoun, Herman (1999) ”A Taxonomy of Real and Virtual World Display Integration”, in Ohta, Yuichi & Tamura, Hideyuki (eds.) *Mixed Reality, Merging Real and Virtual Worlds*. Ohmsha-Springer.

MPEG Video group (1998) ”MPEG-4 Video Verification Model, version 11.0”, *ISO/IEC JTC1/SC29/WG11 (N2178)*. Tokyo.

Murray, Janet (1997) *Hamlet on the Holodeck, The Future of Narrative in Cyberspace.* New York, NY: Free Press.

Nielsen, Jakob (1994) ”Enhancing the explanatory power of usability heuristics”, *Proceedings of the ACM CHI’94 Conference,* 152–158.

Rheingold, Howard (1996) ”A Slice of my Life in my Virtual Community”, in P. Ludlow (ed.) *High Noon on the Electronic Frontier*. Cambridge, MA: The MIT Press.

Roussos, Maria & Johnson, Andrew & Leigh, Jason & Vasilakis, Christina & Barnes, Craig & Moher, Thomas (1997) ”NICE: Combining Constructionism, Narrative, and Collaboration in a Virtual Learning Environment”, *Computer Graphics* 31:3, 62–63.

Sanchez, Jaime & Lumbreras, Mauricio (1997) ”HyperStories: interactive narrative in virtual worlds”, conference paper in the *Fourth Conference on Hypertexts-Hypermedia, Products, Tools & Methods, H^2TPM’97*, Paris, September 1997.

Wallace, G. K. (1991) ”The JPEG Still Picture Compression Standard”, *Communications of the ACM* 34:4, 30–44.