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3D-LIVE - Live Interactions through 3D Visual Environments

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ABSTRACT

This paper explores Future Internet (FI) 3D-Media technologies and Internet of Things (IoT) in real and virtual environments in order to sense and experiment Real-Time interaction within live situations. The combination of FI testbeds and Living Labs (LL) would enable both researchers and users to explore capacities to enter the 3D Tele-Immersive (TI) application market and to establish new requirements for FI technology and infrastructure. It is expected that combining both FI technology pull and TI market pull would promote and accelerate the creation and adoption, by user communities such as sport practitioners, of innovative TI Services within sport events.

Categories and Subject Descriptors

H.5.1 [**Information interfaces and presentation**]: *Multimedia Information Systems* – artificial, augmented, and virtual realities, evaluation/methodology. H.5.1 [**Information interfaces and presentation**]: *User Interfaces* – graphical user interfaces (GUI), User-centered design.

General Terms

Design, Experimentation.

Keywords

3D-Media; Tele-Immersion; Mixed Reality; Augmented Reality; Virtual Reality; Living Lab; Experiential Design; Future Internet

1. INTRODUCTION

1.1 The 'Consumer Innovation' Trend

Today, the Internet is widely used for globally communicating and disseminating information. There is a limitless amount of available online resources and tools to share information and increase the understanding about any specific topic. It is often predicted that the Future Internet (FI) will dramatically broaden both the range of available information and the user's potential contexts and situations [1]. From a technological point of view, the Internet evolves concurrently with many research streams such as peer-to-peer, autonomous, content-centric and ad-hoc networking as well as service and cloud computing that have already explored improvements on network performance, quality of service and user experience. Peer-to-peer networking has demonstrated both the feasibility and economic potential for delivering services to millions of users.

Cloud Computing is a more recent paradigm that allows to transparently sharing among users scalable elastic resources over a limitless network.

Taking a societal point of view while considering the previous advent of user created content (web2.0) that leaded to a tremendous increase of web pages created every day for exposing and sharing societal issues, one could easily predict that plenty of innovative applications/services, for example based on collective intelligence, will be created and mostly by user communities (e.g. crowdsourcing, crowdservicing). Recently, illustrating an economical viewpoint, Von Hippel and colleagues [2] conducted a study, through national surveys, on consumer innovation showing that consumers collectively create a large amount of product/service innovations; hence suggesting that we are entering into the age of the consumer-innovator. Furthermore, they argue that the implication of this new innovation paradigm, [3] considering users as key design players actively engaged, is many folds. Firstly, consumers are turned into developers that should master the new consumer driven innovation process. Secondly, they should consider the rising of really user friendly and powerful tools for designing what they want. Thirdly, the prototyping of products/services is becoming easier (e.g. 3D printing). Fourthly, they should post their design within online shared space hosted by community website (e.g. Thingiverse) and share the effort with community members while looking for the level of adoption and thereby receive signals about marketplace demand. Last but not least, it is getting easier to commercialise an innovation, especially if the innovative product is in fact a software application. It increases the attractiveness of technology platforms to user-innovators in creating open user-friendly interface and developers' toolkits to further assist user communities to share and innovate altogether.

1.2 Engaging Users within R&D

Methodologies already exist for involving users in the innovation process, such as Lead User created by Von Hippel in 1986 and later in 2005 [4, 5] were recently characterised as User-Centric Innovation in NPD [6] while design of most objects is still felt by users through the generated emotional connection as explained in Norman's publications on Emotional Design [7, 8, 9]. Various models of User Centred Design, such as Cooperative Design [10], Participatory Design [11] and Contextual Design [12], are intended to consider user requirements right from the beginning. These 3 models of UCD are compliant with the Human-centred Design Processes for Interactive Systems [13]. Last but not least, Experience Design [14] is more focusing on the user experience quality, through the use of interaction model impacting user perception, than on the number of functionalities. Beside these

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formal methodologies, the Web environment has also induced user-centred approaches such as Web2.0 where users are creating content, Crowdsourcing for opening call-for-solutions to individuals and communities (e.g. Innocentive), Mass Collaboration where a large number of users are creating content to serve the community (e.g. Wikipedia), Wisdom of Crowds [15] for aggregating individual and community opinions.

