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Into the Future: The EPOCH Research Agenda

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Abstract

In the paper which introduced this volume we examined the motivations at the outset of EPOCH, including the major areas in which EPOCH has sought to develop integrated systems. We furthermore analysed the rate of progress in the related field of Computer aided Architectural Design over the last 40 years or so, in order to get a feel for a comparator as surrogate benchmark and to examine the influence that addressing the research needs for CAAD applications had had on basic research in underlying computational research.

1. Introduction

In the paper which introduced this volume we examined the motivations at the outset of EPOCH, including the major areas in which EPOCH has sought to develop integrated systems. We furthermore analysed the rate of progress in the related field of Computer aided Architectural Design over the last 40 years or so, in order to get a feel for a comparator as surrogate benchmark and to examine the influence that addressing the research needs for CAAD applications had had on basic research in underlying computational research.

The previous papers in this volume have amplified on the research results of EPOCH and fleshed out the highlights that were trailed in the introduction. These results have been reviewed from the perspective of progress in applications for Cultural Heritage. In this paper we will review briefly the symbiosis between progress in ICTs in support of applications and basic research in ICTs. We will examine the measures that are needed to support the transitioning of research results to practical deployment in the field and briefly review the range of challenges to future applications of ICTs in Cultural Heritage. To recap on the results of the review through the long history of progress in CAAD, in terms of research results, the important points were that:

1. Fundamental, new computational processes have been developed by those seeking to solve problems firmly rooted in particular applications.
2. These computational processes often, subsequently feed solutions in other application areas.
3. The time lag from initial concept to mature wide-scale deployment as part of accepted tools in application fields is typically 15-20 years.
4. Often application fields beyond the initial one are completely unaware of the origins of the methods deployed or even that they are serving their needs at all.

The rate of adoption appears to be limited as much by continuing slow development in the professions and deployment of capacity, as by ICT research progress. Thus actions are required to support adoption, both by undertaking education and training and by developing infrastructure. We also noted that changing cultural heritage professionals attitudes can be anticipated as a slow process, partly because they are intentionally and appropriately conservative. We will examine the causes and requirements which arise from these observations below.

2. Use-inspired basic research

EPOCH promotes a high degree of inter-disciplinary use-inspired basic research. Similarly to research in CAAD, such research increases the understanding of basic research issues in ICT and, at the same time, allows the development of improved technology for purposes that are specific to cultural heritage.

Use-inspired basic research has been promoted in many ways in recent years as a means of ensuring that publicly funded research is firmly based on providing solutions that have exploitation potential, yet it remains tainted in the way that national and international organisations assess the

worth of scientific advance. Donald Stokes's book "*Pasteur's Quadrant: Basic Science and Technological Innovation*" [Stokes, 1997] provides a framework to set the different types of research in context. Stokes analyses the relationships between differently motivated types of research and his evaluation merits more detailed discussion from the viewpoint of cultural heritage ICT research.

According to Stokes, in the United States, the notion of "Basic Research" whose purity was guaranteed by a separation from conceivable applications, was stressed by the extremely influential federal report "Sciences, the Endless Frontier" which was released in July 1945 by Vannevar Bush in his role as President Franklin Roosevelt's director of the Office of Scientific Research and Development. "Applied Research" was considered to be at the other end of the spectrum and somehow inevitable close to market and inevitable distorted by the need to address market forces. Of course the perceived proximity to market also meant that public funds were inappropriate to fund research which should be funded by the "direct" beneficiaries of the resulting products' inevitable profits. The argument went that basic research should receive the lion's share of public funding because it may not be able to ensure adequate levels of funding in the marketplace.

Research inspired by:		Considerations of Use?	
		No	**Yes**
Quest for fundamental understanding	**Yes**	Pure Basic Research **(Bohr)**	Use-inspired basic research **(Pasteur)**
	No		Pure Applied Research **(Edison)**

Figure 1: *Stokes' Quadrant Model of Scientific Research (after [Stokes, 1997], 73)*

Stokes argued that scientific research should not be conceptualized as a linear progress, but rather that "considerations of use" and "quest for fundamental understanding" represented different measures against which any proposed research project could be rated. As a result of this analysis Stokes introduced four quadrants of research (Figure 1):

- In a first quadrant he placed "Pure basic research" which is understood to be inspired by the quest for knowledge but not by potential use. A paradigmatic example is the physicist Niels Bohr researching on a model of the atom.
- The diagonally opposed second quadrant is reserved for "Pure applied research" which is conducted to develop practical solutions and marketable products. Stokes example for this type of research is Thomas Edison and his work on many marketable, practical innovations.
- A third quadrant contains scientific work rather than focusing on advancing scientific knowledge or developing market-orientated solutions, attention is more on or formalising and embedding existing knowledge or scholarly practices (e.g. taxonomies, handbooks or guidelines). In ICTs such research might generalise a computational approach by developing methods of detecting and dealing with a range of special cases – none of which might use a fundamentally different computational paradigm, but all of which are needed to make the method generally practical.
- The fourth quadrant is reserved for use-inspired basic science. This is understood to have potential practical utility, but researchers who conduct such research do not lose sight of the goal of advancing scientific understanding. The paradigmatic example here is the work of Louis Pasteur. Stokes suggested that "Pasteur's quadrant" should receive most of the interest in national research policies and public funding, providing a combination of advancing knowledge and potential exploitation and return on investment.

