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EXPERIMEDIA – A Multi-Venue Experimentation Service Supporting Technology Innovation through New Forms of Social Interaction and User Experience

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9.1 Introduction

New media applications and services are revolutionising social interaction and user experience in both society and in wide ranging industry sectors. The rapid emergence of pervasive human and environment sensing technologies, novel immersive presentation devices and high performance, globally connected network and cloud infrastructures is generating huge opportunities for application providers, service provider and content providers.

These new applications are driving convergence across devices, clouds, networks and services, and the merging of industries, technology and society. Yet the developers of such systems face many challenges in understanding how to optimise their solutions (Quality of Service – QoS) to enhance user experience (Quality of Experience – QoE) and how their disruptive innovations can be introduced into the market with appropriate business models.

In this report, we present the results of a new multi-disciplinary collaborative approach to product and service innovation that brings together users, technology and live events in a series of experiments conducted in real world settings. Through experimentation we have explored a broad range

of technical, societal and economic challenges faced by technology providers each aiming to create and exploit new multimedia value chains in markets such as leisure and tourism, cultural and heritage, and sports science and training.

The experiments highlight the features of multimedia systems and the future opportunities for companies, as the Internet continues to transition towards the increasingly connected world of Internet of Things and Big Data. We know that putting user values at the heart of design decisions and evaluation is the key to success, and that long term benefits to providers of technology, services and content must derive from enhanced user experience. Engaging users in real-world settings to co-design and assess how technology can be used is now more important than testing how technology will be operated.

We have only scratched the surface of possibility in novel networked multimedia systems yet we believe that the individual and collective results in the report are significant as they are grounded in real-world evidence. A new way of conducting research and innovation has been created that maximises the potential for commercial exploitation and societal impact. We think this is extremely important and when adopted will lead to greater benefits for all.

9.2 Networked Multimedia Systems

Multimedia is the combination of multiple forms of content and is a fundamental element of applications in areas such as communication, entertainment, education, research and engineering. The convergence of technologies for distributed multi-stakeholder systems, data analytics and user experience is dramatically changing the way multimedia systems need to produce, deliver and consume content.

Providers of multimedia systems are now looking to create value by linking people to each other and to locations (both real and virtual) in such a way as to capture the popular imagination, and exploit the desires of consumers to share their experiences, thus creating new channels for revenue creation and advertising.

To create such experiences requires innovative applications that focus on: enhanced personalisation, non-linear story-telling; interactive immersive experiences; creation of social communities which allow people to use 3D environments to communicate and interact with each other; the capture and reproduction of the real world in 3D; and the creation of perceptual congruity between real and virtual worlds.

Of course, these innovative applications will place significant demands on network and content management infrastructures as providers attempt to

deliver guaranteed Quality of Service and enhanced Quality of Experience to communities that dynamically organise themselves around socially distributed, fixed and mobile content. These additional demands will require investment in infrastructure but the expectation is that by linking multimedia and enhanced real-world experiences, consumers will be prepared to make long lasting commitments.

9.3 A Multi-Venue Media Experimentation Service

EXPERIMEDIA is a multi-venue experimentation service for research and development of novel Internet products and services aiming to deliver new forms of social interaction and user experience. EXPERIMEDIA was developed as part of a European research project of the same name within the Future Internet Research and Experimentation initiative (FIRE) [1] (Figure 9.1).

The EXPERIMEDIA project set out to develop and operate a unique facility offering researchers and companies what they need to gain insight into how Future Internet technologies can be used and enhanced to deliver added value media experiences to consumers. The approach aimed to deliver, reusable, cost-effective testing and experimentation facilities, platforms, tools and services for social and networked media systems. The EXPERIMEDIA project developed four foundation elements necessary for experimentation of multimedia systems conducted in real world environments:

- Smart venues: attractive locations where people go to experience events and where experiments can be conducted using smart networks and online devices;
- Smart communities: online and real-world communities of people who are connected over the Internet and available for participation in experiments;
- Live events: exciting real-world events that provide the incentives for individuals and smart communities to visit the smart venues and to become participants in experiments;

Venues, Live Events and User Communities   **Software and Service Platform**   **Market Showrooms**   **Knowledge and Expertise**

Figure 9.1   Four foundation elements of a multi-venue media experimentation service.

- Service Platform: state-of-the-art Future Internet testbed infrastructure for social and networked media experiments supporting large-scale experimentation of user-generated content, 3D internet, augmented reality, integration of online communities and full experiment lifecycle management.

