DigiCULT

The Future Digital Heritage Space

An Expedition Report

Thematic Issue 7

December 2004

Information Society Technologies

The Future Digital Heritage Space
An Expedition Report

Guntram Geser and John Pereira (eds.)

Thematic Issue 7

Content

Preface

Over the past 34 months the DigiCULT Forum project has provided a technology watch mechanism for the cultural and scientific heritage sector in Europe and beyond. This was carried out as a support measure within the Information Society Technologies (IST) priority of the European Union's Fifth Framework Programme for Research and Technological Development.

Backed by a network of peer experts, the project has monitored, discussed and analysed existing and emerging technologies likely to benefit the cultural and scientific heritage sector. To promote the results and encourage early take-up of relevant technologies, DigiCULT has published seven Thematic Issues (including this one) and three in-depth Technology Watch Reports, and presented the DigiCULT.Info e-journal to a growing database of interested persons and organisations. All these products can be downloaded from the project Web site http://www.digicult.info.

With the project approaching the end of its IST-funded phase, we thought it appropriate to carry out an expedition into the possible future of digital cultural and scientific heritage in the next 10-15 years and beyond. This Thematic Issue summarises the results of this expedition as a roadmap which is intended as a navigation tool for boards and directors of heritage organisations and research centres, IT project managers, and curators of digital collections, virtual exhibitions and environments. It should provide them with an overview of innovative information and communication technologies (ICT), systems and applications that may be achieved in the next ten years or so. It seeks to explain the enabling technologies that will be used, the breakthroughs that may occur and the possible impacts that may shape and re-shape the digital landscape in which heritage institutions reside.

Actually, it seems likely that their digital surroundings may develop much faster than these institutions can adopt and employ. This tool may help them to discuss and prepare their places in this landscape in order to become part of it in a conscious and planned way. This could include opportunities to participate in projects that develop 'ambient intelligence' services and applications, allowing them to be among the first to attract on-site and online visitors with compelling new cultural experiences. If this navigation tool is able to help towards these ends, then it will have fulfilled its function.

Acknowledgements

We wish to acknowledge and express our appreciation to the many people who have contributed to the expedition report. In particular, it could not have been achieved without the highly valuable contributions of the 62 experts and professionals who invested their precious time to participate in the DigiCULT online consultation forum. Of these experts twelve have chosen to remain anonymous, but we can mention that most of them are working in either a research centre or a governmental body or agency.

We have the opportunity to express our grateful thanks to the following by name:

Karianne Albrigtsen Aam – Adviser, Norwegian Archive, Library & Museum Authority, Norway
George Abbott – Director, Library Media Services Department, Syracuse University Library, USA
Renata Arovelius – Head of Archives, University of Living Natural Resources (SLU), Sweden
Jacques Bogaarts – Senior ICT Consultant, Nationaal Archief, The Netherlands
Pia Borlund – Research Professor, Royal School of Library and Information Science, Denmark
Paolo Buonora – State Archivist, Archivi di Stato di Roma, Italy
Niklaus Bütikofer – State Archivist, Swiss Federal Archives, Switzerland
Fabrizio Cardinali – CEO, with Fabrizio Giorgini and David Fuschi, Giunti Labs, Italy
Clare-Frances Craig – Advisory service in Western Australia, Museum Assistance Program, Australia
Samuel Cruz-Lara – Associate Professor, LORIA - INRIA Lorraine, France
Ines Cunha Freitas – Superior Officer, Instituto Português de museus, Portugal
Dominique Delouis – CEO, Cultural Heritage On Line, France
Martin Doerr – Principal Researcher, Information Systems Laboratory, and Head of the Centre for Cultural Informatics of the ICS/FORTH, Greece
Roger Drage – Project Co-ordinator, Milton Keynes Museum, UK
Luciana Duranti – Professor/Archival Scholar, University of British Columbia, Canada
Jayne Everard – Service Manager, Artifact: RDN hub for the Arts and Creative Industries, Manchester Metropolitan University, UK
Muriel Foulonneau – Project Coordinator, CIC-OAI project, University of Illinois at Urbana-Champaign, USA
Anne Gilliland-Swetland – Professor, Department of Information Studies, UCLA, USA
Luc van Gool – Professor, University of Leuven & ETH Zurich, Belgium / Switzerland
Stefan Gradmann – Deputy Director, RZZ, University of Hamburg, Germany
Thijs Hannen – Advisor, De digitale archivaris, The Netherlands
Preben Hansen – Researcher, Swedish Institute of Computer Science (SICS), Sweden
Peter Ingwersen – Research Professor, Royal School of Library and Information Science, Denmark
Jussi Karlgren – Researcher, Swedish Institute of Computer Science (SICS), Sweden
Jason Kiss – HCI Analyst, Canadian Heritage Information Network (CHIN), Canada
Elisabetta Lazzaro – Economist, European Centre for Advanced Research in Economics and Statistics (ECARES), Universite Libre de Bruxelles, Belgium
Marcella Lorenzi – Researcher, Evolutionary Systems Group, University of Calabria, Italy
Jari Lybeck – Director, Provincial Archives of Hämeenlinna, Finland
Kirk Martinez – Senior Lecturer, University of Southampton, UK
Gavan McCarthy – Director, Australian Science and Technology Heritage Centre, University of Melbourne, Australia
Brian McLaughlin – Acquisitions Supervisor, Syracuse University Library, USA
Doug Moncur – Project Manager, Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS), Australia
Michael Moon – CEO, GISTICS Inc., USA
Reagan Moore – Director, Data Intensive Computing Environments, San Diego Supercomputer Center, USA
Paul Mulholland – Researcher, The Open University, UK
Patrick Ngulube – Lecturer, University of KwaZulu-Natal, South Africa
Sofia Pescarin – Fellowship researcher, Istituto per le Tecnologie Applicate ai Beni Culturali, CNR, Italy
Alessandro Piva – PostDoc Researcher, University of Florence, Italy
John Poirier – Coordinator of Technical Services, Northwest Territories Archives, Canada
Andrea de Polo – Head of Information Technology, Fratelli Alinari, Italy
Attilio Romita – Senior Consultant, Italy
Donald Sanders – President, Institute for the

Visualization of History, USA
Kazimierz Schmidt – Adviser, State Archives, Poland
Elizabeth Selandia – Art Historian, Member of the Visual Resources Association, USA
Deirdre Sharp – FOI Officer, Norfolk County Council, UK
Alan F. Smeaton – Professor of Computing, Dublin City University, Ireland
Angela Spinazzè – ATSPIN consulting, USA
Sabine Stadler – Social Scientist & Documentalist, Austria.
Suellen Stringer-Hye – Web Developer/Librarian, Vanderbilt University, USA
Gerd-Christian Weniger – Director, Neanderthal Museum, Germany
Hilde van Wijngaarden – Digital Preservation Officer, National Library of the Netherlands, The Netherlands
Richard Wright – Technology Manager, BBC, Technology, UK

Furthermore, we would like to extend warm thanks to our DigiCULT consortium partner **Seamus Ross and his team** at the Humanities Advanced Technology and Information Institute (HATII), University of Glasgow. HATII's team managed the technical set-up of the online consultation forum, and ensured its stable working throughout the consultation phase.

A special thanks to **Michael Steemson**, The Caldeson Consultancy, who summarised expert contributions for the section Technology development and implementation from the heritage sector's perspective.

We also thank **Wernher Behrendt**, Head of Salzburg Research's Knowledge Information Systems Group, who contributed valuable comments on sections of the report that were of particular interest to him.

Finally, we gratefully acknowledge the generous support of **Albrecht Sauer** from the German Maritime Museum, Bremerhaven, who provided us with access to the wonderful and compelling images that illustrate the expedition report.

By acknowledging the involvement of the above individuals and the review process in which they participated, we do not imply their endorsement of the published results of this report. The final responsibility for the content of this report lies solely with the editors.

Guntram Geser and John Pereira, Salzburg Research
DigiCULT Forum project coordinator,
December 2004

INTRODUCTION AND OVERVIEW

TOWARDS THE FUTURE DIGITAL HERITAGE SPACE: AN EXPEDITION

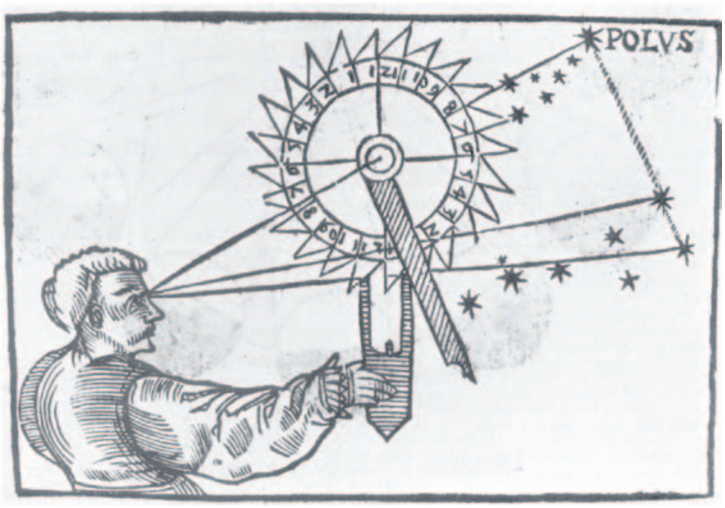
In the past few months, DigiCULT has been on an expedition. The target has been to bring home a research and technological development (RTD) roadmap that outlines what may be expected in a future digital heritage space. Routes should be found for different RTD endeavours, the results of which, within the next 10 to 15 years, may fall into place to create such a space.

This Thematic Issue describes and summarises what we have found. It is an expedition report. Therefore, some observations need to be made with respect to what it has revealed. First, it was a journey in many directions, often into uncharted territories, and we needed to sail fast. Secondly, we found many islands, with very different islanders and views of the future digital heritage space.

However, there is one clear message that may summarise what we discovered. There is little likelihood of a future digital heritage space being created unless ways can be found to bring the different islands closer together. At the end of the expedition report, we give some recommendations on how this may be achieved.

The expedition report is not written primarily for researchers and technologists. Rather, it is intended for boards and directors of heritage organisations, IT project managers, and curators of digital collections, virtual exhibitions and environments. It should provide them with an overview of innovative information and communication technologies (ICT), systems and applications that may be achieved in the next ten years or so. It seeks to explain the enabling technologies that will be used, the breakthroughs that may occur and the possible impacts that may shape and re-shape the digital landscape in which heritage institutions reside.

Actually, it seems likely that their digital surroundings may develop much faster than these institutions and cultural networks can adopt and employ, turning them into blind spots in an emerging 'ambient intelligence' landscape, which would itself benefit from an intelligent digital heritage space. Therefore, we thought it useful and timely to provide the heritage sector with a report that could also function as a tool. Used as a tool, it may help cultural heritage institutions discuss and prepare their places in this landscape in order to become part of it in a conscious and planned way. This could include opportunities to participate in projects that develop 'ambient intelligence' services and applications, allowing them to be among the first to attract on-site and online visitors with compelling new cultural experiences.



THE EXPEDITION'S INSTRUMENTS

On our expedition we have used various instruments to chart in more detail some of the territories and islands visited:

One of the most valuable general maps is the Ami@Life roadmap, which includes some sections on cultural heritage and cultural participation in a future Ambient Intelligence space. As these helped in deciding some of the routes to take, we are including in our report a summary of other major Ambient Intelligence publications as well as a summary of the relevant sections in the Ami@Life roadmap.

The next instrument was a large radar scanner, which we used to find stable islands, as well as some still floating, in the territory of basic RTD and near-market technological development. These islands may form a major basis for the future digital heritage space. However, as most of them do not use the languages of the heritage territories, we are including examples that illustrate their technologies in practical ways that heritage islanders may find interesting

and related to what they want to use. Next on our journey, we sent a signal from our expedition ship to experts from all the islands to tell us their visions of what might be achieved for the future digital heritage space over the next 10-15 years in major RTD areas. We included questions on current limitations or gaps in RTD, major steps or breakthroughs needed, how these should be addressed, and we asked for indications of the time period likely before these could be achieved. A summary of the results of this request forms the major part of our expedition report.

The consultation was carried out via online questionnaires, and 64 experts from the different islands gave us their views and opinions. The messages we received were very different and varied in terms of detail. Some islanders transmitted shorter messages in Morse code; others delivered longer reports that described the state of affairs on their islands.

Other expedition ships

We spotted and exchanged messages with other 'expedition ships' that cruise the Seven Seas of digital and networked cultural heritage. The Calimera (Cultural Applications: Local Institutions Mediating Electronic Resources) project is currently investigating a research roadmap from the perspective of local cultural heritage institutions across Europe. This work is focusing on actions to optimise opportunities for these institutions to play important roles in the digital and networked environment. Its findings are expected to concentrate on measures that would leverage the smaller institutions' capabilities in providing functions like access to resources and sharing of knowledge with local and regional user communities.[1]

A further roadmap will come from EPOCH (Excellence in the Processing of Open Cultural Heritage), a network of about a hundred organisations including university departments, research centres, heritage institutions and agencies, and commercial enterprises. EPOCH's primary objective is 'to integrate the currently fragmented efforts in research directed toward developing intelligent IST technologies for cultural heritage and their use in sustainable Cultural Heritage applications'.[2]

These are but two important ships that are also sailing under the cultural heritage flag, and it is to be expected that their results will be complementary to DigiCULT's findings. There are many more relevant roadmapping activities going on in large research centres and within projects throughout Europe. While these will not focus on RTD issues directly relevant for the heritage sector's organisations, it may be useful to consult their results if readers want to have a deeper analysis of RTD issues related to those addressed in DigiCULT's expedition report (such roadmaps are referenced on pp. 24-32).

Elements of the overall roadmap

Based on what we have found in the course of our expedition, DigiCULT has combined the following elements into an information-rich roadmap:

In the background of the map there is a vision of a Future Digital Heritage Space embedded in a larger Ambient Intelligence (AmI) landscape (pp. 16-23).

On this background, major AmI technological territories, and specimens of applications from these territories, are outlined (pp. 24-32).

Related to some of these territories, six thematic roadmaps give an overview of challenges and possible achievements over the next 10 to 15 years that may lead to advanced systems and applications for the cultural and scientific heritage sector (pp. 33-64).

Furthermore, there is a general assessment of the likelihood of heritage organisations of different sizes adopting and implementing technologies from the broad portfolio of existing technologies that has been monitored by DigiCULT over the last three years or so. Here we also ask how the likelihood of the adoption of future advanced or novel technologies stemming from ongoing basic and applied RTD efforts may be increased through the organisations' active involvement (pp. 72-74).

It is hoped that this overall roadmap will provide a first navigation tool for – and essential understanding and direction in the strategic planning of – a research and technological development agenda related to cultural and scientific heritage, for RTD planners and funding bodies as well as for cultural and scientific heritage organisations and networks.

They may also wish to consider and further discuss the three recommendations given at the end of the report.

[1] As this Issue was being prepared, a draft version of the Calimera roadmap (v.4, 30/09/2004), authored by Professor Peter Brophy from the Centre for Research in Library & Information Management (CERLIM), was available on their Web site, http://www.calimera.org.

[2] EPOCH, http://www.epoch-net.org; Professor Luc van Gool (University Leuven & ETH Zurich, Belgium/Switzerland), who is responsible for EPOCH's technological roadmap, has invited DigiCULT to 'join forces for the topics that we have in common'.

Reference Points, Aims and Scope of the Roadmap

Major Reference Points

The DigiCULT roadmapping exercise has a number of major reference points, in particular the Information Society Technologies (IST) priority of the EU-funded R&D Framework Programmes (FP6: 2002-2006, and also FP7 and beyond). As outlined in its priority documents, its overall objectives are 'to ensure European leadership in the generic and applied technologies at the heart of the knowledge economy. It aims to increase innovation and competitiveness in European businesses and industry and to contribute to greater benefits for all European citizens.' Furthermore, the EU-funded research and technological development (RTD) activities should 'reinforce and complement the eEurope 2005 objectives and look beyond them to the 2010 goals of the Union of bringing IST applications and services to everyone, every home, every school and to all businesses'.[3]

The focus of IST in FP6 is stated in terms of the IST Advisory Group's vision of 'ambient intelligence', i.e. 'the future generation of technologies in which computers and networks will be integrated into the everyday environment, rendering accessible a multitude of services and applications through easy-to-use human interfaces. This vision of "ambient intelligence" places the user, the individual, at the centre of future developments for an inclusive knowledge-based society for all.'[4] A condensed formula of this vision is anywhere, anytime, natural and enjoyable access to IST services for all.

An impression of the IST priority's aims may be obtained by comparing the vision for IST in the Sixth Framework Programme with what forms some of today's general basis in the use of information and communications technologies (see table).

Why a Cultural Heritage RTD Roadmap?

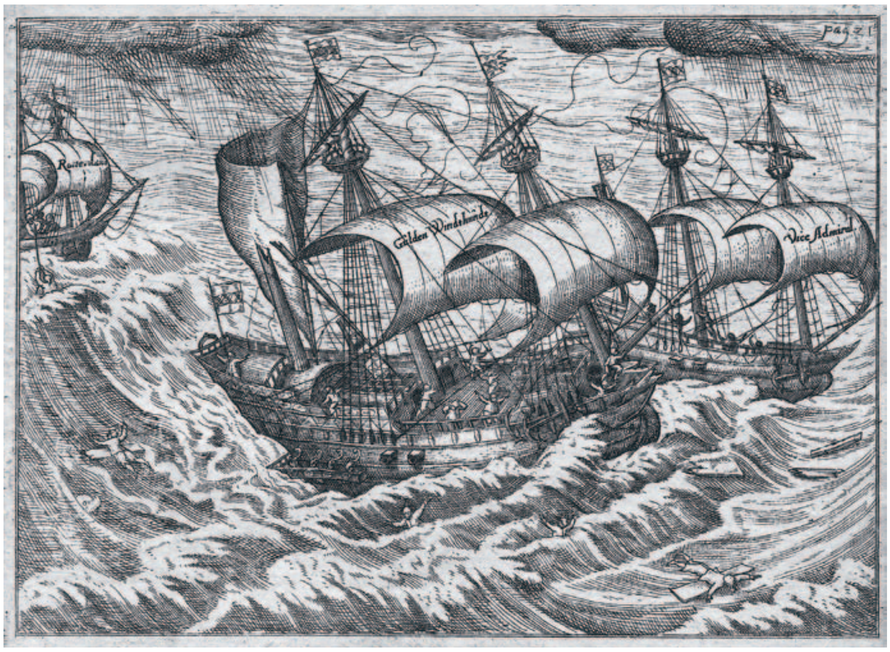
The main benefit of RTD roadmapping is that it gives cues for RTD investment decisions by identifying critical research strands, current limitations and gaps, and ways to leverage RTD investments by coordinating research activities. Furthermore, it may help demonstrate promising directions of RTD and related activities, and methods for monitoring progress along the way. The objective of the DigiCULT roadmap is to produce representations of possible achievements in several RTD areas over the next 10 to 15 years, and to specify in some detail how the related RTD challenges could be addressed.

IST today	**The IST in FP6 vision**
PC based	"Our surrounding" is the interface
"Writing and reading"	Use all senses, intuitive
"Word" based information search	Context-based knowledge handling
Low bandwidth, separate networks	Infinite bandwidth, convergence, ...
Mobile telephony (voice)	Mobile/Wireless full multimedia
Micro scale	Nano-scale
Silicon based	+ new materials
e-Services just emerging	Wide adoption (eHealth, Learning,..)
< 10% of world population on-line	World-wide adoption
Source: *IST priority, Work Programme 2003-2004, p. 7.*	

[3] IST priority, Work Programme 2003-2004 (p. 5), ftp://ftp.cordis.lu/pub/ist/docs/wp2003-04_final_en.pdf, cf. also IST priority, Work Programme 2005-2006, and the further documents available at http://www.cordis.lu/ist/workprogramme/fp6_workprogramme.htm; for information on the eEurope 2005 Action Plan, see http://europa.eu.int/information_society/eeurope/index_en.htm

[4] IST priority, Work Programme 2003-2004 (p. 5), with reference to the ISTAG report *Ambient Intelligence Scenarios for 2010*, http://www.cordis.lu/ist/istag-reports.htm

However, some reservations need to be made. DigiCULT's expedition roadmap can to a certain degree be a useful tool for the purposes mentioned, but it cannot serve all the objectives one would like to address in the context of RTD planning. Often roadmaps are overloaded with expectations of what they should allow for and, in consequence, deliver poorly on them. Such expectations may also seek to discuss the societal and policy implications of the expected RTD results, or to identify, prepare the ground for and even mobilise stakeholders and consortia to target key RTD challenges. Furthermore, even clear statements on specific applications, new products or services, and their likely uptake by businesses or consumers, are often sought. The expedition report addresses the first two issues only as side issues. Instead, it accompanies the core perspective on RTD with a view on the requirements and likelihood of heritage organisations adopting certain types of existing and future ICT applications. This view and the related assessments are given on pp. 72-74.



It may also be worth considering whether there really are RTD challenges specific or even unique to the heritage sector organisations such as libraries, archives, museums and galleries and heritage sites. It is widely understood that these have specific demands stemming from their functions, particularly if they have the mandates of national libraries or archives in a rapidly expanding digital environment.[5] To collect, make accessible, manage and preserve growing numbers of culturally valuable and increasingly complex digital objects for future generations poses major RTD issues, if not a 'grand challenge'.[6]

Another area of major RTD challenges is the creation of new systems and applications that foster and support mediation of the rich cultural heritage and cultural knowledge from one generation to the next. Such technologies will need to form a major part of the future digital heritage space. In particular, there is a need for knowledge systems and applications based on ontologies and other concepts that allow systems to understand and process information on cultural expressions and the manifold relations between them. As such expressions are particularly rich in ideas and meanings, the cultural domain may well be the hardest test-bed for pure research activities in semantic systems. Considering also the evolution throughout history of the different discourses and contexts in which cultural heritage objects have been embedded, there are many further RTD challenges that are of key importance to the inherently multi-disciplinary Arts & Humanities and related scholarly fields.

The above does not try to address what the next user generations may expect to experience when engaged with cultural heritage within the larger framework of cultural participation. While the IT-based cultural industry players such as Sony and Microsoft invest vast amounts of money concentrating on the 'look and feel' of games and adventure-driven immersive experiences, the stakes are even higher for engaging virtual cultural heritage experiences – within reconstructions of historic environments, for instance - which could contain a rich measure of informal learning and knowledge acquisition.

These are merely some areas of RTD needed to progress from simple forms of accessing cultural heritage information to new environments for knowledge-driven uses and experiences.[7] The novel systems and applications that could build on RTD results should lead to new levels of creative exploitation for cultural heritage alongside Arts & Humanities resources and knowledge within a future digital space. In a later chapter we will address this from the perspective of heritage organisations, describing their key roles in the relevant RTD activities (pp. 21-23).

[5] As a major 'global' reference point, see also the UNESCO *Charter on the Preservation of the Digital Heritage* (adopted on 17 October 2003), http://portal.unesco.org/en/ev.php-URL_ID=17721&URL_DO=DO_TOPIC&URL_SECTION=201.html; also their *Guidelines for the Preservation of Digital Heritage* http://unesdoc.unesco.org/images/0013/001300/130071e.pdf

[6] A 'grand challenge' is a visionary goal of research that is not obviously possible but holds the potential for a significant advance in human knowledge and capabilities. However, incremental progress in research and development would not succeed. Major investments and long-term and coordinated inter-disciplinary collaboration would be needed. For further information, see, among many other examples, the UK Grand Challenges Exercise in the area of computing research, http://www.nesc.ac.uk/esi/events/Grand_Challenges/

[7] In addition to our discussion of what makes RTD in digital heritage 'specific', see the ideas of David Arnold: "Mapping the future: Intelligent Heritage - The research perspective" (28-01-2003), http://www.cordis.lu/ist/directorate_e/digicult/publications.htm; Flavio Tariffi: "Intelligent Heritage: The industry perspective" (28-01-2004). http://www.cordis.lu/ist/directorate_e/digicult/publications.htm; and the consultation report "Review and update of the IST Work Programme for the period 2005-06: WP 2003-2004 Strategic Objective 2.3.1.12: Technology-enhanced learning and access to cultural heritage" (31 Mai 2004), ftp://ftp.cordis.lu/pub/ist/docs/consultation_report_2-3-1-12.pdf

Scope of the RTD roadmap

The roadmap covers a broad range of RTD fields, which address challenges relevant for systems and applications that may be used in the cultural and scientific heritage sector. Partly overlapping, these RTD fields concentrate on technologies, systems and applications that may be characterised as:

- 'intelligent' and 'contextual', i.e. allowing for technological and semantic interoperability of heritage resources, and their meaningful 'anywhere, anytime' use via context-aware services;
- natural and enjoyable interaction, i.e. accessing, navigating, and making use of digital heritage resources and environments in personalised, multimodal ways, also including collaborative and community activities;
- digital creation, and re-creation in digital form, of heritage structures (e.g. historic buildings, cultural sites), objects and characters for interactive exploration and use in 3D, augmented and virtual reality environments;
- new generations of large-scale, distributed digital libraries and archives of heterogeneous heritage resources, containing increasingly complex and dynamic objects;
- last but not least, novel concepts, methodologies and techniques that allow for making digital heritage resources and environments persistent, and perpetually accessible and understandable over long periods of time.

These thematic fields are described in more detail at the beginning of each of the respective sections (see pp. 33-64). It is understood that our expedition into these fields can only give a rough, and certainly not comprehensive, picture of the available and emerging technologies from which innovative research and prototype application development for the heritage sector may start.

In a schematic continuum of (a) 'blue sky' and fundamental research, (b) research into new technological platforms and standards, (c) applied RTD in system architectures and components, (d) technological development of application prototypes, (e) near-market application development and system integration, and finally (f) application deployment, the roadmapping generally focuses on phases (c) and (d).

However, if there are ongoing fundamental research activities that may bear particular relevance for the heritage sector, we include them where they represent RTD opportunities that lie further down the road. Furthermore, we understand that there is often a large gap between, on the one hand, plausible-in-principle solutions or prototypes developed in the framework of projects and, on the other hand, complete, turn-key software offerings – systems and tools a user community needs and would like to use. However, in the roadmap we do not consider issues such as custom software development and service deployment.

But, the DigiCULT roadmapping provides an assessment of the likelihood and time horizon of the heritage organisations' adoption of new systems and applications. We think that this dimension is of great interest to stakeholders in the heritage sector. To a certain degree it should also inform the planning and funding of RTD, processes that require an understanding of the likely favourable or unfavourable conditions for an uptake and use of the expected RTD results.

Time Horizons

Before embarking on our expedition, we considered not only the types of 'RTD specimens' we would collect in the course of the journey, but also the time horizon we should create for the roadmap, as this determined which instruments we would need to carry on board. After consultation of other roadmaps, we decided to aim at identifying RTD goals considered by experts to be within reach in the next five to ten years, and to investigate ideas whose realisation might need 10, 15 or even more years. This latter span may seem like 'crystal ball gazing', but our aim also is to encourage thinking about possible lines of research that are of a more 'blue sky' or experimental nature.[8]

Nevertheless, we thought it useful to place the roadmapping exercise in a broader perspective by noting how past forecasts of innovations in ICT have been astonishingly accurate, and what and how long it took to develop the current base of ICT. Finally, it may also be important to consider whether and where the basic ingredients of the future digital heritage space are already available in ongoing research and first prototypes.

Why futurological forecasts in the 1960s for computers & communications showed high accuracy

In an interesting exercise, The Albright Strategy Group assessed a list of 100 technological innovations which, in 1967, Herman Kahn and Anthony Wiener thought would be achieved by the year 2000.[9] A panel of reviewers found that fewer than half of the forecast innovations occurred before the end of the last century. However, one topical field stood out as far more accurate than others: in computers & communications, more than 80 per cent of the forecast innovations were judged to have occurred.

The forecasts in all other fields, including Infrastructure & Transportation, Lifestyle, Health & Human, Defence, Materials, Aerospace, Environment and Biotech & Agriculture, were judged to be less than 50 per cent correct. Among the '10 Best Forecasts' all but one were innovations in Computers & Communications. These included, to give but three examples: 'Inexpensive high-capacity, worldwide, regional, and local (home and business) communication (perhaps using satellites, lasers, and light pipes); 'Pervasive business use of computers'; 'Direct broadcasts from satellites to home receivers'. Also the one exception mentioned, 'Extensive use of high-altitude cameras for mapping, prospecting, census, and geological investigations', was enabled by digital technologies.

According to Richard E. Albright, the main reasons for the greater accuracy of the forecasts in the field of Computers & Communications are to be found in two drivers. First, sustained trends in basic enabling technologies in this field were apparent in the 1960s and have continued to the present. This included semiconductor performance/cost, computing capability, storage capacity/cost, and optical transmission capacity. Second, the scale of investment required for innovation was driven down by the declining costs of the enabling technologies. This allowed contributions by many centres of research and thereby sustained industry learning that brought about a broad range of successful innovations.

