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in Science and Technology
- COST -

Secretariat

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COST 4176/11

MEMORANDUM OF UNDERSTANDING

Subject :	Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action IC1105: 3D-ConTourNet - 3D Content Creation, Coding and Transmission over Future Media Networks

Delegations will find attached the Memorandum of Understanding for COST Action as approved by the COST Committee of Senior Officials (CSO) at its 183rd meeting on 30 November 2011.

MEMORANDUM OF UNDERSTANDING
For the implementation of a European Concerted Research Action designated as

COST Action IC1105
3D-CONTOURNET - 3D CONTENT CREATION, CODING AND TRANSMISSION OVER FUTURE MEDIA NETWORKS

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 4154/11 "Rules and Procedures for Implementing COST Actions", or in any new document amending or replacing it, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to create a cooperation network of European researchers and industry experts, in the field of 3D multimedia networked services and applications for the benefit of academia, industry and ultimately the users of future 3D media technology.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 36 million in 2011 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Chapter V of the document referred to in Point 1 above.

A. ABSTRACT AND KEYWORDS

This COST Action undertakes coordinated research collaboration, at European level, in 3D multimedia creation, encoding, delivery and reception of services and applications over future networking technologies. A scientific framework is devised to integrate the main elements of the delivery chain, such as 3D content creation and encoding evolution, transmission across heterogeneous networks and user consumption, taking perceived quality as an overall key performance factor. Several individual R&D efforts are currently running across Europe, targeted at 3D technologies. This Action aims at beyond this trend by tightening closer together scattered efforts and integrating all technological elements with user 3D quality perception. To reach this goal, this Action fuels cooperation between researchers and industry experts, envisaging production of technical and scientific deliverables for researchers, scientists, engineers and managers, new business model recommendations for content and service providers through joint meetings across academia and industry, plus documentation and multimedia presentations to promote 3D technology in the society. The benefits include increased relevancy of European research, contribution to the development and sustainability of new and better 3D multimedia communications technology and provision of a platform for faster launching and adoption of related new products and services across Europe for end users' beneficiary.

Keywords: 3D Multimedia Services, 3D Media Coding, 3D Media Network Protocols, 3D Quality of Experience, 3D multimedia transmission.

B. BACKGROUND

B.1 General background

Nowadays, a major trend in the scientific and industrial community is to provide a more immersive multimedia experience to end users in different environments (e.g., home, on the move, work, etc). In this context, 3D media has gained momentum due to advances in display technology, signal processing and microelectronics, which allow offering an appealing 3D media experience on consumer electronics platforms that fosters, for example, information presentation and understanding, the user experience, in particular in terms of interactivity and 3D immersion, the natural use and search of 2D and 3D media objects and new business models. It is acknowledged that widespread adoption of new 3D media needs interdisciplinary research between coding control, transport, adaptation and transmission error control mechanisms, strongly tied to perceptual quality metrics. This is a broad research challenge, because the ultimate problem of understanding and guaranteeing acceptable levels of Quality of Experience (QoE) in diverse 3D multimedia networking environments cannot find acceptable solutions without joining complementary knowledge and diverse competencies.

The relevance of this Action is supported on the objective of bringing together scientists and researchers from different, yet related fields, creating a networking cluster in the area of 3D media networking technologies. The Action joins together a wide scope of research topics and technological fields, covering 3D Media content creation tools, 3D Media encoding efficiency, 3D Media transmission and adaptation across heterogeneous content-aware networks, Handling 3D video artefacts and 3D error concealment methods, 3D use cases in different sectors (Entertainment, Education, Gaming, Social Media, Engineering, Medicine), Human perception of 3D, with a focus on quality and comfort/health issues.

Each participant of this COST Action is currently an active R&D player with specific expertise in the area of 3D multimedia. To allow smooth cooperation among the partners, this expertise is overlapping and covers the entire value chain of 3D Networked Media. Therefore, the COST funding scheme provides the most adequate support mechanisms for developing coordinated research, cooperation and networking activities.

The R&D projects carried out within the scope of the COST framework will have the advantage of embedding into their developments relevant input and inner knowledge from related technological fields addressed in projects of other participants. Projects dealing with 3D media networking and transmission issues will provide relevant information for those addressing issues on the content side, e.g., content creation and coding, error handling and application features. Moreover, by delivering the research outcomes in the form of prototype services to a wider society base across Europe, a more comprehensive judgement of user reaction and expected guaranteed QoE and Quality of Service (QoS) levels can be made. The benefits include faster knowledge creation and exploitation across Europe, deeper involvement of young researchers in R&D activities at European level, faster deployment of individual research outcomes in a more structured framework for real life systems, more and better publications increasing the impact of the R&D results produced by each participant.

B.2 Current state of knowledge

There are five different important areas of research and innovation involved in this COST Action and related to 3D content, namely; content creation, content coding, media networking, QoE/QoS evaluation, and applications.

Content creation: The look and feel concept is currently used in descriptions of products and services that signify a user experience when trying a product/service. The elements of visual concepts (look) include, for example: texture, lighting, shadows, reflections, colours, and composition, feel of depth, shapes, structure, and contrast. Examples of the functional concepts (feel) include: responsiveness, overall end-user experience, feel of control, how the audiovisual material affords the expectations of the end user, movements, emotional experiences, and affective mechanisms. The development process of innovative solutions harness the expertise of interaction design, experience scripting and game design. In this Action, all these elements will be considered as research guidelines into the context of networked multiuser applications with optimized, real-time and interactive 3D graphics rendering.

Content coding: Nowadays, several industry-based proposals for 3D video formats have been brought to the market: Multiview Video Coding (MVC), which is an extension of the Advanced Video Coding (AVC) standard, and frame-compatible stereoscopic formats. However, efficient 3D video representations, enabling the reconstruction of an arbitrarily large number of views prior to rendering and Free Viewpoint Video (FVV) allowing for interactively varying the viewpoint, pose new problems and R&D challenges. To address these new requirements, MPEG is initiating a new phase of standardization for 3D Video Coding (3DVC), with the objective to go beyond the capabilities of existing standards by supporting the synthesis of multiple views and enabling advanced stereoscopic processing. The Action will seek to develop joint platforms to deal with all 3D services, requiring flexible configuration of all coding elements to satisfy multiple constraints at the same time, such as real-time (live) broadcast capability, scalability in multiple dimensions including complexity, ease of integration with user-generated content on the fly for better interaction, etc.

