Draft Roadmap of Future Grand Challenges

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Contents

Executive Summary

The objective of this report is to prepare a roadmap identifying the future grand challenges in the Creative Industry (CI) sector addressing in particular the needs and requirements of small and medium sized enterprises (SMEs). It has been developed by the DigiBIC network of European leaders in research, innovation support, industry and finance who are working together to deploy the latest technology and tools to creative industry SMEs.

Today, the traditional separation between research and development activities on the one hand and the use of research outputs by end-users no longer applies as more and more users conceive, develop, build and use new tools and experiences. And as online development tools become more user-friendly and accessible to larger communities of users, new modes of creation and collaboration are constantly evolving.

The challenges and opportunities this new paradigm presents hinge to a large extent around:

1) Backbone technologies for CI
2) Authoring tools for CI
3) Content circulation and rights management issues
4) Content management and preservation
5) CI solutions to societal challenges

Specific challenges addressed in this report include:

Backbone technologies for CI

- Content creation where new research in field such as natural interfaces, material design, 3D modeling tools, distributed 3D data processing and big data visualisation presents many possible application domain from fashion to medical devices or entertainment. In furniture design for example new research has led to new software tools to assist user assisted design and layout.
- In community creation, collaborative 3D modeling tools have become readily available but 3D collaborative environments still require further development. Large scale 3D/4D construction is another promising area identified for future research alongside the use of 3D graphics in diagnostic and therapeutic environments.

Authoring tools for CI

Although in general authoring tools have led to a dramatic simplification of the application development process, further research is needed in the development of authoring tools in some specific domains. Social games for science and culture application is one such domain; other areas

of potential research include modeling/simulation materials degradations which in turn is related to the field of simulation of bio-physical processes.

Content circulation and rights management

Content circulation and rights management is a highly contentious area and one where rapid advances in technology have not been accompanied by a concurrent evolution in legal frameworks. Although developments such as the recent EU directive on orphan works and the increasing use of Creative Commons are steps in the right direction, further research is needed in the development of supporting technologies such as content identification and tracking in particular for rapidly developing areas such as 3D data.

Content management and preservation

- The exponential increase in the volume of content produced has led to significant new challenges for preservation. This document looks at challenges to preservation of artistic objects including the preservation of surrounding artistic environments. Self preserving objects capable of auto-describing environments are identified as one potential significant evolution in this field,
- In terms of content and information extraction, speech to text technologies (STT) for audiovisual content search and structuring and active and passive shape understanding are two of the new research directions proposed in this roadmap.

CI solutions to societal challenges

- The application of technologies developed for the creative industries to other potential sectors is explored, in particular the use of simulation technologies in crisis management systems.
- Finally the need to address the gap between current education and teaching practices and the way in which young people interact with technology is introduced in this report. There is a clear need to develop new applications for the eductionan sector to better equip future generations with the tools to fully participate in the digital world.

In order to seize these opportunities and meet the challenges head on new actions are clearly needed at policy level to improve the potential for commercial uptake and exploitation of research results. This aspect, touched upon here, will be explored in depth in the DigiBIC policy report (due out at the end of May 2013) which will explore in more detail the scope for encouraging and facilitating business take-up of research results and make specific recommendations in this area.

1. Introduction

"Digital content is today being produced in quantities that are deeply transforming the enterprise and the creative industries. Conditions for production and consumption are also rapidly changing as more and more content is produced by users. Organisations, public and private, are faced with maintaining, managing and exploiting increasing amounts of data and knowledge, in environments that are continually changing. New ways of expressing and representing cultural and scientific content in digital form are creating new opportunities for people to experience and share assets."[1]

The EU has invested considerably into research in digital libraries and preservation. However most of this research has been directed towards end users such as libraries, cultural heritage and memory centres. While significant progress has been made in the uptake of tools within these user communities, few if any, concentrated efforts have been made to address the opportunities for dissemination and deployment to the wider Creative Industry (CI) sector.

The DigiBIC project brings together a network of European leaders in research, innovation support, industry and finance working together to deploy the latest technology and tools to creative industries. To date approximately 100 small and medium sized enterprises (SMEs) have benefited from the deployment of new technologies originating in research thanks to DigiBIC.

The objective of this report is to prepare a roadmap identifying the future grand challenges in the Creative Industries (CI) sector addressing in particular the needs and requirements of end-users in the creative industry sector.

2. Methodology

Over a series of conference calls and consortium meeting discussions, the DigiBIC technology partners responsible for this task (INA & ISTI-CNR) sketched a first set of suggested challenges. These challenges took into consideration the partners' backgrounds and areas of expertise, the dynamics of academic research in the CI in recent years and the human and economic resources available to SMEs.

The initial set of proposals was formally reviewed by the DigiBIC innovation partners and the CI SME's engaged in the DigiBIC enterprise network at the consortium meeting in Lappeenranta, Finland in June 2012. The challenges that resonated most among all partners were submitted to the technology partners to be explored in greater depth and more precisely outlined and defined after this meeting.A first version of the roadmap was submitted to the European Commission in September 2012 and widely disseminated for feedback, through the DigiBIC partner and associate partner networks and the DigiBIC High Level Advisory Board (HLAB).

[1] FP7 Cooperation Work Programme ICT 2010 Pg. 50

A meeting took place on November 20 2012 in Luxembourg with representatives of the European Commission to present the first version of the roadmap. At this meeting the EC requested further information about some of the future challenges identified and in particular details of the societal impact of the challenges identified as well as suggestions regarding actions needed to promote change and to encourage take-up of research results.

The draft roadmap was revised accordingly and a final version of the first draft was issued for public consultation at the start of 2013. This version was posted for comment on the DigiBIC website and that of various other public sites in the field of creative industries and it was distributed to partners, associate partners and the HLAB for further feedback and consultation among their respective networks of research, innovation and industry partners.

3. Creative Industries and the Innovation Process

The CI sector comprises a range of activity domains[2], notably:

- Advertising
- Architecture
- Arts and antique markets
- Computer games
- Crafts
- Design
- Electronic Publishing
- Fashion
- Games
- Film, video
- Music
- Photography
- Publishing
- Software conception and development
- Television
- Radio
- Visual and performing arts
- Writing

[2] DCMS (2001), *Creative Industries Mapping Document 2001* (2 ed.), London, UK: Department of Culture, Media and Sport, retrieved 2007-05-26

Other domains related to the CI but more often classified as cultural industries are: cultural tourism; heritage; museums; libraries; sports and outdoor activities; and a myriad of other activities relevant to our way of life (hobbies, pet-caring, health, wealth, genealogy, etc.).

Today the CI sector poses significant challenges for the digital world and its future evolution. Recent years have seen an advent of technologies that are both more user-friendly and more efficient, as well as providing a more simplified access to content. As the internet has become social, **new and original ways of creating and sharing content are transforming human relations and activities at high speed,** breaking the traditional scheme of "one to many" and evolving towards a "many to many" dynamic**. In the cultural industries and the CI sector, users are increasingly becoming the creators as well as the users of their own tools and technologies**. Be it in tool creation, content exchange, production environments, diffusion channels, marketing or even financing, users themselves are shaping the tools and environments with, and in which, they work and fostering new ways of creating and exchanging information.

Reinforcing these developments is the concept of **community**, or groups of interacting users, shaping the way technology advances, and creating, through new uses, new requirements and new forms of collaboration. Creative and community tend to go together and sharing has become one of the main drivers of digital activity. All the major developments within the creative sector of the last five years have been concerned with community building and information sharing.

These trends and their future perspectives pose new challenges for research and industry development. The traditional separation between research and development activities on the one hand and the use of research outputs by end-users no longer applies as more and more users conceive, develop, build and use new tools and experiences. And as online development tools become more user-friendly and accessible to larger communities of users, new modes of creation and collaboration are constantly evolving.

From invention and research to innovation

The three concepts of invention, research and innovation are strongly related to the CI: they represent the process that leads from the idea to the result, following a well-proven route, which can guarantee success to a high degree. Invention is associated with the initial idea, the spark that leads to the conception of something new, which in this domain, can be an artistic or intellectual work, a technology, a process, a service or a usage. No rules govern invention, it can be related to an existing problem or concern, or be totally disconnected with reality.

Research is the process through which an idea or invention is developed, it may be a short or a very complex process, with well established rules and methods as in scientific research or be intuitive; it allows us to prove the feasibility, impact and consequences of an invention.

Finally innovation is the implementation of the new idea; it is the process that translates inventions into products and brings research results from the lab to industry, society or individuals. The final

management of an invention or the real-world application of research results; innovation addresses technical, marketing, sales, organizational and financial issues often absent in the conception phase. It has been strongly challenged as a process in the Internet era where simple ideas have produced huge changes in the use of information with unimagined user consequences. - The great change brought about by IT means that the CI world is no longer divided into content producers and content consumers. This must be addressed in order to permit large industries to continue to develop their activity while at the same time fostering an environment in which personal or community actions can co-exist and lead to the creation of sustainable novel products, services and enterprises.

