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The Challenges of Migration as a Long-term Preservation Strategy: The Findings of TEAM Norway and LongRec*

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Abstract

More and more digital objects are being generated in our time. How to preserve digital objects gradually becomes a problem, not only for culture and history preservation institutions, including libraries and archives, but also for governments and companies. Since 2006, the Norwegian Research Council has funded a joint industry project called LongRec (Long-Term Records Management), which is investigating issues in long-term preservation and exploring the potential for commercial products/services in this area. In this paper, we first introduce the LongRec project. Afterwards, we briefly describe the preservation system in the National Library of Norway. Finally, we discuss our research issues concerning migration, a popular preservation strategy for preservation systems.

Introduction

Digital information is a type of information represented in terms of computer technologies. It differs from traditional information that is written on paper or is engraved on stones. It can be divided into three levels: the physical level, the logic level and the conceptual level. The physical level is the lowest level. It is constituted by digital storage media and corresponding media drivers. Any digital storage medium utilizes some physical characteristics to store digital information like optic or magnetic. Media drivers translate those physical characteristics into bits of 0s or 1s. The bits are organized together by a set of syntactic and semantic rules, which are defined by a format. Each format has a logic model. How to translate bits into the logic model is the main task in the logic level. As a rule, the specification of a format is the key for the translation. Only when we know the specification of the format can we develop an interpreter for the bits. The conceptual level is the top level. The content of digital information derives from a set of digital objects. Digital objects can adapt the same format or adapt different formats. Software applications will finally render those digital objects as a unit in a human readable manner. For instance, a web page includes texts and pictures. If end users like to view the web page, they can use a web browser application that has integrated text and image format interpreters.

From the three levels concerning digital information, we can see that digital information heavily depends on computer technologies. Losing any related components within the levels will make the digital information unreadable. Common risks for digital information are broken hardware, software failure, obsolete hardware/software, loss of format specification, malicious modification, loss of context and organization failure. Thus, preserving digital information is not easier than preserving traditional information. We need comprehensive and careful curation behaviours.

In this paper, we will introduce preserving activities in Norway. We first introduce a joint industry project, LongRec, in section 2. Secondly, we illustrate the preservation system in the National Library of Norway in section 3. Lastly, some research challenges that are being explored and will be explored are discussed in section 4.

Research Background

LongRec is a 3-year research project mainly sponsored by the Norwegian Research Council. LongRec started in 2006 and DNV (Det Norske Veritas) is the project manager. The other partners of this joint-industry project are BBS, Fast Search&Transfer, CSAM, StatoilHydro, the National Library of Norway, the National Archive of Norway, the Norwegian Ministry of Foreign Affairs, the Brønnøysund Register Centre, Norwegian University of Science and Technology (NTNU), the Norwegian Computing Center and Katholieke University of Leuven. Figure 1 illustrates the classification of our partners according to their duties. The first type of partner is business, including DNV, BBS, Fast Search&Transfer, CSAM and StatoilHydro. Fast Search&Transfer and CSAM are solution providers, whilst DNV, BBS and StatoilHydro are industry companies that own many digital documents and much digital data. For example, DNV has many digital documents about marine technologies, and BBS stores much data about transactions between banks in Norway, and StatoilHydro also has a number of documents and experimental data about oil technologies.

The second type of partner comes from government organizations, i.e., the National Library of Norway, the National Archive of Norway, the Norwegian Ministry of Foreign Affairs and the Brønnøysund Register Centre. The National Library of Norway works to protect the culture heritage in Norway. The Library preseves various culture resources, such as radio and television programmes, photographs and books. The National Archive of Noway preserves archival materials from state institutions and makes some of those

* In 2007, the LongRec project was contacted by an archivist of the National Archives of Norway to inquire about possible collaborations between the Norwegian professional community and the InterPARES 3 Project. Norway had already started a collaborative research project called LongRec, whose aims were very similar to those of InterPARES, so it seemed logical to explore an involvement in InterPARES of researchers from that project. Following a meeting between LongRec and InterPARES representatives in May 2007, it was clear to all parties involved that both projects had much to offer each other. Accordingly, in the summer of 2007, LongRec accepted an invitation to constitute a TEAM Norway and to join the InterPARES 3 Project as a special member of its International Alliance. As a result of this arrangement, TEAM Norway is unique among the 15 regional, national and multinational TEAMs that currently comprise the Alliance in that TEAM Norway, through its association with the LongRec project, is conducting independent, yet complementary, research in parallel with the coordinated research being conducted by the remaining 14 members of the Alliance. This unique arrangement benefits both projects by enabling them to more effectively and efficiently build on each other's results, thus significantly enhancing knowledge sharing.