Media Networking/Transmission: In 3D video streaming the subjective impact of network QoS degradation is significantly higher than in classic 2D video because good depth perception is actually a function of many asymmetric parameters such as source rate of stereoscopic streams (i.e., image quality of individual views), spatial and temporal resolution of each view and many other possible impairments arising from networking effects. The current trend for 3D media networking is the use of content-centric networks to solve problems and alleviate constraints of existing Internet technologies when sending multimedia data. There are three transmission modes for multiple-view video, referring to Single Session Transmission (SST), Multi-Session Transmission (MST) and Media-Aware Network Element (MANE)-based transmission. Looking at these recent advances, the transport of 3D multimedia signals over IP packet networks is a natural choice, but the IP itself leaves many aspects of the transmission to be defined by other layers of the protocol stack. This Action coordinates research in 3D media networking where IP offers flexibility in designing novel optimal communications system for various 3D data representations and encoding schemes.

QoE/QoS evaluation: Currently, there is a lack of adequate methods to provide an actual assessment of the degree to which this goal is accomplished and quality issues are currently a bigger concern in 3D media than they were on traditional media. Regarding subjective quality assessment, in addition to factors applicable to monoscopic images stereoscopic viewing entails additional factors such as depth resolution, depth motion, and size distortions (puppet and cardboard effects), and crosstalk effects (producing ghosting), to name but a few. In the case of 3DTV, the literature describes visual discomfort as the primary health matter. Moreover, despite the well-known importance of an adequate auditory stimulation in delivering an immersive experience, the development of 3D technologies has traditionally conceded a preponderant role to the generation and reproduction of visual, as opposed to auditory content. Given the relative novelty of 3D audio systems, there is still plenty of room to develop novel methods of evaluation of user's experienced 3D audio quality and comfort, building up on basic research on auditory perception. This Action will ensure adequate coordination, which is necessary to establish cross-links between ongoing independent research in 3D audio and 3D video. Any advances in this direction will be groundbreaking in the sense that such studies on audiovisual quality have not been done even for 5.1 audio systems.

Applications: 3D Applications on Handheld Devices: Real-time 3D applications on handheld devices are currently under research in the following categories: 1) augmented / virtual reality applications; 2) 3D image applications; 3) 3D video applications. The first category includes the applications to reconstruct a virtual or real+virtual 3D world, such as *Telepresence*, *second-life*, etc. The second category includes stereo images and 3D scenes which are built using images as the source media, such as *Photosynth*, *streetside*, or *street view*. In the last category, 3D video applications include stereo video and free–view / multi-view videos. Future developments are envisaged in several R&D projects across Europe.

Multi-view tracking: The disadvantage of methods using input from a single camera is that they are prone to failing in case of severe occlusion, which is very common in team games such as football. This problem can be alleviated by integrating information from multiple steady cameras, leading to more stable tracking on the scene. Current research considers integration of the tracking data from all cameras by exploiting the geometrical relationships between cameras (i.e., homography) and future systems are expected to evolve using MVC.

Gaming: With respect to creation of immersive, interactive 3D environments with particular emphasis to 3D massive multiplayer online games, there have been several attempts to build a workflow that targets the creation of such environments. Furthermore, similar efforts have been taken in the area of 3D augmented/mixed reality, where a new wave of games exploring the possibilities of 3D augmented/mixed reality have been recently demonstrated.

Social virtual worlds: Some virtual worlds aim at incorporating communications, events and meetings while others aim at e-learning applications or entertainment. Assemb'Live, 3Dxplorer, web.alive, Second Life and realXtend are some of the commercial products that are available as services or as appliances. Further R&D efforts are under way to overcome current limitations.

3DTV: 3DTV is being already provided using the existing infrastructures, but there are many open issues open for further research, such as high quality delivery, efficient bandwidth utilization, seamless IP streaming adaptation and QoS/QoE optimization in multiview video transmission.

B.3 Reasons for the Action

The current 3D networked multimedia technology and services evolution is emerging from several different research fields along an end-to-end delivery chain, which spans from the creative side of 3D content production, to end users ultimately expecting to have good 3D multimedia experience. Such delivery chain crosses through a plethora of diverse technology (e.g., audio and video codecs, wired/wireless/broadcast/IP networks and protocols, fixed/portable receivers, displays, etc), where European researchers of quite different profiles are currently developing projects and innovative solutions without coordinating their efforts towards common goals of scientific and societal relevance. This Action is needed to establish links between complementary research teams and groups within Europe, which will be carried out during the booming period of the next four years, when worldwide research and technology development in the various fields of 3D networked multimedia is expected to witness a steep evolution.

Immediate benefits of this Action arise from more and better research results due to cooperation between interdisciplinary partners enforced by the action itself, better dissemination due to increased number of publications and impact factors, higher awareness of R&D trends in 3D media networking to timely identify and tackle the most relevant issues worldwide, and also active involvement of young researchers in R&D activity at European level. Future benefits include strengthening the research leadership of Europe in this emerging field of rapid evolution and increased capacity as well as establishing the necessary grounds for developing further cooperation in future joint projects.

The research work coordinated within this Action is envisaged to address 3D media services and applications with great impact on society and multimedia industry, such as future 3DTV services either delivered through broadcasting or IP-based content-centric Internet, 3D media in mobile devices, gaming and immersive 3D multimedia applications. Thus, the Action is primarily aimed at scientific and technological advance with significant future impact on the European multimedia market and consumers.