4. Major Challenges

The evolution and future perspectives of the CI depends to a large extent on the following five major challenges:

1. **Backbone technologies for CI**: what currently exists and what needs to be developed? Backbone technologies include environment tools like platforms which are needed in many sectors to optimize existing non-related technologies.
2. **Authoring tools for CI**: there is a continuous need for such tools to improve the quality of production and rendering and to support trends that allow content creators to make their content more easily available.
3. **Content circulation and rights management issues**: there is a need for appropriate legal frameworks where works are protected, authors identified and recognized and where commercial and non commercial initiatives can coexist in harmony.
4. **Content management and preservation**: automatic descriptions are required for authoring and content creation tools are required in order to manage, organize and structure the exponential growth of contents. New methods and approaches need to be conceived so as to guarantee our heritage, to increase access and to ensure content can be securely preserved.
5. **From research to innovation**: what tools and initiatives can help the take-up of new ideas and research results and promote an accessible environment for creative initiatives to become real and sustainable?

Each of these major challenges leads to further technical, societal or economic questions that will be addressed in detail in the following sections with the aim of orienting future research and informing future action plans relating to each challenge.

4.1 Backbone Technologies for the CI

The extensive list of backbone technologies and environment tools can be grouped under the following sectors of CI and industrial activity: [3]

- Content producers/distributors
- Web content
- Social content production and handling
- 3D Graphics
- Animation/cinematography
- Games and gaming
- Audio producing, transmission and management
- Data transmission and management
- Voice producing, transmission and management
- Video Coding/Transmission/Processing
- Image producing, transmission and management
- Speech producing, transmission and management
- Cultural Heritage

Scientific and technological innovations may have an impact on one of these sectors or on several. In fact, in the CI there is often an interrelationship between several sectors - e.g. 3D graphics and

[3] A list of Creative Technologies for the CI is presented in Annex 1

gaming – and so developments in one area may lead to the evolution and invention of new approaches in others. A global challenge here is the efficient interaction between science, humanities, economy and individuals; the study and development of these domains, both individually and the interrelations between them, is often not articulated. Collaborations between science and humanities could lead to new developments for the CI as a whole.

4.1.1 Content creation

Some forms of creation have historically been accessible to all (such as writing or drawing) while others have required developed skills and technology (such as music, cinema, sculpture, etc.). The tendency today is to develop tools that can assist and simplify any creative process with the result that lack of manual ability is no longer an impediment to creating and accessing complex forms of creation. It remains up to the developer then to decide on the value of his/her work and how widely they want to circulate it. Technology will continue to propose more effective and elaborate tools, making the domain of content creation accessible to all.

To follow are a number of specific orientations for future research which could lead to an evolution in content creation:

Natural interfaces

Natural interfaces have been an interesting topic of research in content creation for several years now, although most of the proposed solutions have been limited to a prototypical format.

Recently however, the advent of low-cost devices used for interaction in the context of entertainment (e.g.. Kinect, Playstation Move, Wii, Leap etc.) have proven the possibility to obtain adequate interaction quality with extremely low-cost devices. These devices have been rapidly adopted by end-user communities and a number of different applications implemented in different contexts, including 3D acquisition and medicine.

In addition, touch screen devices are now part of everyday life, and they are now commonly used by society at large. Given these recent developments, natural interfaces are nowadays not only an interesting direction of research for the 3D community, but also a promising field of application for industry. In addition to the entertainment community, where the market is already covered by several large industry players, there are other fields of application that could be boosted by further research in this area. These include the fields of Cultural Heritage, Medicine, 3D Modelling, Collaborative Environments and Complex 3D Data visualization. Research efforts in these fields should be focused not only on providing new ways of interaction, but also on an effective study of their utility, and on the possibility to personalize interaction rules in order to fit any requirement.

3D Printing

Rapid prototyping has been developed over the last decade to support industrial design. It exploits a wide variety of basic technologies to create real-world tangible reproductions from 3D digital models. While initially the range of materials was very limited, modern technologies enable a wide range of materials (plastic, glued gypsum, steel, ceramic, stone, wood, etc.) to be used. At the same time, printing resolution has improved substantially and, consequently, accuracy in terms of reproduction has reached high standards. The majority of current applications require a high level of accuracy, i.e. the printed model needs to be a highly accurate physical copy of the digital shape. For example, several applications require this level of accuracy for aesthetic reasons or for performing functional tests. However, different contexts (toys, artistic reproductions) do not require the same level of accuracy, or even prefer the production of an illustrative version of the digital model.

Hence, by considering accuracy and reproduction rationale, we can classify the various methods into two broad categories:

- Accurate: Modern devices enable almost exact copies of a given shape to be reproduced. To guarantee high reproduction accuracy, the printer and the reproduction material can both be expensive. Further research is required on how to reduce costs in this field without compromising on quality.

- Illustrative: These methodologies fabricate approximate copies of a given object, usually by relying on standard and cheap printing technologies. Further research is required on how to improve quality of production whilst maintaining low costs.

Further research is also required to better understand how these technologies could be applied in different creative industry domains and how they need to be developed to meet specific industry sector needs.

Companies/Industries potentially impacted by this trend include:

- Architectural
- Furniture design
- Toys Industry

Material Design

Today, many manufacturing processes are automated and under algorithmic control. Although the sophistication and capabilities of output devices have progressed, the pipeline of device characterization, simulation, and goal-driven fabrication has remained underdeveloped. Taking full advantage of devices beyond simple 2D printers and monitors remains tedious and fraught with guesswork. We suggest that there are three major challenges which could be the subject of future research:

1. **Printing Mechanical properties**: The possibility of matching the desired mechanical behavior required to print an object with several layers of different materials.

2. **Printing Scattering Properties**: Recreating and matching scattering properties is a nearly impossible task, especially for heterogeneous appearance. However the usage of several different materials may reproduce a particular degree of translucency.
3. **Sampling parameters:** Real-world mechanical and visual effects exhibit multiple sources of complexity, including non-linearity, anisotropy, and heterogeneity. Due to this complexity, simulation methods used to drive the fabrication process must face a trade-off between realism and efficiency. The classical way to achieve highly realistic simulations of mechanical or visual effects is to use complex constitutive models, combined with tedious parametrization.

There are many possible application domains for this technology in modern industry:

- Architecture/Art: Architects and designers may want to match particular lighting effects.
- Fashion design: The garment designer may wants to simulate and match specific behavior thought a sophisticated combination of different materials.
- Medical: The need for materials that have a specific shape and mechanical behaviour is highly desirable in many medical applications (prostheses, small artificial components).
- Entertainment: The printing of human masks or other elements that have a specific elastic behavior may be useful in special effects of mass entertainment.
- Other: Many other industrial contexts may take advantages of such modelling/printing developments such as the tyre industry.

Companies/Industries potentially impacted by this trend include:

- Architectural
- Design
- Medical technologies
- Entertainment
- Toys Industry
- Fashion companies
- Tires production
- Cinematographic Industry

Interactive furniture design and layout arrangements

Within the larger perspective of the democratisation of the design processes, user-assisted interactive furniture design and layout arrangement has emerged most recently as a promising research topic. The common aim behind these new trends is to implement easy-to-use, reliable and effective software tools which are able to drastically reduce the most common planning mistakes made by users who have no training in interior and furniture design.

The proposed approaches vary a lot depending on the kind of features, support and suggestions to be provided to the final user. From the simplest ad-hoc tools released just for testing the furniture

layout of offices and rooms, allowing the user to prescribe room dimensions and select 3D models from a catalogue; to the more sophisticated tools that, given the boundary of the room with the current furniture availability are able to interactively suggest to the user how to improve the proposed furniture layout according to interior design guidelines defined by professional designers.

In furniture design an innovative work has recently been published [Umetani et al. 2012] in which the authors introduced a system for the interactive design of pieces of furniture consisting of multiple planks connected by nail joints. A real-time physical constraints validator had been included in the framework, in order to check the stability and durability of the user-designed model. If a model which is not-physically plausible is proposed by the user, the system interactively proposes to him a range of physically valid alternatives, stylistically homogenous with the user's original model.

Companies/Industries potentially impacted by this trend include:

- Furniture Design
- Interior Design
- Real Estate Market

Automatic/semi-automatic 3D models generation tools for expert designers

In the last decade compelling 3D models were an essential element in the success of videogames and almost a prerequisite for the production of most of today's movies. Following on from the diffusion of computer graphics technologies in the manufacturing, architecture, design, fashion and publishing industries, the demand for new and appealing 3D contents has strongly increased.

