VISION

VIsualization SImulation and visual cOmputing techNologies

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VIsualization SImulation and visual cOmpting techNologies EU position and future potential

VISION study has been funded by European Commission Directorate General CONNECT - Communications Networks, Content and Technology under the tender SMART 2011/0035 Contract Number 30 - CE - 0468335/00-94: "Study on simulation, visualisation and visual computing technologies: EU position and future potential"

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SMART 2011/0035 Contract Number 30 - CE - 0468335/00-94:

"Study on simulation, visualisation and visual computing technologies: EU position and future potential"

Finished to edit in January 2013

The opinions expressed in this study are those of the authors and do not necessarily reflect the views of the European Commission

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TABLE OF CONTENT

ACRONYMS 5
PREAMBLE 7
1. EXECUTIVE SUMMARY 7
2. GLOBAL TECHNOLOGICAL TRENDS, CHALLENGES AND OPPORTUNITIES 16
2.1 TECHNOLOGICAL TRENDS 16
2.2 SOCIETAL TRENDS 18
2.3 MARKET TRENDS 19
2.4 LESSONS LEARNT 20
3 THE MARKET OUTLOOK 21
3.1 OVERVIEW OF 2014 – 2020: SIX YEARS DEVELOPMENT PLAN 21
3.2 BUDGETARY AND SOCIETAL CONSTRAINTS 21
3.3 STRATEGIC GROWTH AGENDA IN THE ICT SECTOR 22
3.4 INVESTORS OUTLOOK 24
3.5 LESSONS LEARNT 24
4. RESEARCH CHALLENGES AND POTENTIAL CONTRIBUTIONS 25
4.1 MULTIMODAL AND NATURAL COMPUTER INTERACTION 25
4.2 ENGINEERING AND MANUFACTURING 31
4.3 DIGITAL CONTENT CREATION, CREATIVE INDUSTRY, EDUCATION AND TRAINING 39
4.4 POLICY MAKING AND SOCIETAL CHALLENGES 43
4.5 SAFETY AND SECURITY 50
5. MARKET DEVELOPMENTS IN THE PERIOD 2015-2020 AND BEYOND 55
5.1 THE RISE OF A NEW ECONOMY 55
5.2 POWER TO PEOPLE 55
5.3 THE INTERNET OF “JOBS” 56
5.4 INNOVATION THROUGH EVOLUTION, NOT REVOLUTION 57
5.5 THE IMPORTANCE OF BEING EARNEST 57
5.5 IMPACT ON VISUALISATION, SIMULATION AND VISUAL COMPUTING 57
5.6 LESSONS LEARNT 58
REFERENCES 60

VISION is a project of Fondazione Graphitech, Italy, and it is funded by European Commission Directorate General CONNECT - Communications Networks, Content and Technology under the tender SMART 2011/0035 Contract Number 30 - CE - 0468335/00-94: "Study on simulation, visualisation and visual computing technologies: EU position and future potential"
More information about the project are available at www.vision4eu.net

ACRONYMS

3D-IC	3D integrated circuit
ABV	Augmented Business Visualization
AGILE	Association of Geographic Information Laboratories for Europe
AIST	Advanced Industrial Science and Technology
API	Application Programming Interface
AR	Augmented Reality
B2E	Business to Employee
BAN	Body Area Networks
BCIs	Brain Computer Interfaces
BD	Big Data
BI	Business Intelligence
BIM	Building Information Modeling
BMI	Brain Machine Interfaces
BYOD	Bring Your Own Device
C2	Command and Control
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CAM	Computer-Aided Manufacturing
CAS	Collective Adaptive Systems
CAX	Computer Aided Technologies
CFG	Context-Free Grammars
CISS	Collective Information System Support
CLT	Cognitive Load Theory
CNC	Computer Numerical Control
COTS	Commercial Off-the-Shelf
CPS	Cyber-Physical Systems
CPU	Central Processing Unit
CSCD	Computer Supported Collaborative Design
CSCW	Computer Supported Cooperative Work
CSE	Cognitive Systems Engineering
CTML	Cognitive Theory of Multimedia Learning
CUDA	Compute Unified Device Architecture
DE	Digital Earth
DE2	Digital Earth 2.0
DEG	Digital Educational Games
DHM	Digital Human Modelling
DLR	Deutsches Zentrum für Luft- und Raumfahrt The German Aerospace Center
DRM	Digital Rights Management
EARSC	The European Association of Remote Sensing Companies
EARSeL	The European Association of Remote Sensing Laboratories
EC	European Commission
EEA	European Environment Agency
EEG	Electroencephalography
EIONET	European Environment Information and Observation Network
EO	Earth Observation
EOG	ElectroOculoGraphy
ERP	Enterprise Resource Planning
ES	Embedded Simulators
ESA	European Space Agency
ET	Embedded Training
EUROGEO	The European Association of Geographers
Euro-Geographics	The association of the European cadastre, land registry and national mapping authorities
EuroSDR	European Umbrella Organisation for Geographic Information
FLG	Few-Layer Graphene
fMRI	functional Magnetic Resonance Imaging
FS	Feature Structures
GDP	Gross Domestic Product
GDSS	Group Decision Support Systems
GEOSS	Global Earth Observation System of Systems
GI	Geographic Information
GIS	Geographic Information System
GMES	Global Monitoring for Environment and Security
GML	Geography Mark-up Language
GPGPU	General-Purpose computing on Graphics Processing Units
GPU	Graphics Processing Unit
GUIs	Graphical User Interfaces
H2020	Horizon 2020
HCI	Human Computer Interaction
HMD	Head Mounted Displays
HMI	Human Machine Interaction
HMS	Holonic Manufacturing System
HPC	High Performance Computing
HRI	Human-Robot Interaction
ICT	Information, Communication Technology
ICT PSP	The ICT Policy Support Programme
IE	Interoperability Experiment
ILCS	Industrialised Low Cost IT Services
INSPIRE	Infrastructure for Spatial Information in the European Community
IO	input/output
IoT	Internet of Things
IP	Internet Protocol
IPTV	Internet Protocol Television
ISP	Internet Service Provider
IT	Information Technology
IUI	Implanted User Interfaces
JC3IEDM	Joint Consultation Command and Control Information Exchange Model
KPIs	Key Performance Indicators
LBS	Location-Based Services
LIDAR	Light Detection And Ranging
M&S	Modelling and Simulation

MaaS	Multimedia as a Service
MEMS	Micro-Electro-Mechanical Systems
MMIs	Mind-Machine Interfaces
MR	Mixed Reality
MVS	Multi-View Stereo
OEM	Original Equipment Manufacturer
OGC	Open Geospatial Consortium
OGCE	Open Geospatial Consortium Europe
OpenCL	Open Computing Language
OpenGL	Open Graphics Library
OR	Operations Research
OR	Operational Research
OS	Operating Systems
OUIs	Organic User Interfaces
p-HRI	Physical Human-Robot Interaction
PA	Projective Augmented
PaaS	Platform-as-a-Service
PCM	Phase Change Memory
PDES	Parallel Discrete Event Simulation
PDM	Product Data Management
PETs	Privacy Enhancing Technologies
PLM	Product Lifecycle Management
PMICs	Power Management Integrated Circuits
PRDL	Privacy Rules Definition Language
PSI	Public Sector Information
QoE	Quality of Experience
QoS	Quality of Service
RIAs	Rich Internet Apps
RS	Remote Sensing
RTD	Research and Technology Development
SaaS	Software-as-a-Service
SAS	Sensor Alert Service
SDIs	Spatial Data Infrastructures
SEIS	Shared Environmental Information System
SES	Sensor Event Service
SET	Strategic Energy Technology
SfM	Structure from Motion
SimSaaS	Simulation Software as a Service
SIR	Sensor Instance Registry

SME	Small and Medium sized Enterprise
SOA	Service Oriented Architecture
SOR	Sensor Observable Registry
SOS	Sensor Observation Service
SPS	Sensor Planning Service
SV	Software Visualisation
TETs	Transparency Enhancing Tools
TUI	Tangible User Interfaces
UI	User Interfaces
UIMs	Urban Information Models
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VA	Visual Analytics
VBR	Video Based Rendering
VE	Virtual Engineering
VF	Virtual Factory
VIM	Visual Simulation Model
VIS	Visual Interactive Simulation
VISM	Visual Interactive Simulation and Modelling
VM	Virtual Manufacturing
VMS	Video Management Software
VoIP	Voice over IP
VP	Virtual Prototyping
VR	Virtual Reality
VSEs	Very Small Enterprises
VSME	Very Small and Medium sized Enterprise
VVA	Validation, Verification and Accreditation
WebGIS	web-based geographical information systems
WebGL	Web-based Graphics Library
WIMP	Window, Icon, Menu Pointing paradigm
WLC	Watching, Listening and Co-designing approach
WNS	Web Notification Service
WPS	Web Processing Service
XML	eXtensible Markup Language

PREAMBLE

This document presents the result of the project VISION – "VIsualization, SImulation and visual cOmputing techNologies: EU position and future potential" which was awarded to Fondazione Graphitech, Italy at the end of 2011[1].

The study was launched in order to help the EC make informed decision for Horizon 2020 (H2020), the post 2013 EU Research and Innovation Programme, within the domains of visualisation, simulation and visual computing technologies (eHealth, eContent, Industrial applications). The study had to identify trends and main players in Europe and outline a crosscutting strategy on top of the several existing activities.

1. EXECUTIVE SUMMARY

The study carried on by VISION has clearly highlighted that, although the research community has been active in the domain of visualisation, simulation and visual computing for several decades, there are several critical open challenges still unresolved today. The complexity of the topics addressed is further emphasised by complex interdependencies among technological, cognitive, market and societal factors that, in turn, encumber any attempt to define quality benchmarks or price/performance ratios to assess developments in the domains of reference.

For this reason, throughout the study, the analysis has been increasingly focused on few well-selected domains carefully selected by narrowing the number of vertical domains subject of the examination. This approach has allowed better framing the most significant issues within the areas most relevant to the study and, consequently, it has helped pin-point the most significant recommendations for H2020.

In particular, as illustrated in the figure below, the analysis of the several domains of relevance was eventually focused along two main dimensions: three high-priority vertical domains and four

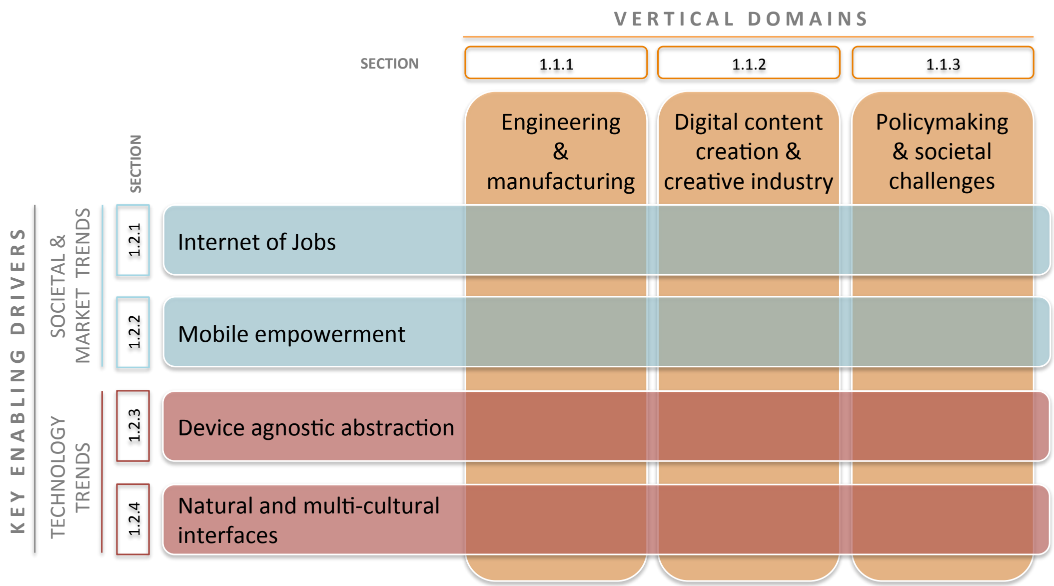


Fig 1: the two dimensions along which the final recommendations have been made

enabling "horizontal" drivers. The latter have been further grouped in societal and market trends and technological trends.

The reminder of this section presents the high-level recommendations for H2020 that have extracted from the larger sets of recommendations that will be illustrated throughout the study. The discussion has been articulated along the aforementioned two dimensions, starting from those related to the various vertical domains to move to those related to the key enabling drivers. Intersection between "vertical" and "horizontal" dimensions will be clearly highlighted throughout the text with the notation (ⓘ section 1.2.3).

1.1 VERTICAL DOMAINS

1.1.1 ENGINEERING & MANUFACTURING

"Mass customisation vs. mass satisfaction"

The engineering and manufacturing domain is being challenged by **fierce global competition** resulting from a number of societal, political, economical and technological factors. Asian manufacturers aggressively compete with European stakeholders through low-cost labour and production processes. US industries instead leverage on faster time-to-market performances, on more vigorous support by a risk-prone financial world and, in general terms, on a more business-oriented mind-set at the whole societal level.

For European manufacturers to survive and be successful within an increasingly globalised market they need to fight competition with Asian and US counterparts on different grounds, by positively leveraging on unique characteristics of European society, economy as well as on specific differences, at the market and societal level, between Europe –on the one hand- and US and Asian countries, on the other.

In Europe, the fast **aging society** is progressively -yet inevitably- affecting the overall workforce. Furthermore, Europe's traditionally high consideration of social aspects is calling for new solutions that can **improve inclusion** of those social groups that so far, have had either played a marginal role within the job market or were unable to proactively contribute to economical growth altogether.

[1] VISION study has been funded by the European Commission Directorate General CONNECT - Communications Networks, Content and Technology under the tender SMART 2011/0035 Contract Number 30 - CE - 0468335/00-94: "Study on simulation, visualisation and visual computing technologies: EU position and future potential"

At the same time, the European market is increasingly characterised by a very mature and conscious pool of consumers who are requiring even **higher-quality products** that can be **custom-tailored** to meet expectations and requirements of each specific user. This trend is further amplified by the progressively ubiquitous access to **"smart devices"** (ⓘ section 1.2.3) and **social networks** by increasingly IT-literate users who represent a significant share of the overall population in Europe, horizontally distributed across different social and age groups. As result, manufacturers are challenged to address requirements of networked users who increasingly base their purchasing choices on the exchange of uncensored product ratings with other peer customers.

Furthermore, the fairly high technological advancement that characterises industrial manufacturing processes in Europe, the increasing data coming from sensors available within various products (e.g. from cars to mobile phones), and the increasing amount of information exchanged through social networking, are contributing to the creation of **very 'big data'** scenarios.

In order to face the aforementioned scenario the study has isolated a number of recommendations to the European Commission, all converging towards a common high-level goal: to promote RTD and innovation activities that can lead to what has been referred to as "mass customisation" and "mass satisfaction".

Rec. 1: *To promote RTD and innovation activities leading to "mass customisation" and "mass satisfaction".*

Both expressions ultimately aspire at delivering a better products or higher customer satisfaction from two different standpoints. "**Mass customisation**" calls for extremely high flexibility across the whole product lifecycle (from design, to manufacturing, to maintenance and disposal) to be able to address specific requirements of individual customers within a very efficient industrialised process. This will require research to study how to ensure higher flexibility, in terms of production rates, and how to make manufacturers re-configure their production in easier manner.

Rec. 2: *To develop intelligent products based on cyber-physical systems, which can communicate with different "players" of the manufacturing processes (e.g. humans, intelligent machinery, robots etc.).*

Furthermore, engineering and manufacturing processes are expected to become more networked and decentralised (ⓘ section 1.2.2). Research will have to explore how to create more intelligent products that, based on increasing use of cyber-physical systems, will be able to communicate with the different "players" within the manufacturing processes, be this humans (e.g. designers, engineers), intelligent machinery, robots, to name but a few (ⓘ section 1.2.3). Research will also have to address how to ensure that these players can interact across the whole supply chain, without being constrained any more to the boundaries of a single manufacturer.

Rec. 3: *To address design and engineering as an integral part of "industry 4.0" vision.*

We particularly recommend that projects, within this domain, will address **design and engineering as an integral part of "industry 4.0" vision** by focusing not only to the shop floor, but extending the scope of projects to the design and engineering stages.

This would enable creation of stronger synergies and development of more effective design tools, for instance capable to account in real time for constraints set by production and manufacturing units. This would also allow for more effective production cycles based on ecosystems where machinery, robots, users are all part of a larger cooperative environment.

In order to limit the complexity set by this scenario, we recommend, in a first phase, to limit the scope of such approach to the intra-factory level and to extend it to the whole market level at later stages of the research programme.

Rec. 4: *To promote medium-sized consortia that can represent real high-tech industrial ecosystems made of a large pivotal manufacturer and several high-tech SMEs.*

Research will have to involve not only large manufacturers but also very specialised SMEs to be able address their specific requirements. In fact, as we are moving towards a more **versatile manufacturing environment**, based on more networked and virtualised products and manufacturing services, SMEs will be playing an increasingly important role in that they will have to provide very specialised competences within an increasingly cross-company, more integrated and virtualised manufacturing process. It is equally undeniable that projects will also have to involve major industrial players (e.g. main manufacturers within the automotive industry) that will play a central role within a highly cooperative environment of smaller companies, to which they will levy their requirements.

For this reason we recommend to promote the creation of medium sized consortia that a large manufacturer with a pivotal role together with a group of high-tech SMEs or VSMEs[2] which can create an "**ecosystem**". The final aim should be to facilitate **clustering of companies** with different competences to jointly create specialised products with high technology.

Rec. 5: *To develop modelling, simulation, visualisation and visual computing hardware and software solutions to create high-tech industrialised products featuring exclusive characters of handcrafted products.*

Research should also address how to create visualisation, simulation and visual computing solutions that can be used by SMEs or VSMEs to create very personalised high-tech products that can reproduce

[2] In this case VSMEs (Very Small and Medium Sized Enterprises) typically refer to experts that are "empowered" (i section 1.2.2) to work within a virtual working environment that has been referred to as "Internet of Jobs" approach (i section 1.2.1).

the exclusive character of an artisan-made product, yet within a highly sophisticated engineering and manufacturing process. For this reason a further key recommendation is to explicitly address within projects, the development of **new modelling, simulation, visualisation and visual computing software and hardware technologies**, as they will be among the most important enablers of the Industry 4.0 vision (ⓘ section 1.2.4). Without significant and consistent investments in these areas Industry 4.0 will simply not happen.

Rec. 6: *To promote projects that can let Industry 4.0 contribute to the growth of the "Internet of jobs".*

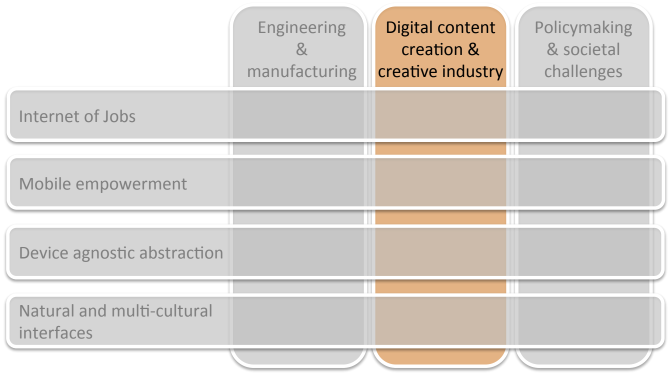
An additional recommendation is to promote projects that can let Industry 4.0 contribute to the growth of the "Internet of jobs" (ⓘ section 1.2.1). For this it is essential to promote creation of new tools that can leverage on a world of distributed processes, distributed manufacturing and logistics. This would help create new jobs and new business processes across Europe throughout the whole supply chain.

Rec. 7: *To facilitate "mass satisfaction" through analytics tools that can extract customers' requirements from very structured and unstructured big data sources.*

On the other hand, in order to address "**mass satisfaction**", we recommend that research will address the creation of advanced analytics tools capable of extracting key pieces of information on user preferences from structured and unstructured 'big data' pools, to create solutions or services that can address the requirements of the largest share of customers. In general terms, significant market relevance will be played in the future by data visualisation, therefore research and innovation should specifically address how to best assist companies through advanced visualisation technologies that can operate as a powerful BI solution on top of big data scenarios (ⓘ section 1.2.4).

1.1.2 DIGITAL CONTENT CREATION & CREATIVE INDUSTRY

"Inspiring ubiquitous expression of human creativity"



The digital content creation and creative industry is underground a profound evolution. The prevailing diffusion of "**smart devices**", including smart TVs, has brought to a paradigm shift that is clearly epitomised by the number of **added value IP services** and platforms (ⓘ section 1.2.3) available now for these devices.

Although the European research community has clearly acquired a strong position within the domain of digital content creation and creativity (ⓘ section 1.2.4), it is a matter of fact that, over the past few years, European visual or interactive industries (e.g. animation movies, video games etc.) have lost ground to the advantage of American or Asian stakeholders. However, the considerable market relevance of the technologies enabling digital content creation, which is worth an estimated at 4 Billion Euros, calls for specific actions that can ensure a **strong industrial positioning** within specific segments among the creative and visual industries where European stakeholders can play a key role.

Past policies leveraging on better exploitation of Europe's cultural assets, have been applied on perhaps excessively **conservative grounds**, frequently leading to the creation of very static content. Perhaps the most notable example of this trend is Europeana that, notwithstanding its unquestionable cultural relevance, it has not explicitly helped European cultural industry create market opportunities from such a rich cultural digital asset.

Based on this position, the study has identified several recommendations promoting RTD and innovation activities in the field of visualisation, simulation and visual computing technologies, that could be summarised by the motto "***inspiring ubiquitous expression of human creativity***". In general terms, the study advocates the creation of tools that can help human beings express their creativity with the same naturality and flexibility that characterised the pre-digital era, yet within a completely digital and ubiquitous scenario. To help this vision become reality, the study has pinpointed the following key recommendations for H2020.

Rec. 8: *To ensure richer experiences based on high-quality interactive media authored by non-specialist users through cloud-based services using personal digital content.*

First, focusing on **content**, a first recommendation is to facilitate the creation and authoring of digital content (including artistic content) derived from personal experience or personal background. It is essential to develop new technologies that can facilitate **content creation for personal use** based on information available of the web in different forms (text, video, images).

In particular, we recommend promoting development of technologies that can let users simply combine available personal online data in a custom-tailored manner to create richer experience. In particular, we recommend fostering development of technologies and tools that can engage the widest community of prosumers[3] in the creation of interactive high-quality digital content that can reflects their personal background and competences (ⓘ section 1.2.4).

[3] These could range from pupils to professors, from experts in a given to domain to artists.

For this we recommend research to explore **cloud-based, advanced media authoring technologies** that can empower normal users (non-specialists) to get full advantage of the huge amount of audio-visual content already available in the cloud, to create media experiences of the future.

Rec. 9: *To foster industrial leadership within the emerging market of Multimedia as a Service (MaaS) market.*

In particular, we recommend supporting the creation of an industrial leadership, of European stakeholders, within the emerging "**Multimedia as a Service**" **(MaaS) market.** This should be facilitated by fostering the creation of a new paradigms whereby multimedia content (be this 3D, video, audio, image, text) with intrinsic associated behaviour, can be accessed through an abstract service layer that can allow users to interact with them in real-time in a completely hardware-agnostic manner (ⓘ section 1.2.3).

Rec. 10: *To develop new forms of content creation and consumption of self-contained "information atoms" that can remove barriers between virtual, augmented and real environments.*

New interactive forms of content creation and consumption should be promoted, based on ubiquitous or spatialised access to content in the real world, promoting new visualisation and visual computing metaphors that can **remove existing barriers between virtual, augmented and real environments**. Research, in particular, will have to account for new trends within the consumer IT market (ⓘ section 1.2.3), promoting explicit use of emerging devices and technologies such as flexible, transparent screens, augmented reality glasses, miniaturised portable projector units, portable brain machine interfaces that can facilitate pervasive, contextualised and personalised access (ⓘ section 1.2.4) to self-contained **information "atoms"**.

Rec. 11: *To facilitate creation of cultural and knowledge paths from automatic aggregation of information "atoms".*

Specific activities should then be promoted to create more structured "knowledge/cultural paths" through automatic higher-level aggregation of such information "atoms". Examples of such "**knowledge/cultural paths**" could allow –among others- creation of very innovative curricula at school or forms of "augmented historical memories".

Future projects should leverage on existing digital cultural assets to develop tools that can help people create further cultural assets, directly addressing market segments such as entertainment, advertisement or tourism industry. This will also positively impact on citizens' sense of belonging to a community, thus strengthening our cultural identity, as well as on economy. In practical term, we strongly recommended future projects to focus on the creation of an abstract platform, to be specialised for specific domain-driven requirements, which could allow content creation, authoring and fruition independently and beyond the various "smart" devices available (ⓘ section 1.2.3).

Rec. 12: *To promote innovation in the domains of digital rights management, content distribution and super-distribution and privacy.*

We further recommend sustaining the aforementioned research and development undertakings with specific innovation activities targeting: a) **Digital Rights Management (DRM),** an evolving key issue that should be properly addressed by the media of the future; b) **content distribution and super-distribution,** in order to ensure alignment of technology with regulatory and legal aspects; c) **privacy issues**, a key aspect in the context of an increasingly ubiquitous and prosumer-centric digital content creation scenario.

