D2.2 Report on the Needs and Requirements of the 3D LIVE Platform

Deliverable data

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Document history

Version	Date	Author /Reviewer	Description
V0.1	06/03/2013	B.Poussard	Initial Structure
V0.2	16/05/2013	All partners	Fusion of contributions, Formatting adjustments
V1.0	31/05/2013	B.Poussard	First Version to be reviewed by 3DLive partners.
V1.1	10/06/2013	All partners	Updates after the first review: - Spelling/vocabulary review - Key terms section moved - Discussion and Conclusion updates - Update needs and requirements details missing for uses cases' scenarios
V1.2	17/06/2013	All partners	Update scenarios in appendix, Update legends and final formatting details.
V1.3	19/06/2013	B. Poussard	Formatting updates
V2.0	21/06/2013	B. Poussard	Final Version
V2.1	25/10/2013	B. Poussard	Modifications thanks to reviewers' recommendations:
V2.2	12/11/2013	B. Poussard S. Asteriadis	Editing the Executive Summary. Formatting modifications. Updating Requirements: [3.1.1], [3.2.1], [3.2.2], [3.3.3], [4.1.1], [6.1.1], [6.2.1], [6.4.1], [6.4.3],
V2.3	13/11/2013	B. Poussard S. Asteriadis.	Adding some words about 3D audio in 6.1.1 + key term 3D Sound. Adding a paragraph in the Golf users' recruitment section and in the concluding remarks. Updating requirements: [1.1.8], [1.1.6], [1.1.9], [3.2.2], [3.5.5], [4.2.2].

			Updating section 6.5.1 Formatting annex page numbering.

Table of Contents

1 Executive Summary

The report on the needs and requirements of the 3D-LIVE platform gathers both the technical specifications of the 3D-LIVE prototype and the user's needs and requirements of the users that leaded to the final specifications. In the first version of the deliverable, a platform has been designed to be proposed to the final 3DLIVE users. It is a set of minimal components and requirements to guarantee the Tele-Immersive experience. This architecture is going to evolve thanks to users' needs and requirements identification, so then the specifications of the scenarios and the different modules will evolve as well.

Thanks to the input of the WP1 deliverables, a study of the previous work done has been conducted in order to situate 3D-LIVE among other Augmented Sport platforms. The result is our platform brings a new kind of experience of Tele-Immersion about more or less complicated activities using Mixed Reality systems including reconstruction of real humans and real environments.

Three scenarios have been proposed by the consortium about skiing, jogging and golfing activities to apply the 3D-LIVE platform. The identification of the needs and requirements of these scenarios led us to a first description of the specifications of the platform that presents in different tables the requirements of the technical components used in 3D-LIVE.

Each requirement owns an identifier and is directly linked to the functionalities exposed in the report on the Conceptual Design of the 3D-LIVE platform (D2.1). To understand those links, traceability matrices indicate which functionality is concerned by the technical requirements.

In upcoming versions of this deliverable, a section gathering reports on the user needs and requirements will be added as the outcomes of the co-creation activities with the users, improving the design of the platform and the technical requirements of it.

2 Introduction

2.1 Summary of 3D LIVE Project

The 3D LIVE project aims to develop and experiment a User Driven Mixed Reality and Immersive (Twilight) platform connected to EXPERIMEDIA facilities (FIRE testbeds) in order to investigate the Future Internet (FI) broadband capacity to support Real-Time immersive situations as well as evaluating both the Quality of Experience (QoE) and Quality of Services when users are fully immersed into Future Internet (IoS and IoT) based live (sport) mixed environments. The main objective consists to explore 3D/Media technologies and Internet of things in real and virtual environments in order to sense and experiment live situations. The combination of FIRE testbeds and Living Labs would enable both researchers and users to explore Future Internet capacities to enter the Tele-Immersive application market and to establish new requirements for Internet technology and infrastructure. It is expected that combining both FI technology pull and Tele-Immersion market pull would promote and accelerate the creation and adoption of innovative sportive events based FI Services by user communities (e.g. sport practitioners).

2.2 Partners in 3D LIVE project

- Collaborative Engineering, Italy (Project Coordinator)
- Centre for Research and Technology Hellas, Informatics and Telematics Institute, Greece
- University of Southampton, IT Innovation, UK
- Arts & Metiers ParisTech, France
- SportsCurve, Germany
- Cyberlightning Ltd, Finland

2.3 Purpose, Intended Audience and Scope

This document is reporting the results of the work achieved in the task T1.2, within the Workpackage 2 (WP2). This task is dedicated to the exploration of the needs and requirements of the 3DLive Tele-Immersive Environment.

This deliverable shows a brief reminder on previous work done about Tele-Immersive Environments and existing Augmented Sport platforms and experiments. Then the three 3DLive use-case scenarios are presented. With the analysis of these scenarios come the needs and requirements identified for this platform, and also for the community of users that will help the consortium in the design process and experiment the platform.

The intended audience of this deliverable is mainly the 3DLive consortium. This document is the reference for the different partners at the implementation stage. It will facilitate the understanding of the assembly of the different modules in the overall system, and give necessary information on the interfaces between the modules. This document will be reviewed after each session of experimentations during the Workpackage 4 (WP4).

The final revision will have a different audience and objectives, and will bring researchers some basis to design 3D Tele-Immersive Environments in the context of augmented sport.

2.4 Related 3D LIVE Documents

AD(1). 3D LIVE	DoW
AD(2). 3D LIVE	D2.1 Report on the Conceptual Design of the 3D-Live Platform
AD(3). 3D LIVE	D1.1 Investigating and Formalise an Experiential Design Process
AD(4). 3D LIVE	D1.2 Study and Create the Holistic User Experience Model

2.5 Functional Description of Workpackages

The Workpackages of the 3DLive project group the tasks over the time considering 3 steps: The Concept Modelling, the Exploration and Prototyping and the Experimentation and Evaluation.

The WP6 and WP5 are continuously active during the entire project as they consist in management and dissemination.

The WP1 is related to the design of the UX Model & Methodology, correlated to the WP2 that is the design of the 3DLive platform. Concurrently to the Design phase, the WP3 starts the prototyping of some components of the platform, while the WP4 prepare the experiment sessions. Once the first prototype is validated, there is an iterative process that consists in experimenting and evaluating the platform, and then a second design phase is necessary to deliver a second improved prototype.

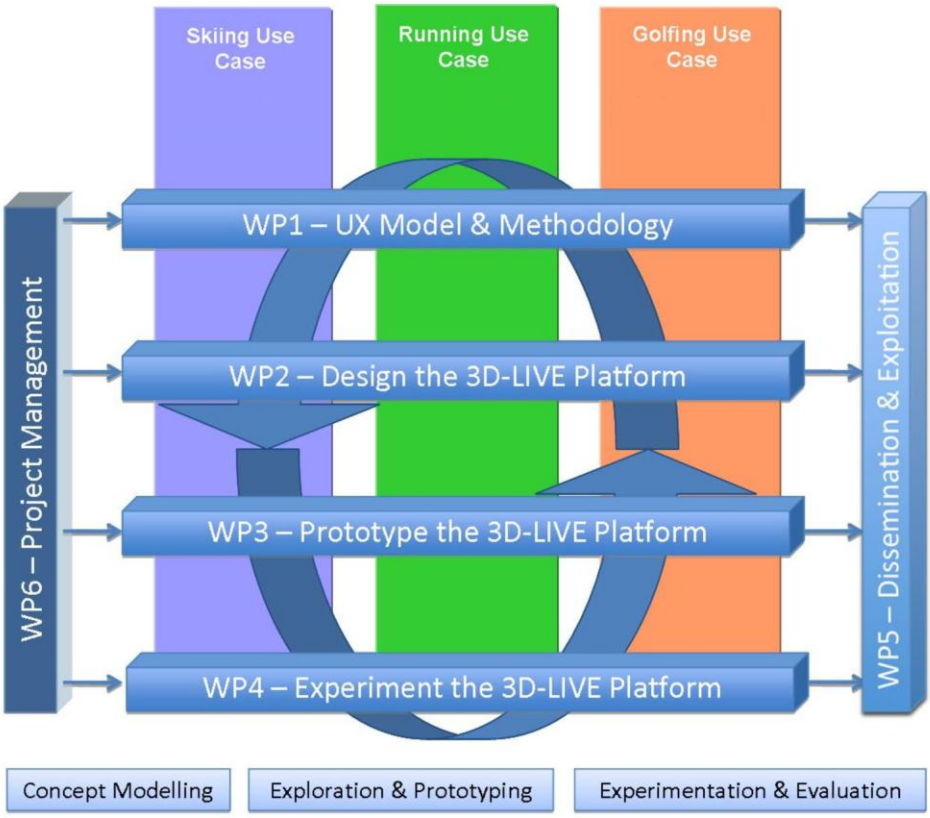

Diagram 1. Structure of the 3DLive Workpackages

2.6 Structure of the Deliverable

This deliverable is structured in the following sections: The section 4 presents the previous work done on Tele-Immersive Environments, Augmented sports existing platforms and experiments. The section 5 describes the needs and requirements of scenarios for the three 3DLive use-cases, that are Skiing, Jogging and Golfing. The section 6 gathers the detailed needs and requirements for each module of the 3DLive platform and the section 7 is related to the 3DLive user community. The section 8 concludes this document.

2.7 Discussion on EC Reviewing team remarks

As mentioned in the reviewers' comments, the table of content and the numbering of pages were very messy. It has been completely reviewed and updated in order to keep a consistent formatting along the report. There are no remaining white spaces due to versions compatibility, the formatting has been controlled by one main author. The executive summaries of the D2.1 and D2.2 were just summing up the 3D-LIVE project as a whole. This section has been updated in both the deliverables to properly describe their content instead.

The methodology to define the needs and requirements was not convincing enough according to the reviewers' comments; what we tried to explain in this document is that technical needs and requirements are often based on partners' knowledge in their different fields of expertise, and based on research work. For instance Sound Spatialization is a standard need to immerse users in a virtual environment; it is even widely used in Virtual Reality systems or in video games. What we do is virtually reproducing real feedbacks to fake the users' senses and brain, and hearing is very important. As a consequence some paragraphs have been added, but no section describing an overall methodology was written.

The report presents technical solutions rather than user needs because the first version is only following the « lead-users » methodology. We described there a first proposal of a framework including more technical needs. With the coming co-creation activities including end users, a section will be added to present their needs and the requirements identified thanks to different workshops and tests with them. This will appear in the last version of this document (and in the D2.1, as it will be impacted as well).

Several requirements were updated and better justified: [1.1.8], [1.1.6], [1.1.9], [3.1.1], [3.2.1], [3.2.2], [3.3.3], [3.5.5], [4.1.1], [4.2.2], [6.1.1], [6.2.1], [6.4.1], [6.4.3]. Some of the requirements presented in this document can not be assessed by a quantitative measurement. We know it and we planned to cover those thanks to questionnaires for instance. Then all the different metrics or questionnaires data to be measured are reported in the deliverables of the WP4 based on work done in the WP1 about the assessment of such a tele immersive environment.

3 Key Terms

Term	Designation
3D reconstruction of humans	*Extraction of 3D information of human silhouette in the form of three-dimensional vertices*
AMQP	*Advanced Queuing Message Protocol: a protocol enabling secure and fast communications.*
BOOST ASIO	*Library able to boost the speed of code implementation*
CAVE	A Cave Automatic Virtual Environment (CAVE) is an immersive virtual reality environment composed of 3 to 6 screen walls creating a room-sized cube.
GUI	Graphic User Interface
HMD	Head Mounted Display
Inertial Sensor	Sensor composed gyroscope, accelerometer and magnetometer, capable to retrieve orientation in space and angular speed.
OpenNI	Standard framework for 3D sensing
OSC	*Open Sound Control: protocol for real time transfers, easy to use.*
QoS/QoE	Quality of Service and Quality of Experience. Look at D1.1, D1.2
RabbitMQ	High-level implementation of the AMQP protocol
SASCube+/SASLab	The two CAVE systems of CLARTE.(Laval, France)
Skeleton	*3D information of body parts*
TeamSpeak	Open Source library enabling audio communications between several clients
3D Sound	A 3D sound (spatialized sound) is a sound emitted in a virtual environment spreading like real sound models and rendered in

	the speakers with specific intensities. It enables users to feel like they know where the sound is coming from.

4 Previous Work

4.1 3D Tele-Immersive Environments

The University of Illinois at Urbana-Champaign [UIUC-TI], the University of California at Berkeley and the University of North Carolina at Chapel Hill have introduced some Tele-Immersion (TI) environment prototypes in different kinds of applications as sport activities, physical therapy, and entertainment. The UIUC-TI categorizes the potential applications of Tele-Immersion including:

- Interactive art
- Distributed interactive education
- Distributed interactive decision support
- Mentor/trainee remote interactions
- Entertainment and gaming
- Social networking
- Social Sciences
- Earth Sciences
- Medical diagnosis/therapy

The different projects of Tele-Immersive Environments allow several users at different locations to interact and communicate in real time in a shared virtual environment. Focusing on sports activities, in the Tele-immersive Environment for EVErybody (TEEVE) lead by the University of Illinois at Urbana-Champaign, researchers try to find out how Tele-Immersion technologies can be accessible to anybody. As prototypes of this project, they developed the Remote Dancing application enabling remote two users to dance together; the first has to dance and the second has to follow with appropriate movements. They also developed the Virtual Light Saber project, which consists in having remote users playing “Jedi Knights” and fighting in a shared virtual space. They is also the Wheelchair Basketball Coaching Project, which consists of the learning of shooting and other basic techniques.

All these different projects display Tele-Immersion environments through simple screen. The result is that there are remote users virtually sharing a virtual environment, but none of these users are really immersed in this virtual space. Immersion in Virtual Reality brings the user to feel inside a 3D virtual scene. To deal with this challenge, researchers try to design 3D environments that contain enough interactivity and vividness, but what is challenging is the way the experience is rendered for the user himself. CAVE systems and Head Mounted Displays are described as the most immersive solutions to render a virtual world for now.

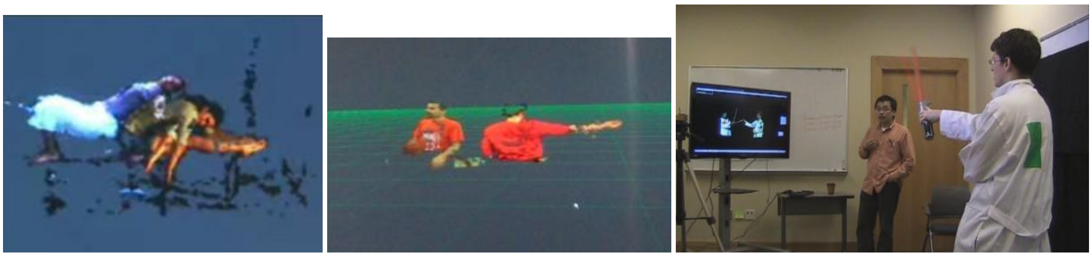

Diagram 2. Examples of tele-immersive projects

The 3DLive project can be situated at the frontier of Tele-Immersion and Virtual Reality, as shown on the diagram below. It will actually enable Tele-immersion of remote users, but the aim is to enable a good feeling of presence of the users themselves in this virtual world as well.

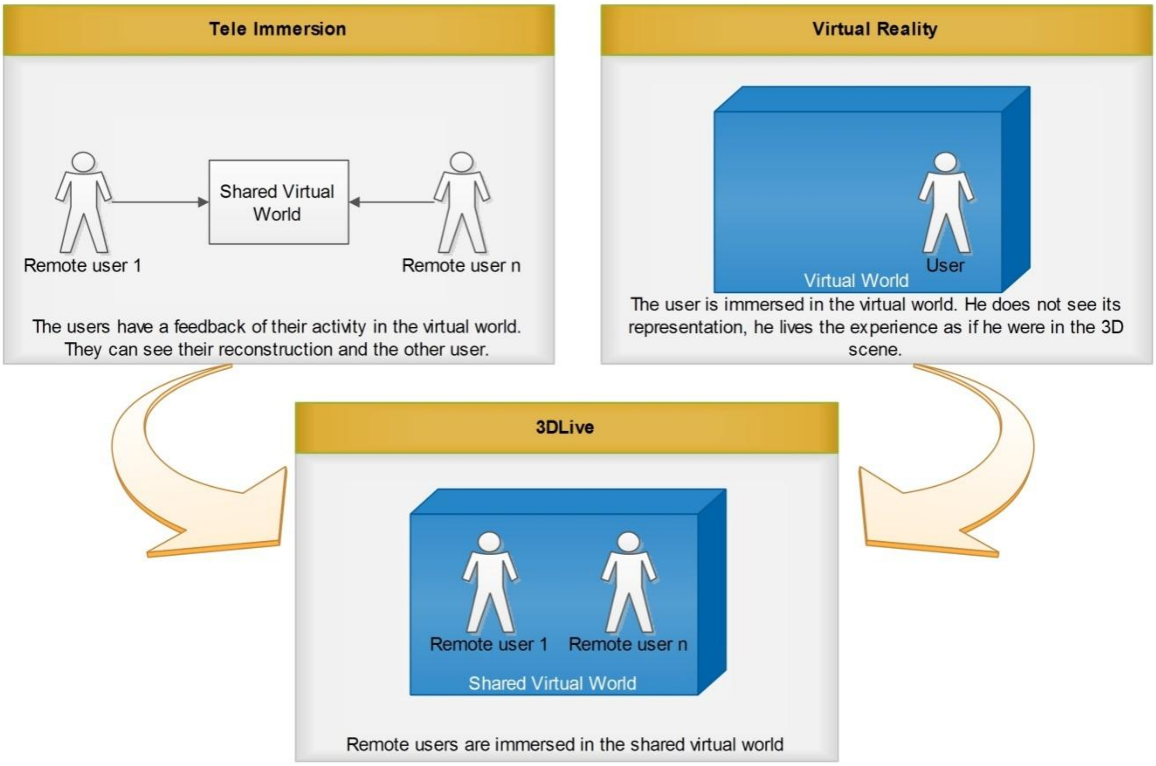

Diagram 3. 3DLive: Between Tele-Immersion and Virtual Reality

4.2 Augmented Sport Experimentations

3DLive is not the first project related to Augmented Sports applications. Many researchers have already built some experiments to assess different aspects of this way to live sports activities. The table below presents the different projects studied in order to locate 3DLive in Augmented Sports applications.

Table 1. Augmented Sports Existing projects

Code	Project	Date	Sport	Location	Main function
AR²	Augmented Reality Air Hockey	1998	Air Hockey	USA	interactive display
BS	Bouncing Star	2008	Ball Game specific	Koike Laboratory, UEC Tokyo	interactive luminescent ball and floor
Cy	Cyclops	1980	Tennis	Bill Carlton, Germany	electronic line judge
DDR	Dance Dance Revolution	1998	Dancing	Konami, Japan	dancing video game
EP	Eyeply	2009	Ball	Austin Hurwitz, USA	visualisation and convey game information
FP	Flyprod	??	All	Aime, Savoie, France	aerial video by drone
FT	FlexTorque	??	All	Tachilab, Japan	haptic arm feedback
GT	Golftek	2010	Golf	Ireland	indoor virtual golf

HE	Hawk-Eye	1999	Ball	Hawk-Eye Innovations Ltd, England	track trajectory of ball
KF	Kick Ass Kung-Fu	2005	Martial Arts	Helsinki University of Technology, Finland	fights virtual enemies with kicks and punches
NG	Net Gym	1999	Bicycles	JONAH BRUCKER-COHEN, NYC, USA	collaborative cycling simulation
Po	Poseidon	2007	Swimming	France	detect drowning swimmer
PP+	PingPongPlus	1999	Ping Pong	USA, MIT Cambridge	sound-tracking ball and reactive visual ping-pong table
RTS	Realtime Sonification	2012	Skiing	Hasegawa Lab., Tokyo, Japan	Real-time centre of gravity feedback by sound
SC	SimulCam/ StroMotion	1999	All	Dartfish, Fribourg Suisse	??
SG	Sonic Golf	2006	Golf	Yale University, USA	indoor virtual golf
SH	SensorHogu	2004	Taekwondo	TrueScore, USA	detect force of hits on body
SoD	Sports over a Distance.	2005	Ball Game specific	ICT Centre & Media Lab Europe, Ireland	user experience of MP distance ball game
SW	Snowwars	??	Snow fight		??

TH	Technohunt	??	Archery	Denver, USA	indoor archery hunting simulation
TI	Tactile Instructions	??	Snowboarding	??	Real-time feedback by tactile stimuli
TnR	Tilt'n'Roll	2010	Skateboarding	Bielefeld University, Germany	record move and analyse tricks
UIS	UIS system	2002	Tennis	??	record locations of pitches
VA	Virtual Archery Bow	??	Archery	University of Applied Sciences, Düsseldorf, Germany	indoor archery hunting simulation
VK	Virku	2001	All	VTT, Finland	virtual fitness center

According to the DIME's Quality Framework, it is possible to locate the 3DLive platform among the other Augmented Sports Applications.

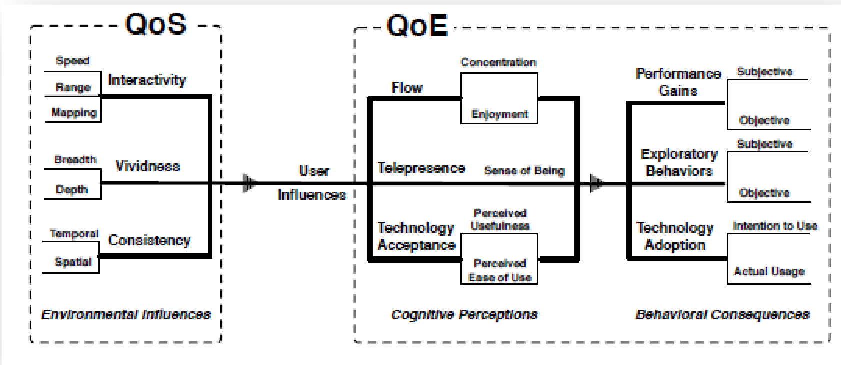

Diagram 4. DIME's Quality Framework

What appears to be comparable information for these different projects seems to be their temporal and spatial consistency.

The consistency in time refers to the "degree of time synchronisation of all states in the DIME systems" (Wu et al., 2009) which depends mainly on networking problematic bringing delays or data loss and creating inconsistencies. Augmented Sports do not necessary include remote players living an experience from different distant locations and so do not need network communications. Hence the temporal consistency in many projects is not a challenging aspect. The most challenging aspect regarding our approach is the spatial consistency. The "spatial consistency refers to the topological scale of state synchronisation". It means that one application must properly understand the global or partial state of other distant applications to insure the consistency between users. As showed on the diagram below 3 groups can be identified. There is a first set of projects that do not take into account much spatial consistency but just give a feedback to users about any activity. Then another area describes projects that give the user a good consistency in space and time, users receive feedback from remote sites that impact their experience. Finally there is an area where spatial and time consistency is insured in the projects and gives users immersion in the virtual environment improving the consistency of their experience. One example project demonstrating this is the "Sports Over a Distance" project.