The combination of live events, venues, user communities and an advanced technology platform accelerates product and service innovation by allowing companies to co-create solutions in real contexts with end-users. EXPERI-MEDIA characterises live events as "any cooperative human activity that can be enhanced through access to real-time information delivered by the Internet". Examples live events include:

- 1000 spectators attending a two day ski championship at a ski resort.
- An athlete participating in a one hour sports training session with a coach and sports scientist.
- A group 50 students attending a one hour interactive virtual reality presentation about ancient Greece.
- A small group of hikers on a day trip on a mountain, a round of golf or a trail run.

There are many socio-technical and economic benefits to experimenters of using live events as the basis of trials and experimental studies. Each live event captures a distinct user experience to be enhanced along with providing temporal and spatial constraints associated the activity such as location, technical constraints associated with available infrastructure and socio-cultural constraints associated with the user communities. Dealing with contextual factors is a major challenge for experimenters aiming to develop generic solutions for Internet deployments and to understand how to address barriers to adoption of technology. In addition the ability of media technologies to connect people in real-time across distant locations can create new opportunities for interaction with live events. From an economic perspective, live events provide technology providers with access to an entry point to a potential market. This entry point can lead to significant direct and indirect sales (Table 9.1).

The EXPERIMEDIA Service Platform consists of a set of media services that have been instrumented for deep levels of observability for use within experimentation and technology trials. Each service has a corresponding service model with QoS metrics that are reported and available to the customer during experimentation. Such detailed metrics are necessary for customers to explore the relationship between QoS and QoE. These types of metrics are typically not available from equivalent commercial services. In addition, a provenance model is offered that allows user-centric activities and interactions

Table 9.1 Benefits and opportunities for experimenters

Socio-Technical Benefits for Experimenters: Testing Opportunities	Economic Benefits for Experimenters: Exploitation Opportunities
observation of individual and community behaviours	access to a potential market, direct sales
experience of scaling for large-scale short-lived communities	working with a customer's customers
adaptation to the environment, considering physical, social and ethical constraints	creation of high impact showcases, indirect sales
adaptation of content according to individual and/or group preferences	engagement and collaboration with stakeholders, potential partners/ suppliers
real-time orchestration allowing for adaptive narratives	
sensors and devices for detection and tracking of feature points	
device capabilities both remote and at a venue	
cooperative or collaborative frameworks	
including dealing with selfish or malicious users	

to be tracked and linked to the detailed metrics reported by the other entities involved. This capability is important to allow experimenters to track users in open studies and to explore correlations between QoE, system interaction and system performance (Figure 9.2).
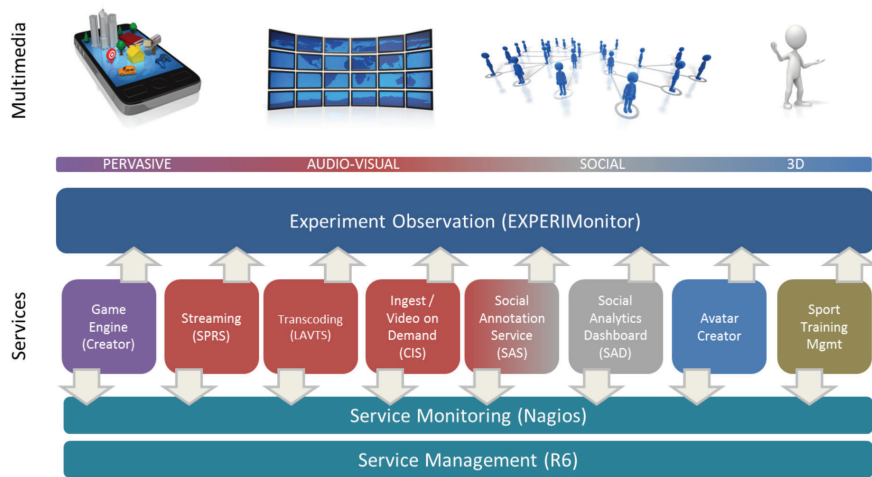

Figure 9.2   EXPERIMEDIA High-level technical architecture.

From the platform point of view the reusability across experiments is a key point enabling multi-domain applications. The media services are technology enablers whose capability allows users to achieve added value through use, either by design (i.e. the purpose is known in advance) or more frequently by openness (i.e. the purpose is opportunistically established by the user). Technology enablers are a key part of future innovation in programmes such as FIRE and the Future Internet Public Private Partnership. Networked Multimedia technology enablers must address the needs novel applications and services allowing them to exploit a range of social, audio/visual, pervasive content and 3D content. The platform offers services to support different types of content considering the distinct characteristics and lifecycles (authoring, management and delivery).