Unfortunately, the creation of high-quality 3D models is a notoriously time consuming and expensive activity. For example, the urban models created for the movie *Superman Returns* took 15 man-years to complete [Müller 2006]. For a small/medium enterprise that lacks 3D modeling expertise and resources this burden can be overwhelming and form an effective barrier to market entry.

A first solution to this problem could be to support a major shift in the production and distribution policy of 3D scenes, moving from the '*model-on-the-purpose'* modality (where every time a 3D scene is needed, it is modelled from scratch) to a '*market & reuse'* of 3D scenes or components. But the major issue remains how to enable faster production process of good quality digital 3D models. Considering all the economic implications we previously highlighted it should not be a surprise that in recent years research activity in automatic and semi-automatic 3D model generation topic has significantly flourished.

Various approaches have been proposed (Combinatorial Shape Synthesis, Procedural Model Generation, Constraints Assisted Model Design etc.) in order to overcome the different challenges presented by 3D model generation topic.

Even if some of these academic works have achieved convincing results (see for instance [Kalogerakis et al. 2012] for the automatic synthesis of new range of 3D models from a set of input

3D meshes or [Müller et al. 2006] for the generation of a whole city using a formal grammar) the problem of automatic or semiautomatic3D models generation is still far from being considered mastered or suitable for commercial exploitation.

Companies/Industries potentially impacted by this trend include:

- VideoGames Industry
- Cinematographic Industry
- Architectural
- Design

Distributed 3D data processing

Although the computational power of home and small PCs has steadily increased, the complexity of 3D datasets and the processing operations required to work on these has also grown accordingly.

Concurrently, smartphones and tablets have started to become viable platforms for the use of 3D data.

In the case of both home/small PC and mobile devices, the need for remote and distributed computation is emerging with the use of the cloud proposed not only for storage, but as an instrument to facilitate easier exploitation of complex 3D data.

Rendering of images and animations has been the first 3D-related task that has been implemented as a remote and distributed service. Nowadays, most modeling and rendering tools have support from 'render-farms' and various companies "rent" remote computational power to both hobbyists and professionals. The last two years has also seen the increased popularity of remote services (developed by research institutions) able to generate 3D content from photos. These two examples have paved the way for more complex and more specific remote and distributed applications.

Among the possible needs for further research:

- Video Tracking: registering a video or a series of images over a 3D scene (computing the camera position, parameters and motion in space) is becoming a standard instrument for digital artists and 3D professionals, like architects and designers, but does require a lot of computing time on a single machine (feature point extraction, camera calibration, bundle adjustment).
- Preparing 3D models for fabrication: depending on the 3D printing or fabrication technology used, 3D datasets require a series of consistency checks and semi-automatic processing steps which are computationally intensive and often out of the accessibility range of people interested in just using 3D printing and fabrication technologies (topology repairing, geometry optimization, subpart splitting).
- Simulation: use of complex 3D datasets to simulate reality (dynamic or static physical simulation, biological/biophysical simulation).

Big Data Visualization

The last ten years have witnessed an impressive advancement in the process of digitization of information, so much so that nowadays one of the main challenges to the information and technology sector is to find ways to store, search,share and visualize these huge amounts of heterogeneous data. The sources of data are countless: data arising from social networks, photograph collections, videos, medical records, traffic monitoring, outcomes of numeric simulation (for example for weather forecasts) etc and the uses of such content are likewise unlimited.

The term 'Big Data Visualization' refers to the specific problem of how to provide a visual representation of this data. This is deployed in two different ways:

- **Visual Analytics:** visual representations and interaction techniques that exploit abstract metaphors and the human eye's broad bandwidth pathway into the mind to let users see, explore, and understand large amounts of information simultaneously.
- **Massive data rendering**: techniques to enable the user to see large amount of physical data, i.e. data that represent observable reality and that do not need semantic metaphors, such as terrains and cities.

The variety of the type of data, the possible uses of it and the people who work with it make the definition of specific breakthroughs elusive. In general terms, the hardware trend of having more and more fast volatile memory has pushed the software solution towards 'In-Memory' database solutions (for example Oracle's Times Ten). A step forward on this path is the use of graphics board memory, which is currently done only for massive data rendering, i.e. where the data are only kept to be rendered with no semantic attached.

A further challenge is to create big data visualization tools that may run on mobile devices. A few examples already exist but targeted to very specific cases (e.g. large 3D models of statues, photographs).

Big Data Visualization is such a multidisciplinary field that, from an end-user perspective, it could impact on potentially every sector. As for development and applications, companies more involved in the pure visualization aspect are specialized in databases and computer graphics and of course hardware producers.

3D technologies for environment applications

Modern Computer Graphics and Vision algorithms allow nowadays for the visualization and the manipulation of very large amounts of visual information. It is sufficient as an example to think of an application like '*StreetView*' from Google Inc. where all the streets of a city are easily navigable through the Internet. This is possible thanks to a combination of 3D acquisition devices, image-based 3D reconstruction techniques and data registration algorithms. In this context, we imagine that it is possible to provide information to city-scale services for environment and monitoring, in the forms

of digital images in practice at no cost or very low cost thanks to the wide diffusion of smartphones. For example, imagine an online service where a tourist or a citizen, can send digital photographs about a certain historical monument, sculpture or archeological site, to support visual monitoring of Cultural Heritage. The service after registering the image in the correct location can check for the degradation caused by pollution or check for damage caused by acts of vandalism. The same technology can be applied to analyze, through its visual effect, the pollution levels of an entire city. Other environmental applications of the same type can be developed to prevent natural disaster, for example the inspection of the status of a river border. Obviously, in this case, the registration of a photograph may be particularly complicated and may require additional information such as the GPS position.

Similar tools can also be applied to support the development of renewable energies. For example, the optimal placements of micro-heolic devices require the approximate knowledge of the 3D volumes of the surroundings in order to evaluate the effective electricity produced.

Companies/Industries impacted by future research and developments in this field include:

- Municipalities and regional authorities
- Green and renewable energy producers and management agencies
- Web-services
- Computer Vision companies

4.1.2 Community creation

Crowdsourcing is a term commonly used to describe the power of communities; it can be applied to many different applications ranging from knowledge creation to financing. It is extremely powerful when… it works. This is a completely open domain for the future, and the full potential of community action is far from being understood. Collective creation is a growing trend; it may concern knowledge or content, where use and reuse offers a very strong incentive to users. The amount of potential new applications covers all domains and activities. Challenges for future research in this field include tools to enable enhanced community interaction and methods for content aggregation.

Collaborative 3D modelling

Collaborative text editing has been a ‘felt’ need, and has been “on the verge” of happening since the advent of the Internet. However, usable and effective solutions have only become readily available in the last few years. Similarly, 3D collaborative environments have been limited so far to bulky VR-CAVEs and proof-of-concept screen-sharing experiences.

The ability, for a group of users, to simultaneously manipulate a 3D environment is still a need for content creators both at the stage of authoring as well as at the stage of presentation to clients.

Tablets and mobile devices are becoming viable platform for 3D use, and seem a good candidate for the development of a new generation of collaborative tools.

Among the possible development directions:

- Augmented reality: collaborative does not mean remote; people working in the same real-world space, sharing localized 3D content through AR.
- Natural interaction: the actual collaboration interaction between users should exploit touch and natural interfaces, more than building upon complex proprietary interfaces like most of the current 3D tools. Complex mouse + keyboard interfaces should be used for single-work mode.
- Lightweight nodes: using tablets and mobile devices make interaction easier, but computation harder, thus requiring a cloud computation support.

Massive 3D reconstruction

The current acquisition pipeline for visual models of 3D worlds is based on the paradigm of *planning a goal-oriented acquisition - sampling on site - processing*. The digital model of an artifact (an object, a building, up to an entire city) is produced by planning a specific scanning campaign, carefully selecting the (often costly) acquisition devices, performing the on-site acquisition at the required resolution and then post-processing the acquired data to produce a beautified triangulated and textured model. However, in the future we will be faced with the ubiquitous availability of sensing devices that deliver different data streams that need to be processed and displayed in a new way, for example smartphones, commodity stereo cameras, cheap aerial data acquisition devices, etc.

For the future, a change of paradigm will probably be necessary: the idea being that the community should be able to take part in the reconstruction process, possibly in an “incidental” two way process (i.e. uploading information to a server while taking photos during a visit). This could lead to the possibility of obtaining a huge amount of new data, but also the necessity to provide new methodologies to analyse, discard and process information.

Moreover, the entire dataset should move from 3D to 4D data capture, where not only the spatial, but also the temporal information is taken into account.