Incubation times for IT innovations

In 2003, the US National Research Council of the National Academy of Sciences published a book on *Innovation in Information Technologies*, which explained comprehensive research on this topic by their Computer Science and Telecommunications Board.[10] The Board's Chair, David D. Clark, writes: 'Ironically, the success of the industries that produce information technology (IT) has caused confusion about the roles of government and academia in IT research.' So, they did an in-depth analysis of the development of many of the generic technologies that represent the basis of the current ICT industries. They found that in most cases fundamental research, in which gov-

[8] Such lines of research would need to follow a more FET-like approach. The IST programme Future and Emerging Technologies (FET) is a nursery of novel and emerging scientific ideas, of 'research that is of a long-term nature or involves particularly high risks, compensated by the potential of a significant societal or industrial impact'. *Cf.* http://www.cordis.lu/ist/fet/home.html

[9] H. Kahn and A. Wiener: *The Year 2000. A Framework for Speculation on the Next Thirty-Three Years* (New York: McMillan, 1967); Richard E. Albright: "What Can Past Technology Forecasts Tell Us About the Future?" January 2002. http://www.albrightstrategy.com/papers/albright_Past_Forecasts.pdf

[10] National Research Council, *Computer Science and Telecommunications Board (2003): Innovation in Information Technology*. (Washington, DC: National Academy Press, 2003). http://books.nap.edu/html/innovation_in_IT/ (see Chapter 1).

ernment-funded university research centres played a decisive role, 'led 10 to 15 years later to the introduction of entirely new product categories that became billion-dollar industries'. This is visualised in the form of 'tire-track charts', diagrams that show the complex interplay of university research and industry RTD, some of the concurrent, mutually reinforcing advances in multiple subfields and, most importantly, 'the long, unpredictable incubation period – requiring steady work and funding – between initial exploration and commercial deployment'.[11]

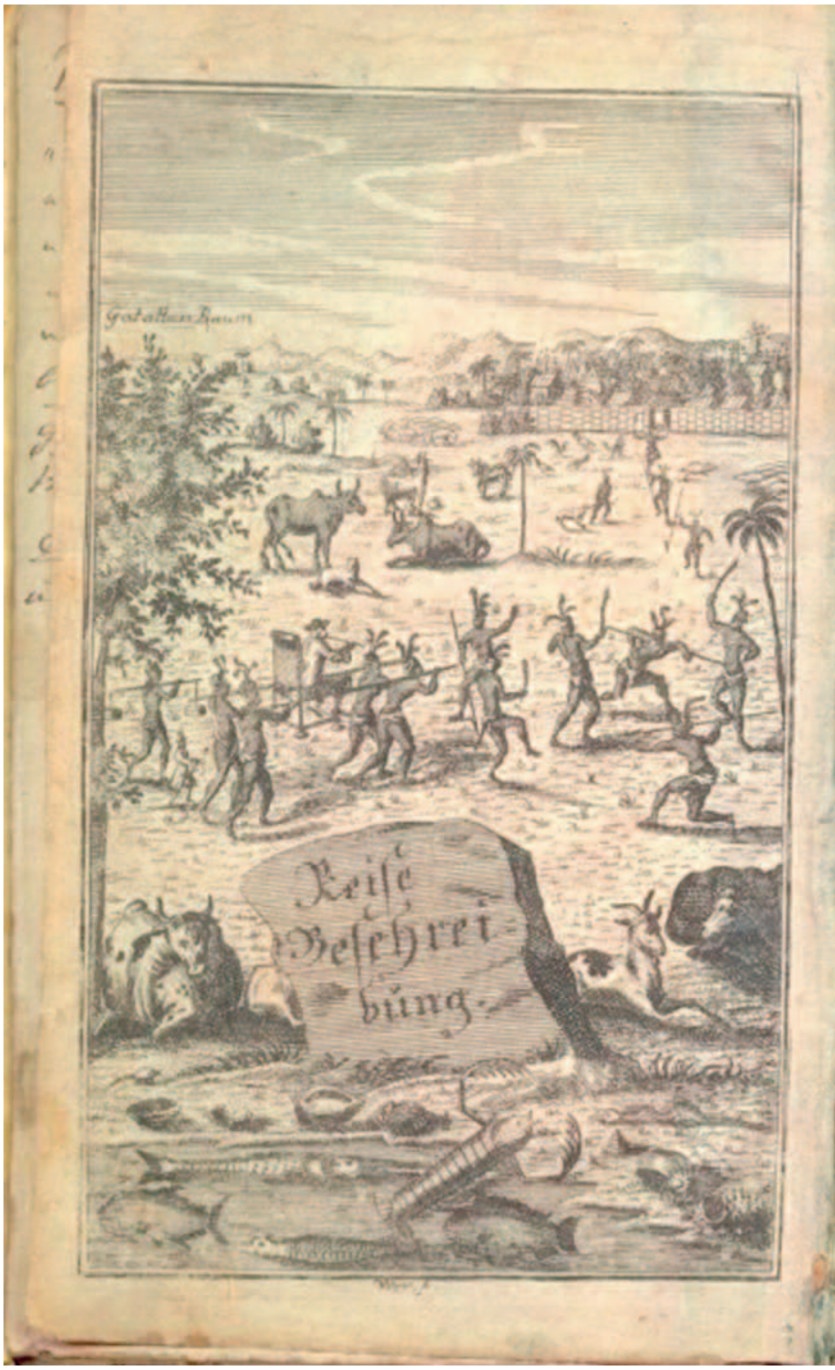
The diagrams also give indications of when commercial products became available and when a one billion dollar market was reached. These include, among others, Reduced Instruction Set Computer (RISC) processors, parallel computing, relational and parallel databases, client/server computing, LANs, Internet, portable communication, graphics, and speech recognition.

Some of the future in ICT is already with us

In an article entitled 'Forward into the Past',[12] Bill Buxton, a renowned 'veteran' IT researcher and designer of technologies that support creative activities, points out 'that most of what passes for new at any given time has in fact been around for quite a while. Or, to steal a line from the science-fiction writer William Gibson, "The future is already here. It is just not uniformly distributed".'

To illustrate this, Buxton gives several examples. One is the following: 'The now ubiquitous computer mouse also took a poky path to market. The first model was built in 1964 by Doug Engelbart and William English, of the Stanford Research Institute in Menlo Park, Calif. By the early 1970s, many of us at Xerox PARC had become point-and-click fans, using state-of-the-art Alto computers. But beyond that little world, few people were aware of the device until Steve Jobs unveiled the Apple Macintosh in 1984. It took Microsoft's Windows 95 to take the mouse mainstream — some 30 years after its invention. The commercialization of research, in other words, is far more about prospecting than alchemy.'

Pointing also to the results of the US National Research Council book on *Innovation in Information Technologies*, he states: 'All this suggests that the technologies that will significantly affect our lives over the next 10 years have been around for a decade. The future is with us (or at least some of us). The trick is learning how to spot it.'



[11] The diagrams are to be found at: http://books.nap.edu/html/innovation_in_IT/ch1_f1.html

[12] Bill Buxton, "Forward into the Past" in *TIME Magazine: Visions of Tomorrow*. Special Report, Vol. 164, No. 15, 11 October 2004. http://www.time.com/time/covers/1101041011/nextessay.html#; http://www.billbuxton.com


Ernst Christoph Barchewitz, Thur.
Der Edlen Ost-Indianischen Compagnie der vereinigten Niederlande gewesenen commandirenden Officiers auf der Insul Lethy,
Neu-vermehrte
Ost-Indianische
Reise-Beschreibung,
Darinnen
I. Seine durch Teutsch- und Holland nach Indien gethane Reise;
II. Sein eilff-jähriger Aufenthalt auf Java, Banda und den Sudwester-Insulen, Glücks- und Unglücks-Fälle, seltsame Begebenheiten, auch remarquirte rare Gewächse, Bäume, Früchte, Thiere, Fische, Insecten, Berge, Vestungen, Nationen, Gewohnheiten, Aberglauben der Wilden, und viele andere Denckwürdigkeiten mehr;
III. Seine Rück-Reise, der dabey erlittene grausame Sturm, und endlich glücklich erfolgte Ankunft in sein Vaterland umständlich erzehlet wird;
Deren bey dieser andern Auflage noch viele merckwürdige Begebenheiten inseriret, mit saubern Kupffern versehen; wobey auch eine ausführliche Land-Charte der Sudwester- und Bandaneischen Insulen, welche in andern Land-Charten und Geographien nicht beschrieben, beygefüget worden;
Nebst
einem vollständigen Register.
Erfurt, verlegts Joh. David Jungnicol, 1751.

Preparing for the Ambient Intelligence Landscape

The DigiCULT Roadmap strongly relates to the vision of Ambient Intelligence (AmI). AmI informs the Information Society Technologies priority of the European Union's Sixth Framework Programme for Research and Technological Development, and is expected to be carried on in the Seventh Framework Programme. Therefore, this chapter first describes the AmI vision. Secondly, a summary is given of parts of the *Ambient Intelligence in Everyday Life* (AmI@Life) pilot science & technology roadmap, which addresses cultural heritage. Finally, technologies that the AmI@Life roadmap considers to be key for the AmI application domains cultural heritage and cultural participation are aggregated in a tabular overview. This should provide a first picture of technologies deemed relevant in innovative RTD towards future systems and applications in these two largely overlapping domains.

The vision of Ambient Intelligence (AmI)

The IST Advisory Group (ISTAG) has, over the past six years, developed the concept of Ambient Intelligence (AmI) as a shared general framework and continual inspiration of research, technological and industrial development for a thriving European information society.[13] Described in the form of a condensed scenario, the AmI vision includes:

In all our living, working, leisure and other spaces information technologies, computers and other devices fade into the background because we are surrounded by intelligent environments with intuitive interfaces embedded in all kinds of objects. The scenario also includes smart mobile devices, personal digital assistants and close to body technologies such as 'wearables' that incorporate interfaces (e.g. 'smart' clothes). The objects and devices connect to various networks and systems and also form ad hoc networks to support us in all kinds of activities. They recognise our presence and changing needs and wants as well as relevant changes in the environment. They respond in a seamless, unobtrusive and often invisible way, nevertheless remaining under our control. We can depend on and trust in these systems, but also opt for voluntary exclusion. In particular, we are no longer forced

How Ambient Intelligence may become real

Jari Ahola (VTT Information Technology, Finland) writes: 'Making AmI real is no easy task: as it commonly takes place with new technologies, soon after high-flying visions we are demonstrated with the first pieces of hardware for the intelligent environment. However, making a door knob able to compute and communicate does not make it intelligent: the key (and challenge) to really adding wit to the environment lies in the way the system learns and keeps up to date with the needs of the user by itself.'

Ahola continues: 'A thinking machine, you might conclude – not quite but close: if you rely on the intelligent environment you expect it to operate correctly every time without tedious training or updates and management. You might be willing to do it once but not constantly even in the case of frequent changes of objects, inhabitants or preferences in the environment. A learning machine, I'll say.'

J. Ahola: "Ambient Intelligence"; introduction to *ERCIM News,* No. 47, p. 8, October 2001. http://www.ercim.org/publication/Ercim_News/enw47/

[13] IST Advisory Group, http://www.cordis.lu/ist/istag.htm; cf. the first major ISTAG report Scenarios for ambient intelligence in 2010, published in 2001, and subsequent reports, http://www.cordis.lu/ist/istag-reports.htm

to conform to computers, take steep learning curves, acquire specific skills and perform complex tasks. Rather, interacting with computers becomes natural and intuitive, relaxing and enjoyable. This involves the opportunity to use all our senses such as voice (natural language), eye movements, touch, pointing, gestures or facial expression for interacting with the various AmI environments. While the IST Advisory Group has developed comprehensive Ambient Intelligence scenarios and published reports on issues such as trust, dependability, security and privacy, it considers AmI to remain 'an "emerging property", and that future scenario building and iterations of the vision should treat AmI as an "imagined concept" and not a set of specified requirements'.[14]

However, there is much ongoing research to develop AmI technologies and applications. To give a few examples: since the beginning of 2001, there have been many interesting projects in the IST Future and Emerging Technologies initiative 'Disappearing Computer';[15] Philips Research has strongly adopted the AmI vision[16] and coordinated the 'Ambience' project (2001-2003), which involved 20 European partners;[17] the recently launched Integrated Project 'Ambient Networks' strives to set new standards for future context-aware, multi-domain mobile networks.[18]

Other major industry players and research centres are working on AmI technologies under different labels such as IBM's 'Pervasive Computing',[19] Hewlett-Packard's 'Cooltown',[20] Xerox Corporation's subsidiary Palo Alto Research Centre where the term 'Ubiquitous Computing' was coined back in 1988,[21] and the Massachusetts Institute of Technology (MIT) industry-sponsored research programme 'Things That Think' and the Oxygen project.[22]

Furthermore, the expanding field of AmI RTD has established places where the multi-disciplinary community of researchers meets, such as the European Symposium on Ambient Intelligence (Eindhoven/NL, 2003 and 2004),[23] the Smart Objects Conference (Grenoble, France, 2003),[24] the International Conference on Pervasive Computing (Linz & Vienna, Austria, 2004)[25] or the UbiComp - International Conference on Ubiquitous Computing (Nottingham, 2004).[26]

Cultural Heritage in AmI@Life

In studies relating to the AmI vision, the heritage sector has been addressed in a fairly general form. The most detailed statements can be found in the *Ambient Intelligence in Everyday Life* (AmI@Life) pilot science & technology roadmap which was developed by the Institute for Prospective Technological Studies of the European Commission's Joint Research Centre (JRC/IPTS) in collaboration with the European Science and Technology Observatory (ESTO) network.

In the AmI@Life roadmap, a chapter that describes a broad range of application areas also addresses cultural heritage among a larger group 'Culture, Leisure, and Entertainment'.[27] Besides cultural heritage this group includes cultural participation ('out-of-house' cultural participation and recreation; creation & art); entertainment, media, avatars (personal information assistants), and sport & fitness.

The section on cultural heritage distinguishes four key functions and assesses the relevance of AmI technologies for them. Furthermore, in a 'function roadmap', timelines are given for some general developments in cultural heritage.[28] In the following we summarise the expected developments in the four key functions.

(1) Preservation & digitisation:

Here the authors mention, for example, regular transfer of digital stocks to new, well-established standards, and highly automated digitisation processes and workflows, but state that it is 'not certain that Ambient Intelligence as such will make a breakthrough'.

General development/timelines: Large-scale digi-

14 ISTAG: *Ambient Intelligence: from vision to reality*, September 2003, p. 3. http://www.cordis.lu/ist/istag-reports.htm

15 IST FET: Disappearing Computer (I+II). http://www.cordis.lu/ist/fet/dc-sy.htm

16 Philips Research. http://www.research.philips.com/technologies/syst_softw/index.html#ambintel

17 Ambience project. http://www.extra.research.philips.com/euprojects/ambience/

18 AN project. http://www.ambient-networks.org

19 IBM. http://www.research.ibm.com/thinkresearch/pervasive.shtml

20 HP. http://www.cooltown.com/cooltown/

21 PARC. http://www.parc.com/research/; the term was coined by their former chief scientist Marc Weiser. http://www.ubiq.com/hypertext/weiser/UbiHome.html

22 MIT: "Things That Think". http://ttt.media.mit.edu; MIT Oxygen project. http://oxygen.lcs.mit.edu

23 European Symposium on Ambient Intelligence. http://www.eusai.net

24 Smart Objects Conference. http://www.grenoble-soc.com

25 Pervasive conference. http://www.pervasive2004.org

26 Ubicomp. http://ubicomp.org/ubicomp2004/

27 JRC/IPTS - ESTO Study: *Science and Technology Roadmapping: Ambient Intelligence in Everyday Life (AmI@Life)*. Compiled and edited by Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI) and Olivier Da Costa (Institute for Prospective Technology Studies), pp. 70-77, June 2003. http://fiste.jrc.es/download/AmIReportFinal.pdf

28 *Cf. Ami@Life Roadmap*, pp. 131-132, and the tables on pp. 138-139.

tisation of written materials in 2003-2005; incorporation of the materials in databases until 2005, first simple applications available by 2005; increased interconnection of databases in 2006-2008; and large-scale digitisation of multimedia materials in 2009-2014.

(2) Organisation of cultural heritage (e.g. classification, metadata, indexing):

Knowledge technologies such as advanced data warehousing (object and multimedia databases) and knowledge discovery in databases (advanced searching & data mining) 'are expected to be major contributors'.

General development/timelines: Generalisation of content-based classification and indexation in 2006-2008 for general access by retrieval systems.

(3) Access to and retrieval of cultural heritage (including digital libraries):

This includes making cultural heritage multimedia libraries widely accessible to everybody, and user-friendly services at low costs for lifelong learning and training. Here the same technologies as for the topic 'organisation' plus cognitive vision (pattern recognition, fuzzy matching, content-based image indexing & retrieval) are 'expected to be very important'. Furthermore, the authors highlight 'any kind of natural-language query' and that 'requirements on communication and networking are also important, high-bandwith access is to be available to distributed large-scale repositories of culture, history and science'.

General development/timelines: Online libraries in 2003; generalisation of retrieval of cultural heritage on demand in 2007-2010.

(4) Intelligent heritage and cultural tourism (historic sites/museums/exhibitions):

Here, according to the authors, 'AmI technologies should play a major role', and the following groups of technologies should be of particular importance - advanced interface and display: multi-sensoriality, multi-modality, multi-lingualism, virtual & augmented reality, 3D displays, telepresence; and the knowledge technologies Semantic Web, advanced knowledge management, advanced data warehousing and converging media.

General development/timelines: First-generation interactive and augmented reality exhibitions in 2003-2005; multi-sensorial, multi-modal exhibitions in 2009-2014; widespread use of virtual reality for education and recreation in 2008-2012; widespread use of virtual environments starting from 2020.

Ami@Life Visions for Intelligent Heritage and Cultural Tourism

In the AmI@Life roadmap, enhancing and personalising visits to historical sites, museums and/or exhibitions is considered very important for intelligent heritage and cultural tourism. The authors expect that the cultural tourism of the future 'will be a combination of exhibitions of real artefacts and access to virtual multimedia material from cultural heritage stored in museums and exhibitions around the world'. It also gives the following visions:

'Recreation and animation of historical and cultural objects or buildings, living experience of travelling through time/or space (visit of the castle in XII century and/or link to similar castles in the same region/country...).'

'Meta-exhibitions: while visiting a painting exhibition, it is possible to virtually access other paintings of the same authors, from the same school, from the same period, of the same geographical location... even if these paintings are in the real world spread all over the world.

It is also possible to consult, at the required depth, information on the painter, the painting technique, the subject of the painting etc. Each visitor can draw his own route through the meta information-space including some of the material present in real life.'

JRC/IPTS - ESTO Study: *Science and Technology Roadmapping: Ambient Intelligence in Everyday Life* (AmI@Life), p. 73.

Key technologies for the AmI application domains cultural heritage and cultural participation

The following table gives an overview of enabling technologies, which in the AmI@Life roadmap are deemed relevant in innovative RTD towards future systems and applications for cultural heritage and cultural participation:

This overview is based on the relevant tables of the AmI@Life roadmap (Annex B.5). In these tables the domains 'cultural heritage' and 'cultural participation' are split into key functions (e.g. preservation as a function of cultural heritage organisations) and for each function the relevant technologies are listed sep-

Communication & Networking	Local and external network: LAN, WAN, civic network; satellite; WLAN & broadband & ad hoc networks; 3G+ mobile systems; Fixed/mobile integration
Software	Large-scale distributed systems; Embedded systems; New and open standards; XML, WML, XSL languages; Intelligent Agents
Microsystems & Electronics (Storage) and Power sources	Networked sensors & actuators; Magnetoresistance technology (PCMCIA), electronic book; Lower power consumption
Displays and User Interfaces	3D displays; Multi-modality & multimedia interface (sound, video, animation, graphic and photographic); Multi-sensoriality; Multi-lingualism; Virtual & augmented reality, Telepresence; Breakthroughs in input/output
Knowledge Management	Semantic Web, ontologies; Advanced Knowledge Management; Networked knowledge sharing; Advanced data warehousing; OLAP, advanced query system; Access, searching and browsing technology; content on demand technology (including AoD and VoD); Converging media
Artificial Intelligence	Content-based image indexing and retrieving; Information extraction; Context-sensitive search & retrieval; Context-sensitive & affective computing; Advanced profiling; Learning & adaptive systems: Speech recognition; Cognitive vision; Fuzzy matching; Entity recognition

arately. As the AmI@Life tables for the two domains as well as their functions show considerable overlaps in technologies, we combined them to avoid too much duplication.

The reasons for including the domain 'cultural participation' are, first, that related activities would certainly also involve cultural heritage spaces and services and, secondly, that what are described as ICT applications for the two key functions of cultural participation may well form part of the digital heritage space.

For the key function 'out-of-house cultural participation and recreation', this includes enhancement and personalisation of the experience of 'out-of-house' cultural activities (related to cinema, theatre, amusement parks, etc.). These may be achieved through, for example, pre-/virtual/multi-modal/augmented real life & post-visits including context-aware location-based services, peer-to-peer and social network applications. For the key function 'creation & art' are mentioned new ways of sharing experience and sensations, of co-production and co-creation between artists, and new forms of art as a result of human-machine and machine-machine interactions.


SIMSON

From Digital Collections to Cultural Experience, Learning, and Knowledge

'People still want to find themselves in heritage resources, and will want to create their own resources…'. An expert from a governmental body or agency

'Bringing heritage resources more close to the public, easier'. An expert from an educational institution

'A parallel virtual cultural heritage, without limit to consumption and experience', Elisabetta Lazarro, ECARES, Universite Libre de Bruxelles, Belgium

'Difficult to answer given that of late there appears to be the tendency to do it like the Americans and let technology lead design, not like Europeans in the past, particularly in Scandinavia, where design lead technology…', Elizabeth Selandia – Art Historian, Member of VRA, USA

Statements from the DigiCULT online consultation forum, October/November 2004

From the overview of what the Ami@Life roadmap expects for cultural heritage and cultural participation in the next 10 to 15 years, we conclude that there is an emerging agenda for innovative RTD in systems and applications able to handle increasingly complex information environments and resources. These systems and applications, environments and resources should ultimately morph into a digital heritage space.

Actually creating such a space cannot be achieved by RTD alone. It needs the involvement of leading heritage institutions and networks. Some 'bottom-up' drive towards the next level of a highly integrated and user-centred digital space may be expected from these institutions and networks. In the past 10 years, they have taken the lead in an evolutionary process that has brought about the current state in the provision of access to digitised and born-digital heritage resources.

These larger institutions and cultural networks have begun to understand that 'access' alone is not enough, perhaps even the wrong mind-set and approach to moving forward.[29] People with an interest in cul-

[29] For a thorough clarification of this observation from one of the most advanced user-centred organisations in the field, as well as the proposed next steps, see the recent study report of the Virtual Museum of Canada: *The Next Generation*, by S. Dietz, H. Besser, A. Borda, and Kati Geber with P. Lévy. Canadian Heritage Information Network (CHIN), 2004. http://www.chin.gc.ca/English/Pdf/Members/Next_Generation/vm_tng.pdf; see also "The Idea of the Next Generation". http://www.chin.gc.ca/English/Members/Next_Generation/idea.html However, in order not to create misunderstandings, 'Access' is still an issue! For example, of the millions of hours of audio-visual heritage only very little is accessible to scholars or the interested public (e.g. the Institut National de l'Audiovisuel [INA] has about 1.5 million hours of such content, but less than 1 per cent is currently accessible. *Cf.* http://www.ina.fr

ture, history, arts and sciences do not really benefit from simply accessing online collections. For example, there is no real benefit in gazing at images online, just as there is little acquisition of cultural knowledge when reading some descriptive information (metadata) attached to images. However, there are millions of Euros being spent on digitising heritage resources, with little likelihood of an educational, social or economic return on investment because the next step towards creating engaging cultural experiences with these resources is not being considered.

However, we have entered the age of the 'experience economy'[30] and the heritage sector may rank considerably below the current level of what the various service industries (including media and entertainment) have achieved so far and are heading for.[31] Consumers today take service for granted. What they are seeking are unique, meaningful and memorable experiences. This is not an argument for turning cultural heritage services into entertainment but a warning that services that do not invite, inspire, engage or immerse will not find a wider use. Consequently, the RTD agenda for the heritage sector should strongly concentrate on applications that enhance experiences and novel ways of imparting knowledge. It should focus on fostering cultural learning at all levels, from school children to lifelong learners.

The next waves of ICT systems and applications should pave the way towards a digital heritage space,

Experience prototyping

As described by the IST Advisory Group in their report *Ambient Intelligence: From Vision to Reality* (September 2003), 'experience prototyping' will be key to turn the vision into a reality. The ISTAG suggests that RTD increasingly needs 'to allow people to live in their own future' in order to bring the research closer to the needs of citizens and businesses. 'Requirements engineering for Ambient Intelligent systems design can no longer be seen as a task that can be accomplished through the development of scenarios and the translation of use cases into system requirements. System functionalities that generate true user experiences can only be determined in a reliable way from feasible prototypes providing proofs of concept. New approaches to prototyping are likely to be key to the successful development of AmI products and services.' Experience prototyping places the emphasis on the quality of the users' interactions and experiences. It should enable design teams, users and clients to gain first-hand appreciation of existing or future conditions through active engagement with prototypes. This extends well beyond the kind of scenarios, use cases, requirements engineering for software design and usability studies that are in practical use today.

This was seconded by many participants in the DigiCULT online consultation forum. To give but two examples: Addressing issues of knowledge provision, Martin Doerr (Head of the Centre for Cultural Informatics, ICS/FORTH) wrote: 'Computer science tends to rehearse trivial reasoning examples (such as white elephants, non-flying birds, student-professor scenarios); e.g. whole conferences on Digital Libraries are held without any significant participation of librarians or user groups. I expect from a stronger involvement in applications a strong increase in pure and applied research challenges. Only bioinformatics has so far reached such a status.' Another participant, Anne Gilliland-Swetland (Department of Information Studies, UCLA) stated with respect to 'intelligent heritage': 'The gap is more in the research and development than in the technology. Information retrieval has not focused on the particular challenges offered by cultural, other language, and historical materials and practitioners have not been sufficiently resourced or trained to participate in such R&D. (...) Incentives have to be given to support the development of testbeds from which generalisable data, benchmarks, and outcomes can be generated.'

ISTAG reports:
Ambient Intelligence: from vision to reality (September 2003), S.27-29.
http://www.cordis.lu/ist/istag-reports.htm;
Experience and application research. Involving Users in the Development of Ambient Intelligence (Final Report, v1, 22 June 2004).
ftp://ftp.cordis.lu/pub/ist/docs/istag-earc_wg_final_report_v1.pdf

[30] Joseph Pine and James H. Gilmore, *The Experience Economy* (Boston: Harvard Business School, 1999); Bernd H. Schmitt, *Customer Experience Management* (New York: The Free Press, 2001); for an earlier work on this topic from the perspective of cultural sociology, see Gerhard Schulze, *Die Erlebnisgesellschaft. Kultursoziologie der Gegenwart*, (Frankfurt a.M./New York: Campus, 1992).

[31] See, for example, the suggestions of Flavio Tariffi: "Intelligent Heritage: The industry perspective" (28-01-2004). http://www.cordis.lu/ist/directorate_e/digicult/publications.htm. See also the trends discussed at the TiLE 2004 conference. TiLE is a major forum for leisure venues and visitor attractions that entertain, educate and inform. This includes museums, science centres, planetariums, aquariums, natural heritage sites, and culturally themed urban environments (e.g. historic city centres). Relevant on-site applications, for example, include audiovisual technologies, multimedia, animatronics, simulation, virtual reality. http://www.andrich.com/tile/downloads/TiLE_2004_Programme.pdf

within a wider landscape of ambient intelligence infrastructures. And a major, medium- to longer-term challenge for the heritage institutions and networks is to connect strongly with this vision and make it work for them and their customers. Ever more massive distributed and embedded computing and communications, smart devices, novel interfaces, positioning and context-awareness technologies, etc. will be provided by the ICT industries. However, when it comes to prototyping novel cultural experiences in ambient intelligence environments, new forms of collaboration and true interdisciplinary efforts will be needed. Therefore, cultural hotspots such as historic city centres, museums, science centres or heritage sites should be strongly involved.

There is a clear need to involve, in a more qualitative and effective way, experts from the cultural, artistic and scientific heritage organisations (e.g. curators, archivists, librarians, educational programme managers) as well as Arts & Humanities scholars and students. Too often purely technology-driven projects, proof of concept with little cultural heritage basis and other shortcomings, have hampered the creation and dissemination of RTD results that would need to find their way into the heritage sector.

A Radar on Developments in Ambient Intelligence Technologies

During the expedition, our radar sets detected a number of interesting developments in some of the technologies deemed relevant in innovative applied RTD towards systems and applications for cultural heritage and cultural participation (*cf.* table on p. 19). Due to space constraints, we cannot address all technologies and, even for those selected, the descriptions must be kept short. The overview is based on a variety of literature, in particular roadmaps that associations, consortia, individual players and projects in different ICT domains have published in the last few years.

We thought it useful to provide a broad picture of technological concepts, likely achievements, and foreseeable impacts that may shape and re-shape the digital landscape in the next ten years. Some of the developments described may even seem far removed from what currently counts as relevant for heritage organisations, but a radar scan would be wrongly adjusted if it did not show strange objects a ship may run into. For example, reflecting on a symposium on future digital libraries sponsored by the National Science Foundation, Clifford Lynch, the head of the US-based Coalition for Networked Information, acknowledges the enormous progress made in digital libraries, but urges recognition of 'the limitations of a research program focusing on digital libraries as we understand them today'. He insists: 'We must be careful not to overly-emphasize the parts of this knowledge ecosystem that are familiar, that we are comfortable with intellectually, socially and economically, to the exclusion of the new, the unfamiliar, the disturbing, the confusing.'[32]

The overview includes local and wider-area information and communication systems, devices and applications visitors of heritage buildings or sites may carry with them, as well as new interfaces and modes of interaction they would expect when they come to (or pass by) a museum, gallery, archive, library, historic city centre or other larger heritage area. The rationale behind the overview is that heritage organisations failing to adopt such systems, applications and interfaces according to their service objectives (e.g. exhibitions or other opportunities to learn about and experience heritage) may become blindspots in the future AmI landscape. Therefore, they may want to prepare strategically for this landscape in order to become part of it in a conscious and planned way.