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Diagram 5. "Sports over a Distance" project

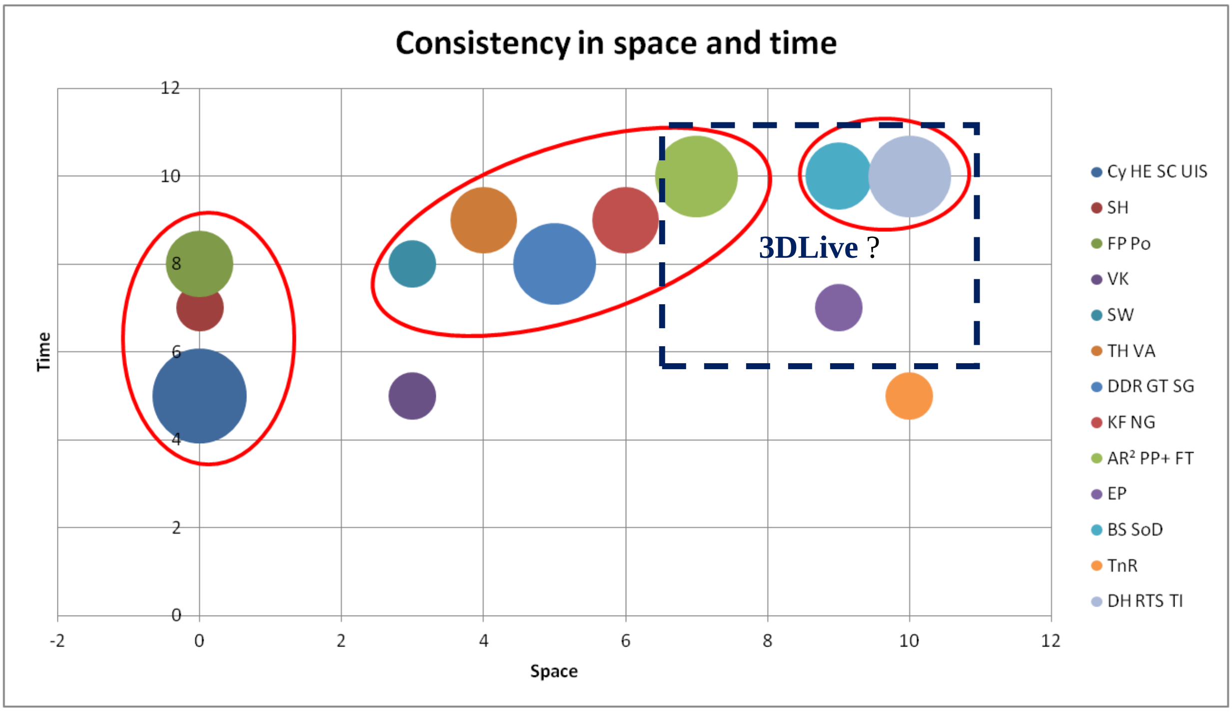

Diagram 6. Temporal and Spatial Consistency of Augmented Sports projects

3DLive aims to appear on this diagram at a high level of spatial and temporal consistency. High-End use-cases may be situated at the max spatial consistency while Low-End use-cases shall have a lower spatial consistency by the way the feedbacks are rendered to users.. 3DLive temporal consistency will depend on the Internet infrastructure, and assess the FI requirements to guarantee temporal consistency in 3D Tele-Immersive environments is one of the objectives of this project.

Most of these prototypes are only limited to one specific sports, but some prototypes include technologies that they can adapt for different kinds of sports, as shown by the diagrams below.

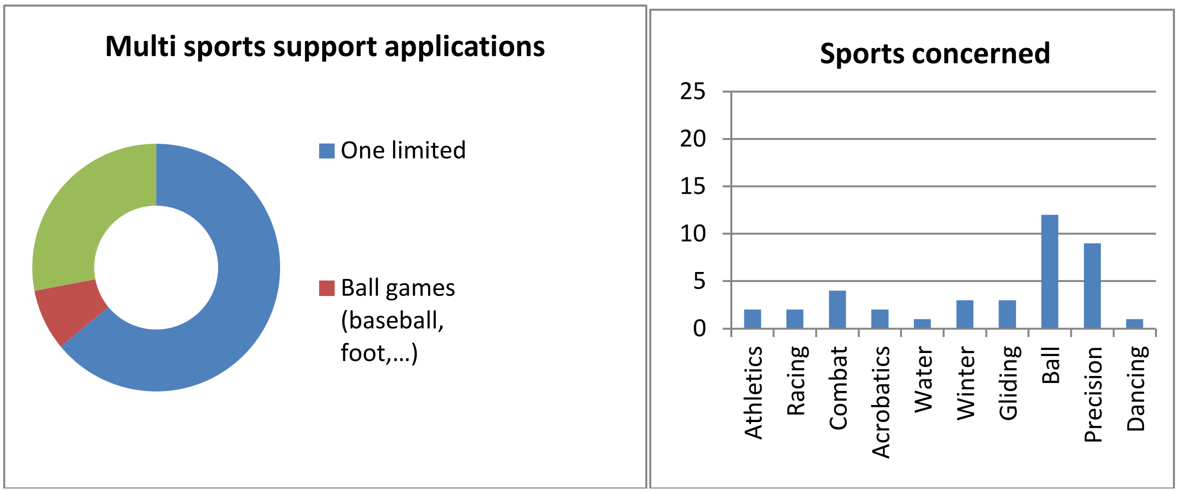

Diagram 7. Sports concerned by Augmented Sports projects

Moreover, sports can be played different ways. Some are in a one player mode and other enable playing with opponents or in a team. Other applications can target training and the end user is then the coach, and not the user who is experiencing a game or other can target the audience and not the sportsmen.

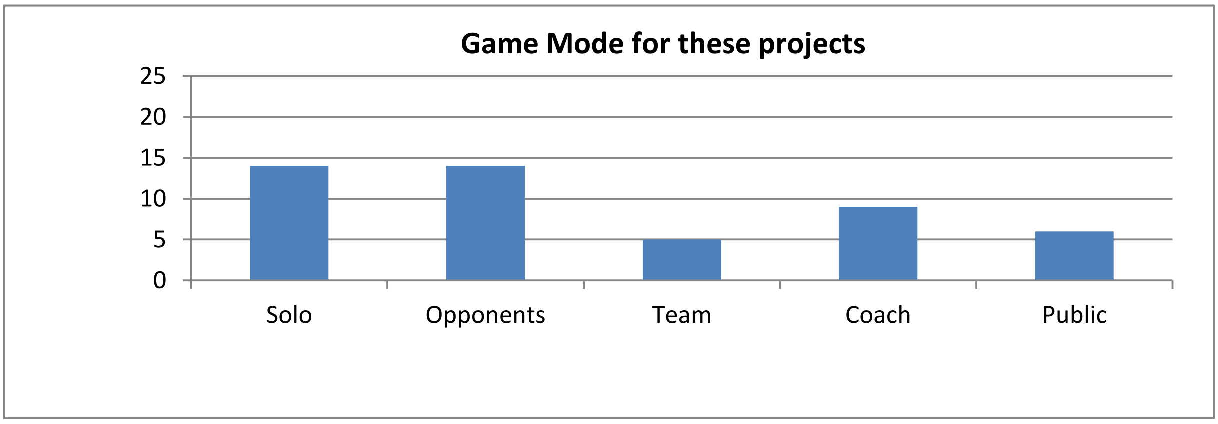

Diagram 8. Game modes of Augmented Sports projects

Looking at the global functions one can identify in these projects, it appears that not many are using some modules such as Activity Recognition and Human Reconstruction. For the 3DLive platform, these two modules are a real added value as they are used together within the same user experience. What is common in the other projects is artefact tracking, body tracking or shared scoring systems. 3Dlive integrate all the features listed in the diagram below.

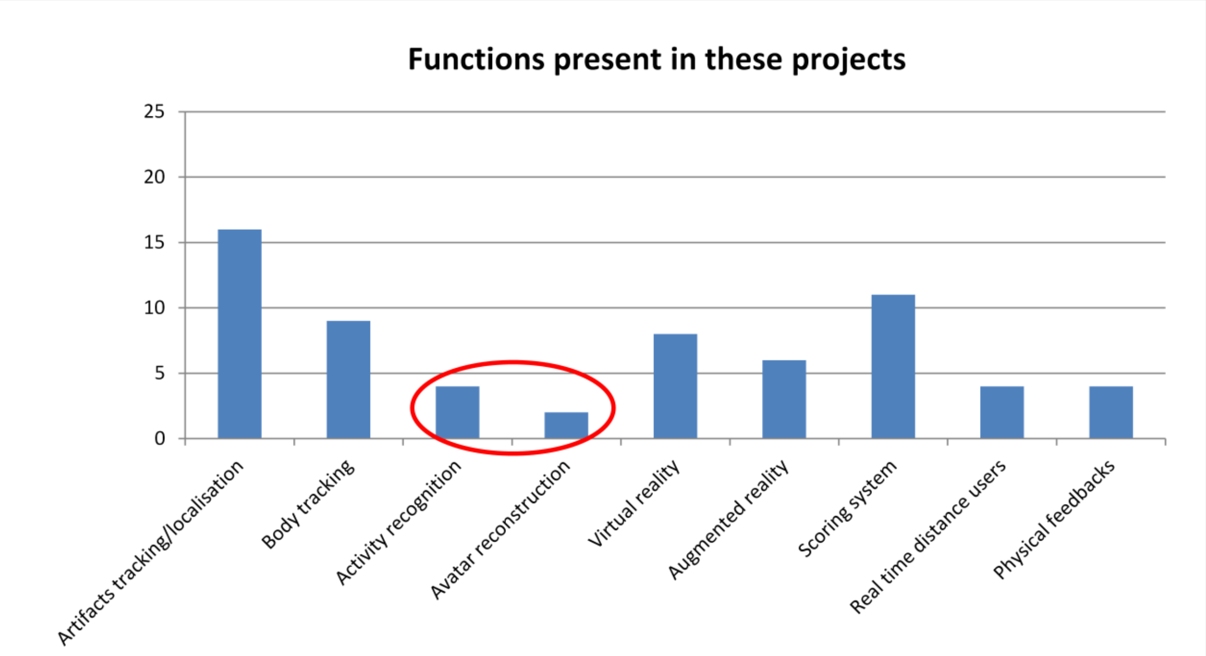

Diagram 9. Challenging functionalities of the 3DLive project among other projects

Taking a look at the different technologies used in these projects it seems that 3Dlive does not bring new stuff to Augmented Sports. What will be new for our case is the use of CAVE systems to render the experiments, and GPS tracking to have correlated virtual and real environments.

Table 2. Technologies used in common Augmented Sports projects

Code	Project	Technologies
AR²	Augmented Reality Air Hockey	Cameras, Electromagnetic sensors, HMD
BS	Bouncing Star	Cameras, Wireless Inertial sensors.
Cy	Cyclops	Cameras, 2DScreen displays

DDR	Dance Dance Revolution	Cameras, 2D Screen displays, tactile interface
EP	Eyeply	Cameras, 2D Screen displays, Wireless inertial sensors, Cloud/Net data
FP	Flyprod	Cameras, 2D Screen displays, Wireless inertial sensors
FT	FlexTorque	Haptic system
GT	Golftek	Cameras, 2D Screen displays
HE	Hawk-Eye	Cameras, 2D Screen displays
KF	Kick Ass Kung-Fu	Cameras, 2D Screen displays
NG	Net Gym	2D Screen Displays, Electromagnetic sensors, Cloud/Net data
Po	Poseidon	Cameras, 2D Screen displays
PP+	PingPongPlus	Projection 2D, Inertial sensors
RTS	Realtime Sonification	Inertial sensors, haptic systems
SC	SimulCam/StroMotion	Cameras, 2D Screen displays
SG	Sonic Golf	Ultrasound sensors, 2D Screen Display, Projection 2D
SH	SensorHogu	Cameras, 2D Screen displays
SoD	Sports over a Distance.	Cameras, Projection 2D, Cloud/Net data
SW	Snowwars	2D Screen displays

TH	Technohunt	2D Screen Displays, Infrared sensors, inertial sensors
TI	Tactile Instructions	Inertial sensors, Tactile interface, Haptic devices, 2D Screen Displays
TnR	Tilt'n'Roll	2D Screen display, Inertial sensors
UIS	UIS system	Cameras, 2D Screen displays
VA	Virtual Archery Bow	2D Screen Displays, Infrared sensors, inertial sensors
VK	Virku	Cameras, 2D Screen displays

To conclude this section, 3DLive platform seems to be an ambitious system at the frontier of Tele Immersive environments, Augmented Sports and Virtual Reality. The 3DLive project brings new solutions to Augmented Sports by the use of Tele-Immersive concepts and activity recognition. Thanks to this platform, several remote users do not only share a virtual space, but can be immersed together in this virtual space, the Twilight space, in the case of an augmented sport experience.

5 Needs and Requirements of the three use-cases' scenarios

The three scenario descriptions are available in appendix. Those scenarios describe the functionalities that the 3DLive platform aims to deploy. Some of the devices mentioned in them are just a part of our technological watch and are not necessary used in the 3DLive architecture.

The table below lists the needs identified coming with the analysis of the three scenarios and the requirements associated to these needs. The last column indicates which component is concerned by the identified needs in order to easily link the different pieces of information. The equipments and devices used in the 3DLive platform are also described in this table.

Table 3. Needs and Requirements for the 3 use-cases scenarios

Scenarios												
Jogging	Skiing	Golfing	Indoor	Outdoor	High-End	Low-End	Followers	Needs	Requirements	Equipments	Software elements	3D LIVE Modules-components
1	1	1	1	1	1	1	1	Interpersonal communication among outdoor and indoor players	Wireless, Real-time	Wireless Headset	VoIP component	5.1 | 5.2
1	1	1	1		1			Sound spatialization for indoor player	Real-time	5.1 speakers	Audio sound spatialization	5.1 | 5.2
1			1	1	1	1		User Interface for indoor and outdoor	Multilingual, user-friendly		Graphic Design Interactions integration Multilingual Coding	1.7
	1		1	1	1	1		User Interface for indoor and outdoor	Multilingual, user-friendly		Graphic Design Interactions integration Multilingual Coding	1.7

		1	1	1	1	1		User Interface for indoor and outdoor	Multilingual, user-friendly		Graphic Design Interactions integration Multilingual Coding	1.7
1							1	User Interface for followers	Multilingual, user-friendly		Graphic Design Interactions integration Multilingual Coding	1.7 | 1.5
	1						1	User Interface for followers	Multilingual, user-friendly		Graphic Design Interactions integration Multilingual Coding	1.7 | 1.5
		1					1	User Interface for followers	Multilingual, user-friendly		Graphic DesignInteractions integrationMultilingual Coding	1.7 | 1.5
1	1	1		1	1	1	1	Location tracking of outdoor players	Wireless, Real-time	GPS sensor	Geolocation on Google map	1.4

1	1	1	1		1	1	1	Position of indoor players	Real-time calculation based on physics laws		Position retrieving in Rendering engine, GPS transposition	1.1
		1	1		1	1	1	Position of indoor 3D objects (golf ball)	Real-time calculation based on physics laws		Position retrieving in Rendering engine, GPS transposition	1.1
1	1	1	1	1	1	1	1	Outdoor and indoor Players' fitness during the activity	Wireless, Real-time	Physiological sensor (armband)	Data Retrieving and Integration in Rendering engine	1.4
1			1		1	1		Activity support of the indoor player	Real-time	Running Simulator (treadmill)	Data Retrieving and Integration in Rendering engine	1.4
	1		1		1	1		Activity support of the indoor player	Real-time	Ski simulator (LE=Wii balance board)	Data Retrieving and Integration in Rendering engine	1.4

		1	1		1	1		Activity support of the indoor player	Real-time	Golf simulator (projection screen and net)	Data Retrieving and Integration in Rendering engine	1.4
1	1		1		1	1		Tracking of indoor Players' gesture	Real-time	motion sensor (Kinect)	Skeleton calculation, transmission	3.1
		1	1		1			Tracking of indoor Players' gesture	Real-time	motion sensor (Kinect)	Skeleton calculation, transmission	3.1
		1		1	1	1		Tracking of golf club	Real-time	Inertial sensors	Inertial data retrieved and translated in the virtual environment.	3.1
1	1		1			1		3D Body reconstruction of the indoor player	Real-time	motion sensor (Kinect)	Mesh and Texture calculation, compression, transmission, decompression and rendering	3.2 | 6 | 1.1
			1		1	1		Visualisation of the indoor player	Real-time	AR Glass, Smartphone or tablet	Animation in the Rendering engine	1.3
				1	1	1		Visualisation of the outdoor player	Real-time	Large screen or video projector	Animation in the Rendering engine	1.3

1	1				1			3D Skeleton reconstruction of the indoor player	Real-time	motion sensor (Kinect),	calculation based on data from motion sensor (Kinect), transmission to rendering engine	3.1 | 6 | 1.1
1	1		1		1	1		3D Activity recognition of the indoor player		motion sensor (Kinect)		4.1
		1	1		1			3D Activity recognition of the indoor player	Real-time	motion sensor (Kinect), inertial sensor on the golf club		4.1
1				1	1	1	1	3D Environment reconstruction	Real-time	Kestrel 4000, Sensordrone, Weather Service.	Bluetooth Gateway, Environment model, AMQP Bus	2
	1	1		1	1	1	1	3D Environment reconstruction	Real-time	Kestrel 4000, Sensordrone, Weather Service	(snow level calculation) environment model	2
1	1	1	1	1	1	1	1	Profile definition	Login, password, information		Link to database	1,5
							1	Access to the application	Anywhere	any PC/tablet	Web Site linked to experiment (HTML5)	

6 Needs and Requirements for the 3D LIVE Modules

6.1 Rendering and Visualisation

6.1.1 Needs identified in the module 1: Rendering and Visualization

One can see evaluating the scenarios that the main needs are the precise reconstruction of the environment, climate knowledge and positioning of mobile objects, avatars, real time information. Here the frequency is at least 60 frames. The graphic quality should include the management of shadows, ambient occlusion, particle effects (rainfall, trails, and fall) and the ambient fog. The video output will be managed in the case of using a CAVE system (for both SASCube+/SASLab in Laval and CAVE system in Oulu). It will be a latest generation PC made for each stage (example: CPU NVIDIA Pro mid-range, Mini 4GB Ram, 3GHz CPU 64-bit). The wireless link to the sensory-motor interface is better but the wiring is also possible function of the cases. Immersion in virtual environments is also increased thanks to audio, the platform must include ambient sounds in addition to voice communications. Those sounds will be processed as 3D sounds to be properly rendered in the space to the users.

6.1.2 *Requirements of component 1.1: Rendering Engine*

6.1.2.1 Functional requirements of component 1.1: Rendering Engine

Req id	**Requirement Designation**	**Criteria**
1.1.1	Download data stream	Support UDP and TCP/IP protocols implementations
1.1.2	Upload data stream	Support UDP and TCP/IP protocols implementations
1.1.3	OS + CPU	Windows: XP SP2 or later / Mac OS X "Snow Leopard" 10.6 or later / Android OS 2.0 or later + Android SDK and Java Development Kit (JDK) + Device powered by an ARMv7 (Cortex family) / Multithread and 64bits recommended
1.1.4	GPU	Product of 2004 or later : DX 9 or later + Shader Mode 2.0 or later + Occlusion Query + Bandwidth 1024 / 2048

		Go for light-maps / OpenGL ES 2.0 for mobile
1.1.5	Frame rate	Min 120 fps to enable stereoscopy in High End Display / 60 Fps if not / 30 Fps mobile.
1.1.6	Draw Calls	200 max for mobile device (count by materials per objects)
1.1.7	Data stream by frame	Max incoming data stream by frame
1.1.8	Interoperability	Ability to deal with external native libraries depending on platforms.(dll on windows, jar on Android)
1.1.9	Weather Data Format	Must be supported on different platforms. (CAVE clustering might not like particle effects, shader effects.)

6.1.2.2 Non-functional requirements of component 1.1: Rendering Engine

The rendering engine intends to retrieve the different data flows coming from the other modules, the different sensors and render these data flows in one unique 3DLive experience. These are the main requirements to a proper implementation within the rendering engines.

Req id	**Requirement Designation**	**Criteria**
1.1.10	Size of Project.	3 Go max (Unity3D)
1.1.11	Size of Application	500 Mo max (Unity3D)
1.1.12	Programming language	C# and Java script for Unity 3D C++ for RealXtend.
1.1.13	Consistency between interface and GUI	Geometry, visual and others feedback
1.1.14	Vertices per cam scene	Several millions max PC / 100.000 max mobile. In case of CAVE, divide by the number of screens.

1.1.15	Vertices per object	64.000 max (warning! Unity convert all polys to tris)
1.1.16	Avatar mesh body	3000 polys max
1.1.17	Fill Rate	GPU processing bound / Example GeForce 8600M GT: 3800 MPix/s
1.1.18	Mesh format	FBX, .dae (Collada), .3DS, .dxf and .obj files After converting: Max, Maya, Blender, Cinema4D, Modo, Lightwave & C heetah3D files.
1.1.19	Skeleton animation format	Position and orientations of predefined joints.

6.1.3 Requirements of component 1.2: Display systems

The display systems will be different depending on the use-cases and the targeted platforms for the different 3DLive users. The Indoor H-E users may use a complete immersive system (CAVE like), while other may use 3D TVs or projectors and outdoor users may use mobile devices and AR Glasses.

6.1.3.1 Functional requirements of component 1.2: Display Systems

Req id	**Requirement Designation**	**Criteria**
1.2.1	Definition	HD for TV/CAVE systems. AR Glasses can display a >640x480 def.
1.2.2	Brightness	AR glasses need a high brightness in order to have a visible image.
1.2.3	Frequency	120Hz when stereoscopy needed

1.2.4	Synchronisation	Stereo glasses have to be synchronized with 3D displays
1.2.5	Distance from users	For 3D TVs, depending on the size of the screen, the user should respect a certain distance.
1.2.6	Tracking	No Interferences IR/Head tracking to enable immersion in the CAVE
1.2.7	Stereoscopy	The active stereoscopy 120Hz will be enabled for CAVE and 3D screens.

6.1.3.2 Non Functional requirements of component 1.3: Display Systems

Req id	**Requirement Designation**	**Criteria**
1.2.8	Field of view	≥ 60° for wide screens / AR devices (CAVE provide full FOV) Non applicable for mobile
1.2.9	Wireless data transfer	AR glasses can be connected wireless if the latency is not too important.
1.2.10	Comfort	The comfort must be correct. For AR glasses, they should not be too invasive. For tablets/Smartphone, the use must be adapted function of what is displayed.
1.2.11	Eye comfort	The stereoscopy must not be disturbing. For AR glasses, the image displayed must not fatigue the eye.
1.2.12	Compatible platforms	The applications displayed will be developed on Unity3D and RealXtend. The devices must support this.

