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1 Introduction

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The Information Society has become the major objective of the worldwide public interest by the announcement of the Global Information Infrastructure (GII) Plan in 1992, and the explosive expansion of the Internet (World Wide Web and Mosaic in 1993) and other information technologies of especially wireless mobile have made globalization inevitable reality. The benefits of the information society and globalization include free access to the worldwide cultural heritage resources of museums for the well being of all citizens, as well as education resources for school.

Museums have the traditional international role as a center of collections for visitors and study, since the museums serve an international community and invariably possess international collections. In addition to the museums' traditional roles, education services at museums have been established as valuable products of the 20th Century in the long museum history (1). Museums are increasingly being recognized as offering a unique opportunities for people of all ages and cultures, and any background to gain information that may not be expected from traditional school education. A visit to a museum is often a child's first contact with material culture of the ancient past and of other societies today. Museums endeavor to do everything possible to ensure that visitors are educated and inspired.

Teaching methods used at between museums and traditional school education are different. At museums, it is user-centered teaching style, and people can learn by direct access to exhibited artifacts spontaneously and at their own pace. Interactive multimedia technology enhances museum's values (2) by providing benefits of digital convergence technology of data and networking technology.

Multimedia stimulates visitors' five senses. Multimedia can retain indefinitely the original quality of real objects. The technology affords access to digitized version, allowing users to manipulate and distribute museum materials. It also permits multiple users simultaneous access to single item, and enables quick and sophisticated browsing of the collections. The combination of multimedia technology with global networks such as the Internet enhances the educational experience and expands it to a

worldwide scale, or in other words, it realizes wall-less virtual classroom in cyberspace. In the cyberspace, contents at different site museums can be searched, accessed and browsed as a single museum server, and collaborative content creation becomes possible among the users as well as the interchange of different museum contents. By the Internet, international horizons of young people can be easily broaden.

The most common method of getting information on the Internet is opening the Web home pages. However, it is usually one-way information dissemination by the homepage creators to the Web clients who must be patient with repeated distribution of huge number of homepages, in which there may be interested information the clients expect. FTP (File Transfer Protocol)-based Internet library was the most common file sharing method among different sites of servers. However, users had to know the FTP site names and file names, and search in turn, which is usually hard to continue to do for the users.

Museum education systems on the Internet should be well organized, and possess effective search and educational tools. The conceptual and technical details and technical feasibility of such systems are required to be experimented for proofing of educational benefits of museum over the Internet. A method is needed to search multimedia information of museums, which located in the vast cyberspace of the Internet as the museum contents of a single federated museum for educational purposes. We call it Global Digital Museum (GDM), which is a virtual global classroom of museums on the Internet. In the cyberspace of GDM, users can search and access multimedia contents of museums in a single easy user interface without knowing file names, data types, and site names of sources to search and access. The user can search and access their interested files by naming their interest. Once the material has been received, they can deepen their knowledge of the subject by using education tools over the Internet as well.

In GDM collaborative work, we addressed a concept, a data model, system architecture of the GDM for the uses of museum education, and technologies of global indexing and search mechanisms, and education tools. We made prototypes of GDM and applied it to real museum contents in a collaborative work among experts of museum research, museum education, multimedia education, and computer science and network.

Our main focus of GDM users is on K-12 school children and their schoolteachers. From discussion on the users among GDM project members, we identified the children who belong to higher grades in primary school of ages between 9-11 years old, and junior high school of ages between 12-15 years old. Their attitudes to contacting with museum information, in any styles, can be referred to as a criterion of responses of all other generations. They have strong intellectual curiosity, they

consider and act spontaneously, and they respond to their new experiences enthusiastically. We could say so from experiences and observations at National Museum of Ethnology and the British Museum.

GDM project team was organized by four institutions such as National Museum of Ethnology, Osaka, Japan, The British Museum, London, UK, Cornell University, Ithaca, USA, and Tokyo Research Laboratory, IBM Japan Ltd. , Tokyo, Japan. Each institution has unique expertise worldwidely recognized in their own domains and shared it in GDM project for the goals.