Preparing for the developments described below ensures that boards and directors, ICT project managers, curators of digital collections, virtual exhibitions and environments have them on their radar screens. Plans for major investments in digital infrastructures, services and applications for online and onsite deployment should take into account the relevant developments. Which could lead to opportunities for participation in 'experience prototyping' projects that develop AmI services and applications in order to gain first-hand know-how, putting these institutions among the first who attract on-site and online visitors with compelling new experiences.

In the following sections we will proceed from micro-level physical up to Semantic Web technologies.

Microprocessors, Systems-on-Chip (SoC) and massive data storage

We have already entered the 'post-PC' era of ubiquitous computing.[33] Computing started with one (mainframe) computer for many people, became one computer per person (the personal computer), and now means many computers per person. For every PC that is sold there are over 100 microprocessors being embedded in all sorts of things in our environment. In the next five to ten years this ratio will skyrocket even further.[34]

In the past four decades microprocessors have shown a dramatic development, which more or less corresponds to 'Moore's law', which states that the complexity of circuits on a silicon chip should double about about every 18 months for the same price.[35] This development is expected to continue for several chip generations, as predicted by the International Technology Roadmap for Semiconductors (2003).[36] According to assessments by the major companies, 'Moore's law' may slow towards 2010, but the reduction in cost per function on the chip would continue at the same rate (approx. 30 per cent per year).

Overall, the base CMOS (complementary metal oxide semiconductor) technology seems to have a lot of life left in it. It is expected to dominate the digital

32 Clifford Lynch, "Reflections Towards the Development of a ‚Post-DL' Research Agenda. Wave of the Future", NSF Post Digital Library Futures Workshop, 15-16 June 2003. http://www.sis.pitt.edu/~dlwkshop/paper_lynch.html

33 An excellent overview of research activities in ubiquitous computing is available at UK-UbiNet. http://www-dse.doc.ic.ac.uk/Projects/UbiNet/links.html

34 Fistera (Foresight on Information Society Technologies in the European Research Area), "Disruptions ahead - Disappearance of the Computer" (2004). http://fistera.telecomitalialab.com/disruptions.htm

35 A detailed discussion of 'Moore's Law' by Ilkka Tuomi describes the several reinterpretations of Gordon Moore's prediction from 1965, and gives ample proof that the factual development of microprocessors corresponded to none of them. See Ilkka Tuomi, "The Lives and Death of Moore's Law" in *First Monday*, vol.7, no. 11, November 2002. http://www.firstmonday.dk/issues/issue7_11/tuomi/ For a somewhat different view, see Jon 'Hannibal' Stokes, "Understanding Moore's Law". http://arstechnica.com/paedia/m/moore/moore-1.html

36 *International Technology Roadmap for Semiconductors*, 2003 Edition, Executive summary. http://public.itrs.net/Files/2003ITRS/Home2003.htm

world for the next ten years. Emerging technologies such as quantum devices, nanotechnology, molecular arrays and biological systems are unlikely to replace CMOS fully in the foreseeable future. Rather, they may complement CMOS technology by extending some of its capabilities.[37] In the medium term, the introduction of new systems design, which includes self-testing and error-tolerant architectures, along with increasing integration levels, will lead to Systems-on-Chip (SoC), for which on-chip micro-networks are deemed to be one of the most promising design paradigms. SoC technologies should basically lead to embedding processing power in any electronic chip, making it much more convenient to package processing power in any appliance or object.[38]

Also data storage devices in recent years have shown remarkable development, with cost decreases of 35-40 per cent per year. Storage capacity will continue to evolve at a spectacular pace. To give but one example, the first generation of Sony's Super Advanced Intelligent Tape (SAIT-1), released in 2002, had a high-speed data transfer rate of 30 MB/s and a recording capacity of 500 GB uncompressed data (compressed 1.3 terabytes) on a half-inch, single-reel cartridge. Sony's intention is to double capacity and performance from generation to generation, achieving 4 TB, 240 MB/s with SAIT-4 in 2008.[39] Such magnetic tape recording technology is not only used as a cost-effective solution for traditional backup and archival storage, but also for new digital media storage and delivery applications such as those used in the broadcasting industry.

Roberto Saracco (Future Centre, Telecom Italia Lab) writes that 'we are on the threshold of a tremendous impact. By 2005 we may expect to have 500 GB of local storage available in many houses, exceeding 1 TB by 2010. This growth of local storage leads to an architectural change in the telecommunication network: today's drive to stream data will fade away. Burst communication will be the one used to download movies. People may tend to create their own cocoon of information locally always ready to tap.' However, with cheap massive storage also becoming available for consumers on carriers the size of a credit card or smaller, completely opposite models are also possible. For example: 'You go to a movie and as you pay the ticket you get, for free, a card with the 200 movies of the year. Back home you plug it in a reader on the television and you can get some peek at them. Should you decide to see a movie you simply ask for the decrypting code to be sent to you (and you'll pay for it). Movie download has shrunk from 2 GB to a few hundred of bytes, what it takes to ask and transfer the decrypting code.'[41]

Today's 'life bits' – tomorrow's 'meet your ancestors' archives

Cheap, massive storage will allow people... individuals, families, groups of friends, communities of practice... extensively to document their documents, images, videos, etc. of events, conversations, meetings, work and so forth.

This is explored in the MyLifeBits project by the Microsoft BARC Media Presence Group.[40] They describe it as 'an experiment in lifetime storage, and a software research effort'. The technical set-up of MyLifeBits includes a large database, tagging tools, hyperlinks, search & retrieval and presentation mechanisms such as timelines.

According to Doug de Groot, who works on avatars and other types of digital life at Leiden University (NL), such a system 'could eventually form the basis for „meet the ancestor" style educational tools, where people will quiz their ancestors on what happened in their lifetimes' (from *Newscientist.com*, 2002).

Sources:

MyLifeBits project: http://research.microsoft.com/barc/mediapresence/MyLifeBits.aspx

Newscientist.com (2002): "Software aims to put your life on a disk" (20 November 2002). http://www.newscientist.com/news/news.jsp?id=ns99993084

Smart sensors and tags

In the next 10-15 years, computers will follow Marc Weiser's dictum: 'The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.'[42] This means that 'intelligence' will increasingly be embedded in all kinds of objects in our living environment like walls, floors, tables, chairs, clothing, toys, pens, etc., ready to enhance our capabilities in everyday activities. The objects will be networked wirelessly, dynamically configurable, and communicate with each other and the user by means of ad-hoc networking.

A key role in this development is played by sensors and actuators. Sensors are tiny devices based on microchips that convert analogue data about anything physical such as light, temperature, acoustics, pressure, force, motion, position, distance, navigation, accelera-

37 *Cf.* European Commission, IST programme, Future and Emerging Technologies (2000): *Technology Roadmap for Nanoelectronics*, Second Edition, Editor: R. Compañó, November 2000, http://www.cordis.lu/ist/fet/nidqf.htm; Giorgio Baccarani (ed.): *International Workshop on Future Information Processing Technologies* (IWFIPT-2001, 3-6 September 2001, summary report), http://www.ercim.org/EU-NSF/IWFIPT.pdf; Consortium of European Companies Determined to Use Superconductivity, "Conectus Superconductivity Roadmap", March 2004. http://www.conectus.org

38 A good description of SoC is given in Luca Benini and Giovanni De Micheli, "Networks on Chip: A New SoC Paradigm" in *IEEE Computer*, January 2002. http://akebono.stanford.edu/users/nanni/research/net/papers/computer02.pdf

39 *Cf.* Sony's SAIT roadmap. http://www.sony.ca/storage/media.htm#

40 Microsoft BARC Media Presence Group. http://www.research.microsoft.com/barc/

41 Roberto Saracco, "Information and communication technologies: disruptions to look for and their impact on countries' evolution strategies, Technology Foresight Summit, Budapest, 27-29 March 2003. http://www.unido.org/file-storage/download/?file_id=10489

42 Mark Weiser, "The Computer for the Twenty-First Century" in *Scientific American*, pp. 94-100, September 1991. http://www.ubiq.com/hypertext/weiser/SciAmDraft3.html

Example: Intelligent carpets
Infineon Technologies AG (Munich, Germany) develops 'Technology Lifestyle Solutions', applications for everyday life into which electronic functions are integrated. For example, together with Vorwerk Teppichwerke (Hamlin, Germany), Infinion's technology lab developed a 'Thinking Carpet', a networked carpet with a self-organising network of microchips. Depending on the desired dispersal of detected signals, the carpet carries from one to 25 sensors per square metre in its backing. Self-organising means: If a sensor fails for some reason, the neighbouring processors can look for a new connecting route, which circumvents the defective region and maintains functionality. This also makes it possible to cut the carpet, replace segments or add new ones at any time. The carpet allows for simple and space-saving placement of sensors for a wide variety of functions, e.g. alarm and climate control. Also guidance systems are possible through light-emitting diodes in the carpet. The prototype was presented at the international Orgatec 2004 trade fair in October 2004 in Cologne, Germany. It is estimated that two years of further development will be necessary before the 'thinking carpet' attains market maturity.
Imagine a future museum in which the flooring (though not a carpet) would sense the visitors, guide them, and also redirect their flow if some exhibition space is already overcrowded.
Sources: "Future requires Visions: Vorwerk Teppichwerke and Infineon are revolutionising the wall-to-wall carpet..." (29 October 2004). http://www.infineon.com (see news archive; the detailed article also contains several images).

tion, speed and so forth into bits and bytes. Increasingly, sensors will bridge the physical and the digital world, and together with actuators form 'context agents' in ambient intelligence networks. Particularly smart are sensors that can be adapted to new functions and conditions during the operating phase or even have self-calibration, self-adaptation and self-diagnostic capabilities.

Sensors on semiconductor basis and fibre-optic sensors (e.g. for use in LANs) are far from being new developments; rather, they have represented enormous growth markets for many years.[43] MicroElectroMechanicalSystems (MEMS) technologies play a key role, making it possible to miniaturise sensors and integrate their sensor elements with microelectronic functions in minimal space. A benchmark for the miniaturisation of sensors is the vision of 'smart dust', an autonomous sensing, computing and communication system called 'mote' packaged within one cubic millimetre (1 mm^3).[44]

There are already a number of ambient intelligence prototypes that incorporate sensor and related technologies, such as the 'smart-its' developed in the European project of the same title. Objects fitted with 'smart-its' can recognise their local environment and share their observations with other objects within the environment.[45] Another example is SoapBox (Sensing, Operating and Activating Peripherial Box for intelligent environments), developed by the Finnish technology centre VTT.[46]

Also important to watch will be the developments in smart tags. It is expected that the costs for active Radio Frequency Identification (RFID) tags might well be brought down from 1 Euro to a few Euro cents per unit. Coupled with a growth in their capability, this would lead to an explosion in the application of smart tags. Low-cost levels may be reached by new fabrication methods for silicon-based solutions,

43 *Cf.* Intechno: "World Report: Sensor Markets 2008. Worldwide analysis and forecasts of sensor markets until 2008", Basle, May 1999. http://www.intechnoconsulting.com/pdfs/E%20Sensors%20Presse.pdf (gives a concise overview of the results).

44 *Cf.* "Desirable Dust", *Economist.com*, 31 January 2002, http://www.economist.com/surveys/displayStory.cfm?Story_id=949030; "Smart Dust. Mighty motes for medicine, manufacturing, the military and more", *Computerworld*, 24 March 2003. http://www.computerworld.com/mobiletopics/mobile/story/0,10801,79572,00.html?from=story_package

45 Smart-Its project. http://www.smart-its.org/

46 VTT SoapBox. http://www.vtt.fi/ele/research/tel/projects/soapbox.html

Information pick-up at exhibitions or heritage sites

In the coming years, growth in capability and dramatic cost reduction will lead to a much wider application of smart tags. In fact, within 10 to 15 years every conceivable object could have a tag – for example, all objects on display in a gallery or somewhere on a larger heritage site. Consider that a host of devices will be able to read the tags, and connect to a database for retrieving information about the objects, their history, meaning, and relation to other objects on display or even in a library on another continent.

The visitor may select the information himself, or set his device in a 'pick-up mode' for capturing and storing the information on, or related to, the exhibition objects he is close to. For example, this could be the URLs of 3D copies of the objects, and other objects that for various reasons may not form part of the exhibition. It could also be the URL of parts of an electronic exhibition catalogue, scholarly articles, or any other information considered to be of value for different user groups. The visitor's device would capture and retain only the information or links he has defined as of particular interest.

At home, in a school class or in a university seminar, he would read the information to a PC, TV set-top box or other terminal, and access the resources on the Web for further study of the 3D objects, for presentation slides, an educational work sheet, etc., in the company of a partner, a child, friends or colleagues. This scenario illustrates that there are many opportunities for connecting an institution's collections with the classroom, the university and lifelong learners at home.

Interesting examples of the current experiments with smart tags are, to name but two examples:

The *Ambient Smart Tags Repositories for Art Learning* (ASTRAL) pilot, designed and implemented by Giunti Interactive Labs in the framework of the WebKit project (http://www.projectwebkit.com), is described in David L. Fuschi / Fabrizio Cardinali: "Using RFID tags for ambient learning & training" in *DigiCULT.Info* 7, April 2004. http://www.digi cult.info/pages/newsletter.php

In a project called *TaggedX*, the Museum of Natural History, in Aarhus, Denmark, with two partners from regional RTD companies, explores the use of RFID-enhanced exhibitions to better educate and entertain visitors. For a description of the learning model and technical set-up, see Farhat Khan, "Museum Puts Tags on Stuffed Birds", 7 September 2004. http://www.rfidjournal.com/article/articleview/1110/1/1/

organic thin-film transistors on flexible polymeric substrates, or just printing electronics directly onto packages of consumer goods or the objects themselves.

Mobiles, Wearables and Personal Area Networks

The 'post-PC' era of ubiquitous computing is also driven by a boom in mobile devices and information appliances that will become ever cheaper, more energy efficient, seamlessly interoperable, configurable over the Internet as well as always and optimally connected. In fact, mobile communication represents a highly innovative area in which Europe has particular strength (e.g. world leadership in GSM).

Much is expected from the next waves of smart phones, although in Europe they currently show a low market penetration of about 2-3 per cent. Mobile entertainment services (other than ringtones and logos) have less than 1 per cent market share. Nevertheless, for the second half of 2004 all major manufacturers (Nokia, Sony Ericsson, Siemens, Motorola) have announced various new products, such as phones equipped with 1.3 mega pixel cameras. Some are even preparing to offer GSM models with WLAN capacity.[47]

Overall, future mobile devices are likely to have much more processing power as well as dynamic memory, multimedia accelerators that allow for a much richer visual experience, and multiple types of wireless capabilities. They will have features such as 'smart hand off', allowing the device to connect automatically to either a Wi-Fi or cellular network depending on the most cost-effective connection available. Furthermore, different kinds of flexible screens may evolve that, for example, roll out of the side of the device.[48]

The major bottleneck lies in the energy sources, where the improvements in the last ten years, i.e. from NiCad to NiMH to Lithium Ion, and currently Lithium Polymer batteries, have been far from revolutionary. Developers of fuel cells believe they have the potential to offer eventually at least ten times the energy density of current lithium-ion batteries for handheld and mobile electronics, all-day mobile com-

47 "Surpassing Expectations" in *Economy Tribune*, September/October 2004, p. 43.

48 *Cf.* David Shier, "The Future of Windows Mobile Devices", November 2004. http://www.pocketpcmag.com/_archives/Nov04/WindowsMobileDevices.aspx

puting on a single battery charge, and considerable gains in battery life. However, due to safety issues they may not make it into handheld and mobile devices for many years, perhaps never.[49]

Increase of power density, control of energy consumption, and creation of long lifecycle batteries are still key research goals. These are important because ubiquitous computing and communication also needs ubiquitous availability of energy sources. Batteries and micro-energy generators will play a crucial role for the emerging ambient intelligence space.[50]

Alongside future generations of handheld mobile devices and personal digital assistants, 'wearables' are evolving rapidly.[51] Such near-body devices form a fairly broad category, which includes, for example, clothing that records biodata, glasses with headphones embedded in the sides and information display via the lenses, leisure and sports wear with integrated MP3 player, mobile telephony and other features, clothing or bags for children with a display for playing games, GPS localisation, and miniature microphone or camera.[52]

Wearables may also form the centrepiece of personal or body area networks that connect the individual to an adaptive intelligent environment. In particular, the fusion of the mass-market electronics and textiles & accessories has a high potential for application areas such as entertainment, security and health.[53] Other areas where wearables are expected to see wider use are various professional environments such as medical care, maintenance and emergency.[54]

Novel displays and interfaces

The next ten years will see a diversification and much wider spread of displays. A variety of technologies are promising to offer new ways of dis-

Some likely innovations in displays and data projection

Bill Buxton, IT designer and consultant, gives the following examples of probable near- to medium-term innovations in displays and data projection applications:

'(...) take a look at the plasma panels that are replacing signs and posters at cinemas and airports. If these devices are being used now, when they cost about $10,000 apiece, imagine what we'll see when technologies like light-emitting polymers and e-Ink allow us to make even larger, thinner and higher-quality displays for perhaps as little as $100. In the mid-1800s, the introduction of the blackboard revolutionized classroom education. These displays could have a similar impact, not only in classrooms (in the form of electronic whiteboards) but also for signs, home entertainment and even interior wallpaper.

'At the same time, we are seeing the emergence of smaller, brighter and cheaper data projectors. The technology in supermarket bar-code scanners is being transformed to create miniature high-resolution color laser projectors the size of a fingertip. Within a couple of years you will see them integrated into your cell phone and pda; if you want to view data that won't fit on such small screens or if you want to look at the information with someone else, you can use those devices to project it onto any wall, tabletop or other surface so it appears as large as you'd like, always in focus.'

Bill Buxton, "Forward into the Past" in *TIME Magazine: Visions of Tomorrow,* Special Report, Vol. 164, No. 15, 11 October 2004. http://www.time.com/time/covers/1101041011/nextessay.html#

49 *Cf.* Ron Schneiderman, "On and On Forever" in *Vision*, September/October 2003. http://www.ce.org/publications/vision/2003/sepoct/p14.asp?bc=dept&department_id=14; see also Shier 2004 (above); forecasts to 2012 for fuel cells are given by ABI research (2003). http://www.abiresearch.com/market_research/fuelcells.jsp

50 *Cf.* Fistera 2004, Fistera Technology Database: Small Devices for Energy Storage/Production. http://fistera.telecomitalialab.com/keepaneyeon.htm

51 For a rich overview of current work in wearable technologies, see http://whisper.surrey.sfu.ca/whisper_lit_review.htm

52 In the area of wearable electronics, industrial cooperations have, for example, been established between Philips and Levi Strauss & Co., Infinion and O'Neill Europe, and others. For images and descriptions of the current generation of products, see http://www.extra.research.philips.com/pressmedia/pictures/wearelec.html; http://www.oneilleurope.com/technical/hub.asp

53 For more information on smart textiles, see EPSRC Network – Smart textiles for intelligent consumer products (UK, http://www.smartextiles.net; Wearable Electronic & Smart Textiles (WEST) Interest Group. http://www.smartextiles.info

54 See the Integrated Project *wearIT@work*, http://wearable-computing.de, which will develop a Wearable Computing Roadmap.

playing visual and textual information, allowing for a seamless presentation of displayed information. There will be lightweight, flat and foldable displays; displays will appear on fabric, on the surface of any object through tiny, overlaying screens; and special paint may turn entire walls into screens. Furthermore, projection of information over glasses as well as 3D presentation of dynamic information may find broader use. A state-of-the art industry report on flexible displays, including chapters on standard as well as new technologies such as particle displays, OLED (Organic Light Emitting Diode) and others, is available from Intertech Corporation (2004).[55]

The emergence of ambient intelligence environments will be accompanied by a proliferation of interfaces other than WIMPs (Windows-Icons-Menus-Pointing devices). In the next 5-10 years, novel interfaces should highly increase the practicality and convenience of digital communication, information acquisition, learning and entertainment. For example, the MEDEA+ Applications Technology Roadmap (2003) highlights the 'overriding importance of better user-tuned interaction capabilities of nearly all applications'.[56] Such user-tuning should ideally be achieved through highly adaptive, personalised interfaces that allow for devices and input/output modalities to be adjustable to each individual.

While single devices may conform to this requirement fairly quickly, a major challenge for AmI environments lies in the interaction design or, rather, the authoring of the users' experiences in an environment. A good example of this is the 'distributed browser approach' suggested by Philips Research. This approach suggests a mark-up language to describe and control the devices within a location. Each device acts as part of the browser and together they render the experience. For example, an experience described as 'warm and sunny' could involve contributions from lights, the TV, the central heating, electronically controlled blinds as well as the ceiling, wall and floor coverings.[57]

Multimodal interaction

It is envisaged that in the near future multimodal interfaces will to a considerable degree enable us to control and interact with the environment and various media in a natural and personalised way. This should lead to highly convenient living environments (including opportunities such as entertainment, learning and creativity), as well as improving working environments in terms of productivity.[*]

Multimodal interaction includes voice, touch, pointing, gestures, eye movements and facial expression to communicate needs and wants. One important element in multimodal interfaces will, of course, be hands-free voice control of applications based on natural language recognition and understanding by computers to process the human input. On the other hand, machine output in the form of well synthesised language as well as language translation are also important features in future interactive environments. For example, experts think that by 2010 it will be possible to achieve a reasonably good translation of natural language. IBM, to name but one example, has set a goal for its research laboratory to have a natural language translator working in 28 languages by 2010.

Gesture or write your story in the air

The image below gives an example of new interface and interaction designs, as developed in studies by Philips Research. Here a girl in a family's children's playroom is interacting with an application that allows for generating a narrative in which she plays a role herself. The scenario includes motion capture by means of a camera and special software. To give another example in this domain, the Korean company MicroInfinity, which, among other technologies, develops advanced human interfaces (motion capture, head-mounted displays with head-movement tracking, etc.), recently presented a three-dimensional input application. With a special pen, words can be written in the air and are converted into a document format.

Sources:

Philips Research – Technologies: Ambient Intelligence, http://www.research.philips.com/technologies/syst_softw/ami/background.html; image: http://www.research.philips.com/newscenter/pictures/systsoft-ambintel.html

MicroInfinity. http://www.m-inf.com

For interacting in virtual and augmented reality environments, future developments should also lead to a more immersive experience. Besides more realistic

55 Intertech Corporation (2004), "Flexible Displays and Electronics: A Techno-Economic Assessment and Forecast", Portland/USA, 2004. http://www.intertechusa.com/studies/FlexibleDisplays/Flexible_Displays_g.htm

56 MEDEA+ Applications Technology Roadmap. Vision on Enabling Technologies of the future, Version 1.0, p. 8, 25 November 2003. http://www.medeaplus.org/webpublic/ExecChapters_ATRM.pdf

57 Philips Research, "PML [Physical Markup Language] - When your room becomes your browser". http://www.research.philips.com/technologies/syst_softw/pml/

* For an in-depth roadmap for RTD and design in novel interaction technologies see: L. Norros *et al.*, Human-Technology Interaction Research and Design. VTT Roadmap, Espoo 2003. http://www.vtt.fi/inf/pdf/tiedotteet/2003/T2220.pdf

and dynamic presentation and interaction, this would involve in particular re-creating the feeling and experience of being present in an environment, a 'sense of being there'. 'Haptics' play a major role in this, i.e. applications that offer force feedback interaction, perception of surface texture, etc., which is very direct and less intellectually demanding than other senses.

AWARENESS OF USER CONTEXTS AND PREFERENCES

In ambient intelligence environments, the information and communication technologies, the context in which they are deployed, and the users who make use of them together form a dynamic system. Therefore, regular or temporary 'inhabitants' of the environment should not be treated as outside the system but placed at its centre, with the technologies responding to their various needs and wishes. The expectation is that 'the applications will evolve around the user and the network will evolve around the applications'.[58]

In user-centred environments, awareness of user contexts and preferences may come from the analysis of sensor, tracking and positioning data, and continuous analysis of the use of services based on dynamic user profiles. The context-aware surroundings should, of course, not be intrusive for inhabitants, but actively support them in accomplishing various tasks by self-determining current context and providing or preparing available resources or services.

Currently, scenarios of context awareness often concentrate on individuals, but context-aware environments will also need to effectively support groups of people such as a family or a work team. Hence, many environments will also need to be capable of tracking and harmonising preferences of group members and currently available resources in an environment.[59]

Capturing, storing and re-using user contexts and preferences in networked environments will need to be accompanied by a sustained level of trust. According to the MEDEA+ Applications Technology Roadmap (2003), we may see 'security, safety and privacy issues penetrating into each person's life and becoming all-pervasive in both private and public domains'.[60]

Prototyping the user context and cultural experience at an open-air museum

Researchers from the Limburgs Universitair Centrum, Expertise Centre for Digital Media (Belgium), have explored the use of a mobile guide in a (prototype) AmI environment set up at the Centrum and the nearby open air museum Bokrijk and Gallo-Roman Museum of Tongeren. Currently, the mobile guide (PDA) works outdoors using GPS to position the user, and Bluetooth to communicate with physical objects that are in the direct neighbourhood of the device. As RFID tags have too restricted a communication range (maximum about 30 cm), autonomous processing units with Bluetooth support are used. Here, the complexity of actually prototyping the visitor experience can only be addressed briefly: For the 'context of use' the researchers use a CoDAMoS context ontology, which is built around four main entities: user, environment, platform and service. Furthermore, a proximity manager is used that provides the relevant map-based information according to the moves and turns of the cultural tourist. The proximity range, i.e. where the tourist should get which information, is different for different objects (the researchers suggest scaling the proximity range linearly with the object's volume and importance). Annotating the interactive maps with information on an object as well as its relations with other artefacts would be the task of a curator of the open-air museum. In this way, the subject-matter expert may well be the one who prototypes the cultural experience by drawing the visitor's attention to a particular artefact, its relations to others, and suggesting an interesting route to take through the cultural site.

Sources:

Kris Luyten and Karin Coninx: "ImogI: Take Control over a Context Aware Electronic Mobile Guide for Museums", Workshop on HCI in Mobile Guides, in conjunction with Mobile HCI 2004 (Glasgow, 13 September 2004). http://research.edm.luc.ac.be/kris/research/publications/mguides2004/luytenconinx-imogi-mobileguides.pdf

Companion Web page to the article: http://research.edm.luc.ac.be/~imogi/

CoDAMoS context ontology, http://www.cs.kuleuven.ac.be/cwis/research/distrinet/projects/CoDAMoS/ontology

58 Autonomic-communication.org, "Autonomic Communication Development", Summary Report: Situated and Autonomic Communications, ed. by Fabrizio Sestini (18/5/2004), http://www.autonomic-communication.org/about/; ftp://ftp.cordis.lu/pub/ist/docs/fet/comms-60.pdf

59 For a broad discussion of context-aware collaborative environments see the COCONET Research Agenda and Roadmap (11 June 2003), http://www.knowledgeboard.com/download/2655/COCONET_D2.3_11_06_2003.pdf

60 MEDEA+ Applications Technology Roadmap. Vision on Enabling Technologies of the future. Version 1.0, p. 8, 25 November 2003. http://www.medeaplus.org/webpublic/ExecChapters_ATRM.pdf

Agent technologies

Intelligent software agents are an evolving concept of computational entities that should have a number of properties such as autonomous, flexible and goal-directed behaviour in open distributed systems. Other important properties are cooperation in multi-agent systems and learning, i.e. the agent software application needs to be able to learn about changes in the systems and how to adapt to them without having to be told.

The classic examples are user-facing applications such as a personal assistant that helps its owner in various tasks such as finding specific information on the Web, the planning of activities such as travel, and even carrying out reservations and negotiating terms of payment. These are application scenarios that handle personally delegated responsibility. However, there are also many possible 'behind the scene' applications such as communications management. Here agents can be used to increase the local intelligence, thus relieving networks from heavy communication loads in the exchange of information between processes. In fact, using software agents to enhance the cooperation of components of distributed systems is one of the key application areas heading at more responsive, intelligent service provision.

Compared with the goals of autonomous, cooperative, flexible and goal-directed behaviour in open systems, agents today are fairly self-contained, limited to particular application fields and functionality. However, according to the AgentLink Roadmap (2003), the field of agent technology should mature fairly rapidly until 2010. From 2009 or so onwards, it should see 'truly-open and fully-scalable multi-agent systems, across domains, with agents capable of learning appropriate communications protocols upon entry to a system, and with protocols emerging and evolving through actual agent interactions'.[61]

Semantic Web Services

Web Services promise to realise a scenario in which people and automated mechanisms may call up and use Internet-based applications on the fly to perform a variety of tasks and transactions. In fact, Web Services allow different computer systems running different software applications to communicate with each other and conduct transactions over the Internet. As self-describing, automatically discoverable services, they may become completely decentralised and distributed over the Internet and accessed by a wide variety of communication devices.[62] In the next few years Web Services may also gain considerable momentum beyond the enterprise level, where they are increasingly used to eliminate the burden of complex, slow and expensive software integration. Instead, Web Services are used as the 'glue' to achieve reliable, automated integration between different systems and applications, based on specifications that are created and approved by respected bodies such as the World Wide Web Consortium (W3C) and the Organization for the Advancement of Structured Information Standards (OASIS).[63]

The Semantic Web is envisaged as a Web of machine-readable information that allows software agents to carry out tasks for humans automatically. In particular, it may be one answer to the 'information tsunami'[64] on the Web by creating growing islands of knowledge representation in an ocean of information that is poorly described and not semantically interrelated to allow for automatic interpretation and effec-

61 M. Luck, P. McBurney and C. Preist, *Agent Technology: Enabling Next Generation Computing*, AgentLink, 2003, p. 3. http://www.agentlink.org/roadmap/roadmap.pdf

62 *Cf.* The CBDi Web Services Roadmap, in particular: Lawrence Wilkes, "ROI - The Costs and Benefits of Web Services", 2003, http://roadmap.cbdiforum.com/reports/roi/; Jason Bloomberg, "The ZapThink Web services roadmap: It's going to be a bumpy ride", 1 July 2002, http://searchwebservices.techtarget.com/originalContent/0,289142,sid26_gci836909,00.html; a lot of further information may be found at http://www.webservices.org; http://searchwebservices.techtarget.com; http://www-130.ibm.com/developerworks/webservices/

63 W3C, http://www.w3.org; OAIS, http://www.oasis-open.org

64 See School of Information Management and Systems, University of California, Berkeley: "How Much Information?" (2003). http://www.sims.berkeley.edu/research/projects/how-much-info-2003/execsum.htm#summary

MuseumFinland – Finnish Museums on the Semantic Web

In March 2004, the pilot version of the semantic portal MuseumFinland was opened on the public Web. MuseumFinland is a portal for cultural content from distributed museums and provides the user with a semantic search engine and semantic browsing facility. The pilot exemplifies how heterogeneous cultural collections from different organisations can be made semantically interoperable and accessed in novel ways by making use of Semantic Web technologies. It has been in development since 2002 by the Semantic Computing Research Group (SeCo) of the Helsinki Institute for Information Technology (HIIT), and currently makes accessible content from the collections of the Finnish National Museum, Espoo City Museum and Lahti City Museum. These museums are located in different cities and use three different relational database schemas, data base systems and collection management systems.