1.2.13	Battery life/charging	Mobile displays must have a battery life>8h, and fast to charge.
1.2.14	Affordability	Depending on low-end/high-end the devices must be affordable by middle class/companies.

6.1.4 Requirements of component 1.3: Rendering Hardware

The rendering hardware has an important role as a component. It will actually define if the computers used for rendering will be able to render properly the applications in the different display systems.

6.1.4.1 Functional requirements of component 1.3: Rendering Hardware

Req id	**Requirement Designation**	**Criteria**
1.3.1	Amount of outputs	For SASCube+: 3 PCs using 2 projectors, 1 PC using 1 projector. (Min 2 outputs for graphic card). For TV system: 1 output min. For mobile devices: built in. For simulation on PC: 4 outputs (with 4 screens needed).
1.3.2	Stereo	Supported on indoor displays.

6.1.4.2 Non Functional requirements of component 1.3

Req id	**Requirement Designation**	**Criteria**
1.3.3	Rendering capabilities	Up to 500000 triangles.
1.3.4	Resolutions supported	Depending on equipment. HD preferred.

1.3.5	Output type	Depending on equipment.

6.1.5 Requirements of component 1.4: Sensory-motor interfaces

The sensory-motor interfaces are mainly divided into two sub components: the sensors and the devices. The sensors aim to retrieve all the different data flows from the users' movements and interactions. The devices are to bring the feedback of a real experience, like the simulators for haptic or audio feedbacks.

6.1.5.1 Functional requirements of component 1.4: Sensory-motor Interfaces

Req id	**Requirement Designation**	**Criteria**
1.4.1	Dimensions	The equipment used indoor have the constraint of the use in the CAVE (dimensions 2m x 2m x 2m).
1.4.2	Update Rate	The sensors must have a sufficient update rate to enable real time interactions. (The update rate is different whether it is possible to interpolate data without disturbing real time rendering).
1.4.3	Accuracy	The data from the sensors must be accurate. GPS around 1 or 2 meters. Angular data around 1°.
1.4.4	Audio	Outdoor users can hear stereo sounds thanks to a headset. Indoor users will have 5.1 audio rendering to increase immersion.

6.1.5.2 Non-functional requirements of component 1.4: Sensory-motor Interfaces

Req id	Requirement Designation	Criteria
1.4.5	Maintainability	Rechargeable batteries for wireless devices. All devices easy to use without much configuration
1.4.6	Max weight	Low-End ski device (WiiBB 150 kg)
1.4.7	Ergonomics	The different indoor sports equipments must provide ergonomics closed to real sports experience.
1.4.8	Range	Wireless sensors may have a range > 5m
1.4.9	Communication	Wireless (Wi-Fi, Bluetooth) or wired
1.4.10	Security	Simulators not risky the 3DLive users. No accident accepted.

6.1.6 Requirements of component 1.5: Social Platform

This component will have a major role in the social interactions between the followers and the users. Followers will need to communicate with one another but they will be able to encourage the 3DLive users during an experiment/

6.1.6.1 Functional requirements of component 1.5: Social Platform

Req id	Requirement Designation	Criteria
1.5.1	Accessibility	Accessible from anywhere in the world, on most of the platforms (Personal Computers, tablets...) thus it must be hosted on a website.

1.5.2	Profiles	The profiles of the followers must have several pieces of informatio1. The followers must log in with their profile/password to have access to interactions
1.5.3	Interactions	Followers can interact with one another. Followers can send small messages/emoticons to users.

6.1.6.2 Non-functional requirements of component 1.5: Social Platform

Req id	**Requirement Designation**	**Criteria**
1.5.4	Graphical Content	Based on existing Animation Putting Content. Keep a uniform Graphic Guidelines
1.5.5	Database	If possible, connected to the PATIO user database.
1.5.6	Communications	From the rendering engine to a website. Maybe PHP POST/GET events adapted

6.1.7 Requirements of component 1.6: Evaluation Tool

The Evaluation Tool is related to the experiments lead in the 3DLive project. All the different metrics and equipment used will be finally defined in the description of the experiments.

6.1.7.1 Functional requirements of component 1.6: Evaluation Tool

Req id	**Requirement Designation**	**Criteria**
1.6.1	Metrics	Metrics defined in the WP4 description of the experiment

6.1.7.2 Non-functional requirements of component 1.6: Evaluation Tool

Req id	Requirement Designation	Criteria
1.6.2	Protocol	AMQP, (ECC custom RabbitMQ implementation)

6.1.8 Requirements of component 1.7: User Interface

The User Interfaces of the 3DLive applications have to enable users from everywhere to use easily indoor or outdoor platforms. The interactions and the visual aspect will be considered as essential stuff in the design of the applications.

6.1.8.1 Functional requirements of component 1.7: User Interface

Req id	**Requirement Designation**	**Criteria**
1.7.1	Ergonomics	The UI must be understandable by users not used to technology. The visual feedback must be insured at each interaction.

6.1.8.2 Non functional requirements of component 1.7: User Interface

Req id	**Requirement Designation**	**Criteria**
1.7.2	Graphic Guidelines	The different applications must follow the same Graphic Guidelines.

6.1.9 Rendering and Visualization: Traceability Matrix

Req / Func	**Relationship**	Req 1.1.1	Req 1.1.2	Req 1.1.3	Req 1.1.4	Req 1.1.5	Req 1.1.6	Req 1.1.7	Req 1.1.8	Req 1.1.9	Req 1.1.10	Req 1.1.11	Req 1.1.12	Req 1.1.13	Req 1.1.14	Req 1.1.15	Req 1.1.16	Req 1.1.17	Req 1.1.18	Req 1.1.19
Relationships																				
F1.**1.1**		X	X						X	X			X							
F1.1.2				X	X		X			X	X	X	X		X	X		X	X	
F1.1.3		X	X	X					X				X							
F1.1.4				X			X				X	X	X		X	X	X	X	X	
F1.1.5		X	X						X				X		X					
F1.1.6				X			X				X	X	X		X	X	X		X	X
F1.1.7				X	X	X	X	X			X	X	X		X					X
F1.1.8				X	X	X	X				X	X	X		X					
F1.1.9				X	X	X	X	X			X	X	X		X					
F1.1.10						X	X							X						
F1.1.11						X	X							X						
F1.1.12				X																
F1.1.13				X																
F1.1.14				X	X								X							
F1.1.15				X	X	X	X	X	X				X							

Req / Func	Relationship	Req 1.2.1	Req 1.2.2	Req 1.2.3	Req 1.1.4	Req 1.2.5	Req 1.2.6	Req 1.2.7	Req 1.2.8	Req 1.2.9	Req 1.2.10	Req 1.2.11	Req 1.2.12	Req 1.2.13	Req 1.2.14	Req 1.3.1	Req 1.3.2	Req 1.3.3	Req 1.3.4	Req 1.3.5
Relationships																				
F1.**2.1**		X		x	X	x	X	x				X	x		X					
F1.2.2		X		X	X	X	X	X				X	X		X					
F1.2.3		x		X	x	X	x	X				X	X		X					
F1.2.4		X	x						X	x	X	X	x	x	X					
F1.2.5		X	X						X	X	X	X	X	X	X					
F1.2.6		x	X						x	X	x	x	X	X	X					
F1.3.1																x	x	x	x	x
F1.3.2																x	x	x	x	x
F1.3.3																		x	x	x

Func \ Req	**Relationship**	Req 1.4.1	Req 1.4.2	Req 1.4.3	Req 1.4.4	Req 1.4.5	Req 1.4.6	Req 1.4.7	Req 1.4.8	Req 1.4.9	Req 1.4.10	Req 1.5.1	Req 1.5.2	Req 1.5.3	Req 1.5.4	Req 1.5.5	Req 1.5.6	Req 1.6.1	Req 1.6.2	Req 1.7.1	Req 1.7.2
Relationships																					
F1.4.1			X	X		X			X	X											
F1.4.2		X	X	X		X		X	X	X	X										
F1.4.3		X	X	X		X			X	X											
F1.4.4		X	X	X		X	X	X	X	X	X										
F1.4.5								X			X										
F1.4.6		X						X			X										
F1.4.7		X			X	X															
F1.5.1												X			X		X				
F1.5.2												X	X	X		X	X				
F1.5.3												X	X	X		X	X				
F1.6.1																			X		
F1.6.2																		X	X		
F1.6.3																		X			
F1.7.1																				X	X
F1.7.2																				X	X

6.2 3D Reconstruction of Environment

6.2.1 Needs identified in the module 2: 3D Environment Reconstruction

The 3D-Live Environment Reconstruction Module (ERM) is related to the WP2 Task 2.1. The main design goal is to project features of the out-door environment into the virtual immersive environment allowing in-door players to share the similar experiences as out-door players. Environment information should be measured using the Bluetooth devices in real-time, and are then streamed into the 3D-Live system for environment reconstruction. The key (functional and non-functional) requirements as identified in the context of environment reconstruction are summarised in **Erreur ! Source du renvoi introuvable.** and **Erreur ! Source du renvoi introuvable.**. It is notable that some of the key requirements may apply to one or more components, but with different evaluation criteria. Apart from these key requirements, each component may also have additional particular requirements that will be listed in component-specific requirement tables.

Table 4. List of key functional requirements of 3D-Live Environment Reconstruction Module

Req id	Requirement Designation	Description
2.1.1	Connectivity & Networking	The 3D environment reconstruction process requires communications across distributed components. First of all, raw environment observations are transferred from sensor devices that are deployed at sites or supplied by third-party Web service need to some relay nodes (e.g. mobile phones), and then shipped to the 3D ERM for environment reconstruction. Therefore stable networking connectivity is one of the key functional requirements.
2.1.2	Data Integrity	The effectiveness of final environment model outputs relies on the raw observations. Therefore it is important to prevent data from loss, being corrupted, etc. while during data transference.

2.1.3	Synchronization	Data synchronization in time and spaces is another prerequisite to ensure accuracy of the environment model outputs. Data synchronization is not only applied to the data fusion process, but also applied when data is collected and transferred.
2.1.4	Extensibility	A component with extensibility should support custom implementation for custom communication protocols, custom algorithm implementations, etc.
2.1.5	Bandwidth	Bandwidth requirements relate on a per-component basis relating to their expected transmission frequency and payload.

Table 5. : List of key non-functional requirements of 3D-Live Environment Reconstruction Module

Req id	Requirement Designation	Description
2.1.6	Performance	The performance refers to those QoS metrics related to performing time, throughput, and data transmission.
2.1.7	Interoperability	Allows heterogeneous data can be exchanged via standard data format or heterogeneous service endpoint interactions via standard service interface definitions.
2.1.8	Platform	Requirements on software, platforms, and hardware.

6.2.2 Requirements of component 2.1: Gateway

The Gateway component is used to pairing with a sensor device or third-party service.

6.2.2.1 Functional requirements of Gateway

Req id	Requirement Designation	Criteria

2.1.1	Connectivity & Networking	The Gateway component must support either Inter-networking or Bluetooth connectivity.
2.1.2	Data Integrity	The Gateway component must guarantee data integrity without data loss.
2.1.3	Synchronization	The Gateway component should be able to synchronize updates from sensor devices or third-party service. To synchronize data from sensor devices, Bluetooth synchronization profiles may be supported when using Bluetooth sensor devices, while HTTP synchronization protocol (e.g. JSONP) can be used when using the third-party Web-based service.
2.1.4	Extensibility	The Gateway component should be extensible to use device-specific proprietary communication protocols.

6.2.2.2 Non-functional requirements of Gateway component

Req id	**Requirement Designation**	**Criteria**
2.1.8	Platform	The Gateway component should be able to work across different platforms (i.e. workstation or mobile platform).

6.2.3 Requirements of component 2.2: Sensor Agent

Sensor Agent (SA) is a software delegate of the sensor device or third-party service. On a sensor is paired, the SA registers itself to the Environment Reconstruction Service (ERS) by publishing the sensor capabilities. It then keeps listening to measurement updates and publishes them to the ERS.

6.2.3.1 Functional requirements of Sensor Agent

Req	**Requirement**	**Criteria**

id	**Designation**	
2.1.2	Data Integrity	The SA must ensure data integrity by avoiding data loss especially in the case of disruptive measurements. A possible solution is that the SA maintains a small-sized storage for caching 'short-lived' measurements.
2.1.3	Synchronization	The synchronization here means that the SA component should be responsive to the measurement updates in a time synchronous manner. The can be achieved by define an event-handling framework.

6.2.3.2 Non-functional requirements of Sensor Agent

Req id	**Requirement Designation**	**Criteria**
2.2.1	Interoperability	The SA should support OGC SensorML and OGC O&M specifications

6.2.4 Requirements of component 2.3: AMQP Interface

The AMQP interface is a client-side interface that is used to connect to and interact with the Message Bus backbone.

6.2.4.1 Functional requirements of AMQP Interface

Req id	**Requirement Designation**	**Criteria**
2.1.1	Connectivity & Networking	The AMQP interface component must support the TCP/IP protocol.

6.2.4.2 Non-functional requirements of AMQP Interface

Req id	Requirement Designation	Criteria
2.1.5	Bandwidth	Given that multiple network paths will be used to delivery environmental observations, each client connection should have enough bandwidth to send its own data payload to the ERS.

6.2.5 Requirements of component 2.4: Data Manager

The Data Manager (DM) is a component that consumes the incoming environmental observations and maintains the lifecycle of received observation data.

6.2.5.1 Functional requirements of Data Manager

Req id	Requirement Designation	Criteria
2.1.2	Data Integrity	The DM must ensure the data integrity while consuming the observation events with losing any data. The data integrity here also means the completeness of data within a specific time interval, because DM will only maintain the data that arrives within the scope of the time interval.
2.1.3	Synchronization	The DM must also synchronize the date time of the observation with the system time the DM is deployed to ensure data consistence.

6.2.5.2 Non-functional requirements of Data Manager

Req	Requirement	Criteria

id	Designation	
2.1.6	Performance	The DM component should provide stable and continuous throughput of data I/O operations.

6.2.6 Requirements of component 2.5: Sensor Data Fusion Service

The Sensor Data Fusion Service (SDFS) component is the key component that generates the environment model. The three-level processes involve data alignment, spatial interpolation and environment event assessment.

6.2.6.1 Functional requirements of Sensor Data Fusion Service

Req id	Requirement Designation	Criteria
2.1.2	Data Integrity	The SDFS takes the point observations as input and estimate values of unobserved points. Therefore the SDFS must ensure the data integrity without data loss of the point-based samples.
2.1.3	Synchronization	The SDFS must implement the data pre-processing facility (level 1 processing) to alignment observations in time and space.

6.2.6.2 Non-functional requirements of Sensor Data Fusion Service

Req id	Requirement Designation	Criteria
2.1.6	Performance	Data fusion processes are of computational complexity. In order to ensure close to ‘real-time’ delivery of the environment model, the SDFS

		component should reduce the computational complexity while maintaining reasonable accuracy.

6.2.7 Requirements of component 2.6: Live Environment Modeller

Live Environment Modeller (LEM) is a component that integrates the environment model outputs with the static 3D models and generates a single 3D model that can be rendered by 3D-Live render engines.

6.2.7.1 Functional requirements of Live Environment Modeller

Req id	**Requirement Designation**	**Criteria**
2.1.2	Data Integrity	The LEM component must ensure the fidelity of the environment model during processing.

6.2.7.2 Non-functional requirements of Live Environment Modeller

Req id	**Requirement Designation**	**Criteria**
2.1.6	Performance	The LEM component should ensure certain system performance such that the modelling process won’t introduce significant delays.

6.2.8 3D Reconstruction of Environment Traceability matrix

Req / **Func**	**Relationships**	**Req 2.1.1**	**Req 2.1.2**	**Req 2.1.3**	**Req 2.1.4**	**Req 2.1.5**	**Req 2.1.6**	**Req 2.1.7**	**Req 2.1.8**
Relationships	22	3	5	4	1	1	5	2	1
F2.1.1	1	X							
F2.1.2	1	X							
F2.1.3	4		X	X	X				X
F2.2.1	1							X	
F2.2.2	2			X				X	
F2.2.3	2		X				X		
F2.3.1	2	X				X			
F2.4.1	3		X	X			X		
F2.5.1	2		X	X					
F2.5.2	1						X		
F2.5.3	1						X		
F2.6.1	2		X				X		

6.3 Body 3D Reconstruction

6.3.1 Needs identified in the module 3: Body 3D Reconstruction

Module 2 encompasses two components, namely the Animation and the Reconstruction.

6.3.2 Requirements of component 3.1: Animation

6.3.2.1 Functional requirements of component Animation

Req id	**Requirement Designation**	**Criteria**
3.1.1	Bandwidth	The skeleton information that needs to be transmitted in real time from the HE user to LE user, in order the HE user's avatar to be animated, is about 4KB per second. Thus, there are no significant bandwidth requirements in this case.
3.1.2	Frame rate	The Kinect is offering its streams at a frame rate of 30fps. Thus, the animated avatar shall have around 30fps.
3.1.3	Motion Mapping	Accurate mapping of the joint's positions on the avatar, by forcing constant geodesic distances between adjacent joints.

6.3.2.2 Non-functional requirements of component Animation

Req id	**Requirement Designation**	**Criteria**
3.1.4	Infrared interference	Installing the Kinect sensors in a way that minimizes the infrared interference among them.
3.1.5	Full body capturing	The capturing setup should allow for full body capturing for each Kinect.
3.1.6	Occlusion	The positions of the Kinect sensors should be such that (self-) occlusions of the user are minimized.

6.3.3 Requirements of component 3.2: Reconstruction

6.3.3.1 Functional requirements of component 3D reconstruction

Req id	Requirement Designation	Criteria
3.2.1	Frame rate	The maximum frame rate is the one provided by the Kinect sensor (30fps). However, due to processing complexity, the anticipated Framerate threshold will be considered at least 5fps, although, practically, it shall be around 10fps.
3.2.2	Bandwidth	3D reconstruction meshes size up to several MBs. (latest estimates 4MB/frame). Given the pre-specified framerate that enables real-time interaction of remote users, it is obvious the need for compressing the 3D reconstruction mesh (see compression module for technical details).

6.3.3.2 Non-functional requirements of component 3.2

Req id	Requirement Designation	Criteria
3.2.3	Infrared interference	Installing the Kinect sensors in a way that minimizes the infrared interference among them.
3.2.4	Full body capturing	The capturing setup should allow for full body capturing for each Kinect.
3.2.5	Occlusion	The positions of the Kinect sensors should be such that (self-) occlusions of the user are minimized.
3.2.6	Programming Language	Given the need for high frame rates, and the processing complexity of the task of 3D reconstruction, it is required to make use of all available resources, that a GPU enabled PC could

		offer. Thus, the requirement in this case is to code in CUDA.

6.3.4 Requirements of component 3.3: ECC metrics

6.3.4.1 Functional requirements of component ECC metrics

Req id	**Requirement Designation**	**Criteria**
3.3.1	Skeleton-Joint difference	Set a threshold (in mm's) for defining good matches between depth map and actual joint position in the Z axis
3.3.2	OpenNi joint Confidence values	More than 80% of joints should be able to be tracked with high confidence
3.3.3	Reconstruction rate	>5fps
3.3.4	Reconstruction visual quality	Better than 17dB with regards to reference sequences

6.3.4.2 Non-functional requirements of component 3.2

Req id	**Requirement Designation**	**Criteria**
3.3.5	Visual Quality	An extra, calibrated camera will be placed as part of the setup. Human's 3D reconstructions from other sensors, will be virtually projected on the corresponding 2-D plane and will be compared against RGB values returned by this camera. Ideally, differences should be very small. This has to be measured.

6.3.5 Body 3D Reconstruction Traceability matrix

Req / **Func**	**Relationships**	**Req 3.1.1**	**Req 3.1.2**	**Req 3.1.3**	**Req 3.1.4**	**Req 3.1.5**	**Req 3.1.6**	**Req 3.2.1**	**Req 3.2.2**	**Req 3.2.3**	**Req 3.2.4**	**Req 3.2.5**	**Req 3.2.6**	**Req 3.3.1**	**Req 3.3.2**	**Req 3.3.3**	**Req 3.3.4**	**Req 3.3.5**
Relationships			5	2	6	6	3	4	1	4	6	3	3	1	1	1	1	1
F3.1.1	3		X		X					X								
F3.1.2	5		X		X	X				X	X							
F3.1.3	7		X		X	X	X			X	X	X						
Fn 1.4	2		X	X														
F3.2.1	2					X					X							
F3.2.2	4					X		X			X		X					
F3.2.3	6					X	X	X			X	X	X					
F3.2.4	7				X		X	X	X	X		X	X					
F3.3.1	3		X					X								X		
F3.3.2	1			X														
F3.3.3	4				X									X			X	X
F3.3.4	4				X	X					X				X			

6.4 Activity Recognition

6.4.1 Needs identified in the module 4: Activity Recognition

Activity Recognition for the three different use-cases (jogging, skiing, and golfing) will be based on the same core algorithms for estimating actions. The algorithms that will be developed will have the ability to merge from one to multiple different modalities (3D information coming from depth sensors, body-attached sensors, etc.), as long as proper training has taken place. More in particular, in the jogging scenario, the human skeleton data are expected to constitute the only source of information for characterizing a jogging activity as slow or fast and whether it is done in a correct manner. Similar will be the case for the skiing scenario, while golf will utilize body-attached sensors and information coming from the Virtual Environment itself.

6.4.2 Requirements of component 4.1: Activity recognition

6.4.2.1 Functional requirements of component 4.1

Req id	**Requirement Designation**	**Criteria**
4.1.1	Motion Extraction	The extracted 3D data need to be as reliable as possible for accurate estimates. The corresponding evaluation metric in ECC (see below) will take care for evaluating proper metrics (good matches between depth map and actual joint position – thresholds in mm's to be defined - in the Z axis and at least 80% of joints tracked with high confidence).
4.1.2	Synchronization	Data from different kinds of sensors must be synchronized and processed on a frame-by-frame basis.