There is no doubt that both national and international policies on the public funding of research have moved strongly in the direction of support for use-inspired basic research and away from the almost exclusive support of blue skies research. Managed programs of research have become the normal means by which the vast majority of public funds are distributed though there is some evidence that this is now felt to have gone too far (e.g. in the establishment of the European Research Council to secure appropriate attention to Bohr's Quadrant). For UK researchers it is significant however that the illustration used in the frontispiece of the UK Government's policy framework "*Science and innovation investment framework: 2004-2014*" [HM Treasury, 2004] was a representation of Stokes's vision of Pasteur's quadrant.

Funding agencies are clearly and appropriately concerned with the link between basic research and impact on wealth creation and quality of life. However in the spirit of "what gets measured gets done," it is easier to focus on direct wealth creation through product as the prime or even sole purpose of undertaking publicly funded research. It is far more difficult to measure the benefits in quality of life or even in terms of secondary beneficiaries of the basic research. In the next section we consider the adoption of technologies, but of course the secondary beneficiaries may not be the adopters at all.

3. From research to innovation and deployment

3.1 Technology maturity life cycle model

The model of technology maturity used in the research agenda definition activity builds on the standard model of the diffusion of innovations (Rogers 1962 and 1995), but includes phases that are often not considered in the application of the process model. In Figure 2 below these phases of R&D, in which new technological methods and prototypes are created, and the early phases of product development are included. In the standard model, the technology diffusion process starts once a functioning and tested (prototype) application becomes available and is adopted by one or more innovative companies in search of a competitive edge. Then, industry solutions appear which usually target larger organisations, and find some early adopters, based on a more stable and scalable solution. Next, competing industry solutions appear which may also

target smaller organisations, and are adopted by a much broader group of organisations, the so-called "early majority". Then, the mature and well-serviced technical solution will find a large, perhaps industry-wide "late majority". Finally, even the most confirmed sceptics will decide to use it.

This model has been questioned and improved by Geoffrey Moore specifically with respect to "high-tech products". (Moore 1991) Moore identified a "chasm" between on the one hand the first users (innovators and early adopters) of such products, which may still to some degree be immature, and, on the other hand, later customers who will only adopt a mature product.

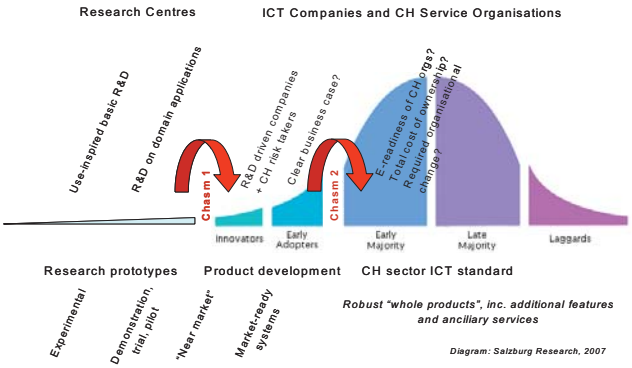

Figure 2: *Phases and chasms in the technology maturity life cycle model*

In the diagram, this is "chasm 2", because, we observe that there is another, earlier chasm regarding the transfer of a research prototype into the product development phase. The research prototype has proceeded from an experimental demonstrator to a "market near" solution, but a "market ready" would require much further development. Hence, we identify two chasms in the diffusion of research results:

- Chasm 1: This chasm concerns the transfer of "near market" ICT prototypes to innovators and other early adopters in the cultural heritage sector. This transfer is hampered by the following situation: 1) there are only few research driven companies that develop results of applied research into robust working solutions for the target market CH, and 2) this market is not characterised by strong incentives for seeking a competitive advantage as well as capability for the risk-taking that is required when adopting novel applications that have not so far proven their benefits. 3) For academic Computer Scientists the research issue is typically regarded as solved once the "near market prototype has been produced and results published. Little career advantage is perceived in further investment of time.
- Chasm 2: This chasm concerns the adoption at a late stage by many institutions in the cultural heritage sector of a more mature application, a whole product with additional features and ancillary services. The main problem here is that most cultural heritage sector institutions are small organisations that lack technical staff and support and are not able to cover the total cost of ownership for ICT applications from their operational budget. Many of them would be happy enough if they could afford a state-of-the-art website, have in place a better collection management system or could enhance exhibitions with interactive displays.
- In more clearly commercial sectors "chasm 1" may be overcome by certain types of technology companies in close collaboration with innovators of a niche market that has specific needs. They form an interface through which results are transferred from applied R&D to revenue generating opportunities. However, even commercial organisations in the field of cultural heritage ICT are often not motivated by profit, and operations maybe a not-for-profit part of a larger organisation or typically cover costs at best. As has been seen in EPOCH's work on socio-economic impact the economic benefits are typically reaped in other sectors (tourism and hospitality). There is a more direct connection between research developments and innovation in other fields where cultural heritage data might be re-used, for example in publishing, building restoration or computer games, but it seems unlikely that sectors will fund basic ICT research to improve initial data capture.

