

## R&amp;D Project Report

# Progress of the Digital Silk Roads project

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## ABSTRACT

NII launched the Digital Silk Roads (DSR) project in cooperation with UNESCO as an international joint research project at NII in April 2001. In December 2001, at a the Tokyo symposium for Digital Silk Roads jointly organized by NII and UNESCO, the Tokyo Declaration was issued. The second International Symposium for the Digital Silk Roads was held at Nara in December 2003. A memorandum of understanding (MOU) between UNESCO and NII was signed by the Directors General of UNESCO and NII in March 2003. Under this MOU, the Digital Silk Roads Initiative Framework (DSRIF) was established as a coordination mechanism for promotion of the Project. The Bamiyan Remains in Afghanistan were archived as the Bamiyan Virtual Museum before being dynamited. Digital archiving of various historical documents, including rare books in the possession of the Toyo Bunko in Tokyo, was carried out. An Advanced Scientific Portal for International Cooperation on the Digital Silk Roads(ASPICO-DSR) was developed to provide a platform for collaboration of Digital Silk Roads studies. Ontology of caravanserais in Central Asia and 3D virtual restoration of the Citadel of Bam are currently being researched.

This paper presents the progress of the Digital Silk Roads project conducted at NII, reporting on the objectives, targeted areas, program concept, architecture, and implementation by reviewing its past achievements.

Ch.1 gives an introductory remarks by K.Ono. Ch.2 overviews of the Digital Silk Roads project by K.Ono Ch.3 describes the digital archive of the rare books on Silk Road in the possession of the Toyo Bunko by T.Yamamoto and S.Sato. Ch.4 presents the virtual restoration of the Bamiyan ruins using DIS technology by T.Kamiuchi. Ch.5 report on the DSR portal sites and its structure by A. Kitamoto . Ch.6 describes the architecture and metadata management of the ASPICO portal by K.Ono. Ch.7 describes resources management techniques by F.Andres. Ch.8 discusses Spacial-Lexical Knowledge Model for the Silk Roads caravanserais by E. Andaroodi. Ch.9 concludes this report with a discussion of perspectives on the future by K.Ono

## KEYWORDS

DSR, DSRIF, Digital Archive, Silk Road, Toyo Bunko, Bamiyan, Virtual Museum, Annotation, ASPICO, Portal, Ontology, Caravanserais

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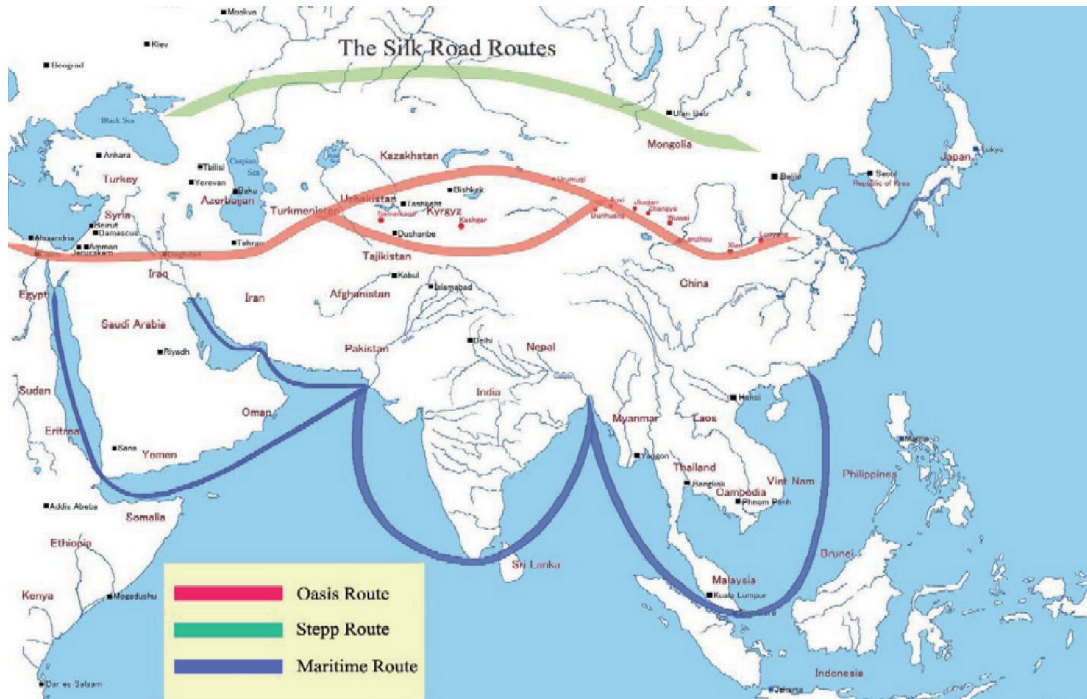


Figure 2-1. MAP of the Silk Road Routes

## 1 Introduction

At present, a great deal of historical, cultural, and natural heritage is on the verge of disappearing due to factors including wars, disasters, and simply the passage of time.

At the same time, current information technologies provide opportunities for recording, archiving, and disseminating digitized information on cultural resources, creating space for intercultural dialogue and new cultural expressions.

NII (National Institute of Informatics) has launched the Digital Silk Roads (DSR) project in April 2001 in cooperation with UNESCO (United Nations Educational, Scientific, and Cultural Organization). The project aims to create a digital archive of cultural heritage in the Silk Road region, and establish a network collaboration system by linking advanced information technology and cultural sciences.

The Tokyo Symposium for Digital Silk Roads, the project's first major international conference, was held in December 2001. The Tokyo Declaration, adopted at the symposium, summarized the discussion and formed a basis for the launch of a full-fledged international collaborative project "Digital Silk Roads", jointly led by NII and UNESCO. [1]

This article reports on the progress of the "Digital Silk Roads", referencing our past achievements. [2][9]

If the DSR project proves successful, it will enable

people to freely explore and experience some of the Silk Road Heritage sites without actually visiting them, which have been merely a dream for many decades. We hope that the Digital Silk Roads project will significantly enhance global cultural diversity.

## 2 The Digital Silk Roads project

As is widely known, the "Silk Road" refers to the numerous trade routes that served to carry silk and other commodities across the Eurasia continent over past centuries.

For centuries, it has served as a major stage for historical events and for cultural exchanges. Vast amounts of information concerning science, technology, art, and religion have been transferred along the Road, influencing many different peoples and their civilizations in the region.

Among them, the most famous are the Desert or Oasis Route from Xian to Kashgar in China, the Steppe Route running through Central Asia, and the Maritime Route from Venice to Osaka.