The acquisition system should have the necessity not only to provide a 3D reconstruction, but also to detect and visualize temporal changes and possibly extract subsets of homogeneous information in a semi-automatic way.

The development of new methodologies in this direction can open up new challenges for the industrial side. The use of social communities to extract and provide information can be extended to 3D data, and extend the concept of information sharing in a new and powerful way.

Interested communities include:

- Environment and Cultural Heritage Monitoring
- Web communities
- Web Service providers
- Content providers
- Security and surveillance

Diagnostic and therapeutic uses of 3D graphics

3D graphics have been part of research projects in the field of medicine for several years. One of the most interesting aspects of its use is the simulation of practical activities, where training is difficult to organize and provide in a realistic way. Most of the experimentation involves the use of haptic devices.

Three-dimensional environments are also part of pilot experiments in neuroscience (i.e. the treatment of patients with phobias) or rehabilitation (i.e. people with balance issues, derived from trauma or surgery). Finally, the use of volumetric visualization is already a common practice in the field of diagnostics.

However, there are a number of possible improvements that are still not fully exploited. A shortlist could include:

- Interactive training: since haptic devices are still quite expensive and moderately hard to maintain, the usability of new low-cost natural interface devices should be studied (i.e. Wii, Kinect etc.). Adding low-cost force-feedback components could make these tools available for the whole medical community. For example a recent study by Italian researchers found that specific and prolonged use of the Nintendo Wii could help inexperienced surgeons to improve their skills at keyhole surgery![4]
- Disease treatment: although the quality of rendering is not a key factor in some treatments fields (i.e. phobias), the possibility to easily create an interactive environment, and eventually collect the results of experimentation, will make 3D data essential for this field.
- Rehabilitation: the availability of low cost interaction interfaces opens up new interesting challenges for the users. This means rehabilitation can be conducted at home, with the aid of easy and appealing game-like activities. The challenge for the future is to define a workflow for the creation of these tools, and the capacity to analyse the performance of the user, and adaptively change the difficulty of the activities to guide him/her through to full rehabilitation.
- Diagnostics: the current reference systems for complex data visualization can be easily extended to improve the everyday work of professionals.

[4] http://www.polygon.com/2013/3/3/4059850/researchers-use-nintendo-wii-to-help-inexperienced-surgeons-improve

Hence, recent developments possibly open up new challenges also for the industry field, where it's now possible to provide low-cost and flexible solutions (both hardware and software).

Interested communities include:

- Diagnostics
- Rehabilitation
- Volumetric Data visualization
- Web Service providers

4.2 Authoring tools for CI

An authoring tool, (also known as *authorware*), is a program that helps you write multimedia or web applications. These tools usually enable users to create a final application merely by linking together objects and defining relations between them. Authoring tools dramatically simplify the conception of new tools and applications and allow easy experimentation with new ideas or concepts. An authoring tool can be seen as the canvas for invention, where a simple idea is easily put to work in order to test its possibilities and feasibility. Authoring tools are simpler to use than programming tools (which involve mastering a programming language) and tend to be oriented to a specific domain of activity. Extremely popular in the CI, authoring tools are well developed in some sectors (such as web conception and development) but totally missing in others.

4.2.1 Easily designable tools

Building new environments, applications or software is becoming increasingly simple for any user without any specific ability for software programming. Yet there is still an important gap when it comes to tools that will more easily permit anyone to conceive simple or complex structures, programs or applications in many different domains. Tools for making tools, e.g. for graphic design and content management, pose a particular challenge.

Social games for science and culture application

Serious games for healthcare, military training, education, cultural heritage, etc. have become extremely important in recent years. They allow users to simulate how they would act in situations which may be difficult to reproduce physically. For example, The Institute for Creative Technologies (USA) has exploited virtual reality simulations or serious games to treat the post-traumatic stress of Gulf war soldiers. It is also important for training e.g. flight simulators. Furthermore, serious games can teach children how to behave in society or the principles of healthy eating (e.g. the Warwick food game) through social games or challenges where the goals are set as the main topic of learning.

Companies such as BlitzGamesStudios, and Epic Games are looking into development in this field as well as research institutions. . For example, Epic Games' Unreal Engine 3 is used by architects to create virtual tours of buildings.

In all these cases, a key element leading to the immersion experience of users is virtual reality and 3D graphics. Creating the feeling of reality can be achieved through research in natural interfaces (e.g. the wii board, kinect, etc.) and high fidelity computer graphics. In the latter case, computer graphics need to produce real-time and highly detailed environments. These environments also need to be perceived as real. Novel displaying technologies are the key to this. For example, HDR displays allow the user to feel real-world light, because they can reproduce a huge contrast and light intensity. Moreover, revisited head-set displays, e.g. the Oculus Rift by OculusVR Ltd., now provides a better immersion experience for the user by exploiting what the users really want such as: low-latency, low price, an easy-to-use Software Development Kit (SDK) for developers, good stereoscopic quality.

To sum up, important challenges in this field are: natural interfaces, immersive display (HDR displays, HDM e.g. Oculus Rift), and high fidelity graphics, all of which still need to be pushed forward to achieve production rendering quality in real-time.

Interested communities:

- Health Care System
- Army/Security forces
- Cultural Heritage
- Teaching

Modeling/simulating materials degradation

The materials of real world objects change their appearance over time as a result of their interaction with the surrounding environment. The rate and extension of these changes depends on many factors including the shape of the object, the exposure to the surrounding environments and the properties of the materials of which it is composed. The processes of aging and weathering have three basic categories of causes: chemical (corrosion, tarnish, color changes due to ultraviolet light); mechanical (peeling, cracking, deposition, erosion and scratches); biological (the growth of biological organisms, skin aging, wrinkling). The accurate and realistic modeling and simulation of these effects are very important in several application fields where the goal is the prediction of the object appearance in the past and in the future.

Hence, two opposite directions can be studied:

- to simulate the future changes of pristine materials, useful in the context of architectural design;

- to reconstruct the appearance of an object in the past, starting from an accurate acquisition and reconstruction of its current state and applying backward the detected weathering effects, useful for example in the virtual restoration of a cultural heritage artwork.

Although several research projects have been dedicated to the simulation and modeling of a small subset of the effects listed above, most of them are limited to a single effect whereas in the real world they evolve in a complex combination. Furthermore, much work remains to broaden the range of effects that can be generated and the scale at which they can be applied. A further improvement must be in the development of interactive tools that, with a minimum user intervention, allow for the simulation of a combination of weathering effects. An important step in this process, which has been partially explored, is the correct modeling of such effects using experiments and real simulation in order to capture, analyze and transfer these effects using different types of measured (chemical, physical and optical) data.

Companies/Industries interested in this trend:

- Architectural Design
- Cultural Heritage
- Cosmetic Industries
- Pharmaceutical
- Entertainment

Simulation of bio-physical processes

Large-scale physically-based simulations are still one of the more demanding processes in digital computation, in terms of required computational power, memory space and execution time.

On the other hand, in the field of entertainment (realtime interactive CG, videogames and Animation/Rendering industry), hundreds of methods and techniques have been developed to perform quasi-physical simulations, which run in realtime or almost-realtime.

Of course, crudely applying these tools for medical purposes or civil engineering would be inappropriate, at best. However, combining the two approaches could prove to be effective.

A first possible direction would be, in a scenario where multiple solutions have to be examined, instead of trying each one with accurate simulations, use quasi-physical methods to do an initial screening to identify the blatant non-working solutions, and only employ accurate methods for the remaining cases, thus greatly reducing time and resource requirements.

A different direction would be to alternate steps of rough simulations with steps of constraint-based adjustment of the simulation data, thus combining the fast response of the realtime quasi-physical simulation with the rigorousness of the physical constraints.

Possible uses:

- Molecular Dynamics, protein folding, molecule docking.
- Environmental simulations (fire, climate, floods, smog).
- Crowd simulation.

Companies/Industries interested in this trend:

- Environmental Engineering
- BioChemical R&D
- Pharmaceutical
- Civil and Mechanical Engineering

4.2.2 Authoring tools for multimedia presentation

The huge increase in the availability of content production devices and tools, from audio recorders, to digital cameras, to 3D modeling software, generated, as a side effect, the need for authoring tools.

The main purpose of multimedia authoring tools is to provide a framework for organizing and editing the large variety of content that a project may consist of involving for example text, images, audio and video streams, and even three-dimensional scenes.

To be effective, authoring tools should allow a large and diverse user population (e.g., from developers, field experts, artists, teachers) to easily generate, edit, organize and present multimedia content on a project basis.

In this context, major challenges arise from the need for a seamless integration of such contents, both from a logical perspective and in terms of visual consistency.