6.4.2.2 Non-functional requirements of component 4.1

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Req id	Requirement Designation	Criteria
4.1.3	Infrared interference	Installing the Kinect sensors in a way that minimizes the infrared interference among them.
4.1.4	Full body capturing	The capturing setup should allow for full body capturing for each Kinect.
4.1.5	Occlusion	The positions of the Kinect sensors should be such that (self-) occlusions of the user are minimized.
4.1.6	Orientation of Depth Sensors	The depth sensors should be placed horizontally, due to the way skeletons are extracted

6.4.3 Requirements of component 4.2: ECC metrics

6.4.3.1 Functional requirements of component ECC metrics

Req id	Requirement Designation	Criteria
4.2.1	Skeleton-Joint difference	Set a threshold (in mm's) for defining good matches between depth map and actual joint position in the Z axis
4.2.2	OpenNi joint Confidence values	More than 80% of joints should be able to be tracked with high confidence

6.4.4 Activity Recognition Traceability matrix

Req / **Func**	**Relationships**	**Req 4.1.1**	**Req 4.1.2**	**Req 4.1.3**	**Req 4.1.4**	**Req 4.1.5**	**Req 4.1.6**	**Req 4.2.1**	**Req 4.2.2**
Relationships		3	1	3	3	2	1	3	3
F4.1.1	3	X		X			X		
F4.1.2	6	X		X	X	X		X	X
F4.1.3	2	X		X					
F4.1.4	-								
F4.1.5	1		X						
F4.1.6	2							X	X
F4.2.1	3				X	X		X	
F4.2.2	2				X				X

6.5 Voice Communications Module

6.5.1 Needs identified in the module 5: Voice Communications

The *Voice Communications* refers to the **Voice Communications** between the users, and is then different from the *Data Compression and transmission* module. According to scenarios, the user has to feel immersed in a virtual environment while communicating with other 3DLive users. Because of the fact that the other remote users are rendered in the virtual environment while experiencing the platform, the main needs are in terms of supporting real time, and playing the sounds from where they should virtually come. One can identify here particulars needs of bandwidth and 3D sound processing.

Needs	**Details**
Bandwidth	480 kbps up to 3 simultaneous users
3D sounds	In order to maximize the presence feeling, audios sounds will be processed into 3D sound. Consequently users will be able to feel voices of remote users where they are rendered in the mixed environment. For instance: the outdoor user can hear in the left listener a remote user standing virtually on his left (and he can see him thanks to augmented reality). On the opposite, the indoor user will take advantage of a 5.1 sound system to here all around him remote users speeking from everywhere around him in the virtual environment.

6.5.2 Requirements of component 5.1: Indoor communication system

6.5.2.1 Functional requirements of component 5.1

Req id	**Requirement Designation**	**Criteria**
5.1.1	Spatial sound	In order to generate the best presence feeling, the speakers have to be 5.1 , as the sound card

5.1.2	Mobility	The speakers will be externally fixed, the microphone has to be wireless

6.5.2.2 Non-functional requirements of component 5.1

Req id	Requirement Designation	Criteria
5.1.3	Autonomy	>5h for the microphone
5.1.4	Range	5 meters
5.1.5	Dimensions	Speakers’ dimensions have to be acceptable to be set up in the CAVE system. Microphone has not to be too intrusive (lavaliere microphone).

6.5.3 Requirements of component 5.2: Outdoor communication system

6.5.3.1 Functional requirements of component 5.2

Req id	Requirement Designation	Criteria
5.2.1	Mobility	Wireless headset with an integrated microphone
5.2.2	Spatial sound	Stereo, 2.1

6.5.3.2 Non-functional requirements of component 5.2

Req id	Requirement Designation	Criteria
5.2.3	Autonomy	>5h
5.2.4	lightness	<200g
5.2.5	Range	10 meters from the tablet

6.5.4 Requirements of component 5.3: Voice Communications client

6.5.4.1 Functional requirements of component 5.3

Req id	Requirement Designation	Criteria
5.3.1	Activation system	Automatic voice activation

6.5.4.2 Non-functional requirements of component 5.3

Req id	Requirement Designation	Criteria
5.3.2	Programming language	C# in Unity3D, C++ in RealXtend
5.3.3	In-app	Communication client must be internal
5.3.4	Compatibility	Communication client must be compatible regardless of the engine.

6.5.5 Requirements of component 5.4: Voice Communications server

6.5.5.1 Functional requirements of component 5.4

Req id	Requirement Designation	Criteria
5.4.1	Channels size	Up to 6 channels

6.5.5.2 Non-functional requirements of component 5.4

Req id	Requirement Designation	Criteria
5.4.2	Programming language	C# in Unity3D, C++ in RealXtend
5.4.3	Application type	The server must be a separate app.

6.5.6 Requirements of component 5.5: Evaluation tool

6.5.6.1 Functional requirements of component 5.5

Req id	Requirement Designation	Criteria
5.5.1	Data format	Data format must match the ECC standard protocols
5.5.2	Connection & networking	AMQP interface must Support TCP/IP to connect to ECC.

6.5.7 Voice Communications Traceability matrix

Req / Func	Relationships	Req 5.1.1	Req 5.1.2	Req 5.1.3	Req 5.1.4	Req 5.1.5	Req 5.2.1	Req 5.2.2	Req 5.2.3	Req 5.2.4	Req 5.2.5	Req 5.3.1	Req 5.3.2	Req 5.3.3	Req 5.3.4	Req 5.4.1	Req 5.4.2	Req 5.4.3	Req 5.5.1	Req 5.5.2
Relationships		1	2	1	1	2	2	2	2	2	2	1	1	2	2	1	2	2	1	1
F5.1.1	2		X			X														
F5.1.2	5	X	X	X	X	X														
F5.2.1	5						X	X	X	X	X									
F5.2.2	5						X	X	X	X	X									
F5.3.1	2													X	X					
F5.3.2	4											X	X	X	X					
F5.4.1	3															X	X	X		
F5.4.2	2																X	X		
F5.5.1	2																		X	X

6.6 Data compression and Transmission

6.6.1 Needs identified in the module 6: Data Compression and Transmission

This module encompasses four components, namely the Compression, Decompression, Transmission and ECC Metrics extraction

6.6.2 Requirements of component 6.1: Compression

The requirements for the Compression component are the hardest constraints that the 3DLive platform will have to handle. The frame rate for heavy data compression has to be insured to guarantee real time aspects.

6.6.2.1 Functional requirements of component 6.1

Req id	Requirement Designation	Criteria
6.1.1	Frame rate of Human 3D Reconstruction	3D reconstruction (preceding coding) should enable near real time data generation. <200ms per frame for 3D reconstruction allows for <300ms execution time per frame (3D reconstruction + compression).
6.1.2	Registration	Point Clouds, extracted from different sensors, should be well registered with each other, so that a realistic human silhouette is extracted and fed into the human-motion-dependent encoder.
6.1.3	Audio Frame rate	The voice compression should be near real time using the common Speex codec. It must not slow down the applications (application frame rate must remain $\geq$ 30 fps).

6.6.2.2 Non-functional requirements of component 6.1

Req id	Requirement Designation	Criteria
6.1.4	Full body capturing	The physical depth sensors setup should allow for full body capturing for each Kinect.
6.1.5	Occlusion	The positions of the Kinect sensors should be such that (self-) occlusions of the user are minimized.
6.1.6	Programming Language	Given the need for high frame rates, and the processing complexity of the task of 3D reconstruction, it is required to make use of all available resources, that a GPU enabled PC could offer. Thus, the requirement in this case is to code in CUDA. The compression of the voice will take place in the rendering engines. The programming languages are C# for Unity3D implementation and C++ for RealXtend implementation

6.6.3 Requirements of component 6.2: Decompression

The requirements for the Decompression component are the hardest constraints that the 3DLive platform will have to handle. The frame rate for heavy data compression has to be insured to guarantee real time aspects.

6.6.3.1 Functional requirements of component 6.2

Req id	Requirement Designation	Criteria
6.2.1	Bandwidth	The Network bandwidth has to enable transmission of needed data-flows. (At least 15Mps download).
6.2.2	Frame rate	The voice decompression should be near real time using the common Speex codec. It must not slow down the applications (application frame rate must

		remain ≥ 30 fps).

6.6.3.2 Non-functional requirements of component 6.2

Req id	Requirement Designation	Criteria
6.2.3	Programming Language	Given the need for high frame rates, and the processing complexity of the task of 3D reconstruction, it is required to make use of all available resources, that a GPU enabled PC could offer. Thus, the requirement in this case is to code in CUDA. The compression of the voice will take place in the rendering engines. The programming languages are C# for Unity3D implementation and C++ for RealXtend implementation.

6.6.4 Requirements of component 6.3: ECC metrics

The ECC metrics component will report the different values measured to insure a QoS for the 3DLive platform.

6.6.4.1 Functional requirements of component 6.3

Req id	Requirement Designation	Criteria
6.3.1	Compression rate	Compression rates should achieve figures better than 1/10

6.3.2	Compression time	Time for compression should be lower than 300ms (on average)

6.6.5 Requirements of component 6.4: Transmission

6.6.5.1 Functional requirements of component 6.4

Req id	Requirement Designation	Criteria
6.4.1	Bandwidth	The bandwidth must be sufficient to transmit the different data flows. (15Mbps upload and download).

6.6.5.2 Non functional requirements of component 6.4

Req id	Requirement Designation	Criteria
6.4.2	Programming language	BOOST ASIO: the library is in C++. The server and client programs will be developed in C++. AMQP: Depending on the side the development is done, one can consider the use of JAVA, C# or C++. TeamSpeak: different languages are available. RealXtend will use C++ while Unity3D will use C# to implement. OSC: different libraries are available in C++ or C#.
6.4.3	End-to-end delay	Depending on the data transmitted, the lowest end-to-end delay should be reached. For human 3D reconstructions, this should be less than 500ms per frame. For lighter packets 150ms is the goal to get real time remote data processed in the mixed environments.

6.6.6 Data Compression and Transmission Traceability matrix

Func	Relationships	Req.6.1.1	Req 6.1.2	Req 6.1.3	Req 6.1.4	Req 6.1.5	Req 6.1.6	Req 6.2.1	Req 6.2.2	Req 6.2.3	Req 6.3.1	Req 6.3.2	Req 6.4.1	Req 6.4.2	Req 6.4.3
Relationships		2	2	1	2	2	3	2	1	2	1	1	4	4	4
F6.1.1	2				X	X									
F6.1.2	2				X	X									
F6.1.3	3	X	X				X								
F6.1.4	3	X	X				X								
F6.1.5	2			X			X								
F6.2.1	1									X					
F6.2.2	1									X					
F6.2.3	2								X	X					
F6.3.1	2							X			X				
F6.3.2	3						X	X				X			
F6.4.1	3												X	X	X
F6.4.2	3												X	X	X
F6.4.3	3												X	X	X
F6.4.4	3												X	X	X

6.7 Evaluation Module

6.7.1 Needs identified in the module 7: Evaluation

The principal requirements identified for the evaluation are those relating to work package 4, in which 3D-LIVE systems will be experimentally tested (T4.1) and then evaluated using the captured QoS and QoE data (T4.2). Specifically relating to the experimentation process we expect to use "the tools provided by EXPERIMEDIA to support the experiment lifecycle, each use case scenario will explore innovative scenario ideas while assessing their value and to discover emerging users' behaviour and usages". Both quantitative and qualitative methods will be used in the analysis of QoS and QoE data collected during experimentation. The analysis will include assessments of "the level of usefulness, emerging uses, users' behaviour, socio-cognitive, as well as evaluating the potential level of adoption by user communities".

Within this scope, the evaluation module's requirements primarily focus on the support of 3D-LIVE experimental processes and the instrumentation of components and users. The capabilities identified here include exercising control over experimental phases; the collection and storage of experimental metrics; and the management of data for subsequent analysis. For a more detailed description of the process and metric support, see the "Report on the conceptual design of the 3D-LIVE Platform" deliverable. A summary of the 'driving' requirements for the evaluation module are provided below:

Driving requirement ID	**Requirement Designation**	**Criteria**
dr1	3D-LIVE system performance (QoS)	It must be possible to capture and record aspects of the system's functional performance during an experiment.
dr2	3D-LIVE system usage (QoS)	It must be possible to capture and record the comparative usage of system functionality during an experiment.
dr3	User interactions (QoE)	It should be possible to capture and record a

		(pre-defined) collection of user behaviours/interactions within the 3D-LIVE system during an experiment.
dr4	User perceptions (self-report QoE)	It should be possible to capture and record the subjective reports of users (perceptions & attitudes) relating to different aspects of their experience with the 3D-LIVE system.

In the following sections, the functional requirements of each of the evaluation module's components have been enumerated based the driving requirements listed above.

6.7.2 Requirements of component 7.1: AMQP Interface

6.7.2.1 Functional requirements of AMQP Interface

Req id	Requirement Designation	Criteria
7.1.1	RabbitMQ connection	A publicly accessible RabbitMQ server must be available to act as a message bus.

6.7.2.2 Non-functional requirements of AMQP Interface

Req id	Requirement Designation	Criteria
7.1.2	TCP connection	The AMQP interface must have a stable TCP internet connection.
7.1.3	Network bandwidth	Multiple network paths will be used to deliver metric data; each client connection must have enough bandwidth to send its own metric data payload to the ECC.
7.1.4	Deployment platform	The AMQP interface must execute within a Java 1.6; C# Framework 3.5 or Qt4.0/C++ platform.

6.7.3 Requirements of component 7.2: ECC API

6.7.3.1 Functional requirements of ECC API

Req id	Requirement Designation	Criteria
7.2.1	QoS metric specification	It must be possible to specify appropriate 3D-LIVE QoS metrics for capture by the ECC
7.2.2	QoE metric specification	It must be possible to specific appropriate 3D-LIVE QoE metrics for capture by the ECC
7.2.3	QoS metric delivery	It must be possible to send QoS metrics to the ECC during an experiment.
7.2.4	QoE metric delivery	It should be possible to send appropriate QoE metrics to the ECC during an experiment.

6.7.3.2 Non-functional requirements of ECC API

Req id	Requirement Designation	Criteria
7.2.5	Development platform	The ECC API must be used with a Java 1.6; C# Framework 3.5 or C++/Boost platform

6.7.4 Requirements of component 7.3: Experiment Monitoring System (EM)

6.7.4.1 Functional requirements of EM

Req id	**Requirement Designation**	**Criteria**
7.3.1	AMQP connection	It must be possible for the EM (part of the ECC) to connect to a RabbitMQ server using the AMQP interface component.

6.7.4.2 Non-functional requirements of EM

Req id	**Requirement Designation**	**Criteria**
7.3.2	ECC deployment	The EM must be packaged as part of the ECC system (including EDM and dashboard)
7.3.3	Run-time	The EM must run on a Java 1.6 run-time.

6.7.5 Requirements of component 7.4: Experiment Data Management (EDM)

6.7.5.1 Functional requirements of EDM

Req id	Requirement Designation	Criteria
7.4.1	Metric storage	It must be possible for the EDM to store appropriate QoS/QoE metric data.
7.4.2	Metric retrieval	It must be possible for the EDM to retrieve previously stored QoS/QoE metric data.

6.7.5.2 Non-functional requirements of EDM

Req id	Requirement Designation	Criteria
7.4.3	Database support	The EDM (part of the ECC package) must be deployed with an appropriately configured PostgreSQL 9.2 database.
7.4.4	Run-time	The EDM must run on a Java 1.6 run-time with JDBC driver support for PostgreSQL 9.2.

6.7.6 Requirements of component 7.5: ECC Dashboard

6.7.6.1 Functional requirements of ECC Dashboard

Req id	**Requirement Designation**	**Criteria**
7.5.1	Experiment control (instrumentation)	It must be possible for the experimenter to control the collection of experimental metrics from the 3D-LIVE components connected to the ECC.
7.5.2	Experiment metric visualisation	It must be possible for the experimenter to view the arrival of metrics generated during the course of an experiment.
7.5.3	Experiment metric storage	It must be possible for the ECC to store the metric data captured in a database.
7.5.4	Experiment metric analysis	It must be possible for the experiment to select metric data sets to export for analysis by a third party tool.

6.7.6.2 Non-functional requirements ECC Dashboard

Req id	**Requirement Designation**	**Criteria**
7.5.5	Run-time	The ECC dashboard must run within a Java 1.6 run-time, deployed as a WAR on Apache Tomcat 7.x
7.5.6	Supporting systems	The ECC dashboard must be connected to a PostgreSQL 9.2 database and a RabbitMQ 2.8.6 message bus.

6.7.7 Evaluation Traceability matrix

Req / Func	Relationships	Req 7.1.1	Req 7.2.1	Req 7.2.2	Req 7.2.3	Req 7.2.4	Req 7.3.1	Req 7.4.1	Req 7.4.2	Req 7.5.1	Req 7.5.2	Req 7.5.3	Req 7.5.4
Relationships		2	1	1	5	5	3	2	2	9	1	2	2
F7.1.1	3	X					X			X			
F7.2.1	3	X					X			X			
F7.2.2	2		X	X									
F7.2.3	3				X	X				X			
F7.2.4	2				X	X							
F7.2.5	3				X	X				X			
F7.2.6	3				X	X				X			
F7.2.7	3				X	X				X			
F7.3.1	2						X			X			
F7.4.1	3							X	X			X	
F7.4.2	3							X	X			X	
F7.5.1	2									X			X
F7.5.2	1									X			
F7.5.3	1										X		
F7.5.4	1												X

7 Needs and Requirements for the 3D-LIVE User Communities

7.1 Profiling of Users

One of the main objectives of the 3D LIVE project consists in studying and creating an appropriate user experience (UX) for the context of Tele-Immersive Environments and more particularly for Augmented Sport Applications. Those sports applications include jogging, skiing and golfing.

This section is intended to define user profiles to be used in recruiting people to the experimentation stage of 3 different use case scenarios (jogging, skiing and golfing).

7.1.1 User Profile

A user profile is a description of personal data associated with a specific user. A profile refers therefore to the explicit representation of a person's identity. A user profile can also be considered as the preferences of a user.

A profile can be used to store the description of the characteristics of person. This information can be exploited by recruiters taking into account the persons' characteristics and preferences.

Persons' preferences of sports activity will be utilized in recruiting people to experiment a User Driven Mixed Reality and Immersive (Twilight) platform as well as evaluate both the Quality of Experience (QoE) and Quality of Services (QoS).

7.1.2 User Profile definitions

A user profile represents a collection of personal data associated with a specific user. Therefore, it is the basis for any adaptive changes to the persons' behaviour. Which data is included in the profile depends on the applied use case scenario. It can include personal information such as users' names and ages, their interests of sports, their skill levels and their goals and plans to develop in particular sports, their preferences and their dislikes or other data about their behaviour in sports activity. Here in this document we consider only jogging, golfing and skiing as a sport activity.

There are four different types for users. Often a mixture of them is used for experiments.

Beginner user

Beginner users are the most basic kinds of users. Beginner user is someone who is just starting at something new to them, or has only recently started. Once they have learned how to do it they are normally willing to learn more. Users' preferences are not registered yet and learning processes are used to get started.

Active user

Active users are more up to date with their sports activity. Active users often have no formal training in their sports. Changes in their interests, their learning progress or interactions with different sports do influence their user profile. The profiles can thus be constantly updated and take the current needs and goals of the users into account.

Amateur user

Amateurs often have formal training in their sports, some amateur users may be considered as a semi-professional. For example, amateur users in sports such as golfing, skiing or running are regarded as having a lower level of ability than professional users. The recruiter therefore can make assumptions about a user even though there might be no data about specific sports, because demographic studies have shown that other users in this stereotype have the same characteristics.

Professional user

Professional user is a person who is engaged in a certain activity for compensation. In sports, a professional is someone who receives monetary compensation for participating.

Professional user profiles often represent only one particular user and therefore the recruiter can’t make assumptions about other users. In contrast to stereotype based user profiles they do not rely on demographic statistics but requires a specific profile for each user. Although users are professionals (and in many cases because of that) they do not want to carry or wear any extra equipment for experiments.

7.1.3 Demographic profile

Demographics are the quantifiable statistics of a given population. Demographics are also used to identify the study of quantifiable subsets within a given population. A demographic or demographic profile is a term used to describe a demographic grouping or as in this case of 3D LIVE, a sports segment.

Demographic profile typically involves age bands, social class bands and gender. In this case of 3D LIVE, social class can be dropped off and other profiles like skill level or favourite sport will be added.

A demographic profile can be used to determine where sports activity should be placed to achieve maximum number of participants.

Demographic profiles can include the following;

Gender:	Male / Female
Age group:	[15-25], [26-35], [36-45], [46-55], [56-65]
Height:	[150-160], [160-170], [170-180], [180-190], [190->]
Weight:	[40-50], [50-60], [60-70], [70-80], [80-90], [90->]
Skill level:	Beginner, Active, Amateur, Professional
Sport;	Jogging, Golfing, Skiing
Goals;	Exercise, Improve, Coach
Outdoors:	Yes / No
Indoors;	Gym / Home
Equipment:	Own / Rental
Used to new technologies/high-tech equipment:	Yes / No
Used / Participated to experiments;	Yes / No
Member of sports Club / Team:	Yes / No

Recruitment from total number of people in different demographical groups will be based on experiment to be tested.

First, total number of matches to the different demographical group will be divided by

- ➔ Behavioural groups (in sports in this case) and after that by
- ➔ Representative persons (selected individuals)

7.2 Recruitment of users

The recruitment of the 3DLive users must be done at the earlier stage of the project. To gather end-users that will experiment and co-design the 3DLive TIE, there are several possibilities.

One solution is to use existing living labs user communities and involve them into the project. This type of users is used to experiments and it can be easy to recruit.

A second possibility is to prospect for users in the different sport structures around the experiment sites. A presentation of the project can be done highlighting its outcomes regarding to specific sports activities. For instance, a presentation of the project made for the future users has to highlight the training and social aspects.

A third option is to create a kind of teaser of the project. This could be a little experiment including some representative components of the 3DLive TIE, and driven on the first 3DLive users. Videos and pictures could then feed the project Website and Social Networks as Facebook/Twitter/LinkedIn.

Anyway first users engaged can easily communicate by word of mouth from a person to another and 3DLive partners must tell them to do it, in order to get a representative sample of the population.

One must notice one important thing: users recruited for one use-case are pleased to participate to other 3DLive experiments.

7.2.1 Management of the community

To confirm the recruitment of one user, and to enable him to stay connected with other 3DLive users, a platform has to be set up. It is possible to do this on the 3DLive website. Users can subscribe to a discussions room on the website login with existing connection ids (like Facebook/Google...) then fill details on a profile page. These details are those needed by the experimenters, according to the profile definition. The most appropriate solution for the 3DLive project remains the use of the PATIO users ‘community platform, on which users can register to keep in touch with the 3DLive project.

Then 3DLive partners and users can feed discussions, publish news or feelings about the experiment they want to try, or have already tried, in order to have a living community.

7.2.2 Users for the Ski use-case

The involvement of users for the ski scenario can be done around every place close to the experiments. For outdoor users, the Schladming community manager can be involved to recruit local skiers (beginners or professional). The places that can be targeted to search users are skiing schools and every public places. As the experiments will take place during winter, two kinds of people will frequent the Schladming station: local people and tourists. The recruitment stage must focus on local people, in order to avoid the risk to lose users for experiments at the last minute. For indoor users, Schladming users can of course participate, but there will be trouble to reach indoor experiment places. Consequently, those users have to be recruited in France. To start near Laval, where the experiments will take occur, the targeted places for recruitment can be high schools, where generally students have time for this kind of activities and gym/sport structures.