Figure 2-1 shows a map of the "Silk Road", with these routes represented by various lines.

The invaluable cultural and natural heritage that still remains along the Silk Roads is certainly a significant witness to human history and should be preserved and

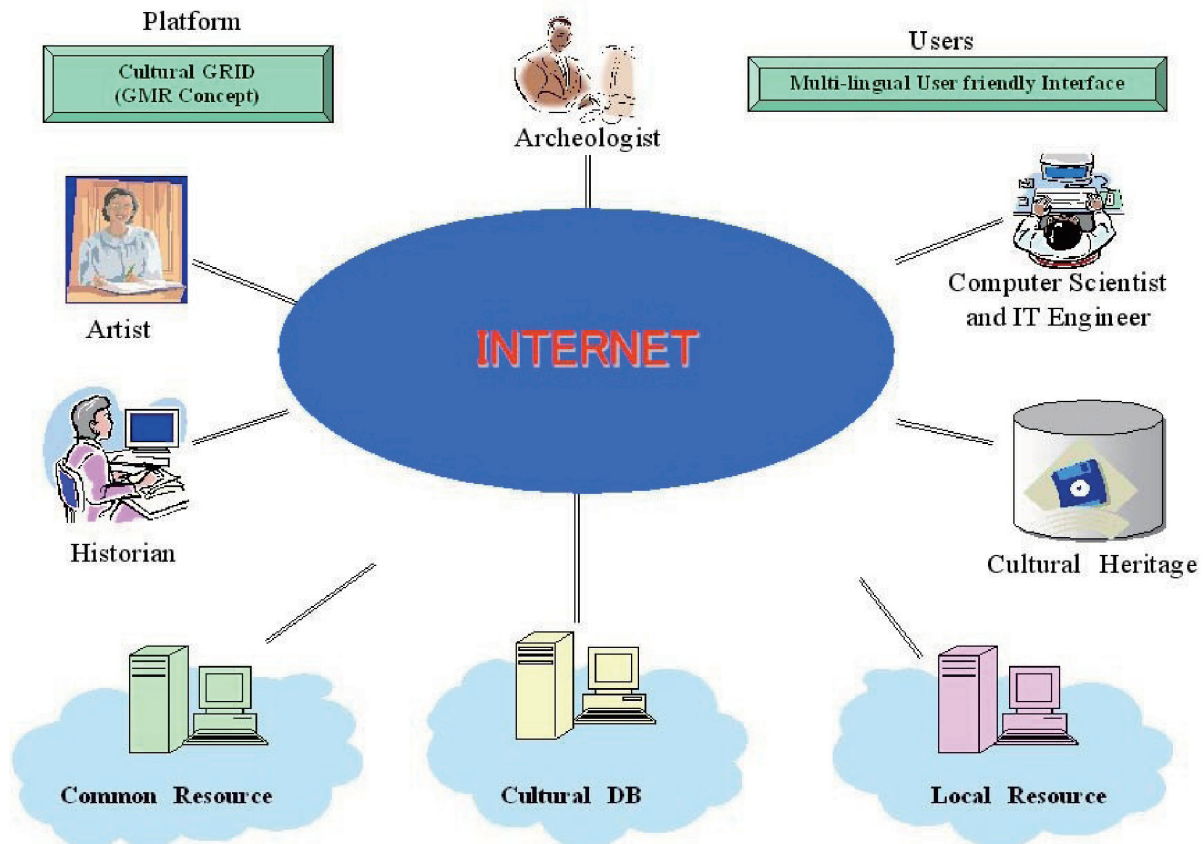


Fig. 2-2 GMR concept

passed on to future generations as a great common asset of all mankind.

### 2.1 Background

A UNESCO project called “Integral Study of the Silk Roads: Roads of Dialogue”, began in 1988. It mobilized numerous experts and institutions involved in research on these routes and succeeded in creating an extensive network for Silk Roads studies. The project resulted in a variety of seminars, research programs, books, films, videos, and photos from expeditions.[7]

Based on such achievements, the DSR project tries to link advanced information technology and cultural studies in order to further enhance interest in precious cultural assets along the Silk Roads. DSR aims to advance the knowledge accumulated through past Silk Road studies with the help of digital technology and promote the use of such knowledge not only among academia but also among the general public the world-over.[5][6]

### 2.2 Objectives and Goal of the DSR project

The project seeks to establish a new approach to Silk Road studies, fusing cultural sciences and information technology through digital archiving and network collaboration.[8]

The Digital Silk Roads project is aiming to create a digital archive of the geographically dispersed Silk Road heritage and develop a system to facilitate the use of the digital archive, based on the concept of a Global Multimedia Repository (GMR) featuring the integration of advanced information technology and cultural themes in distributed environments. In addition, the project aims to establish a means to conserve Silk Road heritage in digital form and make it available to people around the world through digital archiving. The project is carried out through international collaboration and cooperation between Information Technology experts and cultural specialists.[5][6]

The goal of the DSR project is to create digital archives of geographically dispersed cultural heritage contents along the Silk Roads through Internet collaboration and to make them available for retrieval and sharing world-wide. That is to lay the foundation of a

new concept of Silk Road studies in the 21st centuries through the Digital Silk Roads and create a Virtual Museum from Silk Roads heritage resources.

Following this, the project will digitize cultural heritage materials in the possession of UNESCO, as well as those of, some other organizations and individuals, and develop an information infrastructure aimed at fully utilizing such contents.

Finally, building on this foundation, the project will expand its scope to include other major Silk Road cultural heritage sites with a view to completing the Digital Silk Roads Museum in the future.[9]

### 2.3 Program Concept and Approach

We have proposed the concept of a GMR (Global Multimedia Repository), which is designed to solve a number of problems concerning the preservation and dissemination of historical and cultural resources. We initially proposed this idea at the Tokyo Symposium for Digital Silk Roads, held in December 2001. [1],[3]

GMR is a large repository of multimedia cultural resources and can be compared to, an information storage platform where various digitized multimedia materials can be stored and utilized by a wide variety of parties who involved in research and educational activities related to the heritage of the Silk Road.

In order to protect the Silk Roads' -millenarian cultural heritage-, we intend to gather Silk Roads experts, together with information technology researchers, to build digital archives accessible from anywhere, by anyone. Toward this end, a Web-based portal solution will be employed to create, analyze and present the digital heritage database through a standard browser.

Cultural GRID is the new resource management middleware that will be used to realize this concept. It will provide deep resource for the creation of Web sites, museum exhibitions, and educational materials in the forms of CD-ROMs or DVDs. Implementing the GMR concept is a big challenge, and will require building up capabilities for the storing, accessing, and retrieving of large volumes of multilingual multimedia contents related to the Silk Roads.