National Museum of Ethnology was established as one of the Inter-University Research Institutes of the Japanese Government in 1974. This museum is comprehensive research museum of which principal functions as 1) to conduct research and investigation in ethnology, or cultural anthropology, 2) to collect, maintain, and exhibit ethnological materials, 3) through these activities to deepen the general public understanding and awareness of the various societies, cultures, and peoples of the world. Collections of this museum include audio-visual materials as well as artifacts and books and periodicals. HRAF (Human Relations Area File) is another key collection of this museum which is used for the museum collections management and research. It is serving collection databases to domestic scholars, is integrating institute in the Asian countries for development of wider area studies, and is conducting post-graduate education. The uniqueness of this museum is large-scale and advanced computerization, based on that the museum features are efficiently operated. Computer systems are regarded as the museum's infrastructure. Since the computerization project commenced in 1978, National Museum of Ethnology has been working on implementation of three phase solutions. Ultimately this includes museum information services on the Internet. In the first phase of 1978-1982, a library server was established for use by researcher and technical staffs. The second phase between 1984 and 1990 utilized image object servers of artifacts and photo-slide images. The integration of the library and object servers by a high-speed local area network with the addition of a high-quality image server, sound server, and three-dimensional image server are part of the third phases of the solution, which was between 1991 and 1997. They opened Internet web site during this period, for they have a strong intention of developing its public service functions through providing comprehensive museum information based on interactive multimedia and Internet technologies. In GDM project, National Museum of Ethnology provided ethnological research experiences, the experiences of advanced applications of information technology, multimedia museum content creation, and installation and evaluation of the GDM prototype.

The British Museum was established in 1753 as the first public national museum anywhere. This museum has one of the greatest collections (8 million items) of art, archaeology and ethnography in the world. Today it is visited by more than six million people annually —over half of them are international. The Museum has not only

played a significant role in its primary mission to exhibit its collections, but also contributed to research in archaeology and art history and ethnography. Museum Education has also been one of its most important roles. In 1970 an Education Service was established and has provided many educational programmes for schools, universities and adults. In the UK, a national curriculum for schools was developed from 1988 and The British Museum educators have contributed to this process. This has resulted in the compulsory study for children at primary school of topics which include ancient Greece, Roman, Anglo-Saxon and Viking Britain with options including Benin, Asia and the Americas. The British Museum Education Department has developed great expertise in devising paper-based materials including resource packs for teaching teachers about museum exhibits prior to a museum visit and distance learning materials via the www, television and conventional publishing. The Museum is enthusiastic about renewing itself with a new Education Center as part of the Great Court Millennium Project, culminating in 2003 with its 250th Anniversary. The Clore Education Center includes an ICT Seminar Room; the Reading Room has 5o terminals to COMPASS (a public access system database.) The Museum is also developing its educational role through multimedia information access, publications and so on. Digitization including diverse components such as data, graphs, images, video and audio. The British Museum contributed to the GDM by providing their experience in developing educational resources and programmes, creation of museum content and installation of GDM prototype and evaluation.

Cornell University was founded in 1865 as a land-grant institution, consisting of seven graduate divisions and several professional and four graduate schools. Cornell University is now the most comprehensive school in the Ivy League with an international reputation. Cornell has been a national leader in the development and implementation of information technologies and Theory Center is the site of one of the four national supercomputing facilities and provides international access to high-speed computer capabilities. The Cornell library has played a pioneering role in the development and applications of digital imaging technologies aiming to contribute to the use of common standards for domestic capture, storage and transmission. Digital library system on the internet, called as DIENST (Distributed Interactive Extensible Network Server for Techreport) is well known Inter-university project of the U. S. A, and CU-SeeMe is the another most well known network-centric TV conference technology developed by Cornell university. Since 1985, Cornell's Interactive Multimedia Group (IMG, currently Human Computer Interactive, HCI) has concentrated on applying communication research to human-computer interaction design. IMG has been working with NSF projects and library/museum applications in concert by evaluators, designers, programmers and researchers, as well as with other US government organizations. IMG has also endeavored in the research of tools and on-line resources in distributed network learning environments. IMG is skillful with interactive multimedia technology and graphical user interface for education and Internet, and educational evaluation methods of the interaction. IMG of Cornell University gave

advices of interactive multimedia uses for education on the Internet, designed graphical user interface of GDM prototype, and led the GDM prototype evaluation.