9.4 Smart Venues and Experiments

Smart Venues are real world locations that offer live events, communities, infrastructure and relevant data assets to experiments. Smart venues have distinct characteristics and provide context for experimentation. EXPERIMEDIA has three smart venues covering important application sectors for multimedia systems including outdoors and leisure, cultural learning and sports training and science (Figure 9.3).

- Centre d'alt Rendiment (CAR), Spain, is a high performance sports training centre which gives support to athletes competing at an international level. CAR offers a professional environment for small scale (5 participant) controlled experiments aiming to improve training programmes for students, athletes, coaches and sports federations within a dedicated smart building with a private cloud and high performance fixed and wireless network connectivity.

Sports Training and Science @
CAR High Performance
Training Centre

Cultural Learning @
The Foundation of
the Hellenic World

Outdoors And Leisure @
Schladming Ski
Resort

Figure 9.3   EXPERIMEDIA smart venues.

- The Foundation of the Hellenic World (FHW), Greece, is a cultural centre that offers real and virtual exhibitions, congresses and performing arts events aiming to educate people about the Hellenic World. FHW offers a public environment for medium scale (30 participant) experiments aiming to improve visitor experience and the quality of learning through multimedia exhibitions, virtual and immersive reconstruction, and serious games. FHW offers a 3D, dome shaped virtual reality theatre, exhibition places, and cave systems.

- Schladming, Austria, is one of the leading international ski resorts in Austria and part of the Ski Amadé network covering 28 ski areas and towns that make up the largest ski area in Europe. Schladming offers a public environment for medium scale (50 participant) open trials of technology aiming to improve visitor experience within the region. The ecosystem is complex and potential activities are broad but most relevant are winter and summer outdoor sports such as skiing, hiking, mountain biking.

We funded a series of 16 experiments through two open calls. The experiments were conducted by researchers and SMEs at three Smart Venues throughout Europe covering a broad range and complimentary multimedia topics.

- Schladming Smart Venue

  - DigitalSchladming: hyper local social content syndication and filtering
  - MediaConnect: ubiquitous interactive and personalised media
  - PinPoint Schladming: augmented reality mobile applications
  - iCaCoT: interactive UHD camera-based coaching and training
  - Smart Ski Goggles: real-time information delivered to wearable data goggles

- CAR Smart Venue

  - Live Synchro: accurate analysis of choreographed team sports
  - 3D Media in Sports: non-invasive reconstruction of biomechanics
  - CONFetti: interactive 3D video conferencing for collaborative sports training
  - 3D Acrobatics: wireless sensor motion capture and 3D visualisation
  - 3DRSBA: remote 3D sports biomechanics analysis
  - CARVIREN: multi-factor athlete tracking using real-time video and sensor information
  - Augmented Table Tennis: automatic notation analysis system based on vibration sensors and on table surface projection

- FHW Smart Venue
    - NextGen Digital Domes: learning, interaction and participation using social and augmented content.
    - REENACT: serious games and immersive media.
    - BLUE: personalised museum experiences using cognitive profiling.
    - PLAYHIST: serious games with real-time 3D reconstruction of moving humans.

A significant dilemma is balancing research versus innovation activities. Geoff Nicolson of 3M once said "Research is turning money into knowledge, whereas Innovation is turning knowledge into money". Very few organisations complete the full lifecycle in the scope of an experiment. In many cases, impact is achieved much later either in-house by other groups (e.g. industry organisation) or by others exploiting knowledge published research institutions. In fact for research institutions the link between knowledge generation and exploitation in innovative services is significantly weaker. However, by creating multi-disciplinary teams including domain experts, social scientists, legal experts and technologists working with end users it is possible to overcome barriers and accelerate adoption in target markets.

Smart venues are concerned with offering innovative services that deliver enhanced user experience. Knowledge is only a route to that goal. The first open call experiments had an emphasis on knowledge creation rather than innovation due to the characteristics of the partners performing the work. As a consequence, the impact of those experiments was far less and the project strategy was changed to create experiments driven by SMEs for the second open call. Overall six experiments were executed by SMEs, nine by research institutions and one by industry. 18 technology outcomes where identified from the experiments with impact classified as follows:

- Commercialisation (5 of 18): benefit is exploitable in revenue generating products and services.
- Further Trials (4 of 18): promising outcomes justifying further investment in trials to scale up to produce quantitative results or to explore qualitatively in a new application domain.
- Further Research (8 of 18): benefit looks feasible but could not be sustained without significant research and development.
- Barrier (1 of 18): benefit could not be delivered.