Rec. 13: *To foster co-existence of traditional with Internet-centric television.*

If we move our analysis from content to **platforms**, besides the undeniable disruptive advent of mobile technologies and their interaction within a larger content and service ecosystem (ⓘ section 1.2.3), the study has highlighted that smart TVs will play a renewed pivotal role in the digital content creation and creative industry, as they are evolving from the traditional concept of TV to become domestic data, media and control hubs.

Although this evolution can provide significant opportunities, we strongly recommend the Commission **to avoid taking a radical position by disregarding the concept of traditional TV**, as we know it today. Traditional TV in fact still plays a key role, and will keep doing so in the future, whenever massive distribution of content in a simultaneous manner will be required, with a level of accessibility and market penetration that IP technologies cannot ensure.

Furthermore traditional TV is a fundamental component of a number of societal, political, cultural and educational dynamics. For this reason we recommend, within H2020, to avoid "diluting" the traditional concept of TV into a totally Internet-centric TV, promoting instead developments that can ensure co-existence of both worlds.

Rec. 14: *To develop the next generation digital companions capable to provide assistance to users and to communicate with them in a natural way within mixed reality scenarios.*

Last, but certainly least, moving from platforms to **enabling technologies**, we recommend the EC to encourage development of the next generation of personal assistants. In fact, although **personal assistants, virtual companions** or "avatars" are not certainly a novelty within the RTD panorama, however, technologies developed so far were affected by severe usability restrictions, essentially due to their limited language skills and poor semantic understanding capabilities.

Nonetheless, over the last few years, language technologies have progressed to such an extent that the idea of being able to develop

virtual companions capable to provide assistance to users and to communicate with them in a natural way, is now within reach of the research community[4]. It is worth noting that results of research on personal assistants will be extremely functional to the development of next generation robots that will be called to interact with humans through realistic behaviours within medical, assistance, security, emergency or catastrophe management scenarios.

In particular, we recommend research to focus on development of personal assistants in the **context of ubiquitous mixed reality applications**, a niche that so far has not been explored in a consistent manner and that very likely will see a significant rise in industrial and scientific interest after the arrival on the market of consumer AR technologies[5].

However, based on recent past history, we specifically recommend that projects within this topic will have to address very focused issues, delivering robust and reliable technologies that should be eventually validated within real-life scenarios. This will be essential to help the general public overcome **significant unfulfilled expectations** that were generated in the past by overhyped avatars' capabilities in the context of virtual worlds such as Second Life and which eventually caused people to quickly loose interest on these technologies.

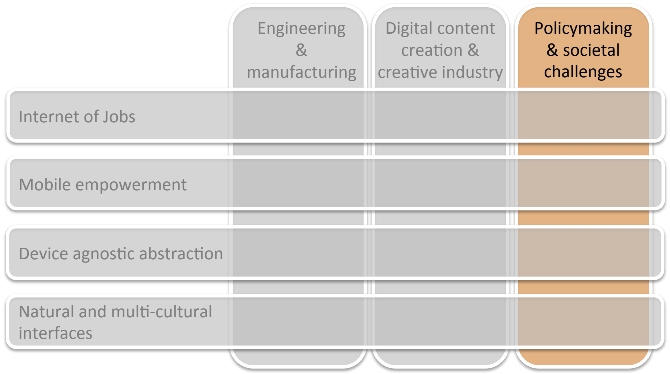
Rec. 15: *To promote a more substantial role of European stakeholders within the videogame industry by promoting innovative forms of games.*

Video games, on the contrary, have contributed to a positive appreciation of virtual assistants as means to improve, to a considerable extent, the quality of the overall experience. With regard to this issue, in particular, we further recommend to promote a more substantial role of European stakeholders within the **videogame industry**.

This will require evolving from the previous conservative positions of the previous Framework Programmes, where games were not specifically addressed "as such" but only as a training-oriented means in the context of so-called "serious games". It is therefore recommended to explicitly support development of innovative forms of games, which should be regarded as: a) a key driver to unleash users' creativity and engagement; b) an important part of our cultural asset[6] and, c) a concrete source of business due to the significant role at the market level of vide games industry[7].

1.1.3 POLICYMAKING & SOCIETAL CHALLENGES

"The planet is the ultimate interface"



The original concept of Digital Earth (DE), as envisaged by Al Gore in the late nineties, has partially become true with the advent of modern 3D geobrowsers or "spinning globes". However, the widespread availability of geospatial information (e.g. satellite and airborne imagery or Geographic Information Systems – GIS), the widespread adoption of geographical web services, the uptake of so-called spatial web applications or "mash-ups", the success of Location-Based Services (LBS), the formidable technological progress in the domain of sensors networks, and the rising success of "smart city" services, all require **revisiting the original idea of DE** within a more complex, articulated and comprehensive vision.

Taking a leading role in the development of the new generation Digital Earth, often referred to as Digital Earth 2.0 or simply DE2, has a strategic value in that it would allow European stakeholders to define not only technological aspects, but also access and governance policies, with potential geopolitical implications similar to those recently emerged during the definition of the governing policies of the future Internet. In fact, the development of DE2 will lead to an interconnected network of technologies and services built on top of a spatio-temporal very 'big-data' asset, an "**Internet of Places**" that will support not only access to geospatial data in an ubiquitous manner, but also -and most importantly- analysis, synthesis and simulation of data at various granularity from local to global scale. Within such a DE2 vision the planet itself becomes the ultimate "interface" of an overarching infrastructure that allows very advanced forms of cooperative simulations. Within this scenario, some key high-level recommendations have been made on top of the vast set of low-level technological recommendations identified throughout the study.

Rec. 16: *To develop spatio-temporal services for interactive analysis and synthesis capable to operate with data at different levels of granularity and indetermination.*

First of all, from an **algorithmic** standpoint, we recommend promoting development of **spatio-temporal simulation algorithms** that can be used to interactively support the process of analysis and synthesis. Such algorithms, to be eventually deployed as services or

[4] An example of advancement of language technologies is the very recent (Nov. 2012) demonstration of real-time automatic translation from English to Chinese made by Microsoft, something not possible only few years ago.

[5] The arrival of consumer technologies including the Augmented Reality glasses by Google (also known as Google Glass Project) or Microsoft will most likely have a disruptive effect fostering an increasing number of AR applications.

[6] It is well acknowledged that videogames can be now considered as an important part of our cultural asset.

[7] The success of companies such as Unity Technologies, which have developed one of the most successful game engines on the market, shows that, in only few years, it is possible to create significant business opportunities. It should be noted that today videogame market is not any more constrained to the domain of game consoles and desktop PCs, but it also includes web browsers, smartphones, tablets, and smart TVs.

cloud-based facilities, should be able to operate at **different levels of granularity, according to information available at various scales or levels of indetermination**, through specific **support for uncertainty** within the underlying data model. This will be important to be able to track the level of indetermination of various information sets across their lifetime and to assess the reliability of a given resource also after a number of subsequent processing steps. **Data preservation** in this context should also be addressed.

Rec. 17: *To develop automatic context understanding and spatio-temporal alignment of structured, semi-structured and unstructured information.*

Research should also focus on automatic mechanisms for **automatic context understanding** and **spatio-temporal alignment** of structured, semi-structured and unstructured (e.g. from crowdsourcing) information extracted from the analysis of multiple resources available for a given area. This information, in turn, could be used for automatic creation –through aggregation- of multi-scale (in case of discreet differentiation between data at different scales) or vario-scale (in case of continuous differentiation of data at different scales) representations. The DE2 community could benefit of a structured approach to various reference systems - spatial, temporal, and semantic.

Rec. 18: *To develop DE2 tools to facilitate inclusion and participation of citizens to governing processes by engaging proactive participation to control of administrative processes and expenditures.*

From a higher-level perspective, we then recommend developing techniques that, based on DE2 service infrastructures, can support better inclusion and participation of citizens to the governing process (ⓘ section 1.2.2). In particular, we recommend the European Commission to pay particular attention to promotion of initiatives involving very heterogeneous consortia whereby RTD stakeholders can collect real requirements from public administrations to create advanced "smart" services. Particularly relevant, for the clear social implications, would be the development of DE2 services that, based on extensive use of large set of geospatial data (including open and linked data), can **improve control of administrative processes** and in particular of **expenditures** of public administrations.

Rec. 19: *To develop tools for "what-if" analysis and to improve control over anthropic activities.*

A further recommendation is to create technologies that can help public administrations **improve control over anthropic activities** and territorial planning. For this reason synergies should be built between stakeholders belonging to the DE world and to the "smart city" community. Research should promote development of geospatial services for analysis and synthesis that can be used for "what-if" analysis with the involvement of many stakeholders.

Rec. 20: *To visual computing techniques designed to facilitate freedom of expression and participation of citizens to public life, including visual computing techniques for consensus building, dialogue and mediation, emerging of ideas, and collective contribution to a given task in the context of very large cooperative scenarios.*

We further recommend focusing on the creation of cooperative applications for grassroots (bottom up) involvement of citizens through new visual computing technologies designed **for a large number of users collectively addressing a given task** (ⓘ section 1.2.4). The potentially very high number of users, for instance in scenarios such as e-democracy and cooperative definition of policies, makes this a particularly challenging issues, requiring development of specialised tools and visual languages to support consensus creation, dialogue, mediation, emerging of ideas. With regard to this, future projects will have to address how to facilitate communication, participation to public life and **freedom of expression** by explicitly addressing inevitable privacy implications, and by developing techniques to prevent impact of lobbies that could manipulate masses in a non-transparent manner.

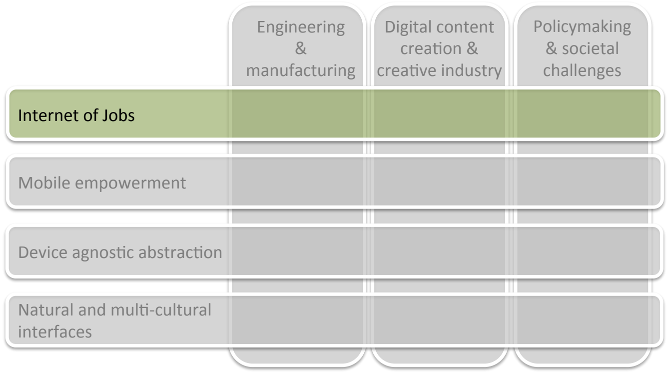
Rec. 21: *To promote delivery of tangible outcomes within a multi-projects ecosystem with well-defined a-priory communication and cooperation constraints involving downstream users within real-life scenarios.*

To conclude, in general terms, we recommend that all projects within this domain should result in **practical and tangible outcomes** (e.g. platform components) whose real impact at the societal level should be validated with the involvement of real downstream stakeholder (e.g. a public administration or citizen) within real-life scenarios. Additionally, major large-scale initiatives addressing "core" DE2 issues should be accompanied by a constellation of smaller-scale projects, involving specialised stakeholders and promoting clear innovation activities. The goal should be to create a **multi-project ecosystem** with well-defined *a-priori* structured communication and cooperation constraints that can ensure exchange of results among projects and maximization of synergies.

1.2 KEY ENABLING DRIVERS

1.2.1 THE INTERNET OF JOBS

"Changing the working landscape through the Internet of Jobs"



The next few years will witness a radical societal shift leveraging on a key evolution of the working paradigm, which will bring a range of opportunities at economical, societal and technological level. As result, the current working environment will evolve from the current "traditional" scenario to the so-called "**Internet of Jobs**".

From a job market standpoint, this evolution will introduce a new paradigm whereby companies will be able to allocate jobs through Internet based on processes closely integrated within the company. The current trend already sees several companies starting to re-structure their workforces, offloading tasks and jobs to communities of experts who are connected to the company through social networks.

This will allow companies to harvest talented people from a potentially much wider pool of experts than today. As a result, companies will be able to leverage on a potentially significantly larger knowledge base thus creating opportunities for more effective business processes.

This evolution, which will leverage on the "Internet of processes", will have a major impact at global level, bringing to an estimated **1.8 Million new jobs by 2040** and with an estimated worldwide market relevance of **140 Trillion US dollars**.

This evolution will considerably **improve inclusion** of those social groups that so far, within the traditional job market, have either played a marginal role or were unable to contribute to the production process altogether[8].

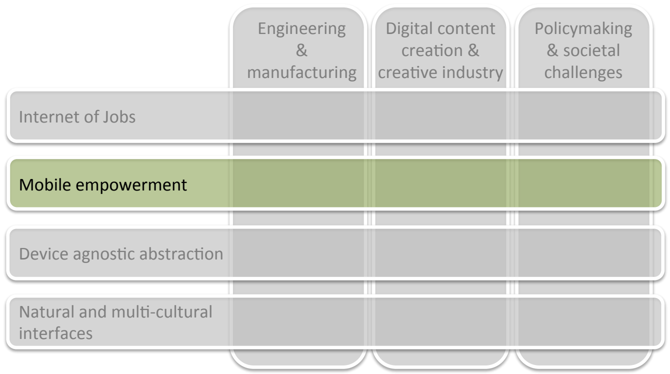
However, this evolution will also bring a major challenge since we will have to ensure that, based on these new company structures and business models, European workers will be able to retain as many of these new jobs, winning **tough competition** with other experts at global level. In fact, those future jobs that will be available from the Internet may not have to be located necessarily in Europe. Should this be the case, our population will loose out working opportunities, ultimately bringing to a contraction of the financial resources available within Europe.

Rec. 22: *To maximise investments on visualisation, simulation and visual computing technologies for education and training.*

For this reason, in order to maintain at least the same employment level we have today, we have to make sure Europe can keep a significant share of these new jobs. The first recommendation is therefore to **maximise investments** on visualisation, simulation and visual computing technologies for education and training that can help European citizens and workers have the best qualifications to acquire these jobs.

1.2.2 MOBILE EMPOWERMENT

"Empowering user to run their businesses from their pockets"



A further recommendation is to promote the development of **software ecosystems** that can help people work in a more efficient way. This may include, for instance, development of advanced cooperative systems capable to support users in a range of different working tasks specifically catering for the requirements of VSMEs (ⓘ section 1.2.2).

Rec. 23: *To develop software ecosystems that can help people work more efficiently and in more cooperative terms.*

The "Internet of Jobs" in fact will most likely bring to a rising number of very specialised VSMEs with key competences, capable to dynamically re-adjust to varying workloads. This, in turn, will require development of new and more usable enterprise platforms and content management systems featuring interfaces that are not only multimedia and multimodal but are also **multi-lingual** and **multi-cultural**[9] (ⓘ section 1.2.4), in order to be able to leverage on the widest possible pool of experts.

A key recommendation emerging from the study is to explicitly address the main amplifying factor of the aforementioned "Internet of Jobs", that is the ubiquitous use of "smart" technologies (ⓘ section 1.2.3) within a blended personal and professional scenario.

Rec. 24: *To develop networked services and front-end mobile applications to run all aspects of businesses (technical, administrative, customer care) from a smart device.*

In particular, we recommend promoting research and innovation activities that can bring to "**empowered" users** through networked services and front-end mobile applications available from smartphones, tables and other "smart" IT devices, tailored for each specific job, that can help people create and manage business in a completely autonomous way. These new technologies should "empower" users, regardless of their societal group, to create new business scenarios based on smart mobile technologies that can be used as business "Swiss knives". As result, in the mid-term future,

[8] Among these social group we can list, for instance, differently abled people or senior people who, thanks to the "Internet of Jobs", could effortlessly work from home, as well as mothers or fathers of young children, who could still be part of a real active working environment instead of facing the choice of (temporarily or permanently) leaving their jobs to take care of their family.

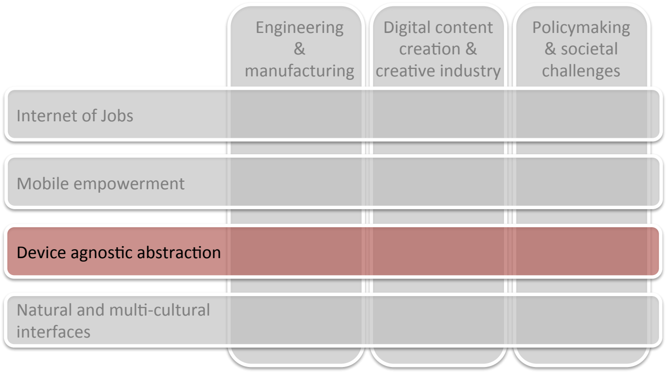
[9] A key example of such a renewed attention to multi-cultural issues is the development of an SMS version of the GMail service by Google especially designed to meet the requirements of South African market. Further examples are the development of specific enterprise-level infrastructures that can support micro companies within developing countries, offering services ranging from publication of web pages on the Internet in an effective way, to provision of simple services typical of classical Enterprise Resource Planning (ERP) systems.

users will be able to run their whole business -including technical, administrative, operational, services activities- from a "smartphone" or tablet, hence the term "business in the pocket".

Such a scenario, which has already started unfolding, will deeply affect not only formal economies but also emerging countries, bringing major societal and economic implications worldwide.

1.2.3 DEVICE-AGNOSTIC ABSTRACTION

"Future-proofing European developments within the smart technology arena"



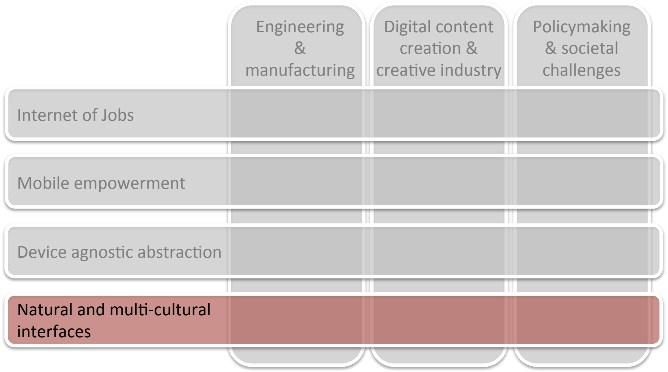
An important further recommendation that may determine the success of European industry within the aforementioned "empowering" scenario (ⓘ section 1.2.2) is the development of **hardware-independent software layer** on top of smart technologies and devices. Such an abstraction layer should decouple application and services development from the underlying hardware.

Rec. 25: *To develop hardware-agnostic software layer ensuring abstraction over underlying smart technologies.*

Since it is likely that European electronic manufacturing industry will not be able to overtake American or Asian manufacturing capability to develop portable IT devices (e.g. smartphone, tablets etc.), it will be important to promote development of hardware-independent software solutions (i.e. APIs) that can operate as an abstraction layer over the different smart technologies. This would allow de-coupling developments of applications and services carried on by European stakeholders from the underlying fast-evolving hardware technologies, safeguarding development and software products from hardware dependencies or unpredicted hardware evolutions on the market that could be imposed by dominant manufacturers.

1.2.4 NATURAL AND MULTI-CULTURAL INTERFACES

"Smart interaction from everything, from everywhere, for everyone"



When studying the human computer interaction domain we can easily predict that years to come will be characterised by a fast evolving technological landscape. Arbitrary shaped non-flat displays, portable augmented reality glasses, micro-projection units, portable markerless gesture tracking systems and increasingly accurate Brain Machine Interfaces will become a commodity. These technologies, until now only available to research labs, will enter the mainstream market causing a profound paradigm shift at the public level. This will require not simply adapting old interaction schemas but it will call for the development of brand new interaction mechanisms that can account, for complex technological ecosystem issues.

Rec. 26: *To move the focus of interaction paradigms from human-to-machine to dynamically changing human-to-ecosystem scenarios.*

Based on the aforementioned outlook, the first recommendation is to promote development of new interaction mechanisms that depart from traditional human-machine interaction mechanisms to **human-ecosystem interaction paradigms**. This will require development of new interaction methods that transparently rely on use of multiple concurrent devices and technologies, whose number, configuration and position can change dynamically within a larger ecosystem (e.g. TV, smartphones, tablets etc.).

Rec. 27: *To promote an innovation-centred activity leading to de-facto hardware-agnostic standardisation on interaction formalisms (incl. user's actions, system feedback and human-machine dialogue).*

Furthermore, based on this scenario we recommend promoting, through H2020, an innovation-centric action aiming at the *de-facto* standardisation of abstract forms of interactions. The result should be a **well-acknowledged formalism** to be used to encode user's actions, system feedback and human-machine dialogue, regardless of the specific hardware being used.

The advantages of such an achievement would be twofold. On the one hand, such a development could have a positive impact at the industrial level, by ensuring stronger positioning of several industries in Europe. On the other hand, the creation of a standardised abstract layer would help European stakeholders become independent from "smart devices" manufacturers, which typically are located outside Europe. This is a similar situation to what was described within the previous section with regard to when the need to create an "abstraction layer" (ⓘ section 1.2.3) to "empower" users of smart devices (ⓘ section 1.2.2) was discussed.

Rec. 28: *To promote a leading role of European industries within the Interaction as a Service (IaaS) market allowing widespread support of advanced forms of interaction from any device or appliance.*

Based on such a standardisation results, H2020 should later promote activities that could help European industries acquire a leading role in the market of "**Interaction as a Service**" (IaaS). These would enable "less smart" devices (e.g. home appliances) to support advanced forms of interaction via interoperable web-services.

Rec. 29: *To promote development of research of AR as context-aware sense-augmenting technology (incl. augmented memory or anticipative interfaces).*

We also recommend promoting research on **Augmented Reality (AR) as a sense-augmenting technology.** Research should explore continuous capturing of information on the surrounding environment and the classification of everyday actions. This should help create interfaces capable to adapt to the context and better support decision-making. Along this line research could bring to the development of **Augmented Memory** systems (for senior users, people with pathological memory loss, etc.) capable to automatically retrieve information of relevance from information acquired through context understanding.

Interfaces should build on top of robust human and cognitive requirements and should promote adoption of increasingly accurate Brain Machine Interfaces (BMI). The coupling of AR with BMIs will be helpful in the context of scene understanding, as BMI will allow easier user-based classification (or "tagging") of the user's surroundings. It will also contribute to the creation of **anticipative interfaces** capable to predict user's **psychophysical** state and transparently adapt to it, for instance trying to compensate for performance losses, e.g. in the context of repetitive actions or tasks.

Rec. 30: *To extend scope and market of human computer interaction research by specifically addressing multi-cultural interfaces.*

A final recommendation is to explicitly allocate resources to the development of interfaces targeted to so-called developing countries. In fact all the aforementioned recommendations essentially address the requirements of users at the "top of the pyramid": i.e. only 1 bil. people out of the entire global population.

H2020 should clearly promote research with an expanded geographical and cultural scope (and therefore market potential) by explicitly considering the requirements emerging from fast-rising markets of emerging countries. For this it is recommended to analyse how to develop effective forms of interactions that respond to specific requirements of countries characterised by availability of less-recent devices and by potentially significant **multi-cultural** requirements. Research within this domain should also explore how to best create interaction mechanisms for professional and consumer applications targeted to illiterate users.

1.3 CONCLUSIONS

In conclusion, in addition to the aforementioned technology-centric recommendations a few general recommendations can be made.

Rec. 31: *To facilitate real-life impact of projects through piloting in real industrial contexts.*

We first recommend the European Commission to better facilitate real-life impact of technologies developed by research projects through their piloting within real industrial contexts and through actions facilitating industrial take-up. Various mechanisms could be explored including, but not limited to, forms of financial support based on incentivising return rates inversely proportional to commercial success of the projects' outcomes. Involvement of non-technical experts dealing with business development at the last stages of review of the project should also be also considered to better assess the impact of the project during its final stages and recommend corrective actions before its conclusion.

Rec. 32: *To ensure long-term persistency of projects' results.*

Furthermore, mechanisms to facilitate long-term persistency of projects' results (software development, documentation, standards) should be explored. Although there is a prevailing good practice to make deliverables public, indeed it is very difficult to reach out the outcomes of a project after it officially terminates its activities. A recommendation is to create mechanisms, similar to those already brought forward by the Joint Research Centre (JRC) of the European Commission in cooperation with European Committee for Standardization (CEN, French: Comité Européen de Normalisation), to create a repository of official deliverables with standardised metadata that allow for easy retrieval and later access.

Rec. 33: *To promote innovation activities that can limit use of legal barriers when used solely to threaten competitors.*

Finally, a further important recommendation is to **promote innovation activities that can limit the threatening use of legal barriers** that are increasingly being created through abuse of patenting or IPR-protecting measures, to intimidate potential competitors from entering the market with similar solutions.

Rec. 34: *To maximise interoperability and take-up of standards.*

A final recommendation is to maximise, within H2020, **interoperability and take-up of standards** if we want European stakeholders to be successful. This will pose new challenges to today's standard procedures since these were originally envisaged by standardisation bodies at a time when the innovation cycle was of 10-15 years long. It is clear that standardisation procedures fall short today with innovation cycles typically being reduced down to 3 to 5 years. Within this scenario, in order to be able to respond in a timely manner to the requirements of industry, particular importance will have to be paid to the promotion of *de facto* standards, typically relying on much more flexible processes, which eventually may undergo a later formal standardisation process.

This will further contribute to make European stakeholders leading players at the global level.