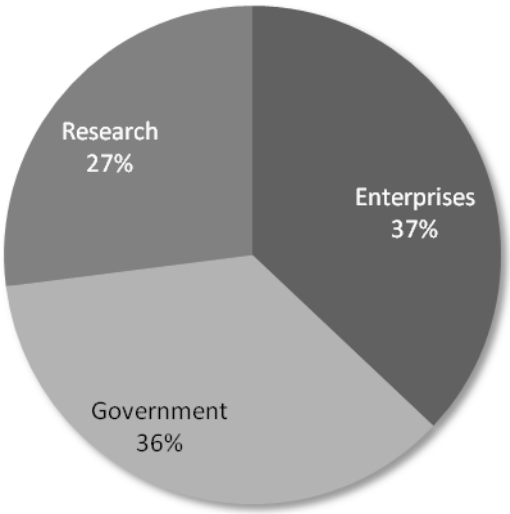

Figure 1. Classification of the partners in LongRec

materials available for use to the public. The Norwegian Ministry of Foreign Affairs works for Norway's interests internationally to safeguard the country's freedom, security and prosperity. The Ministry has many digital documents and emails that should be preserved. The Brønnøysund Register Centre is a government organization, under the Norwegian Ministry of Trade and Industry, which is in charge of managing information about business enterprises in Norway.

The third and last type of partner is research institutions, i.e., NTNU, the Norwegain Computing Center and Katholieke University of Leuven. They are responsible for finding suitable solutions according to the LongRec objective that is defined in the next paragraph.

The primary objective of LongRec is to design a "persistent, reliable and trustworthy long-term archiv[es] of digital information records with emphasis on availability and use of the information."[1] LongRec differs from other digital preservation projects in that it goes beyond "digital preservation" and "records management." Digital information in the LongRec project should not only be capable of being retrieved, read, understood or modified, but should also be capable of being trusted, traced and authenticated according to ownership and authorization while the preserved digital information undergoes several changes with respect to technology, processes and organization, throughout its lifetime.

LongRec has identified five research challenges:

1. Records transition survival
2. Long-term usage
3. Preservation of semantic value
4. Preservation of trust and security
5. Legal, social and cultural framework

These five research challenges cover aspects from administration to use in a long-term storage system. The five research challenges are targeted by four PhD students. The overall research goal is to establish theory, mechanisms and technology that enable users to trust long-term storage of digital information, and to be able to use and update digital information throughout its entire lifetime.

Case Study: Digital Preservation in the National Library of Norway

In this section, we will describe the preservation system in the National Library of Norway. We first describe what resources the National Library of Norway is preserving. Secondly, we introduce the digitizing procedures in their system. Lastly, we illustrate their storage system.

Preserving targets in the National Library of Norway

The National Library of Norway is the nation's memory and knowledge centre. The library takes care of and conveys the national knowledge and cultural heritage through a range of expressions and media. It preserves hand writings, maps, books, journals, newspapers, photographs, films, broadcasting, music and web documents.

Some types of objects have been digitized, e.g., books, journals, newspapers, photographs and web pages. The detailed digitizing procedures are described in the next section. Some have not been digitized, e.g. film, broadcasting and music. Here, 'not been digitized' means that the Library might have preserved some digitized objects, but most objects have not been digitized at all. The reason why the library has chosen not to do digital conversion for these objects is because the digitized objects require much storage space. Moreover, in terms of its current financial and technical limit, the library cannot provide enough technical support for such objects.