3.2 Do the chasms matter?

In considering the needs and mechanisms of addressing the chasms it is first worth asking whether they need addressing. In other words, although there may be much intellectual pleasure in developing and applying tools for use in the cultural heritage sector there are clearly costs which difficult to meet without public support. Is this support justified? Where are the benefits felt? Although these issues have been discussed elsewhere it is worth reviewing them briefly here.

There are substantial economic benefits which accrue where there is a healthy Heritage Sector. International tourism has been estimated to be worth €586 billion in 2006 (€301 billion to Europe) (UNWTO, 2007) – a figure which omits domestic tourism – which can involve greater numbers of tourists and a substantial additional revenue. A survey commissioned by the European Commission in 2002 showed "historical interest" as the fifth most important factor in choosing holiday destinations (after scenery, weather and cost of travel and cost of living), with around a third of visitors rating it as the most important factor.

The entertainment sector, from cinema and historic drama to computer games, makes use of historic content. Increasingly branding and secondary marketing through associations between, for example, films and computer games, has meant that investment in one area of the entertainment sector yields payback in others. The recent phenomenon of tourist trails through the location sets for major films, exemplified by the Lord of the Rings tours in New Zealand, have shown this can extend to locations. There is no real reason why this should not extend into the heritage sector more fully.

Other economic factors such as the attractiveness of a region for inward investment are influenced by the presentation of a historic environment and even economic factors that are perhaps less obvious. The EPOCH Partner EAHTR (European Association of Historic Towns and Regions) coordinates the INHERIT project, which has that produced a major Guidance Report on heritage-led regeneration [INHERIT 2008]; Salzburg Research within the Hist.Urban project has carried out a study on the role of cultural tourism for historic towns and regions in the experience economy [Geser 2007a and 2007b].

Education, for citizen and other purposes, and cultural identity are recognised as important in a multicultural society, and as such they attract government spending. If these aspects can be better achieved through the use of technology then there is an economic, as well as a quality of life argument for doing this. In addition the engagement with ICTs in social contexts will also improve the technical awareness of the workforce of the future – though there may be a parallel obligation on those teaching in the field to help the self-educated obtain a more systematic understanding. Other potential benefits that have yet to be fully explored include the role of ICTs in understanding the legacy of the exploration and colonisation undertaken by European nations. ICTs could help in a number of presentational approaches:

- Communicating the tensions between the discovery of other civilisations and their alteration by colonisation.
- Presenting different perspectives on cultural identity.
- Allowing a better understanding of the issues of displaced heritage.
- Potentially of sharing some level of access to historic cultural artefacts, either through virtual repatriation or virtual access to repatriated material.

There are also benefits in the use of technology in supporting the sustainability of the heritage sector and possibly the Environmental Agenda. ICTs can contribute both to the monitoring and maintenance of the environment and to be used to encourage more even load on the heritage venues, by encouraging broader ranges of site visits and by permitting virtual experiences as a complement to more restricted access to the original physical environment.

Finally there are opportunities to improve the quality of life and equality of opportunities for disadvantaged citizens through the use of technologies to enhance access for many groups to allow them some access and experience of historic environments.

In many ways the above catalogue lists the applications of Cultural Heritage. These are the paybacks for societal investment in preservation and access to cultural heritage assets and ignore the benefits that ICTs bring to the business of cultural heritage research, preservation and maintenance. However they nevertheless continue to provide strong reasons for continuing to develop ICT solutions to cultural heritage assets, providing that the social contract between investors and the sector contuse to exist – namely that investment in the underpinning technologies is matched by enhanced access to the cultural heritage assets.

The "Two Chasms" model also highlights the difficulty of building "end user" perspectives directly into a research agenda – you need users with long term perspectives, lots of altruistic patience and very broad understanding of the research process.

3.3 Addressing the chasms

Chasm 1 addresses the need to get tools from research labs into development as practical tools for cultural heritage. Chasm 2 addresses widespread take up by the sector. Both need addressing for research to have widespread impact.

Chasm 1 has specific characteristics in the cultural heritage sector which have been touched on above. There are relatively few spin-offs for cultural heritage ICT from research centres in Europe – primarily due to the expectation of low profitability in the sector. Such companies that do engage with cultural heritage sector and also are profitable, tend to address the sector as one of a number of areas of activity, with the profitability arising elsewhere. Where the company is accountable to shareholders it is likely that activity in the cultural heritage sector is better described as "charitable works" or investment in making better relationships with governmental bodies.