VISION is a project of Fondazione Graphitech, Italy, and it is funded by European Commission Directorate General CONNECT - Communications Networks, Content and Technology under the tender SMART 2011/0035 Contract Number 30 - CE - 0468335/00-94: "Study on simulation, visualisation and visual computing technologies: EU position and future potential"
More information about the project are available at www.vision4eu.net

2. GLOBAL TECHNOLOGICAL TRENDS, CHALLENGES AND OPPORTUNITIES

Image courtesy of KROMKRATHOG / FreeDigitalPhotos.net

2.1 TECHNOLOGICAL TRENDS

CLOUD COMPUTING

Mainly due to its scalability, cloud computing will continue playing a **disruptive role** [Gartner (2011)] driving industrial growth for the next two decades, since it is very likely that all major software players will leverage on cloud computing. As a result, an even wider uptake of **Software-as-a-Service** (SaaS) applications can be foreseen.

The most substantial challenges of cloud services will be related to **privacy** and **security** of sensitive data being dealt with. Thus, security capabilities and certification programs will see a rising importance, with the consequent growing request for **cloud security certifications.**

Further challenges will be **development of data centre automation** mechanisms and **configuration of management tools**, as well as the definition of clear policies regarding use of personal data, most relevantly in the context of increasing **integration of applications with social networking**.

Last but not least, the widespread availability of cloud services is also going to have important implications in terms of environmental impact and carbon footprint, which may also lead to billing mechanisms for cloud services, including **energy surcharges**, based upon an analysis of their **power efficiency**.

SOCIAL NETWORKING WITHIN THE EVOLVING COOPERATION LANDSCAPE

The past few years have witnessed the rising success of social networking, albeit in the context of **business scenarios.** This has been caused by the need to increase **interaction**, **cooperation** and **sharing of knowledge among people**. LinkedIn, but also Facebook and Twitter, are increasingly used to **establish a dialogue** within and outside companies. This constantly growing connectivity and exchange of data through social networking is revolutionizing marketing and business models, and it is changing the profile of people accessing media turning them from passive consumers to "**cynical multiple source users**" [UK MoD (2010)].

The potential of social networking is particularly significant as an **educational challenge**. Indeed, new opportunities for **life-long learning** could be borne out of pervasive social networking, while the ubiquitous use of mobile device technologies will certainly facilitate forms of **interactive learning in mobile situations**. However, analysts agree that these new forms of **social learning** and **facilitated sharing** of knowledge can have **potentially disruptive effects**, since this fast-changing scenario could "move the technology industry into an age of **hyper-innovation**, where shared information and access to technology building blocks unleash creativity on a new scale" [PricewaterhuseCoopers (2010)].

Anyhow, a similar potential **technology bubble** [Ernst&Young (2012)], or rather **technology boom,** has been already witnessed during late 2011. When trying to look into future trends, PricewaterhouseCoopers (PwC) foresees that, by 2020, social networking will eventually be **pervasive**, and will leverage on ubiquitous access to IT devices, thus helping people interact with each other and better adapt to the local physical environment. Others studies foresee that a radical evolution of the overall social and technical landscape will bring towards network-based relations, yielding ever more complicated structures –in terms of social computing- than those visible today.

The evolving social networking landscape will infer yet another radical change to the concept of the Internet that will evolve from a **network that is connecting people**, typical of Web 2.0 or "social web", to a **network that will be connecting knowledge**, which may be referred to as 'Web 3.0' that, in theory, may ultimately lead to a **network of connecting intelligence** within a so-called **MetaWeb** or, as it is also referred to, Web 4.0 [UK MoD (2010)].

In the specific domain of software engineering, social networking can create **new opportunities** if leveraged in concert with other emerging technologies. An innovative example is **CloudSpokes** (www.cloudspokes.com), a service that allows open source crowdsourcing for development of apps. In addition, other 'agile' or 'lean' forms of software development, such as DevOps (continuous deployment or continuous delivery), will further amplify the role of social networking and cloud computing allowing for continuous release of updated services from complex development processes involving many developers yet ensuring the **highest development cycle flexibility**.

UBIQUITOUS AND SMARTER SOLUTIONS

When looking at the mobile device market, it is clear that consumers have become more technology-savvy and technology-dependent, mainly as a result of the widespread diffusion of mobile device applications. This trend has been driven, from a hardware standpoint, by the evolution in **mobile device processors industry**. The increased processing power will 'mainstream' 3D-user interfaces and even AR, analysts say.

On this regard, the importance of video game consoles, regarded as **smart domestic devices**, is also growing in conjunction with TV technology. Indeed, **digital entertainment** is undergoing a profound change: **collapse of prices** of LED technology, together with **further advances** in display technologies, will contribute to further push this market together with possible disruptive alternatives that may emerge in the future, i.e. based on transparent conducting layer from Few-Layer Graphene (FLG).

The main challenge for the **home entertainment market** will be to create services that can fill the gap between "what pay-tv service providers currently provide and what consumers are capable of utilizing" [EETimes Asia (2012)]. '**Smart' technologies for consumers** will require **'one-stop' systems connecting** to the largest possible information assets and that can leverage on existing social networks via user-friendly interfaces.

When looking at the domain of **mobile computing**, Gartner [(2011)] further predicts that, by 2015, the mobile web domain will reach full maturity. This will not simply require **re-scaling or simplifying applications,** but also the **design of new solutions**. The widespread use of mobile devices will allow a *more agile and ubiquitous workplace*, thus paving the way for delivery of new B2E (Business to Employee) services that can **improve cooperation, access and sharing of knowledge** among employees and sharing of collective knowledge.

As noted by Gartner [(2011)], applications, especially in the **mobile domain**, are already increasingly delivering contextualised and social experiences. As we have now entered a decade of **smarter software**, the challenge is now for software developer companies to make existing software *more usable, self-learning, integrated and custom tailored to enable maximise ubiquitous access, improve productivity, and to reduce costs*.

Smarter interaction technologies will also play a key role, since the need for precise pointing features is increasing with complexity of application. The challenge will be to develop precise **pixel-level multi-touch selection techniques**, especially in the context of mobile devices [Arth (2011)]. **Interaction techniques** will have to support multiple modalities, leveraging for instance on miniaturised emerging eye-tracking technologies and other advances in medical neuro-imaging technologies.

All these developments will contribute to the final end of the old WIMP (Window, Icon, Menu Pointing) paradigm, rapidly replaced by a widespread use of interfaces capable to support **control** through touch, voice and gesture [Gartner (2011)].

Augmented Reality (AR) will also become a commodity, especially in mobile scenarios, and will be backed by availability of more effective **image recognition technologies** capable of extracting and detecting features in the surrounding environment [Arth (2011)]. The main challenge will be the development of an accurate registration for **localisation of users**.

Context-aware technologies and applications too, as well as all new technologies for **exploiting personal location,** will become mainstream and will significantly benefit from the convergence of Location-Based Services (LBS) and mobile commerce services.

A key challenge is the definition of **universal yet flexible interaction paradigms** [Gartner (2011)] based on technologies that can automatically adapt to the various Operating Systems (OS), data and **display ecosystems**.

The widespread development of smarter interfaces will also affect other fields including, most notably, the **automotive domain**. The new interfaces that are or will soon be available on-board vehicles will require -in terms of Human Machine Interaction (HMI)- development of well-acknowledged and user-adaptable interaction styles. Multi-touch technologies[10] will be increasingly adopted for on-board systems to improve ergonomics and to simulate use of buttons, knobs, and sliders, thus reducing the number of mechanical components and therefore increasing reliability. Furthermore, "**connected cars"** will be able to operate as mobile computers, mobile sensors or conveyers of data through **mobile web services**. The challenge will also be to create technologies to connect cars to **mobile offices** and/or to **home spaces**, in order to facilitate ubiquitous learning or working scenarios.

[10] For instance, capacitive touchscreens for support up to 10-finger are already available within cars [EETimes Asia (February 2012)] today and their use will be increasingly functional to detect simple spatial gestures.

Development of advanced forms of HMI will also be important in other domains such as **e-Health**. The evolution of IT infrastructures is happening at such a fast rate that it has been foreseen that practitioners will soon be able to provide health care from a remote location (including from abroad), leading to **ubiquitous health care** scenarios.

Neuroscience may also allow creation of **preventive interfaces** capable to adapt to actions even before they occur, through the analysis of activities of the brain, for instance based on functional Magnetic Resonance Imaging (fMRI) [Tucker (2012)].

Furthermore, sophisticated forms of HMI will also be required to interact with autonomous systems and robots that will operate as assistants. The challenges in this domain will be to develop "multiple autonomous systems and interpretation of the associated information" [UK MoD (2010)].

Lastly, further challenges will be raised by the **interaction between users and real world objects**, also –in the long-term- through development of interaction paradigms based on the so-called **programmable matter**. This is emerging concept of technology that can be programmed to change its physical properties and adapt to external environmental conditions or to change functions.

BIG DATA AND NEW GENERATION ANALYTICS

The concept of '**Big Data**', which has emerged as consequence of the data explosion that we are witnessing today, "refers to datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyse" [Manyika (2011)]. The preconditions for the development of new-generation analytics is based on the **convergence of several factors**, i.e. the quasi-exponential growth in volume of stored data, increasing computing power, and increased potential for analytics to create commercially available tools for data mining, statistical analysis, patter matching etc.

The challenges brought by Big Data scenarios can be found in a very large number of domains, from business intelligence to finance, from smart city services for **intelligent urban management** to smart grids and renewable energy. Within the Big Data umbrella, a significant share is being taken by **multimedia content,** which now accounts for more than half of the traffic going through backbone Internet connections [Gantz (2007)]. Such a growth may require, by 2020, the need for automatic classification or tagging of data transiting over IP. According to McKinsey Global Institute [Manyika (2011b)], **data from sensors** (Internet of Things) will grow at an exponential rate, creating the preconditions for the **Internet of Things (IoT)** to reach a mature state. This will be driven by the increasing precision of sensors, by their widespread availability fitted within mobile devices, as well as by the availability of different sensors data.

Although according to some analysts, the term “Big Data” has been **overhyped**, there is wide agreement on the **need for new advanced analytics**, including **visual analytics technologies,** capable of extracting –through automatic or semi-automatic processes– key indicators from large data repositories. More effective tools to improve decision-making processes will be required as analytical and text mining features will soon become commonplace. **Business Intelligence (BI)** is another important field where next-generation analytics is going to provide **significant added value** and **key competitive advantages**, through the development of decision-making tools that can **detect relevant patterns** from complex highly multi-dimensional data flows.

In fact, being able to deal with Big Data may, in the future, provide companies with a **key commercial advantage**, analysts say. To do so, companies need to build capabilities that can provide **superior aggregation of data** and can ensure **higher efficiencies as well as better quality products**, for examples ensuring sophisticated data fusion and integration, **collaborative learning**, sentiment analysis on social media data, spatial analysis etc.

According to Gartner [Gartner (2011)], **next-generation analytics** will grow along several dimensions. Firstly, technical evolution will allow evolution from traditional off-line to on-line analytics. Secondly, next-generation analytics will be capable of analysing not only historical but also real-time data coming from multiple diverse sources. Lastly, future analytics technologies will evolve from being able to deal only with structured data to being capable of **managing unstructured multiple sources**, while a further evolution will bring to the availability of features that can enable **collaborative scenarios** within a more complex decision-making process.

NEW COMPUTING PARADIGMS AND GREEN COMPUTING

Current trends show the rising uptake of High Performance Computing (HPC) technologies based on cloud or grid platforms or on future computing architectures, e.g. based on photonics and quantum computing paradigms [UK MoD (2010)]. An increasingly important trend sees the manufacturing of **low-energy servers** based on low-power processors borrowed from mobile platforms.

A major driver for new-generation analytics will also be the availability of **storage space**, whose dimensions and performances are constantly improving with adoption of Solid State Disks (SSD), automated tiering and cloud computing. Innovations such as **spintronics**, based on manipulation of electron spin in silicon, or **Phase Change Memory** (PCM) and **3D-IC** (3D integrated circuit), may increase future data storage capabilities, creating ultra-dense hard drives.

In-memory computing is also expected to become mainstream, thanks to the increasing use of flash memory within consumer devices and servers. The widespread use of in-memory computing solutions will bring to several major advances, including *reduced space, heat and low latency, improved performances and robustness*. New scenarios include **in-memory analytics**, event-processing platforms, **in memory application servers**, and **in-memory data management**.

Increasing concerns towards green computing issues, will drive development of next generation toolkits that will allow correlating power, current and voltage with software profiling, thus paving the way to new generation energy efficient applications.

The quest for extended power consumption, especially in the domain of mobile or embedded applications, is also fostering development of ultra-low-power microprocessor and Power Management Integrated Circuits (PMICs) and, ultimately, of battery-free systems that function from **ambient energy**.

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2.2 SOCIETAL TRENDS

Shrinking of European population, mainly due to our economy being likely to grow at slower rate than those of US, China and India, will create a “demographic challenge”, with the number of European citizens set to shrink to 6% of global population by 2040.

Additionally, the **behaviour of citizens**, as consumer of IT products and services, will evolve substantially, together with a **clear increase**

in the use of social networks among less young age groups. As a consequence, this will require increasing use of personalities and avatars, analysts say [UK MoD (2010)].

In turn, this will have profound societal implications, as it will become increasingly difficult to differentiate people by their cultural background owing to the fact that widespread use of social networks will tend to create **globalised cultural backgrounds** with similar identities. The concept of 'identity' itself will be challenged by such a **reduced face-to-face interaction**. Obviously, it is difficult to predict the long-term implications of such a change in terms of **sociologic behaviour** and of perception of local and national identity. However, some analysts foresee that social interactions, fused with virtual reality, may lead to **new forms of interactions** while national identities themselves may decline. The first effects of this trend have been evident in the significant and widespread role of social networks within recent 'Arab Spring' upraise.

The widespread use of social networking is further amplified by the rapidly increasing **success of mobile IT technologies,** even within working scenarios. Indeed, an increasing number of people are using mobile IT devices (typically smartphones and tablets) for both work and personal use, leading to **blended use scenarios**. This trend will affect also the way we work, potentially creating the conditions for some companies to disappear. In fact, together with improved productivity rates, the increasing availability of cloud services and extensive use of social network may soon have a **negative impact on working stability and certainty**.

With regard to this latter issue, analysts have also predicted that increased efficiency in manufacturing industry, mainly driven by improved use of Big Data, will cause an **estimated reduction in working capital** by 7% [Gantz (2007)]. At the same time new **more specialised profiles** will be required by the job market in order to overcome the shortage of qualified workforce capable to take full advantages of such a technological evolution.

Also the **educational environment** will be affected, as advances in understanding cognitive factors may lead to a **profound reformulation of the concept of training**. A future scenario could see the use of screening via **genotyping** or **brain imaging** that could help identify **cognitive capabilities** or limitations to define personalised education mechanisms.

Moving to **healthcare,** Electronic Health Records (HER) will mostly drive investments. Increasing role will be played by services designed to improving efficiency of the whole healthcare system, e.g. by leveraging on various types of **simulations** within the healthcare domain [Barji (2011)].

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2.3 MARKET TRENDS

According to the British investment bank Bullhound [IT Business Edge (2011)], we are entering a time of "unusual circumstances" with slowing European economies and nervousness of markets, with companies being challenged to cut costs to protect margins and delivering innovation [PA (2011)]. Being able to cope with such changes could create conditions for companies to survive or die.

Indeed, capital is moving from labour to technology as technology can improve productivity of existing employees avoiding to hire new staff, and since it has become more difficult for companies to find well-qualified people.

Fast development cycles require more **agile approaches** whereby **diversity management** becomes the main challenge. Companies are becoming more and more aware of the fast-changing scenario and are reacting through creation of **new business models**. New business models will result from exploitation of location data to **create radically new services**. As highlighted by Gartner [2011b], the emerging market of **Industrialised Low Cost IT Services** (ILCS) could have an effect similar to the introduction of low-cost carrier within the transportation industry.

A further significant challenge is to develop co-ordinated approaches to manage information, to **share intelligence across companies**, functions and locations [PA (2011)]. In fact, although smart organisations already exist, the challenge is now on **linking** them to create higher value and further reduce costs. In fact, according to analysts, manufacturing companies could reach **50% reduction of assembly costs through optimised use of Big Data** [Gantz (2007)].

At the same time, new models for value capturing and competition are required. Several newcos are creating **novel business models** to exploit the potential of Big Data, cooperative systems, cloud computing and mobile computing. In particular, e-commerce and m-commerce will grow despite economic turndown requiring new services for strong identity management and authentication. Mobile commerce especially, pushed by diffusion of NFC payments, is set to become mainstream globally after its initial success essentially limited to few geographical areas such as Japan. The diffusion of NFC payments will benefit from technology such as Visa Paywave and MasterCard Paypass, and it will foster the transition towards a **cashless society**. As a result, smart wallets scenarios are likely to increase [Palmer (2011)].

Furthermore, we are experiencing a "**consumerisation**" **process**, a trend whereby consumer technology is becoming more effective and less expensive than professional technology. As a result, the consumer IT market is becoming more relevant. This is especially true in the case of mobile IT technologies due to their extremely high market penetration. Their widespread diffusion is creating a very peculiar trend, often referred to as **BYOD** (Bring Your Own Device), of **using personal devices at work**. Companies are reacting by implementing specific policies to allow use of personal devices within business environments. The combination of this trend with widespread adoption of cloud services, allows for "**asset-free IT functions**" [56], albeit causing security threats that will have to be properly addressed.

Integration between hardware and content will also be a major challenge: tablets are an example where content ecosystems provide an added value if compared to pure technological performances between different models.

Increasing attention also needs to be paid to **seamless integration** and **seamless interaction between mobile devices and PCs** [30]. This will open new opportunities to the development of new brokerage services that can provide access to data and computing resources to a potentially very diverse number of computing devices catering to a myriad of services targeting both retail and enterprises markets.

Last, but not least, although several large global vendors have tried to enter the social network market, Gartner predicts [2011b] that by 2013 the market will be characterised by the **burst of the social networking bubble** followed by a sharp decrease in investments for social software companies. ICT and social media are also fostering a **paradigm shift** with people increasingly sharing uncensored feedback on products thus heavily affecting buying decisions. This is calling for new forms of marketing, including **precision marketing,** to take such a trend into account.

Image courtesy of winnond/ FreeDigitalPhotos.net

2.4 LESSONS LEARNT

To conclude, it has to be mentioned that the advent of the Internet is set to significantly affect the whole business scenario in many ways, since the ever-growing intertwining relations among people, systems and businesses are creating an **extremely information-rich system, a "hyperorganism"** [70] that can provide companies –if properly exploited- unprecedented advantages against their competitors.

it is very likely that widespread availability on the market of a very assorted portfolio of cloud services offering asset-free IT facilities will foster the **growth of a new generation of very agile, IT-infrastructure free companies**, capable to dynamically adapt, and successfully survive to, fluctuating market demand in an unprecedented way. Agile and intrinsically more resilient business will also be an essential requirement to **remain competitive** within the market. Such a new generation of very agile companies will most probably leverage on **new forms of very focused marketing**.

Moreover, the combination of cloud services, mobile computing and social networking will facilitate **growth of lean business structures based on partnerships or cooperation**: this '**fluid' business landscape** will impose a significant strain on large companies that will have to **fight the increasing aggressive competition** and to **fast adapt** their existing solutions portfolio to the fast changing market requirements.

Within such a complex picture, **smart devices are acting as a further innovation accelerator**, either by creating brand new scenarios or simply by setting new requirements for existing ones. The result is a **rapidly changing market demand** often driven by applications using smart devices to perform existing tasks in a different and "smarter" manner.

Finally, when looking at the **emerging technological landscape** advances in computing hardware and software technologies are paving the way to the **gradual convergence of visualisation and simulation**. This trend is being pushed by the availability of highly parallelised Graphics Processing Unit (GPU) and technologies such as CUDA (Compute Unified Device Architecture) and OpenCL (Open Computing Language) that allow use of graphics hardware to run thousands of parallel generic computational threads according to what is referred to as GPGPU (General-Purpose computing on Graphics Processing Units). This convergence has already occurred in few specialised domains.

3 THE MARKET OUTLOOK

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3.1 OVERVIEW OF 2014 – 2020: SIX YEARS DEVELOPMENT PLAN

PREAMBLE

Every ten years, technology faces a double speed increase in terms of numbers of technology innovations and evolving features [McKinsey Quarterly (2012)]. Indeed, the ICT domain is facing rapid developments in fields such as virtualization and cloud computing, matching budgetary constraints of major industries thanks to their pervasiveness. Consequently, **management** needs to understand and decide onto which technology to capitalize, thus recognising which of the ICT trends are the most significant for the business agenda. Moreover, management will have to consider changes in each organisation and how to be able to meet new demands from the market.

TRENDS TO BE WATCHED

Although it is not possible to generalise over various the different types of industries in the market, it is well acknowledged that the majority of them share **similar visualisation**, **simulation** and **visual computing requirements**. However, **visualisation**, **simulation** and **visual computing** have been often relegated to prototyping activities with **modelling** and **simulation** being often intertwined with emerging technologies. However, traditional industries have recently started to consider adoption of **visualisation**, **simulation** and **visual computing** tools within their daily business, from maintenance to phase-out. ICT market trends are also characterised by **anything-as-a-service**, **multisided business models**, and **grassroots innovations** that are changing the business environment.

Senior executives have traditionally looked at most of the aforementioned trends with scepticism or fear, inadequately promoting interdisciplinary analysis that could fully exploit their potential. However, the need for quick responses to continuously new market needs is contributing to make simulation and visualisation technologies emerge as essential tools to **support the decision-making process.** A typical example of this trend is the advent of **business intelligence platforms** that can leverage on consumer's feedback **as primary data source**. In more general terms, simulation and visualisation tools have made it possible to use data-driven insight at all levels of an organisation in order to improve control over internal and external KPIs (Key Performance Indicators).

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3.2 BUDGETARY AND SOCIETAL CONSTRAINTS

New technologies are considered a great opportunity for growing through innovation, especially nowadays: indeed, embracing innovation through ICT is one of the best ways to help business move forward.

In 2011, firms have been globally focused on consolidating trends in the ICT domain, such as cloud, social computing and mobility. In most cases, the technology agenda has evolved into a business agenda [Deloitte (2012)]. For example several enterprises have been forced to promote development of cloud services or social presence for their products and brands, to be able to follow marketing trends now shifting from a user-centric vision to a human-centric approach.

Indeed, firms have to understand that **they need to innovate their IT technologies** also to be able to defend their market positions against direct competitors and emerging markets.

TECHNOLOGY IMPLICATIONS

ICT is now **truly pervasive,** regardless of the type of business, processes and geographical location. Visualisation and simulation technologies will have to **facilitate the development** of those processes and will play a central role across the overall change the business landscape. The **main areas of development** that will occur in the next few years have been presented in the table below.

Topic	Description	Foreseeable evolution	Time range [11]
Project & portfolio manag.	Tracking investment priorities and project performance against objectives.	CIOs will need to monitor dependencies of concurrent activities.	M-L

[11] S = Short term, M = Medium term, L = Long term

Integration	Integration and orchestration of processes across the ecosystem of services will be essential. Multiple interaction styles, with central role of multiple performance SLAs will be required.	This process must take into account any third party involved.	S-M
Information	Master data management, analytics and visualization, including simulation, will become even more important IT processes.		S-M
Security	Security will be increasingly important, not only for traditional IT processes but also as a society need in order to prevent any kind of crime and guarantee privacy and identity of individuals.		S-M

FACING UP OPPORTUNITIES

Most of the organisations are focusing on **business process automation** as one of their top priorities, since data volumes are continuously increasing. The current situation is requiring to create the conditions for positive economical returns and to deploy IT-based ecosystems that will facilitate public and private actors to cooperate for their growth.

The **need for knowledge analytics, fact-based predictions and business forecasts** are becoming a priority in the business agendas, and simulation and visualisation solutions with them. Both private and public bodies have started to define their strategic agendas by taking into account descriptive analytics for predictive results, thus taking a more **holistic approach**.

TECHNOLOGY IMPLICATIONS

It is likely that several business opportunities will emerge from the domains of **knowledge management** and **advanced analytics** capable to facilitate data correlation and consistency checks. Future solutions will be based on advanced statistical models and correlation of huge and disparate data sets. Future trend will leverage on increasing **involvement of users**, also to identify the best design solutions that can meet individual needs.

USER EXPERIENCE

Usability will also become an increasingly important aspect of software design. Human interaction systems will be more central and pervasive in the majority of the business models.

The following table shows how the user interaction will occupy an essential role in the business strategy.

	Challenges	Opportunities
User experience	• Improvements in system interaction, including emotional aspects in the user experience. • Co-design will be essential requirements into involving external resources. • Design will have to leverage on novel interactions devices beyond current I/O technologies.	• Among the most significant market segments we must list: mobile applications, cloud computing, collaborative systems, social applications and services and more. • Design standards and frameworks through increased user engagement. • Multi-touch screens, intelligent cameras, natural user interface (UI) with embedded sensors (gyroscopes and accelerometers).
Web technologies and usability, Rich Internet Apps (RIAs)	• User centric solution will start to be considered more than data-driven ones only. • Single unified user interfaces, and network identity of users with high attention to protect user's data and privacy in the back-end systems and information repositories.	• Designing new technologies with usage patterns in mind and with more abstraction and creativity than the computing dependencies. • Integrating master data management and process orchestration for user's engagement.
Portals	• Modelling user's performance and behaviours will be central in any workflow.	• Mash-ups and applications with many external components, with central focus on how applications are presented and data are visualised. • Business rules will be also aligned toward user's engagement.