[1] LongRec Project, "About the project." http://www.longrec.com/Pages/Default.aspx.

Besides preserving knowledge resources, the library also preserves some obsolete devices to retrieve information from obsolete storage media. Generally, those media are acquired from other institutions and private citizens and companies. For example, DAT[2] is sound storage media developed by Sony in 1980s. Today, Sony has stopped DAT's production. The National Library of Norway has to buy second-hand devices for playing DAT from auction websites or some websites selling second-hand stuff, e.g., eBay[3] and Finn.[4]

Digitizing procedures

Here, we are going to briefly describe the digitizing procedure for books since most digitizing tasks so far are to digitize books. In general, there are four main steps in digitizing books:

1. **Scanning books**. In the scanning procedure, a little manual control is required. People first utilize a machine to divide a book into pages, then use a scanner with higher quality to scan each page, and finally store the scans as TIFF files in an intermediary server before inserting them into the preservation system.
2. **Extracting text from TIFF**. The OCR[5] technique will translate images of handwritten, typewritten or printed text into computer-editable plain text in the intermediary server. The extracted plain text is saved in XML files. The function of the plain text is to help search engines to do full-text search.
3. **Creating metadata**. The National Library of Norway has adopted several metadata schemas, e.g., METS,[6] Dublin Core Metadata,[7] etc. Some metadata about books have been preserved before scanning, e.g., book name, ISBN and authors' name. Some metadata about formats are automatically extracted by JHOVE,[8] which is a web service to generate a format report from a global format registry. They create METS metadata for the whole book, while they also create METS metadata for each page.
4. **Preserving digital books**. Every night, digitized books with their metadata are preserved in the National Library of Norway's storage system from the intermediary server. Before preserving digitized books, two different versions are created in JPEG2000 and PDF. Hence, each digital book has four different formats in the preservation system of the National Library of Norway: TIFF, JPEG2000, PDF and XML. Each format has different objectives. TIFF is popular in library preservation systems. The National Library often gets TIFF files from other libraries. However, TIFF files are too big to be viewed online; hence, the Library converts TIFF to JPEG2000 for viewing online. PDF files are also very big since they are preserved with the highest quality in order to publish or print them again in future, whilst XML is used for doing full-text search.

Long-term storage system

The National Library of Norway uses the SAN[9] storage technology, designed by Sun, to preserve digitized objects. Within SAN, storage devices can appear locally attached to a server. In their SAN, two different tapes and one disk array are connected to the storage system. Tapes are placed in two different sites, i.e., the daily worksite and the preservation site in a mountain. The disks are also placed at the preservation place in the mountain. Figure 2 shows the Library's storage system.

When a digitized object is transferred to the storage layer, it is first preserved in disks with higher performance. However, those disks are too expensive to be used as permanent storage; hence, they serve as caches in a computer system, providing temporary storage. Later, the digitized objects are transferred to long-term preservation storage, i.e., two tapes and disks with lower performance.

Challenges in Migration

In preservation systems, people can adopt several preservation strategies. So far, the proposed preservation strategies include computer museum, emulation, encapsulation, Universal Virtual Computer (UVC), migration on request and batch migration (see Table 1).[10]

In our research, we will investigate migration, including encapsulation, migration on request and batch migration. We chose migration as our main research target since:

- Most digital libraries adopt migration as their main preservation strategy.
- Migration focuses on the digital information itself, and it only requires curators to know format specifications so that people can develop converters. Other approaches have more requirements.
- Some migrations will cause loss of data and functionality. Carefully designed migration processes can overcome this disadvantage.
- Digital information management is easier after migration as digital information is stored in the newest format and the number of formats in preservation systems will not increase. People may employ the latest technology to manage them.

In the migration context, we expect to solve three important issues and develop some corresponding operations. The identified issues are discussed below.