Significant commercial opportunities have been delivered to experimenters highlighting the innovation potential of EXPERIMEDIA. Smart Ski Goggles

will launch a commercial service in the Ski Amade region for the 2014/2015 ski season and there are ongoing negotiations for the commercialisation of the associated lift waiting time service. CARVIREN, 3D Acrobat Sports and 3DRSBA resulted in commercial contracts with the CAR Smart Venue. DigitalSchladming MyMeedia service remains operational 12 months after the experiment and is part of IN2's "staging" strategy and business model. iCaCoT is in negotiation with Schladming Ski School for use of interactive UHD video and annotation system as part of their skier training offering. 3D Media in Sports has received significant commercial interest from weightlifting and cycling communities following a large scale trial with the Movistar cycling team. Augmented Table Tennis has created significant commercial interest from TV broadcasters and the International Olympic Committee.

9.5 Users at the Heart of the System

User centricity is a critical element in the design and development of multimedia systems aiming to enhance user experience. Understanding the needs, wants and limitations of end users must be given extensive attention throughout the design process. We have adopted two main principles in our user centric design processes:

- users are the primary beneficiaries, and other benefits to providers of services and technology will follow from user benefits.
- users who participate in observations are also those same users that realise the primary benefits.

These principles reflect the shift towards the democratisation of Internet services where users play a greater role in generating information and the need to recognise explicitly the cost and benefit of participation. In general terms, designers must consider a multi-stakeholder data value chain where observations are acquired, data are processed by multimedia capabilities and data are transformed into benefits presented to users.

Observation is the process of closely watching and monitoring users and their context. User observations are processed as an inherent part of content delivery (e.g. location and activity tracking in geo-location services) or are used to understand the experience itself (e.g. a user satisfaction survey). From a user's perspective, observations have a cost either directly in terms of time and attention during an experience, or indirectly in terms of loss of right to self-determination (i.e. privacy). Context observations are processed to give additional meaning to Quality of Experience (e.g. a user had a good

time in a group of 15 close friends) and importantly to optimise the Quality of Service delivered by service providers. As context plays a significant influential role in Quality of Experience it is typically the case that service providers have to manage context, including both real-world (e.g. how many people participating) and multimedia context (e.g. how much infrastructure resource, quality of virtual presentations, etc.).

Analysing the experiments we can define six categories of user observations from a total of 95 different user observations:

- Satisfaction (32 of 95): feedback about relative satisfaction with their experience covering aspects such as utility, emotional, subjective, economic, usability and usefulness.
- Online Activities (32 of 95): direct interaction with an application (e.g. interaction logs, web site statistics) that complements the real word activities, and is strongly related with the nature of the experiments.
- Real-World Activities (16 of 95): activity recognition, for example, biomechanics representing the position of body components (e.g. the angle formed by bones in an athlete while performing), higher level human activities (e.g. weightlifting, skiing).
- Collaboration (7 of 95): the relationship to a group, in terms of interpersonal relationships, social interaction, group dynamics (e.g. questions in a group presentation), group enhancement.
- Location (6 of 95): the absolute or relative position of a user where relative means with respect to external elements (e.g. a ski-run).
- Cognitive (1 of 95): the capacity to process information and apply knowledge (e.g. psychometric profile).

The absolute value of observations related to a category is not a measure of importance. A single type of observation can be the most important in a given experiment as it is the most significant factor in delivering the benefit to a user. "Collaboration" highlights that multimedia features aim to benefit users by supporting interaction. The "satisfaction" group is typical of any experimental environment and it is propaedeutic to evolve from experiment to exploitation (Figure 9.4).

Context is more complex as by definition it is anything not related to a user that can influence Quality of Experience. Analysing the experiments we can establish two main high level context categories from the 56 context observations:

- **Real-World Context**: observations related to people and environment conditions associated with real-world activities.

- **Online Context**: observations related to the performance characteristics of the system under test covering aspects such as content quality and infrastructure utilisation.

The significant number of context observations acquired means that the surrounding environment plays a significant role in multimedia systems. In fact, very often the benefit delivered to the user is the combination of context and personal information. Real-world context is highly dependent on the Real-World Activity. Within EXPERIMEDIA this is defined by the nature of the live events being studied at Smart Venues. Real-world context is difficult to observe automatically and in a general way considering the specific nature of live events. EXPERIMEDIA has focused on observing users with some cases of capturing Real-World Context where this is an essential part of the experience and the cost is not prohibitive. In controlled experiences such as those at the CAR where Real-World Activities are well-defined and constrained the Real-World Context is known and can be captured out of band. In more dynamic and open situations at Schladming and FHW it is necessary to observe Real-World Context either directly (e.g. definition of Points of Interest within a geographic region, queue waiting times, etc.) or indirectly (e.g. inferences about group dynamics from temporal/spatial analysis or online interaction).