User engagement solutions require more **complex technological elements** to facilitate the work performed. As a matter of that, the **main business areas** that will be impacted by visual and simulation tool will most likely be: **managed services**; **data management services**; **business rules, orchestration and workflows**; **UI platforms**; and **user experience**.

Lastly, unless new emerging business will disruptively change the rules in the next few years, the **main trends** in terms of software development will have to consider how to drive revenue streams in the mobile business.

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3.3 STRATEGIC GROWTH AGENDA IN THE ICT SECTOR

TOMORROW MARKETS

Market growth in the high-tech sector can be also translated as a first **transformation of products and services** to ***de facto* standardised technology** followed by their transformation into **commodity**. Companies and innovative organisations are dedicating portions of their budget to **investments** for acquiring insights over market and over up to date technologies before competitors.

Such a ***customer-centric* approach** is *de facto* the **new product development strategy** that has conquered the majority of the business actors. **Individuals** are considered the **main source of information** to create products and services, leading to what is commonly referred to as **WLC (Watching, Listening and Co-designing) approach**.

Following this new paradigm, ICT and specifically web 2.0 tools have radically changed the relationship with customers, since many products and services are created *ad hoc* in order to observe customer's behaviours and help companies define strategies to enter new businesses or introduce new solutions.

The following table lists the most promising emerging technologies on the market.

Social aspects	Emerging technology
Watching **(Consumer's needs analysis and social sensing)**	**Data mining** to reveal hidden consumer's behaviours. **Shopper-behaviour-monitoring software** to influence consumer decisions in real time. **Eye-tracking technology** to identify and respond to what attracts customer attention. **3D simulation** to create low-cost virtual environments where to study user-experience.
Listening	**Sentiment analysis software** to align consumer attitudes expressed online with innovation efforts.
Co-designing	**Wiki-like technologies** to use participant ownership to stimulate broader collaboration & information dissemination.
Entering markets or societies	**Electronic suggestion boxes** to broaden and accelerate boundary-less ideation. **Prediction market software** to connect strategic decisions with insights from employee confidence levels.
Reputation **(online and offline)**	**Crowdsourcing software** to use the "wisdom of crowds" to create solutions for and with consumers. **Online consumer communities** to monitor and facilitate customer feedback and insights to improve the business.
Simulating and predicting	**Predictive workforce-analytics software** to use data-driven insight to prepare for or prevent employee attrition.
Business processing automation and BI	**Automated performance-management systems** to identify when, where and how to best deploy talent. **Automated succession-planning tools** to streamline and improve the leadership-replacement process. **Talent pool databases** to capture knowledge of employee skills to assess more accurately readiness for promotion.
Collaborative systems	**Collaborative software (groupware)** to boost efficiency and creativity levels in virtual meetings.
Education	**E-learning platforms** to help remove geographic constraints to employee and/or citizens skills. **Video/computer games** for more engaging training scenarios. **Education management systems** to integrate employee and/or citizens training with personalized paths.
Knowledge management and hiring people	**Managed staffing systems** to maintain knowledge of available candidates to expedite temporary and full-time hiring. **Talent acquisition systems** to ensure a broad geographic search and distribution of up-and-coming talent.
Job markets	**Social media tools** and applications to preview candidates' performance and fitness, even before they apply. **Job marketplace** accessing vast stores of potentially desirable talents with social media outlets so as to engage passive candidates and encourage them to apply. **Virtual applicant screening technology** to reduce talent-scouting costs and allow candidates to be better evaluated.

MARKET ATTRACTIVENESS IN THE ICT SECTOR (VISUALISATION, SIMULATION AND VISUAL COMPUTING)

If we analyse **the attractiveness and the competitive strengths of technologies** and **possible applications and services** that will be created on top of them as main indicators, we can infer that **software developments** will be rapidly evolving with human interaction-centric technologies such as **games, data mining, imaging processing, 3D visual applications**. A detailed **positioning analysis** is reported in the following table.

Vertical Markets	Attractiveness	Competitive Strengths
Health and life science	The majority of pharmaceutical products on the market have been developed in the last two decades. This sector will continue among the most profitable markets for investors. However research has already shown a drastic change in the methodology, increasing the adoption of simulation software that involves biological results.	Simulation for biology and biophysics will play a central role in the health & life sciences, due to the possibility of shortening results and approaching different methodologies at the same time with large cost savings in return.
Consumer	Without any doubt the consumer sector will continue to be the most attractive, but also the most difficult segment, to manage, but return will be also significant for investors.	The entire consumer sector will increasingly depend on visual and simulation solutions. All product and service ecosystems will be affected by the intuitiveness of UI. Companies will have to win competition on different grounds not only limited to pricing models but based on how to reach information of relevance.
Automotive	The automotive sector has made giant steps forward in the last few years into integrating UI systems. The next decade will see the arrival of the new generation intelligent on-board systems that can increase active and passive security.	The use of sensors and intuitive UIs will acquire a primary role in the automotive sector since to their use will be more important for the security of passengers.
Energy	Smart grids and smart metering will drive major investments in the energy sector up until 2020. Utilities and energy traders will base their investments and technology adoption on solution that can facilitate real-time decision support.	The pervasiveness of ICT solutions will enable new business models, which were unforeseeable only few years ago, as virtual power plant. Those solutions will give positive returns in terms of environment impact and limited investments from communities.
Manufacture	The production and supply chain will need to upgrade their internal processes to guarantee security of employees and goods.	The ICT systems will be part of this restructuring process that will imply huge investments within the next decade.

e-Government and e-Procurement

PAs will have similar rules to business firms: they will need to improve their internal and external systems in order to be more efficient and be able to deploy a citizen-centric approach to ensure transparent government at all levels (from local to international).

The so-called smart city approach will be a key driver to transform cities and make them more efficient. New technologies will be required to help policy makers better manage issues such as energy consumption, mobility and social inclusion.

Image courtesy of suphakit73/ FreeDigitalPhotos.net

3.4 INVESTORS OUTLOOK

INVESTMENT TRENDS

The **ICT industry** is expected to reach an overall EUR 3,8 trillion global income [18]. Its main engine will be **networked technologies** and relative applications and services. **Software investments** will be mainly focused into optimising the value chains of several industries and the effectiveness of business intelligence systems that will be mainly based onto the management of the so-called Big Data.

The main indicators predict that **investors**, represented by non-traditional competitors, financial institutions, and strategic M&A operations, will be focusing on those key technologies that will drive innovation into the process of several industries, such as: mobile devices and apps, mobile networks, cloud services (including enabling technologies), Big Data analytics, social technologies, and pervasive solution such as growing network of intelligent & interactive technologies [20].

In the upcoming five to seven years, **investors** will have to evolve to demonstrate the ability to make deals on risky new technologies that will allow disruptive business models in any kind of industries.

Image courtesy of winnond/ FreeDigitalPhotos.net

3.5 LESSONS LEARNT

This section has shown the main **market trends and related investments** in the future; however, it is important to highlight that those technologies not only rise research and development issues, but impact on the business scenarios as well as on everyday life.

Two will be the **main emerging aspects** for technological trends, i.e. technologies that will be a result of R&D process by both academy and industries, or the improvements of existing technologies. There will also be **revolutionary expectations** from basic and applied research. However, this latest development will occupy a residual portion in terms of future trends [22].

One of the **key challenges** will be the **simulation and visualisation of natural phenomena with complex algorithms**, while the large use of technology in the everyday life will requests **highly customisable software** that helps people learn in a more efficient way and improve their performances for targeted and effective interaction.

In 2020, a predominant role will be occupied by **telcos**, due to the highly interconnected nature of a globalised economy and related business models within any industries [25]. Telcos will play the **role of regulators,** which will be crucial to avoid that some actors might occupy dominant positions in the entire market.

4. RESEARCH CHALLENGES AND POTENTIAL CONTRIBUTIONS

The domains of visualisation, simulation and visual computing have undergone a profound evolution due to the fast pace at which hardware is being improved. Within the **visualisation** domain, open standards are also fostering new markets based on use of new devices. The **advent of WebGL** will also open new opportunities through a well-acknowledged web-based platform for 3D content leveraging on HTML 5.

The domain of **simulation** has also being radically changed by the arrival of many-core CPUs, which are expected to feature hundreds of different cores, new memory technologies. A further key factor is the wide diffusion of GPUs which are now increasingly used for general purpose computation (GPGPU) offering a very parallelised computing platform for a variety of purposes. Such a heterogeneous hardware landscape will foster the growth of new simulation solutions.

Last but not least, **visual computing**, a relatively new concept, tries to bring together the fields related with computer graphics and computer vision technologies.

The goal of this section is to analyse **current state of the art** in various domains of reference and to identify research challenges and potential contributions of RTD activities. Due to the large scope of the domains subject of the study, i.e. visualisation, simulation and visual computing, the analysis has been restricted to **macro areas**, selected for their strategic relevance in scientific, industrial, market or societal terms. The five macro areas identified are: 1) Multimodal and Natural Computer Interaction; 2) Engineering and Manufacturing; 3) Digital Content Creation, Creative Industry, and Education & Training; 4) Policy Making and Societal Challenges; and 5) Safety And Security.

The reminder of this section provides, for each of the aforementioned domain, an initial analysis of the state of the art through a wide-range selection of the most significant scientific and industrial trends for the study. Each section is then followed by a number of recommendations that are proposed to address open challenges, in scientific, market or societal terms.

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4.1 MULTIMODAL AND NATURAL COMPUTER INTERACTION

The study of the domain of multimodal and natural computer interaction has taken a Human Computer Interaction (HCI)-centric perspective. In particular, specific attention has been paid to the analysis of emerging interaction metaphors rather limiting the scope of the study to only interaction technologies and devices.

MULTIMODAL INTERFACES

Multimodal interfaces *"aim to recognize naturally occurring forms of human language and behaviour, and which incorporate one or more recognition-based technologies (e.g. speech, pen, vision)"* [Dumas et al. (2009)]. As stated by Forbus et al. (2001), different modalities can be considered as **complementary conceptual channels** that can transmit information on the spatial and semantic nature of the action being carried on. One of the main **advantages** of the integration of different modalities lies in the **widened perceptual and conceptual bandwidth** available to the user to convey information regarding the action performed.

When analysed as such, the concept of **multimodal interaction** refers to the **possibility to create a dialogue** within the system that integrates different (unimodal) interaction modalities within a more human-like communication mechanism.

Essentially, these interfaces fundamentally differ from traditional Graphical User Interfaces (GUIs), since they adopt a **probabilistic approach**. In general terms, multimodal interfaces rely upon **weighting of time-stamped data patterns**, extracted from independent unimodal recognizers that are filtered and then compiled into packets. However, what is important to underline is that the process is **typically continuous**, meaning that the interpretation process can be fed by new events whenever these are received and classified as belonging to the current action.

Historically, several authors have proposed different classification of multimodal interfaces. One of the most well known was proposed by Oviatt (2003) who suggested a **classification of multimodal interfaces** based respectively on concurrent use of *speech and pen*, *speech and lip movement* and *multi-biometric input*. Traditionally, research focused on multimodal integration of speech and lip movements, mostly based on "visible speech" through computer vision recognition of phonetic information.

In more recent times, a number of initiatives have focused on the development of **more intelligent multimodal dialog systems**. These include, for instance, several projects funded by the EC (e.g. FP6 STREP OpenInterface, FP6 NoE SIMILAR, FP6 AMI, FP7 NoTube), and the Cluster of Excellence on "Multimodal Computing and Interaction". The latter provides a good example on the directions that research is taking, i.e. on natural language processing, speech recognition and synthesis, visual computing and synthetic virtual characters [MMCI, 2012].

BODY-CENTRIC INTERFACES

A number of different techniques use the full body or some of its parts as the main means to ensure a **more natural interaction** with the system. Direct interactions through body or arm gestures are **based on human instincts** and therefore require little or no cognitive effort [Song et al. (2012)].

When studying human beings' **body centric interactions**, a main distinction should be made between interfaces **based on kinaesthetic sense** (i.e. motion, application of a force) and those **based on tactile sense** (i.e. specifically touch and tact). Effective **hand tracking** is extremely important, since human beings use hands as an essential nonverbal communication channel.

Modern gesture recognition systems detect movements from continuous input streams, typically through identification of the position of human body joints, while most tracking systems **rely on electromagnetic, ultrasonic, or optical principles** to detect commands. Electromagnetic and ultrasonic tracking systems are often big and cumbersome, while more compact **optical tracking** often provide the best compromise. These **capture** images of the real scene through standard or **stereo-cameras** (e.g. to track **user's hands in 3D**[12]).

Researchers have also explored **use of tactile interfaces** for sensory substitution, for simulation of virtual 3D surfaces, to complement other sensory channels, to achieve telepresence, and for braille systems. **Tactile interfaces based on touch-sensitive surfaces** have become extremely popular with the advent of touch and multi-touch devices. Moreover, **tactile feedback systems** are based on simulation of tactile interaction stimuli from the surrounding world, which can be used to assess the texture properties of an object.

To this extent, one of the most challenging goals is to support navigation and understanding of spatial relationships. Even if this can be done through the use of **Braille maps** [Blasch et al. (1997)], these are cumbersome, expensive and limited in scope. Additionally, they may not offer an adequate level of detail and are expensive to maintain and update. Use of tactile feedbacks through the use of **haptic gloves** has been proposed in the work of Zelek and others [2003], while the use of **Braille devices** with auditory feedback has been tested with good success in the past.

Tangible User Interfaces (TUI) or graspable interfaces are, to some extent, a generalisation of tactile-based interfaces in that allow users to interact with digital content through physical objects or with the physical environment altogether.

Recent success of consumer electronics devices such as Kinect from Microsoft, or Wii™ from Nintendo, has opened the domain of continuous body tracking to the large public. These low-cost consumer-level technologies potentially allow **screen-less interaction** and have been successfully used in the entertainment sector as well as in educational or professional scenarios.

With regard to human-centric approaches, research is also focusing on techniques and technologies to create **user-centric interfaces**. On this regard, a key role may be played by **pico-projectors**[13], which are going to be increasingly adopted as OEM components in mobile devices (e.g. smartphones or tablets), which –together with consumer level Augmented Reality glasses (e.g. by Microsoft or Google)- will facilitate the uptake of new projective Augmented Reality scenarios.

COMPUTATIONALLY RECONFIGURABLE INTERFACES

The concept of computationally reconfigurable interfaces is at the basis of the concept of **Organic User Interfaces (OUIs).** These are born out of tactile interaction with a physical

[12] See Song et al. (2008 and 2012), and Segen et al. (1998).

[13] Their sales are predicted to grow from 0.5 million units in 2009 to 142 million in 2018 [Cowan et al. (2012)].

object fitted with advanced sensor technologies that allow measuring pressure or position of fingers on various surfaces. Their ultimate concept of OUIs, sees the development of elementary components / actuators, often referred to as "claytronics" or "programmable matter", capable to re-shape themselves, to respond to specific interaction requirements. The availability of flexible and free form display technologies is also contributing to the concept of OUIs. An example of this is Miragetable by Microsoft, based on use of a 3D stereoscopic projector which projects content on top of a curved screen.

EXPRESSION, VOICE AND EMOTIONAL INTERACTION

In the past years, research has also focused on the creation of **smarter and more adaptive interfaces**. This has brought to the development of technologies that track and detect expressions or body gestures from movements to infer the user's explicit or implicit (accidental) intentions. Significant attention has been paid to comprehension of **facial expressions**, for instance through detection of mouth movements through **(eye) gaze detection**. Tracking of ocular movement is usually based either on reflected light principles, or on electro-oculography (EOG) or on scleral contact lenses containing an induction coil.

Significant attention has been also paid to the development of **voice-based interfaces**. Early studies were based on **Feature Structures (FS) unification**, a generalization of expression unification in logic programming languages. Later approaches were based on use of engines that make use of pre-defined dictionary and rule sets compiled into **Context-Free Grammars (CFG),** which can be used by the system to retrieve the information required so as to activate the relevant commands from spoken utterances.

A rather recent topic within the computer vision research is the **recognition of emotions** (Kaliouby and Robinson, 2004). Most of these systems combine audio and visual signals or focus on the **detection of expressions** through **Virtual Characters**, the so-called "avatars" or "anthropomorphic user interfaces". These allow important improvements to interaction with complex devices. Ensuring the highest degree of realism through real-like behaviours is still a hot research topic. Synthetic emotional responses and non-verbal communication are far from faithfully simulating real person behaviours.

On the contrary, **audio interaction** is the most promising solution for **visually impaired users**, since speech is for them the **more natural and intuitive** way to command a system and can be used to simplify use of several IT devices.

IMPLANTED USER INTERFACES

Implanted User Interfaces (IUI) rely on use of miniaturized interaction devices implanted underneath human skin. **Advantages** are their **permanent nature** and their potential **invisibility**. However, virtually, there has been no study researching the implications of implanted user interfaces from a human computer interaction standpoint.

A significant challenge relies on the **communication** of information from the interaction devices to the outside environment, which should ideally and wirelessly occur in the context of the so-called **Body Area Networks (BAN). Power supply** represents another major challenge, and should leverage on inductive charging technologies or on energy harvesting approaches. Further criticalities are the **security of the system**, which could be subject to malicious attacks by other users.

Besides the undeniable technical or health implications, the use of implanted interface raises a **number of ethical and social issues** that have been the most important barriers to their diffusion. Social acceptance could however be overcome in particular circumstances, for instance in the case of **Augmented Reality (AR) contact lenses** that, strictly speaking, cannot be regarded as implants.

Very recently, Innovega has marked a milestone in the development of AR lenses, through a contact lens technology called **iOptik™** that allows simultaneous focusing on images projected in front of the eye and on far away objects.

BRAIN AND MUSCLE INTERFACES[14]

Brain- and muscle-based interfaces can potentially provide effective solutions to very different scenarios, where the user is required to interact with the system without physically touching a device. **Brain Computer Interfaces** (BCIs), **Brain Machine Interfaces** (BMI), or **Mind-Machine Interfaces** (MMIs), create a **direct communication channel** between the user's brain and the computer starting from the analysis of brain activity patterns. BMIs are typically made of four components, responsible for, respectively, signal acquisition, signal processing, devices and applications, and an application interface.

[14] The FP7 has funded several BMI-related projects including, BRAIN (BCIs with Rapid Automated Interfaces for Non-experts), BRAINABLE, TOBI (Tools for Brain-Computer Interaction), Muri, NEUROMATH, SM4ALL, BrainGate, BrainGain, and HIVE.

Indeed, studies on BMIs have shown how these can be extremely **effective for neuroprosthetics applications**. Research has shown that BMIs can exploit the fact that most patients are still able to deploy a neural network that allows them to "plan" how to move, also in case of severe neural damages causing mobility impairments. BMI can be used for instance to control the movements of electric wheelchairs.

Further studies have also explored alternative approaches to BMIs based on other **muscular or neurological interfaces**. The reader should refer to the literature, i.e. Saponas and others (2009), for physiological implications of detecting movements from different muscles at the same time. Research work at University of Miyazaki has also shown that it is possible to control wheelchairs through contraction of expressive facial muscles.

PHYSICAL HUMAN-ROBOT INTERACTION

In recent years research has focused on development of **Physical Human-Robot Interaction (p-HRI)** that can ensure effective communication mechanisms between humans and robots, for instance in the context of daily or healthcare assistance. According to several authors, **Physical Human-Robot Interfaces (p-HRI)** are not yet mature to ensure safe use in the context of industrial robots, essentially due to the lack of "efficient collision avoidance mechanisms and proper security measures" [Caputo et al. (2012)].

A notable exception is found in the domain of **exoskeletons** for both military and civil uses. These can be extremely effective when users need to move heavy objects or rescue people. Exoskeletons can help users with motion limitation (e.g. patients), for rehabilitation, or for strength and endurance augmentation.

ACCESSIBLE INTERFACES

With the term **"Accessible interfaces"** we refer to interface mechanisms specifically developed for people with specific mobility, cognitive or visual impairments such as elderly users or for diversely abled people. To better appreciate the implications of creating interfaces for diversely-abled user it is essential to understand the **process that brings from perception to comprehension**. The adoption of these **multimodal interfaces**, relying on more than one interaction modality and their adjustments according to the various age groups, has also been subject of study [Naumann et. Al (2009)]. Result shows for instance that older users tend to interact in a more multimodal manner even though they are less successful at using motion control features.

With regard to users with **serious pathological impairments**, **eye-tracking technologies** are commonly used to control position of the cursor or for eye typing or to improve zooming techniques too. **Brain or muscular interfaces** have been often coupled to Virtual Reality (VR) and Mixed Reality (MR) to create solutions for training patients with cognitive or motion pathologies. The development of Virtual Reality (VR) based interaction metaphors for locomotion is still an open challenge especially when dealing with users with specific motion or interaction requirements including, but not limited to, wheelchair users, users with cognitive impairments or brain damages. A significant research body exists on development of **forms of interaction** for effective locomotion within virtual environment to support the control of electric wheelchairs[15]. **Gesture or full body tracking** ensures interaction with the scene or to support movement rehabilitation of patients. Further researches have focused on portable systems to be used to navigate users in **outdoor contexts**. An relevant example is the EU-funded i-SCOPE "interoperable Smart City services through an Open Platform for urban Ecosystems" project (www.iscopeproject.net/), which is developing visually-impaired-friendly services capable to automatically deliver pre-formatted text describing a given area or route, starting from Urban Information Models (UIMs) and GIS data. Nilsson et al. [2006] have focused on the **usability of MR systems from a Cognitive Systems Engineering** (CSE) perspective, i.e. focusing on high-level goals of the overall systems rather than on visual perception and cognitive abilities of users only.

[15] See the works of Steinicke et al. (2011), and Trewin et al. (2009).

WEARABLE OR PORTABLE INTERFACES

Wearable or portable interfaces are based on technologies embedded in or closely integrated with clothing. More advanced extensions based on tactile commands allow articulated functions through use of conductive threads to create embroidery that can be used to create new forms of interactions. The availability of flexible displays than can be embroidered within clothing, for instance to monitor health conditions, will further expand the scope of these interfaces.

The ultimate extension of wearable and tactile interfaces is the development of **skin-based interfaces** for instance through use of pico-projection and smart sensing technologies used to turn skin into yet another interface. In fact, research has increasingly explored the possibility of creating **portable forms of visual feedback** based on use of either pico-projectors or see-through eyewear. The latter allow superimposition of virtual content on top of transparent lenses through which the user sees the surrounding environment. The use of pico-projectors allows the creation of **Projective Augmented (PA) reality scenarios**.

OTHER INTERFACES

Other more unusual forms of interfaces leverage on feedback based on **unconventional sensory channels**. This includes interactive breath or olfaction-based systems that allow 3D location of fragrances. Other unconventional feedback systems leverage on **taste** (e.g. for food simulator), e.g. through biting interfaces capable to provide taste stimulus and force feedback or "pseudo-gustatory" displays leveraging on cross-modal effect between visual and olfactory AR.

Image courtesy of sscreations/ FreeDigitalPhotos.net

POSITIONING OF KEY EU STAKEHOLDERS

If we analyse the hardware manufacturing market we can observe a fragmented scenario characterised by high-tech SMEs, several of which born as spin-offs of top universities, specialising wireless motion and body tracking technologies for industrial, entertainment, training and medical solutions. A necessarily partial list of players includes: Xsens Technologies B.V. (The Netherlands), Advanced Realtime Tracking GmbH (Germany) to name but a few. A further example of very specialised companies is HiWave Technologies PLC (UK) that manufactures electronic components that enable sound and touch capabilities to be added to consumer, retail and industrial products.

Within the **high-end visualisation market**, besides a number of very specialised SMEs (e.g. manufacturing HMD - Head Mounted Displays), BARCO Display Systems (Belgium) is regarded as one of the top manufactures of projection solutions worldwide. On the other hand, if we analyse the emerging Original Equipment Manufacturer (OEM) pico-projector market, most solutions come from the Far East with limited role being played by European stakeholders.

Within the **Augmented Reality domain**, we should mention a few European RTD institutions including Fraunhofer IGD (Germany) and the Institute for Software Technology and Interactive Systems of Vienna University of Technology (Austria). The latter is coordinating, among other initiatives, OpenTracker an open library that provides device abstraction to support interaction within augmented reality scenarios.

The European academic community is also driving research in the domain of **multimodal interaction** within institutions such as the Technical University of Lisbon (Portugal), the University of Udine (Italy) and Hasso Plattner Institute (HPI) (Germany). A further initiative worth mentioning is the German Cluster of Excellence on "Multimodal Computing and Interaction" (M2CI), with its core partners, Saarland University, Max Planck Institute for Informatics, the German Research Center for Artificial Intelligence (DFKI) and the Max Planck Institute for Software Systems.

Among the various research groups in Europe focusing on **mind/brain Interfaces** we should list the Interdepartmental Centre for Mind/Brain Sciences (CIMeC) of the University of Trento (Italy), the University of tor Vergata (Italy), the Laboratory of Brain-Computer Interfaces at TU Graz (Austria), the Cognitive and Social Systems Group at Laboratory of Computational Engineering of Helsinki University of Technology (Finland) and the Istituto Italiano di Tecnologia (Italy).