More recently, the Living Lab (LL) concept promotes the engagement of users in the value co-creation instead of acting as observe subjects. [16] describes the LL design process with co-create, explore, experiment, and evaluate (including socio-ergonomic, socio-cognitive and socio-economic aspects) new ideas and innovative concepts as well as related artefacts in real life situation and observe the potentiality of adoption by user communities. Living Labs constitute user driven open innovation ecosystems for discovering emerging scenarios, usages and behaviours; they bring together technology push and market pull (i.e. crowdsourcing, crowdcasting, crowdservicing) into a diversity of views, constraints and experience sharing for increasing the domain knowledge. A living Lab is often based on a specific territory and involves a large diversity of stakeholders such as user communities (application pull), solution developers (technology push), research disciplines, local authorities and policy makers as well as investors. While the Living Lab ecosystem, through openness, multicultural and multidisciplinary aspects, conveys the necessary level of diversity, in empowering user communities it stimulates the emergence of breakthrough ideas, concepts and scenarios leading to adoptable innovative solutions. It also allows enterprises, especially SMEs, and users/citizens either as entrepreneurs or as communities to get access to technology infrastructures as well as science and innovation services. The main objectives consist to co-create, explore new ideas and concepts, experiment new artefacts and evaluate breakthrough scenarios in a real life context that could be turned into successful innovations. The social dynamics of such Living Lab ecosystems ensures a wide and rapid spread of innovative solutions through mechanisms such as viral adoption and the socio-emotional intelligence [17].

1.3 3D Tele-Immersion Environment

Tele-immersion is aimed to enable users in geographically distributed sites to collaborate in real time in a shared simulated environment as if they were in the same physical room. This enterprise has engaged the skills of researchers in a variety of disciplines, including computer vision, graphics and network communications. Tele-immersion refers to a set of technologies, which allow individuals to feel as if they were present, or to give the appearance of being present somewhere else than their actual location. The feeling of presence is also referred to as a feeling of immersion. Tele-immersion is aimed to be used in different areas, such as 3D CAD design, ergonomics, entertainment (e.g. games, live events), remote learning and training (e.g. serious gaming, practice sports), coordination of activities (e.g. dancing, rehabilitation), 3D motion capture of body segments. However, Telepresence requires that the users' senses be provided with such stimuli as to give the feeling of being in that other location. One possibility is to use CAVE, or a subset of CAVE to immerse a user into such stimuli. Additionally, users may be given the ability to affect the remote location. In this case, the user's position, movements, actions, voice, etc. may be sensed, transmitted and duplicated in the remote location to bring about this effect. While Telepresence can be achieved in many ways, 3D-LIVE is based on the use a set of cameras to construct a live 3D model of a person and the place with its environmental conditions in which the person will be acting (e.g. skiing, running, golfing, dancing). This has great potential, but is still technically demanding especially regarding the broadband capacity of the network infrastructure to operate the Tele-Immersive situation in Real-Time.

2. THE 3D-LIVE VISION

The 3D-LIVE vision consists in the implementation of the "twilight zone", composed of the Augmented Virtuality and Augmented Reality into a space at the frontier of Virtuality and Reality, mimicking the frontier of either the dawn or the sunset, between night darkness and daylight and vice versa. Toward this vision, the 3D-LIVE framework aims to provide the necessary architecture and technology that will capture and transmit, in real-time, reconstructed information from augmented immersive 3D as real environments including full human body with static/dynamic and multimodal/multi-sensory situations and reproduce (render and visualise) the real augmented environment onto remote sites.

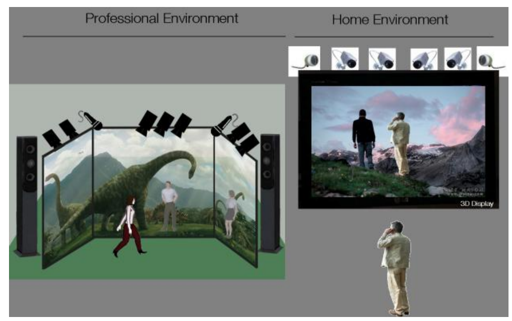

Figure 1. Immersive environment

As Figure 1 and Figure 2 show, 3D-LIVE envisions immersive living rooms for the remote users or more professional setups for the immersive environment creation, either indoor or outdoor, enabling interaction of the users and immersive embedding into remote places.