There are however a number of models for technology transfer across Chasm 1. Firstly a service might be established through which users of the service become more knowledgeable, through the inclusion of training and support. An example would be the EPOCH 3D Web service, with its associated manuals and training. Secondly co-development partnerships of research centres and ICT SMEs for developing market-ready solutions from research prototypes might be used. These rely on clear understanding of the profit motivations and expectations. Thirdly expertise centres that bring together research groups, ICT SMEs and innovative cultural heritage institutions and networks can be used as a means of building inter-disciplinary and inter-organisational understanding, but these expertise centres face the same challenges of sustainable underlying business models. These knowledge transfer models also allow for gaining a better understanding of market demands to feed future research agendas.

Addressing Chasm 2 is equally complex and tends to involve potential early adopters being supported in demonstrating, piloting and testing prototypical applications under real work conditions. This support would typically be paid for mainly by third parties and may well involve the Centres of expertise described above. At this stage a number of hard operational issues need to be addresses if the chasm is to be bridged effectively. This includes systematic consideration of usability for those who need to operate the systems, identifying and developing features which are missing, and understanding the workflows the systems imply. Of critical importance to embedding the new tools will be to ensure interoperability and integration with existing cultural heritage data, management systems and other ICT tools. Finally the return on investment in supporting the deployment exercises needs to be mobilised in terms of the collection, consolidation and dissemination of critical knowledge of what has worked in terms of workflow processes, integration, etc. This experience may well be deployed through the expertise centre that was involved.

4. Short/medium term research priorities

In the short and medium term we believe that priorities ne-ed to focus on continuing to develop the interdisciplinary perspective on ICTs in Cultural Heritage. To be successful as quickly as possible in breaking down the barriers between different disciplinary perspectives some priority should be given to focus on low hanging fruit to continue to build trust and communities of practice, building on the success of EPOCH.

Candidates for the title of (relatively) "low-hanging fruit," which would have paybacks in the shorter term, would be:

a) Improvements and integration of current cultural heritage processes (e.g. improved metadata migration, building on the work of EPOCH with AMA and MAD, to improve integration of existing resources into Europeana).

b) Enhanced Web-based access (e.g. richer content - especially 3D – see below and multi-user virtual environments for shared experiences).

c) Novel cultural tourism services, (e.g. context-aware LBS for cultural heritage routes).

d) Demonstrators encouraging responsible exploitation of cultural heritage (e.g. cultural tourism to museums and branded linkage to edutainment) through linkage and enhancement of content.

These would contribute to the political agenda as well, through being seen to bring fairly rapid benefits. This process should be accompanied by further effort to develop and integrate inter-disciplinary R&D capacity, where we feel that the legacy of complementary activity between EPOCH and CHIRON is a major reference point. Empirically it is clear without a comprehensive analysis that EPOCH has encouraged new clusters, witnessed by new consortia of organisations that met through the activities of EPOCH and are now working together as preferred partners. This has included some additional trans-national cooperation (e.g. in Sweden, the Netherlands, France, Spain, Hungary, Poland, Egypt and Cyprus, where EPOCH had considerably less presence at the start, but which could usefully be the subject of further consolidation/promotion).

Further capacity building with potential for short-term gain could arise from linking up with large scale grid computing infrastructures and using them for cultural heritage purposes to support inter-archive/collection research. There are many new projects and significant investment planned for these infrastructures over the next years (cf. European Strategic Forum on Research Infrastructures, Roadmap Report, October 2006).

In parallel to these developments we need to increase the supply of inter-disciplinary researchers, possibly by increasing the opportunities for mobility (both disciplinary and geographical) of young researchers in cross- and inter-disciplinary research. This development could build on the good practice in the CHIRON Marie Curie Early Stage Training in Research, which has been hosted and included trained mainly by EPOCH partners).

Further we would encourage consolidated opportunities for presenting and discussing results at high quality events, such as VAST, VSMM, Heritage Impact and GRAPP. By consolidation in a few more major events there is an opportunity to build a more consolidates and self-aware critical mass of expertise. Project funded through the Commission should be positively encouraged to use such events to come together and share their experience and expertise. This should be accompanied by mechanisms to ensure easy access to and re-use of results including open access to data and publications.

This area has attracted a lot of attention recently. For example, most recently in the consultation on the EC Green Paper "*The European Research Area: New Perspectives*" (2007), most respondents with regard to the priority "knowledge sharing" called for raw data and publications resulting from publicly-funded research to be made more readily accessible. Empowering this needs reinforcement via amendments to the standard contract, at least in the field of cultural heritage and perhaps a support action to more actively encourage adoption of standards within research projects for interoperability of systems and data. There would also be a need for specific actions to track standards developments for candidates. This is something that EPOCH has sought to do by adopting standards from elsewhere (e.g. OpenSG, METS, Collada light, and Fedora)and by encouraging open Source/Licensing at a useful level (for example: MobiComp and MeshLab) and/or providing open access may be to services (e.g. the EPOCH Web 3D service).