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[2] Digital Audio Tape. See http://en.wikipedia.org/wiki/Digital_Audio_Tape.
[3] See www.ebay.com.
[4] See www.finn.no.
[5] Optical Character Recognition. See http://en.wikipedia.org/wiki/Optical_character_recognition.
[6] Metadata Encoding and Transmission Standard. See http://www.loc.gov/standards/mets/.
[7] See http://dublincore.org/documents/dces/.
[8] JSTOR/Harvard Object Validation Environment. See http://hul.harvard.edu/jhove/.
[9] Storage Area Network. See http://en.wikipedia.org/wiki/Storage_area_network.
[10] See, for example, Kyon-Hoo Lee, Oliver Slattery, Richang Lu, Xiao Tang and Victor McCrary (2002), "The State of the Art and Practice in Digital Preservation," *Journal of Research of the National Institute of Standards and Technology* 107(1): 93-106. http://nvl.nist.gov/pub/nistpubs/jres/107/1/j71lee.pdf; Kenneth Thibodeau, "Overview of Technological Approaches to Digital Preservation and Challenges in Coming Years," in *The State of Digital Preservation: An International Perspective* (CLIR Reports, no. 107) (Washington, D.C.: Council on Library and Information Resources, April 2002). http://www.clir.org/pubs/reports/pub107/thibodeau.html; Digital Preservation Testbed, "Migration: Context and Current Status," Digital Preservation Testbed White Paper, December 2001. http://www.digitaleduurzaamheid.nl/bibliotheek/docs/Migration.pdf.

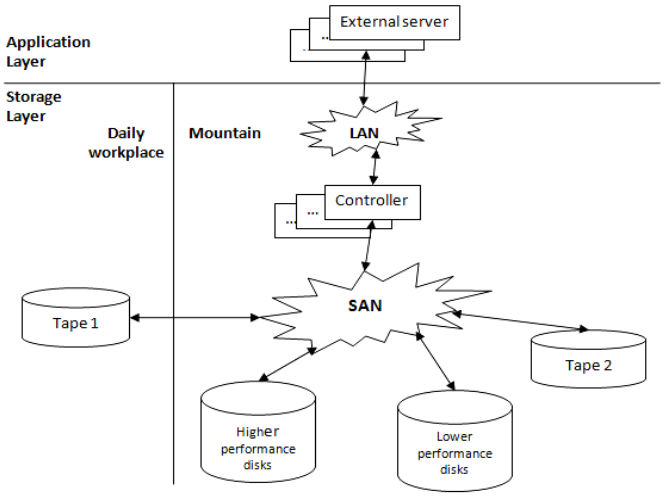

Figure 2. Storage system at the National Library of Norway

Table 1. Preservation strategies

Strategy	Description
Computer museum	The entire old computer system that was used to create digital information is retained.
Emulation	Emulation contains two parts. The first part is to develop a software application to imitate all functionalities of computer hardware. The second part is to preserve all necessary application software to interpret digital objects.
Encapsulation	Encapsulation serves to preserve digital information in its original form with the specification of its format used. People must rewrite the source code of the interpreter so that the interpreters can run on new computers to access the old digital information.
UVC[11]	UVC is similar to JAVA Virtual Machine. All digital information is saved with particular instructions of a UVC. The content can be rendered by a UVC interpreter.
Migration on request[12]	For migration on request, people should preserve the original bit streams in the original format and do migration only when future end users want to access preserved digital information.
Batch migration	Batch migration transforms archived digital information to another format before the old format becomes obsolete.

a) Very large amounts of data in preservation systems

More and more digitized objects and born-digital objects are inserted into preservation systems. In a study[13] released by IDC, it was estimated that the size of the total digital world was 281 exabytes[14] in 2007 and that the annual growth in the digital world is approximately 60%. The amount of digital information should equal nearly 1800 exabytes in 2011. In the National Library of Norway, they see a similar trend, i.e., an approximately 60% increase per year (see Figure 3). In 2007, the National Library preserved 957 terabytes of data.

We have tested the read/write performance of some storage devices, e.g., a hard disk for desktops, an external disk and a memory stick. We found that the hard disk has the highest read and write speed, i.e., both speeds around 50 MB/s, while the memory stick has the lowest read and write speed, i.e., about 10MB/s and 1.5MB/s, respectively. Thus, for those 957 terabytes, we need 232 days if we

[11] Raymond A. Lorie, "A Methodology and System for Preserving Digital Data," in *Proceedings of the 2nd ACM/IEEE-CS Joint Conference on Digital Libraries* (Portland, Oregon, USA: ACM, 2002), 312-319.