Figure 2-2 shows the GMR concept we are proposing.

### 2.4 Project organization

In cooperation with relevant organizations, the project is being led by NII and UNESCO, with participation by a number of scholars and experts from various disciplines who have taken an interest in digitally archiving Silk Roads heritage materials.

Among them are the DIS group of Hitachi Corpora-

tion, the Toyo Bunko, and Kyoto University's Center for Southeast Asian Studies (CSEAS) in Japan.

A research team at the University of Michigan and the ECAI group at the University of California, Berkeley, and University of Hawaii, in the United States, the Ecole d'Architecture Paris Val de Seine in France, the Asian Institute of Technology in Thailand, the Iranian Cultural Heritage and Tourism Organization(ICHTO) of Iran, and Tsinghua University and the Dunhuang Academy in China are also our partners.

Researchers from these organizations will work together through network collaboration, using a global the global ASPICO (Advanced Scientific Portal for International Cooperation for DSR) portal to digitally archive geographically dispersed Silk Road heritage resources.

### 2.5 Project Financing

The project has been financed mostly by a Grant-in-Aid for Scientific Research (KAKENHI) by Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT), a Grant-in-Aid for Publication of Scientific Research Results from the Japan Society for the Promotion of Science(JSPS), and NII's international joint research budget.

UNESCO's Information Society Division supports a travel fund for UNESCO delegates to participate the International Symposium for Digital Silk Roads.

### 2.6 Project History

Since the launch of the Digital Silk Roads project, the following events have taken place as shown in Figure 2-3;

#### 1) Launch of the DSR project

The project was initially launched as an international joint research project at NII in April 2001. In December 2001, the Tokyo Symposium for Digital Silk Roads was jointly organized by NII, UNESCO, and the Japanese National Commission for UNESCO, to review the results of past Silk Road studies and discuss the feasibility of Digital Silk Roads.

The Tokyo Declaration was issued at the close of the symposium. In December 2003, the second international symposium for Digital Silk Roads was held at Nara to present and discuss current and future activities.

#### 2) MOU between UNESCO and NII

A memorandum of understanding (MOU) between UNESCO and NII was signed in March 2003 by the Directors General of UNESCO and NII. In March 2003, the full-fledged international collaborative DSR project was launched with the conclusion of the MOU

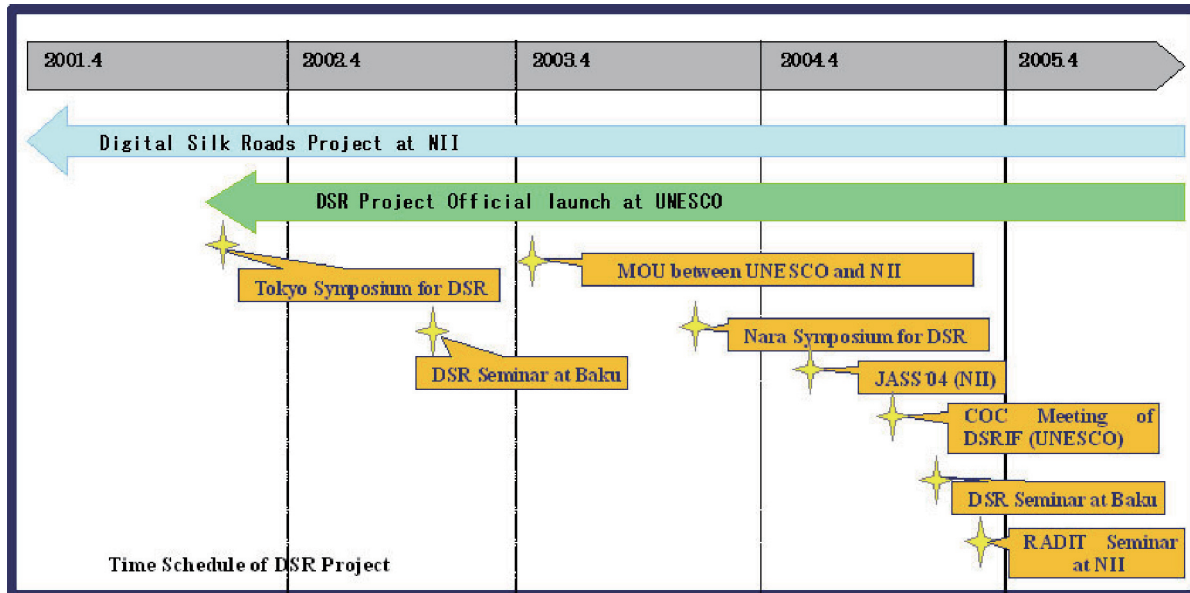


Fig. 2-3 Project History of DSR project

between NII and UNESCO. NII sent an expert to a training seminar related to Digital Silk Roads in Baku, Azerbaijan, in October 2002.

### 3) DSRIF

The Digital Silk Roads Initiative Framework (DSR-IF) was set up under the MOU as a coordination mechanism to carry out the DSR project. DSRIF is an international collaborative framework functioning in interdisciplinary domains of activities with a far-reaching mandate to promote effective digital storage, restoration, and exchanges of cultural heritage resources residing in the Silk Roads region.

The main objectives of the DSRIF are:

- To undertake strategic planning, resource mobilization and management of a DSRIF network to be set up in partnership with universities, cultural heritage centers, UNESCO and institutions created within the framework of the former UNESCO Silk Roads project, and training institutions and IT centers established and reinforced or associated by UNESCO and NII in Silk Roads countries and nearby regions.
- To conduct scientific studies of Digital Silk Roads cultural heritage and cultural diversity led by an international joint team under the co-ordination of UNESCO and NII, taking into account historical, geographical, religious, and multilingual dimensions including the former Silk Roads projects such as Caravanserais in Central Asia.
- To carry out activities in launching, implementing and managing a variety of projects in key areas of dig-

ital technology in the framework of the Digital Silk Roads project.

(d) To offer scholars, researchers, investigators, and other users of cultural and natural heritage resources currently available, and stimulate the sharing of these resources for academic and educational purposes.

(e) To establish centers or academies of excellence for cultural heritage restoration and archiving in the Silk Roads region.

Co-Executive Directors responsible for the DSRIF are Dr. Y. N. Kim (UNESCO) and Prof. Kinji Ono (NII).