The scientific results will be made available through proper dissemination to both the research community and related industry and transferred to professionals using the coordination mechanisms of the Action. Other relevant technical and scientific outcomes will be indirectly transferred to industry by submission to standards, whenever appropriate.

B.4 Complementarity with other research programmes

There are no other COST Actions with the objective of coordinating research covering the different elements comprising the whole delivery chain of 3D multimedia. Therefore this Action has inherent complementarity with other COST Actions. The participants are involved in nationally and EU funded projects dealing with several aspects of 3D media networking which lack of resources to expand wider than local context. This Action is a complementary funding to integrate such projects in a common technological umbrella to widen their scope and increase the impact.

Complementarity with other European research projects can be found in regard to the following projects: Through the **2020 3D Media, 3DPHONE, 3DPRESENCE, DIOMEDES, MOBILE3DTV COAST and SEA** projects, aiming to develop technologies and core applications for 3D content coding and delivery over various platforms and networking technologies. Projects **3D VIVANT, REAL 3D, MUSCADE, FINE** address new 3D content (e.g., 3D holoscopic, 4D holography, Free-Viewpoint 3D video) capture, manipulations and display technologies for immersive networked experience. Projects **FOCUS-K3D, IRIS and 3D4YOU** focus on authoring in 3D environment. The **Qualinet** COST Action is also partially related in dealing with multidisciplinary QoE research, though not specifically aiming at 3D multimedia. Moreover, strong links will be established with the NEM European Technology Platform (www.nem-initiative.org), which is a major community involved in networked media and 3D technologies.

C. OBJECTIVES AND BENEFITS

C.1 Main/primary objectives

The main objective of the Action is to create a cooperation network among European researchers and industry experts in the field of 3D multimedia networked services and applications with the objective of increasing the added value of S&T in scattered R&D projects, for the benefit of academia, industry and ultimately the users of future 3D media technology, jointly integrating 3D content creation and encoding, 3D network-aware applications in ubiquitous network architectures and 3D end-user devices, to reach high levels of user acceptance and quality of experience.

C.2 Secondary objectives

1. Define guidelines and expand current end-user based content production model, existing within game and virtual world communities, into the design for the near future interactive and collaborative services. Previous research on QoS and QoE issues has been mainly focusing on cases where streamed media is the key. This approach has not been able to solve the issues with interactive media consisting of soft real-time elements. The basic understanding and solid background about end user behaviour will be pursued with the aid of rich interaction models.

This knowledge will be applied to service design and development in order to make sure the quality of end user experience is as high as possible. The concept of rich interaction relates to the possibilities of the multi-user game and virtual environment users to act and express themselves in flexible and non-predefined ways. The future application of this concept will consist of (i) multi-modality in terms of forms and media for effective utilisation of various senses; (ii) high level of interactivity in terms of range, frequency and impact of individual interaction forms; (iii) flexibility to select corresponding actions and reactions through simulations and interaction models (e.g., physics model) with limited number of pre-programmed solutions; (iv) automation to allow reduction of mundane tasks and to support simulation of sub-conscious actions; (v) abstraction to enable various levels of control in interaction processes.

2. Develop harmonization mechanisms, providing an evolution and roadmap for 3D coding architectures and algorithms. The current 3D research results reveals a spread of technologies and diversity, such as MVC, Multiview Coding + Depth (MVD), Free Viewpoint Video (FVV), Video + Depth (V+D), Video + DELTA, Side-by-Side (SbS), Multiview Scalable Wavelets, and others, incompatible each other, and trammelling a quick deployment of 3D technology on the marketplace. The Action has the objective of defining a new framework to facilitate a 3D video coding interoperability ecosystem. Within such framework, the objective of the Action is also to extend the current concept of 3D media compression-efficiency into a more sustainable concept of energy-efficiency coding, by developing and integrating concepts of green computing into novel 3D video coding architectures.

3. Develop QoE-aware networking framework where novel adaptation and congestion control mechanisms are devised to optimise 3D multimedia delivery over future media networks in heterogeneous technological environments. Since QoE is not only influenced by dynamic networking conditions, but also by the quality and perceptual relevance of each element of the coded source stream (e.g., stereoscopic view, audio channel), cross-layer methods shall be used in order to make QoE metrics available to network control and adaptation mechanisms.

This Action will provide an ecosystem in terms of transport protocols, seamless mobility and continuity in wireless systems, rate control and transcoding and end-to-end QoE-aware mechanisms. The Action also targets to organise quality assessment sessions in several centres across Europe along with the necessary service emulators or prototypes that will encompass multiple use contexts and ambiances for users. The joint analyses of the acquired subjective assessments will be reflected back to the researchers and standardization bodies in the field to consider them as reliable references.

4. Develop methodologies and procedures for subjective assessment of QoE using 3D multi-modal content, extending existing standards and knowledge for evaluation of the quality and comfort. To achieve this objective, the Action will seek for interdisciplinary expertise and methodologies by exploring measures of quality and comfort derived from psychophysical, psychophysiological and behavioural methods. Such exploratory research will include subjective evaluation of 3D audio because, despite the existence of standards for the subjective evaluation of audio tracks, the introduction of fully spatialised sound introduces some assessments factors of its own, as happened with the transition from 2D to 3D visual displays. The goal is to find out the best suited methodology to evaluate perceived quality and comfort of 3D audio and conjoined presentations of 3D video and audio, by taking into consideration the specific issues of 3D audio.

C.3 How will the objectives be achieved?

The objectives will be achieved as described below.

The results produced by participants dealing with user behaviour and confort evaluation in immersive 3D environments including rich interaction models, will be analised to define sets of requirements to be used in 3D content production. Interaction models and QoE metrics will be brought to discussion by participants involved in human factors and then implemented, tested and evaluated by participants developing novel technology.

A collaborative framework will be created by joining participants with different technical backgrounds around common research goals. Experts in coding algorithms will cooperate with hardware engineers at WG level in order to reach joint results with technological added-value. Interdisciplinary teams will be formed in the Interdisciplinary Assembly to exchange knowledge and establish the necessary cross-links for achieving novel R&D results in QoE-aware 3D media networking. This will be implemented through scientific meetings and missions, involving researchers, engineers and young researchers.