The University of Reading (UK) has also been at the forefront of research on interaction through implants of technology on real nervous systems.

With regard to **cyber-physical systems**, the European industrial landscape includes a number of key OEM manufacturers typical of cyber-physical systems for portable Augmented Reality uses including, among others, micro-cameras, miniaturised gyroscopes, accelerometers, Micro-Electro-Mechanical Systems – MEMS. One of the large –and certainly most prominent- industrial players worth mentioning is STMicroelectronics (Switzerland). The European industrial landscape includes also manufacturers of force feedback (haptic) and kinematic measurement tools such as Haption SA (France), Force Dimension (Switzerland).

At the device level, several hi-tech SMEs also specialise on development of consumer or professional-grade **Brain Machine hardware or software solution** based on processing of Electroencephalography (EEG) and Electro-Oculography (EOG) data, including for instance Guger Technologies OEG (Austria). European SMEs are also manufacturing portable BMI solutions as final products available within the consumer market.

Image courtesy of kromkrathog/ FreeDigitalPhotos.net

RESEARCH AND INNOVATION RECOMMENDATIONS

In the medium-term, research should promote a **holistic approach** leveraging on **portable smart devices**, ambient intelligence, smart sensing technologies, and ubiquitous projection environments. This will enable creation of **intelligent environments** where an ecosystem of devices can seamlessly be used to ensure **interaction** with the surrounding space where **virtual and augmented content** are blended. In particular, this will require the development of **specific interaction devices** for non-flat screens, which will require –in turn- a re-thinking of **current interaction paradigms**.

Additional attention should be also paid to the **development of new means** to represent, access to and interact with contextualised information through the use of **projective Augmented Reality technologies**. This will be fundamental in order to develop **more effective adaptable projective Augmented Reality interfaces** capable to automatically adapt information provided to the user to the specific context. Attention should not only be paid to technical issues, but also to **non-technical aspects** including **societal and communication-level implication**.

The aforementioned research activities will pave the way to the **long-term evolution of Augmented Reality (AR)**, which should evolve into **a truly sense augmenting media**. Particular attention will have to be paid to **enhancing interaction** based on cognitive aspects, especially leveraging on development of **brain interfaces**. Of particular importance will also be the development of **techniques for automatic capturing**, classification and cataloguing of contextual information. In the long-term, it will also be important to **leverage on cognitive aspects and technologies** so as to improve both classifications of information and selective retrieval in order to specifically support decision-making.

The comprehension of the context and actions within the space surrounding the user will allow development of **memory augmentation technologies**. Similarly, it will be necessary to **develop adaptive interfaces** that can adjust to users' psychophysical state. This approach will have to be further pushed and will ultimately lead to the development of interfaces capable to sense users' cognitive and affective state, to predict their evolution, and act accordingly.

In the medium-term, the development of **miniaturised non-invasive motion technologies** should also be encouraged. This development would allow wireless **tracking of human positions, gestures and body language**.

Furthermore, the development of **prototypical solutions for cloud-based facilities** for multimodal interaction should be fostered. With regard to this item, a clear dependency exists with recommendations of **standardised approach to interaction.**

In the medium term, innovation focus on **facilitating the transferring of past RTD achievements** in the domain of **multimodal interaction to industry**. In particular, **innovation** should be promoted to develop **operational network-based input/output software technologies** that could be used to allow for multimodal interaction within daily life scenarios, through interaction with equipment and devices of daily use. For this reason, innovation should leverage on:

- **Increasing success of advanced user-interaction mechanisms** by the "smart device" generation and the consequent interaction paradigm shift.
- Largely **available of broadband Internet connection** at home.
- **Availability of input/output (IO) OEM hardware** at low cost (e.g. sensors, video-cameras, displays).
- Development of **Internet services for multimodal interaction**.

Additional innovation should be promoted in the **domain of projective Augmented Reality** leveraging on the maturity of the users, robustness of miniaturised hardware, and availability of mobile augmented reality software technologies.

Moreover, **synergies** between more ubiquitous multimodal and projected augmented reality technologies could be exploited in order to **promote innovation activities** in the domain of **ambient intelligence and smart homes**, to create consumer solutions capable of more effective or inclusive experience with personal digital data.

Finally, **standardisation** will be a fundamental enabler to maximise the impact of RTD development within this domain. First of all, it will be important to **introduce an extensible formalism** to be used to define user's actions, gestures, commands and feedback mechanisms. To do so, it will be necessary to **identify**, in an abstract manner, those **actions** and extensible mechanisms (e.g. via XML) **for encoding and grouping actions and commands** into increasingly complex, compound interactions.

Image courtesy of nokhoog_buchachon/ FreeDigitalPhotos.net

4.2 ENGINEERING AND MANUFACTURING

Due to the wide nature of this domain, the analysis has taken a **holistic approach** to analyse various macro-aspects that characterise the engineering and manufacturing domain. Such an approach has allowed identifying, from a high-level perspective, **historically relevant fields and areas** where EU stakeholders have played a leading role, as well as **emerging trends** on top of which to define high-level requirements for future research activities.

FROM DIGITAL DESIGN TO VIRTUAL AND AUGMENTED ENGINEERING

The global competition is continuously forcing both large and small manufacturers to the creation of products with better performances and higher degrees of personalisation as well as to reduce costs and through more agile design and manufacturing processes. As a result, the whole product development model has significantly evolved, most notably through the introduction of a wide family of **digital design technologies** often referred to with the term of **Computer Aided Technologies (CAX)**. Indeed, Computer Aided Design, Computer Aided Manufacturing and Computer Aided Engineering (referred to as CAD/CAM/CAE), have deeply revolutionised the engineering and manufacturing domain, paving the way to what is referred to as **Virtual Engineering (VE)**. VE covers the various activities of "product development from concept, design, and analysis/simulation, up to manufacturing"**.** Within the CAD/CAM/CAE domain, several EU stakeholders play a leading role at the global stage, both in the academia and within the industrial world.

As noted by Marion et al. (2012), the **rapid evolution** in the domain of digital design has been caused by **three main factors**, i.e.: 1) availability of rapid prototyping technologies, 2) access to effective collaboration tools, and 3) readiness of CAD systems at low cost for standard PCs.

Over the past year, research has paid significant attention to the **development of visualisation and visual computing technologies for the early stages of the design process**. Indeed, **styling** is one of the key factors for the commercial success of a product. As a consequence, if companies want to remain competitive, they have to **improve efficiency and quality** of the styling process during the initial stage of the design process through specific **Computer Aided Styling (CAS)** tools.

With regard to this, particular attention has been paid to **Virtual Prototyping (VP)**, which can be regarded as the creation of prototypes simulating products or concepts as realistically as possible, as well as their behaviour or their conditions of use, using computer models and techniques based on Virtual Reality. **Virtual Prototypes** are built to simulate morphological, functional and ergonomic features of a given product under various conditions of use in order to assess several aspects. Indeed, **Virtual Prototypes** are essential to optimise the **design of a product**.

Specific research activities have brought to the development of **sketch-based interfaces for biomechanical engineering**, for instance to model myocardial fibre orientation as required in the electrophysiological simulation of the heart.

Despite being indispensable supporting tools, current Virtual Engineering approaches still have intrinsic **limitations**. As noted by Marion et al. [2012], digital design solutions can be "invaluable in visualizing ideas, quickly developing a detailed design and conducting fast iterations". However, serious problems can arise if not "complemented with sound management practices" [*ibidem*]. Indeed, the use of Virtual Prototypes, and more generally Virtual Engineering tools, can produce a **false sense of security**. The fuzziness typical of open design solutions is replaced by "what seems to be a highly evolved design that is then prematurely moved downstream", with very high risks for later production stages.

Other risks, created by the possibility to change the design solution continuously and with ease, are either the **dangerous growth of number of changes**, or the **poor control over them**, as well as the **delayed finalisation of the design process**.

A notable research trend has also explored how to "massif" Virtual Engineering (VE). Indeed, when observing the engineering and manufacturing domain, **mass customisation** can have a manifold interpretation: the first refers to the use of IT technologies to improve the design and manufacturing process so as to extend the range of possible configurations of the products being produced. According to this position, mass customisation is introducing a **significant change in supply chain management,** as well as in simulation of the virtual engineering and manufacturing process.

A second interpretation of the term "massification" refers to the possibility to create **new IT-based services** that represent a more customised form of product, resulting from an engineering process[16]. This represent an **open challenge** especially in the context of web-services, for instance for marketing or commercial applications[17].

The third, and perhaps most interesting, approach to "massification" regards the "**massification**" **of the design process** itself through the **involvement of the large community of stakeholders** within the design process. This usually occurs to properly identify products or service requirements from a large base of users via web-based technologies[18]. In this case, the **challenges** are to **properly identify requirements** with the diverging users' opinions, and the ability to recombine resources, including organisational and value chain resources, to **give customers the possibility to define their own requirements** [Salvador et al. (2009)].

Last but not least, there is a fourth dimension of the "massification" process that sees the **use of consumer non-engineering oriented applications**, such as Second Life, Google Earth or Google SketchUp, for industrial or engineering applications, ensuring affordable software solutions for 3D modelling to visualisation and simulations of complex scenes. A key example is the use of **game-based technologies**, i.e. **game engines**, which are now extensively used for marketing purposes in order to create virtual product configurators or for interactive training applications[19].

MODELLING AND SIMULATION (M&S)

The manufacturing production process is managed through a very complex set of technologies, variables and organisational procedures. Such a very high degree of **complexity** has essentially been the main driver for the development of simulation capabilities in order "to rapidly conduct experiments to predict and evaluate the results of **alternative manufacturing decisions**" [McLean et al. (2003)]. With the advent of virtual engineering and with the availability of very performing computer hardware as a commodity, the role of Modelling and simulation (M&S) is **substantially increasing**.

Research has also focused on **compound approaches to simulation** and multi-objective optimization with the goal to create new hybrid approaches based on optimisation and simulation criteria that allow fast feedbacks to the users

[16] An example of this is Pandora.com, an online service that allows creating customised radio channels that feature several hundreds of thousand channels (361 million as of Dec. 2008), created and played by millions of users every day.

[17] New such services are emerging in the market. Examples are those by My Virtual Model Inc., a Canadian company that allows creating virtual avatars of real people that can use their virtual counterparts test or assess products. Such services, together with availability of low cost 3D scanning technologies, could be used to create new business models for eCommerce.

[18] Example of mass scale design efforts are reported by Richards [2007]. An example was made by Fiat S.p.A. that created Concept Lab, a toolkit that could be used by customers to define their preferences for the design of the Fiat 500. The experience is now being extended to design new version of the popular Fiat 500 model [*500 wants you* (2012)].

[19] The company Unity 3D [http://unity3d.com/] is one of the success stories in this domain, allowing the deployment of interactive applications for desktop, web-based and mobile solutions.

within seconds. However, despite research on M&S addresses clear requirements emerging from industry, **relatively limited progress** has been done in this domain in the past few years. Today, as noted by Gang et al. [2010], one of the key emerging requirements both at the R&D and industrial level [20], is to develop true multi-physics M&S systems.

Europe is also playing a key role in the domain of **3D modelling for engineering and manufacturing**, for instance in the **development of Open CASCADE Technology**. A further relevant initiative is **Code_Aster**, a suite that allows for mechanical, thermal and multiphysical analysis, including analysis of model dynamics and simulation of interaction between fluid and structure or soil and structure.

From a scientific standpoint, particularly relevant is the research on **simulation steering** in the context of computationally intensive tasks typical of **High Performance Computing (HPC) solutions**.

The need for large-scale simulations has also fuelled the domain of **Parallel Discrete Event Simulation (PDES)**. As partial consequence of this, research has explored development of **M&S infrastructures** based on **cloud-based paradigm**. In particular, research has shown that the development of **SimSaaS** (Simulation Software as a Service) over different Platform-as-a-Service (**PaaS**) can allow scalability, better use of physical resources and overall optimisation in terms also of efficiency and lower costs.

The field of simulation and visualisation have also received a extended attention with the **increasingly availability of powerful COTS computing solutions** based on hybrid use of CPU and GPUs (Graphics Processing Units). With the advent of **GPGPU (General-Purpose computing on Graphics Processing Units) paradigm**, research is moving fast along the **Visual Interactive Simulation (VIS)** domain. Concurrently, the concept of **VIM (Visual Simulation Model)** has been introduced by the research community to define a simulation model in the context of graphical interactive environments. The two concepts have been eventually merged within the name of **VISM (Visual Interactive Simulation and Modelling).**

A significant body of research has also focused on **human modelling and simulation** within **two main different scenarios**: the first focuses on modelling of human beings in order to assess level of comfort and ergonomics, while the second corresponds to developed simulation environments where human beings can test their skills and train in a risk-free environment.

With regard to the first group, research has developed **algorithms for generation human-like motion** and computation of joint torques, typically for ergonomics [21] simulations. It should be noted that the **reduction in the total number of injuries** is clearly linked to the application of better ergonomics principle workplace design [Das et al. (1999)]. Additionally, it is well acknowledged that the EU workforce is aging rapidly and therefore it will have to increasingly rely on **ergonomics** improvements within **the workplace** to reduce the risk of short duration injury and long-term illness.

Ergonomics and usability studies have been built on top of **modelling of digital humans** that are used to reproduce "the movements and the behaviour of the human beings" [Di Gironimo et al. (2012)]. These studies have brought to the birth of the so-called **Digital Human Modelling (DHM)** domain. The same technology can also be used for **Virtual Assembly**, i.e. the simulation of the process of assembly-disassembly and check of the feasibility of the proposed operations. In this context, also maintenance operations are to be considered as an integral part of the life-cycle of a system, including the programming of sequences of disassembly for removal and replacement/repairing of defective or failing components [Caputo et al. (2007)].

Moving onto the second family of applications, which see **human beings at the centre of the system**, **simulators** have been traditionally used as **training platform**. The latter represents a very well established industrial domain with manufacturers specialising in both software/hardware simulation tools, and specialised services.

Several of the most relevant simulators have been built for **training military staff**[22]. Among these, **Embedded Simulators (ES)** represents a recent evolution of hardware-in-the-loop and man-in-the-loop simulations.

[20] With regard to this, a mention should be made of EUROSIM, the Federation of European Simulation Societies [EUROSIM (2012)], which organise the annual EUROSIM event, the Congress on Modelling and Simulation.

[21] Ergonomics can be defined as the science of the human factor, whose goal is to study the interaction between man, environment and product, using interdisciplinary knowledge involving physiology, anthropometry, engineering and psychology [Caputo and Di Gironimo (2007)].

[22] This is the case of Synthetic Maritime Training Environment (SMARTE), a tool specifically developed simulator of ships operating in reduced manning conditions.

ES principles move beyond the concept of "man- or hardware-in-the-loop simulations" in that the **user can interact with the real system**, in real operational scenarios, albeit with simulated constraints or events, through connection of embedded systems with a simulation engine. Advantages are manifold, since the operator can interact with the real device, in a real context, but with a simulated scenario.

The key role being played by **Modelling and Simulation (M&S)** and its implications in terms of analysis, training and operations is well acknowledged within the international military world, where it has been acknowledged that it requires procedural, programmatic and cultural changes [Goldiez (2008)]. Within NATO, there have been a number of integration efforts to help improve the exchange of information between C2 (Command and Control) systems. Indeed, the main focus of NATO has been to rapidly allow for **extension of existing infrastructures**, through systems that can **ensure interoperability** with legacy infrastructures[23].

Within the M&S domain, as noted by Cohen et al. [2008], the **major limitations** that need to be overcome in a real scenario are: a detailed modelling of ambient phenomena including weather and other effects; a realistic modelling of degradation of performances caused by reaching saturation limits; and an integration with legacy systems. The military community also shares with the civil world the **need for common VVA methodologies** [Masys et al. (2008)]. Others, i.e. Roman and Bassarab [2008], have highlighted the **need for a *Simulation Interoperability Framework*,** which could be used to create joint simulations between armies from different countries based on common standards and simulation tools.

[23] More specifically, NATO has promoted the so-called C2 Core, i.e. "a subset of the well-known Joint Consultation Command and Control Information Exchange Model (JC3IEDM), multinational C2 data model, combined with the Geography Mark-up Language (GML)-based representations of time and location from the soon to be released Universal Core v2.0 data model [Whitehead et al. (2008)].

FROM VIRTUAL FACTORIES TO AUGMENTED BUSINESS VISUALIZATION

The **increasing complexity** of manufactured products requires **high levels** of flexibility, maintainability, and customisation. **Virtual Manufacturing (VM)** was borne out of the integration of many disciplines and is now commonplace within most aerospace and automobile industries. Indeed, it allows integrating the various typical activities of a manufacturing process, hence reducing production costs and time to market, making it extremely easy to change configurations of products or plants. Some **advantages** of VM are an early detection of errors and the support to decision-making process with regard to manufacturing stages. Moreover, it is possible to **improve efficiency** of the product development through a virtual manufacturing systems, or **Virtual Factory (VF)**[24]. However, although in principle the use of networked technology allows for global, geographically-distributed, network-centric companies, in reality few examples of such approach are found in daily practices, such as **Holonic Manufacturing Systems (HMSs)[25]**.

[24] A number of EU projects have been funded within the FP7 programme, addressing the concept of "factory of the future", among which it is worth mentioning ADVENTURE "ADaptive Virtual ENterprise ManufacTURing Environment"; VFF "Holistic, extensible, scalable and standard Virtual Factory Framework"; and Enviro-Tex-Design.

[25] HMS uses autonomous intelligent subsystems that interact to create a very agile manufacturing system.

From the mid-nineties on, the development of web-based solutions have allowed the creation of increasingly complex **Computer Supported Collaborative Design (CSCD)[26]** tools. The use of web-based applications has **several advantages**. On the one hand, the **management** of the software is **centralised**; additionally, this allows "lowering the threshold for engineers to use remote simulation and post-processing facilities, allowing them to create and analyse data sets on their local workstation or mobile devices" [Niebling et al. (2010)]. However, web-based sharing of data has to be complemented with true **collaborative support** among different members of development and production teams.

Today, the industrial world traditionally follows two approaches to improve cooperation, i.e. **data management** (via PDM and PLM software) and **application integration through creation of complex suites**. In particular, Product Data Management (PDM) and Product Lifecycle Management (PLM) software allow that "the 'right information" is provided to the 'right person' in the 'right time' according to the 'right order'" [see Shen et al. (2008)].

From an **industrial standpoint**, European stakeholders play a key role within virtual manufacturing / virtual factory scenarios, thus allowing the development of **virtual factory solutions**. Within this domain a relevant example is developed by Siemens PLM software, which is acknowledged as the world leader in digital manufacturing solutions, which have developed **Technomatix™**, a solution allowing for

[26] CSCD is defined as "the process of designing a product through collaboration among multidisciplinary product developers associated with the entire product lifecycle" [Shen et al. (2008)].

efficient planning, optimised production systems, and operation validation.

This trend is leading to a **new generation of applications** that are designed for what is referred to as **Augmented Business Visualization (ABV),** "a new paradigm in visualization which provides rich and actionable visual decision making environments on all delivery platforms by connecting portions of documents to business data found in enterprise applications" [Oracle, *AutoVue*].

Visual Analytics (VA) is a relatively new yet emerging practice engineering-related domains, including software production/maintenance and industrial applications. The main trend is to **meet the requirements of developers** for product and process assessment, with the expectations to perform debugging process in a very short time. In such cases, **Software Visualisation (SV)** tool have proved to help speed up product assessment processes.

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POSITIONING OF KEY EU STAKEHOLDERS

At the lowest logical level, it is well acknowledged that the European **computing hardware manufacturing** industry has limited capacity if compared to US/Asian counterparts. Additionally, low-level software specifications including CUDA, OpenGL, WebGL, OpenCL, are being mainly developed by US companies or consortia (e.g. Khronos Group) whose key members are mostly located in US or Asia.

Instead, in the field of **industrial robotics**, several European manufacturers are showing very high innovation capacity. Companies such as like COMAU (Italy), KUKA (Germany) and ABB Group (Switzerland) are developing mobile and cooperating robots capable of working in closer proximity with humans.

From a logically higher perspective, the European industrial and scientific community has traditionally played a key role at the global stage in the domains of **interactive modelling and simulation**. Examples include specialised companies such as EngineSoft (Italy), GNS - Gesellschaft für Numerische Simulation (Germany), Numeca (Belgium), Autoform (Switzerland). Larger players with a dominant worldwide position include as Dassault Systèmes (France), the developer of the product development suite CATIA, the virtual factory software DELMIA and the CSCW solutions SolidWorks DraftSight and BluePrint Now, Missler (France), and Siemens PLM (Germany), developer of the digital manufacturing solution Technomatix™. Possibly hundreds of SMEs complement the activities of these large players through specialised solutions in the simulation market.

The European research community has also acquired a strong positioning within the scientific domains of VA, BIM, GIS, CAD/CAM/CAE, PLM, virtual & augmented engineering and prototyping. Within the domain of CAD/CAM/CAE, European industries are leading both the market of proprietary solutions (e.g. Dassault Systèmes) as well as of open source products, whose most notable example is Open Cascade. The latter is a very popular 3D modelling software by Open Cascade, a company part of the Euriware Group (France), which is used in a range of different domains from aeronautics (e.g. by the European Aeronautic Defence and Space company - EADS), to nuclear plant design, etc.

The European research community has also acquired a strong positioning within the domains of CAD/CAM/CAE, virtual & augmented engineering. Key institutions include Fraunhofer IGD (Germany), University of Bologna (Italy), Polytechnic of Bari (Italy), University of Grenoble (France), CNR (Italy), Technische Universitat Berlin (Germany), and Fondazione Graphitech (Italy).

Électricité de France (EDF) R&D is a main player driving the development of solutions covering the whole workflow from creation of CAD geometries to meshing and conversion to physical data, from calculation of the simulation to final post-processing. EDF R&D, together with the French Atomic Energy Agency and Alternative Energies Commission (Commissariat à l'Energie Atomique et aux Energies Alternatives - CEA), EURIWARE/Open Cascade and further partners, play also a key role within the open source world of numerical simulation.

Many European RTD institutions are also actively contributing to the development of **VR** and **simulation technologies** such as CERV - Centre Européen de Réalité Virtuelle (France), Fraunhofer IGD (Germany), ETH Zürich (Switzerland), to name but a few. With regard to industrial solutions for **simulation for ergonomics** it is worth mentioning the leading solutions DELMIA Human, by Dassault Systèmes (France), JACK by Siemens PLM software (Germany) and RAMSIS Human Solutions (Germany). RTD institutions have also acquired a very prominent position in the use of VR for ergonomics. This is the case of Polytechnic of Milan (Italy) and the University of Naples Federico II (Italy). The former has developed solutions for accessibility assessment of in-vehicle commands and force feedback, while the latter has created low-cost high-performance VR solutions for ergonomic simulations, simulation of Human-Robot interaction, virtual maintenance, virtual training and Virtual Design Review sessions.

If we analyse the scientific community working on networked simulations, it is worth highlighting the efforts by the Computing Center University of Stuttgart (Germany), which leads the development of COVISE. Additionally, Arts et Métiers ParisTech (France) have promoted PythonOCC an open initiative for CAD-based web services, visualisation and simulation. A further mention should be made for VSG - Visualization Sciences Group (France) that develops Open Inventor.

Within the **BIM market** companies such as Nemetschek (Germany) play a significant role at global level. Within the **GIS domain** European SMEs are contributing to several open source solutions that are increasingly conquering market shares traditionally controlled by US companies such as ESRI, Autodesk, Intergraph and Bentley.

Lastly, moving the focus of the analysis to **cyber-physical systems**, the Deutsche Forschungszentrum für Künstliche Intelligenz - DFKI (Germany) and the Fraunhofer Alliance Production (Germany) have been among the most actively engaged institutions to study future product, production, automation and logistics development systems.

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RESEARCH AND INNOVATION RECOMMENDATIONS

True **convergence of modelling and simulation**, from a computational standpoint, will greatly leverage on a **fast evolving hardware landscape**. Indeed, very highly parallelised hardware will introduce radical performance improvements. This will require the research community to learn how to simulate the availability of future computing platforms, including extremely high-parallelised hardware or hybrid configurations, for scientist to be able to develop and validate **new approaches to modelling and simulation (M&S).** In the long term, this may also require the **development of extensible software libraries (APIs)** that can be used by non-computing experts to run M&S tasks without being aware of underlying computing requirements of highly parallelised heterogeneous hardware infrastructures.

A key requirement for the **convergence of modelling and simulation** is the definition of unified, cross-domain, abstract modelling and simulation (M&S) representation. This will first require a **cross-disciplinary capacity-building action**. Such an action will have to lay the foundation of a **cross-discipline**, extensible abstract model to represent data, metadata, algorithms and processes. The **model** will have to cover all the phases of the **digital content lifecycle**. This will also enable, in the long-term, the development of truly interchangeable **virtual models**. A comprehensive analysis of **privacy and security provisions** will also be essential in this phase.

From a purely modelling and visualisation point of view, the data model will have to be based over a **unified representation** that can ensure interactive modelling and modification of both continuous and discrete 3D geometries and simulation models. In particular, this will require research to develop **new representation schemes**, and, for this reason, it will be necessary to **develop semantically rich 3D model descriptions** and **knowledge representation technologies**. Additionally, the model will have to comprehensively define, formalise and encode the degree of "uncertainty" across different stages of modelling and simulation lifecycle.