7.2.3 Users for the Golf use-case

Both the Indoor and Outdoor experiments will occur in Laval for the Golf use-case. It means that the recruitment must focus on Laval and around users. The best place to engage users for this scenario is the Laval Golf Course itself. Some advertising can be done and 3DLive can count on the support of the Golf staff. Moreover, some kind of experiments as the "Augmented Putting" can be done to retain and gain users.

Based on meetings with the director of the Laval Golf course, the targeted users can be all golfers from various levels of skills. It was proposed to us to gather a group of at least 10 golfers including professionals, seniors and younger golfers. In any case neither a beginner nor a person who never played golf can be authorized by the green keeper to play on the golf course. Those people could just experiment 3DLive thanks to the simulator instead.

7.2.4 Users for the Jogging use-case

For the Jogging use-case, 3DLive can take advantage of the PATIO community to recruit users. In the case it is not sufficient; the process of recruitment can be done the same way than the two other use-cases.

8 Discussion and Conclusion

8.1 Discussion

The 3DLive project is an ambitious Research Project with many technical challenges to face. The main challenge is related to the Tele-Immersion. To establish a Tele-Immersive UX, the 3DLive modules deal with 3D Reconstruction of Humans and Environment.

The 3D Reconstruction of Humans in real time is a complicated research purpose and no stable technology (combination of hardware and software) has been developed yet capable of reconstructing a complete updating textured mesh of a person. 3DLive is going to explore the use of this concept by displaying in a remote immersive system a reconstructed user. Hence, we will have to tackle the problematic of reconstruction and compression of a textured mesh at one specific place, transmission of the coded mesh, decompression and rendering at the remote place. Each of these parts is challenging because the mesh must be realistic, transmitted with a sufficient frame rate and low latency, moreover the rendering must be consistent with the user experience. The target frame rate is >5fps, but even a low frame rate will be hard to reach depending on the computer capabilities and the network infrastructure set up at the different places concerned by transmission can impact on both the frame rate and latency. We will then have to assess how this reconstruction, even with a low frame rate, can improve the user experience. The other challenging part of the reconstructions of humans is the extraction of the skeleton of one user, and in both cases we will have to retrieve several kinds of data flows (positioning, orientation...etc) to properly render in the virtual world the reconstructed mesh or the animated avatar, in order to insure the consistency of the experience between the remote users in the twilight space. The tracking of outdoor movements will be also a difficult part since we want to retrieve the orientations of all joints, transmit the data to a server in order to animate an avatar in a 3D engine without data loss.

About the Reconstruction of the environment, 3DLive will propose a framework allowing the indoor users to visually feel the environmental conditions of the outdoor place. The 3D models of the different environments must be realistic and the changes (weather conditions and else) in the virtual environment must be realistic too, and done in real time according to real changes.

About the rendering part of this project, we have to be careful as the content will have to be adapted on several platforms, and sometimes specific platforms without any standard rules of design interface. For instance, the applications that will have to be rendered in the CAVE systems (in Oulu and in Laval which are different display technologies) the 3D and 2D content will have to be rendered specific ways. The same applies to the AR glasses, where users will have to see some augmented content but also interact with application. With the AR glasses, no real support exists to develop applications and tele immersion has not been deployed on such platforms. The other challenge of 3DLive identified here is correlated to the exploration of new usages on Augmented Reality glasses.

Finally the challenging item of the 3DLive platform is the management and the synchronisation of all the data flows to enable the users to feel immersed in the same experience.

8.2 Concluding Remarks

The 3DLive platform is based on an iterative design process, and the two sessions of experiments will be decisive for the final description of the architecture of the 3DLive framework. The documents D2.1 and D2.2 might be refined depending on our results concerning both Quality of Service and Quality of Experience. Moreover, the needs and requirements of the users have not been taken into account in this first deliverable as the co-creation activities are just starting. The first proposed platform is a consistent framework to demonstrate to those potential users the capabilities of such tele-immersive environments. It has been created thanks to internal workshops between the 3DLive partners and discussions with potential users at the early stage of the project. The outcomes of the different workshops and experiments with the users will lead us to modify this proposed design, improving or maybe downgrading sometimes the functionalities depending on the needs of the final users.

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10 APPENDIX A: Jogging Scenario

INTRODUCTION

The running scenario enables users to run together on the same track, regardless of whether they are indoors or outdoors.

In the running use case there will be exactly one real world user and one virtual world user, though the implementation and design work will be prepared for many more users jogging at the same time and place.

A community of users will be gathered, composed of runners willing to take part in the Experiential Design Process (co-creation, exploration, experimentation and evaluation).

This document presents several existing technologies and products that are part of our technological watch, as they constitute potential solutions in the 3D-live framework. They helped us in the design phases of the 3D-live platform; however, please note that all the devices mentioned in this scenario will not necessarily be used in the 3D-Live platform due to different reasons such as costs, lack of SDK or reliability.

OBJECTIVES

3D-Live main research goal is to investigate the impact of 3D Tele-Immersive Environment (3D-TIE) on people's behaviour and feelings when sportsmen (golfers, skiers, joggers) practice together from indoor and outdoor situations.

The main objectives of the running scenario are:

- Explore the technological feasibility of a 3D-TIE for Running;
- Embeds social aspects;
- Experiment the scenario appropriateness;
- Evaluate the user experience of runners immersed in 3D-TIE;
- Explore the "Twilight Space" (a space between Augmented Reality and Augmented Virtuality) impact on people behaviour and feelings.

The final and ambitious objective is to enable four "users" to experiment simultaneously the Running scenario, for the following reasons:

- To test high-end (displaying real-time full capture of a runner) and low-cost solutions (displaying an avatar animated just with the running speed information available);
- To integrate human live capture. It is not possible to capture the outdoor runner, as the technological platform to perform the live capture needs 4 Microsoft Kinect. If the outdoor runner does not wear AR glasses, only a second indoor runner could visualize the other indoor runner live capture).
- To test two technical solutions for the outdoor runner (low-cost and high end)

CHALLENGES

The running scenario gathering runners from indoor and outdoor situations has several options and related challenges, such as:

- How to render 3D model of the running track for the indoor user, when the outdoor user selects a route which is not predefined
- How to show the virtual user to the outdoor runner, or is the spatial audio enough to create feeling of co-presence?
- How to track accurately the elevation of the outdoor runner and reproduce it to the indoor user, without glitches?
- How to perform collision detection algorithms between avatars and real reconstructions?
- How to deal with recognizing running performance in real time, tackling a series of problems like data dimensionality and real time inference.
- How to compress bulky data of 3-D reconstructions of humans and transmit them over the network. Compression-Transmission-Decompression should allow for adequate coding and a satisfying visual result to the end user.
- Reconstructing motion and isosurface of a person running on a treadmill implies occlusions caused by different parts of the equipment or self occlusions. As a multi-Kinect framework will be adopted, novel algorithms for optimal skeleton extraction shall have to be utilized.
- Most of the above issues will demand research on the development of novel techniques, algorithms and methods, with an eye on low computational complexity, resources costs and high accuracies.

SETUP AND HARDWARE

In the following sub-sections, the equipment needed for each indoor (high-end vs. low cost) and outdoor case (with different options) is described.

Acronyms:

- **OR-HE**: **O**utdoor **R**unner – **H**igh **E**nd solution
- **OR- LC**: **O**utdoor **R**unner – **L**ow **C**ost solution
- **IR-HE**: **I**ndoor **R**unner – **H**igh **E**nd solution
- **IR-LC**: **I**ndoor **R**unner – **L**ow **C**ost solution

Outdoor

Basically, the outdoor runner has to wear sensors to capture his movements, a GPS tracking device and a mobile phone (to transmit data stream) with a Bluetooth headset for real time communication with others.

The difference between low cost and high end solutions depends on three criteria:

- GPS: a robust and precise GPS device provided by for OR-HE *or* Smartphone integrated GPS for OR-LE; The GPS integrated in the Smartphone will have a lower update rate and a lower precision.
- Sensors: full set of inertial sensors for OR-HE *or* Smartphone integrated sensors for OR-LE (e.g., accelerometer and 3-axes gyro) enabling positioning of the outdoor runner;
- Rendering: augmented reality see-through glasses *or* none.

OR-LC Low-cost solution

For tracking sensors we will rely on Smartphone integrated sensors (commonly accelerometer and 3-axes gyro) for two reasons:

- It is “free” (for us and for the user), as basic sensors are already included in common Smartphones;
- It’s in agreement with the idea of developing mobile platform applications

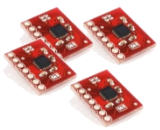
For GPS, we can use the one which is integrated in common Smartphones (which is simple to interface with a mobile platform application via available SDKs).

Finally, in this low cost case, the user has no means to "see" others runners, but she could talk with them with a Bluetooth headset. Whether the voice will be transmitted over IP connection or telephone line, may affect the cost for the end user. This could be taken into account in the materialization phase of the use case.

OR-HE High-end solution

In addition to the Smartphone, the user wears physiological sensor.

In addition to the GPS, Inertial sensors on the body of the user can be used to retrieve joints orientations and animate the avatar rendered to the indoor users.



The outdoor runner could wear AR glasses to "see" the indoor runners (e.g., Laster MG1[1])

However, such equipment requires electrical power and graphics and calculation bandwidth. Integrating this kind of technology is very challenging in the 3DLive framework.

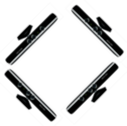
Indoor

IR-LC Low-cost solution

- HDTV to show the other users in a 3D environment

[1] http://www.laster.fr/produits/MG1/

- Wireless headset for communication and ambient sounds
- A set of 4 Kinect for the 3D Reconstruction



- An off-the-shelf treadmill OR a step meter software for the Smartphone which may be combined with a stepper
- A workstation for rendering, capture, transmission, communication
- Physiological sensors.

The IR-LC will see a 3D realistic model of the running track with environment.

The outdoor runner will be represented as an avatar. This avatar will be animated in real time using GPS data from the outdoor user.

The other indoor runner using IR-LC equipment will be represented as a reconstructed 3D human, while the IR-HE runner will be represented as an avatar.

IR-HE High-end solution

- CAVE system: an open cube with 8 HD stereoscopic passive projectors (two for the floor and six for the walls). Optical head tracking allows to adjust in real-time the images to the point of view of the user.

- A set of 3 Kinect sensors to capture the human

- Wireless headset for communication and ambient sounds
- A custom treadmill enabling feedback

- A workstation for rendering, capture, transmission, communication
- Physiological sensors are optional

The IR-HE will see (with stereoscopic glasses) a 3D realistic model of the running track, displayed in an immersive environment (the indoor runner could see "around her").

As in the low-cost solution, the outdoor runner will be represented as an avatar (no change).

The other indoor runner using IR-HE equipment will be represented as an avatar animated from their real gestures.

The other indoor runner who is using IR-LC equipment will be directly represented with his 3D Reconstruction.

This will involve a series of steps for the distant user's 3D reconstructed model to be correctly captured, registered, compressed, transmitted and, finally, decoded in order to be projected to the H-E user. All steps of the above chain should be real time and satisfy the need for good visual quality. For this reason, a series of novel algorithms will be developed and their usability and acceptability within the frame of the scenario will be evaluated.

Sensors and technology available

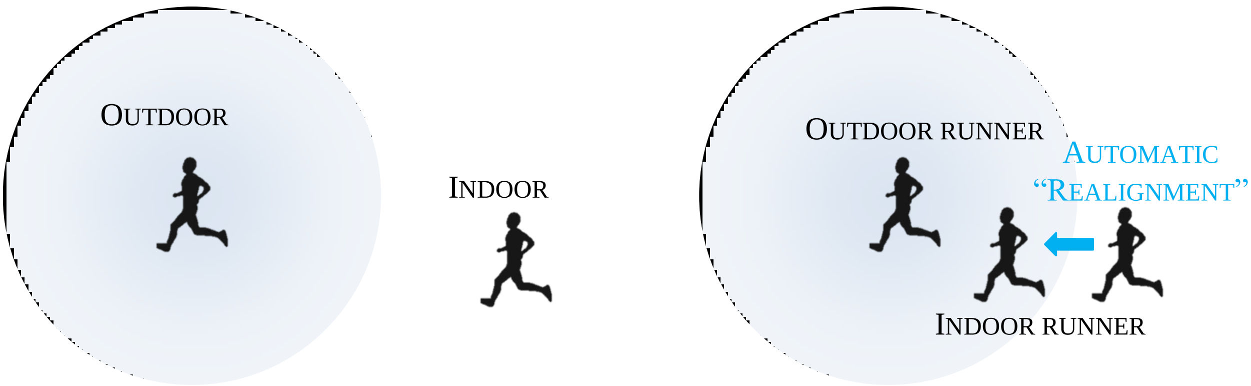
Sensors / Tech	**Scenario**
Internet Server and client side	3D Internet server and client side for the whole experiment set
Running track model	In order to implement the 3D LIVE operative scenario for running, we need a 3D modelled track.
Physiological sensors	The outdoor runner wears some physiological sensors
	CAVE setup: – Eight HD 3D projectors – Computer equipped with NVidia graphics card – Four Microsoft Kinect 3D camera **Runner** setup in Cave: – Modified Treadmill – Smart phone with Bluetooth – Bluetooth headset – Bluetooth Physiological sensor (Heart rate, skin inductance, skin temperature) **Runner** setup in real life: – Smartphone with GPS and GPRS data – SportsCurve mobile hub for the secure data transmission – Bluetooth headset – Bluetooth Physiological sensor (Heart rate, skin inductance, skin temperature) Server side: – Ubuntu Linux server in a cloud
Transmission of data from the physiological sensors	Data needs to be transmitted from the real life site through the 3D Internet server. This is done by the specifically developed SportsCurve mobile data hub. This hub transmits all captured sensor data to the 3D Internet server
Transmission of data to the outdoor runner	Data about virtual reality needs to be transmitted to the real life site from the 3D Internet server, in order to provide the runner with augmented reality features. This data is sent to the Smartphone of the

	runner. The Smartphone has a Bluetooth / Android link to the glasses.
3D reconstruction. of the outdoor runner	Acquired data needs to be processed in order to create the 3D model of the runner (avatar) and to be projected on the CAVE system
3D reconstruction. of the indoor runners	Human live capture and 3D reconstruction at ~>5 FPS from indoor LC to be projected in the CAVE system. 3D model of the indoor HE (avatar) to be projected on the HD TV.
Encoding and transmission of the 3D reconstructed indoor humans	3D (indoor) reconstructions of the indoor runners need to be encoded and transmitted so as to allow for multiple distant runners to be shown in the virtual environment
Rendering and visualisation of the 3D reconstructed indoor runners	The 3D reconstruction need to be rendered and projected on the 3D the CAVE system The reconstructed avatar needs to be rendered on the HD TV.
Rendering the indoor runner into the augmented reality of the outdoor runner	Rendering the indoor runner into the augmented reality of the outdoor runner

SCENARIOS

Game rules and objectives

The game principle is not to reproduce a competition or an opposition: it is to allow two remote runners (one on the ground, the other inside) to run together, even if their skill levels are different. This implies a readjustment of the position of the indoor runners to keep them in the neighbourhood of the outdoor runner and to allow them to see each other ⇒ the virtual world user cannot go too far ahead nor behind the real world user, he is being "dragged with".



The outdoor runner is the centre of the referential because it is easier to artificially slow down or accelerate the "simulation" of the indoor runner than ask the outdoor runner to go faster or slower.

The rule of the “game” could be some kind of “regularity rally” (or time speed distance rally) where all the runners try to respect a predefined time and, the closer they are, the more points they earn. The predefined time could be chosen at the beginning among all runners, based on the lowest skill level. A list could present different time (from green to black or orange).

All the performed tracks will be saved into a database for future reference and examination for the user. It is possible to run a track against past performances to see how much own performance has developed. All the data is saved into the database complete with sensor information.

An activity recognition module will be running in the background. This, in real time, will process data related to human motion, as coming from IR sensors. Thus, the module will be aware of the kind of motion (standing, walking, running) the runner is performing and, based on anthropometric rules, positive or negative feedback will be returned to her or him. For instance, a series of features, related to body parts positions, velocities and angles will be evaluated, in the context of the detected motion, and proper advice will be returned to the runner. This module will be available to the indoor users, as their full body motion will be retrieved explicitly, using the Microsoft's Kinect Sensor.

Prerequisites

The running track is modelled in advance (no real time capture).

There is a continuous audio link between users.

They can hear each other breathing and speech from the direction they are in the modelled 3D world.

Jogging scenario

- real world user runs a predefined or a custom track
- if the real world user deviates from the predefined route, it becomes a custom track
- there is a continuous audio link between users
- they can hear each other breathing and speech from the direction they are in the modelled 3D world
- the 3D world is modelled off-line before going to the track in case of predefined tracks
- in case of custom track, the world is modelled on the fly based on various data available, e.g. Google maps, satellite images and so on
- the virtual world user cannot go too far ahead nor behind the real world user, he is being "dragged with"

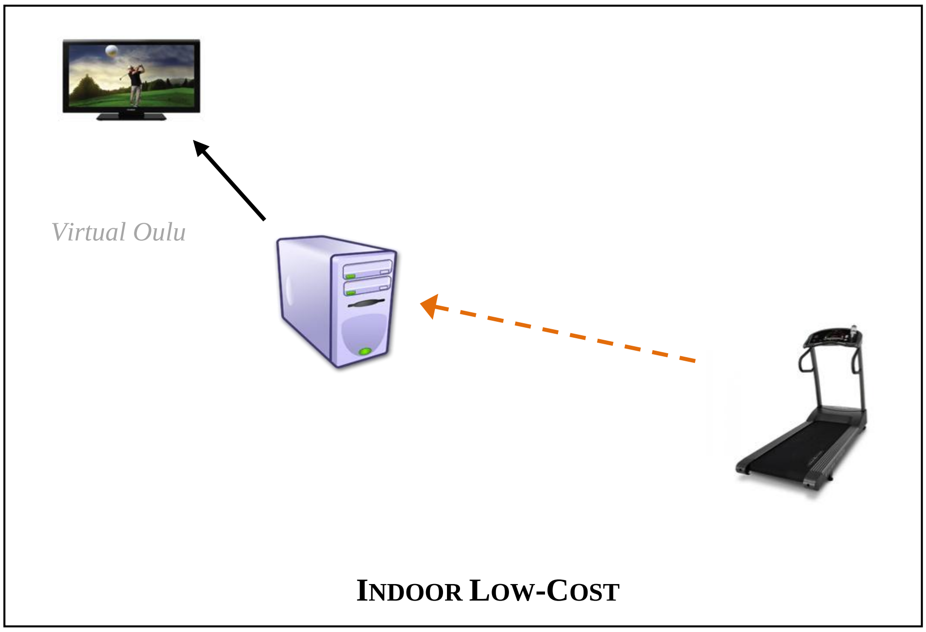
Creation of a custom track

- When a user starts a custom track on a specific location, the 3D scenery is created around him
- The creation is a separate process that takes less than a minute
- the landscape around is created so that it facilitates the given sport, for jogging 10km by 10km area is created around the user, it is extended when needed
- the custom track creation is also done if the user deviates from the predefined track/area
- the custom track is created based on height map information, terrain textures are based on the time of the year and possible from satellite images and/or GPS coordinates
- predefined 3d objects are used to inhabit the environment, different kinds of trees and rocks for nature, different buildings and blocks for an urban environment, a little bit of artistic touch to add liveliness (i.e. random cars at urban areas, animals at forests etc)

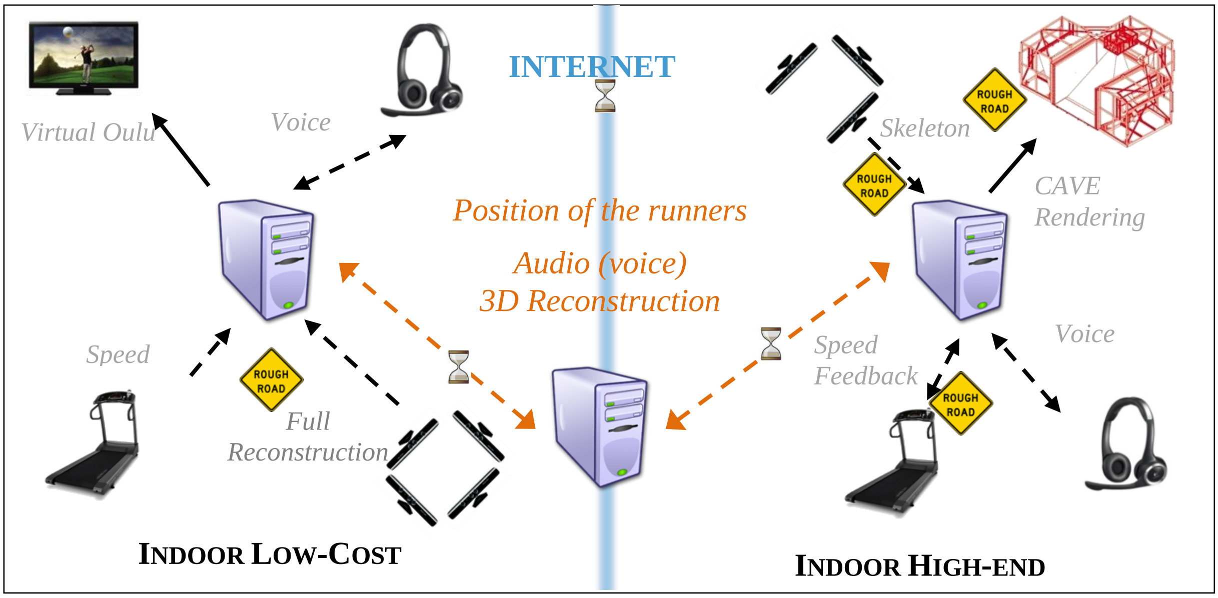
Scenario Configurations

We need to proceed step by step and to test different **technical** configurations before trying to assemble all the “modules”. We propose the following progressive schedule:

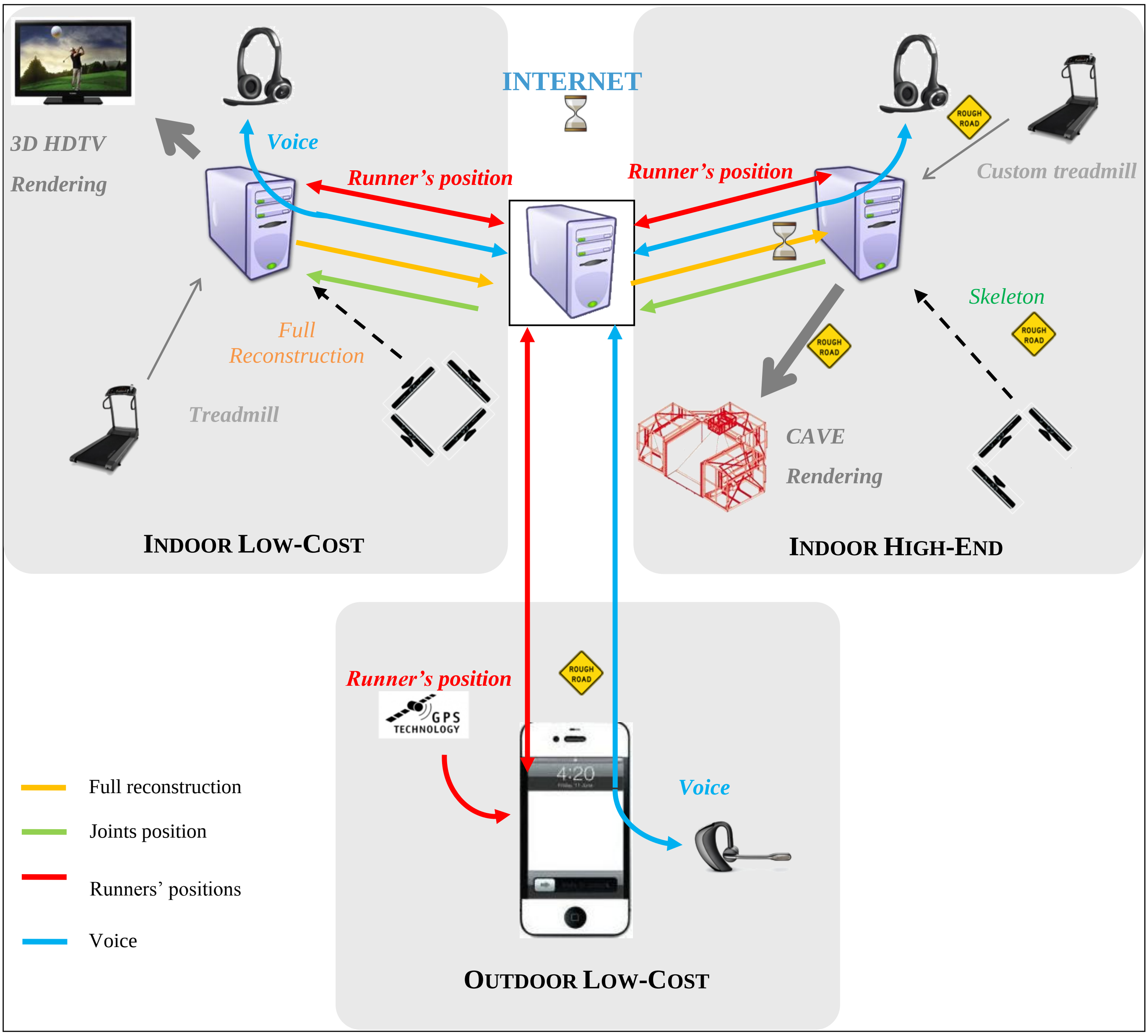
- **Configuration 1**: ***IR-LC*** → this will allow us to work on different general problems
    - Modelling of the running track
    - Modelling of avatars
    - Animation of avatars
    - Adapt the “game rules”



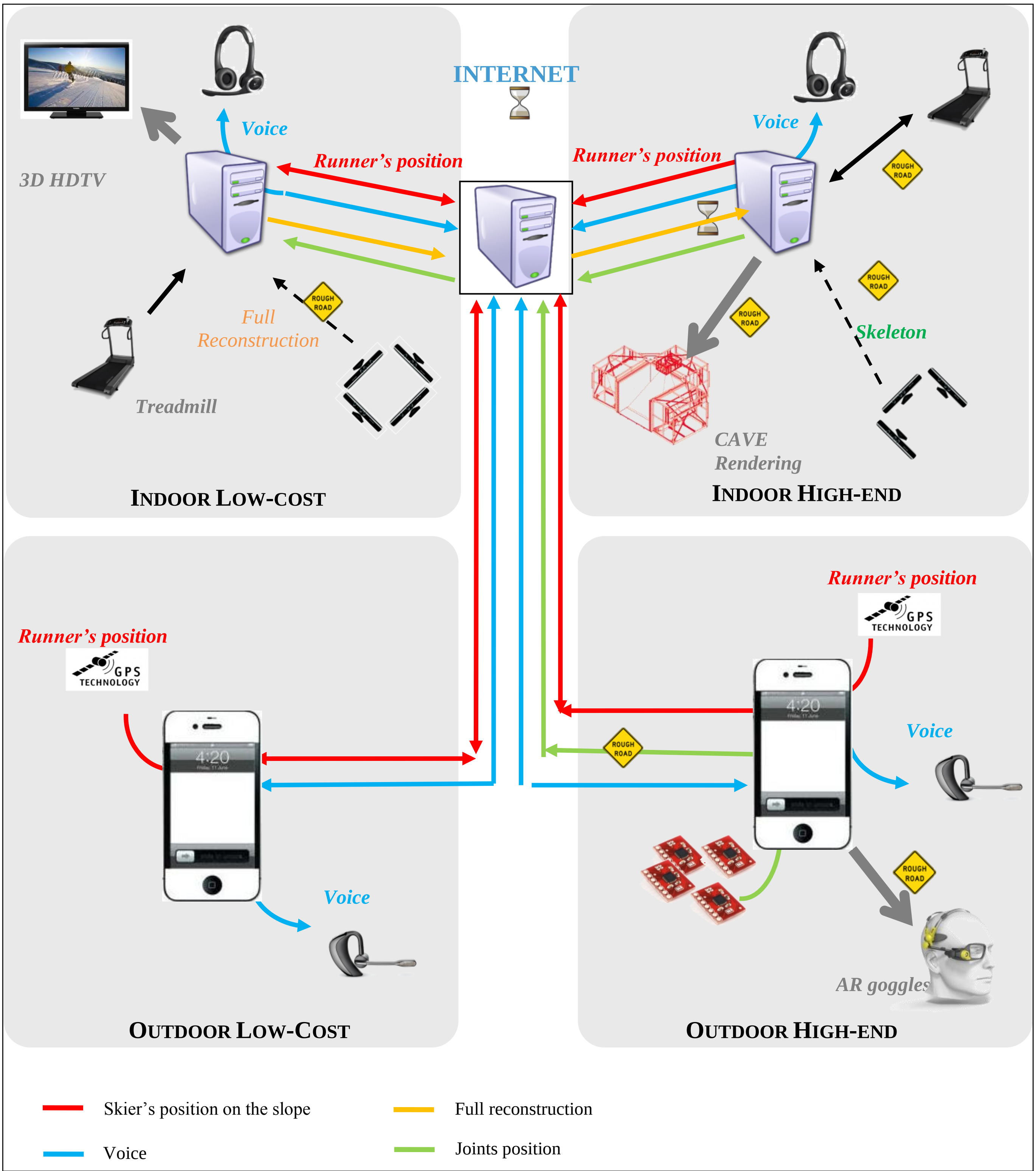
- **Configuration 2**: ***IR-HE*** **+** ***IR-LC*** → this will allow us to work on specific problems related to integration of human live reconstruction in the 3D engine and the integration in the immersive system
  - Communication / network
  - Integration of human live reconstruction in 3D environment
  - Test locally the sending of human live reconstruction between two computers with errors/problems simulation during the transfer
  - Test a solution for dynamic platform



Configuration 3: ***3 runners (OR-LC + IR-LC + IR-HE)*** → this will allow us to work on specific problems related to remote / local transmission



Configuration 4: ***4 runners (OR-LC + IR-LC + IR-HE + OR-HE)*** → final experiment with all the different setup



RESSOURCES

Equipment & Differences

Equipment	Outdoor runner – Low Cost	Outdoor runner – High End	Indoor runner – High End	Indoor runner – Low Cost
Rendering / Display	N/A (no visual feedback)	If AR: AR goggles (e.g. Laster MG1/Google Glasses)	OULU CAVE system	3D TV HD
Capture of the runner	sensors integrated in the Smartphone	Custom set of inertial sensors	ART IR cameras (SAS^3+) / Kinect sensors	4 Microsoft Kinect
View of the runner sent to other runner	N/A (no visual feedback)	If AR: Avatar animated in real-time using joints position	Full 3D real-time reconstruction	Avatar animated in real-time using joints position from Kinect sensors
Audio capture/rendering of the runner	Bluetooth earphone		Bluetooth headset/5.1 audio system	
GPS	Smartphone integrated GPS	SportsCurve GPS	N/A (calculated position)	N/A (calculated position)
Unit for calculation and rendering	Smartphone	Smartphone/embedded computer	PC + CAVE cluster	PC
Others			Custom Treadmill	Normal Treadmill

11 APPENDIX B: SKIING Scenario

INTRODUCTION

The Ski scenario will involve 3 players, one on the real ski slope (Schladming ski station with FIRE facilities) and two players in indoor conditions (one using high end immersive equipment in Laval, a second one using a low cost solution (CERTH). This measure will allow us to test different degrees of cost/immersion solutions simultaneously and in particular to experiment human live capture and transmission (CERTH).

The Ski activity could involve skiers with different levels. To preserve the "team" spirit (i.e. to avoid having skiers with 100 m between them, concentrated on their "own" descent), slower skiers will always stay in the same "area" with the faster one.

A technology will support the Ski scenario platform with different components (based on cost and immersion considerations) and set-ups for indoor and outdoor players.

A community of users will be gathered from skiers and non-skiers willing to take part in the Experiential Design Process (co-creation, exploration, experimentation and evaluation).

This document presents several existing technologies and products that are part of our technological watch, as they constitute potential solutions in the 3Dlive frame. They helped us in the design phases of the 3Dlive platform; however please note that all the devices mentioned in this scenario will not necessarily be used in the 3DLive platform due to different reasons such as costs, lack of SDK or reliability.

OBJECTIVES

3D-LIVE main research goal is to investigate the impact of 3D Tele-Immersive Environment (3D-TIE) on people behaviour and feelings when sportsmen (golfers, skiers, joggers) practice together from indoor and outdoor situations.

The main objectives of the Ski scenario are:

- To explore the technological feasibility (visualization rendering, data transfer, real-time skier 3D reconstruction, realistic avatars, platform for realistic movements, stereoscopic view) and propose a library of components which could be gathered to create the user experience;
- To embed social aspects through Ski 3D-TIE for a demanding sport with various internal and external parameters;
- To experiment the scenario appropriateness through Ski 3D-TIE prototypes, and assess the choice for the ski "rule";
- To evaluate the user experience of skiers immersed in a Ski 3D-TIE;
- To explore the "Twilight Space" (a space between Augmented Reality and Augmented Virtuality) impact on people's behaviour and feelings.

CHALLENGES

The ski scenario gathering players from indoor and outdoor situations has several options and related challenges, such as:

- Survey, experiment and evaluate affordable sensing equipment allowing to capture the movements of indoor and outdoor skiers, and to recreate the "shape" of the real ski slope for indoor skiers and to reconstruct (full body) of an indoor skier;
- Realize a realistic 3D modelled view of the Schladming ski slope and, if the need arises (no pre-existent models), test equipment to "scan" the Schladming ski slope;
- Pre-model a library of realistic posture and animation of a real skier (to assist avatar animation using sensors data) ;
- Interface the sensing equipment with the "cloud" in order to use the motion data for:
    - Animating an avatar in real time ;
    - Rendering a indoor skier live capture ;
    - Mapping the real position of the outdoor skier on the modelled ski slope ;
    - Displaying physiological information if needed ;
- Interface a VoIP (Voice over the internet) web-application (e.g. Skype/TeamSpeak) for the social interactions (e.g. Bluetooth headset or microphone and speakers) ;
- Survey, experiment and evaluate affordable Augmented Reality glasses for improving the immersive experience for the outdoor skier (seeing avatars of indoor skiers superimposed on the real view of the ski slope);
- Explore the immersive feeling of skiers related to their location (indoor or outdoor), their equipment (AR glasses, headset for outdoor skiers – platform, displays, avatars vs. live capture for indoor skiers) ;
- Combine many devices using IR tracking technologies (A.R.T. and Kinect) in the same confined space without interference.

SETUP AND HARDWARE

The final and ambitious objective is to allow three "users" to experiment simultaneously the Ski scenario, for a series of reasons:

- In order to test high-end (displaying real-time full capture of a skier) and low-cost solutions (displaying an avatar animated with a low-cost motion capture solution);
- To integrate human live capture. It is not possible to capture the outdoor skier, as the technological platform to perform the live capture needs at least 4 Microsoft Kinect. If the outdoor skier does not wear AR glasses, only a second indoor skier could visualize the other indoor skier live capture).
- We want to test 2 technical solutions for the outdoor skier (low-cost and high end)
- Software-related research challenges are posed, regarding:
    - Human 3D reconstructions and transmission over the network. This will entail the investigation of novel algorithms, both in terms of reconstruction and compression-transmission-decompression. Motion information will be of high value
    - Physical alignment between avatars and human reconstructions, coming from different physical locations and captured with different equipment (inertial sensors, GPS)
    - Activity Recognition of skier. The use of affordable equipment poses a challenging aspect at evaluating skier's performance, in real time. As the features that can be extracted can be of high dimensionality, dedicated algorithmic solutions are being investigating for keeping only statistically important information and coming up with dedicated classification schemes.

We describe, in the following sub-sections, the equipment needed for each indoor case (high-end vs. low cost) and for the outdoor case (with different options).

Acronyms:

- **OS-HE**: **O**utdoor **S**kier – **H**igh **E**nd solution
- **OS- LC**: **O**utdoor **S**kier – **L**ow **C**ost solution
- **IS-HE**: **I**ndoor **S**kier – **H**igh **E**nd solution

- **IS-LC**: **I**ndoor **S**kier – **L**ow **C**ost solution

Outdoor

Basically, the outdoor skier has to wear sensors to capture his movements, a GPS tracking device and a mobile phone (to transmit data stream) with a Bluetooth headset for real time communication with others skiers.

The difference between low cost and high end solutions for outdoor skiers depends on three criteria:

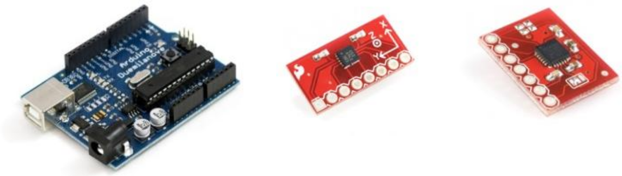
- GPS: GPS module or Smartphone integrated GPS provided by SportsCurve;
- Sensors: full set of sensors or Smartphone integrated sensors (e.g., accelerometer and 3-axes gyro for Apple iPhone.
- Rendering: augmented reality see-through glasses or none (intermediate solution: displaying information's on goggles using a small screen).

OS-LC: Low-cost solution

For tracking sensors, we can explore two means:

- Rely on Smartphone integrated sensors (commonly accelerometer and 3-axes gyro);
- Build our own prototype using an upper number of sensors, like for example 2 sensors for the knees and one for the upper body.

Prototypes using basic sensors could be built using open source electronic prototyping platform, such as *Arduino*[2] :



It seems that the best solution is the one using Smartphone, for two reasons:

- It is "free" (for us and for the user), as basic sensors are already included in common Smartphones;
- It's in agreement with the idea of developing mobile platform applications (i.e., Apple iApps and Android Apps);

For GPS, we can use the one which is integrated in common Smartphones (which is simple to interface with a mobile platform application).

[2] http://www.arduino.cc/

Finally, in this low cost case, the user has no means to "see" other indoor skiers, but she/he could talk to them with a Bluetooth headset, thanks to his Smartphone. An intermediate solution could be to integrate a smart screen directly in the goggles (e.g., *Recon Instruments MOD Live*[3]), to display his live information and data from skiers (speed, time to respect for the game …). This solution could enhance the user experience of the outdoor golfer, and could be proposed as an option in the low-cost solution.

How much it will cost (excluding software and hardware development tool)?

- **1 Apple and/or Android Smartphone = min 300 €**
- **1 Bluetooth earphone = 40 €**
- **Possibly 1 *Recon Instruments MOD Live* (or similar) = 400 €**

<u>OS-HE: High-end solution</u>

For tracking sensors, high-end solution could rely on *XSens*[4] *products*, like *MVN Biomech* system (see below), composed of 17 (for full body capture) inertial motion trackers. The problem is there is no SDK to retrieve

In our case, a custom set of inertial sensors from SportsCurve will be deployed on users' bodies, in order to track necessary skeleton joints.

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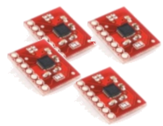
[3] http://www.reconinstruments.com/products/snow-heads-up-display

[4] http://www.xsens.com/





For GPS, we can use a GPS tracking module from SportsCurve.

Finally a better experience, the outdoor skier could wear AR glasses to "see" the other indoor skiers (e.g., Laster MG1[5])



However, such equipment requires electrical power and graphics and calculation bandwidth. Moreover it is a new technology and integrating it is a very challenging point in this scenario.

How much it will cost (excluding software and hardware development tool)?

- **XSens MVN Biomech = 50 k€ (!!)**
- **AR glasses as Laster MG1 (8 k€, lent?)**
- **SportsCurve sensors = 0 k€ (for free)**

[5] http://www.laster.fr/produits/MG1/

Indoor

Indoor solutions will imply 3D live human reconstructions. We chose to perform the 3D live reconstruction of the indoor "low-cost" skier only, for several reasons:

- If we try to reconstruct the indoor "high-end" skier, the physical platform will be also depicted in the reconstructions. And using a simple *Wii Balance Board* doesn't fit for a high-end solution, which has to provide a great user experience;
- The high-end solution should provide the best user experience that is the reason why we have to propose the rendering of the reconstruction to the high-end indoor skier, even if it appears contradictory to use 4 Kinects for the low cost case; it is the low-end skier that will be fully reconstructed and projected to the high-end skier.
- We have to test different solutions adapted to different network configurations (i.e. limited bandwidth). Transmit 3D live human reconstructions suppose a good bandwidth;
- The CAVE system from CLARTE (SAS3+) is equipped with last IR tracking and motion capture cameras.
- The activity of users will be recognized aiming two things:
    - Help the skier to improve his skiing stance.
    - Add interactions in the indoor app.

The indoor- HE skier will have the possibility to receive continuous feedback regarding her/his performance. This will take place thanks to the parallel execution of an Activity Recognition module. Using sensor's feedback regarding skier's joints positions, motion history and expected movements, a clustering algorithm will be investigated. Following a subspace approach, the module will achieve process on the fly, at a low-dimensionality feature space that will be able to withhold only statistically important information. A coarse classification of activities will be:

1. Comfort Stance

2. Snowplough

3. Full stream position

The algorithm will discriminate among the above categories and will, also, provide feedback to the user, regarding performance at each of them, utilizing a series of anthropometric features. Moreover, this scheme will be linked to the interactions in the Virtual Environment and provide necessary suggestions to the indoor skier.

→ **Low-cost case: 4 *Microsoft Kinect* with for full 3D real-time human reconstruction**

→ **High-end case: Set of IR cameras + reflexive markers (included in SAS^3+) with a physical platform for skeleton capture to animate an avatar in real time**

IS-LC: Low-cost solution

- Feedback video of the player on the real course and an animation of the H-E skier: HDTV or video projector (stereoscopic view)

- Cluster of 4 *Microsoft Kinect* to capture the full body of the user. Based on both *Microsoft Kinect* and reconstructions CERTH can provide the movements of the user in a body skeleton format.

- Wireless headset for communication and ambient sounds

- A Wii Balance board, to detect the pressure under users' feet and enable controls in the virtual world.

- Physiological sensors if needed

The IS-LC will see (with NVidia stereoscopic glasses) a 3D realistic model of the ski slope.

The outdoor skier will be represented as an avatar. This avatar will be animated in real time using movement sensors data received from the outdoor skier on the real ski slope. If the outdoor skier wears a full set of we could simply animate the skeleton of the avatar in real-time. If the outdoor skier wear only few low-cost sensors, it will be necessary to interpolate the correct position of the outdoor skier with the most probable posture of a pre-built library.

The other indoor skier (IS-HE) will be represented as an avatar. The *ART* IR cameras in the high-end solution will capture the "skeleton" of IS-HE and will send the positions of the joints, which will be used to animate the avatar in real time.

How much it will cost (excluding software and hardware development tool)?

- **4 *Microsoft Kinect* = 0 k€ (for free by ITI)**
- **1 TV HD or Video projector 3D ready = 0 k€ (for free by ARTS)**
- **Wii Balance board (80€)**

<u>IS-HE: High-end solution</u>

- CAVE *SAS3+*[6] system: an open cube with 4 big HD stereoscopic displays (one for the floor and three for the walls). Optical head tracking (from *ART*[7]) allows to adjust in real-time the images to the point of view of the user.

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[6] http://www.clarte.asso.fr/realite-virtuelle.php/sass.html

[7] http://www.ar-tracking.com/home/

- Capture of the movements of the skier can be done with the ART tracking or with Kinect sensors. Kinect sensors enable the users not to have too many devices on their body.



- Wireless headset for communication and ambient sounds or 5.1 sound system enabling 3D sounds.

- A physical platform to simulate the movement of a real skier (e.g., ProSki Simulator Basic Model[8] or Skier's Edge T5 Classic[9])


[8] http://www.ski-simulator.com/basic-ski-machine/

[9] http://www.skiersedge.com/products/t5/index.html

- A workstation for rendering, capture, transmission, communication
- Physiological sensors if needed

The platform will be "passive": it will be used to allow the skier to do realistic movements; *ART* tracking system can be used as the real input to recognize the user movements and update the rendering. Else the platform can be equipped with sensors to retrieve the angular movements.

The IS-HE will see (with stereoscopic glasses synchronized with CAVE rendering) a 3D realistic model of the ski slope, displayed in an immersive environment (the indoor skier could see "around him").

As in the low-cost solution, the outdoor skier will be represented as an avatar (no change).

The other indoor skier (IS-LC) will be directly represented using the live 3D reconstruction (from CERTH). This will involve a series of steps for the distant user's 3D reconstructed model to be correctly captured, registered, compressed, transmitted and, finally, decoded in order to be projected to the H-E user. All steps of the above chain should be real time and satisfy the need for good visual quality. For this reason, a series of novel algorithms will be developed and their usability and acceptability within the frame of the scenario will be evaluated.