Sources:

MuseumFinland: http://museosuomi.cs.helsinki.fi

Project information in English is available at http://www.cs.helsinki.fi/group/seco/museums/

A detailed description of the technological set-up is given by Eero Hyvönen *et al.*, "Finnish Museums on the Semantic Web: The User's Perspective on MuseumFinland" in *Museums and the Web 2004*. http://www.archimuse.com/mw2004/papers/hyvonen/hyvonen.html

In *DigiCULT Thematic Issue 3: Towards a Semantic Web for Heritage Resources*, May 2003, we published a primer on Semantic Web languages & technologies (XML, RDF ontologies, agents), which used the Finnish project as key example. See http://www.digicult.info/pages/Themiss.php

tive re-use. Key to realising the Semantic Web vision is syntactic and semantic mark-up of the descriptive information on Web resources based on standardised Web languages (XML, RDF, DAML+OIL, UML, OWL) that allow integration of information on the basis of generic and domain-specific ontologies.[65] Such ontology-based information (metadata) should enable software agents to 'understand' and reason over the information, and carry out tasks such as filtering, selecting and retrieving Web resources according to the specific interests of the users.

The use of semantics is not confined to user-facing applications. It will also be necessary to compose, federate and create flexible and adaptive service infrastructures. Actually, 'the final step' in autonomous computing is considered to be 'leveraging meaning into the network, using semantics and context to ensure both that communication technology takes full advantage of the context in which it is used, and that the context is well-served by the technology deployed. For instance, the notion of adding semantic tags to information exchanges – letting the network "know" what it is transporting – can be a key enabler for adaptive and other intelligent behaviour.'[66]

[65] James Hendler defines an ontology as 'a set of knowledge terms, including the vocabulary, the semantic interconnections, and some simple rules of inference and logic for some particular topic'. J. Hendler, "Agents and the Semantic Web" in *IEEE Intelligent Systems*, pp. 30-37 (quotation p. 30), March/April 2001. For further information, see J. Davies, D. Fensel, F. van Harmelen (eds.): *Towards the Semantic Web. Ontology-driven Knowledge Management*. (John Wiley, December 2002).

[66] Autonomic-communication.org, "Autonomic Communication Development, Summary Report: Situated and Autonomic Communications", ed. by Fabrizio Sestini (18/5/2004), http://www.autonomic-communication.org/about/; ftp://ftp.cordis.lu/pub/ist/docs/fet/comms-60.pdf

DigiCULT's Online Consultation Forum

Previous Thematic Issues focused on one family of technologies and were in part based on the results of a group discussion involving about ten experts.[67] In order to engage as broad as possible an expert group in the expedition towards the future digital heritage space, we established an online consultation forum on the DigiCULT Web site that operated for two weeks from 27 October to 12 November 2004.[68] The consultation spanned the following five themes, which were described briefly with respect to their scope:

T1: Intelligent & Contextual [MEANING],
T2: Natural & Enjoyable Interaction [EXPERIENCES],
T3: Create/Re-create [3D/AR/VR]
T4: Large Scale & Distributed [AUTOMATION]
T5: Persistent & Perpetual Access [PRESERVATION]

The short pieces of information given on these themes in the online forum are reproduced at the beginning of the following chapters respectively; an exemption is T1, which we found more useful to divide into 'intelligent heritage' and 'contextual cultural information'.

In the online forum, for each of the themes the same set of four questions was used:

Q1: What do you envisage could be achieved in this RTD area over the next 10-15 years?
Q2: What are currently the main RTD limitations or gaps that prevent us achieving this vision?
Q3: Considering these issues, what are the major steps or breakthroughs in RTD needed to achieve the vision? – How should these be addressed?
Q4: For each of the major steps or breakthroughs, please indicate the time period in which it is likely to be achieved (e.g. B1 in 20XX, B3 beyond 20XX).

Furthermore, the experts were asked to add any other information they considered valuable for creating the DigiCULT RTD roadmap.

Sixty-two experts from research centres, heritage organisations, cultural networks, educational institutions, and government bodies and agencies participated in the roadmapping exercise.[69] They answered the online questionnaire for at least one theme, and many of them gave their opinions on more than one or even all themes.

The following chapters summarise the contributions to the online consultation, which amounted to a document of about 200 pages. We found it useful to split the experts' contributions into two groups, one concentrating on 'hard' RTD issues, which includes research and development extending into a transition phase from RTD results (e.g. prototype applications, specifications, testbeds, pilot projects, etc.) to robust near-market solutions.

The other group of contributions concentrates on issues that may affect the uptake of new systems and applications by heritage organisations in favourable or unfavourable ways. The latter group of opinions is summarised on pp. 65-71. This summary is followed by an assessment of the likely adoption of certain already available and future technologies by institutions of different sizes.

67 *DigiCULT Thematic Issues 1-6*, http://www.digicult.info/pages/Themiss.php; brief information on the forum participants is to be found at http://www.digicult.info/pages/forum.php

68 See http://www.digicult.info/pages/drr_index.php

69 See the brief information on the participants in the Acknowledgements.

Theme 1: Intelligent Heritage

In the short piece of information given on the consultation platform, 'intelligent' was associated with the technological and semantic interoperability of heritage resources, particularly in relation to the vision of a Semantic Web. This includes new approaches in making heritage resources self-describing, retrievable and presentable based on conceptual models (e.g. semantic frameworks, ontologies, controlled vocabulary) and/or content features (e.g. content-based analysis, clustering and retrieval).

Experts' views

It is envisaged that semantic-based systems will provide people with better ways of dealing with an increasing information overload. This would involve not only finding what one thinks could be relevant, but also connections between areas of knowledge not previously considered. While for general searches 'brute-force' search mechanisms such as Google will most certainly remain dominant for a long period, one participant thought that with additional semantic analysis one might expect search engines to provide a scholars-only response with relevant academic resources, and responses suitable for a school child with learning material appropriate to its age group.

However, the world and the human interests are much more diverse than what separates a school child from a distinguished arts & humanities scholar. Regarding the scientific domains, Stefan Gradmann (University of Hamburg/RRZ, Germany) saw a considerable difference between the 'hard sciences' with their clear thematic restrictions (e.g. 'heart diseases') and fields of hermeneutic scholarship.[70] He expected 'robust and reliable semantically based operations on resource level to be available within the next

[70] Defined most generally, hermeneutics is the science of interpretation. On the important role hermeneutics should play in the design of human-centred ICT applications, see Terry Winograd and Fernando Flores: *Understanding Computers and Cognition: A New Foundation for Design* (Norwood, NJ: Ablex, 1986).

10 years for most of the hard sciences', while others might present 'major semiological obstacles'. Here metadata would be vital for semantic operations for at least another 20 years, 'even though some semantic "drilling" on resource level may be feasible in the meantime on the basis of semantic frameworks and – most important – affordable language engineering resources (lexica, morphological normalization tools etc.)'. However, Gradmann warned that there might be fundamentally inappropriate semantic approaches. As probably 'the' major breakthrough in intelligent systems, he suggested 'a machine that would model "understanding" in a hermeneutical sense, at least to some degree. This machine would to some extent carry out the very operations Weizenbaum's Eliza was only just faking to perform. I expect a "Non-Fake-Eliza" to be operational around 2010.'[71]

A warning against likely inappropriate uses of semantics

'In my vision the decisive gaps are not technical ones: I am rather certain that advances in Semantic Web and language engineering technology will be more than impressive, even though major investments will be needed (and made!) in that respect. The decisive limitation probably will be one of cultural differentiation: the basic requirement for conceptual models to function adequately is a proper recognition of the "semiological divide" that separates hermeneutically based scholarship from empiricist STM science. These two "cultures" have very different assumptions regarding the relation between linguistic signs and "things", between "concepts" and "words". Ignoring this difference would cause a fundamentally inappropriate use of semantic frameworks and ontologies in a hermeneutically driven context!' – Stefan Gradmann (University of Hamburg/RRZ, Germany)

Jacques Bogaarts (Nationaal Archief, The Netherlands) envisaged systems that allow users 'to point to a cultural heritage object, the real thing or a digital presentation of it, and as a result get all the contiguous material (objects and information) that is available'. For developing such applications, better cross-domain 'contiguity models' and algorithms would be necessary. These would take into account the fact that cultural heritage objects are mostly physical things, not digital, but also allow for defining and processing the contiguity of representations of physical things and born-digital objects (including products of imagination, e.g. chimera). Bogaarts and other experts agreed that for such applications new conceptual frameworks (e.g. CIDOC Conceptual Reference Model) needed to be applied to get much above basic models such as online thesauri.

Browser: Some interesting Semantic Web resources and projects

Currently, we may distinguish between grass-roots cultural heritage developments towards the Semantic Web making use of XML and RDF, and 'the fundamental route' of creating strong reference models and generic, foundational ontologies.[72] Much is expected from the cross-domain reference model CIDOC-CRM, of which version 4.0 was released in March 2004, and which has so far found only limited use in RTD projects (e.g. in the SCULPTEUR project).

For the more immediate future [2005-2009] we may expect a wider use of XML, and a slowly increasing uptake of RDF. Currently, tools for semantic annotation, ontology building and 'controlled vocabularies' (e.g. thesauri) on the basis of domain-specific ontologies are 'booming'. 'Merging' the current generation of domain-specific ontologies (for describing heritage objects) with 'middle-layer' and generic top-ontologies may be achievable only in a timeframe of ten years; working 'real-world' applications with reasoning mechanisms (software agents) may not appear until after that.

Some interesting resources and projects include:

Nick Crofts, M. Doerr, T. Gill, S. Stead and M. Stiff, (eds): "Definition of the CIDOC Conceptual Reference Model", March 2004 (version 4.0). http://cidoc.ics.forth.gr/official_release_cidoc.html

Standard Upper Ontology Working Group (SUO WG), References to Ontologies. http://suo.ieee.org/SUO/Ontology-refs.html

SWAD-Europe: Results of an EU-funded project in support of the W3C's Semantic Web Activity through research, demonstrators and outreach efforts. http://www.w3.org/2001/sw/Europe/ (for example, see their thesaurus activities and links)

On-To-Knowledge.
http://www.ontoknowledge.org

OntoWeb. http://www.ontoweb.org

WonderWeb. http://wonderweb.semanticweb.org

[71] "Eliza" is an Artificial Intelligence program that was created by MIT scientist Joseph Weizenbaum in the early 1960's. Weizenbaum named it after Eliza Doolittle, the figure from the musical *My Fair Lady* which is based on Bernard Shaw's classic *Pygmalion*. The program's mission was to attempt to replicate the conversation between a psychoanalyst and a patient.

[72] *Cf.* the interviews with Janneke van Kersen and Nicola Guarino in *DigiCULT Thematic Issue 3: Towards a Semantic Web for Heritage Resources,* May 2003, http://www.digicult.info/pages/Themiss.php

Kirk Martinez (University of Southampton, UK) expected for ontologies in the next 10-15 years 'a more common use of relatively few ontologies (so that interoperability is easier) relating to cultural heritage (e.g. CIDOC CRM – but others are needed too!)'. This would also be one of the cornerstones needed for a European Semantic Web based search engine for cultural heritage in member states of the European Union and beyond.

Martinez saw major current limitations as 'immature ontologies and relatively few users of it; difficulties getting a unified approach to using it and building semantic interfaces to digital collections in museums, libraries etc.' To kick-start the next level of RTD in these areas, funding needed to be reserved for some key (and maybe risky) projects. Good documentation of emerging standards for use in real deployments would help to achieve a more unified approach throughout the heritage sector. Martinez noted, furthermore, that there is currently 'little re-use of technologies made in one project – software is written and dies/is archived rather than used. The Open Source community shows us the way to keep the ball rolling on this area.' He urged that reinventing the wheel in each project should be stopped, by sharing maintained Open Source components.

A participant from the archival field noted that 'work on ontological harmonisation around a robust conceptual reference model is only beginning (i.e. CIDOC CRM is now starting work on harmonisation with FRBR, EAD and TEI[73]). When this work is complete we can proceed to testing this as a possible strategy for deeper query searches… In the next five years we should begin to have a good idea of whether this sort of logic will lead us in the right direction.' Besides ontology harmonisation and testing for good data-mining results, visualisation and clustering would also need to receive considerable funding in order to develop innovative forms in which to represent the results from deep query searching.

Paul Mulholland from The Open University (UK) was convinced that applications using future semantic frameworks could also support new forms of meaningful exploration of resources, beyond current search & retrieval interfaces. However, he currently saw a clear lack in 'the right semantic interfaces for exploration', e.g. for future ambient access spanning the use of different devices in different contexts.

Anne Gilliland-Swetland (Department of Information Studies, UCLA, USA) wanted over the next 10-15 years to see a lot of new work 'to enhance information retrieval of cultural materials that go beyond the limitations of classic approaches – in particular, exploiting the richness of archaic, and alternative language usage, and different notions of context', and this also should lead to 'new ways of developing virtual exhibits of cultural heritage materials and of facilitating classroom learning'.

The main RTD gap Gilliland-Swetland saw in today's dominant form of technology development where, for example, information retrieval showed little interest in the 'particular challenges offered by cultural, other language, and historical materials'.

'Knowledge preferenda'

Michael Moon, CEO of GISTICS Inc., provided DigiCULT with the following model of future collaborative knowledge creation, sharing and delivery: 'Each individual represents a multi-dimensional user type; each user type represents a unique hierarchy of "need to know" categories of knowledge or "preferenda". In the future, individuals will "subscribe" to a variety of specific knowledge-domain agencies; each agency will model the entire contents of the Web according to its domain-specific taxonomy (hierarchy of preferenda); a community of practice will create and maintain each domain-specific taxonomy and, therefore, the quality of search-results "outputs". Thus, each serious user will subscribe to a managed commons and community of practice; each subscription will constitute a "standing request" for relevant inputs of a particular domain. As in the iPod nation where "you are your playlist", in the managed knowledge commons "you are your standing request with a tree of knowledge". One's subscribed profile for need to know will define your information use pattern and, therefore, your role and responsibility as a knowledge worker in a post-information society.'

RTD for realising this scenario would need to concentrate on 'collaborative tools for auto-classification of "dark content" (text or image with robust metatagging) as well as good garbage (for garbage in, garbage out) in the form of robustly characterized content and assets'. Also necessary are communities of shared concern or knowledge who develop 'a global/federal "content-data model" by which to define, organize, and type the info preferenda'. In future information exchange environments for nomadic users, peer-led learning circles would interact via mobile multimedia messaging or mobile broadband.

73 Functional Requirements for Bibliographic Records (FRBR), http://www.ifla.org/VII/s13/frbr/frbr.htm; Encoded Archival Description (EAD), http://www.lcweb.loc.gov/ead/; Text Encoding Initiative (TEI), http://www.tei-c.org

On the other hand, practitioners were not sufficiently resourced or trained to participate in such RTD. Gilliland-Swetland demanded incentives to foster 'the development of testbeds from which generalisable data, benchmarks, and outcomes can be generated. More practitioner training/professional education in this area needs to be encouraged and provided. Funding initiatives should highlight this as a priority area to encourage existing researchers to work in this area.' She thought that, with appropriate funding for RTD and practitioner education, some good testbed developments could be achieved around 2008.

The most detailed suggestions of what could form an RTD plan in the field of 'intelligent heritage' came from Martin Doerr. He is head of the Centre for Cultural Informatics of the Institute of Computer Science (ICS), which forms part of the main national research centre in Greece, the Foundation for Research and Technology – Hellas (FORTH).[74] In order to give as complete a summary as possible of Doerr's ideas and suggestions, in what follows we include larger quotes from his three-page contribution.

Doerr started off with the suggestion that what has been achieved over recent years in technological and economic terms in enterprise knowledge access via data-warehouse technology 'could be used as an analogy for large clusters of cultural and other institutions to provide *interdisciplinary* research nets'. Over the next 10-15 years, 'we could come to a situation, where large clusters of *semiautonomous*, *complementary* (and not only homogeneous in content) information sources can be accessed for research, education and public interest under virtual global schemata of great generality, which are basically top-ontologies. Knowledge Organization Systems (thesauri, gazetteers etc.) can be used like Dynamic Linked Libraries as global resources that allow for relating information from different resources immediately *without costly* and *ambiguous data clearing*. A kind of Semantic Grid could be based on a generic architecture of how to link unique references to *events*, persons, places, periods, objects, *event types*, person roles, object types across servers. This could effectively connect archives, libraries and museums on the base of *referential networks* and *not* only on the often meaningless *equality of subject*.'

Related to this, Doerr thought that 'new query paradigms fully supporting access to partially complete knowledge and to answer inductive/deductive questions could be defined' and also that 'content-based analysis could bring recognition of factual relations and events to the same level as recognition of concepts and entities'. For feature recognition in images he expected little progress with respect to fully automatic subject detection; even in 10-15 years' time this would remain an area 'restricted to limited, highly controlled contexts'.

Asked what currently represents the main RTD limitations or gaps for sound progress in 'intelligent heritage', Doerr gave the following list:
'(a) Interdisciplinary collaboration… Even though the EC propagates it, the evaluation is done by domain specialists that declare any true interdisciplinary work as non-innovative.' With respect to what was missing in particular, Doerr mentioned 'systematic investment in semiautomatic approaches to indexing, metadata and KOS creation and quality control', and 'systematic investigation of the real user questions and the discourse structure in science and humanities'.

[74] The Centre for Cultural Informatics 'pursues a comprehensive, cross-disciplinary approach to supporting the entire life-cycle of cultural information and documentation procedures for the benefit of the preservation, study and promotion of cultural heritage'. It has several current co-operative projects with cultural institutions and scientists from the humanities such as, to name an outstanding example, the Special Interest Group for the CIDOC Conceptual Reference Model (CRM). *Cf.* http://www.ics.forth.gr/isl/cci.html; CIDOC CRM, http://cidoc.ics.forth.gr

He added, 'one could argue, that virtually all information access systems for cultural data are naively built, at best related to evaluating user satisfaction, rather than controlling their fitness against real research scenarios'.

'(b) Underestimation of the general complexity of cultural contents and overestimation of the application specificity': Doerr observed that 'this leads to the political conviction that IST should not deal with too application specific issues, which in turn leads to a situation where the commonalities of wider domains are never understood due to lack of evidence from the specific case'. For real progress in applications, he suggested concentrating on cases of high intellectual complexity from the 'soft sciences', 'so that research challenges are not defined by computer science theoreticians but are founded on reality'.

'(c) Systematic investment in joining different applications that can benefit from an integrated approach, such as in food-safety and agriculture, biodiversity and natural history, archaeology and ethnology, history and sociology, etc.'

'(d) Preparing ground for collaboration on standards across disciplines and applications.'

'(e) Further, systematic investment in top-ontologies of relationships. The whole ontology research has so far widely ignored the role of understanding relationships for information integration. The CIDOC CRM is a rare example.'

Last but not least, Doerr added, *'(f) Lack of truth warranty in integrated systems'* (which among other issues he explained further, see below).

With respect to questions such as: What would represent major steps or breakthroughs in RTD needed to achieve the vision? How should these be addressed?, Doerr considered and outlined the following points which we are reproducing quoted in full for the most part:

'1. Specific mapping technology: Domain experts must have tools to annotate how the structure of their dedicated databases and legacy systems relate to a generic ontology, so that automatic and semiautomatic data transformation and mediation can be driven. IT experts are unable to comprehend application semantics and domain experts are unable to define parsing rules.'

'2. Analysis of real user questions, research situations and scientific discourse in terms of formal top-ontologies (such as ISO/CD 21127). Case studies of real research achievements in terms of KR [Knowledge Representation]. Engineering of compact top-level ontologies with very wide applicability. Harmonisation of ontologies.

'3. "Open World" query languages and systems: A query should return: Objects known to fulfil the query, objects known as not fulfilling the query, objects that may fulfil the query, but the system has not enough knowledge to decide. Metadata, database designs and distributed architectures of databases with schemata of different levels of detail that make the unknown explicit to the query system and user.'

'4. Massive investment in data cleaning (duplicate removal) techniques and architectures and algorithms to negotiate and preserve the notion of identity of objects between semiautonomous sources. Standards, algorithms and strategic Knowledge organisation systems need to be developed. Information integration is normally perceived as a "one shot" action. In reality, it must be a constant element of federated systems. Theory needs to be developed into how a global index to a federation of continuously changing resources can *converge* to better and better stages of knowledge rather than degrade over time.'

'5. "Intuitive User Interfaces" that render to the user the notion of "what the source knows" rather than trying to answer the user question directly. In normal cultural databases the search space is almost empty. 99% of all legal combinations of parameters return an empty answer. The user rapidly gives up. The source does not inform sufficiently what it is about, which terms it understands, where information is rich, if the user chooses the wrong term or if the source has no data.'

'6. Relate factual and categorical data: Databases are mostly geared to describing facts. Science is mostly about concepts. Manufacturers produce objects but describe product models.' This point would, as Doerr explained further, require 'coherent storage and querying across instantiation levels' to allow for queries such as… "In which kinds of biotop do monkeys live?", "Which observations support this?", "What was the first camera?", "When was this technology replaced and why?", "Who may have influenced Einstein on his theory?".' Furthermore, effectively relating factual and categorical data would require 'coherent theories and ontologies about metaclasses and meta-relationships, and relations between classes and metaclasses (…), databases, maintenance algorithms and query systems.'

Finally, representing the top level with which intelligent cultural and scientific heritage would integrate, or relate to other domains of knowledge and disciplinary practices:

'7. Unified or harmonized top ontologies of relationships (and classes) for historical descriptions of artefacts, geohistory, palaeontology, archive material and literature reference; IPR management, planning, social roles, norms and norm viola-

tion; categorical knowledge in science, biology, ethnology, geology, paleontology, sociology etc.'

Doerr added an important note in which he addressed how the predominant notion of a Semantic Web needs to be adapted for 'intelligent heritage' sources and knowledge providers: 'Museums and scholarly researchers are curators of knowledge, and not administrators such as libraries. Whereas the Semantic Web paradigm assumes that interaction with the source providers is not possible/not scalable, in the cultural scenario the source providers have a strong interest to improve their sources and work on specific scientific targets. Therefore they can be mobilized to produce federated systems with very high data quality standards. The goal must be to create larger and larger bodies of integrated knowledge without losing their validity and truth warranty. Harvesting scenarios are only auxiliary tools as first finding aids.'

Further ideas and suggestions on this issue are to be found in the chapter on Natural & Enjoyable Interaction (p. 45).

DigiCULT RTD Navigator: Intelligent Heritage

The following table gives a condensed overview of what the experts thought could be achieved in this RTD area over the next 10-15 years. After a short summary of what they considered to be the current limitations or barriers, the experts' suggestions are grouped into the phases 2005-2009, 2010-2014, 2015 and beyond. The timeframes and, where given, years indicate when a certain methodological and/or technological gap could be closed or some other RTD breakthrough be achieved. These assessments are of course dependent on the condition that appropriate funding levels, RTD collaborations and other requirements are met.

2004: Current limitations/barriers

Some of the major present limitations are very well summarised by Kirk Martinez as 'immature ontologies and relatively few users of it; difficulties getting a unified approach to using it and building semantic interfaces to digital collections in museums, libraries etc.'

In particular, there is a need

- to further develop domain, middle- and top-level ontologies;
- to employ new conceptual frameworks (e.g. CIDOC CRM);
- to evaluate how these work with descriptive standards such as FRBR, EAD and TEI;
- to provide detailed documentation of emerging 'good practices' in real deployments;
- to develop semantic interfaces that provide strong evidence of the cost/benefit ratio of intelligent heritage in terms of improved access to, and use of, knowledge resources.

2005-2009

Overall: A phase of further development in theories and methods, and first convincing results

A stronger focus on harmonisation of (domain) ontologies

Better harvesting, clustering and visualisation of descriptive information (metadata)

Advancement in the engineering of top-level ontologies with wide applicability

Further development and testing of semantic search tools and applications

2007: Theory: 'Open World' query languages and systems (*cf.* M. Doerr, p.38)

2008: First results: Some unified or harmonised top-level ontologies of relationships (and classes) for descriptions of heritage, Arts & Humanities, and other disciplines' knowledge resources

2008: First steps in making ontologies usable for truth warranty in integrated systems (that would need to consistently relate factual and categorical data)

2008: Further developments in semantic databases, maintenance algorithms and query systems

2008 (ongoing): High demand for theoretical advances in coherent ontological frameworks (e.g. relations between classes – meta-classes – meta-relationships)

2008: First results (M. Doerr: if addressed strategically, otherwise maybe never): Analysis of real user

questions, research situations and scientific discourse in terms of formal top-ontologies (such as ISO/CD 21127)
2008: Case studies of real achievements in terms of knowledge representation
2008-2012: Specific mapping technology for domain experts
2008-2015: Massive investment in data cleaning (duplicate removal) techniques and architectures and algorithms for information integration

2010-2014

2010: More intuitive user interfaces 'that render to the user the notion of "what the source knows"…' (M. Doerr)
Around 2010: A 'Non-Fake-Eliza' to be operational
Wider spread of affordable language engineering resources (e.g. data normalisation and cleaning tools)
Some first results in 'semantic drilling' at resource level also in 'soft' fields of scholarship (based on semantic frameworks)

2015 and beyond

Mainly for some 'hard' science resources, reliable semantically based operations at resource level
2015-2020: Methodology for a global index to a federation of continuously changing resources that may converge and result in an increasing rather than degrading level of accessible knowledge
2015-2020: 'Open World' query languages and systems, running real applications

Generally, what could be achieved over the next 10-15 years?

'Semantic markup that is as common as HTML is today'. (A participant from the archival domain)
'Usable and useful semantic exploration interfaces'. (P. Mulholland)
'A European Semantic Web based search engine for cultural heritage of the member states of the European Union and beyond'. (K. Martinez)

Theme 2: Contextual Cultural Information

In the information given on the consultation platform, 'contextual' was associated with 'anywhere, anytime' seamless use of heritage information in dynamic contexts. This includes applications that allow for meaningful, context-aware interaction with information resources, involving context management in terms of location as well as tasks and social and physical situations. In a local Ambient Intelligence environment, applications would involve (for example) mobile technologies, location-based systems, and embedded networks of sensors in heritage buildings, sites or areas.

Experts' views

Context' is an extremely broad and widely used term. For example, Arts & Humanities scholars may discuss 'the historical context', i.e. the circumstances that surround the creation and use of a cultural artefact, a historic event or situation. In information search & retrieval & visualisation, the scholars may want to find 'contextualised' study material, e.g. historically related documents or images that may be spread over archives and libraries throughout Europe and beyond.[75] Viewed from the perspective of the provider of such an information system, the 'user context' to serve will be mainly academic historical research. A full-blown ambient intelligence (AmI) environment for a historic city centre would need to understand a multitude of user contexts as the needs and wants of the visitor may change, for example, from 'historical information about this old building' to 'where can I find a souvenir shop'.

Fabrizio Cardinali, Fabrizio Giorgini and David Fuschi (Giunti Labs, Italy) summarised their expectations of what over the next 10-15 years might be

75 Such a novel visualisation and contextualisation environment applied to European history sources has been developed in the VICODI project, http://www.vicodi.org; for their prototype solution, see http://www.eurohistory.net

achieved as 'ambient intelligence able to track the user, and provide him with contextualised information, based on the profile of the user; content delivery independent from the user device; mixed use of location-based systems and RFID for accessing the information'. Described from the user's point of view, according to Alan Smeaton (Dublin City University, Ireland) this would include: 'Personalised access to cultural heritage artefacts from home and mobile (the main access areas), which is aware of "local" context, i.e. where I am and what I am currently doing and why I need access, as well as more "global" context such as what is popular among all users or users like me, and finally has a long-term model of what I have already seen, when I saw it, etc., a kind of personal digital memory.'

But Professor Smeaton, and other forum participants who addressed the research area of context-aware systems, saw a need for strong conceptual frameworks on which to base future RTD efforts. For example, Peter Ingwersen (Royal School of Library and Information Science, Denmark) stated that there is currently 'a lack of conceptual frameworks dealing with contexts of various kinds for a variety of media and task situations that may suggest hypotheses and solutions'. Pia Borlund (Royal School of Library and Information Science, Denmark) emphasised that an improved and well-documented understanding of information seeking/searching behaviours of all kinds of users of heritage resources is required for designing flexible interactive and intuitive applications.