In the field of Computer Graphics, this could mean the generation of complex scenes consisting of large multi-resolution 3D models integrated with gigapixel static (i.e., photographs) or dynamic (e.g., video streams) imagery, text annotation, or virtual hotspots.

The authoring tools should allow users to organize, design, and produce a multimedia project by means of well-known processes, such as storytelling and flowcharting.

Companies/Industries interested in the trend:

- Publishing Industry
- Entertainment Industry

Interested communities:

- Research
- Teaching
- Knowledge dissemination

4.3 Content circulation and rights management

The challenge of content circulation and rights management is as much ethical as technological at a high level. Nonetheless, the volume of content created daily, implies a need for continuous analysis of the legal environment of all the components and a dynamic approach to the ways contents are used and the implications it has for creators, right-holders, right-management and free access to information in general. Policymaking is probably one of the greatest challenges for a complex and multilingual region such as Europe; common legal frameworks and effective rules need to be envisioned and implemented. This problem also has technical implications related to content identification and monitoring which will provide the necessary confidence in legal solutions and trans-national uses.

4.3.1 Creating an enabling environment

When working on research in the CI domain, challenges must be framed within the context of users' expectations and the state of art of their uses. For example there is a very clearly defined user environment regarding sharing and communication in social media e.g. Facebook model, Youtube model and all their related functions: sharing, RSS flux, Twitter, etc. Equally well-defined is the software development environment where communities tend to be quite active in programming languages (e.g. Java or Perl) and object-programming languages (e.g. Javascript and Smalltalk). These communication tools and languages condition the development methods, the use of accessible software or object libraries and their related results such as open source, freeware, or even commercial outputs. Both environments constrain future works and developments. Whatever new use is proposed will be based on these user environments and practices, unless a new use proposes a completely new way of user participation. For example before the existence of Facebook or Youtube, the uses of social media as we understand them today were not conceivable and were originally proposed to users without knowing to which extent they would be accepted.

Adapted legal environments

User expectations and market developments must be taken into consideration by policy makers. Users want content and there are many barriers to access. These are mainly legal, concerning content rights and the fact that content has historically been embedded within an economic chain where authors, publishers and distributors were involved. The internet has created an expectation among users that content should be free (even violating rights) but current legal frameworks are not designed for the circulation of contents conveying few or no rights (Creative Commons is a first

response to this situation). Legal environments should be adapted to new uses but generally they are not.

At a European level some important initiatives have been taken in recent years in order to facilitate access to contents through adapted legal environments applicable to all European countries. The Europeana[5] project, for example, has made great efforts in order to analyse the problems and propose solutions at a European level. Yet from a legal or rights management perspective there are many discrepancies in rights management across Europe. Countries have developed different legal environments, rights and descriptions of their rights so that managing rights at a European level is very complex today. Initiatives have been undertaken to try to improve this situation. The PrestoPRIME project, for example, has developed an international glossary of rights[6] which simplifies the understanding of contracts and right protection levels. The objective with time is to simplify negotiations and permit a maximum of users to understand the conditions of use of a protected content.

In the meantime, major tensions continue to exist between users and the legal environments in which new uses are developed. The “one to many” approach on which previous economic models were built no longer applies. The evolution of regulations and laws is a very slow process and efficient ways must be found to permit new uses to be established within existing legal frameworks in the short-term. New economic models to facilitate CI end-user SME’s access to new technologies must also be developed. In the medium-term homogeneous legal and market regulatory environments should be developed at a European level.

4.3.2 Access to content

As outlined previously, users face many barriers, mainly legal, when trying to access content. The existence of efficient tools for monitoring content circulation and identifying right holders is essential to ensure the efficient use and reuse of contents.

Another impediment to accessing content concerns the technical quality of the content. For example, in the video domain many contents are accessible but few are of good technical quality. Reusing sound and image content is only possible if these will not be totally degraded when reused. This implies that more high quality content should be accessible for download (within the appropriate legal environment) and also download times should be reduced in order to facilitate the use of better quality content.

Public domain and copyright works

The two main domains which control access to cultural content are:

[5] http://www.europeana.eu/portal/rights/terms-and-policies.html
[6] http://prestoprime.eu/project/public.en.html

i. *Works in the public domain*, or works whose intellectual property rights have expired, been forfeited, or are inapplicable and are thus publicly available;

ii. *Works under copyright*, where many different kinds of rights may apply, from author rights to related rights and moral rights, which are not available unless the rights are managed with the right holders (or through intermediate actors on behalf of right holders).

Concerning public domain and orphan works, one of the first initiatives undertaken by Europeana was a Public Domain Charter[7] published in May 2010 which describes the nature of the public domain and the principles and guidelines for its preservation and access in the digital era. Europeana insists on the fact that **all public domain material should be properly identified so users know if the content is accessible or not; however the difficulty is to have that information embedded in such a way that it is easily identifiable**. The Europeana portal displays metadata concerning cultural objects within Europe and strong efforts are being made so that all the contents inventoried within the portal contain a clear right description.

Another important issue addressed by the European Union recently concerns *orphan works*.. Directive 2012/28/EU of the European Parliament and of the Council of 25 October 2012 sets out common rules on the digitisation and online display of so-called orphan works. Orphan works are works like books, newspaper and magazine articles and films that are still protected by copyright but whose authors or other rightholders are not known or cannot be located or contacted to obtain copyright permissions.

Concerning copyright works, Creative Commons[8] (starting in 2001) has provided an innovative new model in recent years that allows creators to develop a copyright license free of charge for the public. Creators can thus decide and communicate which rights they reserve or share with other creators and users. This new modality of use is gaining importance mainly among public and sharing environments as well as within content production communities such as Wikipedia where all the contents produced are under the Creative Commons license.

The most pertinent and complex issue for the use of works regards contents under copyright protection, which concerns most of the recent works and productions thus those which are the most attractive for users. Two main issues are of concern here: **access to material under copyright** and **reuse of contents under copyright**.

Access and use of copyright material

Access to copyright material: Within the context of cultural heritage, this issue is already considered within 'Legal Deposit' which permits access to works under copyright within a well-defined physical environment without any possibility to make copies of the material, just visual access. However, this solution is becoming less and less acceptable to users accustomed to accessing

[7] http://pro.europeana.eu/web/guest/publications
[8] http://creativecommons.org/

everything from home and in many countries it is restricted to researchers only. Yet it is the only efficient solution today to guarantee protection of contents and the only one accepted by right-holders. **For this situation to evolve, technical devices ensuring an efficient protection need to be developed or methods of access that will temporarily present a document or parts of it for consultation only**. These technical solutions have to be robust enough to be accepted by right-holders.

Use of copyright material: The only answer to this is to "pay the rights". Many commercial websites exist today, which propose access to content under protection and permit the use or reuse under contractual conditions. However there are many drawbacks to this from a technical point of view, as well as from a legal perspective as indicated above.

From a technical point of view, due to the huge amount of information accessible today on the web, it is often very difficult or impossible to find or track the right-holder associated with a content found on the web outside of a commercial website. There are **no efficient tracking systems** capable of giving rights associated information regarding a specific content even if some initiatives have been undertaken in the past in order to create identification databases (ISAN[9] for the audiovisual domain, or ISBN). These initiatives are complex to implement and imply that content right-holders need to take a specific action to declare their contents, often implying a cost. **The development of more efficient and cost-effective content identification tools should thus be a priority.**

4.3.3 Content identification and tracking

Technology for content identification (who is the owner, where can I find this content?) as well as content tracking (is this content legally used?) are strong issues subject to regular discussions between the right holder community (we have to be able to keep track of rights) and the general user community (we should be able to use any content!). Without trying to verify all content circulating on the web, it is important to have tools for marking, identifying, monitoring and tracking the use of content. These issues may have important economic impacts depending on how content is used and who is using it.

Intellectual Property Rights management for 3D data

Along with the widespread use of the internet, shielding digital data from theft and misuse has become a major issue for legal data owners.

A lot of efforts, in terms of economic and human resources have been spent in recent years by the digital entertainment industry in order to enforce the protection of software, digital images, movie

[9] www.isan.org/portal/page?_pageid=168,1&_dad=portal&_schema=PORTAL

and audio files. Digital Right Management technologies for traditional multimedia data are nowadays a standard practice.

Conversely only a few technologies have been specifically developed to protect 3D data content and this kind of data is becoming more common.

In fact current 3D digitization technologies allow the creation of extremely precise 3D models of many physical objects in a really efficient way. Initially developed for industrial purposes these 3D scanning technologies have spread to different application fields, especially in cultural heritage (CH) study and preservation. Many relevant projects concerning 3D scanning and CH have been presented in the last few years highlighting the level of accuracy that can be achieved by a model produced by a 3D scanner.