Subjective evaluation tests and procedures for networked 3D media quality, including multi-modal content and heterogeneous technological factors will be defined by joining together existing experience among different participants and linking together individual results in order to ensure consideration of QoE contributing factors from the whole 3D media delivery chain.

Promote dissemination in a technological interdisciplinary environment by organising an annual conference with a technical programme covering all topics related to 3D media networking and heterogeneous content creation, delivery and consumption. Publications in journals and books co-authored by different participants also contribute to increase the added-value and impact of European research. Active participation in interest groups and standards bodies will spread dissemination to wide audiences

Transfer of knowledge and enrich research activities will be primarily accomplished through interaction with the IF. The IF also contributes to increased relevancy of R&D activities by bringing real-life applied research problems into the Action. Use of testbeds and 3D media equipment by young researchers participating in STSM also contributes to the actual implementation of a network of European experts through knowledge exchange and its practical application in collaborative R&D work.

End users will be involved in the R&D activities dealing with human factors and QoE. This will validate the R&D results obtained within the Action towards the objective of reaching high levels of user acceptance and QoE, which is also a contributing factor for market development and ultimately for the benefit of society in general.

C.4 Benefits of the Action

It is a matter of fact that the 3D technologies are significantly impacting major ICT markets, such as: television, cinema, gaming, engineering and medical imaging. As to the television and cinema sectors the world is already experiencing the enhancement of the QoE when watching 3D movies and documentaries with respect to traditional 2D versions. The game development is another important sector where the 3D experience can be used to increase the immersion of the player in a game. In the medical sector the 3D technologies are allowing the doctors improving the accuracy in disease diagnosing, healing and rehabilitation. Importantly, adequate QoE management will have impact in a wider variety of professional users of 3D technologies in the near future, resulting from the development of QoE assessments tools adapted to a broader variety of utilization contexts, that will be more taxing on the user's perceptual and cognitive skills than the average entertainment contents.

This Action will have technological impact by stimulating the exchange of latest achievements and transfer the research results into product and service development for the benefit of European ICT stakeholders. 3D coding efficient algorithms will help the European market to still keeping a privileged position in terms of technology in the field of coding. The benefits for the 3D multimedia industry will be the more competitive 3D content delivery and consumption architectures using low energy consumption algorithms in 3D coding and new architectures to propose cheaper and faster solutions to any kind of device. Public awareness about 3D media technology will be increased particularly the relationship between user perceived quality and specific features of technology. The liaison with the NEM Technology Platform, which is the main community of expert involved in 3D technologies, will contribute spreading the project results to the entire community. The Action shall also contribute to a number of activities carried out within the NEM community, such as the provision of Position Paper, Strategic Research Agendas, and the NEM Summit.

C.5 Target groups/end users

In general, by the wide domain adoption of the related technologies jointly optimised within this Action by major consumer electronics manufacturers, internet service providers, content production companies and multimedia broadcast companies, European communities will start receiving the researched products and multimedia services. This in turn will ensure the sustainability of the further research attempts in the related area to increase the service levels and broaden the business model for stakeholders. In the case of the 3D coding efficient algorithms, the main business area are the hardware manufacturers, especially the companies which are nowadays developing chips and boards to general purpose systems (e.g., PCs) or for dedicated machines (e.g., codecs for the broadcasting industry in dedicated machines). In the case of service, application and network providers, the Action results will be used to enable optimised services with better network utilisation and higher levels of user satisfaction. The results of QoE-aware networking will provide relevant information for network design and new technology specification. In the case of application developers, the results of the Action will be used to produce more realistic immersive environments than those existing today, by using new design concepts based on 3D multi-modal content capturing and consumption within the user context.

The work carried out within the scope of this Action will contribute to the media sector in general inasmuch as it satisfy a real necessity, namely, developing evaluation methods adapting to the increasingly complexity of the experiences delivered to the user. In addition, the methods developed in the Action may have impact on future standards for the evaluation of multimodal 3D contents. Some of the stakeholders mentioned before are involved in the preparation of the Action. Academic and R&D institutions will exploit the Action results evolving their own R&D work upon innovative knowledge created in the different fields covered by the Action. These are the main stakeholders involved in the preparation of the proposal.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

The scientific programme of this Action is built over the fields within the scope of the corresponding Working Group (WG), which correspond to different elements of an integrated end-to-end delivery chain. The most important research tasks to be coordinated by the action lie in the following areas:

3D Content Creation:

- The technological enhancements consist of seamless integration of groupwork tools, virtual communication support and next generation game system. For example, by integrating webcam-tracked capture and mapping of expressions, avatar-based personal identity platforms, thematically enriched audiovisual content and other communication technologies, it is possible to develop an enhanced 3D application suite targeted at utilitarian sector. With the satisfactory QoE, these applications provide enormous added value to the whole ICT and information systems sector. The Action harnesses the high-end technological solutions and de facto open source components in order to disseminate these enhancements.
- The content-oriented enhancements consist of 3D audiovisual material framework that supports real-time and dynamic editing, modifying and experiencing of the content. The domain of interactive 3D applications is currently dominated by entertainment games. However, majority of these do not support the real-time interaction with all the content. Research within the context of this Action builds on top of existing de facto standards and advances the frontier of 3D Internet applications by introducing a set of games industry methods, processes and tools for content-oriented development work.

- Most of the currently available 3D video content is captured using stereo cameras, though some multi-camera systems are emerging. However, the huge amount of data emanating from large multi-camera setups turns such systems unpractical for home-users delivery. Moreover, currently established methods of displaying 3D images, such as those based on light polarization or active-shutter techniques, still cannot provide a truly realistic 3D viewing experience in an ergonomic and cost-effective manner. The Action comprises research on novel methods that aim to reconstruct the light field, such as 3D holoscopic imaging (also known as integral imaging), to accurately representing the original scene around the display device, with the objective of giving the user a truly 3D viewing experience without the drawbacks of stereoscopic or multiview autostereoscopic systems. This novel approach is becoming a serious alternative for autostereoscopic 3D systems since it eliminates most drawbacks and thus contributes to increase the user QoE. The challenging results to be achieved will allow fully 3D images to be visible with bare eyes, exhibiting continuous motion parallax throughout the viewing zone and presenting a variety of many different views, depending on the observers' position.