Several experts saw major gaps in RTD in context capturing as well as effective use of the context information, e.g. for information access. There were first approaches in the instrumentation of capturing of context and use history, but contextual elements such as the task and other situations in which content is searched and used would need much further research. Such elements should be captured, and indexed for re-use, when interaction processes occur, e.g. when using tagged information on mobile devices in a larger heritage area. Task context-aware systems might well be first developed for work situations within the wide range of different cultural heritage institutions.

Preben Hansen (SICS, Sweden) highlighted the fact that people perform both professional and everyday tasks in a social and cooperative context, and demanded that this should receive much more attention in RTD towards context-aware systems and applications. 'People will interact with other people and objects synchronously and/or asynchronously in a distributed context, together creating new objects and information.'

Location – context ontologies

With respect to the importance of context in location-centric applications within AmI environments, (e.g. smart buildings) the role of context models and contextual ontologies should be noted, which represent the major approaches in managing context information. Context models provide database-style management functionality and offer interfaces for applications to query available context information or receive notifications on context changes. Contextual ontologies are developed for applications that should have a thorough representation of knowledge, as they are expected to reason over the context information and to react accordingly.

At the First International Workshop on Advanced Context Modelling, Reasoning and Management held in conjunction with Ubicomp 2004, Christian Becker and Daniela Nicklas (University of Stuttgart) proposed combining the two approaches in order to mitigate current weaknesses when following a single approach. At the University of Singapore's Institute for Infocomm Research, a research group has developed an upper-level context ontology called CONON, which provides extensibility for adding domain-specific ontology, e.g. for experiments in their connected home lab. They have implemented the ontology and logic based context-reasoning schemes, and conducted some interesting performance studies to evaluate the feasibility for context reasoning in pervasive computing environments.

Sources:

C. Becker / D. Nicklas, "Where do spatial context-models end and where do ontologies start? A proposal of a combined approach" (7 September 2004), http://pace.dstc.edu.au/cw2004/Paper16.pdf; see also the other workshop contributions at http://pace.dstc.edu.au/ContextWorkshop2004Program.html

X. H. Wang *et al.*, "Ontology Based Context Modeling and Reasoning using OWL". Workshop on Context Modeling and Reasoning (CoMoRea) at PerCom'04 (14 March 2004), http://www.comp.nus.edu.sg/~gutao/gutao_NUS/CoMoRea2004_gutao.PDF

Context-aware information delivery, according to Jussi Karlgren (SICS, Sweden), would also include the capability to provide a user with answers 'on any of several levels of abstraction with generalization based

on personally tailored criteria', as well as making the users of information 'aware of its character, quality and style? [For example] "This is Stonehenge. It is an old prehistoric cult and burial site." And in another voice "It is a landing site for UFOs".' If information bits from different sources and discourses become 'mixed' in a heritage context (e.g. a heritage site), a contextually aware system might present the latter statement, 'while making the user aware of its character'.

DigiCULT RTD Navigator: Contextual Cultural Information

The table below gives a condensed overview of what the experts thought could be achieved in this RTD area over the next 10-15 years. After a short summary of what they considered to be current limitations or barriers, the experts' suggestions are grouped into the phases 2005-2009, 2010-2014, 2015 and beyond. The timeframes and, where given, years indicate when a certain methodological and/or technological gap could be closed or some other RTD breakthrough be achieved. These assessments are of course dependent on the condition that appropriate funding levels, RTD collaborations and other requirements are met.

2004: Current limitations/barriers

A general observation of the experts who addressed issues in 'contextual' cultural information is that there is a need for much better conceptual frameworks on which to base RTD efforts. Such frameworks would need to deal 'with contexts of various kinds for a variety of media and task situations that may suggest hypotheses and solutions'. (P. Ingwersen)

Considerable advances are required in the understanding of all kinds of heritage information users, based on well-documented and analysed information seeking/searching behaviours in various user contexts. Furthermore, there would need to be a shift from a predominant focus on single-user contexts to cooperative situations and tasks.

2005-2009

Overall: A phase of more focused research, emerging frameworks and tools

Development of workable frameworks

Improvements in the understanding of different contexts of accessing and using heritage resources

Development of better instrumentation for capturing context information and use history

First prototype applications for 'heritage resources in context'

Contextual elements, e.g. information on changing user situations and tasks in which content is searched and used, need much further research.

Design of more dynamic and flexible interactive applications

2010-2014

First results in task-related context capturing for work situations

Some intelligent (re-)uses of context information, which is captured, indexed and analysed during interaction processes (e.g. in mobile information access and use)

Contexts of cooperative tasks receiving much more attention

Applications able to cope with distributed (user) contexts still in its infancy; first steps with respect to asynchronous user situations

2015 and beyond

Emerging platforms/technologies for collaborative contexts, also for synchronous interaction with other users and shared tasks

More effective (re-)use of contextual information from user interactions for improved retrieval and delivery of content

Context-aware information delivery on several levels of abstraction according to personally tailored criteria (including making users aware of different discourses from which they stem)

Privacy issues definitely need to be sorted out

Generally, what could be achieved over the next 10-15 years?

'I envision a digital community where a person can gather the information needed regardless of what kind of institution the resources are owned by. The person will not have to know where he or she is getting the information. Regardless of what role you have; a student, researcher, mother, tourist you should be able to get the right sort of resources you need at that time and in the role you have.' (K. A. Aam)

'Ambient intelligence able to track the user, and provide him with contextualised information, based on the profile of the user; content delivery independent from the user device…'. (F. Cardinali *et al.*)

Theme 3: Natural & Enjoyable Interaction

In the information given on the DigiCULT online consultation platform this theme was stated to concentrate on natural, enjoyable ways of interacting with digital heritage environments, and on making use of rich heritage resources. Targeting a variety of user and consumer situations, such as education and lifelong learning, entertainment and tourism, this would include:

- applications for personalised and dynamic access to large repositories of intelligent digital heritage resources, including collaborative and community activities;
- new ways of navigation and use of heritage resources, e.g. visually driven interfaces, dynamically generated thematic maps, chronologies and narrative elements, and trails through large collections; and
- multimodal and natural language interaction with augmented and virtual reality environments (e.g. rich and dynamic 3D structures, simulations and game-like action spaces).

It was also noted that concepts and tools for creating animated 3D, augmented and virtual reality are addressed under the theme "create/re-create" [3D/VR/AR].

Experts' views

Gavan McCarthy (Director, Australian Science and Technology Heritage Centre, University of Melbourne) stated that 'this area is ripe for picking from our perspective. We have been developing data sets with systematically managed multiple parameters over the last twenty years that are ready for advanced visualisation.' However, he also saw considerable limitations for actually creating and maintaining new applications for cultural experiences based on such data sets, 'especially the legacy issues and the need for transportability through time'. Furthermore, McCarthy considered as key issues 'that funding is made available for product-based projects in the humanities but not research projects looking at cultural informatics. Significant work has been done in this area around the world but it has tended to become complex and inward looking and create a jargonistic language that inhibits broader understanding.'

Martin Doerr (ICS/FORTH, Greece) stated that 'applications for personalised and dynamic access to large repositories of intelligent digital heritage resources will become real only after semantic inter-

operability is resolved. Intelligence needs very large background knowledge.' Regarding virtual reality (VR) and visual knowledge rendering, Doerr foresaw that in about 10 years these would replace partially verbal communication and training. This was because 'VR systems could effectively connect to knowledge bases and allow for exploration of alternative interpretations and hypothesis building'. However, in order for this to happen a much deeper understanding of scientific discourse and cognitive studies on the processes of non-verbal thinking would be needed. Furthermore, the ergonomy of handling visual interfaces should receive more attention.

In particular, Doerr warned: 'If the nature and structure of the discourse in humanities is not understood, we continue to produce computer games. The humanities sector must understand the challenges and be involved in new models of gaining scientific merits.' The rationale for this is that if future user portals and various virtual reality systems should become real mediators of rich cultural knowledge, a major change in Arts & Humanities knowledge markets would need to happen. Rich knowledge able to describe, explain and interpret cultural heritage with reference to historically different contexts and discourses, may never be mediated by 'intelligent machines'. Therefore, scholars would need to be involved on a scale and to a degree never seen before. This would challenge the established internal mechanisms of how scholars create and receive recognition for their contributions to the disciplinary stock of knowledge.[76]

Paul Mulholland (The Open University, UK) thought that a 'better use of narrative in the personalised presentation of digital heritage resources' could be achieved, depending in part on enhancements in the 'modelling and inference of user behaviour when exploring physical and virtual exhibitions'. Mulholland also expected more use of augmented reality (AR) and mixed media for learning and entertainment. But, for educational applications better tools and guidelines for using such technologies would be required. Overall, novel approaches in user modelling, inference from user behaviour, and adaptive hypermedia and AR applications that provide an engaging coherent experience he saw as research strands that would extend well over a period of 15 to 20 years.

Fabrizio Cardinali, Fabrizio Giorgini and David Fuschi (Giunti Labs, Italy) added that collaborative virtual museums where students and experts could interact through their avatars might be achieved before 2010. For the educational deployment of AR applications with head-mounted glasses (HMG) and similar devices, appropriate models would need to be developed and validated, to allow for meaningful uses which they expected to appear around 2010.

Interestingly, few other participants mentioned novel interfaces and interaction devices. For example, Sofia Pescarin (Fellowship researcher, CNR ITABC, Italy) thought that novel 3D interactive interfaces would allow more direct access to complex and multimedia information, and that the use of gesture interaction systems should be explored much further. However, she saw a lack of cooperation among laboratories working in the related fields of research.

Jacques Bogaarts (Nationaal Archief, The Netherlands) envisaged completely new geographies of 'cyberspace' on the Web in which relationships between objects show themselves 'naturally'. Building such a future digital heritage space 'that is as exciting as a visit to Jurassic Park' could only be achieved within large creative cooperations. Basic requirements would be a not primarily technology-driven modelling of Web content, huge amounts of digital resources with high-quality metadata, and interfaces to interact more directly with the content.

On the DigiCULT online consultation platform, introducing the theme of 'natural & enjoyable interaction', large repositories of intelligent digital heritage resources were mentioned. In an interesting note a participant from a university-based research lab asked: 'Why the emphasis on large collections? It would be more helpful to think of myriads of small collections and how these can be aggregated and re-aggregated according to the needs of the user.'

Jussi Karlgren (SICS, Sweden) requested more and better informed information access research that would lead to 'flexible tools for the identification of informational items and topical structure in documents', which were missing for text as well as other media types. Strong analysis tools should be able to 'really model topic, style, foreground and background, usefulness etc., rather than the presence or absence of surface features in the information items (this line of research is proceeding apace)'. However, he mentioned that relevant research in this direction 'is going on at the research frontiers of HCI and IR at present – the next few years should show some disjointed publications and some exciting new prototypes that may provoke some discussion'.

Enhancements in natural & enjoyable interaction away from 'keyboards and cumbersome displays', according to Karlgren, would require considerably 'more advanced methods for the tracking and identification of the social function of information'. He elaborated this further, 'most of the information analysis research so far has treated information separat-

76 See also page 66, where Doerr's statements on this major topic are quoted more fully.

ed from its use, and when use has been discussed it has been topically oriented, problem-solving type use. The basic reason for human communication is social – to express joy, enthusiasm, frustration, contentment, annoyance, rage. Systems could have and need to have hooks and affordances to model and cater for the expression of emotion in interaction.'

With respect to major steps or breakthroughs in RTD that would need to be achieved, Karlgren suggested that 'more and better information access research' should include: 'research on and models of situated information use, including collaboration and distributed information access away from the desktop (also proceeding apace); research and prototype development on the emotional components of information access behaviour and on the emotion of culture (taking first steps)'. Such research would involve (and often be driven by) mobile communication device manufacturers as a 'crucial survival factor' and would be 'noticeably emergent with new types of mobile phone handsets, handheld PDAs, laptops etc. within the next decade'.

Roger Drage (Milton Keynes Museum, UK) expected that over the next 10 to 15 years 'ever greater degrees of realism/authenticity in creating reconstructions and realisations of the past in scenes, buildings, experiences, etc.' as well as 'deeper immersion in the exploration of different cultures via ICT' would be achieved. Furthermore, Drage thought that 'reliable voice recognition systems will gradually play an ever more key role'; however, the technology would 'need to advance a lot before it is properly viable as a navigation system'. In the short-term perspective, he suggested the adoption of XML technology 'as the nearest thing we currently have to seamless interaction and the basis for future development'.

A major issue was also seen in the required multilinguality to allow as many users as possible to benefit from novel ways of interacting with rich multimedia content. Samuel Cruz-Lara (LORIA – INRIA Lorraine, France) addressed this topic with regard to broadcast digital heritage applications, which would need to build on new software technology and standards. Drawing on results from the Jules Verne project,[77] Cruz-Lara highlighted the opportunity to exploit open standards (MHP-Java, Java Flash), advanced video compression protocols (H264), and emerging standards for object-oriented interactive digital media (MPEG-4, MPEG-7 and MPEG-21).

For this thematic overview, Cruz-Lara's description of the essential role of multilingual linguistic information in the management and provision of interactive heritage applications seems particularly valuable to summarise. Linguistic information, he stated, 'bears most of the descriptive content associated with more visual information', and may be text describing pictures or video sequences, information presented to the user graphically or via a text-to-speech processor, menus in interactive multimedia or TV, subtitles, dialogue prompts, or implicit data appearing on an image (caption, tags, etc.). Therefore, it is crucial to be able to adapt such content efficiently to the linguistic needs of the user. Cruz-Lara highlighted the need for a flexible specification platform for elementary multilingual units that may be either embedded in multimedia content or used autonomously to localise content.

For future multilingual interactive digital heritage applications, Cruz-Lara stated that 'the main issue is being able to define and to integrate standards from ISO IEC MPEG committees and standards from ISO TC 37: Terminologies and other language resources, more specifically, Computer applications in terminology (SC3), and Language resources management (SC4).' He added: 'Within an optimistic approach, we think that integration of MPEG standards and Terminology and Language Resources Management should be achieved by 2010. Within a pessimistic approach, integration may never be achieved.'

DigiCULT RTD Navigator: Natural & Enjoyable Interaction

The table below gives a condensed overview of what the experts thought could be achieved in this RTD area over the next 10-15 years. After a short summary of what they considered to be current limitations or barriers, the experts' suggestions are grouped into the phases 2005-2009, 2010-2014, 2015 and beyond. The timeframes and, where given, years indicate when a certain methodological and/or technological gap could be closed or some other RTD breakthrough be achieved. These assessments are of course dependent on the condition that appropriate funding levels, RTD collaborations and other requirements are met.

2004: Current limitations/barriers

For distributed heritage information systems, Kari-anne Albrigtsen Aam stated that 'the main limitation will be to present the resources as seamless as possible, considering the different ways of presenting, both technical and cultural, in the different sectors'. Overall, the heritage sector (in particular, institu-

77 Jules Vernes Project, http://led.loria.fr/en_collab.php; a detailed summary (28 November 2004, in French) is given at http://led.loria.fr/download/source/1.

tions that exhibit objects) will need to make a shift from a focus on information provision to user experiences. Much more cooperation between heritage organisations and development centres is required. Examples of best practice need to be well documented and published.
Areas where progress depends on advanced technologies at reasonable cost include: reliable voice recognition systems, natural language processing, automatic translation services.

2005-2009

Overall: A phase of intensive development and experimentation
A much broader adoption of XML technology 'as the nearest thing we currently have to seamless interaction and the basis for future development' (R. Drage)
More effective user modelling applications
Considerable improvements in personalised access to heritage information
Better interaction models (e.g. pedagogical) for the use of 3D/VR/AR applications and devices
Much further development of collaborative virtual museums with avatars for students and experts

2010-2014

Enhancements in the modelling and inference of user behaviour when exploring physical and virtual exhibitions
Use of multimodal interaction systems explored and tested much further
Better use of narrative in the personalised presentation of digital heritage resources
Novel interfaces and interaction devices (e.g. 3D/AR interactive interfaces) allowing for enhanced interaction with complex and multimedia information
Considerable advances in multilingual access
Increased focus on optimising the ergonomy for handling enhanced visual and haptic interfaces
More research on, and prototype development for, emotional components of interacting with heritage objects; better modelling of emotional expression in multimodal interaction with other users

2015 and beyond

Advances in the modelling of scientific discourse
Cognitive studies on the processes of non-verbal cultural thinking
VR and visual knowledge rendering partially replacing other means of knowledge mediation
VR systems able to connect more effectively to knowledge bases for exploring alternative interpretations and hypothesis building in real research situations
Logical architectures connecting interpretation, alternatives and background information

Generally, what could be achieved over the next 10-15 years?

'Easy and appealing user interfaces and navigation possibilities'. (J. Lybeck)

Theme 4: Create/Re-create: 3D/VR/AR

In the information given on the DigiCULT online consultation platform, this theme was stated to concentrate on the creation and re-creation of digital historic heritage objects and characters (e.g. avatars), architectural structures, and archaeological or historic sites for interactive use in augmented and virtual reality environments.

This includes:

- tools for data capture and modelling in three dimensions (including 3D GIS for cultural and natural sites) with high accuracy in shape and texture, tools for element extraction, virtual reconstruction from fragments, etc.;
- concepts and tools for expressive scene design and scripting, and dynamic rendering and seamless integration of animated 3D components in augmented/virtual reality environments, allowing multimodal interaction;
- collections of, and non-textual, metadata for reusable 3D components, VR building blocks, avatars, etc.; definition of declarative exchange formats and requirements for component-based application development.

Experts' views

Actually all our tangible heritage is three-dimensional (including material objects such as historic records and manuscripts). Therefore, interactive 3D objects and environments are regarded as a key area of research and development towards information-rich representations of heritage objects, buildings, sites, etc., and new forms of mediating cultural and historic knowledge. 3D objects and environments may form part of virtual reality (VR) or augmented reality (AR) simulations. What distinguishes such simulations is that VR delivers an entirely computer-generated 'world', while AR, also often called mixed reality, combines real with virtual elements to create an environment to interact with.

On the question 'What do you envision could be achieved in this RTD area over the next 10-15 years?', Martin Doerr (ICS-FORTH, Greece) answered, 'everything'. However, he pointed to limitations and gaps in standardisation of VR formats with enough flexibility, and the stability of such formats. Furthermore, he saw a 'missing connection of

interpretation, alternative and evidence' in RTD concentrating on advanced 3D/VR/AR applications. In particular, Doerr urged that the theme, as stated on the online consultation platform, 'does not touch the question of the scientific value. A VR representation, e.g. of Troy, has no scientific value, if the parts cannot be connected to evidence, alternative representation and references.' To prevent any technology-driven approach, the overall question should be: 'When will these things be useful for research and education? Then the true challenges will appear.' For example, 'a scholarly useful product must have a lifecycle of decades, not years'.

An Italian archivist envisaged that over the next 10 years the current wave in experimenting with virtual reality technologies in archaeology would be extended by applied RTD for other historical periods and environments. This would include urban history (urbanism, architecture, etc.) represented as a 3D virtual environment 'allowing the user to "see" a place over time, from ancient to contemporary times'. Before that, applications with 2D cartography would 'offer more and more opportunities to localise cultural heritage in space, linking contemporary cartographic services online to digitized historical maps'.

The archivist expected that the first generation of immersive and knowledge-driven VR environments for the development of historical towns over several centuries would appear only in 10 years' time, and would require large interdisciplinary research efforts 'before beginning with the IT issues'. In particular, it could not be achieved if there were no stable, long-term collaboration of urban historians from various disciplines, IT researchers & developers, regional and city archives, museums and libraries, public administrations and major tourist associations.

A participant working for a governmental body or agency addressed issues in the digitisation of heritage resources that were needed for the creation of novel information-rich environments. He or she requested from RTD over the next 10 years to concentrate on 'flexible, standardized, user-friendly and with AI supported tools for digitisation of ALL kinds of cultural heritage materials'. The participant saw the main gap for considerable advances as the fact that technology-centred researchers were 'missing knowledge about the nature of cultural objects and about the way cultural heritage organisations are maintaining and creating their collections'. This hindered considerably the 'integration of available technologies and AI applications into the design of tools and systems'.

The participant outlined a three-step plan, how this should be addressed, and the time needed to achieve

State-of-the-Art in 3D/VR/AR

Given the predominant focus of our forum's participants on 3D technologies, we thought it useful to give the following three examples of state-of-the-art research and development that uses 3D objects and environments for virtual, augmented or mixed-reality applications. Links to three further interesting projects in this RTD area are added.

La scena di Puccini

One of the most intriguing recent works in this area is the exhibition 'La scena di Puccini', which took place from September 2003 to February 2004 at the Ragghianti Foundation in Lucca, Italy. The exhibition was developed by Sensing Places, an offspring of M.I.T., led by Flavia Sparacino in close cooperation with opera scenography and subject-matter experts from the La Scala Opera theatre in Milan. They strived not only to give life to the original opera set designs and illustrations of the main characters in full costume, but, in fact, to develop a model for the museum of the future. Sensing Places transformed the drawings of numerous set designs and characters into animated 3D computer reconstructions, with the characters moving and singing famous arias, and the costumes showing a realistic flow and drape. Key tools for these 'reconstructions' were Alias Wavefront Maya 4.5 for character modelling and animation, and the Syflex plugin for cloth animation. Shown in an immersive cinema the animations were played by custom proprietary software written in C++ and DirectX. The networking programs that connect the screen with an interactive carpet of light were also based on C++ and used the RPC communication protocol. Besides the immersive cinema, other IT-based features of the exhibition included an interactive table that functioned as a multimedia exhibition catalogue and novel wearable audio/video guides.

For detailed, richly illustrated descriptions, see Flavia Sparacino, "La scena di Puccini" (2003), http://www.sensingplaces.com/papers/pucciniSetDesigner.pdf, and "Scenographies of the Past and Museums of the Future: From the Wunderkammer to Body-Driven Interactive Narrative Spaces" (October 2004), http://www.sensingplaces.com/papers/acm_2004_sparacino.pdf

Lifeplus

Lifeplus was an EU-funded IST project (03/2002-11/2004), which undertook to push the limits of current Augmented Reality (AR) technologies. It explored the narrative design of fictional spaces created in real-time on a head-mounted display (HMD) through a combination of real scenes and realistic 3D simulations (plus computer-generated sounds) of humans, animals and plants. Lifeplus concentrated on the archaeological visitor attraction Pompeii as the main showcase. Leading-edge techniques were used for character simulation including cloth and hair, facial emotion software for realistic expressions, and artificial life algorithms for behavioural animation.

For the fine-tuning of what the visitor actually sees on the HMD, special software was developed by the British project partner 2d3. This software interprets the input from the camera attached to the HMD, to derive the positional and perspective information crucial for an accurate match between the real and virtual elements. Without this information, the added virtual elements would not 'sit' in the scene realistically. Andrew Stoddard from 2d3 states: 'We've used leading-edge computer-vision techniques in our products for several years now, but this is the first time that anyone has been able to move a camera through a scene and have the software to work out in real-time where it is and how it's moving.'

See the project's Web site: http://www.miralab.unige.ch/subpages/lifeplus/; and the detailed article: "2d3 develops real-time camera tracking for EU augmented reality project" (29 September 2004), http://www.2d3.com/jsp/company/press-article.jsp?id=469

CREATE

The CREATE (Constructivist Mixed Reality for Design, Education, and Cultural Heritage) project explores and develops technologies that allow users 'truly interacting within a mixed reality environment by modifying it, building upon it, appropriating pieces or parts of it, testing ideas that are triggered by given or pre-existing elements, and actively participating in problem-solving and critical thinking in an activity which they find relevant and engaging.' Prototype applications will be realised for a cultural heritage/education scenario and an architectural/urban planning and design review scenario.

Web site: http://www.cs.ucl.ac.uk/research/vr/Projects/Create/

Further interesting projects:

Archeoguide: Augmented Reality-based Cultural Heritage On-site Guide. http://www.archeoguide.org

ARCO: Augmented Representation of Cultural Objects. http://www.arco-web.org

SCULPTEUR. http://www.sculpteurweb.org

real progress: 'Step 1: Solve issues related to textual material. Though a lot has been done more needs still to be done! Especially if we look at really hard material, such as non-western textual tradition, etc. or old material (e.g. for material before 1800 the level of automation in digitisation is crude). – Still 5-8 years of work. Step 2: Video, Audio; again: a lot has been done, but the real challenges are still not solved. Automated extraction of features within video and audio, applications suitable also for the end-user, etc. – More than 5 years. Step 3: 3-Dimensional objects. A wide field which is still in a very dynamic stage. – More than 10 years.' The participant also noted that 'automation for digitisation is NOT a research field *sui generis*, but needs input from other research fields and application areas; the communication between users, researchers and companies is even more important than in other research fields.'

Jacques Bogaarts (Nationaal Archief, The Netherlands) wanted for the future to see archival objects 'in a digital form that is very close to the original, for example, a collection of papers bound together should be presented in the same way. Software that operates on these objects make it possible to turn the pages and to search in the objects. (…) Metadata must be extracted in a highly automated way from the archival objects themselves. Today's tools (NMR, OCR) are not adequate for these kinds of manipulations.' Bogaarts requested RTD to build 3D scanning tools that can handle archival objects in the way described, and OCR-like technology for archival hand-written text; however, he thought that it may take until 2020 for such technologies to emerge.

Alessandro Piva (PostDoc Researcher, University of Florence, Italy) highlighted the need to further develop existing Digital Rights Management Systems (DRMS) to address the complexity of the rights clearing and licensing management for the heterogeneous, multimedia collections of many heritage organisations. In particular, he thought that 'there are no current valid solutions to the problem of limitation and tracking of use of multimedia content', and available image processing applications in the field

of cultural heritage were not properly designed for its requirements. Piva expected that the 'design and standardisation of secure data hiding technologies for IPR protection' might be achieved in 2010, while advanced image processing tools, developed in cooperation between heritage experts and ICT specialists, could appear in 2008.

Fabrizio Cardinali, Fabrizio Giorgini and David Fuschi (Giunti Labs, Italy) saw major limitations in the performance of current 3D capturing systems as well as shortcomings in the languages used to code 3D objects. They expected that improved 3D acquisition systems could become available in 2007, better algorithms for 3D reconstruction in 2008, and a new efficient language for coding 3D objects (beyond X3D) around 2010.

Actually, the RTD strand of 3D objects, models and environments received most attention. Sofia Pescarin (Fellowship Researcher, CNR ITABC, Italy) saw a need for more powerful 3D laser scanners with a capture rate of 25 scenes/s and with integrated GPS. A major gap she considered to be the fact that the parameters of the commercial market would not suit applications for the cultural heritage sector. However, Pescarin also saw major difficulties in establishing interdisciplinary groups that would share and exploit 3D objects and other advanced objects among institutions and projects. Therefore, appropriate conditions would need to be set and mandated for, e.g. EU-funded RTD projects.

Kirk Martinez (Senior Lecturer, University of Southampton, UK) also urged that 3D scanners and AR/VR software would need to be developed to allow for a much easier deployment in heritage organisations. He expected that this could be achieved within 3 to 5 years if funded, but up to 10 or more if not. As the RTD target, he saw European manufacturers being able to provide the heritage sector with 3D scanning technology specifically adapted for cultural heritage applications.

Last but not least, Luc van Gool (Computer Vision Laboratory, ETH Zurich, Switzerland) provided us with a detailed roadmap for RTD towards the future generation of 3D scanning, modelling and automatic registration. Gool described the current main limitations of RTD in this area, which included a fairly low scanning speed (although fast structured light and stereo methods were becoming available). Wide baseline matching was considered difficult in general, but would need to be solved, e.g. for automatic crude registration. Furthermore, improving 3D acquisition systems would need a combination of multiple strategies into a single system; the same would be required for combined geometric–radiometric analysis. However, Gool thought that the following might be achieved 10 to 15 years down the road:

'1/ On-line scanning: 3D models should be built up during the scanning. The model is being shown on the screen while performing the scanning, as it grows. One can immediately inspect the completeness and the quality of the result. Off-line data processing has the disadvantage that the lack of certain data (i.e. the presence of holes in the model) or erroneous data only become clear when it is too late.

2/ Integrated shape and surface reflectance modelling. 3D scanners do yield 3D shapes, but not the precise radiometric properties of the surfaces, which are nevertheless crucial to fully visualise the true appearance of the object.

3/ Opportunistic 3D modelling: currently there is no single 3D acquisition technique that can deal with all types of shapes and surfaces. Methods may have difficulties with narrow structures, deep cavities, specular reflectances, etc. Future systems could be hybrids that deal with much broader classes of objects by (automatically) adapting their modelling strategy.

4/ Automatic registration: typically, 3D data come in as partial patches. These then have to be glued together to form complete models. There are good solutions for fine-registration, but these require good initialisations, which are usually obtained by first manually puzzling the pieces together in more or less correct relative positions. Fine docking is then done automatically. This crude puzzling also ought to be done automatically, i.e. there still is a need for robust, crude registration algorithms.'

As areas where breakthroughs in RTD could be achieved in the shorter term, Gool considered stable online scanning, for which so far only academic prototypes have been demonstrated (around 2007); and combined geometric and radiometric analysis – 'to a large extent an issue of efficient optimisation algorithms' (around 2008). These, and possible RTD breakthroughs considered to be more demanding, are included in the table below.

Professor Gools' analysis of 3D scanning, modelling and registration shows that there are still major bottlenecks for the technology to be declared fully mature. We would also like to point out that many experts and practitioners from the heritage sector stated a considerable demand for high-quality 3D scanning technology, less so for AR/VR, and they urged that this needed to be adapted specifically for the sector's purposes and budgets.

DigiCULT RTD Navigator: Create/Re-create: 3D/VR/AR

The table below gives a condensed overview of what the experts thought could be achieved in this RTD area over the next 10-15 years. After a short summary of what they considered to be current limitations or barriers, the experts' suggestions are grouped into the phases 2005-2009, 2010-2014, 2015 and beyond. The timeframes and, where given, years indicate when a certain methodological and/ or technological gap could be closed or some other RTD breakthrough be achieved. These assessments are of course dependent on the condition that appropriate funding levels, RTD collaborations and other requirements are met.