A high-resolution 3D model of a CH masterpiece is a valuable product with an intrinsic significant commercial and cultural value. Distributing it in an unprotected way could generate a loss of revenue orreputation (i.e. unauthorized replicas of a statue or unauthorized production of merchandising) for the cultural institution owning the intellectual property rights on the original artifact.

Other application areas, such as entertainment and online commerce, may also require protection of 3D graphics content. 3D character models developed for use in motion pictures are often repurposed for widespread use in video games and promotional materials. Such models represent valuable intellectual property, and solutions for preventing their piracy from these interactive applications would be very useful.

In the area of online commerce, a number of internet content developers have reported the unwillingness of clients to invest in 3D graphics projects specifically due to the lack of ability to prevent theft of the 3D contents.

Companies/Industries interested in this trend:

- Industrial Design
- Entertainment Industry
- Online Commerce

Interested communities:

- Cultural Heritage

Fingerprint based technology for content identification

Video and audio fingerprint technology is one of the most promising technologies for content identification and tracking. Based on a minimal set of elements capable of describing a fixed or moving image or sounds, this technology is extremely efficient for copy detection and comparison in

general. The recent advances in this domain as well as in scale-invariant feature transform (SIFT) technology (efficient for comparing features or elements between images) have produced a set of effective tools for analyzing and comparing large data-sets of images and sounds.

One of the great advantages of digital fingerprinting is that it is not an intrusive technology, which means that no information is inserted in the image and it is impossible to know if a fingerprint of an image exists.

The applications are huge in many domains and are starting to be widely used:

- Copy detection: used to detect if two audiovisual streams are identical or similar. It permits the detection of unauthorized uses of protected content (e.g. video material on a UGC site) and is robust enough to detect many kinds of image modification. Another use, less oriented towards security, permits a user to find the origin or owner of a given image or set of images. This can be very useful when searching for right holders and best quality copies.
- Content search: in more advanced versions, fingerprinting can be used to match contents within contents (finding the same element among different images). This is efficient for transversal searches among different images of a same element.
- Web and media analysis: used to analyse video streams or programs to search for redundancies, repetitions and similar structures.
- Audio and video separation: increasing amounts of audiovisual material are separated in order to use sound independently of image. Cross searches permit the tracking of video sources of audio material.

The different application domains are:

- Copy detection for security control
- Contents analysis for digital humanities
- Content evolution and diffusion through media and internet channels
- Monitoring content use

Efficient at a very large scale, this is a very promising technology for the analysis and understanding of the web as a whole.

4.4 Content management and preservation

One of the greatest achievements of our society is the ease with which digital content can be produced, shared and distributed. The volume of new content created increases daily at huge rates, which presents mounting challenges related to the storage and archiving of cultural goods as well as the need to efficiently transmit at increasing speeds the contents among users and actors. The richness of a society depends upon its memory, upon its capacity to remember and retain the

elements of its past for future generations and within the context of constant reuse of content in new and inventive forms. The corollary to memory is description; we need to describe and document all that is produced. Historically this documentation has been produced by hand, with thousands of individuals creating the indispensible metadata that allows the identification, search and understanding of content, but also of software, tools and knowledge.

Within this context our society is rapidly descending into a documentation "blackhole", where most of the content produced is not identified, described and, if this continues, doomed to loss. Very few institutions are capable of storing extensive documentation and data for effective retrieval. Innovation is urgently required in this domain in order to start recovering the billions of non-documented or inventoried objects created by humans in the last twenty years. Some solutions are within sight: embedded descriptions within objects and automatic descriptions of processes are some of the perspectives which may lead to the advent of description farms and intelligent content based search tools capable of indexing huge volumes of data.

4.4.1 New challenges for preservation

Who and what we are depends on who and what we were and what we keep of our past. Archiving is an indispensable human activity. However, never in the past has our society been so fragile concerning the preservation of its everyday production. Emerging trends in this field look at how archiving can be conceived as a part of content production in any domain of activity. Concepts like: self-preserving objects, preservation within production, emulation systems, knowledge preservation, quality assessment, are some of the directions in which intensive research is required to develop solutions. New objects are continuously appearing which bring new challenges for archiving and long-term preservation: 3D objects, games, complex objects composed of hundreds of individual objects, hybrid objects; these represent some of the challenges for the future of archiving. And the greatest challenge of all is to link preservation to access.

Preservation is becoming increasingly complex in the digital age, where the traditional concept of "object" is losing its meaning and when we are challenged by new complex objects which demand new and original approaches in order to assure their long-term preservation. Preservation concepts have also evolved, and preserving contents is not necessarily related to an archival usage but is more and more related to reuse and repurposing due to the availability of relevant tools and the nature of content creation today.

Preserving complex objects becomes then a global challenge for many domains where production generates large amounts of structured or unstructured information. Several use-cases have been identified concerning preservation needs, which are already challenges but are likely to become even more complex with time:

Preservation of artistic objects

This domain concerns all contents associated with artistic creation and performance. A work of art may be much more than an object to be kept; in many cases it is a complex arrangement of digital and often analogue contents or objects that tend to be immersed in a specific digital technology environment. The challenge here is not to keep a testimony of an artistic action or work, but to be able to re-instantiate the work in different environments and in a non-defined future time-span.

This demands not only specific methods for organizing information within the creation process but equally defining relations and functions of all the related objects[10]. A more structured and OAIS based project was developed from 2005 to 2008 and explored the technology to assure preservation of complex objects. Its results were specific technological environments within the artistic domain[11].

Preserving the environment to preserve the work

When analysing preservation methods today within the artistic domain, the most common approach is to take a given work or object, describe its production context and environment as best as possible, eventually associate other material or documents and thus create a set of metadata or related material that describes that particular work. The difficulty with today's approach is that describing the object does not describe the work; within artistic creation and performance other information exists which is almost always necessary to recreate a work. This knowledge is generally within the artists minds' or embedded within the people intervening within a creation process (this concept is applicable to any archival environment; there is always "knowledge" associated with objects or works; at the least the knowledge needed to understand the description of the work).

The situation is complex from a procedural point of view since often the archival process is completed after the production process by different individuals. Much of the knowledge is lost even if it was available during the production process.

The concept developed here is to build working digital environments, which can follow the creative production process and keep track of the actions undertaken and the importance of these actions. These tools would build a description during the production process which can be updated and commented on by the creators with graphics to follow processes and automatic or assisted indexing in order to create priorities in the way documents are accessed[12].

Self-preserving objects

Environment descriptions are the access road to self-preserving objects. Managing preservation through time is a complex issue where human intervention is constantly required in order to check the integrity and preservation needs of objects. These validation and checking actions could be a

[10] A performing work can consist of dozens of files, schemes, software, hardware or physical objects. An initial attempt to describe the complexity of relations and the potential methods was developed from 2001 to 2004 by Ircam (www.ircam.fr) GRM (www.inagrm.com) called MUSTICA.

[11] http://www.casparpreserves.eu/

[12] An interesting French progam, GAMELAN (http://www.gamelan-projet.fr/co/accueil.html) explores how these tools can be built and applied to a production environment.

part of the objects themselves, thus creating an environment capable of monitoring the state of the preserved objects, even of different natures, and managing the necessary action on an object-based approach that could guarantee that the necessary preservation actions are done in the precise moment.

These use-cases show the difficulties arising in a digital world, where millions of objects are created daily and where most of them lack any description. Since description is mainly done by humans, the need for auto-describing environments would be an indispensible evolution in order to manage efficiently the search, retrieval and use of today's productions.

4.4.2 Content and information extraction

Our use of content to date has mainly been based on human made documentation represented through text, which permits search and retrieval actions. As less and less contents are documented, how can technology bridge the gap between information extraction and semantic identification? Identifying what is inside contents is the main challenge for search engines in the future. The great challenge is teaching machines how to recognize and efficiently identify information based on images, sounds or context and to use this information to search for content as well as to structure content for preservation and further reuse. The big risk is the creation of content which in a short period of time will be lost due to a lack of indexation and cataloguing. The development of tools for managing and organizing huge amounts of undocumented information are clearly a high priority.

Using Speech to Text Technologies (STT) for audiovisual content search and structuring

Within any audiovisual archive, the main tools for searching and finding audiovisual contents are based on text descriptions. These descriptions have historically been hand-made with a precise set of fields allowing efficient documentation such that the contents can be easily found through a text-based search engine. The speed of content creation today, professional or personal, versus the time needed to make a proper description of a document; is increasingly creating a strong shift between the amount of described material and the amount that is not described; the latter representing more than 90% of the content available on the web.

One of the technologies being increasingly used in the last years to address this challenge is automatic speech to text transcription also called computer speech recognition. This technology is based on the analysis of the speech of a person, which is segmented into small sections which are then compared to a phonetic data-base related to language models. The most important issue with speech to text transcription is the accuracy of the transcription and the difficulty therein is to transcribe person or geographical names for which it is necessary to "teach" the system a list of words (a thesaurus or a simple list for example).