3D-LIVE is a visionary research in the field of 3D Tele-Immersive Environment as being part of the broad domain of the Future Internet that will make innovative usage of the Future Internet. A number of challenging issues are addressed in 3D-LIVE, such as 3D Tele-Immersion and Real-Time Interactions with complex data fusion and transmission as well as sensors in the Cloud for evaluating the viability of a Twilight Platform and for testing the broadband network capacity.

3D-LIVE Tele-Immersive Environment (Twilight Platform) will be applicable to different sport activities as applications with high social value through the transposition of isolated sport practitioners from remote locations into a single social-sport live event with even participants acting from the real physical location seeing the remote participants through the use of stereoscopic glasses. These kind of 3D-LIVE applications will also have high health value for users not only from the consumption of calories but also from the mental health point of view (less isolation) and from the experiential learning to practice sport activities (community effect) with the most appropriate body movements avoiding muscle and ligament inflammation in the long run. It could also be used for getting the support of a trainer and for evaluating how much body movements are close to the ones of professional sportsmen.

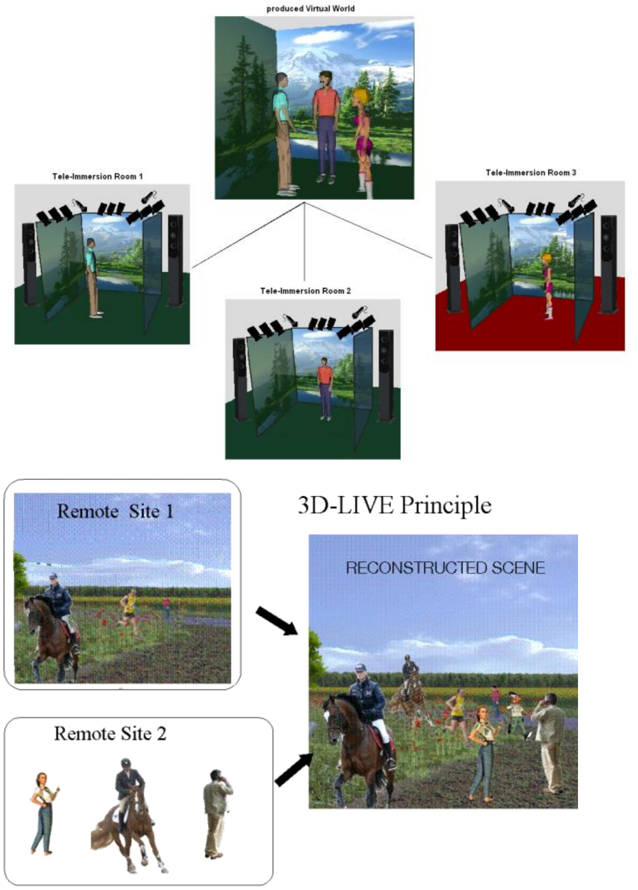

Figure 2. The 3D-LIVE principle of interaction among remote users in a shared environment (top), and of augmenting scenes of live events with remote users (bottom).

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3. EXPERIENTIAL DESIGN

Experience Design [14] is more focusing on the user experience quality, through the use of interaction model impacting user perception, rather than on the number of functionalities. Beside these formal methodologies, the Web environment has also induced user-centred approaches such as Web2.0 where users are creating content, namely: Crowdsourcing for opening call-for-solutions to individuals and communities (e.g. Innocentive); Mass Collaboration where a large number of users are creating content to serve the community (e.g. Wikipedia); Wisdom of Crowds [15] for aggregating individual and community opinions. Few years ago, the Living Lab concept has emerged with the goal of engaging users in the value co-creation instead of being only observe subjects. According to Pallot [16] the Living Lab experiential design process consist to co-create, explore new ideas and concepts, experiment new artefacts and evaluate (including socio-ergonomic, socio-cognitive and socio-economic aspects) breakthrough scenarios in a real life context that could be turned into successful innovations. The social dynamics of such Living Lab ecosystems would ensure a wide and rapid spread of innovative solutions through mechanisms such as viral adoption and the socio-emotional intelligence [17]. More recently, Pallot and colleagues [18] created a holistic model of User Experience that would be continuously evaluated within the experiential design process in order to bridge the gap between perceived needs and real needs.

An iterative Living Lab process and technology platforms (see Figure 3) allow the sharing of knowledge and crystallising the collective work of multidisciplinary teams and user communities. Technology platforms offer science and innovation services for co-creating, exploring, experimenting and evaluating innovative ideas, scenarios, technological artefacts and solutions. Hence, new concepts, artefacts and solutions emerge from the resulting increase of knowledge acquired through accumulated experiences in different areas.