### 2.7 Major Achievements of the DSR Project

Major achievements made so far can be summarized as follows:

#### 1) Tokyo Symposium for Digital Silk Roads

“Tokyo Symposium for Digital Silk Roads” was held between December 11th and 13th, 2001. A public audience of 330 attended open lectures and more than 100 scholars and experts on information technology and cultural sciences from Japan and abroad gathered to discuss how to preserve and restore Silk Road heritage as well as how to make it available worldwide as a significant resource. The discussion culminated in the adoption of the “Tokyo Declaration on the Digital Silk Roads”, which centered on the creation of a new approach linking cultural studies and information technology.

A proceedings incorporating not only the presented papers but also poster sessions and exhibitions was published after the Symposium. [1]

2) Nara Symposium for Digital Silk Roads

Two years after the Tokyo symposium, a Digital Silk Roads symposium was held in the city of Nara, which at on point was considered Japan’s gateway to foreign cultures.

A number of excellent invited presentations were made on the current status of research for Digital Silk Roads and the fusion of cultural studies and digital

technology. A session to formulate future UNESCO strategy for promoting the DSR project was organized.

The session was followed by an awards ceremony at which DSR prize were awarded to the top three presentations. In addition, a study tour to some UNESCO World Heritage sites in Nara was offered after the ceremony.

The average attendance of the open sessions was some 240, and that of the expert sessions was around 150. About 50 scholars and experts took part from overseas, including many from nations along the Silk Road .

This symposium demonstrated the significant progress that had taken place after the Tokyo Symposium, and explored the new themes such as GIS and the Maritime Silk Road. [2]

Figure 2-4 shows the posters for the symposia. Figure 2-5 shows the cover sheets of the proceedings. Figure 2-6 shows the scene from a session at the Nara Symposium.

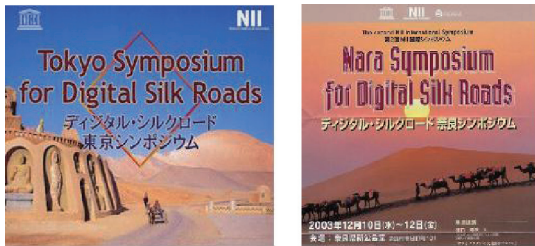


Fig. 2-4 Posters for the symposia



Fig. 2-5 Symposia proceedings



Fig. 2-6 A session at the Nara Symposium

3) Digital archiving of rare books of the Toyo Bunko

Digital archiving of various historical documents, including rare books in the possession of the Toyo Bunko, an internationally renowned Asian studies library, was carried out. The main contents of this archive forms the “Image and Manuscript Database”. Among the library’s reputed collections of historical importance, one of the most famous is the “Morrison Library,” which consists of 24,000 books about China and Asia written in various European languages. [11][14][20][21][22]

4) The prototype Bamiyan Virtual Museum

After the Afghanistan war, a number of programs to support the country’s recovery were launched.

The Digital Silk Roads project supported these programs.

Afghanistan’s Bamiyan Buddhist ruins have been reproduced virtually as they were before their destruction under Taliban rule, using Hitacji’s DIS(Digital Image System).[10] The prototype was created using the photos taken some 30 years ago in and around the Bamiyan ruins. The virtual museum was press released and opened to the media in April 2003. [19]

5) Reproducing the Bamiyan Buddhist Ruins on Video

The Bamiyan Buddhist ruins have been re-created on a high-definition digital video. One-hundred fifty photos, chosen out of a total of one thousand taken by Mr Takashi Echizen 25 years ago, were digitized with a high-definition scanner. To serve as the bases for the digital restoration, the video is unique in that, rather than employing traditional CG or virtual reality tech-

nologies, it was created based on digitized 35-mm photos with actual images of the ruins before their destruction.

6) ASPICO Portal

The “Advanced Scientific Portal for International Cooperation for Digital Silk Roads” (ASPICO-DSR) was developed by NII in cooperation with UNESCO.[15] This portal allows participants to create and store metadata through their personal workspaces. In addition, it provides a cooperation environment to discuss resources before releasing them into public arenas and to build multilingual textual contents. Thus, researchers can access high quality information without physical or social constraints. A new version of ASPICO which capable of performing ontology-based Metadata Management is currently under development.

7) The JSPS Asian Science Seminar (JASS’04)

The JSPS Asian Science Seminar (JASS’04) on Advanced Digital Technology-Assisted Cultural Archive and Preservation Along the Maritime Silk Roads was held in July 2004 at NII under the umbrella of DSRIF. The Seminar included 10 days of advanced training for young researchers in various fields in research methodologies related to the Maritime Silk Roads. The Seminar informed the participants of current practices on cultural resource management, including digital archiving, preservation and metadata management.

8) Southeast Asian Interactive Atlas 500-1500 A.D.

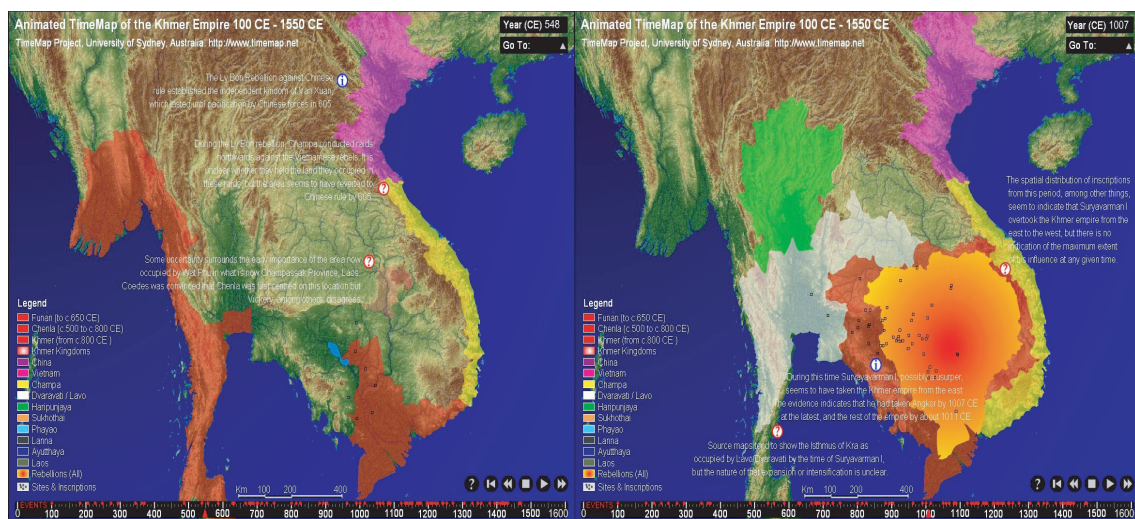
These study aims to develop a dynamic form of his-

torical inquiry: visualizing cultural and ecological information across time and space on a digital map interface. Data on the natural and cultural history of Southeast Asia, linked to location, suggests relationships among cultures, societies, and the natural environment.