Making inferences about Real-World Context and Activities from Online Context and Activities is an essential part of multimedia systems and experimentation especially in situations where the cost of direct observation is
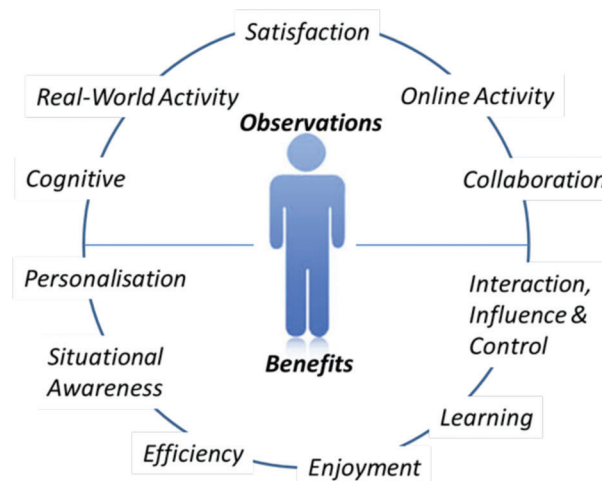

Figure 9.4 User centric observation and benefits model.

prohibitive either through software or feedback from users. EXPERIMEDIA's hybrid metric and provenance model offers a foundation for such analytics. The hybrid approach provides the ability to collect large quantities of measurement data (e.g. service response times, network latency, user satisfaction, etc) whilst allowing for exploration of causation between observations within such data (e.g. user satisfaction in relation to service response time). Also, it is recognised that Internet of Things domain has made significant progress in acquiring real-world context across a broad range of dynamic situations. There is an opportunity to deliver increased benefits by strengthening the relationship between User and Real-World Context observations.

Online Context is of significant interest to service providers who use this information to manage resources and optimise the delivery of multimedia services, including adaption of the quality of content. As such Online Context is an important facet of experiments that focus on the relationship between QoE and QoS. Of course this depends on the nature of the study but the advantage of the EXPERIMEDIA Platform is that it is already instrumented for Observation of Online Context to ensure that important technical information was available to experimenters. Typically experiments have identified the significant Online Context observations related to delivery of a desired Quality of Experience. These include the quality of context (e.g. accuracy of biomechanics data, video quality), network performance (e.g. delay, bandwidth) and cloud performance (e.g. CPU utilisation).

9.6 Making a Difference in the Real-World

Digital technologies are most useful to society when used to deliver enhanced real-world impact and benefits. Online interaction alone, such as digital games, can bring enjoyment but longer lasting satisfaction is achieved by using digital technologies in support of real-world activities. We focus our experiments on this area by defining, measuring and analysing user experience (UX) where multimedia systems support the interplay between real-world Live Events and online activities. Live events create the main context for user experience. We have explored events such as a sports training, a night out in a town, attendance at large scale sports events, and visiting an exhibition.

Studying UX is a complex endeavour. The International Standard Organisation (ISO 9241-210) defines User Experience as "a person's perceptions and responses that result from the use or anticipated use of a product, system or service". UX includes all users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviours and accomplishments that

occur before, during and after the use of product, system or service. The experiments themselves focused on distinct UX aspects enhanced through multimedia features. Exploring the experiments we identify seven high level user benefit categories from 61 measurable benefits:

- Learning (22 of 61): acquisition or improvement of a skill/ability, a key goal of the CAR and FHW.
- Efficiency (11 of 61): support for increasing the productivity processes in terms of time, effort or cost to complete the intended task or purpose. Efficiency is a common quantifiable measure for all activities associated with live events.
- Interaction, Influence & Control (10 of 61): interacting with the surrounding context for influence and control. (e.g. remote access to training sessions, or incorporation of a remote expert in an education session).
- Situational Awareness (10 of 61): understanding of when/where/why something is happening, so as to maximize the active participation of the user in the experience. This benefit pertains to the delivery of the right thing (information/support/other) exactly when it is needed.
- Enjoyment (5 of 61): the enjoyment a user has in the performed activities, a primary goal of Schladming Venue as a tourist destination.
- Personalization (3 of 61): tailoring the information to maximize user satisfaction including expressing themselves in social networks.