[12] Phil Mellor, Paul Wheatley and Derek Sergeant, "Migration on Request, a Practical Technique for Preservation," in G. Goos, J. Hartmanis and J. van Leeuwen, eds., *Proceedings of Research and Advanced Technology for Digital Libraries: 6th European Conference, ECDL 2002 Rome, Italy, September 16-18, 2002* (Berlin: Springer-Verlag, 2002), 516-526. http://eprints.whiterose.ac.uk/3757/1/wheatleyp1_MigrationOnRequest.pdf.

[13] John F. Gantz, Christopher Chute, Alex Manfrediz, Stephen Minton, David Reinsel, Wolfgang Schlichting and Anna Toncheva, "The Diverse and Exploding Digital Universe: An Updated Forecast of Worldwide Information Growth Through 2011," IDC white paper (March 2008). http://www.emc.com/collateral/analyst-reports/diverse-exploding-digital-universe.pdf.

[14] 1 Exabyte = 1024 Petabytes = 10242 Terabytes =10243 Gigabytes = 10246 Bytes

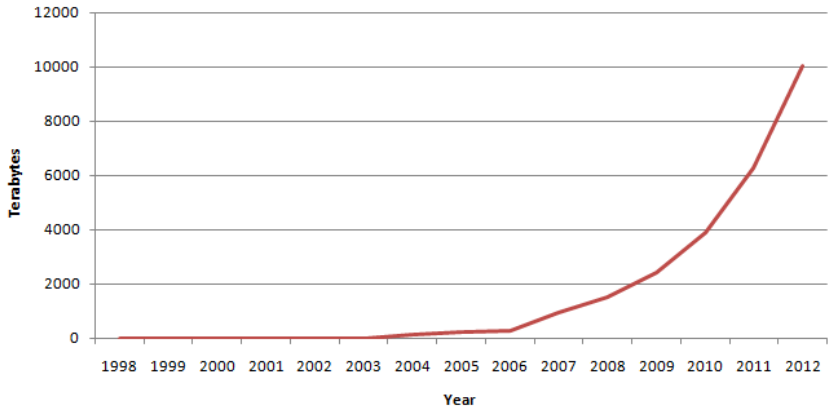

Figure 3. Data size at the National Library of Norway

use the hard disk, whilst we need 7743 days if we use the memory stick. According to the National Library of Norway's latest experience, the library spends circa three months to copy all preserved digital information to new storage media. The library is beginning to worry whether it will have enough time to transfer data if the data size still increases with the same speed, i.e., 60% per year. We have identified a research question:

How much data can we afford to migrate in terms of the limited migration time and cost?

So far, we have designed a mathematical model to calculate the migration time with respect to six parameters: *data size*, *read or write transfer bandwidth*, *access time*, *file processing speed*, *network transfer bandwidth* and *the number of replicas*. Currently, we are doing some experiments at the National Library of Norway for evaluating our mathematical model.

b) Lack of a comprehensive migration framework

When people discuss migration, most of them focus on format conversion. For example, Rosenthal et al. proposed three approaches to do migration in terms of when people carry out migration.[15] Strodl et al. also proposed an approach to evaluate pairing formats for an original format.[16] They combined their solution with an intelligent decision support system designed by Ferreira et al.[17] Finally, they created a web service called Plato[18] to provide an automated preservation planning environment.