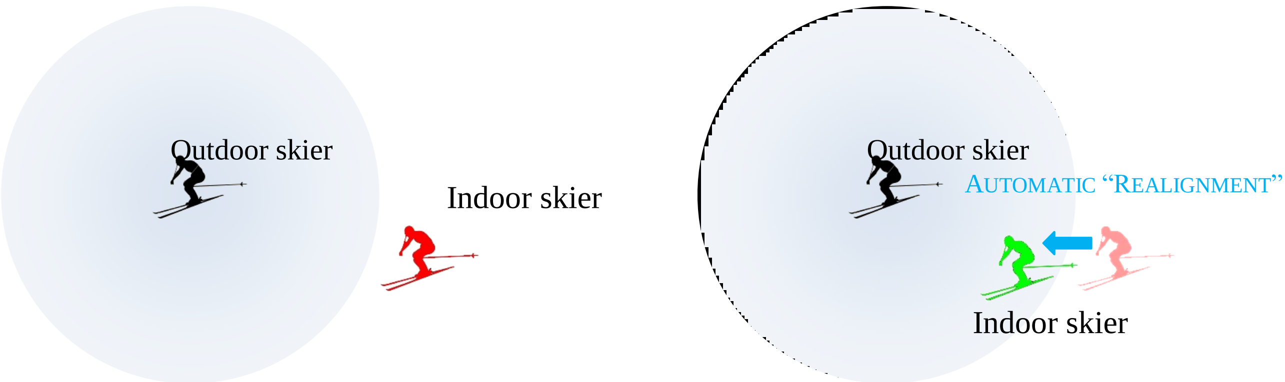
How much it will cost (excluding software and hardware development tool)?

- **SAS^3+ = subcontract of ARTS**
- **ART IR camera and IR targets (included in the SAS^3+)**
- **1 Kinect = 0 k€ (for free by ARTS)**
- **1 physical platform like *ProSki Simulator Basic Model* (≈ 800 €) or Skier's Edge T5 Classic (≈ 1000 €)**

SCENARIOS

Game rules and objectives

The game principle is not to reproduce a competition or an opposition: it is to allow two remote skiers (one on the ground, the other inside) to ski together, even if their ski levels are different. This implies a readjustment of the position of the indoor skiers to keep them in the neighbourhood of the outdoor skier and to allow them to see them each other ⇒ the virtual world user cannot go too far ahead nor behind the real world user, he is being "dragged with".



The outdoor skier is the centre of the referential because it is easier to artificially slow down or accelerate the "simulation" of the indoor skier than ask the outdoor skier to go faster or slower.

The rule of the "game" could be some kind of "regularity rally" (or time speed distance rally) where all the skiers try to respect a predefined time and closer they are, more point they earn. The predefined time could be chosen at the beginning between all the skiers, based on the lowest ski level. A list could present different time (from green to black or orange).

Prerequisites

The ski slope is modelled in advance (no real time capture).

The Schladming ski slope is equipped with Wi-Fi hotspots or 4G antenna to support the data stream between the other remote sites.

There is a continuous audio link between users.

They can hear each other breathing and speech from the direction they are in the modelled 3D world.

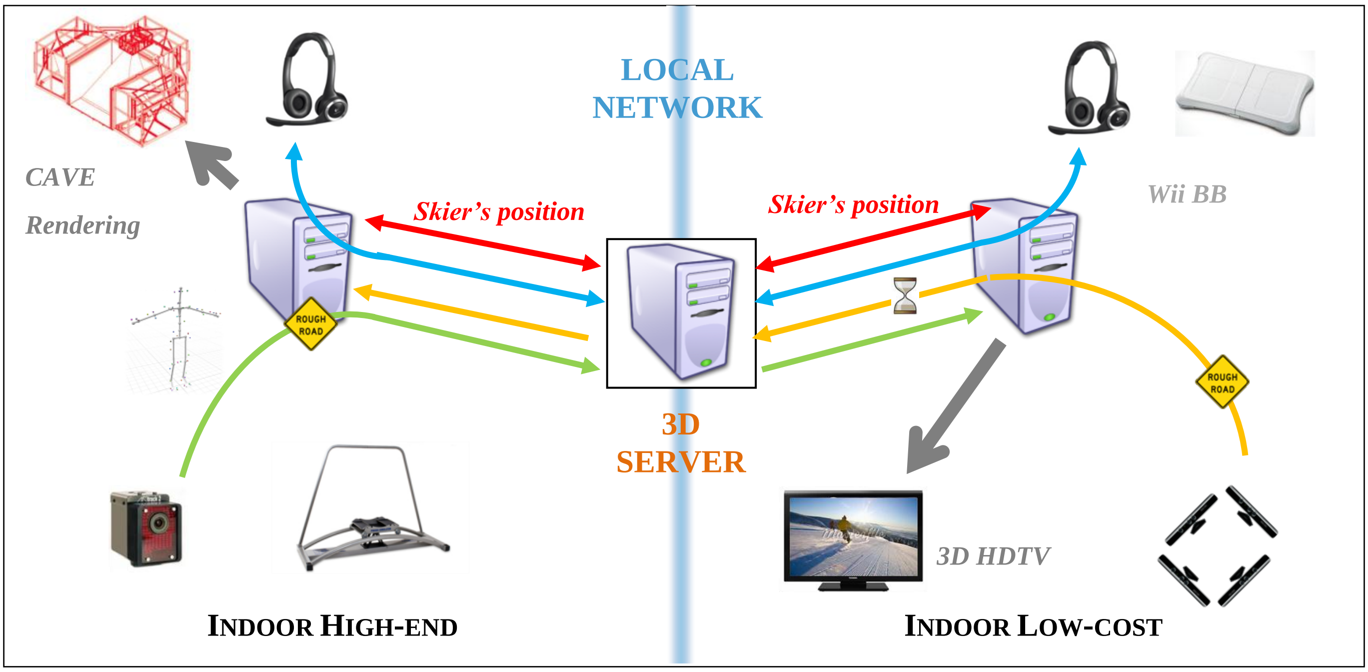
Scenario Configurations

Keys

Technological difficulties

Potential latency

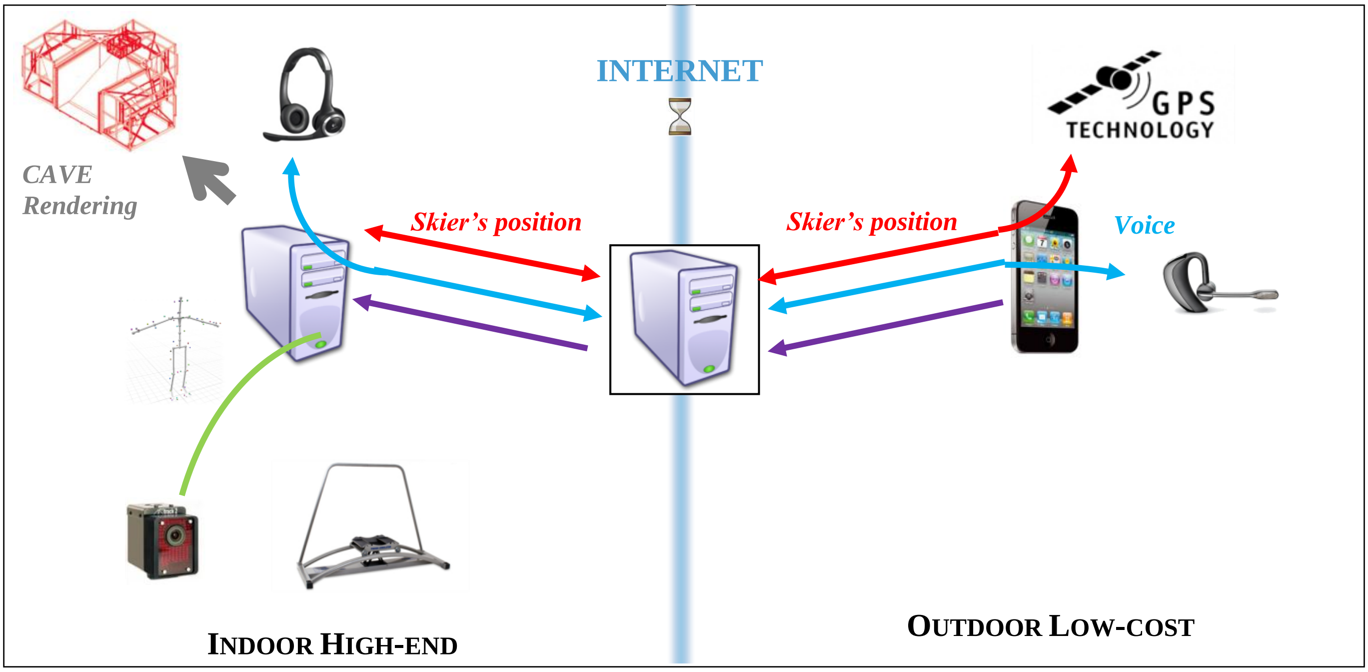
Configuration 1 ***2 indoor skiers (HE and LC) – 2 in Laval (France) then 1 in Laval + 1 in CERTH (Greece)***



IS-LC sees an avatar of IS-HE animated in real-time using joints position from the *ART* IR cameras of the SAS^3+ or from a set of 3 Kinect sensors.

IS-HE sees an a real-time reconstruction of IS-LC from the clusters of 4 *Microsoft Kinect*

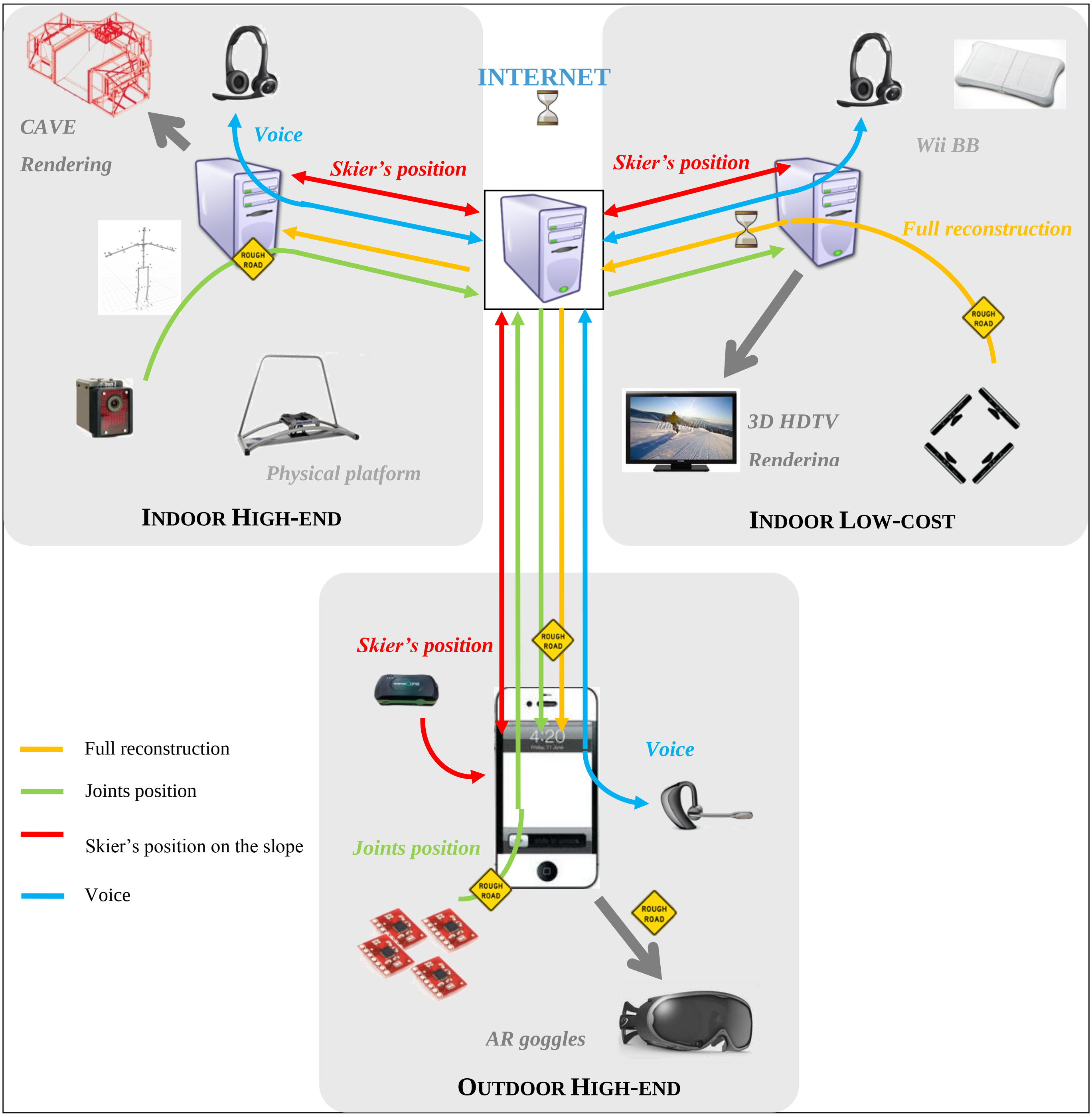
Configuration 2 ***1 indoor skier (HE) – Laval, France + 1 outdoor skier (LC) – Schladming, Austria***



OS-LC has no visual feedback from IS-HE.

IS-HE sees an avatar of OS-LC, with most probable posture calculated from data of the Smartphone (accelerometer).

Configuration 3 *1 indoor skier (HE) – Laval, France + 1 indoor skier (LC) – CERTH, Greece + 1 outdoor skier (LC) – Schladming, Austria*



IS-LC sees an avatar of IS-HE animated in real-time using joints position from the *ART* IR cameras/ the Kinect sensors of the

SAS^3+ and an avatar of OS-HE animated in real-time using joints position from inertial sensors.

IS-HE sees a real-time reconstruction of IS-LC from the clusters of 4 *Microsoft Kinect sensors that exist in the indoors L-E physical space* and an avatar of OS-HE animated in real-time using joints position from inertial sensors.

OS-HE sees a real-time reconstruction of IS-LC from the clusters of 4 *Microsoft Kinect* and an avatar of IS-HE animated in real-time using joints position from the *ART* IR cameras of the SAS^3+ or from a set of 3 Kinect sensors.

RESSOURCES

Equipment & Differences

Equipment	Outdoor skier – Low Cost	Outdoor skier – High End	Indoor skier – High End	Indoor skier – Low Cost
Rendering / Display	N/A (no visual feedback)	AR goggles (e.g. Laster MG1)	SAS^3+ CAVE	3D TV HD
Capture of the skier	sensors integrated in the Smartphone	Custom set of inertial sensors	ART IR cameras (SAS^3+) / Kinect sensors	4 Microsoft Kinect
View of the skier sent to other skiers	N/A (no visual feedback)	Avatar animated in real-time using joints position	Avatar animated in real-time using joints position from Kinect sensors	Full 3D real-time reconstruction
Audio capture/rendering of the skier	Bluetooth earphone		Bluetooth headset/5.1 audio system	
GPS	Smartphone integrated GPS	SportsCurve GPS	N/A (calculated position)	N/A (calculated position)
Unit for calculation and rendering	Smartphone	Smartphone/embedded computer	PC + CAVE cluster	PC
Others			Physical platform to allow realistic movements.	Wii balance board

Laster MG1 (~ 8 k€): http://www.laster.fr/produits/MG1/

ProSki Simulator Basic Model (~ 800 €): http://www.ski-simulator.com/basic-ski-machine/

12 APPENDIX C: GOLFING SCENARIO

INTRODUCTION

The Golf scenario takes place within the context of "scramble" play where normally two pairs of golfers are playing as a team against each other. In the golf scenario two golfers (one outdoor and the other indoor) play their respective golf ball from the tee box. The following shot takes place at the team's selected best ball position resulting of what they think is the best one out of the two shots. They both play each time from their selected ball's location starting from the tee box until they put the ball in the hole of the corresponding green. Scramble play can occur on a 9 or 18 holes golf course and is explained in more details in the section entitled "rules of golf".

Furthermore, the golf scenario includes some specific features for followers that they can keep an eye on the progress of the game having a shot tracking web-app accessible for example on their smart phone or tablet (see the Appendix on Followers for Golf) and where they can send encouragement tweets to their most favourite team.

It should be noticed that scramble golf play is an excellent approach to teach golf through the level of practice of the best golfer in a team that could be composed of low and high handicap golfers (low handicap golfers are good practitioners while high handicap golfers are novice golfers). The "team" spirit is another great aspect of the scramble play as it allows embedding some social issues that avoid getting bored when a golfer plays alone.

A technology platform will support the Golf scenario with different equipment and set-ups for indoor (participants will be either golfers or non-golfers) and outdoor players (participants will be golfers due to golf course practicalities).

A community of users will be gathered from golfers and non-golfers willing to take part in the Experiential Design Process (co-creation, exploration, experimentation and evaluation).

OBJECTIVES

3D-LIVE main research goal is to investigate the design of 3D Tele-Immersive Environment (3D-TIE) and impact on people feelings and behaviour when they practice sport (golfers, skiers, joggers) together in real-time from indoor and outdoor situations while evaluating the resulting user experience.

The main objectives of the golf scenario are to:

- Co-create with users a 3D-TIE for Golf and explore its technological feasibility;
- Embed social aspects (notion of team and followers) in the 3D-TIE application for Golf;
- Experiment the scenario appropriateness through the 3D-TIE prototypes;
- Embed training aspects thanks to Activity Recognition through the fusion of Skeleton data from the user and inertial sensors tracking the golf club. (Optionally use of Kinect 2 located on the golf cart pull, Outdoor Activity recognition with inertial sensors on body joints).
- Evaluate the user experience (UX) of golfers and non-golfers immersed in a 3D-TIE for Golf (see D1.2 on User Experience);
- Refine the 3D-TIE platform design based on the resulting UX (see D1.1 on the Experiential Design Process)
- Explore the "Twilight Space" (a space between Augmented Reality and Augmented Virtuality) impact on people feelings and behaviour.

CHALLENGES

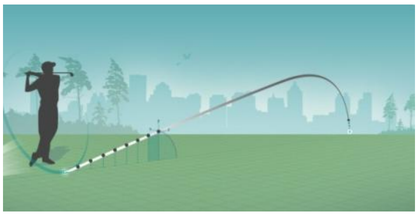
The golf scenario, by gathering players from indoor and outdoor situations, has several options and related challenges, such as:

- Survey, experiment and evaluate affordable sensing equipment and software allowing to capture:
  - Physical holes data on a real golf course;
  - Environmental data on a real golf course;
  - Body gesture data for tracking the golf swing (indoor and outdoor) [*. The feasibility will depend on the maturity and cost of the technology (e.g. Kinect 1 or 2, cheap high speed camera, inertial sensors on body joints)];
  - Motion data of the golf club (indoor and outdoor) for getting the necessary parameters allowing computing the flight of the ball.
- Interface the sensing equipment with the "cloud" in order to use the golf club motion data for:
  - Calculating the expected flight (3D trajectory) of the "virtual" (indoor) golf ball and its resulting physical location on the golf course, using an existent algorithm;
  - Helping to locate the real (outdoor) golf ball on the golf course;
- Explore the rendering software for the feasibility of representing:
  - The captured hole(s) of a real golf course,
  - The golf balls and the flights of the golf balls
  - Eventually indoor and outdoor golfers (represented in the form of skeleton or avatar) if feasible (see the above * as it depends on the capture of the golf swing gesture) for increasing the immersive feeling;
- Explore the immersive feeling of indoor and outdoor golfers when:
  - a capture of their respective golf swing gesture (see the above * on feasibility) appears on the screen of the other remote golfer;
  - They both vocally interact through e.g. a Bluetooth headset.
- Interface a VoIP (Voice over the internet) web-application (e.g. Skype) for the social interactions (e.g. Bluetooth headset or microphone and speakers);
- Reconstruct the real environment conditions in the virtual scene. Virtuality must match reality as much as possible.

SETUP AND HARDWARE

Description of the equipment used for each situation (in this case, we have 2 players, one indoor and one outdoor).

This use case is based on an inertial sensor on the golf club. This inertial sensor will provide motion data of the golf club during the golfer's swing for hitting the golf ball that will be used for computing the golf ball trajectory and the approximate final position of the ball on the golf course. This inertial sensor will be used for the indoor and the outdoor golfer. It will contribute to simulate virtually the entire game, which will facilitate the tacking of the golf ball flights.



Acronyms:

- **OG-HE**: **O**utdoor **G**olfer – **H**igh **E**nd (N inertial sensors for covering body joints, with N=3, 7 or 11 depending on the feasibility, and GPS in tablet or Smartphone)
- **OG-LC**: **O**utdoor **G**olfer – **L**ow **C**ost (inertial sensor and GPS in tablet or Smartphone)
- **IG-HE**: **I**ndoor **G**olfer – **H**igh **E**nd (2 displays: large screen and video projection on the other wall)
- **IG-LC**: **I**ndoor **G**olfer – **L**ow **C**ost (1 display: only one computer screen or home projector)

Note: we will test 3 different situations (2 indoor golfers and then 1 indoor golfer with 1 outdoor golfer). Normally, the context of scramble play is more suited for 2 teams of golfers competing against each other meaning in this case that there will be 2 teams of 1 OG + 1 IG. The Low-cost (LC) solution is easier than the High-end (HE) requiring 2 displays

Teams configurations:

- **IG-HE** + **IG-LC** or IG-LC + IG-LC (does not require the availability of 2 displays)
- **IG-HE** or **IG-LC**
- **OG-HE** or **OG-LC**

Indoor

There are currently a lot of golf simulators available on the market; some of them allow a certain degree of immersion. The most common ones use a flexible projection screen while some others have a net in front of a screen. The player can swing and hit the golf ball as if he was on a real course but with the simulated environment around him.

An option is to consider adding to the main front screen, a second screen, perpendicular to the first, so that the IG can see his playmate outside. The following diagram shows what could be the interior device.

The indoor configuration is composed of:

- 1 main screen allowing the golfer to see the 3D rendering of the first hole of the real golf course
- 1 optional webcam above the screen for video streaming the actions of the IG
- 1 optional second screen to see the other golfer in action

On this basis, it is possible to define two distinct configurations that differ in cost and the level of user experience. For low cost configuration, we will use only one split screen. For IG High End solution, a CAVE cannot be used as the golf club could be destroying some high cost equipment by accident.

Note: 3D body reconstruction is not planned in the golf scenario. A body skeleton will be used for comparing the golf swing. One or more *Microsoft Kinect* can be used in order to capture the posture of the golfer (not to be used for reconstructing the golfer). In that case, CERTH could record, with one or more *Microsoft Kinect*; a set of swings as performed by experienced golfers (in indoor environment), and extracts posture characteristics of those swings and stores them in a library. Then, while the indoor, inexperienced golfer performs his swing, we will in real time compare his posture with the ones in the library and advise him on how to better perform. To this aim, dedicated tools for Activity Recognition are being developed. The idea behind Activity Recognition in the context of the Golf Scenario is to allow for the Virtual Environment to define the expected Action (shot type) of the inexperienced golfer, depending on the golf ball position and the target hole. Based on this, the appropriate swing of the shot type recorded in a library will be extracted and correlated to the performed swing. The library, represented as a set of clusters (?), will define a distance (correlation?) metric and, based on this, the inexperienced golfer will be informed regarding the executed action. Another possibility is to show the most appropriate shot type's swing to the novice golfer before hitting the golf ball and then compare it with the one of the experienced golfer.