The project started in 2002 as an External Joint Research Project at NII with members of ECAI Southeast of the University of California, Berkeley who sought to share their data with other scholars. Kyoto University’s Center for Southeast Asian Studies, in order to strengthen the joint information platform, has been digitizing its own holdings of maps, artifacts, photographs etc., and uploading maps and charts of Vietnam, Laos, and Cambodia. The Archaeological Computing Laboratory at the University of Sydney, which developed TimeMap, has constructed a database of the history of the ancient Khmer Empire that can generate an animation to spatially express the empire’s expansion and decline. Figure 2-7 shows the ancient Khmer Empire’s expansion and decline. The project will be linked to the work of Digital Silk Road, contributing to a larger understanding of the dynamics of trade and exchange not only in Southeast Asia, but also throughout the Eurasian continent.[21]

9) The National Cultural Heritage Online System

This project has been promoted by the Agency for Cultural Affairs, MEXT, to create a single Web portal tying together most major museums in Japan. The most advanced feature of the system is a prototype information system that provides easy and effective access to the digital repository on cultural heritage in Ja-



A.D. 548

A.D.1007

Fig. 2-7 The ancient Khmer Empire’s expansion and decline



Fig. 2-8 Home Page of NII Imaginary Museum



Photo



3D Model

Fig. 2-9 3D Model of the Entrance of Bam

pan.[18] The type of virtual museum envisioned for Digital Silk Roads, the “NII Image Museum” (Figure 2-8), is incorporated in this system.

10) Web Portal and 3D-VR restoration of the Citadel of Bam

In order to preserve the memories of the monument of Bam destroyed by an earthquake on December 26th 2004, a home page consisting of a collection of photographs and videos donated from various organizations and individuals was set up on the Web.

NII, in cooperation with ICHTO (Iranian Cultural Heritage and Tourism Organization), started a 3D reconstruction of the Citadel of Bam, inviting other organizations to collaborate and coordinating the project.

A 3D model of the entrance of the Citadel of Bam was created in cooperation with Dr. Kawai of Waseda University, GITI.

Figure 2-9 shows the photo before the earthquake and the 3D model of the entrance of the Citadel of Bam.

11) Multilingual and lexical terminology for caravanserais

Caravanserais are buildings which were constructed to shelter the men, goods and animals of caravans.

In order to establish an inventory of caravanserais, a multilingual terminology for caravanserais and a design for a lexical description model for historical architecture terminology are being investigated.

Research is currently focusing on proper ontological model for visualizing and presenting the special data of caravanserais.

2.8 Future perspectives

One main feature of the project is to provide a global platform for collaboration of the world’s scholars through a network based on the GMR concept. As a common platform to serve this purpose, a multimedia open-source software centering on ASPICO-DSR is available not only to specialists but also to the public.

The database, which interacts with existing systems, features an intelligent, user-friendly interface that focuses on multi-language processing and metadata.

Major technical goals are as follows:

- 1) to collect historical and cultural heritage resources
- Currently the most important task is to collect the historical and cultural materials in Silk Road countries, digitize them, and store them in a database so as to enable the researchers involved to input any available related data, filling in missing information and further improving the restored images in the database. The scheme doesn’t only aim at ordinary visual repro-



duction; it intends to realize 3D-VR restoration in the future, taking into account the spatial configuration within which artifacts are located.

2) to find a new automatic process for the creation of metadata, and annotation of such digital contents so as to improve access to, retrieval of, and interaction with multimedia cultural content[3][4][6]

For this purpose we are constructing ontology for cultural heritage domains, focusing on the caravanse-rais of the Silk Roads in collaboration with domain experts who have rich knowledge in the field. Ontology is very important for data exchange among DSR researchers, museums, digital libraries, and digital archives. We are currently developing a domain ontology covering concepts relevant to cultural heritage information.[12][13]

3) to ensure interoperability between distributed multimedia repositories

Existing multimedia information systems such as digital museums and digital libraries have mostly been built in isolation, using incompatible methods. In order to solve these problems, DSR puts emphasis on finding architectures that provide a common framework for multimedia objects combination and exploitation in distributed multimedia cultural heritage environments. Gateway function interconnection between different resources is also under development.

4) to develop suitable interfaces for the digital repository

The DSR seeks to address the question of how various devices can handle the presentation of multimedia information and be adapted to fit users' preferences, languages, capabilities, cultures and other characteristics. A multilingual interface in particular, is the key issue for inter-cultural collaborative studies.

5) to enhance the DSR portal to benefit users

The Web portal of DSR aims at facilitating international joint research by making important archive materials available online, along with other related information. The Virtual Laboratory for Digital Silk Roads will be organized using the DSR portal.

### 3 Toyo Bunko Rare Books Digital Archive

#### 3.1 Overview

In this part of the DSR Project, we have created a digital archive of some of the rare books on silk road studies held by the Toyo Bunko.

Toyo Bunko ("The Oriental Library") is a library and research institute specializing in Asian studies. It was founded by Hisaya Iwasaki (1865-1955), the third

president of the Mitsubishi Enterprise Group who, in 1917, purchased the whole private library of George Ernest Morrison, a rare collection of 24,000 books about China and other Asian countries in European languages. Morrison was a long-time resident of China and wrote for the London Times, and later served as political advisor to the Office of the President of the Republic of China. Iwasaki added other books, in European, Japanese and other Asian languages, to the collection and established the Toyo Bunko in 1924. Currently with 880,000 books, the majority of which in European languages and many in various Asiatic languages, it is one of the five leading Asian studies libraries in the world and the largest such one in Japan.

We based development of the digital archive on the following principles:

1) Meticulous and high-precision digitization of the whole of the material

In digitizing precious books, we have used a book cradle<sup>1</sup> to minimize the impact of opening the pages for photographing. Cover-to-cover photographs of the books were taken in high-resolution (over 4000x4000), high-fidelity cameras for long-term preservation and for further digital processing. With such precise images, most books can be seen in greater detail than just looking at the book with the naked eye and can be used as a material for detailed research, such as comparative studies of different versions of the text. Such images can also be used for migration to other platforms, should such became necessary with the passage of time, and shall be appropriate for future use as a higher grade media output.