International Business Machines, Corp. or IBM Corp. is the worldwide leading company in the computer industry and information technology industry, and IBM Japan is the subsidiary firm in Japan. Tokyo Research Laboratory (TRL) is one of IBM's eight research facilities, which does research in close collaboration with each other, maintaining a steady exchange of vital technical information and keeping cooperative relations. Its aims are to contribute widely to the scientific and technological community through research on information technologies and, as an industrial research institute, to promote fundamental and applied research that will be a basis for the firm's products, solutions and services. TRL's research activity range from theoretical fields such as computer science theory, via advanced technologies such as computer languages, magnetic storage, security and pervasive computing, to applied technologies such as multimedia, natural language processing, voice processing and the others. TRL also conducts joint work with the governments, universities, other research institutes, and customers in order to maintain a high level of research. Application domains of TRL computer and network technologies are academic societies, education, social welfare, medical, and culture. Results are made public through presentation to academic societies and publications in technical journals. IBM Corp. has made many contributions to cultural heritage and digital library by providing advanced computer and network technologies through IBM Research laboratories such as TRL (3), as well as contributions to education societies. TRL managed GDM project progress with National Museum of Ethnology, and TRL designed and made GDM prototype by providing multimedia and network technologies, which was based on studying of requirements given from experts of museum and education at National Museum of Ethnology, British Museum, Cornell University and others than GDM project member.

As one of the first joint projects between the governmental research institutions and industrial laboratories, which was guided from the Japanese government in 1985, National Museum of Ethnology and IBM Japan started joint research project on image database of the museum's artifact collections in 1986 and successfully ended in 1988. In this project, image database systems were prototyped which consisted of optical disc based hierarchical storage architecture for terabyte volume of image data, PC-high resolution display based interactive quecery and browsing of full color images, and image retrieval based on relational algebra and similarity of color and shape of digital images. We applied computer technology to other areas of ethnological research museum role (4). The next advanced computer application project between National Museum of Ethnology and TRL of IBM Japan was "Multimedia Applications in Museum," (1992-1995) in which we made several multimedia prototypes for the evaluation of its acceptance by the museum visitors. For that purpose we set the prototypes in the open exhibit spaces of National Museum of

Ethnology at different sites to make on-site evaluation. The multimedia systems were hypermedia pointing system, hyperlink learning system, multimedia database system, and videoconference system (5, 6). In this project, we made hypermedia project report on CD-ROM, which was the first hypermedia content created in National Museum of Ethnology and demonstrates the project overview and achievements by multimedia. In the second joint project, we intended to study feasibility of multimedia usefulness for museum exhibition or museum education. Technical output from our second joint work was used at two special exhibitions of Australian Aboriginal and Latin American Music held by National Museum of Ethnology in 1994-1995.

From observations of museum visitors responses to our prototypes at the exhibitions, advantages of multimedia were recognized and we were convinced of benefits of multimedia based museum education. We also had chances of understanding of well acceptance of multimedia by museum experts and education experts as useful complementary tools to their conventional ones at some international academic conferences. However they were off lined systems, not connected to the Internet, yet. Our interest in the next trial was combination of multimedia and the Internet and its application to museum education which is regarded as extension of museum information services. Possible quick extension of the Internet was already recognized after World Wide Web and MOSAIC were informed from limited number of sources, but actually it was being used by some large enterprises only for their new business opportunities at that time. Meanwhile, the Internet explosion was recognized among general users of USA and Japan from 1995 or 1996. There was no global search system of multimedia on the Internet when we started feasibility study of GDM in 1993 and for another several years, but only document based search system such as DIENST (Distributed Interactive Extensible Network Server for Techreports) of Cornell University were found. DIENST was most advantageous reference for our first step of GDM architecture. We roughly had some perspectives such as heterogeneous multimedia data modeling, appropriate protocol, man-machine interactivity, easy man-machine interface and system performance on the Internet, which were key technical factors of GDM prototype from the system point of view.