2004: Current limitations/barriers

Most experts saw a considerable limitation in terms of a lack of high-quality technologies/software for developing and experimenting with 3D/VR/AR applications and environments at a reasonable price. With respect to 3D technologies it was often stated that these would not conform to the requirements of the heritage sector. Furthermore, gaps in standardisation, flexibility and stability were considered as major barriers.

On the other hand, warnings were expressed to prevent technology-driven approaches that would show a 'missing connection of interpretation, alternative and evidence' (M. Doerr), because the scientific value of VR/AR environments is often not considered. RTD projects would need much more involvement of heritage subject-experts and Arts & Humanities scholars.

Other major requirements were considered to be: education & training of many more experts; further development of Digital Rights Management Systems (DRMS) for complex rights clearing and licensing management.

2005-2009

Overall: Considerable improvements in technologies, much more experimentation and consolidation of best practice

Development of 3D scanners and AR/VR software for much easier deployment in heritage projects

Sharing and cooperative exploitation of 3D objects and other complex objects among institutions and projects (mandated in publicly funded projects)

More sophisticated DRMS for limiting and tracking of use of multimedia content

Broader adoption of, and experimentation with, 3D/VR/AR applications and devices in exhibition spaces; validation of 'best practices'

More often large, longer-term interdisciplinary research and development efforts in 3D environments involving regional and city archives, museums and libraries, public administrations and major tourist associations

2007: Stable online scanning

2008: Improved algorithms for 3D reconstruction; and combined geometric and radiometric analysis

2009: Efficient 3D modelling of large pieces or scenes, including automatic crude registration, i.e. fully automated solution of large 3D puzzles

2010-2014

2010: Automated extraction of features of video and audio resources including for end-user applications

2010: Secure data hiding technologies for IPR protection

2010: New efficient language for coding 3D objects, beyond X3D

2012: First truly opportunistic 3D modelling systems

2015 and beyond

2015: First generation of immersive and knowledge-driven VR environments for exploring historical towns over several centuries

2020: OCR-like technology for archival hand-written text

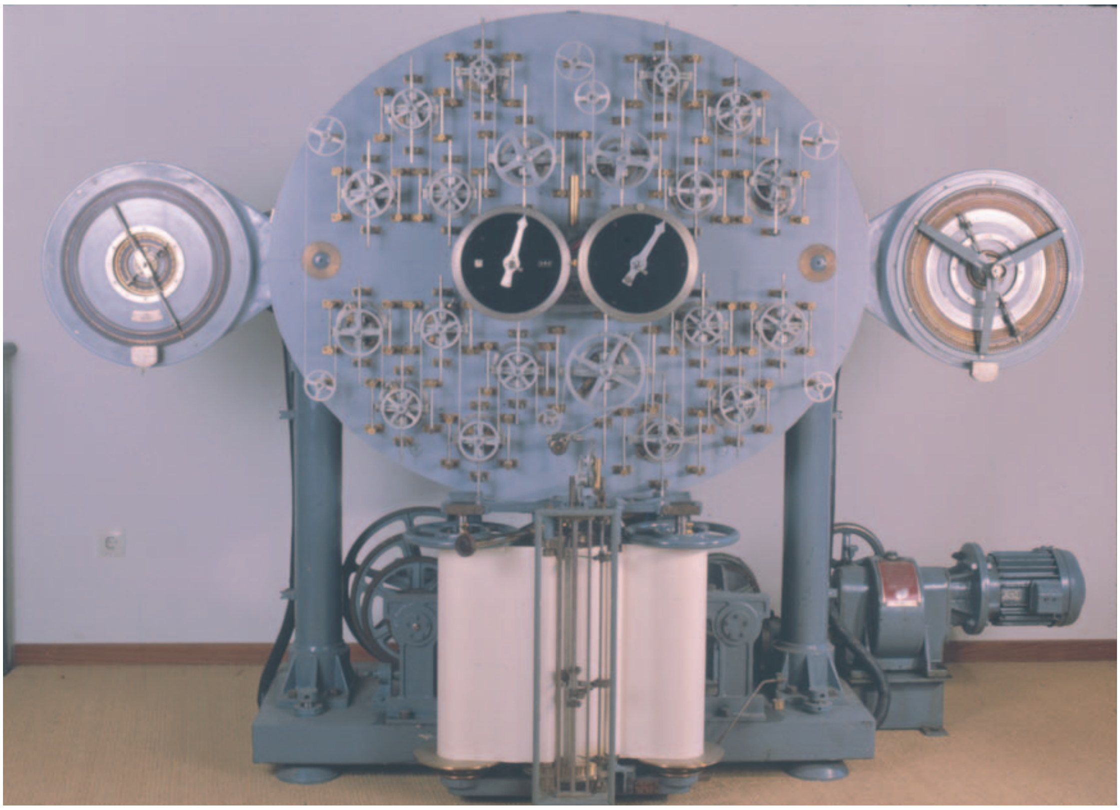
2020: 3D systems and tools that allow for reproducing archival objects (e.g. incunabula with illuminations) as well as handling them in similar ways to the physical objects; furthermore, highly automated ways to extract metadata from the archival objects themselves

Generally, what could be achieved over the next 10-15 years?

'A huge step forward in the levels of realism and interactivity, thanks to ever more powerful graphics, processing and storage systems now appearing' and 'navigation systems which would allow users to explore, rather than just be guided round a predefined tour'. (R. Drage)

'The cultural sector is in competition with many other sectors („entertainment" broadly speaking). The vision is that the products can meet this competition, both with regard to content and technology.' (J. Lybeck)

Theme 5: Large Scale & Distributed Information Systems



The DigiCULT online consultation platform stated that this theme was to concentrate on new generations of large-scale, distributed digital libraries and archives of heterogeneous heritage resources, containing increasingly complex and dynamic objects that change over time, together with an enormous range of granularity of information.

This area of RTD includes new methodologies, applications and tools for:

- highly automated creation, description, indexing, interlinking and overall management of large volumes of distributed digital heritage resources;
- tracking, extraction, analysis and recommendation of information sources within and across sectors, domains and disciplines;
- ensuring the transparent and intuitive access to next-generation digital libraries and archives for users with varying needs and capabilities – and for professional and recreational purposes alike – including applications for real-time or asynchronous collaboration, and the effective sharing and re-use of heritage resources.

Experts' views

Donald Sanders (President, Institute for the Visualization of History, USA) wanted for the next 10-15 years to see 'the development of globally accessible libraries of linked virtual heritage data so that teachers, students, scholars, the public, anyone can traverse time and geography from within a single software environment'. This environment would allow for 'gaining access to multidimensional, multimedia networks for personalized and collaborative uses, accessed via personal or community-wide display systems from hotspots everywhere'. The main gaps that Sanders saw as affecting RTD towards this vision are 'lack of demand for the data in 3D or 4D interactive formats; lack of storage h/ware and server capacity to output streaming worlds and related linked datasets to personalized or community-wide display systems; funding; lack of leaders in s/ware development or data acquisition; and lack of cooperation among the creators, capturers, and storers of such data and worlds...'.

Sanders also noted that 'we need to think outside

of the current buzzwords and technology terminologies that tend to constrain or biasedly define and restrict the conversation'. In particular, what would be required, besides global cooperation, funding, and access to leading-edge hard- and software, is 'creating the need among the general public who must come on board as wanting access to our data otherwise we have no audience, no user base, and no rationale for doing it all (other than it is fun sometimes and leads insiders to gain new insight into the past)'. He insisted: 'Certainly, global access to all the wonderful things that we will be creating is a noble goal, but unless we can demonstrate that millions will demand our content, demand new content, and demand new functionality from our content (as from the downloadable music revolution; and the computer and video game world), we will remain a quaint curiosity. Likewise, unless our worlds become more sophisticated, globally accessible, easily navigable, and linked to multiple databases (that is, more than merely pretty pictures of the past) we will not gain the attention, the funding nor the credibility it will need to build large libraries.'

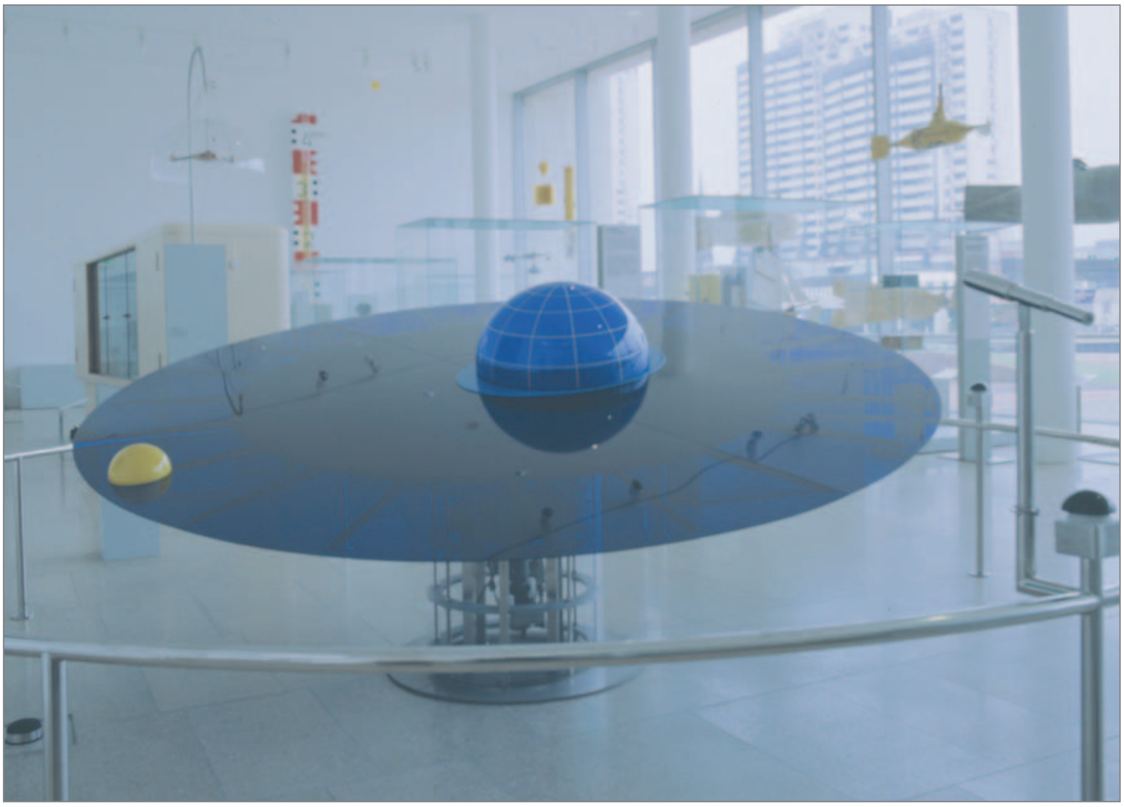
Sabine Stadler, an Austrian social scientist and documentalist, stated that the user-friendly information society, providing equal, easy and transparent access to information, has not as yet come into being. With respect to heritage resources, she criticised the fact that the existing digital collections and applications 'are completely different… and do not refer to any kind of personal attitudes of the user'. She suggested that breakthroughs in RTD may be found if inspired by 'visions of a public on the Net, a space in the Net and the interchange of users'. As she had worked intensively on social conditions and developments in Eastern European countries, Stadler thought that, with regard to a common European digital heritage space, a main limitation could be 'that the new member states are a terra incognita in the field of IT and IT use for all, for the development as well as for the collectors, users and researchers'. She called for a dialogue to be established, 'as the new Europe is the enlarged one', and a major step for the next three years would be to do 'nothing else than let the Eastern Europeans, Balts and Cypriots declare themselves'.

Dominique Delouis (CEO, Cultural Heritage On Line, France) wanted to see in the next 10-15 years 'access to archives in a transparent way in his own language for each European citizen'. He envisaged that this will be achieved 'through sophisticated language technology making translation on the fly, taking into account the context of the archive by using large existing archives and already existing translations (alignment techniques)'. A main limitation for this vision Delouis saw as the 'low level of technology used in the large archiving system which uses old standards such as MARC'. However, he considered a major step towards this vision to be the setting up of 'a European IP [Integrated Project] on multilingual access to the European archives, a kind of Language MINERVA project with test-beds', which he expected could be operational in 2010.

A participant from the archival domain hoped for a much stronger 'linking of different languages in common subjects catalogues and finding aids', which in the coming years would make it easy, for example, 'to find all books relating to "Renaissance bridges" independently from the language of the require [*sic*]'. Generally, he considered language processing to be a 'very complex matter, and clustering does not give very reliable results. The same can be said about OCR in manuscripts or also in ancient editions'. Improvements in clustering analysis for content indexing and OCR techniques were viewed by the archivist to be still important RTD issues. However, for multilingual services to materialise, also spanning archives, libraries and museums, he thought that 'an institutional cooperation framework must be created by the European Commission'. He suggested that 'all mentioned aspects should be defined within 5 years, any other planning has to wait for medium-range results'.

Another participant from the archival domain thought that current major barriers to achieving intelligent distributed systems were 'confusion between data and metadata (and how they are handled); groups continuing to turn to dated technologies such as Z39.50; continued over-reliance and bending of DC [Dublin Core]'. As the way forward, the archivist suggested the use of concepts and technologies that are 'all within our grasp', such as 'greater use and implementation of the CIDOC CRM; acknowledgement that interoperability can be obtained without common data structures; increased reliance on multi-lingual thesauri and moves away from flat file terminology lists; and greater use of XML-based exchange protocols.' What could be achieved over the next 10-15 years the archivist considered to be 'semantic markup that is a common as HTML is today'.

Gavan McCarthy (Director, Australian Science and Technology Heritage Centre, University of Melbourne) suggested that 'open, complex network concepts based on contextual entities (people, organisations, concepts, functions, places, events etc.) show enormous promise for the archive world'. Through



building such an information infrastructure 'much could be achieved, but in the first instance it will probably only happen in small pockets'. However, for the period 2006-2008, McCarthy wanted to see 'the emergence of demonstration systems made up of a few trusted "nodes", and the development of international standards for relationship mapping – particularly in the archive area'. But, he warned, 'international standards development is a very slow process, but an extremely important mean by which knowledge and thinking are developed and transmitted. It also has to be recognised that it is a political process and may be thwarted for all sorts of reasons that are not directly related to the RTD.'

Also addressing semantics-based heritage information services, McCarthy thought that it would be 'difficult to make significant progress in this area in the next 10-15 years beyond demonstration models'. The Science and Technology Heritage Centre, which he leads, had started some projects 'using XML-based data sharing systems based around contextual information rather than resource information directly'. However, McCarthy saw a major limitation for progress in this area in the 'quality of legacy data and systems that are not compliant with the emerging context information standards (ICA, CIMI, etc.)'.

What McCarthy hoped for in the short term of around 2005/2006 was the realisation of well-documented XML-based demonstrator systems for content delivery and presentation. This would require significant funding for substantive development projects, because, as McCarthy made clear, 'the difficulty is that you need to do this with real data – which makes the projects look more like products than the real research and testing that is required'. However, such 'leadership by example' as well as 'the utilisation of the great strength of the web/internet community which is the free sharing of knowledge and technology' could represent a major breakthrough.

A critical assessment of the development towards enhanced distributed information systems also came from Muriel Foulonneau. Having worked as IT advisor for the French Ministry of Culture and participant in the Minerva Europe project,[78] she is currently coordinating a large-scale collaborative project of the Committee on Institutional Cooperation (CIC), which represents major mid-western US universities. The CIC-OAI Metadata Harvesting Service Project, headquartered at the University of Illinois at Urbana-Champaign, is commissioned to build a metadata portal to enhance the access to digital library resources of the participating universities.

Foulonneau provided a checklist of technologies that over the next years would need considerable improvement to allow for enhanced information provision. Related, but not limited to her field of work, this included novel tools for creating, managing and disseminating metadata, including all types of meta-

[78] Foulonneau, among other works, prepared and edited an in-depth report on the use of the OAI-PMH in the heritage sector; "Open Archives Initiative – Protocol For Metadata Harvesting: Practices of cultural heritage actors". Editor: Muriel Foulonneau (Relais Culture Europe, France), September 2003. http://www.oaforum.org/otherfiles/oaf_d48_cser3_foullonneau.pdf

data; automatic metadata generation; a redefinition of information retrieval through other types of information than descriptive ones; applications that allow users to browse different granularity levels of information; and content-based analysis.

However, Foulonneau spotted current RTD limitations that included: 'few adaptations of full-text information retrieval tools to structured content; the same for content-based image retrieval'; 'few attempts to promote multilingual access to cultural content' and, last but not least, 'lack of communication with other sectors such as education'. Foulonneau saw the clear 'necessity to adapt technologies to cultural heritage applications', and expected that around 2009 novel tools could become available partly through adaptation from other application areas, and 2011 could see the development of a new generation of metadata-based tools.

With a view on the automated processing of massive distributed bio- and ecological data, Renata Arovelius, Head of Archives at the Swedish University of Living Natural Resources, stated that an adequate metadata model, as well as a proper technical solution, was missing. She thought that in 2005-2008 more 'international cooperation: scientists/ICT/archive/library – joint projects' would be necessary to achieve 'joint strategy/generic model and standards' beyond 2008.

Jacques Bogaarts (Nationaal Archief, The Netherlands) saw a major RTD requirement for 'tools that automatically or semi automatically (expert support) extract data from archival records (machine- or handwritten, maps, etc.) There should also be tools to convert these data to formats that are recognisable in a modern context, for instance project old maps on current ones, resolve complicated multi-layer indexes to direct access (archivists will know what I mean).' However, Boogarts expected that the necessary software might become available only in 2020.

Martin Doerr (ICS-FORTH, Greece) stated: 'The biggest obstacle is the separation of scientists and technology for automated and non-automated methods. Exactly as artificial intelligence has failed and Information Retrieval stagnates since years, a purely automated approach is doomed to fail. The quality of purely automated methods is unacceptable to scholars. Similarly, multi-modal methods are superior to individual algorithms. There is virtually no research in quality assessment of individual results of automated methods: Can an algorithm separate out which item is correctly treated by an automated method, and which may be not? So that the investment in manual intervention can be directed to the "difficult cases", saving money without compromising quality.'

Doerr considered the major RTD step to be taken as the development of 'technologies that allow for a graceful interaction of manual and automated procedures. Automated procedures are needed to initialize material for manual processing, to refine manual processing without destroying good human decision, and to learn from human decisions. Only multimodal techniques will be successful. Integration of automated learning, statistical methods, user behaviour evaluation.' If strategically addressed, major achievements could be achieved in 2008-2010.

Kazimierz Schmidt (Adviser, State Archives, Poland) provided DigiCULT with an extensive description of requirements needed for the consistent creation, management and integration of distributed heritage resources of which we can only mention a few points. Schmidt envisaged that over the next 10-15 years 'precise finding in large distributed resources, existing in most different forms, and aggregated in most different institutions will be possible, if we agree common, bright standards of the classification and description'. He added that 'it is not enough to accept standard markup language (like the XML family) which let us to describe any structure (i.e. EAD) – we need to agree the structure of metadata'.

Schmidt pointed to the collaborative success of Dublin Core, 'but as every solution on so general level this is not satisfactory information (in details) for any institution professionally collecting records'. Detailed descriptive models, in his view, should be defined according to types of documents and used across the different domains of heritage organisations (e.g. for photographs, as prepared by the cross-domain SEPIA project[79]). A further important requirement would be to agree on how to construct stable, unique ID numbers, and the process of linking this unique ID to following versions of the same document; for example, using an 'original' ID as a part in subsequent versions of a document, which would allow future users to find not only individual documents but the 'family of its versions'.

Schmidt also addressed the need to change some attitudes towards electronic resources. This included the comment that 'digital records very often are treated as documentation separate from the traditional record files, photographic, audio-visual, sound material etc; and colleges (universities) teach "the electronic documentation" as a separate subject'. Furthermore, Schmidt urged not to let every institution build 'their own' digital collection, rather data centres should be established, to which smaller local institutions should also be enabled to connect.

79 SEPIA: Safeguarding European Photographic Images for Access, http://www.knaw.nl/ecpa/sepia/; see also the papers from the SEPIA conference: "Changing Images: the role of photographic collections in a digital age" (18-20 September 2003), which form a rich resource on issues in (digital) photographic heritage, http://www.knaw.nl/ecpa/sepia/conference.html

DigiCULT RTD Navigator: Large Scale & Distributed Information Systems

The table below gives a condensed overview of what the experts thought could be achieved in this RTD area over the next 10-15 years. After a short summary of what they considered to be current limitations or barriers, the experts' suggestions are grouped into the phases 2005-2009, 2010-2014, 2015 and beyond. The timeframes and, where given, years indicate when a certain methodological and/or technological gap could be closed or some other RTD breakthrough be achieved. These assessments are of course dependent on the condition that appropriate funding levels, RTD collaborations and other requirements are met.

2004: Current limitations/barriers

According to most experts, this RTD area needed to overcome the following limitations or barriers in order to achieve significant progress:

- Quality of legacy data and systems, e.g. traditional descriptive standards (e.g. MARC) and continued use of dated protocols (e.g. Z39.50); even for Dublin Core 'continued over-reliance and bending' was criticised.
- Low level of information technology in many heritage organisations (e.g. archival IT systems)
- Inadequate middleware, which hinders transparent and precise access to heterogeneous types of resources
- Few adaptations of advanced retrieval tools for structured (textual) content as well as multimedia content
- Too little promotion of multilingual access to heritage content

Furthermore, heritage data centres would need to be established to which smaller local institutions could also connect. Creating and managing not only large repositories but also small-scale yet interoperable digital collections was considered as a challenge.

2005-2009:

Overall: An increased use of combinations of 'best in class' technologies and standards

More widespread use of stable, unique ID numbers and established standards for employing them (e.g. in versioning of documents)

Increased uptake of XML-based exchange protocols

2005-2006: Realisation of well-documented XML-based demonstrator systems for content delivery and presentation (with massive 'real data')

2006-2008: Emergence of demonstration systems for more open, complex network concepts

2006-2008: Development of international standards for relationship mapping (e.g. in the archival sector)

Increased reliance on multilingual controlled vocabulary (moving away from flat-file terminology lists)

Further development of descriptive models for certain types of resources (e.g. photographs) that are used across different heritage domains

Stronger combination of different automatic retrieval and analysis mechanisms

Research in quality assessment of individual results of automated methods

Achievements in technologies 'that allow for a graceful interaction of manual and automated procedures' (M. Doerr)

2010-2014:

Novel tools for (automatically) creating, managing and disseminating different types of metadata

Considerable progress in clustering analysis for content indexing, and in content-based analysis

Emergence of applications that allow users to browse different granularity levels of information

More sophisticated language technology allowing some translation on the fly (including use of existing translations; alignment techniques)

2015 and beyond

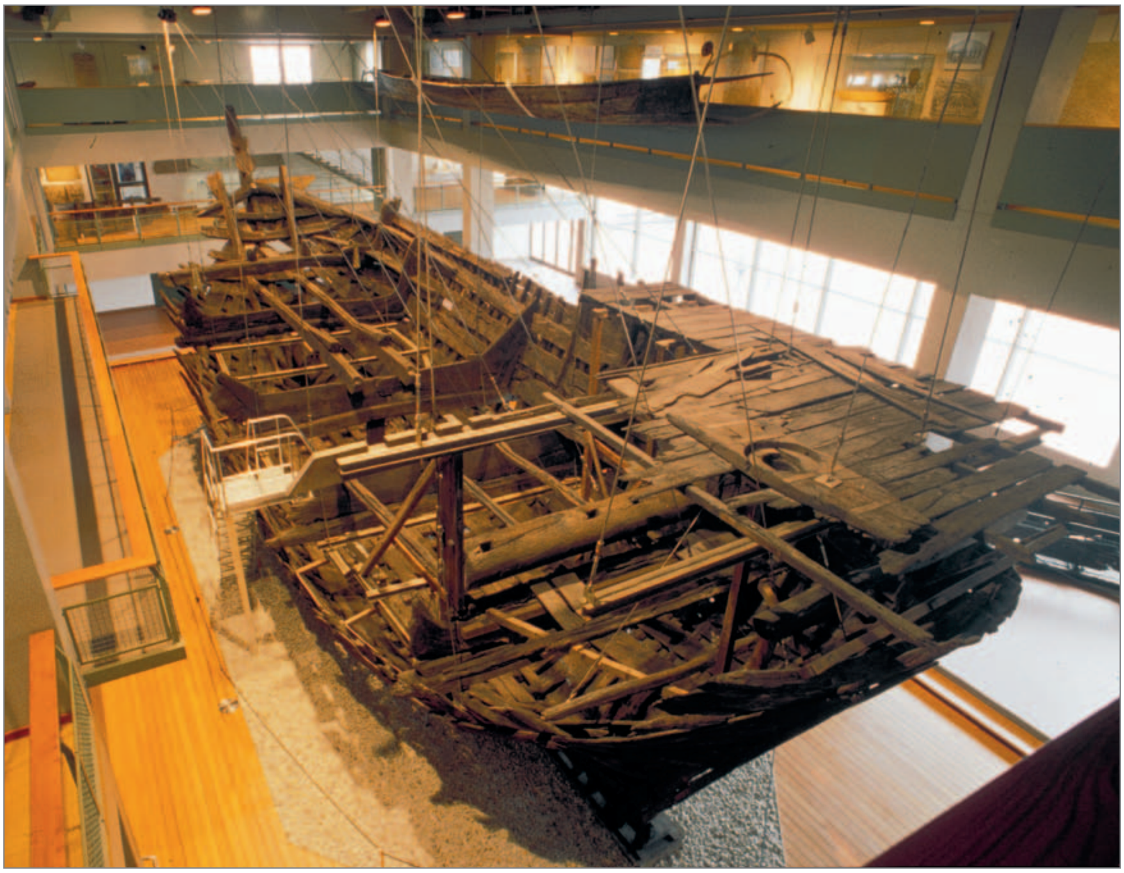
Tools that automatically or semi-automatically extract data from archival records (machine- or hand-written, maps, etc.), convert them to modern formats, e.g. for projecting old maps on current ones, and resolve complicated multi-layer indexes to direct access (J. Bogaarts)

Generally, what could be achieved over the next 10-15 years?

'A Charter of Rights of Open Access to all digitised cultural artefacts… Could be years away, there are too many vested interests in this sector…' (R. Drage)

'DigiCULT could articulate where the national/regional institutions sit with the local/personal… Help people to manage their own heritage?' (A participant from a governmental body or agency)

THEME 6: PERSISTENT & PERPETUAL ACCESS



In the information given on the DigiCULT online consultation platform, this theme was stated to concentrate on novel concepts, methodologies and techniques to make the digital environment as stable as the physical – not only in terms of perpetual accessibility, but also remaining understandable over time. This includes:

- advanced platforms, tools and services to support long-term preservation and perpetual availability of digital heritage resources in as yet unknown future environments;
- preventing the loss of and restoring access to heritage artefacts in obsolete formats, or which are too rare or fragile for regular physical access; this also includes capturing and preventing loss of endangered intangible heritage;
- issues of long-term preservation of increasingly complex and changing objects, including knowl edge organisation systems, vocabularies, thesauri, ontologies, etc.

EXPERTS' VIEWS

This theme emerged as the one where political, institutional, and research and technological development issues are most intertwined. Consequently, the suggestions also touched political issues such as international mechanisms to ensure a much higher standardisation of formats and durability of commercial software. We thought it valuable to include such suggestions in the summary, but have not included them in the RTD navigator.

Political and institutional requirements

A participant from a research centre thought that the next 10 to 15 years could see the creation of large-scale repositories, automatic metadata harvesting, and automatic migration. However, he urged: 'Don't talk about technology as the solution or even the central issue. It is not developing things but learning to work with things.' He explained further:

'Not RTD is the main issue for the cultural sector but organizational power, experience and knowledge level of staff, clear policies and structural funding. We have more technology than we can deal with, and techies finally can't solve problems. Technology is moving faster than the joint knowledge base of people doing the work and than funding levels. Everyone wants to try out everything and we lack stable structures (financial, expertise, organizational) to build on to. Just scattered projects and too many diverse demands on the sector.'

Hilde Van Wijngaarden (Digital Preservation Officer, National Library of the Netherlands) wrote that a strong limiting factor of what currently could be achieved was that digital preservation 'has for too long been only the concern of the cultural heritage sector, while the issues at hand are technologically challenging. The CH sector needs the co-operation of computer scientists and software developers.' Furthermore, she saw a 'lack of concern for durability when developing innovating technologies. Partly as a result of this lack of concern, establishing and maintaining standards is difficult. This should be of major concern to governments or international organisations, who should stimulate work on durability issues in the technological sector.'

Political issues regarding more stable technologies, software and other industry standards were also addressed by other participants. This Hannen (Advisor, De digitale archivaris, The Netherlands) suggested: 'There should be strictly demands/or standards to software developers coming from an authority, such as W3/DoD, so that all users know that this software is reliable to use.' Elizabeth Selandia, an art historian and member of the Visual Resources Association (USA), elaborated the key point in more detail: 'Competition fosters invention, but in digital, with each new invention comes the need to support the archival storage of the outcome. Hence, diversity in applications makes the problems of preservation and presentation very difficult for digital libraries and archives, both.' As a political breakthrough towards bettering the situation, she suggested: 'Mandating a required cross platform and user support for earlier versions of the software would be a start. Demanding specifications that required the perception that any given software is not the end of the line but needs future migration support would be a next. – These suggestions should have already been in place and need to be instituted immediately, so get started ... now!'