The experiential design process is an iterative process (see Figure 3), also named the Living Lab process, that links together the four activities to be carried out within a Living Lab whatever is the innovative scenario to be explored:

- Co-create ideas of new concepts, artefacts and/or innovative scenarios as sessions of collective creativity involving all concerned stakeholders and especially users;
- Explore alternative scenarios in setting the scene through the use of different immersive techniques within a live environment;
- Experiment alternative scenarios in prototyping concrete application/services through the use of a technological platform also within a live environment;
- Evaluate alternative scenarios on the basis of metrics for measuring the Quality of Service as well as the Quality of Experience that would allow anticipating the potential degree of adoption by user communities.

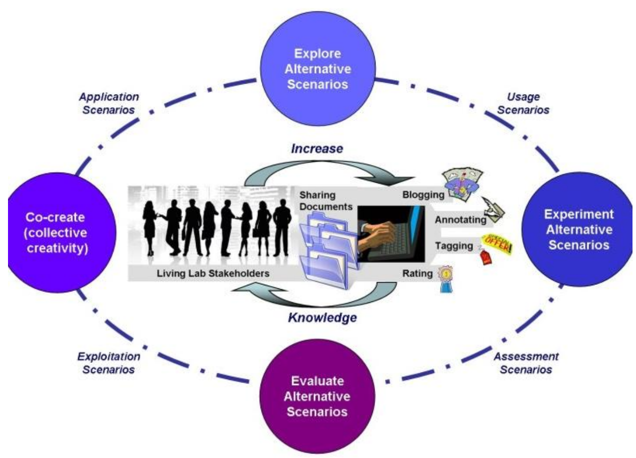

Figure 3. The Iterative Living Lab Experiential Design Process [16, 18]

While the Living Lab ecosystem, through openness, multicultural and multidisciplinary aspects, conveys the necessary level of diversity, it enables the emergence of breakthrough ideas, concepts and scenarios leading to adoptable innovative solutions. A Living Lab Empowers user communities like it is done with Web 2.0 [19, 20] applications such as YouTube, Flickr, Delicious, or Twitter where users are creating content and value. There are even examples of stigmergic [21] or mass collaboration where citizens collectively create content (e.g. Wikipedia) for the benefit of the society at large.

The main objectives consist to explore new ideas and concepts, experiment new artefacts and evaluate breakthrough scenario that could be turned into successful innovations. There are different application examples such as eHealth, Ambient Assisted Living, eInclusion, eTransportation, eGovernment, Smart Cities, ICT for Energy, and ICT for Environment. The Social dynamics of the Living Lab approach ensures a wide and rapid spread (viral adoption phenomenon) of innovative solutions through the socio-emotional intelligence mechanism [17]. The experimentation and evaluation of the resulting scenarios and artefacts are driven by users within a real life context through a socio-economic, socio-ergonomic and socio-cognitive as well as adoptability perspectives.

4. DESIGNING THE TWILIGHT PLATFORM

4.1 Tele-Immersive Environments

Some Tele-Immersion (TI) environment prototypes have been introduced by the University of Illinois at Urbana-Champaign [UIUC-TI], the University of California at Berkeley and the University of North Carolina at Chapel Hill under USA-NSF grants. For example, the Tele-Immersion Lab (TI Lab) at the University of California, Berkeley, develop and experiment Tele-Immersion technology allowing geographically distributed users to communicate and interact in real-time through a shared virtual environment. Users are captured by a set of stereo (depth) cameras which digitize the user into a cloud of points or a 3D mesh which can be compressed and shared with remote locations. Through the true 3D capture, the geometry of the real scene is preserved and mapped into the virtual environment. The research in Tele-Immersion thus combines 3D computer vision, collaborative virtual reality and networking.

For the past eight years, TI Lab, supported by NSF, CITRIS, HP Labs, EADS, and Mellon Foundation, developed multimedia end-to-end system that can capture people in 3D in 360 degree-view interacting over the network in real time. During the period of 2005 to 2011, they have demonstrated their Tele-Immersion technology in several different areas. Initially, they have experimented with distributed dancers [22, 23]. Dance collaborators have challenged the integration of pre-recorded dancers with live performance of remote dancers. They have performed several remote experiments with the focus on long-distance network transmission jointly with Prof. Nahrstedt's Tele-Immersion group from University of Illinois Urbana Champagne. TI Lab has also investigated the value of teaching and learning of physical exercises with this technology as oppose to just having a simple two-dimensional video [24]. The results of the study, conducted in collaboration with Prof. Bailenson of Virtual Human Interaction Lab (VHIL) - Stanford University Stanford University, showed that people were able to better recognize and learn movements through the 3D immersive feedback as compared to regular video.