It is also necessary to reach a critical mass of high-quality digital content, spanning a broad range of artefact types (including 3D, image, film, text, audio, etc) augmented by consistent and interoperable metadata. As with any resource whose value lies in sharing (e.g. telephones) the value of sharing cannot be realised until there is a critical mass with which to share. The EDL "i2010: Digital Libraries" [EC, i2010] initiative is clearly a major framework for this but it needs to be broadened to include a full range of artefacts and their appropriate metadata, along with semantically-based searching. At present this appears to be mainly driven by national libraries with low involvement of museums, monuments and other sites, and very little in the area of 3D content.

The challenge of 3D digital content in the EDL context includes a major challenge in the actual digitisation technologies. There are many circumstances for which current technologies are inadequate and a substantial effort of continually reducing cost/increasing quality of the whole 3D production chain will continue for some time. There have been important contributions by EPOCH researchers to this goal, e.g. EPOCH 3D Web service and MeshLab, but even with a complete set of tools spanning the full variety of artefacts, a challenge remains in achieving the buy-in from cultural heritage institutions to documentation campaigns based on 3D digitisation. There are good reasons for adoption, but significant work to address potential.

A final medium-term challenge is to investigate the relatively unexplored potential for user-created content. The evidence for the pressing nature of this challenge is all around us (on the web, for example, in personal web-sites, MySpace, flickr and YouTube), but there is relatively little in terms of integrating this with the establishment of cultural heritage institutions and there are many operational concerns to be addressed. For example what does "curatorship" mean in such a world?

All of these challenges are real and relevant, but, as discussed in the paper introducing this conference, this research needs to be seen as transitional. It seem certain that the cultural heritage professionals will work in different ways in the future and that there will be new and as yet unexplored ways of appreciating the evidence of the past. Given that we have to set priorities in the short term it seems obvious that the highest priority should be awarded to those elements that place us in the best position to meet the longer term "grand challenges". These stepping stones have been called "foothill projects" in the UKCRC Grand Challenges exercise.

5. Longer term challenges

In both the UK and North America there has been a slow but significant development of the notion of "Grand

Challenges" – usually expressed as some vision that cannot be addressed with current technologies or systems and requires some significant results in basic computing science before the tools that can meet the challenge can be developed. At present nine grand challenges have been identified within the UK scheme (see [UKCRC], one of which concerns the challenge of "*Bringing the Past to Life for the Citizen*" [Arnold *et al*., 2006]. In North America the Grand Challenges program has been formulated around a series of workshops on specific research themes [CRA].

However although the notion of Grand Challenges appears to encourage a view that use inspired basic research will find a more central place in the research community, in practice very few of the challenges so far formulated are in fact grounded in specific application domains. In addition many of the managed programs of research struggle to encompass inter-disciplinary viewpoints and the motivations of eventual applications can lead to unrealistic expectation of the timescales for exploitation. This is directly related to the two Chasm model described above. In our opinion there is too much of an assumption that research projects should invariably finish with results that can move directly to commercially exploitable results. This expectation is inevitably conflict with the requirement that the whole be pre-competitive and hence there must of necessity be additional development to be undertaken after the project and before competitive products generating revenues can be marketed. This tension is in part grounded in the need to secure political support which is often gained on the basis of predictions of direct economic benefit.

After considering five scenarios for future cultural heritage activity, the EPOCH Research Agenda maps the resulting requirements into ICT research challenges into subareas. Each of these contains some early (mid-term objectives) and some longer term (very difficult) problems:

- **Novel data capture** in many formats under a variety of conditions.
- **Semantically-based representation**, search and research and the enabling technologies and information structures to support the processing.
- **Novel presentation formats**.

The EPOCH research agenda concludes with two other areas where the research issues are not particularly reliant on specific application area

- Mobile, distributed and networked systems, and
- Long-term availability (Preservation, data migration etc. including standards for data, business processes and legal frameworks, DRM, IPR, collected and derived works etc). In this area there are elements which are specific to the cultural heritage domain but much in common with other areas.

We will now consider the challenges in the first three of these areas further.

Under the heading of **novel data capture** are the very wide range of artefacts and environments that have heritage significance which are magnified by considerations of accuracy, volumes of data, variety of capture conditions and particular considerations of material types. A recently convened event involving invited experts from the digital libraries and cultural heritage areas agreed that there were no areas of digitisation that could be regarded as solved problems.