The accuracy of transcriptions depends on the context, the clarity of the acoustic signal, and the language model (is it today's language?). Different language models may be needed in function of the nature of the information that has to be transcribed. For many years computer developments were oriented to obtaining the highest possible accuracy approaching 100%, however today with context being so important and the use of language so flexible, this is considered to be practically impossible. However there are numerous possibilities to apply speech to text, in order to obtain different kinds of results, which can be classified into large categories:

- Use of STT as a documentation tool, which will help to make a description file following a documentation model
- Use of STT as a tool to navigate among large collections of contents which have been transcribed and use different semantisation techniques in order to extract the general sense or to find a particular name or place.

Among the uses of transcription, we may identify:

i. Full-text indexing as the first annotation layer by default, in order to allow to prioritize phases during manual documentation
ii. Full text indexing for exert search
iii. Keyword identification for navigation
iv. Keyword identification to aid in the annotation through controlled descriptors
v. Transcription as a navigation tool
vi. Transcription as a basis for segmentation through thematic changes in text
vii. Transcription for alignment by semantic field comparison
viii. Transcription as a representation of a sequence, possibly associated with other representations.
ix. More generally, transcription can be used as a representation of a sequence to associate it with additional resources

As previously stated one of the main difficulties is to extract "named entities", which means firstly, to be able to identify them and separate them from other language concepts and secondly, to match them with existing lists of words (structured or not). Models can be built by using textual resources (such as online newspapers, books or articles) however this method tends to create models very close to writing; whereas the real challenge is building models to transcribe more spontaneous ways of speech. Related problems concern speaker identification, several simultaneous speakers, regional accents, speakers talking on top of other sounds.

Active and passive shape understanding

Shape understanding means enriching the traditional research process with a novel set of digital measurement tools, which allows for the extraction and formalization of geometric and statistical properties that characterize the shape of an artwork. Those digital representations may also be

employed for educational purposes to efficiently visualize artistic concepts which are inherently abstract and difficult to represent otherwise.

In order to achieve this, we must develop a new generation of shape representations and analysis tools. Those representations should be flexible, rich in semantics and meaningful enough to capture and model, at different levels of detail, high-level concepts such as: a semantic shape-driven decomposition of a shape; the sculpting style; the artist's technique; structural global characteristics (intended as the meaning of the represented subject, as perceived by the user) capable also of supporting more intelligent comparison features.

Possible applications of these high level shape descriptors may involve:

- Active shape understanding: capture the essence of a shape, such as the style to be used as an active information to transfer on other geometries or to study and classify automatically a given shape. This information can be used actively as support for the study of a given piece of art.
- Passive shape understanding: Represent the shape of an object such that is it possible to retrieve similar ones from a repository.

Interested communities include:

- Educational, university CH scholars.
- Entertainment, fast modeling for games or movies
- Industrial, shape abstraction for high-order surface representation.

4.5 CI Solutions for Societal Challenges

Crisis Management Systems

The concentrated localization of government buildings and critical infrastructure sites, within or close to dense urban environments, is a source of serious security risks that are hard to anticipate. In recent years, a great variety of threat agents have affected various public buildings with national and often transnational importance. Protecting these important sites from multiple evolving threats and restoring their functioning after an incident can be extremely challenging in an urban setting. The characteristics of large cities - with their complex geospatial environments, traffic congestion problems, large numbers of inhabitants and tourists, visiting dignitaries, various events, and complex population mixes - create significant challenges and constraints for crisis and security managers. In meeting these challenges, responsible administrators suffer from a lack of undisputed knowledge with regard to the most effective security concepts for protecting these sites.

Although several systems have addressed the training of main actors in the scenario of crisis - management, they are generally aimed at a specific subset of the problem (for example concerning a specific site and /or a specific situation). There are still several needs to be addressed that would have a clear impact on how efficiently a crisis is handled:

- hardware/software solutions for training people in charge during a crisis. Such a system should support the strategic and operational actors in the field, providing them with tools to gather information from all levels, display it for more users and allow them to interact with it, record everything that happens during a crisis in simulation and provide tools for debriefing;
- hardware/software solutions for crisis simulation. The goal of such tools would involve simulation of an extremely complex system such as the life in a city, and therefore may realistically be considered only to some extent;
- to study an effective symbology that can be shared by different countries. At present, each country of the EU has its own set of symbols, and only a few of them are actually used.
- software solution to plan special actions for securing Cultural Heritage from possible crisis scenarios, such as, for example, devising a plan for museums in case of flooding or earthquakes.

Companies/Industries interested in this trend:

- Security agencies
- Governments (nationwide and citywide)
- Civil and Mechanical Engineer
- ICT companies

Teaching and education

Many comments are regularly made about the great distance between pedagogy as it is conceived today in schools and the different levels of educational courses; and the way young children and students live and manage technology. A strong gap exists here. Pedagogical methods need tools which are easy to build and configure in order to adapt them to different teaching situations. The digital revolution is only slowly reaching into the classroom and there is a need for configurable tools so teachers can structure their courses as well as original methods for teachers to present and analyse information to pupils while permitting the learning process to take place. The challenges for research are to develop pedagogical publishing tools, collaborative tools, annotation tools and interaction tools.

Visual Forensic and authentication

The term ‘digital forensic’ refers to all the devices and techniques involved in the recovery and analysis of data coming from hard disks, mobile phones, or other digital devices. The term encompasses the computer graphics and computer vision software tools and algorithms developed

in recent years to support investigation hypothesis, to make it easier to collect more information about a crime, or to analyse the scene of a crime. These types of software tools are now widely used and have gained importance in modern scientific investigations; for example, analysis related to security problems like a car accident where analysis of the accident can be made by taking measurements directly on digital photographs exploiting Computer Vision techniques. Another example in modern investigations is the employment of High Dynamic Rrange (HDR) spherical images at a crime scene in order to quickly build a 3D prototype of the scene itself and/or to analyze it to discover things that are not possible to notice with normal digital photos.

Another topic related to visual forensics, that has appeared recently in the Image Processing community, is analysis of images (or part of images) to identify what part of the image is real or if parts have been manipulated in some way to communicate misleading information.

These lines of applied research which take into account recent advances in Computer Vision and Graphics, appear to be very promising both in terms of their effective support to scientific investigations and their potential for revenue generation through the development of novel software tools and algorithms. Some examples of tools which could have a high impact in this field are:

- tools for 3D rapid prototyping from images to allow a fast reconstruction of the crime scene to test investigation hypothesis
- physically-based animation tools for the rapid prototyping of ballistic hypothesis
- tools to measure the correlation of challenging visual information , for example to measure the probability that a certain track corresponds to the one made by specific shoes (or tyres) and other similar findings
- image authentication tools to identify manipulation and the type of manipulation

Companies/Industries potentially impacted by this trend:

- Surveillance
- Security
- IPR and watermarking
- Computer Vision companies
- Computer Animation companies

5. Bridging the innovation gap

At national and European levels, a large number of tools and support actions have been directed towards bridging the gap between academic research and industry. However, the experience of the DigiBIC project, examining the potential for commercial exploitation of research results emerging from research projects, has clearly demonstrated the innovation gap between these results and commercial exploitation. Despite initial indications of outcomes with promising commercial potential for CI SMEs, Technology Readiness Level (TRL) indicators have shown that more than 75% of outcomes from the FP6 & FP7 research projects involved cannot be considered ready for exploitation.

New actions are thus clearly needed at policy level to improve the potential for commercial exploitation of research results for example including in the eligibility criteria of future calls the involvement of relevant innovation partners capable of ensuring that outcomes reach a minimum TRL level of 7 by the end of project funding, by ensuring that complex IPR issues (as raised elsewhere in this document) are adequately addressed and solutions agreed between partners before project funding runs out. The DigiBIC policy report (due out end May 2013) will explore in more detail the scope for encouraging and facilitating business take-up of research results and make specific recommendations in this area, including the need to:

- develop innovative ways of encouraging SME participation in research projects (e.g. organising specific competitions and pitches allowing SME players to select and co-fund some research projects that would be especially relevant to them)
- develop innovative ways of benefiting from research projects for small industry players (e.g. providing easy access to affordable modules by allowing SMEs to invest very small amounts of money into collaborative research)
- develop new intellectual property strategies favouring smoother, quicker and more scalable transfer of innovation
- focus international research commercialisation schemes on acceleration programmes based on sound business models, ideally performed before the end of the research project and aimed at developing sustainable sales channels and strategies for each research result
- provide small budget and funding schemes for support, packaging, user-friendliness and design

6. Next steps

This revised draft roadmap is currently available for public consultation until the end of April 2013. A final version will be submitted to the European Commission and published on the DigiBIC website (www.digibic.eu) in May 2013.