2) Wide and rapid usage of the web pages

We have made the material freely accessible through the web, from anyone in the world, as quickly as possible. Some of the materials are very rare, possibly the only copy in the world, and although some others are classical textbooks, not everyone can access them for study, especially in places such as Silk Road regions. Web pages were initially made with minimal manual intervention by using IT methods such as OCR and automatic translation, although those processes are known to leave errors. The resultant web pages (900x900 color, and 2000x2000 gray) were made public as soon as possible, so that worldwide users can make use of them even while the data is being cleaned and further improved upon. Precious human resources such as Silk Road researchers were utilized for organizing thesaurus and for checking translation of important parts of data. Correcting OCR errors in the

<sup>1</sup> <http://www.humi.keio.ac.jp/docs/digital/html/bookcradle/bookcradlemain.html>

Table 3-1. Materials digitized in FY2002

Title	Author	Notes	Total Image
Die buddhistische Sp_tantike in Mittelasien Vol.1 : Die Plastik Vol.2 : Die manichaeischen Miniaturen Vol.3 : Die Wandmalereien Vol.4 : Atlas zu den Wandmalereien Vol.5 : Neue Bildwerke Vol.6 : Neue Bildwerke II Vol.7 : Neue Bildwerke III	Le Coq, Albert von	Featuring artifacts collected during four expeditions by Le Coq. Vol.1 : Sculptures Vol.2 : Manichaeian Miniatures Vol.3 : Mainly introducing murals Vol.4 : Mural designs Vol.5 : New pictures Vol.6 : New pictures II Vol.7 : New pictures III	681
Ein Tagebuch in Bildern	Mumm, Alfons, Freiherr von Schwarzenstein	A collection of photographs in China	277
Results of a scientific mission to India and high Asia Atlas Part I~IV	Schlagintweit-Sakünlinski, Hermann von	Reporting the results of their expedition. Those featuring sketches and drawings of Kharakhorum and Kunlun Mt. are extremely rare.	57
Views of China	Morrison, George Ernest (?)	A collections of photographs in China	53
Storia della Spedizione scientifica italiana nel Himàlaia Caracorùm e Turchestan cinese	Filippi, Filippo de	History of an Italian science expedition to the Himalayas, Kharakhorum and Chinese Turkistan.	595

body of text will be done as time and resources are available. It was hoped that users will cooperate by reporting errors etc.

### 3) Multilingual access,

As we expect the material to be used in many parts of the world, the web site page titles and messages are at least bilingual in English and Japanese. Also, the table of content and figure captions were extracted and translated (if they are not originally) into English and Japanese, and made into separate web pages. All the words in the original text were digitized by using a multilingual OCR software, and combined with the translated indexes, made searchable by GETA<sup>2</sup>. However, by using a multilingual thesaurus accumulated by MASS (Multilingual-term Accumulation Support System) in this project, which will be described in Section 3.3, important specialized terms such as place names, persons' names and names of cultural artifacts are searchable in several (up to eight) languages.

There are 35 books (about 9,000 pages) on our web-

site<sup>3</sup> now, as described in more detail in Section 3.2 In Section 3.3, the development of a multilingual thesaurus by using a software we have developed, MASS. In Section 3.4, the multilingual search capability in our web site realized by using the multilingual thesaurus will be described.

### 3.2 The contents and characteristics of the material

In this project, we have chosen materials in several European languages (French, Italian, German, Swedish and English) describing 19<sup>th</sup> Century and early 20<sup>th</sup> Century European expeditions, which are important for the study of the Silk Roads, and some ancient Chinese historical texts, that describe the Central Asian regions. All materials are without copyright restrictions and all pages, cover to cover, are available to be accessed as images. The following tables 3-1 to 3-3 list materials digitized and put on the web in this project between fiscal year 2002 and 2004.

Many of these materials are authored by well-known explorers from different European countries. They write them from different points of view on their own and others' expeditions and give various descriptions of Central Asia's societies, cultures and heritages. What is common to them are their desire to describe

<sup>2</sup> <http://geta.ex.nii.ac.jp/>

<sup>3</sup> <http://dsr.nii.ac.jp/toyobunko/>

Table 3-2. Materials digitized in FY2003

Title	Author	Notes	Total Image
Cathay and the way thither : being a collection of medieval notices of China Vol.1,2	Yule, Henry, Sir	His most important work for Silk Road study. Vol.1 : Text and maps Vol.2 : Text, map and index	990
Explorations in Turkestan : with an account of the basin of Eastern Persia and Sistan. Expedition of 1903	Pumpelly, Raphael	A report of the 1903 excavation of the Annau and Merv ruins.	362
Explorations in Turkestan, expedition of 1904 : prehistoric civilizations of Anau, origins, growth, and influence of environment Vol.2	Pumpelly, Raphael	A report of the 1904 expedition. Physiography of Central-Asian deserts and oases.	327
史記第百二十三卷大宛列傳第六十三	Si ma qian	No. 63, Vol. 123, "Account of Ferghana", Records of the Grand Historian of China	42
前漢書卷九十四下匈奴傳第六十四下	Ban-gu	No. 64 bottom, Volume 94 bottom, "Account of the Xiongnu", Historical Records of the Former Han Dynasty	66
前漢書卷九十五西南夷兩粵朝鮮傳第六十五	Ban-gu	No. 65 bottom, Volume 95, "Biography of Yunnan, Nanyue, Dongyue and Korea", Historical Records of the Former Han Dynasty	52
前漢書卷九十六上西域傳第六十六上	Ban-gu	No. 66 top, Volume 96 top, "Geographical Accounts of the Western Area", Historical Records of the Former Han Dynasty	44
前漢書卷九十六下西域傳第六十六下	Ban-gu	No. 66 bottom, Volume 96 bottom, "Geographical Accounts of the Western Area", Historical Records of the Former Han Dynasty	52
Ot Kiakhty na istoki Zheltoi Rieki	Przheval'skii, Nikolai Mikhailovich	"From Kyakhta to the source of the Yellow River"	594
Mongoliia i Kam : trudy ekspeditsii Imperatorskago Russkago geograficheskago Obshchestva, sovershennoi v 1899-1901.gg Vol.1~5	Kozlov, Petr Kuzimich	"Mongolia and Kham, Achievements of the Geographical Association Expeditions in Imperial Russia v1899-1901.gg" Vol.1~3 : Text, photos and maps Vol.4 : Maps Vol.5 : Text, colored pictures and map	1435

and publish what they found and saw in great detail, for scholarship's sake. Many things that they described have since lost, due to war (both in Asia and in Europe,) vandalism, greed or just by the force of nature, and for some, these pages may be their only record left. The contents of this digital archive, therefore, is a

valuable source of information for the study of not only archaeology or history, but also folklore, art history, geography, religion, politics, linguistics and other fields.