IG-LC: Low-cost solution

- Feedback video of the player on the real course and virtual golf course on the same screen (split view): HDTV

- Camera which transmits images from the IG to the OG: HD webcam

- Capture of the golf club motion: inertial sensor
- Capture of golfer's physiological data: armband

IG-HE: High-end solution

- Feedback video of the player on the real course: video projector HD short focal length + speakers


- Camera which transmits images from the IG to the OG: HD webcam 1080

- Visualization of the virtual course (screen of "game"): video projector + projection screen + net



- Capture of the golf club motion: Inertial sensor on the golf club.
- Capture of golfer's physiological data: armband
- 3 Kinect sensors and inertial sensor on the golf club to compare the golf swing of the indoor golfer with swings of experienced golfers.

Outdoor

The outdoor display device is a touch screen tablet on which the golfer can see:

- The video "in live" of his playmate indoor
- A virtual view of the course where his position, the final position of the ball that he just hit and his opponent / partner will be displayed. This display will also give information on the game rounds (see next section).

The idea is to equip a golf pull cart with a touch screen tablet, a webcam, a GPS sensor and a wireless connection either 3G+, 4G or Wi-Fi for sending and receiving data.

In addition, the OG has an inertial sensor on the golf club for collecting the golf club motion data that allow computing the golf ball trajectory. However, the OG will locate his golf ball on the golf course through the GPS sensor. The camera can transmit video streaming from the OG to the IG.

The GPS sensor provides in real time the position (geographical location) of OG on the course. This position is rendered on the 3D virtual course that is displayed on the screen.

OG-LC: Low-cost solution

- Tablet for the feedback of the game, information of position, trajectory and visualization of the IG with Augmented Reality. GPS integrated in the Tablet. It is also the computer that transmits data to the IG.

- Golf club + inertial sensors for capturing the motion.
- Earphone enabling voice communications

OG-HE: High-end solution

- Tablet for the feedback of the game, information of position, trajectory and visualization of the IG with Augmented Reality. GPS integrated in the Tablet. It is also the computer that transmits data to the IG.

- Golf club + inertial sensors for capturing the motion.
- Set of inertial sensors on the body of the OG-HE
- Camera 1080p (optional) for the video feedback of the users.
- GPS sensor provided by SportsC for high precision

- Headset enabling voice communications

SCENARIOS

Game rule and objectives

The game principle is not to reproduce a match or an opposition: it is to allow two remote players (one outdoor on the golf course, the other indoor in a kind of golf simulator environment, or two indoor) to play together. The idea is that each golfer plays his golf ball and then they decide the best position out of the two shots and continue to play from the selected ball position.

In the following part, we will present the game between the indoor golfer and the outdoor one, because this implies a readjustment of one of two golfers on the ball of another player, once it the best ball position is decided. This readjustment is very challenging in the situation real versus virtual.

We will then present the game between two indoor golfers. This situation is rather similar to the previous one but implies some differences, in particular concerning the way they reach their ball position, as none of the two will have to walk to this location.

Prerequisites

The Hole 1 of Laval golf course, par 4, is modelled in advance (no real time capture) for carrying out the experiments.

The two golfers have a display device that allows seeing the trajectory of the ball (see previous section).

The OG has an "accurate" GPS.

Each player has a screen with the 3D representation of the first hole on the golf course and the ability to display the trajectory of their respective ball and the final position.

The OG can visualize its position in real time on the 3D course.

The two players discuss together in order to select the best ball position so that the party can continue from this position.

Game turns (IG + OG)

Beginning

The 2 players can talk to each other through their video return and sound return. For OG, this is done through the screen that is on the golf cart pull...

OG confirms his position on the screen ⇒ The view of 3D virtual course of IG is automatically updated to arrive at the same starting position [*flying view movement*].

First round

<u>OG is playing first</u>

OG begins to play and hit the ball. The inertial sensor provides the golf club motion data that allow computing the golf ball trajectory that is rendered in the application.

IG sees the trajectory of the ball and its finishing position.

OG can visualize the final position of the ball on the mobile display device.

<u>IG is playing second</u>

IG hits the ball. The inertial sensor provides the golf club motion data that allow computing the golf ball trajectory that is rendered in the application.

OG sees the trajectory of the ball and its finishing position on the mobile display device.

IG visualizes in real time the ball trajectory and its final position.

IG-HE, through the Activity Recognition module, can also compare his swing to an experienced golfer's swing and get some advices to better perform for the next shot.

Another possibility is that IG takes a quick look at the proper-recorded shot type depending on the location and position of his golf ball in order to reproduce it.

Arbitration

The two players see the position of the two balls on the course and discuss. They agree and conclude, for example, that the OG has the ball in the best position.

Move

OG moves to the ball. He is assisted by the display on the screen of his position on the golf course and of the estimated ball position according to the computing of the golf ball trajectory. He can see the position of the ball thanks to augmented reality.

Once there, OG confirms its final position via the mobile display device (e.g. tablet or Smartphone). This allows an accurate retiming if the calculated position of the ball was not precise enough.

The position of the virtual ball is updated according to this data ⇒ The view of 3D virtual course of IG is automatically updated to arrive at the same starting position [*flying view movement*].

Second round

IG is playing first

IG begins to play and hit the ball. The inertial sensor provides the golf club motion data that allow computing the golf ball trajectory that is rendered in the application.

OG sees the trajectory of the ball and its finishing position.

IG visualizes in real time the ball trajectory and its final position.

IG-HE can also compare his swing to an experienced golfer’s swing and get some advices to better perform for the next shot.

Another possibility is that IG takes a quick look at the proper-recorded shot type depending on the location and position of his golf ball in order to reproduce it.

OG is playing second

OG hits the ball. The inertial sensor provides the golf club motion data that allow computing the golf ball trajectory that is rendered in the application.

IG sees the trajectory of the ball and its finishing position.

OG can visualize the final position of the ball on the mobile display device.

Arbitration

The two players see the position of the two balls on the course and discuss. They agree and conclude, for example, that the OG has the ball in the best position.

Move

OG moves to the calculated position of the ball shouted by IG. He is assisted by the real-time display on the screen of his position on the golf course and of the estimated position of the IG ball. He can see the position of the ball thanks to augmented reality.

OG can confirm his final position to the system.

The position of the virtual ball is updated according to this data for the 2 players ⇒ The view of 3D virtual course of IG is automatically updated to arrive at the same starting position [*flying view movement*].

The OG gives always the starting position of each round, validating his position once he reaches it.

Game turns (IG-LC + IG-HE)

Beginning

The 2 players can talk to each other through their video return and sound return.

The 2 golfers start at the same position.

First round

IG-HE is playing first

IG-HE begins to play and hit the ball. The inertial sensor provides the golf club motion data that allow computing the golf ball trajectory that is rendered in the application.

IG-HE and IG-LC see the same view: the trajectory of the ball and its finishing position.

IG-HE can also compare his swing to an experienced golfer's swing and get some advices to better perform for the next shot.

Another possibility is that IG takes a quick look at the proper-recorded shot type depending on the location and position of his golf ball in order to reproduce it.

IG-LC is playing second

IG-LC hit the ball. The inertial sensor provides the golf club motion data that allow computing the golf ball trajectory that is rendered in the application.

IG-HE and IG-LC see the same view: the trajectory of the ball and its finishing position.

Arbitration

The two players see the position of the two balls on the course and discuss. They agree and conclude, for example, that the IG-HE has the ball in the best position.

Move

The view of IG-HE and IG-LC is updated to arrive at the same starting position [*flying view movement*] that corresponds to the position of the ball of IG-HE.

Second round

This time, IG-LC is playing first. The sequence remains the same

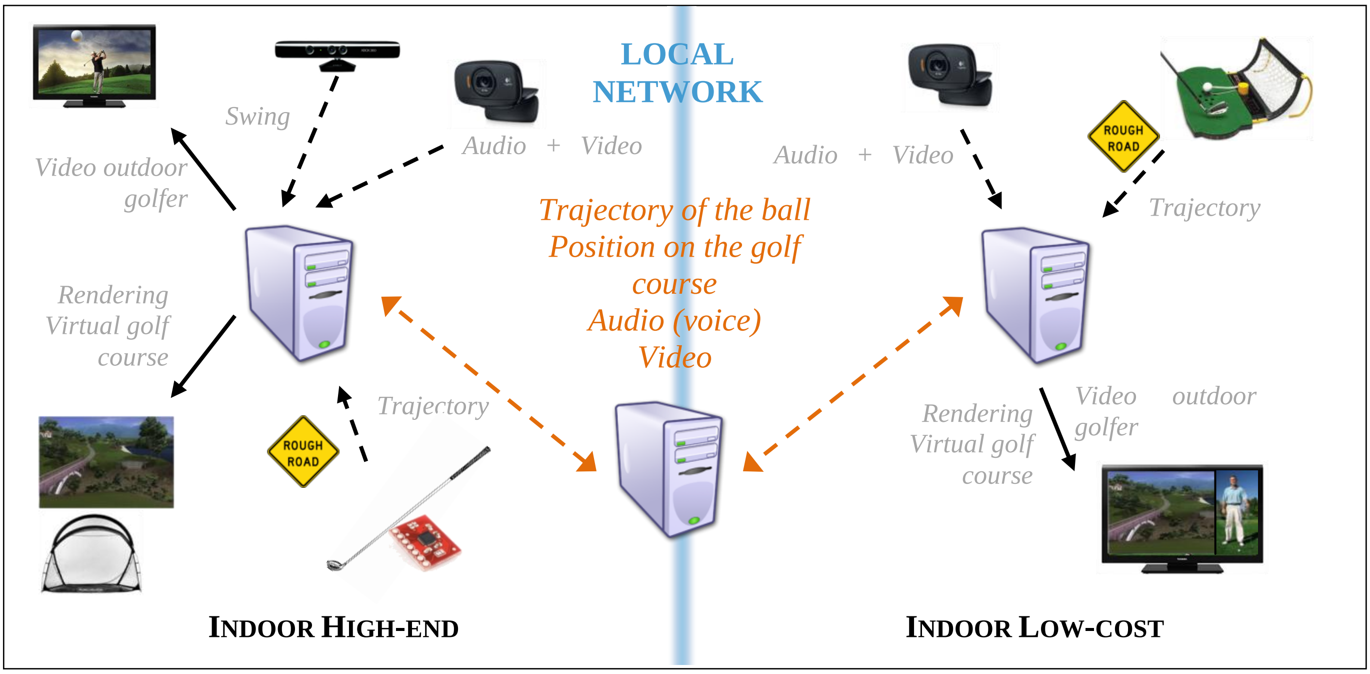
Scenario Configurations

Keys

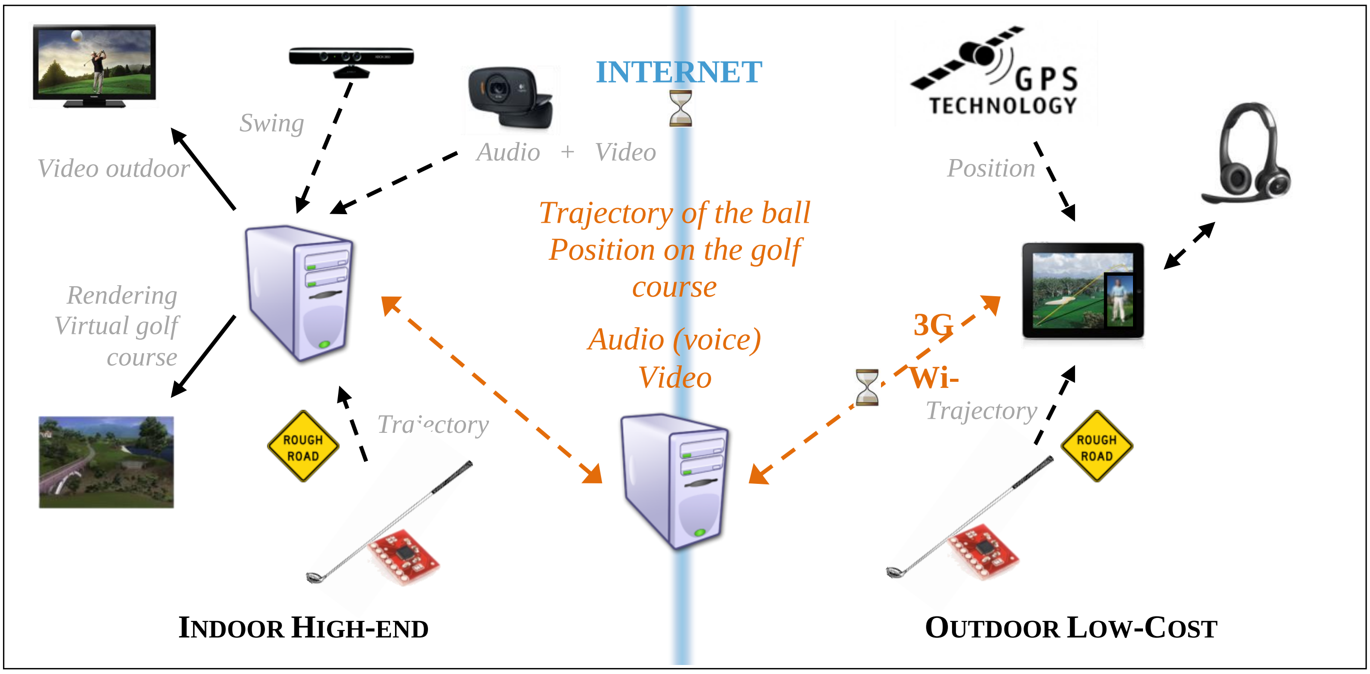
Technological difficulties

Potential latency

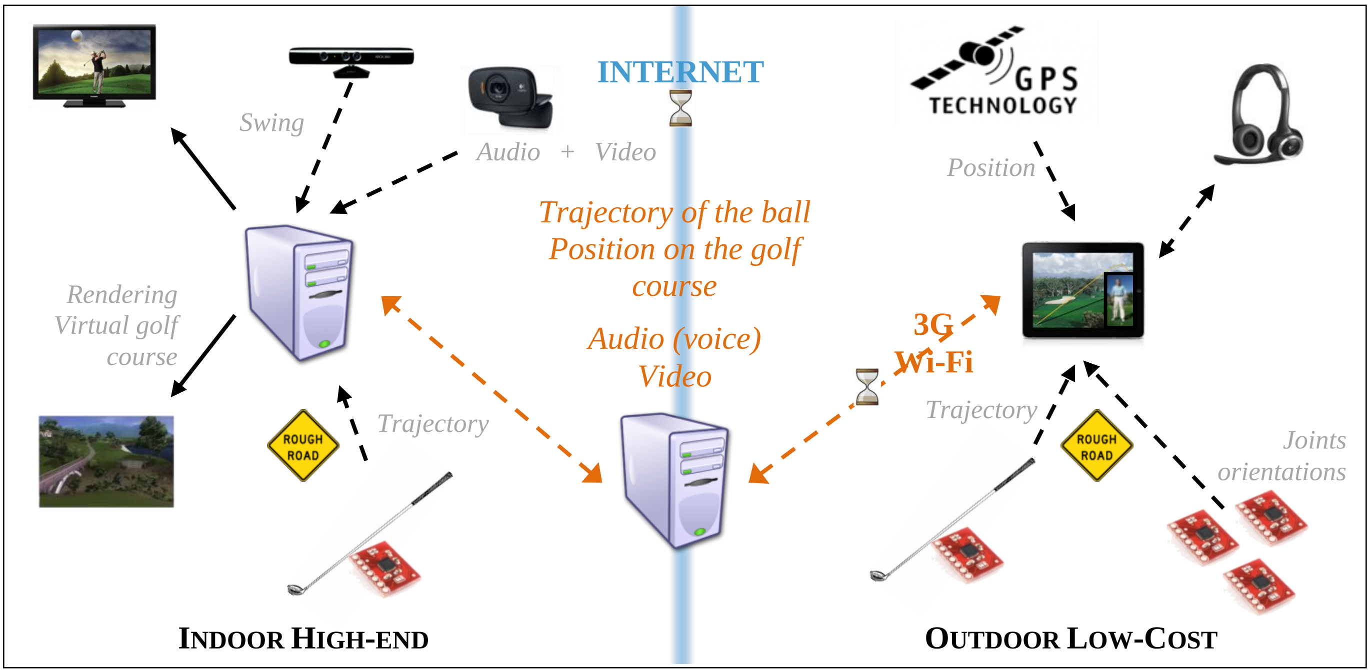
Configuration 1 ***2 indoor golfers (HE and LC) – Laval, France***



Configuration 2 ***1 indoor golfers (HE) – Laval, France + 1 outdoor golfer (LE) – Laval Golf, France***



Configuration 3 ***1 indoor golfers (HE) – Laval, France + 1 outdoor golfer (HE) – Laval Golf, France***



RESSOURCES

Equipment & Indoor/Outdoor with Low-Cost or High-End Differences

Equipment	Outdoor golfer – High End	Outdoor golfer – Low-Cost	Indoor golfer – High End	Indoor golfer – Low Cost
Inertial sensor for capturing the golf club motion	Inertial sensor on the Golf club	Inertial sensor on the Golf club	Inertial sensors/Golf club	Inertial sensors/Golf club
Activity recognition related to the different types of shots	Optional: Depends on the sensors on the body of the user	N/A	Microsoft Kinect/Inertial Sensors	None
Display of the golf course	iOS / Android Tablet	iOS / Android Tablet	Video projector 1080 Projection screen Protection net	TV HD (split screen)
Display of the other golfer			TV HD	
Voice of the other golfer	Headset	Earphone	5.1 sound system / Wireless Headset	5.1 sound system / Wireless Headset
Audio capture of the golfer	Headset	Earphone	Microphone/Headset	Microphone/Headset
Video capture of the golfer (optional)	Webcam HD 1080 (optional)	Webcam HD 1080 (optional)	Webcam HD 1080 (optional)	Webcam HD 1080 (optional)
GPS	SportsCurve GPS	Smartphone integrated GPS?	N/A (calculated from Vitual Scene)	N/A (calculated from Virtual Scene)
Others	Golf equipment: balls + clubs			

13 APPENDIX D: Followers' Social Platform Scenario

INTRODUCTION

During each 3DLive experiment, followers must be able to see how are the users evolve and interact with them. The Social Platform aims to gather all the followers on only one website, on which they have an interactive access to the experiment from anywhere.

OBJECTIVES

The main objectives of the Social Platform are:

- Explore a way to follow a Tele-Immersive Environment from anywhere
- Enable social aspects from one follower to an user
- Enable social aspects between followers
- Evaluate the impact of the followers' aspect in the user experience

SETUP AND SCENARIO

From anywhere and any platform, followers interested in the 3DLive experience must have access to interactive content of the experiments. In order to deal with that point, this platform will have to be set up on a website. The best way to guarantee the multiplatform accessibility for now is the HTML5 language.

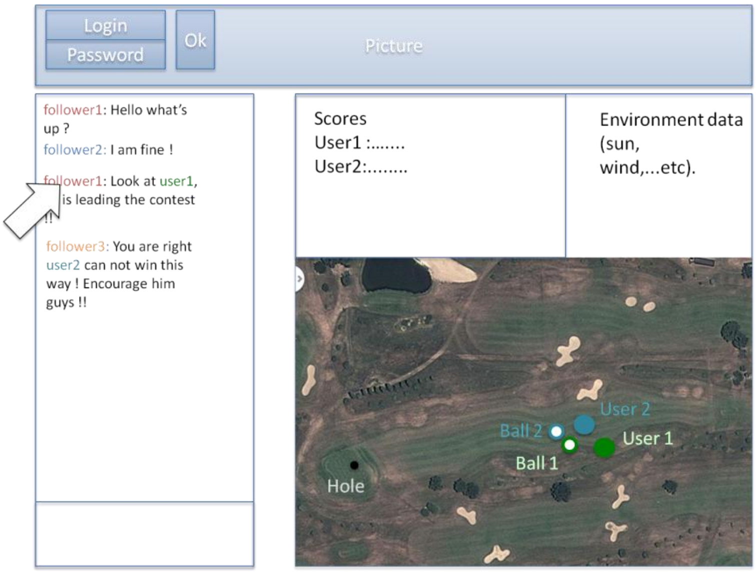
The scenario can be represented by these steps:

1. Access to the website

Followers that access to the website can see a webpage where three components are important: A login area, a chat area and a monitoring area. As they open this webpage they can see all the content but cannot interact. So they can see logged followers chatting, and they can see the evolution of the users on a slope.

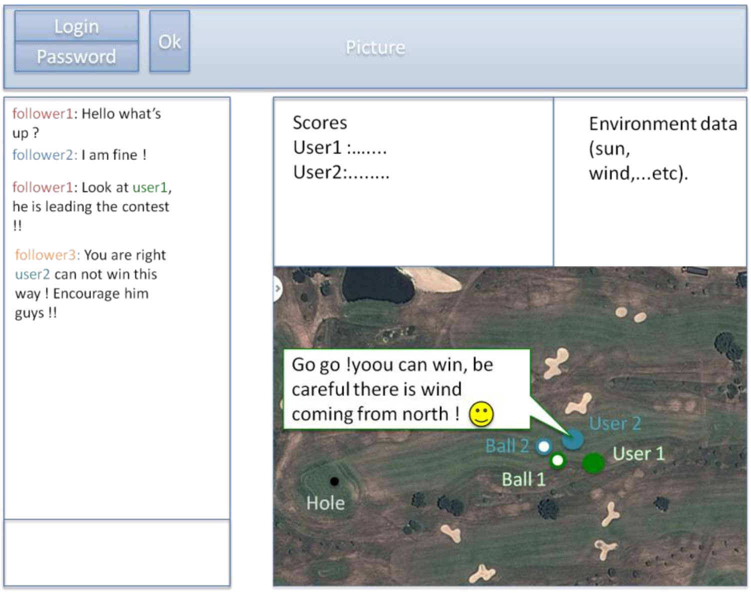
2. Log in

As soon as they are logged, they can chat with other followers and have access to interactive content. They will be able to check followers' profiles and send messages to the 3DLive users.



3. Interact

The chat box will be a standard chat tool, but the interactions with the followers could be by touching/clicking the proper user point in the monitoring frame.



The message will be displayed on the 3DLive user's screen/display while experiencing the platform.

SPECIFICATIONS

The Three scenarios can use the same structure for this platform: Only the position of the 3DLive users will be displayed. Only the Golf scenario will require an adaptation: Followers will be able to see ball trajectories shot after shot: so the actual position the ball will be displayed, and lines representing trajectories for previous shots will be displayed.