It should be noted that the development of a unified representation would be also beneficial for the creation of **assistive visual computing solutions for engineering and manufacturing**. At the user level, the development of new M&S methodologies will also require to develop **new interaction metaphors** that can better support a more integrated workflow. This will initially occur through systems that can provide typical modelling functionalities of CAD within a CAE simulation environment and later through software providing multi-domain M&S capabilities. This will require, in the medium-term, development of **functional**

based approaches to modelling and simulation of heterogeneous systems, while, in the long-term, this approach will have to lead to automatic environments for model manipulation and functional verification.

From a **perceptual standpoint**, research will have to develop **3D capturing interaction** and force **feedback technology** to overcome the perceptual gap between virtual and physical 3D environments. Furthermore, in the long-term, research will also have to address how to support operators through **automatic adaptation of the visualisation of multi-dimensional content** based on automatic context understanding.

Particular attention should also be paid by research on how to facilitate the **set-up of the simulation phase**, considering scenarios of **multi-disciplinary simulations**. This could also include, in the long-term, development of **visual approaches** that can enable simple configuration, modular composition and clustering of M&S processes and their re-use across the community of other users. This will also require the development of methodologies for concurrent configuration management specifically addressing '**Big Data**' **scenarios**. Such a **multi-domain** research activity will also require considering **multi-faceted requirements** both in technology and interaction terms.

The evolution of the M&S landscape will also have implications in terms of **simulation and data flow/interactivity,** due to the development of sophisticated networked M&S capabilities that are going to leverage on increasing availability of **cloud-oriented scenarios**. From a **visualisation standpoint**, this will require the development of **network-based visualisation technologies** that can support interactive creation and modification of a scene within service/cloud-oriented graphics systems that can provide remote visualisation and interaction facilities. **Networked visualisation technologies** will have to support a very large range of hardware visualisation ecosystems. In the long-term perspective, networked graphics systems will have to provide **assistive real-time feedback** in the context of 'big data'.

Additionally, it will be necessary to develop **efficient mechanisms** to allow true simulation steering in the context of online distributed simulation scenarios and, in the long-term, to develop collaborative interactive simulation steering for improved cooperation and decision-making. This will require improving the **overall M&S efficiency** by allowing users to interactively change the simulation conditions while it is executed within a **networked infrastructure**. Thus, the development of **efficient mechanisms** for optimisation of dataflow will be needed. In turn, this will make **new requirements** emerge that will call for distributed simulation architectures beyond SOA and HLA. This may also support **new paradigms to green computing,** allowing development of M&S optimisations mechanisms that account for sustainable approaches to data flow in the context of cloud-based simulation services. This will entail the development of **new business models and billing mechanisms** capable to dynamically re-allocate processing capabilities of M&S services within the cloud.

From an **innovation standpoint**, innovation activities should be promoted to facilitate the **creation of a market of networked M&S**, especially targeting Embedded Simulation (ES) and Embedded Training (ET) scenarios at business and consumer level. The widening of scope of future M&S at consumer level, together with the constant growth of 'big data' scenarios, will have to be addressed through the development of **new interactive and Visual Analytics (VA)**, ubiquitously available by non-data mining experts through smart devices. The implications of such a shift regarding the domain of **simulation and advanced visualisation in the context of analytics** will be significant.

The forthcoming availability of **new visualisation solutions**, including flexible screens and more complex projective augmented reality applications, in the context of increasing 'big data' scenarios, will require research to develop **intelligent mechanisms** to access heterogeneous data sources and visual interfaces, **low-level graphics management mechanisms**, and **new forms of well acknowledge abstract representations**, as well as to define **analytics paradigms**. Those facilities should be available within M&S systems featuring visual analytics specifically designed to enhance cognitive and analytical insight of operators also through **automatic context adaptation**. Those VAs should be designed to promote **exploratory and mapping processes** based on extremely reactive and perceptually engaging simulation/VA techniques.

Additionally, research should also address **behavioural changes at the societal level** that see users adopt increasingly nomadic working scenarios based on the use of consumer smart devices always connected to the network. This should be facilitated through the development of **new forms of cooperative visual analytics methodologies** that allow ubiquitous access and remote sharing of M&S tools and results. The long-term evolution of this approach will require the development of **very sophisticated VA tools for M&S** that can leverage on cooperation of very large number of concurrent users with different profile. This will support the emergence of "**collective intelligence**" and the creation of "**hyper innovation**" **processes** that may positively affect the production process.

In the medium-term, research will also have to address the evolution of **cyber-physical and intelligent systems in the context of future engineering and manufacturing**. In general terms, research will have to develop new forms of intelligent de-centralized, manufacturing execution systems based on cooperating self-organizing systems of people, robots and products. On the one hand, this will require research to develop **effective techniques** to let robots immediately react to changes based on understanding of 3D scenes and planning actions within 3D environments. On the other hand, this will require the development of **gesture recognition** and **easy-to-use multi-touch interaction metaphors** explicitly designed to control industrial machines and robots, further rising the need for development of new **Physical Human-Robot Interaction paradigms**.

Research should also explore **cognitive HRI issues**, studying communication and mutual understanding between human and robots, including how to render "intentions" of robotic systems and pre-emptively show them through forms of augmented communication between human beings and machines. In the long term, this trend could bring to the development of **intelligent production environments**.

Additionally, research should address development of **specific interaction mechanisms and intelligent tools** that could be used to retrofit existing manual workstations in manufacturing systems, to assist and support human operators during their working activities. This, in turn, may require the development of **more effective algorithms for human-like motion generation** to faithfully reproduce movements and behaviours of human beings.

In the medium term, research will have to address **how to expand the scope of Cyber-Physical Systems (CPS)** to the cyberspace with virtual representations. As a result, the whole production process will have to be redesigned by developing systems capable to deal with intelligent products thought as agents providing specific information. If we further extend this approach to the long-term future, research will have to explore **how to allow truly self-aware and self-executing manufacturing processes**. Within such manufacturing processes, machinery and the system as a whole would be able to interact, plan production, self-control, and report problems, as well as accounting for constraints such as energy consumption or delivery time. The implication of such an approach will be significant and will allow **further integration between design and production process**. In the long-term, research could address development of **integrated systems** where machine tools suggest designer optimal sequences of operations or materials to achieve a set of complex design requirements.

Similarly, research will have to explore **how to maximise** such an increased **interaction** across all stages of engineering and manufacturing to create **automatic mechanisms for programming robots and Computer Numerical Control (CNC) machinery**. In particular, research should explore **how to use semantic technologies** or **communication patterns** that are closer to the human way of thinking, to ensure effectiveness and safety of operations. In the long term, this may bring to truly **smart manufacturing processes** whereby the system is capable to detect manufacturing operations to be performed, directly from the CAD model. Additionally, the evolution may require research to address **auto-healing processes**, to allow machineries to automatically repair or -at least- to autonomously plan maintenance activities.

However, such an extended view of the manufacturing environment will require research to develop **secure communication mechanisms** that can ensure safe exchange of data between machinery or production systems across different companies.

This scenario highlights the **need for enhanced training** that can let employees safely practice with new and existing tasks either through virtual simulation of manufacturing processes or by "enhancing" the production environment and turning it into an augmented training system. This, in turn, calls for **development of better output devices**, such as better portable displays, for augmented reality training. Innovation will also be needed to promote **development of desktop-based, low-cost and easy-to-use multimodal interfaces** to study maintenance and inspection methodologies.

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4.3 DIGITAL CONTENT CREATION, CREATIVE INDUSTRY, EDUCATION AND TRAINING

In September 2009, EC-funded FP7 Project **CReATE** [2012] published a report on how innovations in the ICT would foster the **Creative Industries** which identified **five research priorities:** 1) Visual and interactive experience; 2) Tools for productivity plus intelligent automation; 3) Digital distribution; 4) Mobility plus interoperability; and 5) User-producer-interaction.

Gartner's report on strategic top ten technologies for 2012 [Gartner (2012)] confirms the **key role of digital content creation technologies** whose importance will rise over the next few years through improvements to user experience, mobility, and changes at the consumption paradigm level. Research on **Visual Computing** can clearly act as a **catalyst for all these trends and priorities**.

Gaming also represents a **key industrial domain** that has significantly contributed to the development of digital content creation techniques, ranging from tracking of people to acquisition of 3D content.

AUTHORING STAGE

Several initiatives have focused on the **authoring stage**, trying to remove limitations typical of the authoring process and make it easier for content producers to operate[27]. Furthermore, a significant research body is focusing on **automatic acquisition of data through image-based methods**, including real-time pose acquisition [Nöll et al. (2010) and (2012)].

In particular, **reconstruction of (rigid and dynamic) objects / scenes** has become of major interest in recent years in various application areas, through use of depth-cameras (also referred to as time-of-flight or **TOF camera** [Cui et al. (2010)]). This has immediate use in several domains of relevance, from archiving of cultural heritage to digital arts[28].

DISTRIBUTION STAGE

With regard to the distribution stage, initiatives have focused on **taking advantage of new network technologies to distribute multimedia content**[29]. From a distribution standpoint, it is worth recalling that the use of Internet for user-generated content has reached a significant dimension. The impact of public being reached by Internet-based content distribution mechanisms is significant especially due to the wide success being enjoyed by image and video sharing.

CONSUMPTION STAGE

Projects such as **2020 3D MEDIA** [2012] have focused on the consumption stage of 3D media. Further projects, such as **3DPRESENCE** [2012], have brought to advances in the visualization and interaction research by creating a **telepresence system** where users can interact via eye contact and gesture recognition.

Indeed, most of the projects provide advances in three main fields: **inclusion of 3D virtual contents** in the multimedia value chain, semantic information attached to multimedia contents, and standards that support all these concepts along the whole value chain.

CROSS-DOMAIN USE

It should be noted that research has also explored the development of **visual computing technologies** applied to the domain of multimedia content creation beyond leisure. **Technology-enhanced learning**, for example, is a field that

[27] An example is the CASAM project, which proposes techniques for automatically annotating multimedia content [Zavitsanos et al. (2010)]. Further projects are FOCUS-K3D [2012], which has developed means to include semantic information into new 3D media content modelling and processing tools, and 3D4YOU, which develops technology for creating and delivering 3D contents for 3DTV systems [2012].

[28] It should be noted that the acquisition of a scene with high spatial resolution and accuracy in real-time is extremely important also for a number of other domains beyond creative industries from medical applications, to industrial simulation engineering domains, since it would allow the creation of one-to-one virtual parts, i.e. virtual representation of each given product with associated lifecycle information.

[29] ADAMANTIUM project [2012] has developed a Multimedia Content Management System focused on the improvement of the user experience for IPTV (Internet Protocol Television) and VoIP (Voice over IP) services [Arnaud et al. (2010)], while the project 2020 3D MEDIA [2012] fulfils all the value chain for 3D media creation and delivery, but mainly focusing on distribution and presentation.

will highly benefit from these advancements. Indeed, the **inclusion of 3D Computer Graphics contents** within multimedia in a common virtual place and the possibility to interact in real time with teachers and other students, will be one of the main future factors that will contribute to improving the learning process.

MOBILE DATA CONSUMPTION

The wide success being enjoyed by smartphones and other mobile solutions will be a further driving factor for content creation and distribution, and it will lead towards platforms that maximize the benefit of media sharing from mobile Internet platforms. Recent statistics show how the access to mobile Internet through smartphones or other portable devices is dramatically increasing. The impact of this trend has **profound social implications**, with particular regard to the **fast development of social networking** and the large success being enjoyed by **mobile social networking**.

EDUCATION & TRAINING

Learning material is typically based on **multiple representations**, such as text and images. The use of such **multiple communication channels** is essential both to maximise the efficiency of the learning process, as well as to help narrow the scope of the content in order to avoid misinterpretations [Ainsworth (2006)]. However, several studies have highlighted the increasing difficulties that may emerge from the swelling complexity due to processing of diverse communication channels. From a **learning standpoint**, two main approaches exist: the **design-oriented approach** and the **engagement-oriented one** [Florax et al. (2010)]. The former, which builds upon previous theories such as the **CTML (Cognitive Theory of Multimedia Learning)** and the **Cognitive Load Theory (CLT), focuses on the design of materials** to be used for learning. The second, the engagement-oriented approach, encourages an **active learning process**.

Examples of training applications cover a **wide range of scenarios**. Indeed, VR applications are often used for training applications with little attention being paid to entertainment [Narayanasamy et al. (2006)].

Combining playing with teaching, and therefore learning, has been traditionally been acknowledged as **one of the most effective didactic strategy**. Several studies have also predicated the so-called **"pedagogy of play"**, which emphasises the importance of playing within the first years of life. Indeed, the playing experience has to be considered as a whole, since play is "a meaningful aspect of long-life education" [*ibidem*], and of **lifelong learning**[30] too.

Particularly important is the scope of education and training applications in the context of the so-called **"digital natives"** [Prensky (2003)]. The latter term is now commonly used to address the generation of people used to multi-tasking, who have grown up using digital devices and who, using a language analogy, "speak" the digital language as a mother tongue. In contrast, **"digital immigrants"** [Prensky (2003)] are those who have adopted digital media in their lives only in later years and who can interact with digital devices at a significantly higher cognitive cost.

[30] Lifelong learning is one of the principles stated by the *Common European Framework for Languages*, in which it is stated that the learning process lasts for a lifetime.

The European Commission has paid great attention to developing the education and training sector across Europe. This is why a European Commission's Lifelong Learning Programme appeared on 2007 with the aim to let people take part in a stimulating learning and training experiences throughout the continent, regardless of their age.

In more recent times, the **potential of electronic games** has been discovered and extensively exploited so as to create more engaging forms of teaching and training, also known as serious games, learning games, or **Digital Educational Games (DEG).** One of the most relevant aspects of DEGs is their **interactive behaviour and user friendliness**, together with a sound teaching strategy based on gaming metaphor. The **advantage** of serious games is their **cost effectiveness** and the **risk free nature** they offer.

In previous years, few scientists argued that DEGs entertaining nature did not necessarily ensure a sound learning process [Klawe (1998)]. Authors highlighted the fact that educational effectiveness of DEGs is still to be proved with clear arguments, and that further research is necessary to provide clear evidence of their learning capabilities. This initial yet minority sceptical position is now eventually contrasted by a very **large research work which acknowledges the didactical effectiveness of Digital Educational Games (DEG)** and their key role in various training and teaching scenarios. Moreover, DEGs are well acknowledged for being very **effective at building motivation** [Prensky (2003)].

DEGs have been traditionally targeted to **children**, in order to help them develop theoretical and practical skills, leveraging on the very attractive nature of video games. As a result, DEGs typically build **positive feedback loops** where users are encouraged to experiment with the learning environment without fear for making mistakes or being judged by a teacher, with clear benefits for the learning process.

However DEGs have also been successfully employed with **adults** in order to help create competences that would else require expensive or dangerous training within a risk-free, interactive and stimulating environment. Research has also explored the use of DEGs in **elderly** users. The role of DEGs to **senior** users has been subject of study by the **ElderGames** project. The result was the development of several game-based solutions, based on MR and other interactive technologies, or to help monitoring and improving cognitive performances of users.

The use of interactive games for training can also leverage on use of **gaming devices**, such as **Joysticks or Nintendo WiiMote™**. The use of these devices lets players interact with the game through direct actions without any intermediating level of abstraction. These solutions are particularly familiar to young users and are clearly associated to fun, and therefore make the game more attractive with the consequent added value in terms of engagement and learning experience [De Amicis, 2009]. Moreover, the use of such devices can also leverage on so-called **enactive knowledge**, a form of knowledge based on the **active use of hands for apprehension tasks** [Enactive Network, (2012)].

Additionally, the web is rich in portals providing access to **web-based educational games**. A notable example for its quality and mission is the Official Web Site of the Nobel Foundation [Nobelprize (2012)] offering access to 29 interactive learning games on various disciplines and difficulties, or the BBC portal on schools and games [BBC (2012)], which provides access to a selection of different games on different subjects according to age ranges.

Moreover, the development of DEG can significantly **benefit from the use of mobile platforms**, featuring high-resolution screens, localisation technology, high wireless connectivity and other sensors. The number of devices sold is deeply affecting the way people consider mobile computing, and has important implications for training and learning use[31].

Image courtesy of sscreations/ FreeDigitalPhotos.net

POSITIONING OF KEY EU STAKEHOLDERS

Although the European consumer and professional electronics market sees a significant participation by Asian manufacturers there are few leading European brands that manufacture innovative solutions including, Philips (The Netherlands), Nokia (Finland), Ericsson (Sweden), Löwe AG (Germany), Technicolor SA (France) or ARRI (Germany) the largest manufacturer of professional motion picture equipment in the world. In general terms, European companies mainly offer high quality products for the entertainment and media market while Asian manufactures cover the entire spectrum of the offer.

At software layer European stakeholders have acquired a strong positioning in the definition of standards and protocols. Notable examples among others are, audio and video codec developed by Fraunhofer IIS & HHI (Germany) and Thomson. In other more specific domains, including multi-language user interfaces, automatic translation, 3D rendering, emotional interfaces, etc. European research groups are regarded at top of the state of the art.

At a higher level of abstraction, Europe is one of the main drivers of professional solutions for content creation, service deployment, development, etc. Highly qualified universities (with 5 European universities within the top 17 best worldwide), very competitive research centres, including Fraunhofer (Germany), VTT (Finland), TNO (The Netherlands), Joanneum Research (Austria), IK4 (Spain), CNR (Italy), etc.), place Europe among the most relevant players in this field.

Among the very large number of leading companies it worth to mention some of them such as Brainstorm Multimedia (Spain), leaders in the market of virtual sets and live Augmented Reality broadcasts, or Fluendo (Spain), leader of professional streaming solutions, to name but a few.

On the other hand, the multi-platform cloud-oriented virtualized service market is characterised by strong American predominance with European ISPs and content providers, including broadcasters, trying to extend their business to acquire a strong position.

[31] Among the first works, we should mention the project Frequency 1550, which has developed a mobile city game where pupils could use mobile phones to perform location-based media-assignments and learn about the history of Amsterdam. Further examples include the Mobile 3D City project and its application for mobile devices (iPhone) to explore the city of Paris.

The European content creation industry include key leading stakeholders such as British Broadcasting Corporation – BBC (UK), appreciated worldwide for its high quality content, Endemol (UK), the world's largest independent production company, or Bertelsmann SE & Co. KGaA (Germany). The market is also characterised by thousands of SMEs specialised in specific tasks across the wide content production process ranging from scripting to animation, to production, to editing.

Image courtesy of kromkrathog/ FreeDigitalPhotos.net

RESEARCH AND INNOVATION RECOMMENDATIONS

The domain of **3D Interactive TV** is particularly important for the potential impact at the societal level. Current and future development is transforming TV sets into the control centre of home environment, as well as the main hub and gateway of digital content of various types. From an innovation standpoint, the domain would significantly benefit by moving market results and achievements in the domain of **multimodal interaction**. Indeed, the commercial success of products such as Nintendo Wii™ and, more recently, Microsoft Kinect™ clearly shows that the market is ready for **interactive applications** that use **natural forms of interaction** such as gestures, voice, or face recognition. Extensive achievements from research and development should be brought to the market in order to **improve dialogue and reduce cognitive load** between the virtual users and the TV and the new generation services provided through it. Additionally, research should develop **new interaction paradigms** that take into account multimodality and multi-language support and automatically adapt to device capabilities. Further enhancement of user's experience should also be promoted through the development of **new interaction paradigms for future multimedia content** to facilitate content creation, interaction, sharing and modification of resources with other users.

Research should leverage on the **increasing ubiquitous availability of multiple screens** available through smart devices. In particular, research should focus on how to best leverage on the combined use to improve user's experience. Research should **yield common frameworks**, supporting OS-agnostic "second screen" interaction mechanisms.

Furthermore, research should also study how to **improve a dialogue with the users** through development of more realistic **3D avatars** that can feature more autonomous capabilities, also in the context of **storytelling.** Research on **interaction** will have to be complemented by studying emotional detection and feedback that, in the long-term, may lead to the development of techniques based on **advanced context understanding**. In the long term, this should lead research to address **development of effective algorithms**. Moreover, research should explore **how to expand the current scope of multimedia** to include new features that could enrich the final user's experience. Research should also aim at **improving users' experience** through the development of device independent 3D audio definition and dynamic device dependent reproductions, as well as truly real-time speech and dialog technologies capable to adapt to arbitrary communication styles. Finally, research should further explore **augmentation of other senses** to provide a more comprehensive immersion.

Particular attention should be paid to facilitate **fusion of broadcasting and IP networks** by bridging current technological gaps to ensure seamless interoperability between service & contents and devices. In the long term, this may lead to **future convergence of Service Provision, User Interaction and Content Delivery Technologies**. Research should also address development of **highly efficient scalable codecs** for single video encoding. The **improvement of content fruition** should also be achieved through robust automatic translation or subtitling facilities.

Research and innovation should also address **how to introduce new cloud-based services** that could provide added value within the value chain. Efforts to **improve quality of experience (QoE)** by users should be coupled with activities aiming at defining device-independent metrics.

The **significant fragmentation** currently existing in terms of technologies and TV platform should be addressed, through a medium-term action, through a Europe-driven standardisation initiative to **define an open standard.** This should allow structuring current and future media information in a homogeneous and meaningful way, as well as the development of a **common framework for multimedia interoperability.** Further long-term standardisation should be promoted to **establish adoption of common control and data transmission standards** for all home devices (UPnP, web services, ECMAScript, HTML-5, etc.).

With regard to improving users' experience, interactive TV would benefit from the **development of standardised, hardware-agnostic formalisation of interaction mechanisms** to ensure interoperable adoption of various devices and ecosystem to ensure a more compelling experience.

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4.4 POLICY MAKING AND SOCIETAL CHALLENGES

The very complex scenario we are experiencing poses **serious challenges** to policy makers, who are required to define policies to improve quality of life, social cohesion, inclusion, environmental quality, and sustainability. This scenario in turn is being made more complex by the **increasing systems complexity** of modern cities and by societal factors such as **increasing population**.

Information and visualisation tools are now at the basis of the decisional process for policy makers at global and local level. Indeed, city planners make a large use of visualisation tools and try to understand possible forecasts on the basis of politician's decisions. In turn, this requires the **deployment of sophisticated technologies** at various stages of the policy-making process, in order to be able to collect representative and reliable information from the territory and from the population, to be able to identify requirements, trends, patterns, and ultimately to define the most appropriate policies. The technologies used are a **combination** of urban planning technique, urban economy and system modelling.

DATA COLLECTION

The first phase of the policy cycle is the **identification of the problem**, which is then used to define the agenda. The single biggest challenge is to be able to maximise the benefit of ever increasing availability of structured repositories, including data warehouses and distributed sensor data networks, as well as the availability of unstructured data. **Availability of public data** is also growing as the result of initiatives, which "democratizes the exchange of information and services" [Hoffmann (2012)][32].

Analysis of information/indicators related to the territory essentially leverages on **several visualisation techniques based on statistics (chart-based) and mapping metaphors**. Some of the most famous approaches include **cartograms**[33]. A further possible alternative can be provided through use of the so-called "**unclassified choropleth maps**", created by overlaying a grid-based structure on top of a standard map, whose cells are coloured according to the value of a class [Raffaetà et al. (2011)]. However, these visualisation, albeit powerful, require **specific background knowledge** that make these approaches not suitable in the context of applications targeted to non-expert users.

[32] This is in line with other European initiative, such as the EC Directive on Re-Use of Public Sector Information (PSI) (2003/98/EC), which "encourages and strives for extensive publication and opening of open government data" [Donovang-Kuhlisch et al. (2011)].

[33] A cartogram is "a thematic map that visualizes statistical data about a set of regions like countries, states or provinces" [De Berg et al. (2006)].

A number of interesting techniques have been developed for **visualizing movement patterns of people** by using a multitude of different visualisation techniques, such as heat maps[34] or other trajectory clustering techniques.

Other more articulated map-based approaches rely on the **combination** of different representations within the same map scene. This can be useful to show complex patterns together with a number of various measurements, albeit at the price of reduced readability.

In the past few years, improvements in terms of visualisation and processing capabilities have brought to the **rising of the geovisualisation field**. Geovisualisation addresses the development of map-based interfaces to represent information based on interaction and visualisation metaphors that leverage on the concept of "landscapes".

Moreover, the widespread diffusion of **web-based geographical information systems (WebGIS)** is having a profound effects at the policymaking level, as it is fostering the creation of complex infrastructures of geographical web-services whose data can be accessed through simple web clients. This trend is significantly leveraged on the widespread diffusion of the so-called **Spatial Data Infrastructures (SDIs)**[35].

From a software standpoint, SDIs are traditionally deployed as federated enterprise-level infrastructures designed according to the principle of **Service Oriented Architecture (SOA)**. The traditional **multi-tier approach** include the lowest data level, where all the distributed repositories are logically located, a middleware where all the services are logically deployed, and the final higher level of application layer where clients are found.

The distributed model allows creating infrastructures articulated according to administrative or geographical basis, whereby each member of the federation is responsible for management, publication and update of their own data, while benefitting from interoperable access to other services managed by other members of the federated system[36].