The majority of benefits are produced through processes that enhance raw data collected from multiple information sources. "Learning" is a primary benefit in all CAR and FHW experiments due to learning being a key objective of the venues. NextGen Digital Domes focused on how augmented reality can prime student knowledge prior to virtual reality presentations whereas REENACT introduced a role playing game that allowed participants to enact and discuss historical events. "Situation awareness" is another common user benefit demonstrating how through sensors and analytics users are provided with better knowledge of surrounding context. Geo-spatial and temporal data were essential elements of Smart Ski Goggles and Pinpoint Schladming. "Influence and control" demonstrates the increased possibility of controlling and influencing real-world situations through remote interaction with multimedia (using or being part of the content). PlayHist, CONFetti and 3DRSBA all use networked collaborative working to enable remote users to interact and influence training and learning sessions whilst measuring the efficiency or setting up 3D capture equipment. Greater "enjoyment" is an important benefit across all venues but was not expressed significantly at professional environments such as CAR where objective performance gains were a priority.

9.7 Real-Time Interactive and Immersive Media

The games industry has a significant impact on business and innovation models of the digital era. In many ways, the games industry are forerunners of innovative content, services and business models of a growing digital economy. Consequently the games industry is preparing the way for the other sectors where the digital revolution has not started yet. An industry-changing dynamic is the transformation of multiplayer gaming, built on vast networks of players interlinked by broadband across continents and growing further still by leveraging social networks. With capabilities strengthened further by the generational leaps in 3D graphics, gameplay mechanics, and collaborative platforms, gaming is partnering with and spurring growth in other media segments.

Gaming technologies have been a source of inspiration in EXPERIMEDIA through the adoption of game engines, 3D sensors and advanced presentation technologies across a range of applications. Novel algorithms have been developed in 3D Media in Sport using data from the low cost Kinect sensor, built for the Xbox console. Using 3D information, the algorithms provide athletes and coaches with real-time performance insights in both weightlifting (i.e. speed and trajectory) and cycling (i.e. aerodynamics) applications. Serious games were adopted by REENACT and PlayHist as a way of increasing quality of learning for students visiting the FHW Smart Venue and presented in the immersive Tholos Dome and on mobile devices. A set of abstract game design patterns were defined as part of the second methodology to provide constructs for creating effective gameplay independent of specific game types and technology implementations.

The multi-domain coverage of the EXPERIMEDIA Platform has created opportunities for transfer of multimedia technologies developed within the lifetime of the project across sectors. Technical advances in one sector can be rapidly transferred to other sectors via the platform, accelerating the opportunity for innovation. For example, real-time 3D reconstruction of moving humans from Kinect is a core capability of the EXPERIMEDIA platform. Initially the capability was developed for high performance sports training the generic capability of 3D acquisition from visual and depth sensors was identified to have potential for collaboration between remote users in different situations to be placed into virtual environments. This led to use of the technology at the FHW Smart Venue for including expert actors into serious games within PlayHist.

What is clear is that novel real-time interactive media delivery mechanisms are transforming social interaction models and immersive experiences. People

increasingly connect to each other for work and leisure using augmented and realistic 3D reconstructions of the real world delivered over heterogeneous networks in real-time to indoor and outdoor locations. These capabilities are driving infrastructure requirements. A 3D reconstruction of a moving human from a Kinect sensor produces 100 MB of data a frame (future HD sensors will have much higher data volumes), and with transmission rates of 8 fps with compression of 1:30 a bandwidth of at least 8 Mb/sec is required. Quality of experience requirements in tele-immersive applications requires synchronisation precision of less than 100 ms with a fixed end-to-end latency. Data demands are driving the need for experiments exploring QoS and UX techniques such as end-to-end QoS over fixed and wireless networks, context-based content/infrastructure adaptation and synchronised stream and event processing.

We know that live events are a major driving force for mass audiences. Through digital production, broadcasters can now deliver content more efficiently, flexibly and with greater scalability. However, audiences are demanding enhanced real-time participation in live events and this goes beyond what is possible with current models of media creation and consumption. The next logical step in media production will be the creation of more meaningful relationships between the players at live events, the spectators and the massive online communities at home or on the move. Currently, broadcasters are only skimming the surface of social interactions: posting of viewers opinions such as tweets or blogs alongside programme summaries, capturing an essence of audience engagement through "likes", encouraging personalised media production through user submitted photos or videos, etc. Broadcasters, Games Providers, Event Managers, and to some extent the online communities themselves, must work together closely to offer more engaging and immersive user experiences which can encompass all of the different actors across the various zones of participation.