3D Media Coding Efficiency:

- The 3D video data in the form of multiple viewpoints (with associated per pixel depth map videos) requires a much wider bandwidth for transmission than that of the conventional 2D video. Hence, it is essential to develop a compression suite to encode the multiple views with the least payload and therefore bandwidth demand. All types of redundancies existing within the multi-view set (including any kind of redundancy among colour texture and depth map) needs to be exploited in a hybrid manner to optimize the rate-distortion performance of the coder. Unlike the 2D video, the distortion metric for the multiple viewpoint video does also need to cover the rendering artefacts resulting from the lossy compression of colour texture and depth map. Scalability in the dimensions of viewing space as well as the time, resolution and quality is essential to convey adaptability to the network conditions. New syntax elements enabling a viewpoint scalable multi-view coder need to be investigated. A low latency in decompressing target bit-streams among the multi-view stream needs to be maintained.

In addition to these, another important area of research will be to investigate the extent to which a total number of viewpoints that is feasible to be delivered using the available techniques and sources can create an acceptable viewing space. This way, incorporating the advances in reliable viewpoint rendering techniques as well, the total load of 3D information to create the desired scene (free-viewpoint, stereoscopic pair or multi-view) can be minimized.

- When considering other types of 3D video content, such as those based on the light field reconstruction, new types of spatial and temporal redundancies appear, mostly related to the 3D video content acquisition process, namely to the optical setups based on microlens arrays. Hence it is essential to explore these redundancies to achieve high compression efficiency. In addition, it is important to develop coding architectures that would be as much as possible independent of the particular acquisition setup.
- High efficiency video coding requires high computational resources, i.e., high processing power and energy consumption. This is particularly true for 3D video coding because of the increased number of prediction search operations involved. Coordinated research effort will be made to achieve efficient algorithms not only in terms of computational cost, also to allow an easy implementation over new generation of ultra-low power multicore processors. Both coding and decoding complexity will be tackled under different approaches. Complexity scalability methods will be investigated to optimally control the computational cost of coding decisions and data structures.

3D Media Transmission and Adaptation across Heterogeneous Content Aware Networks:

- The research in this topic is concerned with transmission and adaptation of 3D coded video to match heterogeneous communication networks, diverse terminal equipment and user interaction. Suitable perceptual quality metrics for optimizing the subjective quality of adapted 3D video streams are under investigation to devise useful distortion models. Whenever the pre-stored 3D video does not match either the network or the user terminal characteristics, the compressed stream must be adapted to comply with the actual constraints imposed by the different elements of the delivery chain. Solutions for these types of problems will go far beyond the current state of the art, because this is quite different from the well-known cases dealing with 2D video. 3D video quality perception includes several new aspects which need a lot more research in order to be properly included in adaptation of coded streams. Besides the image quality, which does not even need to be equal in both views, 3D video quality depends on the perceived depth, depth distortions, as well as the presence, naturalness and eye strain experienced by users. Therefore classical 2D video adaptation methods based on simple rate-distortion optimisation are no longer suitable for dealing with 3D video. Instead, perceptual quality metrics must be devised and a new generation of adaptation algorithms will hopefully emerge for 3D video seamless internetworking. In this respect, it is anticipated that adaptation of 3D media services will be triggered as a policy enforcement decision by a prototype service management framework, so that 3D delivery matches user context and network status.

  The aim is to achieve both service personalisation and QoS/QoE assurance by utilising: i) Server-side adaptation, for optimisation of one-to-many single-stream 3D content, such as multicast streams; ii) In-network adaptation, where 3D media streams are processed by the network elements themselves; an approach that is best suited for multicast traffic, where different delivery paths may have different capacities; and iii) Client-side adaptation, in the case where 3D media streams are to be re-transmitted or re-distributed in a local manner (e.g., within a home network).

Handling 3D Video Artefacts and 3D Error Resilience

- This research addresses the problem of handling 3D video artefacts and error resilience methods to minimize the subjective impact of transmission errors in decoded 3D video signals. This work is particularly focused on robust coding mechanisms, error resilient syntax and packetisation methods combined with error concealment methods for coping with transmission errors in IP and/or broadcast/wireless channels. Existing spatial and temporal interpolation techniques will be under further research and development in order to achieve efficient perceptual robustness and concealment techniques in 3D video. The 3D quality will be evaluated using both objective metrics and subjective testing. Since error resilience mechanisms have a major influence on concealment and restoration of missing information, such type of dependencies will be also investigated with the objective of improving the perceived quality at the end user terminal. The error resilience tools already included in current 2D video codecs are being studied for the 3D case and shall be extended in order to find novel efficient solutions for depth coding and by devising optimization algorithms capable of minimizing depth distortion, jointly with spatial and temporal distortions. The additional level of dependency between views also brings a new dimension into the problem of error propagation, which will be carefully considered.

3D QoE Evaluation Metrics

- Research regarding QoE involves the development of multimodal assessment tools based on psychophysical methods, a set of mathematical techniques aimed at characterizing perceptual processes such as detection, discrimination and scaling of sensory stimuli. A key question in this regard is what are the basic perceptual determinants of perceived quality and comfort as such issues are still being researched for traditional 3D delivery methods and debates as to the most adequate assessment methods are still unresolved. Thus adequate methodologies for the assessment of quality and comfort issues related to audiovisual 3D are in much in need of a coordinated research effort. Another task deals with the cognitive aspects of QoE, by means of cognitive and psychophysiological measures obtained in human experiments while the variables of interest are manipulated.