Table 3-3. Materials digitized in FY2004

Title	Author	Notes	Total Image
Ancient Khotan : detailed report of archaeological explorations in Chinese Turkistan Vol.1,2	Stein, Mark Aurel	The academic report of his first exploration in Central Asia. Vol.1 : Text, illustrations and appendices Vol.2 : Plates of photographs, plans, antiques and Mss., with a map of the territory of Khotan from original surveys	826
Serindia : detailed report of explorations in Central Asia and western most China Vol.1~5	Stein, Mark Aurel	The academic report of his second exploration in Central Asia. Vol.1~3 : Text Vol.4 : Plates Vol.5 : Maps	2145
Den vandrande sjön	Hedin, Sven Anders	“The Wandering Lake” A report of his last exploration in Central Asia.	464

### 3.3 Multilingual-term Accumulation Support System (MASS) and the multilingual thesaurus

During the project, necessity of a tool for collecting specialized technical terms, such as names of people and places, religious terms and terms in archeology and art history, was felt. It needed to be accessible over the internet from all over the world (some of our collaborators are in China and Austria,) and it had to be usable as a tool for cooperation and standardization among translators, proofreaders and those who develop summary and index web pages. The user had to be able to search and update the data base independently, and the result of the update should be reflected immediately. It needed to have a simple enough user interface usable for computer novices, and most important, it had to be usable in any language within the Unicode. As there are many variant spellings of the same term, especially in the current field in which terms for several European languages are transliterated Asian words, a fuzzy (non-exact) matching which can find those variations is essential.

We looked for it but found none, at least as an open-source software, so developed it. The software, MASS (Multilingual-term Accumulation Support System) consists of a server, which uses a relational database system (in our case MySQL) to provide a web service, and client package, whose user interface looks like Microsoft Excel(the user needs to have it installed) but actually is not Excel but a front end for the database.

The user interface is shown in Fig. 3-1 to Fig. 3-3. As the program starts, it is in the search mode (Fig. 3-1). The user enters a term (word or phrase) and

searches if there is a close match (the same spelling except for upper/lower case difference and presence/absence of diacritical marks.)

In Fig.3-2, the system reports no close match, so the user chooses “Expand Search” from the mouse right-click menu.

Fig. 3-3 shows the result of the expanded search.

The first record shows the intended match, “Kizil” or “Qyzil” instead of “Kizyl” but is sufficiently close. In the third record, “Jizya,” the substring “izy” matched, with edit distance 2.

In the second record, the Soundex algorithm detected similarity between “Kizyl” and “gao ju li”, judging perhaps that K and g are sufficiently close, vowels i and ao are can be safely ignored, and consonants z and j could be the same sound.

At this stage, if “Kizyl” were a genuine word found in the text, the user could add it to the database. (Actually it is a fictitious entry used for the explanation.)

Another feature of MASS is automatic romanization (transliteration into lower-case alphabet) by using a Perl library program. For latin alphabet expressions, it takes away diacritical marks (accent symbols) and converts upper-case characters to lower-case. In Chinese, it generates pinyin. In non-latin alphabets such as Hangul, Kiril and Thai characters, it transliterates using one of several standard methods. The procedure is not error-free, but in most cases it is reasonably correct. For Japanese Kanji, it still tries to generate pinyin, so it is turned off in MASS. Actually, in MASS the feature can be turned on or off for each language.

The system uses two fuzzy-match algorithms, edit

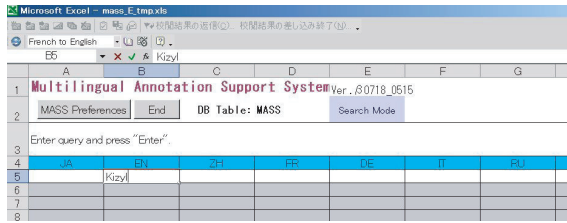


Fig. 3-1 Start of the MASS client

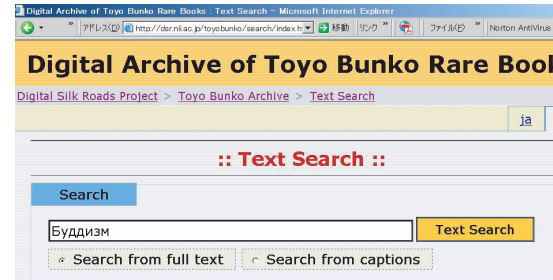


Fig. 3-4 Searching in Russian for

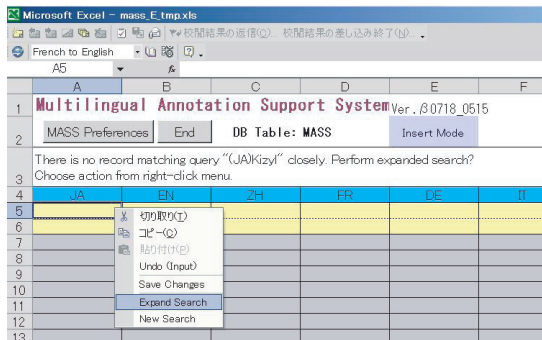


Fig. 3.2 Choosing "Expand Search"