Besides format conversion, some researchers discuss storage migration. For example, researchers proposed the refresh approach or the replicating approach in ISO 14721:2003, the Reference Model for Open Archival Information Systems (OAIS);[19] and Wheatley defined the basic preservation approach.[20]

We believe that future end users should have four requirements for preserved digital objects: *Accessibility*, *Viewability*, *Understandability* and *Trustability*. Accessibility requires that end users should be able to retrieve the preserved digital objects from storage media; viewability requires that end users should be able to read the preserved digital objects with the help of some software; understandability requires that end users should be able to fully understand what the preserved digital objects tell them; and trustability requires that end users should be able to trust that the content of preserved digital objects is trustworthy and that the digital objects themselves are authentic. However, currently proposed migration strategies mainly focus on format and storage migrations; thus, they cannot fully satisfy the requirements from the future end users' viewpoint. As a general rule, we think that the comprehensive migration framework should answer questions like the following:

- What are the reasons for doing migration?
- How to evaluate the situation before migration?
- What is the migration target?
- How to choose storage media?
- How to choose the best pairing formats for current formats used in preservation systems?
- How to choose the best converter when we have many format conversion applications?
- What issues exist for preserved data when doing a migration?

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[15] David S. H. Rosenthal, Thomas Lipkis, Thomas S. Robertson and Seth Morabito (2005), "Transparent Format Migration of Preserved Web Content," *D-Lib Magazine* 11(1). http://www.dlib.org/dlib/january05/rosenthal/01rosenthal.html.

[16] Stephan Strodl, Christoph Becker, Robert Neumayer and Andreas Rauber, "How to Choose a Digital Preservation Strategy: Evaluating a Preservation Planning Procedure," in R. Larson, E. Rasmussen, S. Sugimoto and E. Toms, eds., *Proceedings of the 7th ACM/IEEE-CS Joint Conference on Digital libraries* (Vancouver, BC, Canada: ACM, 2007), 29-38. http://www.ifs.tuwien.ac.at/~strodl/paper/FP060-strodl.pdf.

[17] Miquel Ferreira, Ana Alice Baptista and José Carlos Ramalho (2007), "An Intelligent Decision Support System for Digital Preservation," *International Journal on Digital Libraries* 6(4): 295-304.

[18] Christopher Becker, Miquel Ferreira, Michael Kraxner, Andreas Rauber, Ana Alice Baptista and José Carlos Ramalho (2008), "Distributed Preservation Services: Integrating Planning and Actions," in B. Christensen-Dalsgaard, D. Castelli, B. Ammitzbøll Jurik and J. Lippincott, eds., *Proceedings of the 12th European Conference on Research and Advanced Technology for Digital Libraries* (Berlin: Springer-Verlag, 2008), 25-36.

[19] Consultative Committee for Space Data Systems, "CCSDS 650.0-B-1: Reference Model for an Open Archival Information System (OAIS)," Blue Book, Issue 1, January 2002. http://public.ccsds.org/publications/archive/650x0b1.pdf.

[20] Paul Wheatley (2001), "Migration–A CAMiLEON Discussion Paper," *Ariadne* 29(2). http://www.ariadne.ac.uk/issue29/camileon/.

- What issues will trust and security generate when doing a migration?
- What issues will the management system generate when doing a migration?

c) What metadata should be preserved for migration?

Metadata are data about data; they provide supplementary information about an object. For instance, Lavoie and Dale surveyed four existing preservation metadata schemes, developed by CEDARS,[21] NLA,[22] NEDLIB,[23] and OCLC,[24] respectively, and then proposed a metadata framework.[25] In addition, OAIS has defined six types of metadata: *reference*, *provenance*, *context*, *fixity*, *packaging metadata* and *access aids*.[26]

However, we have yet to find an article that discusses metadata in migration in general. We also found that most libraries have no unified metadata; each library preserves its own metadata. Thus, we plan to discuss metadata issues in general. Problems concerning metadata to be discussed will be:

- Which metadata are preserved in most preservation systems?
- Which metadata are necessary to do migration?
- Which metadata can improve trust?
- Which metadata should be updated after migration?

Conclusion

More and more people and institutions have begun to worry about how to preserve their digital information in the long term. In this paper, we summarized some work related to preserving digital information in Norway. We expect to design a comprehensive migration framework and a corresponding migration metadata framework so that we can preserve digital information without losing anything, i.e., functionalities, contents and people's trustworthiness. In addition, we plan to develop some practical operations for facilitating any migration strategy. We believe that scientists in information management, developers of long-term preservation systems, librarians and curators will benefit from our research results.