9.8 Economic and Social Viability of Data Value Chains

Data value chains are at the core of the future digital economy, bringing opportunities for digital developments that build on the increasing availability and processing of all types of data. Today, data value chains focus on intelligent use of data to enable the creation of new products, the optimisation of the production or delivery processes, the improvement of the market, new organisation and management approaches, and the reinforcement of research and development cost reduction of operations, increase of efficiency and

better and more personalised services for citizens [2]. However, it's clear that although big data and value chains are driving the new industrial revolution, without design and engagement of the creative industries, such information at worst is meaningless and at best sub-optimal [3].

We have designed and explored many data value chains associated with outdoor leisure activities and sports performance. Smart Ski Goggles is delivering a commercial service to be launched in 2014/2015 ski season. The service enhances visitor experience while skiing on a mountain by delivering real-time information and navigation system using state-of-the-art data goggles incorporating a heads up display. Information about lifts, slopes, weather, hospitality, social media and navigation are integrated into a single application allowing users to explore the region according to their interests. Mixed data were considered including a combination of open, closed, free and personal data. Data and service providers within the local region were engaged to explore cost, revenue and price points for business models supporting long term viability of the service.

What is clear from engaging in a regional ecosystems is that dealing with closed data is fundamental to economic viability. Many business models of the web are built on advertising where data assets can attract large scale online populations. This is not the case for regional data assets that are highly localised. For example, Pinpoint Schladming delivered augmented geospatial open data but the limited user base in Schladming and the availability of information through other channels reduced the potential value of geo-location data application.

Another challenge with data value chains building on open data is as soon as a data asset attains value, owners will have a tendency to close data to protect value rather than contribute it back to the open data pool. Also value is often realised due to scarcity resulting from production costs including costs (e.g. privacy, time, etc) for users involved in observations. For example, lift waiting time was considered high value for skier navigation but the camera installation and video analytics costs were high. Viable solutions required commercial agreements between lift operators, technology providers and the mobile application provider. Price points in business models must consider that the benefit to users must be greater than the cost of data production.

Data value chains were central to improving training programmes and athlete performance at the CAR Smart Venue making extensive use of wearable and non-invasive techniques to capture biomechanics and physiological information. High performance training is a complex endeavour requiring continuous support from specialists responsible for analysis of multi-factor

data. Coaches and doctors need accurate measurements in order to offer the correct feedback for performance improvements and the avoidance of injuries. Feedback must be timely and often instantaneous to increase the efficiency of training sessions. 3D Media in Sports used 3D information from Kinect cameras for real-time calculation of cyclists' aerodynamic performance and optimal weightlifting speed and trajectory. 3D Acrobatics used wearable inertia sensors to calculate detailed biomechanics data whereas CARVIREN used wearable device (WIMU) to collect a wide range of athlete data.

The success of solutions in CAR's environment were not driven by economics but the cost of participation by athletes in terms of ergonomics, inconvenience or time. Training sessions are carefully scheduled and choreographed. Wearable technologies that inhibit movement or take significant time to put on or calibrate are deemed unacceptable unless the information captured has significant benefits (e.g. injury avoidance). As a consequence, current techniques have been lab-based and not part of everyday training routines. Experiments conducted in EXPERIMEDIA demonstrated the possibility of moving advanced measurement techniques from the lab to the field without introducing significant costs to the athletes. What we see at CAR in terms of multi-factor measurements will be representative of wider society in future as communities realise visions for quantifying self through wearable technologies.

9.9 Innovation whilst Respecting Privacy

Multimedia systems are developed with human participants and in particular require an increasing understanding of human behaviour and experience to provide meaningful collective experiences to individuals and society. Acquisition, processing and protection of personal data is an essential system feature which must be provided in the context of privacy legislation. Of course, the privacy debate has raged in recent years as US social network providers experiment with society's appetite for disclosing personal information. In many ways, European service providers are not operating on a level playing field but if we believe in preserving and promoting European values, legislation that incorporates such values must be respected.

We have successfully delivered European product and service innovation in the context of EU privacy directives such as Directive 95/46/EC; ii) Directive 2000/31/EC; iii) Directive 2010/13/EU. Although compliance with the correct ethical oversight directives is often perceived as a barrier to progress, performing experimentation in their frame can in fact prepare solutions for

European markets. We use a Privacy Impact Assessment (PIA) methodology to uncover potential privacy risks with multimedia systems and at the same time propose mitigation strategies. Early analysis of the PIA allows for sufficient time to implement the necessary amendments and safeguards to ensure that privacy is taken into account by design, rather than being added at the end of the project development. With the appropriate safeguards, systems were able to collect personal data, profile users and track users indoors and outdoors. Some of the features included the use of secure data storage, encrypted transfer, controlled and auditable access for different classes of data distributed over the same channel and obscuring/removing user identities at source (e.g. in the user's own smartphone or home network, depending on application) to prevent direct user tracing.