Even in the most researched area of digitisation of printed works to extract text sources there were significant gaps (e.g. OCR of pre-1840 Gothic typefaces – which covers a very large percentage of Germanic literature). Whilst progress continues to be made [Muller *et al*., 2005], digitisation of materials such as glass, fur, jewels or historic fabrics are still challenging in any form and largely unsolved for effective techniques to capture digital representations that will sustain a range of desirable analyses, without damaging the artefacts. Interactions between materials and with the complex and detailed geometry of many cultural artefacts present further challenges [Mudge *et al*., 2005]. For example the intricate geometry of an ornate and decorative piece might interact with the material properties of antique filigree gold, carved ivory or jade.

Apart from materials issues, there are unsolved problems due to environmental challenges. For example, the digitization of masonry fragments on an archaeological site would require measurement techniques operating *in situ* (i.e. without lifting fragments) and potentially in very inaccessible situations.

Consider for example the challenge of digitising the temples of Karnak (Figure 3) or Ankhor Wat (Figure 4). The sheer scale of the sites coupled with the intricate detail required to represent all aspects of the content mean that there are no representations or digitisation techniques yet capable of tackling the challenge in a way that will be fit all purposes.

Figure 3(a): *A view over the site at Karnak*

Figure 3(b): *Stones in storage, carved on more than one side from re-use. How would/should these be presented or used in digital reconstruction?*

Figure 3 (c): *The challenge of semantics – a carving with a mix of hieroglyphics and the appearance of a spreadsheet. What do you record? What's the significance? Physical objects; broken parts; surface damage; Hieroglyphics; Semantic content?*

Figure 4(a): *Part of a temple at Ankhor Wat under re-construction in a project which started in 1908*

Figure 4 (b): *Part of a Bas Relief at Angkor Thom depicting stories of war*

Figure 4 (c): *Refurbished element – what should be the significance in a digital model of the "original"?*

Semantically-based representation, search and research and the enabling technologies and information structures to support the processing. This area includes the need to access multi-lingual sources, including languages which are no longer spoken and challenges to identify co-references (the referencing of the same heritage items (e.g. events or people) from multiple sources and often on the basis of incomplete and/or alternate identification (e.g. languages, synonyms or alternate spellings). Knowledge discovery in these circumstances might be more traditionally undertaken by experts "digging around" in archives manually and the challenge is to investigate how far "excavation in the digital domain" is possible and useful.

Figure 5 (a): *Museum at the Temple at My Son, Vietnam, a World Heritage Site, which was bombed during the American War*

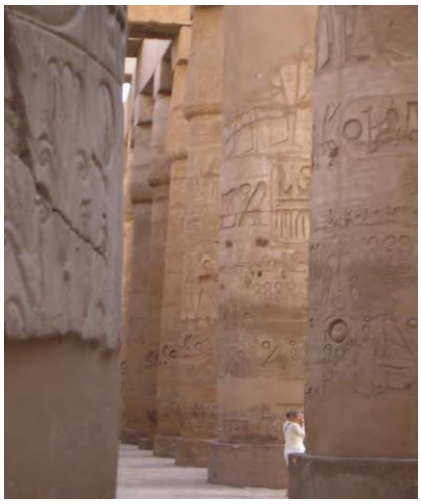

Figure 5(b): *Some of the columns at the temple of Karnak, decorated with hieroglyphics*

Also in this area specific techniques are needed for the representation of cultural information - with very specific and somewhat idiosyncratic characteristics. These include potentially significant development of knowledge over time. The knowledge of the past has normally been lost and then gradually re-discovered. The discovery may be an extended process with many interim hypotheses of what (for example) a particular building was like or used for, which are refined as more information and evidence is uncovered. Although there are other disciplines that share some of these characteristics (e.g. medical diagnosis or the process of scientific discovery, itself often considered part of our heritage) cultural heritage imposes additional challenges. Most obvious amongst these are:

(i) That, where information is factual, the facts were available at some time in the past even if they are now lost.

(ii) That facts are often overlaid with differing multi-cultural interpretations based on political convictions or belief systems.

(iii) The cultural meaning of artefacts may change over time.

Figure 5 shows two places with radically different meanings to segments of current society.

Given that the dominant themes of much surviving tangible heritage involve either commemoration of war or celebration of religious beliefs, it is unsurprising that the same artefact or environment may embody completely different meanings to different people.

Again elements of similar issues may arise in other applications – for example virtual environments may need to represent and highlight different aspects for different users. For example, members of the emergency and security services would be trained to look for and act on different features at a reconstructed incident than perhaps the general public, but the cultural heritage sphere is probably the most intense example of this application-driven requirement.

Figure 5(c): *Cambodian Temple used in the filming of "Laura Croft: Tomb Raider" probably visited at least as much for the interaction of trees and temple and for the film connection as for the values it originally represented*

Novel presentation formats. Having captured the information base and organised our knowledge of it in ways which allow the extraction of information, there is the inevitable demand to be able to visualise information and create experiences or presentations for many purposes. In this area there are many similar requirements on effective communication with widely differing groups and few of the challenges can be realistically described as "unique to cultural heritage". An example of challenges which apply to many domains would be authoring tools which generate engaging, multi-modal experiences tailored for particular groups of users.