In relatively few years, new interactive solutions, such as **3D geo-browsers** (e.g. Google Earth, Microsoft Bing Maps, NASA World Wind), have been the cause for a profound '**paradigm shift'**, whereby common users, and not only GIS experts, can access geospatial data from the web. This includes high-resolution satellite or airborne imagery, on top of which a plethora of geographical information is made available in a user friendly way[37].

On the other hand, if we look at the **current official infrastructures** (i.e. SDIs), we find a **number of critical limitations**, the first of whom resides in the very complex **way data are indexed and searched within these infrastructures**, hence bringing some limitations, such as poor scalability, a limited searching features, limited support for spatialization of non-geographical data, and no support for visualisation of uncertain data across the whole data pipeline.

The second limitation regards the **data access paradigm**, typically based on a **tile-based approach**, whereby the scene is divided in "tiles", i.e. regular patches of terrain, created through the recursive subdivision of the terrain. A logical structure in layers allows for separation of different resources and logical stacking.

The advantages of these very simple approaches is the easy scalability, as the same approach can be scaled up to global level and increased in resolution according to the specific needs of the application (through iterative subdivision of patches). Transmission of data can be then ensured through standardised protocols, most often from OGC (Open Geospatial Consortium), according to the different data types being requested.

The third limitation regards the **approach to processing and simulation**. Within current infrastructures, processing and simulation occur through services that are made available as **WPS (Web Processing Service)** standard. Several solutions have been proposed to adopt this model also in the context of more articulated computing paradigms, thus developing an interoperable communication layer based on XML between the client and the grid computing infrastructure. However, the proposed approach is still very limited.

The fourth limitation regards the **collaboration features**. Enabling group/collaborative work with geographic information (geocollaboration) is a fundamental research challenge, with potential high impacts in that would allow operators from different agencies or public organisations to

[34] Heat maps are based on the simple concept whereby each single pass is recorded as if it were an increment in the temperature of a pixel, with the final map rendered with the total of all the trajectories.

[35] SDIs are integrated frameworks capable to provide access to an interoperable federated geographical web-service.

[36] Recent initiatives, such as the ICT PSP project BRISEIDE [Prandi et al. (2012)], have developed an SDI for spatio-temporal data management, authoring, processing, analysis and interactive visualisation.

[37] An example of research in the area is the SPIRIT project (Spatially-Aware Information Retrieval on the Internet) [2012].

cooperate and interact on analysis of geospatial data to define common policies.

Moreover, an essential step towards an "open government" process can be reached through the **involvement of citizens within the policymaking**. One of the emerging "open government" trends today is based on **crowdsourcing**[38]. The typical crowdsourcing strategies are based on **common interests**[39]. However, when leveraging on crowdsourcing there are a **number of challenges** to be tackled, i.e. the sheer size of data to be handled; the assessing quality of crowd sourced data; the use of real-time location-based services raises severe security and privacy issues caused by traceability of people's location, interest or actions; and, last but not least, this fast evolving scenario raises unprecedented issues related to information ownership.

CONSENSUS ANALYSIS[40]

From a policy-making perspective, it is important to highlight that it has been acknowledged that there is **close correspondence between real-life community behaviours and those within social media communities**[41]. Therefore, it is important to relate indicators from social networks with those regarding societal groups that have generated them.

Research has recently focused on the **analysis of social media content** through what is referred to as "**sentiment analysis**" [Kivran-Swaine et al. (2011)], a field that analyses the overall feeling towards specific topic, through analysis of content being published on social media.

Within such a complex scenario, mining and proper visualisation play a key role to help define critical data patterns within such a 'big data' scenario. In recent years, **Visual Analytics (VA)** has emerged as the discipline that integrates interactive visualization with efficient computation and Analytics for effective problem solving.

DECISION MAKING AND COLLECTIVE INTELLIGENCE FOR POLICY FORMULATION

The subject of decision-making and the development of tools to help people take more informed and better decisions have traditionally been the subject of a specific research field referred to as **Operations Research or Operational Research (OR)**. Research in decision support systems, and particular **Group Decision Support Systems (GDSS),** has focused on the development of tools for idea generation, negotiation and decision forming processes.

Moreover, several research works have explored the **emergence of collective intelligence** from a large crowd of stakeholders through the development of **Collective Information System Support**. Some authors refer to this concept by using the term "**group intelligence**" [Woolley et al. (2010)] or, to a larger extent, "**civic intelligence**". The study of the so-called collective systems analyse how the collection of the individuals with a common goal can be considered as a complex cognitive system featuring "competing dynamics patterns" and "winning coalitions" among others.

The concept of **Collective Adaptive Systems (CAS)** has recently emerged in response to the need, by the scientific community, for the development of technologies capable to leverage on massive forms of collaboration. The bases of all complex systems are evolving, adaptive, dynamic **networks**.

Moreover, it is acknowledged that only the application of collective knowledge provided by large numbers of people may enable accomplishments of very complex and multi-faceted tasks with unprecedented speed, accuracy and scale. However, the main scientific challenges to be addressed are: 1) how to make such collective intelligence emerge, and 2) how to coordinate the collective decision support process[42].

ENVIRONMENTAL MONITORING

If we analyse which issues already have, or will have, a direct impact on people including, but not limited to,

[38] Crowdsourcing is a well-known approach to collect information from large crown of users, typically through web-based technologies or through mobile devices within different Location Based Services (LBS) scenarios.

[39] Particularly relevant for environment monitoring is a group of initiative that leverage on the concept of "users as sensors". With particular regard to this latter issue, a joint work between Vrije Universiteit Brussel and Sony has brought to the development of an application to detect noise levels with the use of smartphones, which can be operated as remote microphones to create comprehensive noise maps [see Maisonneuve et al. (2009)].

[40] Relevant EU-funded initiatives in the field of Visual Analytics including, most notably, the VISMASTER project 'Visual analytics - Mastering the information age' [Vismaster (2012), and Visual-Analytics (2012)]. Several other relevant works include GapMinder, Geovista, Graphviz, TIARA and OPAvion.

[41] Several studies have shown the link between physical and virtual communities, i.e. the one of Crandall et al. [2010], Welser et al. [2011], Gilbert et al. [2009], Pennacchiotti et al. [2011], and Quercia et al. [2012].

[42] When looking at funded projects specifically focusing on supporting the policy making process, we must list some promising projects, i.e. Nomad – "policy formulation & validation through non-moderated crowd-sourcing" [Nomad (2012)], urbanAPI [2012], PADGETS – Policy Gadgets Mashing Underlying Group Knowledge in Web 2.0 Media [2012] –, MOSIPS – Modelling and Simulation of the Impact of Public Policies on SMEs [2012] –, and +SPACES – "Policy Simulation in Virtual Spaces" [2012].

environmental and **social inclusion issues**. In particular **global warming** and other environmental issues are increasingly involving a larger number of aspects that have direct impact on people's life. Within this scenario, simulation and visualisation technologies are playing a twofold role, i.e. are essential to scientists and decision makers, as well as playing a key role as "attention grabber" to people becomes increasingly aware of the extent their activities can impact on the climate.

Increasing computing power, improved **Earth Observation (EO) techniques** and quality of data have brought to significant improvements in simulation terms [Nocke et al. (2010)]. Indeed, **simulation of climate changes** is a direct result of the earth information acquired through the observation science. In the latest years, this activity has tremendously evolved with the availability of satellite technologies and web-based infrastructures to access updated data online. **Earth Observation (EO) technologies** have brought a revolution in our ability to survey and map our global environment. Moreover, access, distribution and processing of **Geographic Information (GI)** and **Earth Observation (EO)** data have been recognised as a basic precondition to **better monitor the environment.** EO is also an essential support to **strategic environmental decision-making within developing countries**. Earth observations have also direct impact in terms of **management and assessment of natural hazards**. Indeed, there is a large community of experts that are working on the assessment of natural risks[43].

Recent experiences clearly testify the growing requests for geospatial services and infrastructures emerging from the international community. This is the case of initiatives made by UNGIWG, the United Nations Geographic Information Working Group, or ESA – The European Space Agency, and NASA. Additionally, the success of systems such as **Google Earth** or **NASA World Wind** has facilitated the visualisation of this data.

SUSTAINABILITY

According to the Energy Green Paper [Commission of the European Communities (2006)], Europe and especially the European Union have entered a new era as far as **energy consumption and sustainable development** are concerned. The **Strategic Energy Technology (SET)** plan lays out priorities concerning research in a variety of energy technology areas to create a more stable and sustainable **energy consumption model**.

The EU digital agenda has focused on **investments** in favour of an increase in the diffusion of **ICT technologies** in the EU Countries, having recognised that ICT and broadband technologies are key contributors to the GDP growth at global level [Agarwal (2011)], since *"*strategic planning and programming is essential for achieving sustainability and good multi-level governance". Indeed, the new generation of distribution networks, or the so-called ***smart grids,*** takes into account the **networks stability**.

City planners strive also to perform ***contingency analysis*** in order to assess the availability of sources (energy, water, etc.) with the increase of population, which shows the ability to operate the power grid for better reliability and efficiency within a certain geographical area.

Improved ICT-enabled mobility is another key challenge cities are investing significant resources on. Although there is an emerging consensus that current patterns of transport activity are not environmentally sustainable, there is not a unique vision of what might constitute a "sustainable transport". To this extent, the **growing social awareness on sustainability**, together with a fast evolving scenario in terms of technologies and infrastructures, is having significant effects in terms of public attitude towards transportation.

However, there is a **lack of effective solutions**[44], the massive use of **personal travel guidance systems**, which is reality today, offers great potential to increase the efficient use of transport networks. Research has also focused on **V2V (Vehicle to Vehicle)** and **V2I (Vehicle to Infrastructure) communication technologies**, in order both to improve security and to reduce environmental impact by minimizing congestion and providing smoother traffic flows.

From the technological point of view, the **large number of software technologies** available and used by routing systems underlines the need for a higher level of **abstraction** over different technologies that can provide harmonised access to the wide range of data available. As highlighted by EC-funded

[43] Several EC-funded initiatives, including the projects BRISEIDE - BRIdging SErvices, Information and Data for Europe [2012], and ORCHESTRA [2012], develop technologies to improve prevention and then management of crisis in the context of natural risks through GI (Geographic Information) and VA (Visual Analytics) tools.

[44] The EC is working to improve citizens' quality of life and strengthen the economy by promoting a sustainable urban mobility and an increased use of clean and energy efficient vehicles through the EU Green Paper "Towards a new culture for urban mobility" [Commission Of The European Communities (2007a)].

projects **COOPERS** [2012] and **CVIS** [2012], **interoperability** is one of the main barriers to overcome.

Within such a **multi-faceted scenario**, integrated (cross-field) strategic planning becomes crucial to ensure sustainability. One of the pillars of this vision is the concept of "**smart cities**". Within the smart cities context, **green IT applications occupy a central role** in order to build up more efficient energy infrastructures that will have a low environmental impact on people with the focus to make better and sustainable urban areas in the short term[45].

Many companies have already started to target an interesting business perspective from the smart cities opportunity and to create commercial offers for city administrators in order to meet citizens' expectations[46].

HUMAN CENTERED CHALLENGES

The current evolution of hardware, software and communication technology is pushing modern societies towards a **hyperinnovation process**. Hyperinnovation relies on **lowering barriers** between different people, technologies, markets or industries to radically foster new cross-boundary approaches[47]. However, hyperinnovation, by its own nature, requires **re-thinking traditional planning** of research activities by taking a truly multi-dimensional approach.

The convergence of increasing processing power, more natural human-computer interfaces, more effective simulation tools and, most importantly, the availability of very effective communication and cooperation platforms is de facto creating the conditions for such an era. In fact, wide development of web 2.0 tools and collaborative solutions, as well as increasing success of social trends, are having profound impact at the societal but also the scientific community level [Witt et al. (2012)], with consequent impact on ICT development process.

Furthermore, the **workplace** is being **redefined** by a number of economic and social trends, including merging between work and personal life, increasing costs of fuel that is fostering remote cooperation in place of physical travelling, ubiquitous access to Internet, new working scenarios such as "the-office-on-the-go". Such a different landscape requires **new user-experience centric methodologies** to define the concept of the workplace of the future.

Moreover, the **increasing availability of robots** capable to provide assistance to various tasks paves the way to **new cooperative scenarios** where humans plays a central role with the support of robots. Several authors have developed specific **Human-Robot Interaction (HRI) technologies** for a wide range of uses [Keebler et al. (2012)]. However, it is indisputable that, within several scenarios, "**human performance is still of indispensable importance**" [Riether et al. (2012)]. Even so, it is well acknowledged that a **social-oriented use of robots** will be increasingly part of our lives. Studies in this direction already exist albeit predominantly in the military domain, aiming at the creation of mixed robot/soldiers teams[48].

Hyperinnovation also leads many computer-unlettered persons to consider the Internet as an **alternative form of interacting with others**. Most interestingly, an increasing number of senior users are starting to use ICT technologies. Without any doubt there are many factors that have contributed to this success, such as the **affordability of ICT services**. Moreover, many transnational organisation and also local governments are making significant investments in order to allow equal conditions for people to accessing digital content.

The most advanced democracies have also incentivised those tools in order to increase a **communication-based means of participation**, but also a **bidirectional channel to speak to citizens**. The so-called electronic participation (or **eParticipation**) has become a reality in the latest few years when many political events have met the large and active participation of people through use of new media and social web. The common process has followed an analogous process: "information", "consultation" and "active participation" are the main components of non-organized citizen communication [Velikanov et al. 2010].

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[45] The EC has funded a large number of projects specifically addressing to smart cities, including, but not limited to, i-SCOPE [2012], SMART-ISLANDS [2012], OpenCities [2012], City SDK, Fireball [2012], Commons4EU [2012], and PLUS [2012].

[46] For instance, in 2009, Telecom Italia started a project called "Smart Town", to create a community of developers and suppliers to build up a series of applications and services on top of a proprietary infrastructure that serves the city administration with an infrastructure for energy savings and for providing personal digital communication services to citizens. Outside Europe, a key example is u-city, the smart city initiative promoted by the South Korean government, whose aim is to create the conditions towards the realization of a ubiquitous society.

[47] According to Harris [2002], there are few principles for hyperinnovation: first of all, rather logically, more interconnections yield more innovation possibilities; secondly, the likelihood of unexpected events increases with the complexity of the system; and, finally, the degree of novelty and complexity determines the time to market of a new approach.

[48] Cooke et al. (2010), Evans et al. (2010), and Jentsch et al. (2011)

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POSITIONING OF KEY EU STAKEHOLDERS

European stakeholders have a strong positioning within the DE2 arena, including –but not limited to- the University of Nottingham (UK), Polytechnic of Milan (Italy), University of Delft (The Netherlands), or the University of Bonn (Germany). Within particular regard to geovisualisation, a key role is being played be several institutions including, ITC - Faculty of Geo-Information Science and Earth Observation of the University of Twente (The Netherlands), Fraunhofer IAIS and Fraunhofer IGD (Germany), Fondazione Graphitech (Italy), Hasso-Plattner-Institut, Potsdam (Germany), Technische Universität Berlin (Germany), University of Heidelberg (Germany). Most of the aforementioned RTD institutions are also significantly contributing to several relevant standardisation communities by OGC - Open Geospatial Consortium in the domain of 3D geospatial data, service-based visualisation and 3D visualisation of geospatial scene. These standardisation activities see the involvement of further stakeholders including OS - Ordnance Survey (UK), Institut Geographique National – IGN (France), Laboratoire des Sciences de l'Information et des Systémes (LSIS) at Aix-Marseille University (France) and –most notably- 52°North Initiative for Geospatial Open Source Software GmbH (Germany), very active in the standardisation of geospatial processing services (e.g. WPS) and Sensor Web Enablement (SWE in particularly on SOS, SAS, SES, SPS, WNS, SIR, SOR).

The JRC – Joint Research Centre of the European Commission is one of the leading actors in the domains of Spatial Data Infrastructures. In particular the IES - Institute for Environment and Sustainability - Digital Earth & Reference Data Unit, is coordinating the initiatives under the umbrella of the INSPIRE Directive[49] as well as in the development of the Global Earth Observation System of Systems (GEOSS). An equally important role is also being played in the definition of the European vision of DE2. ESA, the European Space Agency, DLR (Deutsches Zentrum für Luft- und Raumfahrt The German Aerospace Center) and EEA (European Environment Agency) not only have a key role in the provision of Earth Observation services and data, but also in the definition of the DE2 roadmap and in the development of related technologies, especially with regard to processing of DE2 data through network-based services.

Of relevance for DE2 are Among the various initiatives on Open and Linked Data among which we should mention LinkedGeoData by the Universität Leipzig (Germany), which advocates the extension of the very successful OpenStreetMap initiative, initially started by UCL – University College London (UK), through Linked Data principles.

[49] Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007L0002:en:NOT

A number of key high-tech European companies also develop **high-tech devices** for geospatial use including, Leica Geosystems –now part of the larger Swedish Hexagon Group (Sweden). Several SMEs provide advanced services or technologies ranging from rule-based systems for geospatial-data integration to cloud-based technologies for geospatial data, including, but not limited to, 1Spatial (UK), M.O.S.S. (Germany), Terradue Srl (Italy), Terrasolid (Finland).

With regard **portable AR applications for visualisation of geospatial data** a particular mention has to be made for Wikitude GmbH (Germany) and Layar (The Netherlands) which have developed two of the most successful reference platform for consumer portable augmented reality applications.

European stakeholders have also built a consolidated positioning within the scientific domain of **geovisual analytics** with significant research activity being carried on to create efficient tools that can extract relevant patterns within multi-dimensional data flows characterised by a geospatial dimension.

Within the domain of DE2, ecosystems aspects have a particularly critical role. For this reason a particular mention should be made for various European efforts towards the creation of "**system of systems**" based on geospatial infrastructures. Initiatives such as SEIS, INSPIRE, GMES, EIONET are producing a cascading effect, from the European level, down to National, regional or local administrative level, by enforcing use of standardised technologies to access, manage and process geospatial information. This has contributed, in turn, to the creation of a very large community of experts and a large number of SMEs with significant specialisation in geospatial technologies and interoperability of spatial information, which represent an important asset to exploit.

Last, but not least, the **professional associations** grouping a large community of stakeholders in relevant domains deserve a particular mention, including EuroGeographics, EUROGI, EuroSDR, AGILE, EUROGEO, EARSC, EARSeL.

Image courtesy of kromkrathog/ FreeDigitalPhotos.net

RESEARCH AND INNOVATION RECOMMENDATIONS

A range of different **high-priority advancements** is required to move towards an **operational Digital Earth 2 ecosystem**. Firstly, research should move beyond today's standard metadata management by developing more effective forms of access and management of metadata, significantly relying on visual analytics to effectively operate in the context of 'big data' scenarios scaling up global scale.

A further essential issue is to provide **comprehensive support** for time as native dimension in the context of spatial data as well as mythologies tools to crawl, index, store, search, access, process and visualise spatio-temporal data.

In particular, research should explore **how to automatically extract the spatio-temporal (position and time) context** from multiple resources.

Additionally, research will have to explicitly address **development of automatic crawling and indexing** for such data. Similarly, new approaches will be required to search them within 'big data' scenarios. These will have to **allow new data retrieval processes** based on non-declaratory searching mechanisms, supporting formulation of spatio-temporal requests characterised by ambiguity or search by examples or by similar contexts.

Moreover, research will have to address **how to effectively represent intangible aspects** typical of **individual** (habits, customs, personality, emotions) and **collective behaviours** (social grouping, competitive patterns).

Improvement of cooperation capabilities should also be significantly developed through the **elaboration of CSCW (Computer Supported Cooperative Work) metaphors,** explicitly leveraging on spatio-temporal dimensions**. Cooperation** should be also supported through the development of **visual computing technologies** specifically designed to explore optimal visualisation and interaction strategies among large number of participants to collectively address a given task.

Furthermore, in the long-term, research will have to address cooperation in the **context of very large and complex systems**, thus addressing development of spatially-related Collective Anticipatory Systems (CAS). Developing system-mediated conceptual and semantic negotiation mechanisms should also extend cooperation. This would allow different components of the DE2 "ecosystem of systems" to cooperate so as to ensure improved support to operators, scientists or decision makers. Lastly, the facilitation of innovation processes among GIS stakeholders can bring to a **comprehensive set of access policies** to DE2 data and processes Standardisation recommendations.

Building on several **on-going standardisation initiatives** (incl. EC INSPIRE directive), innovation activities should be promoted leading to the definition of a **set of common abstract representations** for long-term standardisation**.** Indeed, a **long-term standardisation effort** is required for the definition of cross-domain acknowledged formalisation of concepts, representations and processes. The initiative must involve stakeholders from multiple disciplines and will have to **produce common specifications** that can enable truly interoperable cross-science or multi-science simulation mechanisms.

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4.5 SAFETY AND SECURITY

ENSURING PRIVACY AND SECURITY

The development of Internet services has moved the control of privacy away from people for this reason **privacy issues** are a main concern in domains such as public administration or eHealth services. The latter pose a key challenge due to the sensitiveness and confidentiality of the data being stored. Moreover, the **advent of social networking** has amplified this issue.

Privacy Enhancing Technologies (PETs) and **Transparency Enhancing Tools (PETs)** have seen limited adoption in the recent past, both because of technical reasons, including limited integration with existing infrastructures, as well as for cultural reasons whereby limited users' awareness perfectly meets industry's craving for personal data[50].

Some research works focusing on protection of data controllers and subject have proposed **solutions** to formalise the definition of privacy rules through the definition of **PRDL (Privacy Rules Definition Language)** to make sure that privacy policies are compliant with the law.

Other works have explored the issues of **software survivability** following security violations. Indeed, accidents caused by breaching on log-in systems are the most frequents. Finally, research has also focused on specific security requirements of complex computing platforms, including grid-computing infrastructures. Past events have shown how such security breach can occur and the widespread effect that they can have.

SECURING OUR INFRASTRUCTURES

EU transport and energy communication infrastructures are a complex set of inter-organizational and inter-regional systems whose proper functioning is critical to our societies. Unfortunately, such a **highly complex system** is **vulnerable** to natural or man-made **disaster events**. Some episodes have shown that critical infrastructures truly represent a key target for terrorists since affecting them cause a major impact on the society. As stated by AISCAT [2006], EU's first top priority actions should be to provide adequate support for crisis and management of major events.

Additionally, **cyber-attacks** can have disastrous effects. In particular, the evolution of **Cyber-Physical Systems (CPS)** [Yan et al. (2012)] requires a new approach to security research. For this reason, proactive risk management should make use of equipment and methods capable of monitoring and assessing the state of the various networks systems, as well as a large range of information coming from the environment and, increasingly, from people.

Recent years have seen a rapid rise in the **use of geospatial applications** in the **security** domain. Such applications are more and more used in conjunction with technologies for "data mining and automatic data extraction, Earth Observation (EO) and Remote Sensing (RS), Visual Analytics (VA)" [Conti et al. (2011)]. The significant number of international initiatives that have been promoted at the international stage, leading to the creation of software infrastructures to manage static and real-time environmental data, has proved the role being played by geospatial technologies in the security domain[51].

The role of spatio-temporal information is being also exploited in the context of the so-called "**predictive policing**", i.e. use of computer model predictive models based on the distribution of crimes over the city and other conditions, so as to identify patterns of crime and predict

[50] Examples of interfaces allowing users to configure visibility of their personal data are Google Dashboard [Google (2012)] or Amazon's Recommendation Service, while an interesting example of sustainable privacy management approach has been proposed by the PrimeLife project [2012], funded by EU FP7.

[51] Among the most relevant initiative we should mention: Global Monitoring for Environment and Security [GMES (2012)], SEIS - Shared Environmental Information System [SEIS (2012)], EIONET - European Environment Information and Observation Network [Conti et al. (2011)], or GEOSS - Global Earth Observation System of Systems [GEOSS (2012)].

where further crimes may occur at a given times in the future.

Indeed, **planning how to handle acute crises** is of prime importance for an adequate response, and that can only be developed through a comprehensive training. Operators need to be capable of accessing, distributing and processing a wide range of data, in order to support the decision-making process to save lives and huge costs.

Recent natural disasters have dramatically shown the scope of this issue and highlight the **challenges** in terms of cross-agency training, where having access to harmonized and interoperable data have an essential importance. Indeed, an efficient management of such a complex system of networks is inevitably dependent on cross-border collaboration and simulation. Developing tools for a modelling and simulating crisis scenario within cross-border scenarios is in fact essential to **support training of crisis managers** and to properly **validate different crisis scenarios**.

The report made by AISCAT [2006] stresses the urgent need for formalised methodological and simulation approaches to risk management of EC. In line with the European Programme for Critical Infrastructure Protection**, simulation and training tools need to be developed** so as to anticipate proper countermeasures. Recent geo-political developments, generated by the enlargement of the EU countries to new nations first, and by increasing financial crisis later, amplify the scope of this issue and poses new challenges.

However, current training systems are either plain extension of GIS systems, and therefore do not provide simulation of mitigation actions, or are closed software solutions, therefore not ensuring interoperable access to operational data, or are procedure-based software. Research activities are addressing the current scenario, for instance by creating **interoperable infrastructure for simulations**[52].

Researchers have increasingly addressed the use of serious games for learning and training simulation since the 1990s[53]. The instant feedback and risk-free environment invite exploration and experimentation, stimulating curiosity, discovery, learning and perseverance. Flight simulators, for example, are now considered essential in professional pilot training[54].