Cognitive aspects refer to higher-order cognitive capabilities such as attention and reasoning, a key issue considering that the irruption of 3D on the internet will undoubtedly bring this mode of experience to the online experience, and therefore not only to entertainment activities, but also to the professional realm. Thus, new issues affecting cognitive load and modes of information representation have to be elucidated. Further research within the QoE field should tackle usability issues both in the cognitive and sociopsychological aspects of the 3D audiovisual experience, by means of the described methodologies in addition to the usual ethnological usability studies.

D.2 Scientific work plan methods and means

The scientific work plan will be implemented through the COST mechanisms defined in the Action, comprising:

a) Exchange of scientific and technical information and producing joint reporting on latest 3D media technology developments and identification of open research problems classified as short, mid and long term.
b) Identification of future 3D multimedia services and applications with definition of requirements and specifications based on user-centric approaches.
c) Establishment of an European framework for cross validation of QoE models and metrics targeted for specific usage environments 3D, taking into account the cultural diversity dimension across different countries and within each country.
d) Contribution to standardization activities within relevant ISO/IEC, ITU, ETSI and IETF committees. This includes benchmarking, tools and methodologies for creation, coding and transmission and consumption of 3D video, 3D audio and conjoined presentations.
e) Creation of interdisciplinary research teams across Europe and dissemination of new research results through technical and scientific publications co-authored by different participants in the Action.
f) Organisation of an annual European workshop on 3D Media Networking (3D-MedNet) with academia and industry participation along with technology presentation and focus on user-driven approaches to deal with 3D media technology.

g) Production of a publicly available 3D media content data base, explicitly characterised by technical information, perceptual features and target usage scenarios, which will be open for researchers and R&D engineers across Europe.

E. ORGANISATION

E.1 Coordination and organisation

The Action is supervised and coordinated by the Management Committee (MC) following the COST rules and procedures.
The scientific and technical activities of the Action are organised in two levels: i) the interdisciplinary level, by means of the Interdisciplinary Assembly, and ii) the specific level, implemented through the WG. The Interdisciplinary Assembly is composed of all participants in the Action. The WG gather participants with common interests in the context of each particular WG and are responsible for coordination of the corresponding activities.

A WG leader is elected among its members, who will be responsible for promotion and organisation of relevant cooperation actions within the WG and to be proactive within the Technical Committee along with other WG leaders in their contribution for the overall objectives of the Action.

The Technical Committee (TC) is composed of all WG leaders. It is responsible for establishing the necessary links between WG for the successful implementation of the Action as a whole and for acting as necessary whenever relevant deviations are detected. Continuous monitoring of WG activities is performed by the corresponding WG leader and the TC.

An Editorial Board, nominated by the MC, with at least one member from each WG to coordinate the process of writing up scientific and technical books in the different fields of the Action and to ensure that the Action Web site is always updated for dissemination of the results.

The Short Term Scientific Missions (STSM) and the Training Schools are coordinated by the MC.

The Industry Forum (IF) is composed of representatives of selected European industries with relevant activity in the 3D multimedia market. Members of the MC are responsible for proposing the industries and their possible representatives in the IF, to be approved by the MC. The IF members are not necessarily involved in the R&D work coordinated by the Action. The IF acts as an external interface and advisory board to the MC, by bringing in the industry views about the future of 3D media technology and market and providing feedback about the Action coordinated activities.

E.2 Working Groups

This Action is organized in 6 WGs, which coordinate the scientific and technical activities within its scope. Each participant joins one or more WG, where the outcomes of his own research work fit better. Any participant may move from one WG to another at the end of each year.

WG1: 3D Content Creation (technology evolution, context-aware 3D audio-visual capture, augmented reality, applications scenarios: entertainment, social media, education, etc)

This WG will mainly focus on the technologies required for the realization of virtual environment so that users may act and express themselves in flexible and non-predefined ways. The concept consists of multi-modality in terms of forms and media for effective utilisation of various senses, high level of interactivity in terms of range, frequency and impact of individual interaction forms, flexibility to select corresponding actions and reactions through simulations and interaction models (e.g., physics model) with limited number of pre-programmed solutions, automation to allow reduction of mundane tasks and to support simulation of sub-conscious actions, abstraction to enable various levels of control in interaction processes.

WG2: 3D Media Coding (standards and beyond)

This WG coordinates the research on emergent 3D video coding technologies, particularly focused on standards like H.264/MVC, MPEG-C and H.264/SVC and adaptation of 3D video coding to heterogeneous network topologies, in new 3D video coding frameworks that offer a optimal trade-off between high efficiency and low complexity, with special focus on 3D scalability tools and perceptual quality metrics. In the new 3D media coding architectures two level complexity levels will benefit from cooperation between different participants. At first level based on abstract 3D algorithms modelling, analyzing algorithms, data dependency, number of processing stage, critical paths and theoretical architecture. The second complexity level will cover the 3D video coding implementation modelling, addressing statically resources like memory size and number of processing units; and dynamically resources like computation and communications resources required in terms of data transfer per time unit.

WG3: 3D Content-Aware in Ubiquitous Networking Environment (network architectures and protocols, QoS-QoE optimisation, adaptation for internetworking).

This WG is concerned with coordinating actions and scientific collaboration in novel techniques for transporting 3D Video in core network (network coding), novel transport protocols for 3D MVC video (DCCP, TFRC, etc), MVC packetisation schemes for 3D video, rate adaptation and control, 3D video delivery across heterogeneous mobile networks (Seamless 3D video delivery in mobile users). This WG also coordinates the research efforts on content aware network architectures that may allow the 3D media delivery over heterogeneous and autonomic infrastructures at maximum-possible QoS/QoE and in an end-to-end approach, along with synergy between the service and network planes, maximum flexibility to support a variety of business models, expandability and also scalability. The aim is to come up with contributions to the specification on a novel/prototype architecture that comprises an innovative service environment with overlays of interconnected 3D-centric user equipment and a novel network environment, featuring inherent 3D content awareness, with virtual overlays dedicated to 3D media transport. Towards such architecture, the major challenge is to establish a flexible user environment, on top of the Network/Service ones, in order to provide ubiquitous 3D content access in various usage scenarios over heterogeneous wired/wireless terminals featuring real-time QoE monitoring.