BLUE used personal data to correlate cognitive profiles with movements and personal preferences, to see if this knowledge can enhance user experiences in their visit of museums. The cognitive profiles where calculated using a Facebook game and are sensitive personal data. BLUE analysed privacy consequences by exploring questions such as whether the profile would be published on or at least known by Facebook? What if an employer sees it? What if the cognitive style is identified wrongly? An analysis of Facebook's Platform Policy highlighted there is no obligation to send back to Facebook the interpretation or observations on cognitive profiles of the user derived from information extracted from Facebook APIs. If however, the user chooses to publish these results on their profile, then they will be available to their friends, as well as to Facebook.

This example highlights a significant challenge for multimedia systems building on popular social networking sites. PinPoint Schladming, Digital Schladming, MEDIAConnect, BLUE, REENACT and CARVIREN all built on the Facebook Application Programming Interfaces (APIs). Developers are required to use the API in accordance with rules on leveraging content from the underlying social networks as defined in developers' Terms & Conditions ("T&C"). What's clear is that compliance with the Social Networks' T&C can significantly influence system architecture considering rules for publishing content and the increasingly stringent rules for extracting content. Platform providers monitor closely the application ecosystem and demand that the developers cooperate with them, especially in case the application requires a large amount of API calls. Through Terms and conditions Social Network providers maintain their position of power within multimedia systems that rely on social media content.

9.10 Conclusions

Multimedia systems are characterised by those that acquire, process and deliver multiple forms of content in services and applications where user experience is a significant factor for their success. The features of multimedia systems are extremely broad covering all aspects of content lifecycles such as low level signal and image processing, data fusion, transcoding, compression and decompression, network transmission, and rendering. Multimedia systems evolve and are intrinsically linked to content forms that they support.

In recent years, the forms of content available and way content is produced and consumed has changed significantly. Mobile devices, wearable technologies, sensors, cameras and online services are acquiring an increasing array of pervasive, social, audio-visual and 3D content about real world environments and how individual and communities behave. In addition, novel immersive environments, augmented reality devices and high definition displays are transforming user experiences.

Through a multi-domain approach we have identified and explored a cross-section of challenges that are associated with multimedia features and their application. We have presented the features of and opportunities for networked multimedia systems building on the results of experiments conducted at the EXPERIMEDIA facility. We have demonstrated the benefits of the EXPERIMEDIA approach for delivering innovative products and services to specific markets as represented by Smart Venues by conducting experiments at Live Events. Significant commercial opportunities have been delivered by experiments highlighting the innovation potential of EXPERIMEDIA experimentation services realised by ensuring users who participate in observations must also be the same users that realise the primary benefits.

Risks in implementing multimedia solutions in a live context where lots of people are involved are various. For example, defining technology solutions without a business cases or not being able to properly address privacy issues. Both of these can be mitigated, if not completely removed, using EXPERIMEDIA methodologies demonstrating that concerns, for example, regarding privacy and ethical oversight are not a barrier to innovation in experimentally driven research.

CAR's high performance training plans across multiple sports have been radically changed through multi-factor sensing, high definition video and video conferencing technologies. New knowledge has been generated that shows how Quality of Learning can be improved through serious games, personalisation and interactive media technologies at FHW. Real-time geo-spatial

information and social recommendation have enhanced visitor experience at Schladming.

What is clear is that networked multimedia systems have huge potential for socio-economic impact and will be transformed through the continuing convergence of infrastructure technologies and the increasing availability of data from IoT platforms and Big Data analytics. However, to realise the benefits of this digital revolution users and user benefit must be at the centre of design processes, and creative experience designers will have a major role to ensure that the explosion of data can be turned into enhanced experiences and sustainable data value chains.

Acknowledgements

References

[1] European Future Internet Research and Experimentation.
[2] OECD (2012) report on 'Exploring data-driven innovation as a new source of growth', DSTI/ICCP(2012)9/REV1, p. 13.
[3] Designing the Digital Economy, Embedding Growth Through Design, Innovation and Technology, http://www.policyconnect.org.uk/apdig/sit es/site_apdig/files/report/463/fieldreportdownload/designcommissionre port-designingthedigitaleconomy.pdf