Author Biographies

Feng Luan received his Bachelor's degree at Northwest University, China (2002). After working at a bank as a software engineer for three years, he moved to Uppsala University, Sweden, to pursue a Master's degree, which he received in 2007. He currently is pursuing his PhD at the Norwegian University of Science and Technology (NTNU) in Trondheim, where his research topic, "Records Transition Survival – When Used Several Decades," focuses on the long-term preservation of digital information. He is a member of TEAM Norway of the InterPARES 3 Project and a member of the LongRec project.

Mads Nygård received both his Master of Science (Siv.Ing.) and Doctor of Science (Dr.Techn.) degrees from NTH (the Norwegian Institute of Technology, Trondheim), in 1979 and 1990, respectively. From 1983 to 1997, he worked for SINTEF (the Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology, Trondheim) as Section Head, Research Manager, Principal Research Scientist and member of the Board of Directors. In 1997, he joined NTNU (the Norwegian University of Science and Technology, Trondheim) as Full Professor in the Computer and Information Science department. He has also worked for UNDP (the United Nations Development Program) developing Information and Communication Technology education in Bangkok, Thailand, and in Beijing, China, and for OECD (the Organization for Economic Cooperation and Development). His main research interests are distributed systems, database systems and operating systems. He currently is Chairman of the Board of Directors at UNIK (the University Graduate Centre at Kjeller, Lillestrøm) and a member of the Board of Directors at TEKNA (the Norwegian Society of Chartered Technical and Scientific Professionals). He is also a member of TEAM Norway of the InterPARES 3 Project and a member of the LongRec project.

After studying mathematics and chemistry, Lars Gaustad trained in sound production and for 15 years worked in film, video and theatre doing sound design and recording. In 1992, he was engaged by the National Library of Norway to establish a restoration department for film, sound and video, which he ran for 8 years, before moving on to an advisory position on digitisation and long-term preservation at the Library. Since 2000, he has also held a position as lecturer at The Royal Danish Academy of Fine Art in Copenhagen with responsibility for teaching restoration and preservation of Machine-readable Media. He holds positions in several international organisations, including Chair of the IASA Technical Commission (International Association of Audiovisual Archives) and the Standards Committee WG on Transfer Technology in the Audio Engineering Society. He is also a member of the AES Technical Commission on Archiving, Restoration and Digital Libraries, the Joint Technical Commission AES SC-03/ANSI-PIMA IT9-5, and the European Union Commissions Expert group on digitisation and digital preservation. He is also a member of TEAM Norway of the InterPARES 3 Project and a member of the LongRec project.

Inger-Mette Gustavsen is Principal Researcher at DNV (Det Norske Veritas) Research & Innovation, Oslo, Norway. She has a Bachelor of Science degree in Informatics and a Master of Science degree in Management. Her experience is wide-ranging, spanning IT operation, knowledge management, project management, consultancy, information management, IT auditing, information security and research. Her main area of interest is information management with a focus on long-term preservation, compliance, information quality and use of digital information. She is currently the Director of TEAM Norway of the InterPARES 3 Project and is also the Project Manager for the LongRec project.

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[21] CURL Exemplars in Digital ARchiveS project. See http://www.webarchive.org.uk/ukwa/target/99695/.

[22] National Library of Australia. See "Preservation Metadata for Digital Collections," at http://www.nla.gov.au/preserve/pmeta.html.

[23] Networked European Deposit Library. See http://nedlib.kb.nl/. See also Catherine Lupovici and Julien Masanès (2002), "NEDLIB – LB 5648: Metadata for long term preservation," NEDLIB Consortium. http://nedlib.kb.nl/results/NEDLIBmetadata.pdf.

[24] Online Computer Library Center. See http://www.oclc.org.

[25] OCLC/RLG Working Group on Preservation Metadata, *Preservation Metadata and the OAIS Information Model: A Metadata Framework to Support the Preservation of Digital Objects* (Dublin, Ohio: OCLC Online Computer Library Center, 2002). http://www.oclc.org/research/pmwg/pm_framework.pdf.

[26] Consultative Committee for Space Data Systems, "CCSDS 650.0-B-1," ibid.