WG4: 3D QoE-QoS Evaluation (perceptual metrics in 3D networked video, QoS-QoE mapping)
This WG will bring to group discussion an analysis of the methodologies and tools that represent the state-of-the-art on the evaluation of the quality of service and experience in 3D video. Appropriate assessments will then be carried out for major application scenarios in the cinema, television and gaming sectors. The testing will be performed in a distributed way by selecting 3-5 centres among the Action partners to conduct the testing independently. The WG will develop the necessary concerted actions and joint efforts to set up a joint network of centres across Europe to organise QoE assessment sessions based on realistic conditions. Relevant outcomes of the WG include definition of requirements and setup procedures for establishing new methods for cross-validation of QoS-QoE models in user-centric application scenarios of 3D media networking.

WG5: 3D End-User Devices (technology evolution, 3D Displays, user quality perception)
This WG concentrates its coordination efforts on end-user devices, namely in a very visible part of any 3D media system, which is the display and its properties. One highly intriguing and also commercially interesting category of novel displays is mid-air displays, which enable projected images to float in free space. The visual quality of the current mid-air displays is adequate (~VGA) for especially entertainment applications, but it is a major limitation for the full exploitation of the invention. The image quality depends directly on the turbulence of air and fog flows. Laser-based (PIV) fluid mechanics measurements of the flow, clearly indicate that the optimal flow has not been reached. Novel structures and materials can highly improve the flow and subsequently the image quality even to HD. Earlier experimental studies confirm that all stereoscopic and VR techniques work well on mid-air displays, even though they impose also specific challenges. On-going tests to select novel and low-cost trackers, sensors and upcoming pico projectors are expected to provide important results to enable feasible mid-air VR and augmented reality (AR) displays. The interactive mid-air VR displays will be a novel category of displays and stretch the limits of the basic technology. The result will look like what the general public or media often describes as “holographic” or "StarWars" display. Conceptually they enable many new paradigms, metaphors and possibilities also for user interfaces, telepresence, etc. Ultimately they could be embedded into everyday life artefacts such as collaborative meeting room displays.

WG6: Next Generation 3D Multimedia

In the near future, 3D multimedia services and application will certainly evolve from currently available technology to new directions, many of them unforeseen at the present. For instance, current stereoscopic 3D systems still exhibit various drawbacks that limit their widespread use, such as: i) the viewer needs to wear special glasses or headgear to get the depth perception; ii) only a single scene viewpoint is displayed to the various users, which means that when the user moves around the display device the viewing perspective does not change (i.e., there is no motion parallax); and iii) the viewer may experience visual discomfort and fatigue. 3D holoscopic imaging is seen as possible future approach to overcome some of these problems, allowing fully 3D images to be visible with bare eyes, exhibiting continuous motion parallax throughout the viewing zone and presenting a variety of many different views, depending on the observers' position.

To tackle prospective evolution, this WG is concerned with the identification of next generation 3D multimedia services and applications. The activities in this WG will cover the quantification of system requirements for different services to be reported to each of the other WGs.

E.3 Liaison and interaction with other research programmes

Participants in this Action are actively involved in R&D projects regarding the development of technologies for the capture, postproduction, distribution and exhibition of audiovisual 3D content, and they lead tasks in related projects, namely to the measurement and characterization of QoE for professional and end users. In this particular field, interaction with the Qualinet COST Action is foreseen in their specific activities related to 3D media QoE at the WG level. This Action will also promote a close interaction with other research programs with objectives in the field of 3D networked multimedia. In particular, this will be the case for other European research programs in FP7, EUREKA, and COST. Foreseen coordination with other programs includes, for example, FP7 projects (e.g., MUSCADE and 3D VIVANT). Interactions will take place in form of exchange of information and dissemination of results, but also by seeking to join forces for contribution to international standardization efforts, common short courses and tutorials, joint special issues in scientific journals and recognized conferences on topics of common interest.

Implementation of interaction and exchange of information with other research programmes will be done through meetings, seminars and the Training School. Each WG leader promotes the participation of researchers and professionals involved in related EU funded programmes in the WG meetings and Training Schools, inviting them to brainstorming discussions, seminars and lectures to exchange relevant information about major scientific findings outside the activities coordinated by the Action.

E.4 Gender balance and involvement of early-stage researchers

The MC members will be active in promoting balanced participation from their countries in order to ensure a global balanced participation, with particular focus in early-stage and female researchers. This will be done through personal contacts with R&D group leaders and industry managers, following from the initiative of the MC members in their countries. In its first meeting, the MC will define a marketing strategy defining the best approach to accomplish the best results. Whenever an adequate balance is not possible to achieve, a detailed justification must be provided by the MC.

The STSM are primarily targeted to involve early-stage researchers is cross-country activities and preferably in complementary research in regard to their own expertise to widen individual capacity in dealing with the interdisciplinary aspects of 3D multimedia technology. This is also pursued through the training schools, which must always include the different elements of the 3D multimedia delivery chain in the programme. Balanced participation in the training schools will also be particularly encouraged and monitored by the MC.

F. TIMETABLE

The Action is planned for a total duration of 4 years. The research activity of the participants in the field of 3D multimedia networking is expected to be running for the whole duration of the Action as well as the coordination activities within the scope of each WG. The MC will meet 3 times/year to manage the Action according to COST rules and procedures. The WG meetings will take place immediately before the MC meetings, in the same location. The IF meetings occur at the same time and place as the MC in order to enable interaction with its members. An average of 9 Short Term Scientific Missions (STSM) per year are planned to take place (taking into account that all participating countries will be involved in one STSM/year).