Figure 4(b) is an example of story-telling at a cultural heritage site. There are many of these in civilisations all over the world. The story of the Roman invasion of Romania is captured in stone on Trajan's Column in Rome, and exhibited in the Victoria and Albert Museum in London and also in Bucharest, as plaster casts taken from the original. Although the casts are explained the significance of the way the story develops around the column is not.

However there are specific needs which arise from both the sector itself and the nature of the data to be presented – most obviously how the uncertainty underpinning hypotheses and the multiple perspectives on the significance are presented to an audience. These challenges are exacerbated when the audience may have unknown background, interests, beliefs and motivations – for example as internet users – again in common with many applications over the internet, but probably of particular significance in cultural heritage.

From the perspective of the graphic community one area which it may be surprising to find listed as part of "visualisation and communication" in the EPOCH research agenda is "reconstruction" – which in graphics might often be considered part of data capture (i.e. modelling to create digital artefacts) but, for most cultural heritage professionals, visualisation is the creation of interpretations from the basic evidence and hence an analysis and "output process" from the primary evidence to inform the cultural heritage professional. Part of visualisation is in fact to test hypothesis to see whether the evidence that exists can be put together in ways which fit both the hypothesis and the constraints inherent in the evidence.

This is an area where great progress has been made under EPOCH with the work of Luc Van Gool's group at ETH, Zurich on grammar based modelling of architectural form. This has taken work which was demonstrated for a simpler class of problem in principle in the 1970s [Yessios, 1975] and largely forgotten. The new tool, CityEngine, has been used to fit models of buildings based on Roman architectural styles of the period to the ground plans of a section of Pompeii. [Mueller *et al*., 2006].

This difference of perspective highlights another concern firmly based in the application domain – the concern that, since "anything can be modelled" and visualised, the technology actually enhances presentations that are pure fantasy or, worse still, based on scant evidence, and produces believable but unsupported conjecture. For these reasons an important part of creating reconstructions and other derived forms is to record the provenance, including cross-reference to the evidence base and reconstruction methods used, to document the background to a reconstruction. The London Charter [London, 2006], which describes this type of documentation as *paradata*, is an attempt guidance in this area and appears to be attracting interest and support. Part of this challenge includes a desire to be able to display reconstructions in ways which reflect the degree of uncertainty inherent in the resulting model. As yet there are no generally accepted paradigms for this but the use of non-photorealistic rendering techniques appears an attractive option.

Identification and provenance history also needs to be maintained during repeated manipulations in the creation of derived and collected works. This must work across the typical image processing, graphics and CAD manipulations with data structures involving hierarchy, instancing, etc. and data manipulations (mesh decimation, stitching, surface extraction, compression, feature extraction, etc.).

At the interfacing level the domain shares all the challenges of other interactive applications, plus additional, and as yet unsolved, issues in the area of multi-cultural as well as multi-lingual interfaces. The issues shared with other application domains would and include design of interactive systems which engage and entertain the public (c.f. games), and how to measure effectiveness in engagement in ways which support/enable the design of better interfaces. Finally the design of interfaces to tools to support research methods is an area in common with other areas of the humanities.

In fact in this research agenda there are aspects which can be considered as lying in each of the four quadrants of Stokes' diagram. In ICT, research undertaken with a view to generating fundamental understanding could be targeted at underlying theory or indeed, in Stokes's classifications, research where the understanding of representation and computational process can be applied to solutions which are independent of specific applications. Generic technologies, which are mentioned in various places here, could fit this definition of research in Bohr's Quadrant. The potential for cultural heritage a medium for progressing basic research in Computer Science has recently been addressed [Arnold, 2007].

6. Longer-term research activities

The previous section has made it clear that there are many aspects of cultural heritage that we are a long way from being able to digitise analyse and convey with current technologies. Research to underpin novel activities by curators/historians would seem to be a priority. This would favour the areas of "Novel Data Capture" and "Semantically-based representations, search and research", but since some of the mission is about communicating with the public this implies that presentation should also be a priority. The choices are therefore likely to be more about which alternatives in these areas show most promise.

For example, constraint-based, evidence-based visualisation (i.e. to the computer scientist "reconstruction"), will involve understanding of the semantics of shape and representation of hypothesis. The constraints that can be handled at any time and the degree to which evidence can be detected automatically and explained will dictate the most promising directions of research.

One priority which is as much a priority for the cultural heritage community as for the ICT community is the integration of intangible heritage and user-created content within the analysis and presentation of tangible cultural heritage . A second priority affecting strategically important sites is to find ways of maintaining access at an appropriate level whilst capturing the interest of visitors at environmentally sensitive sites. Currently it is estimated that around 2% of sites have around 50% of the visitors and 8% have 75% of the visitors.