Annex 1: List of themes and tracks related to Creative Content Technologies[13]

General themes:

- **Content producers/distributors**
- **Web content**
- **Social content production and handling**
- **3D Graphics**
- **Animation/cinematography**
- **Games and gaming**
- **Audio producing, transmission and management**
- **Data transmission and management**
- **Voice producing, transmission and management**
- **Video Coding/Transmission/Processing**
- **Image producing, transmission and management**
- **Speech producing, transmission and management**
- **Cultural Heritage**

All these rely on technology needed to produce advancement.

Content producers/distributors

- Product-innovation and creative content platforms;
- Creative processes;
- Product and content innovation;
- Knowledge representation for content creativity;
- Content injection, cashing, storage, and distribution;
- Producing and transmitting streaming content;
- Content localization services;
- Content and customers profiles;
- Documenting and content authoring;
- Authorizing topic-based content;
- Content customization and metadata;
- On-demand content;
- Content retrieval from archives (alarm-based, time stamp-based);

[13] Sources:
International Conference on Creative Content Technologies
http://www.iaria.org/conferences2013/CONTENT13.html
Conference on Information Technologies for Performing Arts, Media Access and Entertainment:
http://senldogo0039.springer-sbm.com/ocs/home/ECLAP2013

- Content management solutions and systems;
- Unstructured content environment;
- Indexing and search, filtering, information retrieval, Emotion analysis;
- Multi-channel content delivery/publishing strategies;
- Content reuse

Web content

- Architectures and frameworks for Web content;
- Web content mining;
- Content retrieval on multimedia Web;
- XML and non-XML Web content;
- Ontology and semantic for processing Web content;
- Recommenders for Web content;
- Content-driven workflow design and management;
- Web content performance, accuracy, security, and reliability;
- Web content modelling;
- Web content-based applications
- IPR management systems;
- Web and media analysis
- Web representation

Social content production and handling

- On-line content;
- Games technologies;
- Multi-user and mono-user games;
- For-kids contents and programs;
- Social content and tools (YouTube, FaceBook, etc.);
- Open portals (e-Democracy, e-Health, etc.);
- Email lists challenges (membership, spamming, etc.);
- Virtual social communities;
- Hybrid real and virtual reality technologies
- Media Annotations and tagging, solutions and interfaces;
- Social media technologies and solutions;
- Recommendations and suggestions, collective intelligence;
- Collaborative and cooperative systems;
-

3D Graphics

- Interactive 3D graphics;
- High-performance 3D graphics;
- Mixed and augmented reality;
- Interactive on-line gaming;
- Animated humanoids and complex reactive characters;
- 3D documents and web/multimedia;
- User-interface for real-time 3D graphics and virtual environments;
- Innovative 3D web applications /industry, science, medicine, technology, culture/;
- 3D content creation technologies and tools;
- Interactive 3D graphics for mobile devices
- 4D technologies and tools;
- Augmented reality solutions;

Animation/cinematography

- Computer animation;
- Computational cinematography;
- Virtual videography;
- Autonomous interactive characters;
- Traditional animation and 3D computer animation;
- Re-cinematography;
- Casual video;
- Cinematography;
- Image stabilization;
- Virtual Cinematography;
- Relighting through computation

Games and gaming

- Massive multiplayer game development and gaming (MMOGs);
- Serious and educational games;
- Video game development and authorship:
- Game modding by users;
- Plot and narrative approach to games;
- Mono and multiplayer games and environments;

- Console and computer based games;
- Game engine customizing;
- Game middleware components;
- Game and rendering engines;
- Game threading;
- Control devices;

Audio producing, transmission and management

- Audio transmission and reception systems and devices;
- Audio processing and tools for large events and installations;
- Digital audio transmission signal processing;
- Audio transmission over Internet;
- Audio Multiplexing Transmission Systems;
- Stereo audio transmission signal;
- Digital infrared audio transmission;
- Multi-stream and multi-path audio transmission;
- Wireless-compressed digital audio;
- Audio transmission;
- Perceptual coding for audio;
- Transmission and storage;
- Laser audio transmission;
- Synchronizing video and audio transmission;
- Wide-band audio transmission;
- Index-frame audio transmission;
- Digital audio transmission rights;
- Noise in wireless audio transmission;
- Audio tools and products;
- Standards

Data transmission and management

- Data transmission and reception mechanisms and techniques;
- Enhanced tools for video data integrity;
- Data mining, filtering, and reporting;
- Secure data transmission;
- Transmission media and data encoding;
- Text reading devices (super-pen, pen-elite, reading-pen);

- Scanned and generated lossy (progressive) multi-page text; (
- Visually) lossless mechanisms;
- Pricing data transmission;
- Differential data transmission systems;
- Data transmission equipment and transmission rates;
- Delay-constrained data transmission;
- Undersea and satellite data transmission techniques;
- Performance evaluation of data transmission;
- Multicast data transmission;
- High speed data transmission;
- Data transmission control;
- Integrity and privacy in data transmission;
- Data transmission standards
- Data and media protection;

Voice producing, transmission and management

- Planning and implementing voice networks and systems;
- Voice transmission systems;
- Voice transmission performance;
- Quality real-time voice transmission;
- Metrics for quality of voice transmission;
- Stereophonic voice transmission systems;
- Header compression for VoIP over WLAN;
- Voice over IP solution for mobile radio interoperability;
- VoIP over cable TV networks;
- VoIP over Wi-Max;
- WiFi and cellular dual mode phones and services;
- Voice over WLANs and Wi-Fi to cellular roaming;
- Multilingual and natural language processing;
- Voice transmission via the Internet;
- Wi-Fi voice transmission;
- Bluetooth-based Ad-Hoc networks for voice transmission;
- Standards for voice processing and transmission

Video Coding/Transmission/Processing

- Video coding standards (H.264, SMPTE 421M, AVS-China);
- Video coders and decoders;
- Video analysis, indexing and summarization;
- Video surveillance and privacy;
- Network video recorders;
- Video streaming;
- Video data integrity (error detection, error resilience, error concealment, tamper resistance);
- Video hashing;
- Motion detection, object tracking;
- Distributed video coding;
- Video quality assessment;
- Omnidirectional video;
- 3D video

Image producing, transmission and management

- Model-based progressive image transmission;
- Wireless image transmission;
- Computer generated images;
- Image security, scrambling, and regions of interest;
- Timing requirements for image transmission;
- Transmission of still and moving images;
- Protocols for low bit rate;
- Error-prone image transmission;
- Energy efficient image transmission;
- Multi-technology image formation;
- Devices for image capturing and processing (cams, web-cams, etc.);
- Scanning and sampling, quantization and halftoning, color reproduction;
- Image representation and rendering, display and printing systems; Image quality assessment;
- Image search and sorting, video indexing and editing; Integration of images and video with other media;
- Image authentication and watermarking;
- Image storage, retrieval and multimedia;
- Image and video databases;
- Generic coding of moving pictures;
- Media stream packetization;
- Modes for archival playback;

- Image-based applications;
- Standard for image processing;
- Image analysis and segmentation;
- Image filtering, restoration and enhancement;
- Image representation and modelling;
- Pattern recognition

Speech producing, transmission and management

- Tooling, architectures, components and standards;
- Voice modulation, frequencies;
- Linguistics, phonology and phonetics;
- Discourse and dialogue;
- Speech analysis, synthesis, coding, and recognition;
- Speech enhancement and noise reduction;
- Speech features, production, and perception;
- Speech coding and transmission;
- Speech signal processing;
- Spoken language generation and synthesis;
- Speech QoS enhancement;
- Speaker characterization and recognition;
- Spoken language resources and annotation;
- Spoken/Multi-modal dialogue technology and systems;
- Spoken language information extraction/retrieval;
- Speech transmission technology for the aged and disabled;
- Audio-visual speech processing;
- Biomedical applications of speech analysis;
- Spoken document retrieval;
- Speech processing in a packet network environment;
- Automatic speech recognition in the context of mobile communications;
- Human factors in speech and communication systems;
- Automatic speech recognition and understanding technology;
- Speech to text systems;
- Spoken dialog systems;
- Multilingual language processing;
- New applications of spoken language technology and systems

Cultural Heritage

- Creative technologies for cultural Heritage;
- Production, Consumption, Creative Reuse of cultural content;
- Content digitization & preservation practices;
- Linked Open Data, aggregated media;
- Linked Open Data based API
- Metadata quality, mapping and ingestion models and tools;
- Cloud based solutions for storage and archiving;
- Long-term archiving;
- Self-archiving objects