The STSM may take place any time because these will be arranged by request and after previous approval of the MC, following the initiative of any participant to propose an STSM. One Training School per year will be organised in the last three years of the Action period, leaving the first year for starting up of the other coordination activities and planning of the Training Schools. The Editorial Board will meet twice a year (Q2 and Q4) in order coordinate joint publications, namely co-authored books addressing interdisciplinary topics.

Year 1	Year 2	Year 3	Year 4
3 MC meetings	3 MC meetings	3 MC meetings	3 MC meetings
9 STSM	9 STSM	9 STSM	9 STSM
	1 Training School	1 Training School	1 Training School
Workshop 3DMedNet	Workshop 3DMedNet	Workshop 3DMedNet	Workshop 3DMedNet
3 WG meetings	3 WG meetings	3 WG meetings	3 WG meetings
2 Editorial Board meetings	2 Editorial Board meetings	2 Editorial Board meetings	2 Editorial Board meetings
3 IF meetings	3 IF meetings	3 IF meetings	3 IF meetings

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: EL, ES, FI, FR, IT, NL, PT, TR, UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 36 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

Dissemination is a horizontal activity in this Action, crossing all Working Groups, involving all partners and targeting diverse audiences. Dissemination of results will be done for both the industry stakeholders and for the scientific European community. As indicated in sections C4 and C5 target groups include the hardware manufacturing industry and the devices manufacturers to be provided with the efficient algorithms for 3D coding. Other target groups include 3D content creators and application developers such as those in the games industry and broadcasters, namely those using 3D IPTV platforms and the Internet to deliver the next generation of 3D media services. Internet access providers are also included in the target audiences for dissemination of results, namely those related to quality of service (QoS) and quality of experience (QoE).

Overall, the target audiences for the dissemination of the results include several types of European actors playing quite different roles in the broad area of 3D multimedia networked services. These are identified as the academic research community actively working in specific aspects of 3D multimedia; the European industry competing in different sectors of the 3D multimedia market, such as services, applications and product development (e.g, hardware and device manufacturers), networking, broadcasting and consumer equipment; international standards bodies (e.g., ISO, ITU, IETF, DVB) with relevant activity in the field; interest groups within professional organisations (e.g. IEEE); government agencies and consumer associations concerned with specification and monitoring of the quality of emerging 3D multimedia services, products and consumer equipment.

H.2 What?

A full set of dissemination activities will be undertaken in order to contribute to increasing the Action impact and exploitation potential, by widely disseminating the results and objectives. In addition, each participant will also contribute to project dissemination activities individually.

Website: A project website will be designed and implemented, following a content oriented approach to better disseminate the project concept and outputs. It will feature an attractive and innovative user interface and be regularly updated.

Documentation: A comprehensive set of documentation will be created, namely a white paper, a fact sheet, a reference powerpoint presentation for the Action and a poster for dissemination.

Contributions to events: Contribution to a great number of events will be sought to maximize the Action impact. Thus, during the full Action lifetime, the participants will be very active in the organisation of targeted demonstrations, participation and contribution to relevant conferences.

Publications: This is one of the more traditional ways of promotion, which includes selected journals, newspapers, scientific or targeted publications, multidisciplinary books, bulletin, newsletters, publication and diffusion of advertising material, brochure, etc. the Action will prepare a number of professionally designed promotional materials for external people.

Workshop: The annual workshop planned to be organised within the scope of this Action, the Workshop on 3D Media Networking (3DMedNet), will be a major dissemination forum of the Action activities for researchers and professionals actively involved in cutting-edge technology development. The workshop will be used for publication of relevant results of this Action and also as a cross-disciplinary discussion forum for promotion of innovative research. The workshop shall be organised, to ensure its success, within the context of a larger event such as the NEM Summit (www.nem-summit.eu).

EC Dissemination mechanism: The project will pursue knowledge dissemination and maximum networking with other ongoing relating activities by making maximum use of the EC supported dissemination mechanisms, such as publication of Action information on the official sites of EC. The Action will participate in EC Conferences and the clustering meetings organised per thematic area. Particularly in what concerns technological/scientific dissemination to the annual events organised under the auspices of EC, such as the IST conference and IST summit, apart from paper presentations, the Action will aim to conduct demonstrations in the Exhibition area.

Standardisation activities: The Action outcomes will also be presented to the relevant ITU standardisation groups. One of the most important is the Study Group 12, which is **r**esponsible for Recommendations on performance, QoS and QoE for the full spectrum of terminals, networks and services ranging from speech over fixed circuit-based networks to multimedia applications over networks that are mobile and packet based. Included in this scope are the operational aspects of performance, QoS and QoE.

Interest Groups: Dissemination of the COST Action will also be carried out through the 3D rendering, processing and communications (Acronym: 3DRPCIG) and Quality of Experience for Multimedia Communications Interest Group (Acronym: QoEIG) of the IEEE Multimedia Communication Technical Committee (IEEE MMTC). The goal of the first interest group is to provide an international forum for researchers, developers, manufacturers, students and end-users to exchange knowledge, discuss R&D results, explore the latest state-of-the-art methodologies and study the effectiveness of these findings in terms of time, space and quality. The aim of the second interest group is to promote research and development in the new and emerging area of QoE for multimedia (i.e., video, voice, and image) communications. It will allow dissemination of the Action achievements to reach as much as a thousand of researchers working on multimedia communications.

H.3 How?

Relevant outputs of this Action will be innovative knowledge along with new concepts and technological results with impact on academia, industry, and users of 3D multimedia technology. Dissemination in research community and academia is done through scientific publications in peer-reviewed journals, presentations in international conferences and publication in the respective proceedings. The Action will also publish books by renowned European publishers, gathering prospective authors from within the Action's participants and coordinating the inclusion of relevant results achieved in the course of the Action activities.

The Action outcomes will also be presented to the relevant standardization groups where partners are actively participating. The public web site of the Action will also be a major dissemination method targeted at industry, government bodies and general public using technical reports and non-technical on-line publications suitable for interested communities and users. Short electronic booklets with concise information about the major results of the Action will be made available on a regular basis in the web site, targeting non-specialised user communities interested in 3D technology.