In collaboration with Institute for Data Analysis and Visualization (IDAV) of University of California at Davis, they have been developing software tools which incorporated their 3D Tele-Immersion technology for real-time interaction in collaborative virtual environments. In 2007 they have performed a set of experiments with geographically distributed geoscientists that were able to interact in real-time with volumetric data while seeing each other in the 3D space using a CAVE. The visualization was implemented using an open source development tool Vrui [25].

Figure 4. Examples of Tele-Immersive Experiments

However, current TI systems are a few steps back from changing the way people collaborate and interact from remote sites, thus minimizing the physical distance, enriching communication with immersive experiences and limiting the need of travelling. But it is one of the greatest technological challenges for the future Internet. Apart from the required bandwidth needed for delivering huge amounts of data, current protocols cannot properly handle challenges in the future. Further research on network models, protocols, and synchronization is needed.

4.2 3D Real-Time Reconstruction and Activity Recognition

Major component of the success of a TI system is the realism of the environment that a remote user is embedded in. This requires realistic 3D reconstruction of the rest of remote users and the surrounding region. Thus, such a system should have modules capable of processing the large amounts of visual data and extract the required 3D information. On top of that, in order the remote users to be synchronized; the 3D reconstruction should be real time to enable natural interaction between the remotely embedded users.

In the recent years, Vasudevan and colleagues [26, 27] have developed a real-time CPU-based stereo reconstruction algorithm which reconstructs depth information from two camera views. The general idea of their algorithm is to perform accurate and efficient stereo computation of the scene by employing fast stereo matching through an adaptive meshing scheme. The mesh is created based on the detected variance of different image regions. Special properties of the mesh used in our encoding, allows for fast and robust implementation of post-processing algorithms. Their mesh-based algorithm also encodes the depth information with high compression ratio to minimize the size of packets sent over the network.

Multi-view stereo based methods take into account information from all the captured images and offer the reconstruction of the foreground. Depending the type of information used, these methods are classified into three categories: silhouette based [28, 29, 30, 31], space carving approaches, which force the surfaces in all captured images to have photometric consistency producing the photo- hull. The third class of methods is the surface fitting methods, such as level- set based methods [32, 33, 34] or graph cuts based methods [35, 36]. Depth information may also be incorporated in the surface fitting optimization function to improve efficiency and accuracy. 3D-LIVE leans towards utilizing such approaches, in order to exploit in full the capabilities that Microsoft Kinect cameras would offer, since they seem to offer an affordable and very efficient solution, as already CERTH/ITI has experienced in [37] (see Figure 5).

Figure 5. Multiple Kinect –based 3D reconstruction, produced from CERTH/ITI in [37].

Realistic reconstruction can be strongly benefited by motion analysis and activity recognition. Such information helps on realistically animating the reproduction of a human, improving the interaction and synchronization with the rest of the users in the TI environment.

State of the art solutions for accurate motion capture are based on markers' tracking, e.g. the Vicon [38] or Codamotion [39] systems, which suffer from specific limitation. They are difficult to set –up and calibrate, while markers get often occluded by each other, or lost by rapid movements or rapid illumination changes. On the other hand, wearable sensors, overcomes some of the optical system drawbacks, as in [40, 41, 42]. Inertial measurement units have also been utilized in [43, 44], which remain accurate only for short periods of time. An interesting approach that seems to offer valuable insights for the purposes of 3D-LIVE was proposed in [45, 46]. These methods employ a database of pre-recorded motion of the target activities, e.g. ski movements in 3D-LIVE case, and match the captured ones with the learned ones. Further, 3D-LIVE will investigate on ways to utilize the marker-less and sensor-less Microsoft's Kinect system that offers a skeleton based depiction of the motion, based on the experience already gained through the REVERIE[1] project from CERTH/ITI [47, 48, 49]. 3D-LIVE could utilize and extend such solutions to fit its needs by building extra "limbs" for each specific activity or sport (e.g. the skis and the ski-sticks could each be an extra limb) and produce specific motion analysis.