A participant from a governmental body or agency in Europe summarised his view of the current problems, and gave pointers on how to solve them: 'A chaotic and unbalanced digital marketplace: More "push" to employ open systems'; insufficient generic user specifications: more generic user specifications – and especially agreeing them more quickly'; 'lack of enforcement of such standards as exist: more enforcement – e.g. by making open systems/generic specifications mandatory in awarding project funds' and, finally, 'complexity of metadata standards: simplification'.

Drawing on her long-standing experience acquired from, among other activities, her work as director of the major InterPARES 1+2 projects, Luciana Duranti (Professor/Archival Scholar, University of British Columbia, Canada) made it clear that a comprehensive and sophisticated conceptual framework is needed 'that will allow us to identify, in each cultural and technological context, the entities to be preserved and their digital components, and the methods for preserving them in an accurate and authentic way. This is the presupposition to the development of any policy, standards, or specific strategies. Once created, this framework will have to be constantly refined and the outcomes of its use will of course be always new because of the constant technological change.'

Duranti saw the major limitations to developing and maintaining such a framework in 'the amount of financial support going towards multidisciplinary and international research, the lack of continuity in such support, the ridiculous limits that they prescribe, and the politics of granting agencies and institutions, which rather support new research than ongoing research, and only pay lip service to international and multidisciplinary collaboration'. She urged that developing the aforementioned conceptual framework is a complex and long-term task, and that 'any interruption implies an immeasurable loss of ground… What needs to happen is the creation of research "institutes", as opposed to projects, initiatives, etc., which are supported on a continuing basis by international money coming from agreements, for example, among the EU Commission, North American research agencies, Chinese and Australian institutions. Something like CERN, for example, but with a small administration (bureaucracy hampers research) supporting a large group of scholars of all spheres of activity that produce cultural heritage and from all parts of the world.'

Duranti added that it would not be acceptable that in research areas such as physics, biology, etc. permanent infrastructures capable of carrying out uninterrupted international and multidisciplinary research are possible, but when it comes to preserving digital cultural, scientific, artistic and other societal important heritage some projects, committee work, workshops, and similar things should be possible. Setting up an international research centre for digital preservation,

Duranti stated, '…could take from 1 to 10 years. If it takes so long, we will be so behind in finding appropriate solutions that much of our cultural heritage in digital form will be lost.'

Also, Anne Gilliland-Swetland (Department of Information Studies, UCLA, USA), Co-Director of the US InterPARES project team, made it clear that the 'lack of a systematic preservation infrastructure is going to result in a significant loss of digital assets (digital assets = not only content, but all supporting metadata) as well as diminution of their ability to be trusted'. Besides the reluctance of key stakeholders 'to take ownership of the long-term questions', Gilliland-Swetland thought it important to recognise that 'rights legislation also undercuts the ability of researchers and repositories to develop new preservation technologies'. However, what she hoped for was that in the next few years an infrastructure could be developed 'that spans not for-profit and for-profit sectors and has a viable economic model'. The latter would include an 'increased understanding of the economics of long-term preservation, including a way to conduct cost-benefit analyses over complex variables such as time and cultural and personal empowerment values'. Other major steps for framing and driving RTD in digital asset preservation management Gilliland-Swetland considered to be securing government and commercial sector 'funding commitments, commercial software development, and more openness to supporting preservation technology requirements in digital intellectual property legislation'. With respect to commercial software development, she saw a demand for 'off the shelf software designed according to archival specifications to assist organizations in preserving their digital assets'. Gilliland-Swetland would not give a timeframe, but stated that major breakthroughs in long-term digital preservation management were not hindered by technological issues; 'technologically they could be developed now'.

Richard Wright (Technology Manager, BBC, UK) suggested the building of a European Digital Heritage Repository as a sustainable environment where digitised/digital content could be stored and accessed; 'among other features, this repository would provide a common catalogue to archived works of recorded music, broadcasting, performing arts – and all the myriad small digital collections that currently have no sustainable home'. The 'biggest breakthrough' for such a venture Wright thought to be 'probably political – seeing that a European cultural collection is a valid and necessary EC task. We don't have European museums. In the digital world, there is every reason to consolidate "digital heritage" at the European level: sustainability, cross-national and cross-cultural research, economy of scale, common access, multilingual access.' Given such a political breakthrough, 'communication with all European sources of material needs to be established, and a legal framework (such as Creative Commons) needs to be adopted to support "donation" of material to this European collection/umbrella.'

Wright also mentioned that discussions on a possible European role in holding 'digital culture' had already started, as in a recent Den Haag meeting 'Strategies for a European Area of Digital Cultural Resources' (http://eu2004.digitaliseringerfgoed.info). So he thought it not impossible that a European commitment could happen by 2006. With respect to the expense of building and maintaining a European Digital Heritage Repository, Wright thought that this 'could be addressed by RTD in cost-effective repositories, but more significantly by research in broader and deeper access methods: new services, comprehensive metadata, usable search tools'. More specifically, he suggested that a funding model should be developed, 'involving RTD in European-level integration of national (or local) repositories, and effective mechanisms to link a European repository to commercial uses' as well as 'exploitation of existing projects

Political and institutional issues… selected statements

'Preservation responsibilities should become more orderly and routine, but will need to be funded on a recurrent, not a project, basis'. A participant from a governmental body or agency

'The research tends to be piece-meal, generally not well co-ordinated, and with the developed world taking the lead'. Patrick Ngulube (Lecturer, University of KwaZulu-Natal, South Africa)

'Promulgation of Creative Commons licences, see http://www.creativecommons.org.uk' and 'international certification of preservation services, for example, "We have used the PREMIS guideline" so a certain baseline is agreed upon'. A participant from a governmental body or agency

'Quality predicates for companies that guarantee a certain life-time of their products to a national agency'. Martin Doerr (ICS-FORTH, Greece)

'Simplification of intellectual property, copyright regimes to enable easier digitisation/preservation access to cultural heritage'. A participant from a governmental body or agency

and prototypes at the European level'. Given a commitment on the European level based on such a masterplan, 'the actuality should be developed over the ensuing five years: say 2006-2011'.

Technologies for persistent and perpetual availability of digital heritage resources

Hilde Van Wijngaarden (Digital Preservation Officer, National Library of the Netherlands) gave a concise summary of the general state-of-play in technological and organisational requirements for the long-term preservation of digital heritage resources. She described this as follows: 'Recent years have seen growing awareness and activity in the area of digital preservation of cultural heritage. Secure storage has been the first issue to have been addressed, permanent access issues have now emerged as the focus of attention. Looking at the work that has been done, especially during the last two years, a lot can be achieved over the next 10-15 years.'

Wijngaarden summarised the overall technological challenge as 'developing tools that can carry digital artefacts through time without damaging their authenticity on the one hand and facilitating user access on the other'. With respect to the organisational dimension, she called for the setting up of 'cross-sectoral co-operation (data-institutes, commercial companies and the cultural heritage sector have to work together) with distributed services and shared knowledge and tools.' Wijngaarden added, highlighting the need to proceed on the organisational level: 'Both technical and organisational aspects can advance enormously during the next 10 years. This is because most of the knowledge is there, so we can advance to the next step of developing and setting up the organisational structures.' In particular, such structures would 'need to cross the boundaries of the cultural heritage sector to work.... When the CH sector can work together with technical sciences, major steps forward can be taken.'

While emphasising organisational issues, Wijngaarden also summarised the major RTD challenges for the next ten or more years. These included: 'An urgent step is the development of working tools and worked out procedures for permanent access to digital objects. Migration/conversion has to be tested and evaluated and emulation has to receive the attention it deserves to develop a working tool for the future. Emulation can offer a solution for maintaining the accessibility to complex digital objects but never has been developed yet for preservation purposes (the National Library and National Archives of the Netherlands will start a project beginning of 2005).' Given the necessary funding and willingness of technology partners (commercial and scientific), Wijngaarden expected the development of the aforementioned tools and the setting up of cross-sectoral cooperation in the years 2005-2010, and the implementation of powerful distributed preservation services in 2005-2015. She added, 'the next few years are crucial and a lot can be achieved'.

Gavan McCarthy (Director, Australian Science and Technology Heritage Centre, University of Melbourne) stated that this theme addressed 'the long term problem and one that has been a thorn in the side of the digital world'. He considered a general understanding of 'persistent identity management and open network citability' as two essential requirements to start with, 'but looking further ahead we will need greater computing and processing power and the ability to share the processing load in a grid environment'. McCarthy thought that the required easy sharing of data and processing resources would demand a re-thinking of established process and business models. Therefore, as a major step ahead, which should happen in the next few years [2005-2008], he suggested 'a general change in thinking and the tapping into the science processing grids for access to computer storage and processing power'.

George Abbott (Director, Library Media Services Department, Syracuse University Library, USA) considered the following as worthwhile RTD aims in the area of digital preservation and perpetual access: 'Exploration into the development of self-replicating systems. Through the use of such standard practices as routine backups of digital data on servers and others online (as opposed to offline) storage systems applications can be developed to automatically migrate data to benefit from technological development. The development of applications to perform unattended reformatting with built in automatic controls for maintaining and/or improving the quality and functionality of the original.'

As some current RTD limitations or gaps towards achieving this, Abbott mentioned 'maintaining accessibility across a number of platforms for access. Need for more open source applications. The design of many web pages today is optimized for specific browsers making migration and long-term preservation more difficult.' Regarding digital migration he saw no major steps or breakthroughs in RTD needed: 'Most of the major steps are human resources related, providing support and the work force to accomplish the migration. The research breakthroughs revolve around some sort of automated reformatting and preservation ideally preserving all steps in the reformatting process. Dedicated centers should be developed devoted to

Grid computing

The development of Grid technology is driven by a vision of making massive computing and storage resources available as a service on demand. Practical implementations include most notably the open source Globus toolkit and the Unicore project. Standards are being developed for Grid computing by the Global Grid Forum (GGF). In addition to many academic and research institutions, about thirty IT industrial players are committed to Globus, or involved in the GGF, or both. These include, for example, Microsoft, Hewlett Packard, IBM, Sun, Dell and BEA. What motivates these industry players is the goal to achieve resource virtualisation and a massive scaling of computing infrastructure and services through effective resource sharing. Actually, enormous processing power may be harvested at relatively low cost, 'on-demand'. Considered as further down the road is the enabling of application sharing and clustering.

Sources:

Brian Carpenter, "What is Grid Computing?" (26 February 2003), http://www.isoc.org/briefings/011/index.html

Ian Foster, C. Kesselman, J. Nick, S. Tuecke, "The Physiology of the Grid: An Open Grid Services Architecture for Distributed Systems Integration" (22 June 2002), http://www.globus.org/research/papers/ogsa.pdf

Globus toolkit, http://www.globus.org

Unicore project, http://www.unicore.de

Global Grid Forum, http://www.gridforum.org

Major European Grid computing projects, 2001-2004: European DataGrid http://eu-datagrid.web.cern.ch/eu-datagrid/, and EUROGRID, http://www.eurogrid.org

preservation.' Such centres could assist by providing guidance and support in 'a continued diligence and continuous migration anticipating the future'.

John Poirier (Northwest Territories Archives, Canada), a coordinator of technical services with expertise in dealing with photographs, sound recordings and moving images, suggested that the following could leverage digital preservation: First, authoritative guidelines, which should build on best practices. These practices needed to be reviewed, consolidated and published. With an eye on the various sizes and capabilities of the heritage institutions, Poirier stated: 'Guidelines should be flexible in terms of enabling institutions with varying levels of resources and skills to obtain best results for resources invested. Considerations would include reasonable quality and above all long-term viability of product.'

Secondly, Poirier called for 'a strategy for dealing with changing storage and file format technology'. He insisted that there needed to be more attention to what smaller institutions require, for example, 'much research and planning seems to be geared toward the top echelon of people and institutions involved with preservation. There seems to be a gap in terms of developing approaches that, while not absolutely perfect, will enable the small fry in all their diversity to have a good shot at simple, good quality and affordable preservation methods.' Poirier explained further: 'It is (in a way) fine for institutions like the Library of Congress to develop massive proprietary systems. Not so fine for the lesser lights, especially when off-the-shelf approaches could do the job as well if not better. I cite IPTC captioning for image files, adapted for archival purposes via a convention for extra fields, as an example. A segment of RTD ought to be devoted to finding, adapting, and promoting commercially developed solutions.' A participant from a governmental body or agency added some further practical measures that could generally leverage the work in digital preservation: 'high-quality and understandable documentations and publications of projects which are available free of charge; advice from practitioners at an affordable price'.

Martin Doerr (ICS-FORTH, Greece) wrote that, generally, 'the problems are more social than technical. National agencies should monitor availability of key technologies that may render media unreadable and maintain standards recommendations for formats they monitor. Companies could acquire quality predicates if they guarantee a certain life-time of their products to a national agency.' With regard to RTD issues, Doerr saw a lack of 'systematic investment in migration (mapping) technology'. In the area of such mapping technologies (as described in theme one) he thought that by 2010 some real progress could be achievable. Doerr noted that 'migration is inevitable in long terms'; however, 'the solution is there when continuous migration, carrier multiplication and monitoring has become institutionalized'.

Doerr considered as an area where focused RTD could bring about good results in the medium term: 'standardized risk management software for decision support in cultural institutions (catastrophes like fire, technology change, carrier aging, connected to valid data from a preservation agency)'. Such software could become available around 2008. Furthermore, he high-

Selected projects and publications

ERPANET… the Electronic Resource Preservation and Access Network, has established an expandable European Consortium, which makes viable and visible information, best practice and skills development in the area of digital preservation of cultural heritage and scientific objects. The project also serves as a virtual clearinghouse and knowledge-base in this area.
http://www.erpanet.org

InterPARES… the International Research on Permanent Authentic Records in Electronic Systems, aims at developing the theoretical and methodological knowledge essential to the long-term preservation of authentic records created and/or maintained in digital form.
http://www.interpares.org

A practical and information-rich online tutorial... *Digital Preservation Management: Implementing Short-term Strategies for Long-term Problems.* Cornell University Library/Research Department (2004), http://www.library.cornell.edu/iris/tutorial/dpm/index.html

DPC/PADI What's new in digital preservation… http://www.dpconline.org/graphics/whatsnew/, a joint service of the Digital Preservation Coalition (DPC) and Preserving Access to Digital Information (PADI) that provides a quarterly summary of selected recent activity in the field of digital preservation compiled from several sources.

A research agenda for digital archiving and long-term preservation… *Invest to Save.* Report and Recommendations of the NSF-DELOS Working Group on Digital Archiving and Preservation (2003), Margaret Hedstrom and Seamus Ross et al., http://delos-noe.iei.pi.cnr.it/activities/internationalforum/Joint-WGs/digitalarchiving/Digitalarchiving.pdf

lighted the fact that standardised preservation monitoring software would be needed, which could also be achieved around 2008. However, he mentioned that in an RTD proposal a work package to create a carrier monitoring system was taken out because the reviewers regarded this as not innovative. He added: 'At the Germanische Nationalmuseum, a brand-new RAID server crashed completely, even though it has a theoretical lifetime of some 10,000 years. (In Prague, whole libraries were flooded. Not to speak about Iraq)'

Reagan Moore (Director, Data Intensive Computing Environments, San Diego Supercomputer Center, USA) wrote that preservation environments up to the demanding tasks of long-term digital preservation and access would need a support community for sustainability (funding, domain expertise). As a major requirement, however, he added: 'For sustainable preservation environments, the collections must be shown to provide information and knowledge that would otherwise be lost. This means that the preserved collection must be capable of supporting knowledge generation/data mining to identify those items that address today's questions. This in turn means that the preserved collection is useful if it can be processed, new organizational structures can be applied, and discovery can be supported for purposes different than the original guiding preservation policies.'

Regarding the technological set-up, Moore suggested building on 'data grid technology, which provides the infrastructure needed to manage technology evolution, and automate processing of collections', as well as being able to 'support the long-term data management'. Major current RTD limitations or gaps he saw in 'the equivalent of a digital ontology… that characterizes the structure of a digital entity and defines the operations that can be performed on the structures. We then need a display ontology that characterizes the operations needed for display. Preservation (emulation) then consists of mapping from the operations that can be supported on the digital entities to the operations required for display. Migration is transformation of the ontologies onto new relationship encoding formats (such as RDF).'

Considering these RTD issues, Moore described some major steps or breakthroughs required to close existing gaps as follows: 'The challenge is that the encoding formats for text, spreadsheets, slides are quite complex. We need better languages to describe ordering of operations that are needed to interpret bits, transform to ascii, transform to text structures, and transform to display mechanisms. The goal is generic software that supports self-describing objects in terms of their internal structures and the allowed operations for manipulating those structures.

Another major step is the development of constraint-based data management systems. This is the recognition that the consistency constraints imposed for authenticity, the access control constraints, the viewing transformation constraints, will also evolve over time. We need to be able to dynamically apply new constraints to a preserved collection, as well as to be able to define the constraints under which the collection was originally created.' The timeframes Moore gave for when this is likely to be achieved are included in the table.

DigiCULT RTD navigator: Persistent & perpetual access

The table below gives a condensed overview of what the experts thought could be achieved in this RTD area over the next 10-15 years. After a short summary of what they considered to be current limitations or barriers, the experts' suggestions are grouped into the phases 2005-2009, 2010-2014, 2015 and beyond. The timeframes and, where given, years indicate when a certain methodological and/or technological gap could be closed or some other RTD breakthrough be achieved. These assessments are of course dependent on the condition that appropriate funding levels, RTD collaborations and other requirements are met.

2004: Current limitations/barriers

General measures required for ensuring progress in RTD and organisational frameworks for long-term preservation/availability of digital heritage resources include:

- establishing much stronger cross-sectoral cooperation between heritage organisations, research institutes and commercial IT players (expected for the period 2005-2009);
- regularly reviewing and consolidating the knowledge and best practices from many 'scattered projects' (e.g. in the form of authoritative guidelines to be made mandatory by funding bodies);
- setting up stable mechanisms for developing further the existing joint knowledge base against a background of rapid technological change (e.g. in international research centres);
- developing strong economic models of, and evidence for, the benefits in long-term digital preservation, also addressing copyright/IPR issues that may hamper the preservation of valuable heritage resources.

Some specific suggestions include: Focus on cost-effective repositories; authoritative standards recommendations for formats; monitoring by dedicated agencies of technologies that may render media unreadable.

2005-2009:

Overall: A phase of maturing base technologies and procedures, including many more Open Source applications

Further development of self-replicating systems; standardisation of practices such as routine online backups of digital data on servers

Development of applications which perform unattended reformatting with built-in automatic controls for maintaining and/or improving the quality and functionality of the original

Enhanced working tools for testing and evaluation of migration procedures

2005-2008: Increase in computing and processing power through the ability to share resources using GRID technologies

2008: Standardisation of preservation monitoring software

2008: Standardisation of risk-management software for decision support, backed up by valid data from an authoritative agency, e.g. regarding carrier aging and technological changes

2008: Improvements in constraint-based data management systems towards dynamically applying new constraints to a preserved collection, as well as being able to define the constraints under which the collection was originally created (*cf.* R. Moore)

Until 2010: More investment and progress in mapping technologies (*cf.* M. Doerr, p.38)

2010-2014

More powerful distributed preservation services, in particular through wider use of data GRID technology for the infrastructure needed to manage technology evolution

2010: Progress in better structure-modelling languages able to describe the ordering of operations that are needed to interpret bits, transform to ascii, transform to text structures, and transform to display mechanisms. (*cf.* R. Moore)

2015 and beyond

2015: Digital ontology(ies) characterising the structure of a digital entity and defining the operations that can be performed on the structures

2015: Display ontology(ies) characterising the operations needed for display

2015 and beyond: A generic software that supports self-describing objects in terms of their internal structures and the operations permitted for manipulating those structures (*cf.* R. Moore)

Generally, what could be achieved over the next 10-15 years?

'Off the shelf' methods and software designed to assist smaller heritage organisations in preserving their digital assets (A. Gilliland-Swetland, J. Poirier)

Technology Development and Implementation from the Heritage Sector's Perspective

Getting to grips with the technologies: the Cultural Heritage sector dilemma

After all the hype, advice and guidance, the cultural heritage sector still has difficulty getting to grips with the opportunities and excitements of the digital world. That is the conclusion of many of the sector observers who commented in the DigiCULT roadmap survey.

They had answers and suggestions aplenty but, despite some notable achievements among Europe's museums, libraries and archives, that was their general belief.

Polish State Archives advisor Kazimierz Schmidt puts it down to individualism: 'A serious hindrance in making digital resources is not only the lack of standards but also the natural wish of libraries and archives to stay independent. It seems that this need to stand alone is caused by fear of the loss of their existing positions as important, indispensable institutions of the culture,' he said, adding 'This reluctance to co-operate in establishing standards stems from thinking collections are too exceptional, requiring exacting, exceptional approaches.'

He summed up, setting the tone: 'Perhaps it is time to say a very unpopular sentence: Trying to support a local archive without plans to link it to a data center equals spending money for nothing.'

Gerd-Christian Weniger, Director of the Neanderthal Museum,[80] in Germany's Nordrhein-Westfalen region, wrote more briefly: 'Cultural institutions are lacking money and personal capacity for digital registration of their collections. Many curators do not understand themselves to be part of a cultural service for the public.'

Chicago consultant and art historian Angela T. Spinazzè[81] said it as strongly as any: 'As a community, we have very little shared vision. It is difficult to see the big picture when most institutions are still gazing inwards trying to digitize their singular collections. A more outwardly focused agenda would be beneficial as a means to bridge gaps and bring together data and information previously generated for institutional purposes into a larger knowledge sphere. Even collaborative projects often end with closed systems. We would do well to encourage connectedness and awareness of a larger context.'

The concern went on and on. A Southern Hemisphere commentator thought: 'Perhaps rather than technical blocks there are emotional blocks and control issues to be resolved.' And another North American wrote: 'There is a lack of common goal in this arena, in part fostered by the commercialization inherent in software and hardware development. What is needed here is a moral commitment to knowledge perseverance and, therefore, preservation. When this is in place, things might be better, not worse.'

Others saw shortages of cultural heritage-trained technicians and lack of 'ownership' of long-term preservation questions raised by development of digital technology. Yet another researcher feared apathetic 'lack of pressure from a central body to use standard vocabulary and little knowledge among the people doing the work on the ground in sites, museums, etc.'

Project Coordinator for Britain's Milton Keynes Museum,[82] Roger Drage, was sure 'seamless access to all heritage and cultural artifacts through web technology' could be achieved, adding, 'we are already a long way down this particular road'. However, he urged: 'The limitations aren't technical but conceptual, legal and cultural in nature.'

Denmark's Dr Pia Borlund, an associate professor in the Information Studies Department at the Royal School of Library and Information Science in Aalborg, was worried on behalf of digital system users whom she defined as 'researchers, pupils, students, professionals, museum guests, museum people, archivists, etc.'

She wrote: 'Potential users are not always interested in changes such as new information systems. They know what they have and how to work it. That is enough for them. In other words, attitude problems of users and their willingness to participate in user studies may also be a challenge to overcome.'

A major step to meet this challenge would, she said, be to get people to work together, to listen to and learn from each other. She emphasised: 'By "people",

80 http://www.neanderthal.de

81 ATSPIN Consulting. http://www.atspin.com

82 http://www.mkmuseum.org.uk

I mean information scientists, computer scientists and cultural heritage people.'

Swiss archives lecturer Niklaus Bütikofer, a director of the EU's ERPANET project,[83] had another angle on Dr Borlund's user challenges. What was baffling the sector leaders was 'how to motivate people to "use" heritage information and objects and how best to present the objects and related information to the user'. Heritage providers often did not have adequate description and context linking cultural objects to provide users with sufficient information to find and understand them.

All this was solvable, he thought, with continuing study and evaluation of user needs and behaviour. How long would it all take to achieve? He was not going to be drawn on that. He wrote: 'This is an ongoing activity which should lead to continuing improvements.'

Surely, the provision of carefully devised metadata would solve the problem for all time, would it not? Not necessarily, said one state archivist, avowing: 'A problem is the strong belief that a common metadata set could be found, which is false. If we have different meaning, we will always have different description/metadata sets.'

Poland's Kazimierz Schmidt had sympathy with this thought when he was responding to the roadmap's large distributed resources theme. He wrote: 'Precise finding in large distributed resources, existing in most different forms, and aggregated in most different institutions will be possible, if we agree common, bright standards of the classification and description. It is not enough to accept standard markup language (like the XML family), which let us to describe any structure (i.e. EAD) – we need to agree the structure of metadata. The success of Dublin Core shows how necessary this is. But, at so general a level, this is not satisfactory for every solution in institutions.'

Senior ICT consultant at the Netherlands Nationaal Archief, Jacques Bogaarts, thought the sector could help itself with this problem. He wrote: 'Cultural heritage institutions should undertake large digitisation projects creating huge amounts of digital objects with high quality metadata. The main problems now lie with the lack of directly available metadata for web content.' And the problem facing that task was almost as insoluble. 'Modelling of web content is mostly technology driven and existing bandwidth is not enough to do really interesting things,' he said. 'Artists and other creative people should be working together with ICT-people to create a cyberspace that is as exciting as a visit to Jurassic Park.'

Greek technologist Martin Doerr, Head of the Centre for Cultural Informatics of the Institute of Computer Science, ICS-FORTH,[84] addressed the self-help problem, too. There were no gaps in the RTD processes. Rather, he said, it was a 'question of social promotion'. He wrote: 'Semantic interoperability has to be solved. If the nature and structure of the discourse in humanities is not understood, we will just continue to produce computer games.'

His solution struck at a basic tenet of academic and cultural heritage scholarship: 'The humanities sector must understand the challenges and be involved in new models of gaining scientific merit. Currently, scholars are rewarded by hoarding material and creating unique conclusions. If the material becomes public, the scholar loses scholarly merits and there is no longer a mechanism to ensure scientific quality of the data. So we lose scholars and data. The scholarly merit has to be redefined.'

The Greek researcher set the sector his own, arresting challenge: 'Active participation of scholars is needed. Market chances are there for scholars to serve as curators of publicly available knowledge. Knowledge must be presented not as a pseudo-objective timeless truth in an anonymous database but as the personal provision of people and organisations that warrant for their contents or express their best opinion. A database must become a scholarly publication. Knowledge and knowledge producers must be visible throughout the information life-cycle. This should become part of standards, lived practice, database designs, and intellectual property rights discussions.'

83 Electronic Resource Preservation and Access Network (ERPANET). http://www.erpanet.org

84 http://www.ics.forth.gr/isl/cci.html

The technology is there, but so are legacy data, skill and fund shortages

Many respondents to the roadmap survey were under the impression that technology had not developed far enough to meet cultural heritage needs, but others were more sanguine. All agreed, however, that it was not always an easy task applying what was available.

Australia's University of Melbourne Science and Technology Heritage Center Director Gavan McCarthy,[85] commenting on technological and semantic interoperability, wrote: 'It will be difficult to make significant progress in this area in the next 10-15 years beyond demonstration models. We are currently working with the National Library of Australia using XML-based data sharing systems based around contextual information rather than resource information directly.'

He said the problems lay in: 'Quality of legacy data and systems that are not compliant with the emerging context information standards (ICA, CIMI, etc.). Perhaps the biggest issue is with the very poor understanding of this area of development in general (it is new) by managers, executives, IT folks and cultural heritage practitioners – and especially those handing out the research funding.'

Another respondent, discussing methodologies for large-scale, distributed libraries, thought 'a great deal could be achieved on this area of RTD'. He wrote: 'The technology is already available to digitize and preserve collections and metadata schema are much more advanced and flexible in order to deal with the description and retrieval of these collections.'

Milton Keynes Museum's Roger Drage knew about the 'ever more powerful graphics, processing and storage systems now appearing' but had strong misgivings. He put it simply: 'The production of the final product is still dependent on the expertise of external firms rather than the cultural sector itself. The final outputs are therefore variable in quality.' His solution was simple, too: 'One way for the cultural sector to engage with this area is for someone to create a basic "shell" program to allow museum/gallery/cultural sector staff to produce their own interactive tours as a basic/intermediate level. It has been done with web-page creation software, why not with this?'

Jari Lybeck, Director of the Provincial Archives of Hämeenlinna, Finland, noted 'a wide variety of tools (technically speaking)' and was concerned that 'content planning needs more attention; co-operation between content experts on the one hand and IT-specialists on the other'.

It was a theme echoed by a number of other commentators. Italian consultant Attilio Romita saw many small limitations preventing heritage sector institutions achieving their aims. He wrote: 'Not one big gap, but a lot of small ones to access and use the information. Some network problems; some tool limitations; the expert's sometimes don't know the tools; the users are not good at finding the information.'

Swiss archivist Niklaus Bütikofer agreed, commenting: 'Regarding technology, all means are already available, but some of them are still expensive for widespread use, for example, information for outdoor heritage objects. What else would be needed? Explore creative new ways of presenting cultural objects, always accompanied by study and evaluation of user needs and behavior.'

Many participants mentioned costs. Portugal's Museum Institute (Instituto Português de Museus) has a string of exciting projects including *Matriz*, an online catalogue of information on museum holdings.[86] The Institute's Senior Officer, Inês Cunha Freitas, hoped that, within 10-15 years, Web sites for the Institute's 28 museums would be up and running. She said: 'All sites must be dynamic and updated in a system of back office/front office. Sites must develop towards dynamic interfaces and permit creation/publishing from the user's side.'

There were still some technical barriers, but, she said: 'What has constrained us in terms of achieving this goal is the lack of financial and human resources.'

In Britain, researchers and curators hold similar hopes for developing three-dimensional and virtu-

85 http://www.austehc.unimelb.edu.au

86 IPM, http://www.ipmuseus.pt; Matriznet, http://www.matriznet.ipmuseus.pt

al reality processes. Kirk Martinez, a Senior Lecturer in Britain's University of Southampton, is seeking 'some real deployments in publicly accessible museums, libraries, etc., with "industrial strength" hardware and software' and 'new interaction methods tuned to public access'. He was troubled by 'a lack of 3D models and virtual reality software in cultural heritage institutions'. He thought: 'A project should help build the resource in partnership with some key, keen and able sites.' But, here too, the stumbling block was funding. He forecast gloomily that the project could be achieved 'in three to five years if funded, 10 to 20 if not'.