The **use of 3D serious-game approach**, involving training and trainees, allows for higher level of engagement with stronger emotional commitment, thus increasing the retention of experience and competences gained in the training session by the stakeholders. Trainers and trainees can operate within a 3D interactive simulated environment capable to model crisis conditions. In contrast to most other forms of learning games, however, **simulations** are generally **virtual representations** of the real world and do not implement any didactic or pedagogical strategies which are essential for the learning of strategies and behaviour within crisis situations.

However, the **main limitations** of current serious gaming systems are the fact that the environment does not provide real simulations in physical or engineering terms. The majority of simulation and training systems focus on **security and "war games" training**, rather than emergency response training.

With regard to simulation, the simulation of the humans has a particular role, not quite from a visual point of view but, most relevantly, from the behavioural one. **Rule-based models** allow achieving more realistic human movements in case of low and medium density crowds. However, they cannot simulate contact between people and therefore are unfit to simulate behaviours such as “pushing”. On the other hand, further approaches, such as **cellular-automata**, are fast and simple to implement, but do not allow for simulation of contact between agents. Several crowd simulators borrow from the empirical study of Helbing and his concept of Social Forces, which uses repulsion and tangential forces to simulate interactions between people and obstacles, as well as realistic ‘pushing’ behaviours[55] or small grouping of people that tend to act together [Pan (2006)][56]. **Crowd simulators** are also available as commercial solutions to simulate movements of people, and to simulate evacuations and assess building’s capacity for safe evacuation.

TECHNOLOGY FOR EMERGENCY MANAGEMENT[57]

Crisis management is a particularly complex task that traditionally involves several stages: from emergency

[52] See the works of De Amicis et al. [2009a, b and c], Conti et al. [2009], and De Amicis et al. [2010].

[53] Freitas [2006], Holzinger et al. [2006], and Mitchell et al. [2004] provided such an in-depth overviews of existing approaches to Digital Educational Games (DEGs) or Serious Games.

[54] The most famous example is the very popular Microsoft Flight Simulator, comprehensive flight simulation software that is used for professional training as well as for recreational gaming [Microsoft (2012)].

[55] See the works of Helbing et al. (1995, 2000 and 2002)].

[56] This is the case of the software Viswalk by PTV (Germany) [PTV AG (2012)], which can be used to simulate evacuations of buildings or behaviours of masses at large scale events.

[57] Several projects have proposed use of information coming from citizens to improve prevention and response in case of emergencies, including 911.gov [Shneiderman et al. (2007)], or MobileMap [Monares et al. (2009)].

planning to response, recovery and mitigation. **Management of the emergency** is typically based on a **command and control (C2) infrastructure** [Quarantelli (1998)] that controls both first responders and command staff. During crisis, operators are subject to very high pressure to operate in the most appropriate way in the shortest time. Operators may also be affected by the so-called "**thread rigidity syndrome**" [Turoff et al. (2004)], where additional pressure is caused by the fear of losing control over the crisis. Furthermore, the entire process requires **coordination** of an increasingly higher number of stakeholders, including volunteers and citizens.

The aforementioned issue define, from a software perspective, a **number of specific human computer interaction requirements** that software for emergency management should address. For this reason, human computer interaction factors should drive the **development of software** to be used at the various stage of the emergency management process. However, in practice, today emergency operators typically rely on tools like WebGIS services, smartphones and wireless connections. Inadequate communication between those in the scene of crisis and decision makers can have fatal consequences. Indeed, a **good communication is essential to effective coordination** after disasters or crisis. Communication between various decision makers and operators, in emergency situations, can be of vital importance.

Moreover, the **use of mobile phones** and the **availability of mobile Internet connections** have very quickly changed the scenario, as people start sharing information as soon as a crisis event strikes. However, this concept of "**people as sensors**" [as highlighted by Laituri et al. (2008)] is posing a **serious challenge** to security forces and responders who are increasingly struggling to handle such a growing amount of data, even since responders are increasingly ill prepared to produce useful knowledge from the flow of information and data.

Social networks especially have proved to be particularly effective being landline Internet connection more resilient to mobile phone networks to large-scale disasters. Such a dynamic approach raises new issues, in that the received information is typically unorganised, with sudden peaks of information. In fact, the main risk is to avoid an **information overload**.

Several **applications** have been developed to share information about the surrounding environment. An example is **VibN** [Miluzzo et al. (2011)], which proves how mobile technologies can be effectively used to continuously sense the environment. Recent EU-funded projects have developed systems that rely on mobile devices to access based on location of users[58].

When we analyse the aforementioned social network landscape, we notice that Internet is witnessing the **increasing role** being played by **images** and, above all, **videos**. However, recent research works have demonstrated the technical feasibility of creating a 3D scene reconstructed from a set of images [Callieri et al. (2008)] or, more remarkably, from casual real-world footage [Ballan et al. (2010)] coming from mobile phones [El-Saban et al. (2009)] through so called **Video Based Rendering (VBR).**

[58] For instance, iTacitus [2012], AGAMEMNON [2012], IPerG [2012], and the project Urban Tapestries [2012]

Georeferenced content can be combined together to provide an **overview of a specific area or event during its progression**. This information can be used to **gather images** targeting the same point and the combination of these from different viewing angles can recreate a 3D representation of the captured item[59]. Given a set of input images in a community photo collection, **Structure from Motion (SfM)** is able to reconstruct a sparse geometric model consisting of the 3D positions of matched image features, while **Multi-View Stereo (MVS) techniques** [Seitz et al. (2006)] take a set of images with known camera parameters (position and orientation of the camera, focal length, image distortion parameters) as input that can be determined in separate calibration steps or reconstructed using SfM[60]. There are many methods for capturing 3D scenes from a single-camera video sequence. Although, each has advantages and disadvantages, the **Structure from Motion (SfM)** is one step ahead since it can be used to solve real life problems. On the contrary, other techniques are used to extract 3D shapes in controlled 3D environments.

The aforementioned approaches, available in real-time during crisis events, can be used to deliver **high context awareness to operators**, to provide vital information to the citizens, and to security forces on "how to avoid" -for the former-, and "how to handle" -for the latter-, such events. The challenge is to **evolve** from traditional image-based detection of unexpected patterns to 4D (3D plus time) based threat identification through the analysis of 3D contents over

[59] Now, 3D information can be reliably extracted in a completely automatic way, as done by Microsoft's Photosynth [2012], where users can create 3D visualizations from photo collections.

[60] Recently, the 4D Cities project has demonstrated the possibility to view a progression of registered photographs showing the evolution of a site over time.

time of features within the scene[61]. Particular attention should be given to the **dynamic 4D reconstruction** of scenes including people, for instance based on video streams coming from users or from security cameras.

Image courtesy of sscreations/ FreeDigitalPhotos.net

POSITIONING OF KEY EU STAKEHOLDERS

The European stakeholders are world leaders across all industrial markets related to safety and security, employing an estimated number of 180,000 staff EU-wide[62].

At the data level, particularly relevant is the impact of security research on personal freedom and privacy carried on in Europe, advocating concepts such as "privacy by design", that carried on in the context of the DEMOSEC (DEMOcracy and SECurity) cluster

[61] Examples of computer vision bases approaches have been developed by Joanneum Research in Austria so as to detect unusual situations from video streams with learning features that can help to understand unusual situations in unusual conditions.

[62] A recent study has shown that overall security market in Europe has grown tenfold over the past ten years reaching 100 billion Euros in 2011 and with an estimated turnover ranging between 26 and 36.5 billion Euros.

At the hardware manufacturing level, European industrial community is playing a key role in the security system hardware domain and, more specifically, in the market of security video cameras and related systems including miniaturised cameras, to control hardware, to transmitter / receivers, network vide recorders, to encoders, to analysis hardware (processing units), Video Management Software (VMS) targeted to video surveillance, motion or activity detection, tracking of people / hardware and video analytics.

Some key hardware manufacturers in this field include BOSCH Security Systems (Germany), Geuterbruck (Germany), AXIS Communication (Sweden), Milestone Systems (Denmark), Pomelit (Italy) and IndigoVision (UK) that well withstand competition from Israel (e.g. VISIONIC and Magal Security Systems), Japan (e.g. Sony), USA (e.g. Arecont Vision and Allied Telesis) or China (e.g. Hikvision Digital Tech.).

With regard to relevant software solutions, several research groups in Europe play a key leading role in the domain of automatic reconstruction of scenes from images or videos as well is other computer vision, data mining, patter detection and visual analytics fields. Some of the most prominent institutions include: the Centre for Mathematical Sciences at Lund University (Sweden), Cambridge University (UK) (camera pose estimation within city scenes); University of Oxford (UK) (object matching in video); University of Oslo (Norway) (real time identification of 3D shapes from images and videos); National Technical University of Athens (Greece) (spatial matching); INRIA (France) and LJK - Laboratoire Jean Kuntzmann (France) (feature matching methods for image-based searching within large scale repositories); Technische Universität Darmstadt (Germany) and DFKI (Germany) (3D reconstruction from multi-view stereo techniques).

European stakeholders also play a driving role at the highest logical level, by developing complex automated integrated hardware/software solutions for 3D scanning. Among the most relevant examples we should mention the low-cost 3D reconstruction solutions developed by the Visual Computing Lab at CNR-ISTI (Italy), Fraunhofer IGD (Germany) and Augmented Vision Group at DFKI (Germany).

Specialised companies such as Detec A/S (Norway) are leaders of integrated video surveillance solutions, while Neuricam (Italy) manufactures security cameras with embedded processing and analysis capabilities for neural networks or intelligent sensor networks.

Image courtesy of kromkrathog/ FreeDigitalPhotos.net

RESEARCH AND INNOVATION RECOMMENDATIONS

Research should address the development of **technologies for automatic 4D** (i.e. 3D plus time) **scene reconstruction**. In particular, research should address the reconstruction of **static and wholly or partially dynamic scenes**. Moreover, research will also have to develop **4D reconstruction**

algorithms that can leverage on the availability of future computing platforms featuring very large number of many core processors.

Research should also **define data structures** specifically designed to encode, access and transmit 4D data over the network. This will allow development of **self-learning 4D shape analysis algorithms** to be used to detect specific features within a 4D scene and track their evolving behaviour over space and time. In particular, research should study **how to identify both single features and aggregated systems**.

Such achievements should be complemented with the **development of 4D crawling and indexing mechanisms** that automatically find (crawl) and classify (index) relevant information within the spatio-temporal continuum. Furthermore, research of non-conventional searching paradigms should improve spatio-temporal searching within 4D contexts.

The aforementioned research will pave the way to the development of **four dimensional visual analytics solutions** that, based on learning mechanisms, can enable identification of abnormal patterns. Such mechanisms will have to operate in both an automatic or semi-automatic way and, for them to be used by safety and security operators, will have to be deployed and validated in operational scenarios.

By extending this approach to the long-term vision, research may **bring to automatic mechanisms** that, leveraging on information available from thousands of concurrent live video stream, can **identify specific features**, and to track them in space and time and automatically identify abnormal patterns over time and present them to the users. To do so, research will have to explore, in the long-term, **mechanisms for formulation of "dynamic knowledge"**, capable to classify behavioural or data patterns as normal / interesting / abnormal according to the specific context.

5. MARKET DEVELOPMENTS IN THE PERIOD 2015-2020 AND BEYOND

Although '**big data**' are, after all, a novelty for many users, in earnest, they are nothing more that an **extremely large pool of traditional data**. These can span from traditional databases, to user profiles, to relatively new information, or in general any other data source that is available through any possible means.

Companies are increasingly in **need for tools** for analysing 'big data' and inferring key indicators to better monitor and assess business performances as well as to identify opportunities for new businesses. Collecting this information is not complex. What is even more demanding instead is to store and organize this information in a structured fashion and, above all, to be able to extract synthetic indicators in a certified and reliable form. In turn, the **ultimate challenge** is to be able develop an **automatic system** that can help users take informed decisions based on this plethora of information, in order to better manage a business, improve competitiveness and profitability.

Image courtesy of worradmu/ FreeDigitalPhotos.net

5.1 THE RISE OF A NEW ECONOMY

Over the last 20 years, **Internet** has deeply transformed all sectors of the economy and has become a powerful driving force for economic growth. Indeed, the **"Digitization" process**[63] has operated as an economic multiplier to amplify the value of connectivity and job creation impact. If we consider the Internet economy as an independent economic field, **Internet is already outpacing other key traditional sectors**. By 2016, three billion users will be online, researchers say.

The growth of the Internet, as a market and technological domain, is already **affecting the labour market** by generating more jobs. Understanding the extent of this growth will be essential for managers to be able to make informed decisions on investments and business strategies.

Image courtesy of jscreationzs/ FreeDigitalPhotos.net

[63] The "Digitization" process is the large scale adoption of smart ICT services in the context of consumer and business applications.

5.2 POWER TO PEOPLE

It is evident that the evolution of the Internet has had a **radical collective impact**, hence pushing to an increasingly **higher degree of digitisation and hyperconnectivity**. In few years only, we have moved from the very first "**Internet of Data**" to the concept of "**Semantic Web**", further followed by the so-called "**Internet of Things**" and "**Internet of Services**", which are now eventually evolving towards the so-called "**Internet of Processes**"[64]**.**

The Internet of Processes may further be articulated along two main directions. On the one hand, there will be **digital processes for industries**, which will ensure all the functionalities required for production, development, or design of products, often referred to as "**Industry 4.0**". However, on the other hand, we will also have **to deal with digital processes** designed to respond to requirements of economic and commercial nature. This second group of digital processes will lead to what is often referred to as "**people empowerment**".

However, the evolution towards the Internet of processes will also **change the role of users**, who will be transformed **from mere consumers to *prosumers*** who participate to the design, production and distribution of services and goods. This will bring to a **revolution** in both economy and the job market.

[64] Processes, within this context, are referred to as "digital" processes within a larger value creation chain. A typical example of integrated set of digital processes can be found within the automotive or aerospace industry for "virtual prototyping" (VP). VP is performed through a complex set of closely integrated computer-assisted tasks that are all performed "digitally".

Image courtesy of pakorn/ FreeDigitalPhotos.net

5.3 THE INTERNET OF "JOBS"

An example will help appreciate the impact of such a change: if we analyse today's software industry, we can observe that most large software developers do not directly address directly their **final customers**. In fact, companies rather employ their **in house staff** to train and certificate a **community of experts** whose job is to ensure that the technology is properly deployed, customised and maintained at the final user's premises. The "experts" are also in charge for the final user trainings as well as to deal with later technical assistance and customer support in general. The **advantages** of this approach for the software company are evident, in that they ensure the highest possible flexibility and quick adaptation to changing market requests without having to rely on internal paid staff.

Moreover, we could envisage that in the near future, thanks to the increasingly availability of "digital services", it will be possible to **extend this approach to a further level**. Indeed, today the organization of the typical industry is usually based on **internal structures**.

The hyperconnectivity scenario is redefining the way people, machines, software and companies can operate, by allowing for distributed and more agile approaches to making business. As a result, **industries** could radically change their organisational structure through a **new management model** based on the Internet of Processes. **Non-core jobs** would be therefore negotiated, contracted, and monitored through a specific **digital platform** that would resemble a job "stock market", whereby different jobs are "outsourced" to the Internet by a variety of industries.

External experts would be able to interact with the companies through their own **smart devices**, based on "processes" that would be integrated within the existing working and production pipeline, yielding what a **new scenario** that could be referred to as the "**Internet of Jobs**".

This evolution will certainly have **complex societal, economical and political implications**. Those against this model argue that this will cause job losses, and therefore, there will be a strong need for highly qualified and trained experts. On the contrary, those advocating this evolution argue that many more positions will be created through what is referred to as "**mobile empowerment**".

Experts will be able to work for several industries, providing specialised services and products of all types. This evolution will also bring new significant opportunities in that people from the virtual space will be able to take jobs from everywhere. In general, **new organisational and economic scenarios** could significantly affect our daily lives: people would be able to work ubiquitously connecting to a portal where digital processes will be available. Alternatively new hybrid models could emerge, where physical buildings could host continuously re-configurable "**job kiosks**".

This evolution may also **change the business landscape** in that it may facilitate the creation of a significantly **larger number of Very Small Enterprises** (**VSEs**) and the reduction of **Large Companies**. Additionally, **new business models** will appear, based on very agile small informal teams that are able to re-organise their internal structure according to varying demands. This will bring to **brand new business paradigm of "virtualised" companies** where "digital processes" will be assigned to a "crowd" of experts.

Such a distributed approach will require **development of new models** that can ensure security of information and privacy of data. This will also require further **technical or policy-level evolution**, to avoid that companies become more vulnerable to cybercrimes.

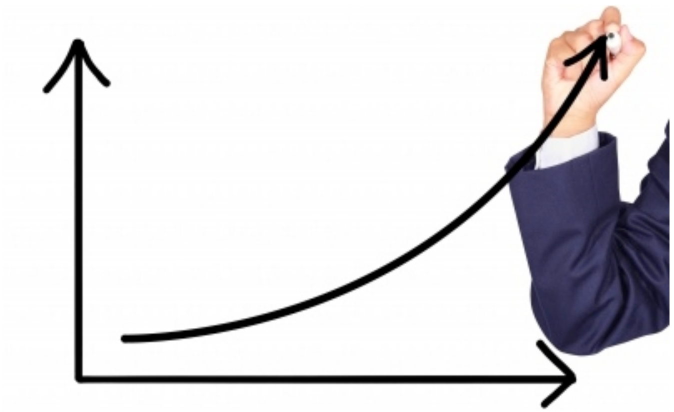

Image courtesy of pakorn/ FreeDigitalPhotos.net

5.4 INNOVATION THROUGH EVOLUTION, NOT REVOLUTION

An essential factor that will determine the final acceptance of the Internet of Processes will be the **acknowledgment**[65] of its relevance and impact on industry. For this reason, **an evolutionary, rather than revolutionary, approach** will have to be considered and developed along three dimensions, i.e. business, technological and of human resources.

Firstly, **industry** will be able to move jobs to the Internet, within the so-called "internet of jobs". This will bring, as a result, to a radical **social shift**. Secondly, **teenagers**, i.e. those aged 12-17 by 2015, will be the first "smart device" and social media generation, for whom "mobile empowerment" will be a very natural concept. Extending the metaphor of "digital natives"[66], they will be the first generation of "smart & social" natives. As a result, this will bring to a significant **paradigm shift**. Finally, from a technological standpoint, the most significant trends will be driven by the **widespread diffusion of 'big data' across all business and personal domains**. This will generate considerable needs for new generation software that can provide visualisation, simulation and business intelligence based on latest hardware developments. This will bring to the third, **technological shift**.

Image courtesy of watcharakun/ FreeDigitalPhotos.net

5.5 THE IMPORTANCE OF BEING EARNEST

As highlighted by Deming and Dricker, by leveraging on 'big data' managers can "measure", and therefore "know" about a significantly larger set of indicators regarding the business they manage. Additionally, they can directly leverage on such an increased awareness to deploy a **more effective decision-making process** that, in turn, will lead to more rewarding performances.

Indeed, in the near future, companies will be able to accomplish things that, until short ago, managers could only dream of. This **evolution will be fuelled by 'big data'** that appear to be much more effective than traditional analytical tools that were used in the past. As a result, we will be able to plan more effective initiatives based on evidence, data and rigour in place of actions relying on instinct and intuition. Thus, the wisest leaders will regard the use of 'big data' as a **managerial revolution.**

Image courtesy of nokhoog_buchachon/ FreeDigitalPhotos.net

5.5 IMPACT ON VISUALISATION, SIMULATION AND VISUAL COMPUTING

MAKING SENSE OF 'BIG DATA'

The implications of the aforementioned scenarios for the domains of visualisation, simulation and visual computing will be very significant. Within the 2015-2020 timeframe, the need for software solutions capable of filtering useful data out of 'big data' resources will dominate the market.

CATERING FOR A NOMADIG WORKING ENVIRONMENT

The evolution of nomadic working paradigms will have to be accounted for, to be able to work form everywhere through any device. In particular, the market will need **solutions with new user interfaces** that can ensure the most efficient

[65] The acceptance of disruptive technologies by top management heavily influences their market success. A classical example is the limited initial market success of Virtual Reality (VR) technologies. In their early days, VR was considered too radically different (and risky) by the top management of the automotive industry, who did not advocate this technological revolution. Their success occurred only when the more junior management, who acknowledged the potential of VR within the industrial processes, saw their adoption as a way to promote their careers.

[66] Marc Prensky coined in 2001 the term "digital natives" digital native in a paper titled *Digital Natives, Digital Immigrants published*.

interaction between the user and the "processes" available from the Internet, rather than between the user and an object. **User-friendliness** will be extremely important, which will also have to be ensured through **increased use of multimodal interfaces**. The fact that people will be able to contract jobs from everywhere will require interfaces not only to be multimodal but also multi-language, multi-user, multi-cultural. Additionally, **new forms of simulation and animation** will have to be specifically developed to interact with processes.

A COOPERATING PROFESSIONAL WORLD

The **cooperation dimension** will be also equally important. There will be a strong need for solutions supporting cooperation among different remote and nomadic users with different expertise to help them dynamically rearrange and cooperate on a project-basis. This will trigger **new social dynamics within the job market**. For this reason, professional software will have to maximise the potential of social networking within business scenarios, bringing cooperation features to a larger dimension.

SOME DATA PACKETS ARE MORE EQUAL THAN OTHERS

Within such a hyperconnected scenario, the large development of processes and the huge expansion of information being exchanged through the network may challenge network's operator capacities. The increasing traffic will probably outpace the infrastructures available, and it will require **development of mechanisms for information prioritisation**. This, in the medium- to long-term, may lead to radical evolution of the Internet as we know it, actually resulting in the creation of **different Internets**.

Such a differentiation, on the one hand, may seriously **challenge the overall *net neutrality*** and, on the other, may **raise significant issues** in terms of overall Internet governance, with potential complex political implications. From a technical and economic standpoint, the **role of regulators and policymakers will be vital to avoid creation of barriers to market**[67].

ONE STOP SHOP FOR ALL

Lastly, we can envisage that the market 2015-2020 will be characterised by a **significant growth of Very Small Enterprises (VSEs)** created by those empowered "experts". Due to the increasing mobile and ubiquitous working trend, these software tools will have to allow "experts" to run their company based on a smartphone or tablet. Such a "**mobile empowerment**" will certainly call for **custom-tailored solutions** that can support "experts" within their daily professional activities, by providing usable access to the "digital processes" they need.

As a result, the market will have to provide **applications specifically customised to respond to very vertical business requirements** and to provide access to both technical and administrative "digital processes" required to run a business within an infrastructure-free and lean working environment. Moreover, we will probably witness a widespread adoption of vertical solutions that can turn standard smartphones into "*engineerphones*", "*plumberphones*", "*nursephones*", "*doctorphones*" etc.

[67] S. Dutta and B.at Bilbao-Osorio (Eds.) (2012). The Global Information Technology Report 2012. Living in a Hyperconnected World. Insight report. The World Economic Forum.

Image courtesy of winnond/ FreeDigitalPhotos.net

5.6 LESSONS LEARNT

Our society has become **increasingly hyperconnected**. Such a hyperconnectivity is profoundly changing our society. At the societal level, it is also affecting social services, governing styles, and the geopolitical landscape[68].

This **paradigm shift** has yielded an unprecedented **set of opportunities**, brought by ubiquitous access to information, **but** it has **also** brought to **new threats**. These do not only comprise violations of privacy and security breaches, but also include information overload. In fact, ubiquitous exposition to a variety of different digital media is already transforming

[68] The most notable example of the influence at geopolitical level has been the influence of social media on the so-called Arab Spring that occurred in 2010.

our brains' neural circuitry[69]. The **"smart & social" generation** is certainly a clear example of such an evolution. However, despite humans' adaptation capabilities, our overall brain capacity is not being increased. As a result, the increasing availability of 'big data' will have to be necessarily offset **by increasingly efficient tools** that can extract information of relevance for the final user, according to the context they are operating in. The fact that 'big data' scenarios are emerging in the vast majority of domains, further amplifies the importance of this issue.

The **evolving business scenario**, that is moving towards "**mobile empowerment**", is complementing this issue. The 2015-2020 timeframe will be characterised by a "mobile empowerment" of people, essentially driven by the maturity reached by the "smart & social" generation and by an "all things digital" society.

As a result, within the 2015-2020 timeframe, business success and, in some cases, survival of several large and small businesses, will substantially depend on their **ability to withstand the ever increasing 'data tsunami'**. In fact, the evolution of businesses will be significantly determined by their **capability to turn such an increasing 'infobesity[70]'** into an opportunity to deliver more accurate, intelligent, personalised and ubiquitous solutions through the Internet.

For many companies, and not only those operating within IT domain, being able to leverage on smart devices, Internet of Processes and 'big data' will not even be a choice. It will most probably become a **matter or 'survive, or perish'**.

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[69] According to Maryanne Wolf, the author of "Proust and the Squid: The Story and Science of the Reading Brain", earl study show that constant exposition to digital data flow changes our neural circuitry level, similarly to what occurs when humans are introduced to reading.

[70] The term 'infobesity' which refers to a situation where a person's decision process is overwhelmed by information overload, was coined by A. Toffler in the early 1970s within his book "Future Shock"

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