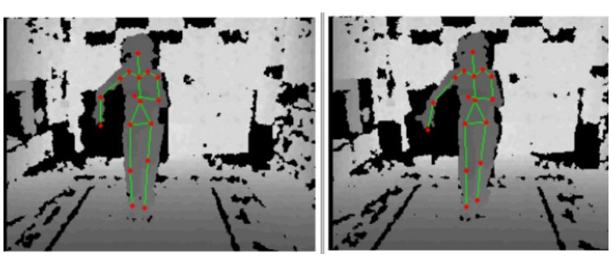

Figure 6. A skeleton tracking snapshot on a pair of depth map recordings; green segments correspond to limbs-torso, while red dots to joints. Results from CERTH/ITI work in [47].

[1] http://www.reveriefp7.eu/

3D-LIVE motion analysis and activity recognition will offer a valuable tool, for comparing the moves between two individuals, such as the ski tutor and the athlete. Modelling the tutor's activity, the athlete's moves will be compared, through an optimization procedure that estimates the tutor's pose fitting to the athlete's pose at each video frame.

The proposed approach is based on the involvement of users in the Experiential Design Process. Indeed, the participation of the users is recognized as a positive and a necessary element in the design of artefacts. Three main theoretical frameworks deal with the involvement of end users in the design process: user-centered design, participatory design, developmental and continued in use design. In models of user-centered design, the user is seen as a source of information on the use [50] to whom designers refer during the identification of the needs and the evaluation of the artefact [51, 52].

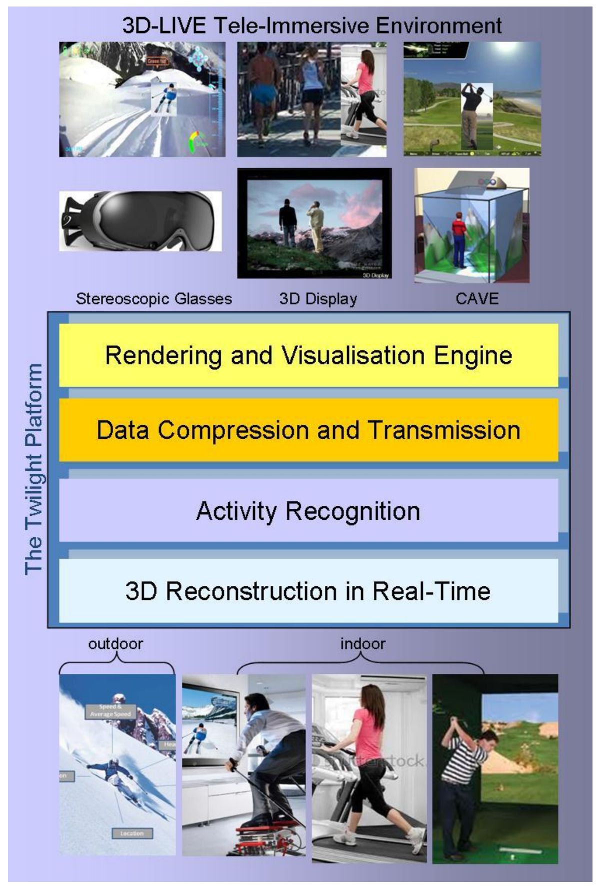

Figure 7. The Overview of the 3D-LIVE Tele-Immersive Environment

Some authors [53] argue that it is better to adopt a participatory approach in which users are considered as co-designers [54, 55]. They play the role of future users who need to be educated and trained to the future use of the design products. They have to further the design of the new tool by imagining solutions and evaluating the proposals made by other co-designers [56]. An empirical study [57] has attempted to analyze the role of users in the process of participatory design, but it does not provide precise empirical evidence on the real contribution of designers and users to the actions of needs construction, or to the phases of the design.

The participatory approach is acknowledged as developmental in nature by [58] and continued in use by others [59, 60, 61, 62, 63]. The design process is led by users jointly with developers and involves mutual learning, thanks to which the artefact and the activity of users grow together. In models of participatory and continued in use design, users are involved in the design of the usefulness of the artefact and are able to provide designers for the advantages or benefits associated with the produced functionalities. We will use a method derived from the I²I method which is based on these two frameworks.