But always, almost inevitably, it came back to techno-blindness. A British university Web site manager took a mournful view: 'The technology is already available to digitize and preserve collections. Metadata schema are much more advanced and flexible in order to deal with the description and retrieval of these collections. Limitations lie with that lack of standardization and compatibility.

'For instance, digitized images take up a lot of file storage space and can take some time to download, especially when there is such a wide range of software, hardware and browsers in use. File storage capacity needs to be increased and affordable. I understand this is on the way, if not already here, but I'm not sure it's reached my university yet!'

And, after all, money may not be the real problem. Polish State Archives' advisor Kazimierz Schmidt thinks it is more than that. He said: 'Probably, we have got enough money for managing highly automated large volumes of distributed digital heritage resources. But we have to change the attitude to the problem. Having a lot of individual libraries and archives was good in 19th and 20th centuries for analogue collections. It was good for users who had a library or archive close by. But, nowadays, as a user, I do not care where the library is.'

Consultant Angela Spinazzè seems sure that Mr Schmidt is right. She characterised the problem thus: 'Memory institutions must begin asking new and different questions. They have to open up to new ideas and help transform the semantic space into a perspective space.

'Actions such as:

- multimedia documentation;
- development of community-based ontologies and a knowledge network;
- the realization of centers of excellence that can serve not only other professionals but begin to establish new relationships based on shared goals and objectives.

'These steps will require us to use the next decade thoroughly in a well thought out manner. The first step is to analyze what has been done, map it, visualize it and present it in a way that demonstrates the large gaps that exist. That step is followed by conversations based on concepts and concrete issues derived from the initial analysis.

'Perhaps at the same time there is an attempt to map content pockets to technological infrastructure capacity. In other words, what content do we have that actually can be used, effectively, in a mobile environment? The answers will make it clear just how far we are from realization of a practical and useful approach to ubiquitous information access, management, and collection.'

But now, the Good News from the digi-champions of Cultural Heritage

All in all, it sounds like a rather gloomy prospect. But it is not. There is good news, too. Many of the roadmap contributors had upbeat stories of success, brilliant ideas and optimistic plans. There were, for example, the splendid initiatives of Portuguese museums, guided by the national museum institute (IPM); projects like the 3D avatar of the country's fourteenth-century warrior King Dom Joao the First.

The Alberto Sampaio Museum in Guimarães,[87] north Portugal, holds the 'loudel' (buff coat) the king wore at the Battle of Aljubarrota, the most important battle in the country's struggle for independence. The precious garment hangs in a showcase, badly damaged and very fragile. IPM superior officer Inês Cunha Freitas explained:

'The presentation of this artefact could be greatly enhanced by adding a virtual 3D presentation in which an avatar of King Dom Joao I, wearing his restored "loudel", returns from the past to tell the story of the battle and how the "loudel" came to the museum, allowing an educational and entertaining travel through space and time without stepping outside the museum. It is considered that the interactive nature of the proposed presentation will enhance learning associated with the historical period concerned.'

The problem was that access to state-of-the-art technology was limited for local cultural institutions. How could this be overcome? The IPM officer thought: 'An important breakthrough would be co-operation between museums, universities and technology centres.'

87 http://www.geira.pt/malbertosampaio/, an image of the 'loudel' is to be found in the section collections/textiles.

There is hope, too, for personalised access systems that know, as Professor Alan Smeaton of Dublin University's Centre for Digital Video Processing put it, 'where I am and what I am currently doing and why I need access, as well as more "global" contexts such as what is popular among users like me, what I have already seen and when I saw it … a kind of personal digital memory. There are wonderful projects like *MyLifeBits*[88] at MS Research that are instrumenting the context and history capture.' The problem: 'There is no successful work being done yet on effective use of context in information access,' said the Professor.

A government agency officer had good news on topic maps to enhance navigation. The writer gave the examples of the 'fast, satisfying access' to trails through the Australia Picture Australia[89] project, a history cooperative by over 30 cultural heritage organisations and local authorities, and the showcases in the New Zealand National Digital Forum's collaborative online museum Matapihi[90] ('Open the window') accessible in English and Maori, New Zealand's official languages.

Roadmap contributors had even bigger ideas and hopes for cultural heritage institutions. US University College Los Angeles Professor Anne Gilliland-Swetland considered that automation of large-scale holdings was the field where most development was occurring, 'in part because there is an alignment of commercial and government, as well as cultural heritage sector interests'. Now, she thought: 'Prior experience with information retrieval research would seem to indicate that nifty new technologies and metadata approaches must be developed by researchers with links to both the practice base and any commercial interest, to ensure widespread implementation through readily available software.'

The Professor's hoped-for 'nifty technologies' were just the sort of thing other experts were looking forward to in their schemes for improving digital holdings for institutions.

Roger Drage hoped for microfilm-based heritage assets in a digital format that would be freely and widely accessible. He also looked for 'a degree of sharing and accessibility which the public would like to see and would mean a wholesale review of attitudes to copyright – especially where organisations refuse to allow any copying or will charge for the privilege'.

Andrea De Polo, head of IT for Italy's 150-year-old photographic agency, Fratelli Alinari,[91] was optimistic about 'focused projects, for example, in the area of automatic indexing'. He forecast that new technologies would soon be available for better results.

Suellen Stringer-Hye, Web developer and Systems Librarian for the Jean and Alexander Heard Library at Vanderbilt University in Nashville, Tennessee, looked for 'subject portals using XTM'. She reckoned: 'More time needs to be spent experimenting with XTM to establish the strengths and limitations of this technolo-

88 MyLifeBits Project. http://research.microsoft.com/barc/mediapresence/MyLifeBits.aspx

89 PictureAustralia. http://www.pictureaustralia.org/trails.html

90 Matapihi. http://www.matapihi.org.nz

91 Fratelli Alinari SpA, Florence, Italy. http://www.alinari.com

gy.' She thought that sophisticated, easy, Open Source tools were not readily available. There were a few good prototypes, she said, but interface development in the public domain was primitive.

The Tennessee librarian's mention of 'Open Source' tools reflected many other expert commentaries.[92] Kirk Martinez thought there was too little re-use made of technologies created for a particular project. Software was written and died or was archived rather than used. He said: 'The Open Source community shows us the way to keep the ball rolling on this area.' And he saw a major advantage in 'maintained and used open source components we can all use to build rather than reinvent in each project'.

Brian McLauglin, Acquisitions Officer at the Syracuse University Library, US, was certain of his wish list: 'Creation of open source standards, vocabularies for indexing objects and next-generation XML resources.' And he wanted answers to the question of 'what or who controls the marketplace.' Addressing what he observed to be the situation in the United States, but may be the case in other countries, he said: 'State historical associations compete with their own state libraries and they both, individually AND together, compete with the Elseviers of the world. This effort MUST be larger than "Ivy-League" university research projects!' he said.

As a major step forward, he considered: 'We have National Academies of Science, and National Academies of Education and we could use a "National Academy" (that visible!).' It could sponsor conferences and raise the questions DigiCULT's roadmap was asking. Further, he sought: 'An investment in identifying stakeholders who may not KNOW they are stakeholders! DigiCULT's thematic approach is useful for framing data collection and synthesis.'

His colleague, George Abbott, Director of the university's Library Media Services Department, had similar hopes. He wanted to see more attention given to 'maintaining accessibility across a number of

92 See *DigiCULT Technology Watch Report 3*, December 2004 (chapter: *Open Source Software and Standards*). http://www.digicult.info/pages/techwatch.php

platforms for access and the need for more open source applications'. He was troubled that 'the design of many web pages today is optimized for specific browsers making migration and long-term preservation more difficult'.

Neanderthal Museum Director Gerd-Christian Weniger saw tourism value in cross-media online access to collections of major European museums and narrative stories of European prehistory and history using objects from the museums as proofs. He said: 'Part of the presentation should be all kinds of tourist information to encourage visiting and the preparation of tours. Millions of Europeans are making holidays in Europe and should have easy contact with the cultural heritage.'

The problem? 'The components for this kind of virtual network are already available but cultural institutions lack money and personal capacity for digital registration of their collections. Closer cooperation between tourist companies and cultural institutions would create a win-win situation.'

BBC Technology Manager Richard Wright had an even bigger dream. 'The biggest breakthrough is probably political – seeing a European cultural collection as a valid and necessary EC task. We don't have European museums. In the digital world, there is every reason to consolidate "digital heritage" at the European level: sustainable, cross-national and cross-cultural research, economy of scale, common, multilingual access.' He warned that his dream was 'seen as too expensive and not the EC's business'.

But he had an answer: 'The expense could be addressed by RTD in cost-effective repositories and by research in broader and deeper access methods: new services, comprehensive metadata, usable search tools. Communication with all European sources of material needs to be established, and a legal framework, such as *Creative Commons*,[93] needs to be adopted to support "donations" of material to this umbrella European collection.'

Jason Kiss, from the Canadian Heritage Information Network, wrote: 'Sustainability is a basic limitation for all envisioned RTD developments. With research and development occurring at such a great pace and in such volume, time to investigate and digest it all is a limiting difficulty.' He also sought 'more research into completely novel business models that do not borrow from past models'.

Karianne Albrigtsen Aam, of the Norwegian Archive, Library & Museum Authority, wanted 'a stronger frame of international standardization regarding compatibility of data; tools to present and offer resources to the public. To make everyone run in the same direction, we need international guidelines that can be used locally or nationally'.

And so the ideas came bursting through: a copyright framework allowing content valuation and exploitation; more idea sellers to make institutions aware of new opportunities; flexible, interactive, intuitive user-friendly systems that support the curiosity of users; reliable voice recognition systems; navigation systems for exploration, not just guided tours; and many more.

One writer got a bit carried away, though. A government body officer thought that among new products worthy of creation should be a digital presence 'to save disappearing cultures such as Maori, indigenous Australians, Nuie and Yorkshire.' Nuie Islanders, Aboriginals and Yorkshiremen may be dwindling breeds, but New Zealand's *tangata whenua* (people of the land), the Maori, are burgeoning, their numbers, culture and language happily growing exponentially.

That apart, what the roadmap responses reveal is the growing risk that small cultural heritage institutions will be left behind as the main focus of information and communication technology (ICT) development in the heritage sector concentrates on medium to larger institutions. The reasons for this unfavourable development are not primarily technological in nature but organisational. They can be summarised as the institutional 'trilemma'[94] of lacking human resources, lacking funds, lacking technical skills.

A broader perspective is given in *The DigiCULT Report. Technological landscapes for tomorrow's cultural economy*,[95] which addresses key issues of political frameworks, organisational change, exploitation, and existing and emerging technologies. Valuable further recommendations that concentrate mainly on improvements for smaller institutions may be found in a recent report on an *e-Europe agenda for local services* by the PULMAN Network of Excellence.[96]

93 Creative Commons, US-based online project offering 'flexible copyright for creative work'. http://creativecommons.org

94 Guntram Geser, "Assessing the readiness of small heritage institutions for e-culture technologies", *DigiCULT.Info* Issue 9, November 2004, pp. 8-13. http://www.digicult.info/pages/newsletter.php

95 *The DigiCULT Report. Technological landscapes for tomorrow's cultural economy.* Guntram Geser and Andrea Mulrenin (Luxembourg: European Commission, DG Information Society, 2002). Available for download at: http://www.digicult.info/pages/report.php

96 PULMAN: *Public Libraries, Museums and Archives: the e-Europe Agenda for Local Services.* Final Report of the PULMAN Network of Excellence. Edited by Rob Davies (Luxembourg: European Commission, Directorate-General Information, 2003).

Technology Adoption by Heritage Institutions: A Bird's Eye View

Size matters

In the summary of input from the heritage sector experts and practitioners, no distinction was made between large institutions or smaller ones. However, when it comes to adopting, implementing and using technologies… size obviously matters! Smaller institutions, trying to match the large ones in providing community services, face major disadvantages with the new technologies, especially in finding qualified personnel and funding resources.

When assessing the feasibility of a heritage institution making use of advanced information and communication technology (ICT), two important points need consideration.

First is the institution's capacity in terms of budget, staff, collections and users. The second factor is the smaller institutions' fiscal restrictions against following up new technology ventures.

In order to establish quantitative reference points, DigiCULT gathered data on the varying sizes of heritage institutions. The survey could not find widely used and empirically based schemes, so compared available data from statistically relevant surveys and other sources.[97] The table below summarises the results in a scheme that may be elaborated further, but is sufficiently detailed for the present purpose (for example, there is no category for 'very large' or 'major' institutions which may have an annual operational budget of over € 10 million).

This overview should make clear that most of the smaller and even many of the medium-size institutions will not find it easy to cover the total cost of ownership (TCO) for certain more advanced ICT applications beyond, for example, a simple Web site.

The most pressing factor that hampers heritage institutions in their efforts to leverage their IT environment is the lack of staff. A typical small institution will have fewer than five full-time equivalents, with only a fraction of them being professionals concerned with the institution's core business (e.g. curators, librarians, archivists, pedagogues). A common problem for small institutions is that, while the limited number of professional staff available may be able to ensure that the institution provides its core services, there will be little time to track down the necessary funds that would allow them to finance any ICT venture.

Smaller institutions' efforts in following up new technology ventures are limited by lack of financial leeway. A typical small institution will work on an operational budget of no more that €100,000 while a medium-sized institution may have up to €1 million at its disposal.

Needless to say, these budgets leave scarcely any room to finance ICT projects out of the operational financial resources. Consequently, institutions interested in developing and realising technology projects need additional funding. However, for many institutions, even the preparation of applications for project grants stretches limited personnel resources already hard-pressed during planning and implementation phases of a project.

Furthermore, experience from many initiatives

	Small	Medium	Large
Annual operational budget (in €)	< 100,000	100,000- 1 million	> 1 million
Staff in full-time equivalents (FTEs) (professional, support); volunteers not included	< 5 FTEs	5-10 FTEs	> 10 FTEs
Number of collection objects	< 10,000	10,000-100,000	> 100,000
Number of annual visitors: museums	< 7,000	7,000-30,000	> 30,000

97 Most useful surveys were Canadian Heritage Information Network (CHIN): Information Technology in Canadian Museums (1999), http://www.chin.gc.ca/English/Reference_Library/Information_Technology/; CHIN 2004 National Membership Study. Summary Report, http://www.chin.gc.ca/English/Members/Reports/Membership_Survey/index.html; Library and Information Statistics Unit (LISU) at Loughborough University (2001): UK Museums Retrospective Statistics Projects, http://www.mla.gov.uk/documents/ev_domus1.pdf; Scottish Museums Council: National Audit of Scotland's Museums and Galleries (2002), http://www.scottishmuseums.org.uk/audit/index.asp

shows that projects carry the risk of distracting institutions from core business and imposing activities that prove to be unsustainable after the funding period. Critics further point out that the majority of such projects favour financing the technological infrastructure, that is, the hardware and software equipment, over the development of the 'wetware', i.e. the technical skills of the programmers, operators and system administrators. Given the institutions' 'trilemma' of lack of funds, lack of human resources, lack of technical skills, there is little likelihood of small to medium-size institutions being able to participate in research and technological development projects that develop new prototype applications and systems. Even the larger institutions may have difficulty engaging with projects to which they are required to bring their cultural und scientific heritage expertise and knowledge.

So, new ways need to be found that allow cultural heritage organisations to participate in RTD projects, in particular, to work with researchers and technologies on the hard challenges of their 'softer' themes like archaeology, history, the arts, and so on. Most importantly, they will need to participate in what is called 'experience prototyping', which means making sure that the culturally interested (especially those not easy to impress) experience cultural heritage resources as enriching, valuable to learn and know more about.

Which technologies should the heritage institutions actually adopt to do this, and which ones can they afford, given their limitations in budgets and skilled technical personnel? Which technologies, beyond a simple Web presence or a low-cost collection management application, would suit smaller institutions without the risk of potentially unsustainable and unmanageable technologies?

DigiCULT's technology monitoring and assessment

With digital technologies developing rapidly, the heritage sector needs some mechanism to identify technologies that will bring benefits and provide a certain amount of sustainability over a reasonable timeframe. Since March 2002, this has been one of the tasks of the DigiCULT project.

In a way, DigiCULT started this expedition report by monitoring and assessing, over about three years, a broad spectrum of technologies likely to benefit the heritage sector. The project has identified and evaluated a total of 20 technological families, the proven ones as well as those that are emerging, identifying their benefit, potential and appropriateness to the cultural heritage sector.

The term 'technology' has been understood and used in its broadest sense to cover methods, standards, hardware, software applications, as well as interesting concepts like 'Learning Objects', software development, and service models like Open Source solutions, ASP, etc.

In addition to the expedition report, some important questions are: Which technologies monitored by DigiCULT are likely to find wider adoption by institutions of different sizes? Why is this so? And what is the likely timescale? The next questions then, of course, would be: What about the next families of new, or advanced generations of existing, technologies? Is there any chance of adopting these?

In the diagram below, technologies monitored by DigiCULT before embarking on the present expedition are clustered according to two criteria: the size of the institutions likely to adopt certain technologies, and the timeframe for this adoption.

All of the technologies included in the diagram are covered in chapters of the *DigiCULT Technology Watch Reports*[98] and/or a *DigiCULT Thematic Issue*,[99] which are available for downloading (free of charge). The publications contain case studies of interesting projects. The Technology Watch Reports provide many scenarios for institutions of varying sizes in the different cultural domains … archives, libraries, museums, galleries, etc. … on how they might implement and use the technologies.

What the diagram illustrates is the expectation that, over the next six years, only the large cultural heritage 'players' will adopt the latest group of technologies: Virtual Reality, cultural agents and avatars, new user

98 *DigiCULT Technology Watch Reports* (Report 1, February 2003; Report 2, February 2004; Report 3, December 2004). http://www.digicult.info/pages/techwatch.php

99 *DigiCULT Thematic Issues*, 1-6, 2002-2004. http://www.digicult.info/pages/Themiss.php

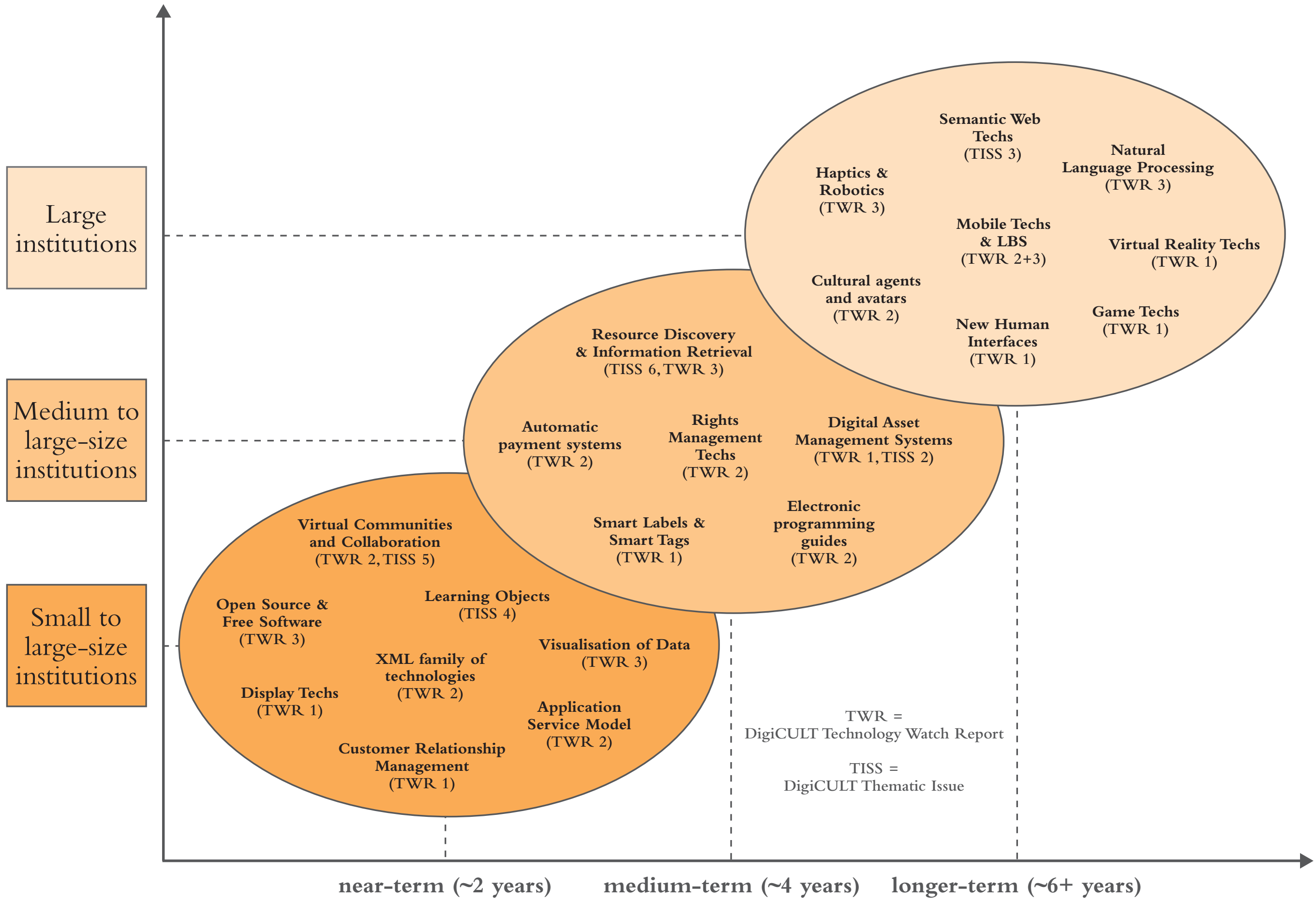


Diagram: Technology adoption assessment for small to large-size heritage institutions

interfaces (e.g. multimodal), games (e.g. multi-player online environments), haptics & robotics, mobile & location-based services, natural language processing, and Semantic Web technologies.

These technologies will largely remain beyond the reach of small and medium-sized institutions. The initial investment for developing and implementing such state-of-the-art applications plus costs of running the application on a regular basis – the total cost of ownership (TCO) – are likely to be prohibitive for most institutions.

There may be scope for simple, low-cost Web-based applications of games and virtual reality, but these are unlikely to become strong and longer-term attractions. As the diagram illustrates, small and medium-sized institutions will have to follow other strategies to attract on-site and online visitors such as virtual community projects, for example in regional history.[100]

Regarding management systems for digital assets, rights/licensing and payments, smaller institutions themselves will not find a business case as they do not, for example, hold an appropriate volume of marketable collection objects. However, such technologies may become relevant if smaller collections are digitised in the framework of a national or larger regional initiative, and the *digital* assets, rights and related transactions are then managed by digital heritage service centres. Thereby, collection metadata of smaller institutions could also be included in resource discovery networks, and some of their resources (e.g. photographs, postcards) may form highly valuable parts of Learning Objects in cultural and social history.

100 For a more detailed analysis, see Guntram Geser, "Assessing the readiness of small heritage institutions for e-culture technologies", *DigiCULT.Info* Issue 9, November 2004, pp. 8-13. http://www.digicult.info/pages/newsletter.php

Summary and Recommendations

With this expedition report, the DigiCULT project outlines to a certain extent a research and technological development (RTD) roadmap for a future digital heritage space.

Routes have been charted for RTD endeavours in different, partly overlapping thematic areas, the results of which may fall into place within the next 10-15 years to create such a space.

Given the broad scope of technologies addressed, the roadmapping expedition could not have hoped to come up with a more detailed representation of exactly how and when this may happen.

The report strongly relates to the vision of Ambient Intelligence (AmI), which informs the Information Society Technologies priority of the European Union's Framework Programmes for RTD.

This priority is itself informed by the European Union's goals for 2010 to bring IST applications and services to everyone, every home, every educational, social and cultural institution, and to all businesses – thereby enabling a highly dynamic and inclusive European knowledge-based society and economy.

Therefore, the expedition report also accompanies the core perspective on RTD with a view on the requirements, likelihood and time horizon of heritage organisations of different sizes adopting certain already available and future ICT that may stem from the ongoing RTD efforts. This dimension of the roadmap will be of greater interest to stakeholders in the heritage sector, but may also be useful for RTD planners and funding bodies.

For boards and directors of heritage organisations, IT project managers, and curators of digital collections, virtual exhibitions and environments, the report should provide an overview of innovative ICT systems and applications that may be achieved over the next ten years or so. It is to be expected that the application of these technologies will significantly shape and re-shape the digital landscape in which heritage institutions reside.

Therefore, we wish to offer the following three recommendations, which may be useful for ensuring the creation of a thriving and inclusive future digital heritage space, within a larger ambient intelligence landscape formed by IST applications and services:

Recommendation 1: Create opportunities for discussing and preparing the places and roles of digital cultural, scientific and artistic heritage in an emerging ambient intelligence landscape

We suggest that opportunities should be created at the European and national levels for larger heritage organisations and networks, as well as major tourism agencies, academic and educational institutions, to discuss and prepare the roles and places of digital cultural, scientific and artistic heritage in an emerging ambient intelligence (AmI) landscape.

Such opportunities will be needed for the heritage organisations to become part of this landscape in a conscious and planned way. They will need to connect strongly with the AmI vision and make it work for them and their customers.

Recommendation 2: Create opportunities for heritage information experts, professionals and users to participate more fully in the prototyping of IT-enhanced cultural experiences as well as novel ways to mediate cultural knowledge

The next waves of ICT systems and applications may well pave the way towards a digital heritage space capable of handling increasingly complex information environments, applications and resources. However, when it comes to prototyping IT-enhanced cultural experiences and novel ways to mediate cultural knowledge, new forms of collaboration and true interdisciplinary efforts will be needed.

A digital heritage space within an ambient intelligence landscape cannot be created by technological research and development alone. Experts and practitioners from – and clients of – cultural, artistic and scientific heritage organisations (e.g. curators, archivists, librarians, educational programme managers), Arts & Humanities scholars and students, and experts from cultural hotspots such as historic city centres or larger heritage sites need to be involved in a more qualitative and effective way.

Recommendation 3: Create structures that prevent cultural heritage organisations becoming blind spots in the future digital environment

Given the rather slow uptake of new technologies by many heritage organisations, it seems likely that they will become blind spots in an emerging ambient intelligence landscape. There is enough evidence that their digital surroundings will develop much faster than these organisations and smaller cultural networks can adopt and employ.

In fact, for smaller and also medium-sized institutions the benefits of most current and future technologies will need to be realised within national and larger regional initiatives. In such initiatives, a leading role will require to be played by digital heritage networks, innovative and inspiring examples of which already exist in the European Union's member states. Furthermore, there will over the coming years be an increasing demand for supportive digital services centres and ICT training programmes for technical and non-technical staff on how to handle new technologies.

Such funded mechanisms should enable smaller institutions to keep the costs and risks of digital heritage resources and services manageable while not being excluded from new technological developments.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DigiCULT: Project Information

DigiCULT Forum is an IST Support Measure (IST-2001-34898) to establish a regular technology watch that monitors and analyses technological developments relevant to and in the cultural, scientific and artistic heritage sector over the period of 34 months (03/2002-12/2004).

In order to encourage early take-up, DigiCULT produces seven Thematic Issues, three Technology Watch Reports, along with the e-journal DigiCULT.Info.

DigiCULT draws on the results of the strategic study 'Technological Landscapes for Tomorrow's Cultural Economy (DigiCULT)', which was initiated by the European Commission, DG Information Society (Unit D2: Cultural Heritage Applications) in 2000 and completed in 2002.

Copies of the DigiCULT Full Report and Executive Summary can be downloaded from or ordered at: http://www.digicult.info.

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DigiCULT Thematic Issue 1 – Integrity and Authenticity of Digital Cultural Heritage Objects builds on the first DigiCULT Forum held in Barcelona, Spain, on 6 May 2002, in the context of the DLM Conference 2002.

DigiCULT Thematic Issue 2 – Digital Asset Management Systems for the Cultural and Scientific Heritage Sector builds on the second DigiCULT Forum held in Essen, Germany, on 3 September 2002, in the context of the AIIM Conference @ DMS EXPO.

DigiCULT Thematic Issue 3 – Towards a Semantic Web for Heritage Resources builds on the third DigiCULT Forum held on 21 January 2003, at Fraunhofer IPSI, Darmstadt, Germany.

DigiCULT Thematic Issue 4 – Learning Objects from Cultural and Scientific Heritage Resources builds on the fourth DigiCULT Forum held on 2 July 2003, at the Koninklijke Bibliotheek - National Library of the Netherlands, The Hague.

DigiCULT Thematic Issue 5 – Virtual Communities and Collaboration in the Heritage Sector builds on the fifth DigiCULT Forum held on 20 October 2003, at Napier University, Edinburgh, Scotland.

DigiCULT Thematic Issue 6 – Resource Discovery Technologies for the Heritage Sector builds on the sixth DigiCULT Forum held on 9 March 2004, at the Archivio di Stato di Roma, Rome, Italy.

DigiCULT Thematic Issue 7 – The Future Digital Heritage Space: An Expedition Report builds on the contributions of 62 researchers and professionals from or related to the cultural, scientific and artistic heritage sector to a DigiCULT online consultation forum, which was active in October/ November 2004.

IMPRINT

This Thematic Issue is a product of the DigiCULT Project (IST-2001-34898).

Editors:

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Images:

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Graphics & Layout:

Jan Steindl, Salzburg Research

ISBN 3-902448-04-0
Printed in Austria.

DigiCULT Consortium:

salzburg research

UNIVERSITY of GLASGOW

www.digicult.info

ISBN 3-902448-04-0