7. In conclusion

It should be clear from the proceeding discussion that there are many, many remaining technical challenges. There are also new cultural heritage challenges. One of these relates to being able to imagine far enough ahead and to envisage where the technology could take you, in order to shape where it does take you. When you can do anything – what do you choose to do?

Much of the value of the inter-disciplinary interaction will be lost if we don't build trust between the communities. Large and complex systems are inherently complex and hence open to suspicion. Trust, innovation and change take time.

EPOCH has been a tremendous challenge and we believe very successful, but as with many successful learning exercises, the more you begin to see progress, the more you realise what a long way there is to go! We believe the EPOCH Research Agenda has pointers to productive directions of research for many years to come.

8. References

[Arnold and Geser, 2007] Arnold, D. and Guntram, G.: *Research Agenda for the Applications of ICT to Cultural Heritage*. Preliminary Edition, EPOCH Publication. Budapest: Archaeolingua, 2007.

[Arnold 2007] Arnold, D.: "Cultural Heritage as a Vehicle for Basic Research in Computing Science: Pasteur's Quadrant and a Use-inspired Basic Research Agenda", in Proceedings of cultural heritage Stream at EUROGRAPHICS 07, (Prague Sept 3rd-7th 2007). Eurographics Association, 2007.

[Arnold *et al*., 2006] Arnold, D., Chalmers, A., Day, A., Duce, D. and Willis, P.: "Bringing the Past to Life for the Citizen", Grand Challenge 9, 2006. http://www.bcs.org/server.php?show=ConWebDoc.4724

[CRA] Computing Research Association. http://www.cra.org/grand.challenges/

[EC i2010] EC, i2010 web page: i2010 – A European Information Society for growth and employment, http://ec.europa.eu/information_society/eeurope/i2010/

[Geser, 2007a] Geser, G.: Historic Towns and Cultural Tourism in the Experience Economy – Concepts and Requirements. Salzburg Research, *Hist.Urban Study Repor*t, May 2007, http://www.histurban.net/downloads/publications.html

[Geser, 2007b] Guntram, G. (2007b): European Historic Towns and Cultural Tourism in the Experience Economy, 35-59, in: Niccolucci, Franco (ed.): *Digital Applications for Tangible Cultural Heritage. Report on the State of the Union - Policies, Practices and Developments in Europe*. Volume 2. Budapest: Archaeolingua, 2007.

[Havemann and Fellner, 2004] Havemann, S. and Fellner, D.: "Generative Parametric Design of Gothic Window Tracer", in *Proceedings of VAST 2004*, Y. Chrysanthou, K. Cain, N. Silbermann and F. Niccolucci) (eds.) 2004.

[HM Treasury, 2004] HM Treasury, Department for Trade and Industry and Department for Education and Skills. (July 2004) Science and Innovation Investment framework 2004-2014 (Crown copyright, 2004). Available online (Feb 2007) at: http://www.hmtreasury.gov.uk/spending_review/spend_sr04/associated_documents/spending_sr04_science.cfm

[INHERIT, 2008] INHERIT: *Investing in Regeneration. A Guide to Successful Urban Heritage*. Norwich: EAHTR, 2008.

[London, 2006] *London Charter for the Use of 3D Visualisation in the Research and Communication of Cultural Heritage*; Charter home page, http://www.londoncharter.org

[Moore, 1991] Moore, G.: *Crossing the Chasm. Marketing and Selling High-Tech Products to Mainstream Customers*. New York: Harper Business, 1991.

[Mudge *et al*. 2005] Mudge, M., Voutaz, J., Schroer, C. and Lum, M.: "Reflection Transformation Imaging and Virtual Representations of Coins from the Hospice of the Grand St Bernard." *Proceedings of VAST2005: 6th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage, Eurographics Symposium Proceedings*. Eds. M.Mudge, N. Ryan and R.Scopigno, 2005.

[UKCRC] Grand challenges in Computing Research, http://www.ukcrc.org.uk/grand_challenges/index.cfm

[Muller *et al.*, 2006] Mueller, P., Wonka, P., Haegler, S., Ulmer, A. and Van Gool, L.: "Procedural Modeling of Buildings", *Proceedings of ACM SIGGRAPH 2006 / ACM Transactions on Graphics*, 2006.

[Muller *et al*., 2005] Muller, G., Bendels, G. H. and Klein, R.: "Rapid Synchronous Acquisition of Geometry and Appearance of cultural heritage Artefacts" *Proceedings of VAST2005: 6th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage.* 2005.

[Rogers 1962] Rogers, E. M.: *Diffusion of Innovations*. New York: The Free Press, 1962.

[Rogers 1995] Rogers, E. M.: *Diffusion of Innovations*. Fourth Edition. New York: The Free Press, 1995.

[Stokes, 1997] Stokes, D. E.: *Pasteur's Quadrant: Basic Science and Technological Innovation*. The Brookings Institution, Washington, 1997.

[Yessios, 1975] Yessios, C. I.: Formal languages for site planning, in C.M. Eastman (ed.) *Spatial*