There remain other issues we should to address in GDM project than the system related one such as content and man-machine user interface. All four GDM members were familiar with creating multimedia content for their own purposes, so that it was easy to work on the GDM content creation. It is not so much difficult to create content of high quality and high level as to understand importance of content. For creating high quality and high level GDM content, we considered that expert knowledge of researchers and curators must be incorporated in it. Since domain of researchers joined GDM from National Museum of Ethnology was ethnology, or cultural anthropology, we selected their research areas of ethnology for creating the GDM content. Easy and sophisticated man-machine user interface was another key factor for GDM project. Interaction between user and museum education system must be interactive by

highly designed graphical user interface and natural interaction flow. It required experts' knowledge and skill.

National Museum of Ethnology proposed the 21st Century Museum Vision in which it defined itself as the worldwide Ethnology information-providing center. GDM could be regarded as the initial trial of the vision deployment, and for successful implementation of GDM project we needed partners who could share their expertises of education and multimedia. It was the Museum Service Division of the British Museum and IMG of Cornell University to whom we proposed GDM to join. They have had many significant experiences and achievements in the education areas of museum education and interactive multimedia applications, respectively. They were enthusiastic of co-working on GDM by sharing their skills, and we started GDM project in September of 1995 and co-worked until March of 1999.

This report covers all GDM project key issues we addressed, which includes GDM background, concept, prototype, evaluation, and its future. This report conveys mainly three subjects. The first subject is related to GDM background such as overview of museum education from different points of views of characteristics or advantages of museum education by comparison to conventional school education, and advantages of applying multimedia and Internet technologies into museum education. Mainly National Museum of Ethnology team reported it. The second subject is detail description of GDM prototype, which we made during this joint work as the main purpose, and in this report the details of GDM technology of system design, system architecture, and implementation are described. IBM TRL team who was in charge of it. Details of GDM user interface design is discussed by Cornell team. We created GDM multimedia contents of some ethnological cultures such as Mongolia, Korea, Indonesia, Aztecs and Mexico of which details including indexing are explained by the teams of National Museum of Ethnology and the British Museum who dedicated to each expert area. We applied HRAF (Human Relations Area Files) code to indexing the GDM contents for global search on GDM prototype, which is explained by National Museum of Ethnology team. GDM was evaluated its usefulness by several times at different sites from academic point of views such as interactivity of multimedia on the Internet, and reports of which method and results are followed, for which Cornell University team was responsible. Achievements from GDM and some issues of GDM development are summarized based on the previous chapters. The third subject is future direction of GDM. From GDM project, we learned many things about museum role of information services such as education, exhibition and others, and some idea of future direction of GDM are discussed in the last chapter by National Museum of Ethnology, the British Museum, and Cornell University. In the Appendix, there are administrative data such as chronology of GDM project, all GDM project members including supportive persons, achievements list, and glossary which will be helpful for the readers understanding of whole features of GDM project.

Our efforts to promote usage of the Internet and multimedia technologies in museum education could not have been successful without the partnership among the GDM members of National Museum of Ethnology, the British Museum, Cornell University and IBM Japan. To achieve GDM project required far more than the technology that was the focus of most computer science and the Internet. Linkage between the technologies and the domain expertises of ethnology, museum and education was crucial for making GDM efforts successful. All the GDM members devoted themselves to their roles during the whole period of this collaborative work. We got cooperation of schoolteachers and students who joined the GDM prototype evaluation programs, as well as helpful cooperations from many staffs and students of the GDM members whenever we needed their help. We are grateful very much about their participations and contributions to the GDM achievements. Finally, we would like to mention that GDM project was one of pioneering efforts of museum education or museum information services, and we wish to share our experiences and promote discussion with all experts in the areas of museum, education, computer technology and the Internet, who are interested in museum education or museum information services. We are grateful to Dr. H. C. Koh, East Rock Institute, New Haven, CT, who advised on using HRAF in indexing the GDM contents.

Notes

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3) Jung-Kook Hong, *"Arts, Culture and Mecenat, A 21st Century Vision," Complete Proceedings of Int'l Mecenat Conference '95*, pp. 260-265, 1995.
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5) Jung-Kook Hong, Junichi Takahashi, Masahiro Kusaba, Shigeharu Sugita, "An Approach to the Digital Museum-Multimedia Systems for an Ethnology Museum," *Proc. 3rd Int'l Conf. Hypermedia and Interactivity in Museums* (ICHIM '95/MCN'95), San Diego, CA, Oct. 9-13, 1995, pp. 87-95.
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