This method describes a design method of virtual reality artefacts. Precisely, we add seven steps to the initial I²I method to better take into account the user in the design of innovative systems. These steps - proposed on the basis of the literature – were validated during the design of Appli-Viz'3D that is a virtual reality software to help design and sale of children's products [64]. The above picture (see Figure 7) introduces the overview of the envisaged 3D-LIVE Tele-Immersive Environment with the Twilight Platform and its foreseen components.

5. CONCLUSION

Tele-immersion is aimed to enable users in geographically distributed sites to collaborate in real time in a shared simulated environment as if they were in the same physical room. This enterprise has engaged the skills of researchers in a variety of disciplines, including computer vision, graphics and network communications. Tele-immersion refers to a set of technologies, which allow individuals to feel as if they were present, or to give the appearance of being present somewhere else than their actual location. The feeling of presence is also referred to as a feeling of immersion. Tele-immersion is aimed to be used in different areas, such as 3D CAD design, ergonomics, entertainment (e.g. games, live events), remote learning and training (e.g. serious gaming, practice sports), coordination of activities (e.g. dancing, rehabilitation), 3D motion capture of body segments. However, Telepresence requires that the users' senses be provided with such stimuli as to give the feeling of being in that other location. One possibility is to use CAVE, or a subset of CAVE to immerse a user into such stimuli. Additionally, users may be given the ability to affect the remote location. In this case, the user's position, movements, actions, voice, etc. may be sensed, transmitted and duplicated in the remote location to bring about this effect. Telepresence can be achieved in many ways. The 3D-LIVE project has selected the one that is to use a set of cameras to construct a live 3D model of a person and the place with its environmental conditions in which the person will be acting (e.g. skiing, running, golfing, dancing). This has great potential, but is still technically demanding especially regarding the broadband capacity of the network infrastructure to operate the Tele-Immersive situation in Real-Time.

The 3D-LIVE project will experiment and evaluate different immersive solutions such as CAVE, 3DTV and auto-stereoscopic displays to offer visually immersive experiences. The success of the movie “Avatar” is a great example of the user experience, satisfaction and thirst for more immersive experiences. However, the discomfort of stereoscopic glasses shifts the research interest to glass-free, auto-stereoscopic solutions. Furthermore, the audience acceptance of the 3D effect, leads the market to investigate on other visually immersive applications, since people want to be able to see depth in other every-day applications. In this project the knowledge is gained on which parts of the user experience benefit from the autostereoscopy. The knowledge is also generalized to fit a variety of use cases as well.

To enhance the user immersion into an augmented environment, a standard CAVE environment provides a cube, in which user enters. Cube’s walls are typically rear-projected displays that give the feeling of presence into the virtual environment. Stereoscopy can make a Cave more immersive and enhancing the user experiences. The suspension of disbelief is stronger when the quality of the simulation inside a Cave is of higher quality, therefore it is within 3D-LIVE goals to utilize an appropriate Cave setup for the given use cases. The knowledge will be generalized so that any suitable use case can benefit from the findings.

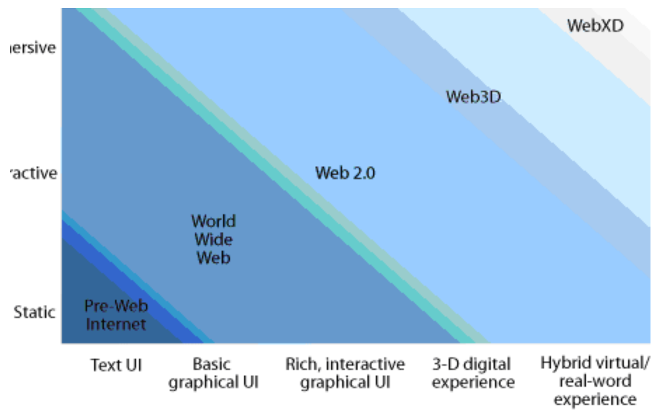

Figure 8. Richness of experience (Source: Forrester research Inc)

All the above mentioned advances will be integrated and extensively tested in the most appropriate FI facilities that offer the essential testbed resources to permit stakeholders to gain insight into how Future Media Internet technologies can be used and enhanced to deliver added value media experiences to consumers within a legally compliant and ethical framework.

According to that strategy and the evolution of the user experience needs (see Figure 8) we can foresee that the first class of 3DTI services could be marketed between 2013 and 2015 according to the results that 3D-LIVE will give in terms of user acceptance.

6. ACKNOWLEDGMENTS

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