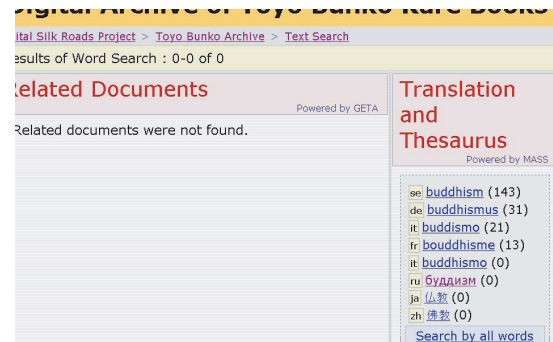


Fig. 3-5 Multilingual search result

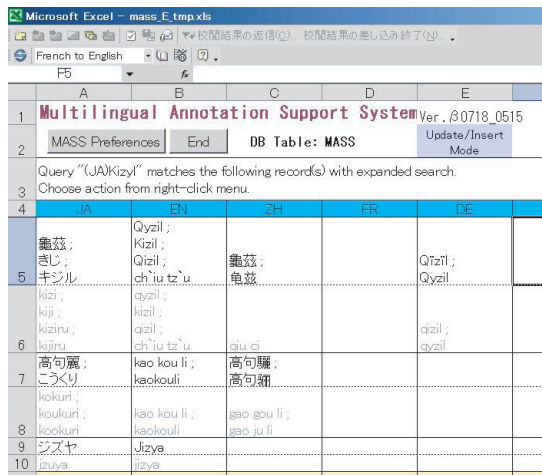


Fig. 3-3 Result of the fuzzy matching

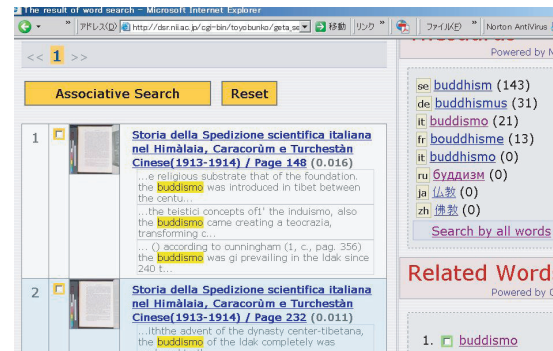


Fig. 3-6 Result in Italian

distance and soundex, for finding technical terms with similar but variant spellings. There are several parameters which can be set to optimize the search. They are, the maximum edit distance, the percentage of the edit distance within the length of the shorter term to be compared, and whether the soundex is added to widen the search or not. Different values of those parameters can be set for different language.

MASS has helped in standardizing translations and terminology within the project. It was also used for international workshop related to DSR, and was highly popular among the Asian participants. At the present

time it is only on an internal server (separate from the main Web server), but the system will be made available as an open-source software in the near future.

### 3.4 Multilingual text search by using the multilingual thesaurus

MASS can be used in several ways, including organizing data for hierarchical thesaurus. However, we will describe usage of its product for multilingual text search in the main web site.

Say, for example, a user in Russia wanted to search the database for “Buddhism.” As shown in Fig. 3-4,

The user can use Russian in Kiril characters for the text search.

The word does not appear in the current database, but as shown in Fig. 3-5, there are 143 hits in English (buddhism), 31 in German (buddhismus), 21 in Italian (buddismo) and 13 in French (bouddhisme).

Fig. 3-6 shows the result of choosing the Italian hits. This demonstrates that, as long as the relevant words are in MASS, the full-text search can be done using any of the languages in the database, with results obtainable in the same or any other language contained therein .

The authors thank the team members who programmed the MASS system, loaded it with multilingual contents, and helped correct mistakes there.

## 4 Prototype of the Bamiyan Virtual Museum

### 4.1 The outline of the Bamiyan Virtual Museum

The Silk Roads prospered as a trade route between East and West for many years, and much of the cultural and natural heritage from that period has survived. Unfortunately, however, much of that heritage has continued to suffer from natural degradation as well as destruction by human agency, and the situation has now reached near-crisis proportions. Faced with this situation, an international collaborative project known as “Digital Silk Roads” has been developed for the purposes of digitally preserving world heritage, to promoting cross-cultural and cross-disciplinary exchanges and to creating new intellectual assets utilizing the preserved data.

As a part of this project, we urgently need a system to archive cultural heritage, including fading remains and traditional performing arts, in a digital format. These data will be utilized for research, with the research results utilized for a wide variety of purposes within society.

As the project’s first step, NII and Hitachi have jointly been developing a prototype virtual museum of the archeological remains of the Bamiyan Valley in

Afghanistan (hereinafter referred to as the “Bamiyan Virtual Museum”), a World Heritage site, which requires urgent conservation measures of conservation after having suffered further a great deal of damages recently, both at the hands of the Taliban and in the Afghan war.

The Bamiyan remains lie in a valley in the Hindu Kush Mountains , 2,500 meters above sea level. There are about 750 caves in the cliffs within the valley, cliffs which rise to a height of 150 meters above the floor of the valley and have a total width of 1,300 meters. The remains in these caves are extremely important archeological resources for understanding , what society was like , during the era in which Bamiyan prospered.

Strategically situated in a location central for travelers from all directions and in the middle of the famous Silk Roads, this religious center was a common meeting place for different cultures and ideologies since the ancient times, leading the inhabitants to have a unique worldview.

Today, the remains are in a very fragile state as a result of abandonment, military action and dynamite explosions. With this mind, we have employed our DIS technology to record the remains in order to decipher their significance.

The first step was to collect existing images of the site. Prof. Higuchi had taken photographs of Bamiyan before the former Soviet Army launched their attack against Afghanistan in 1979. These photos were digitized and stored in a database for effective use in academic and artistic researches.

We also undertook virtual reconstruction of the remains establishing a digital archive system, that efficiently searches, and exhibits the desired information.

This system runs on two proprietary engines, developed by Hitachi, one is a user-friendly, high-speed display engine that instantly shows desired images, and the other is a script language engine that flexibly copes with further expansions, and/or changes in func-



Fig. 4-1 Bamiyan Valley in Afghanistan



Fig. 4-2 Bamiyan Virtual Museum



Fig. 4-3 Exhibition at the Nara Symposium for Digital Silk Roads

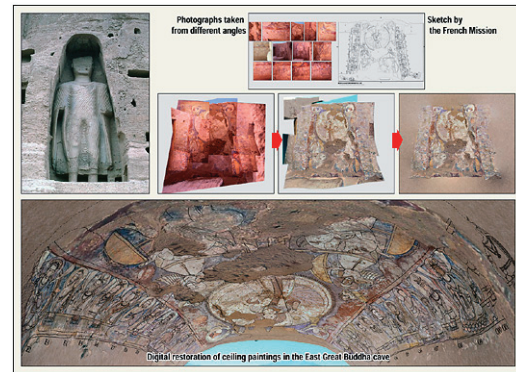


Fig. 4-4 Digital restoration

tion.

The engines are controlled by a touch panel, and show the selected images on a 50-inch high-definition plasma display.

Data retrieval starts with a panoramic view of the remains. Images resulting from a specific search can be magnified or compared with other images, without sacrificing speed.

One of the advantages of the system is its ease of operation, even for those unfamiliar with computers, and high-speed access to the searched data. You can navigate easily through the details of the Bamiyan remains simply by touching the maps and images displayed on the panel. The search results also include lists of research materials, such as mural paintings, interior structures, etc. categorized by cave. These images

may be further selected for a closer look on a large high-definition display.

Moreover, a range of display formats is available; any part of an image, can be magnified or compared or combined with others. Explanatory captions can be added.

The Bamiyan remains hold numerous important mural paintings; one on the ceiling of the East Great Buddha cave, in particular shows the integration of Buddhism with Indian, Persian, and Greek myth. We are working on a digital restoration of this mural using a proprietary process. The process started with photographs of the painting taken at several angles along with existing sketches done by the French Mission in the 1920s. DIS filters corrected for the difference in camera angles and color tones among the photos, as

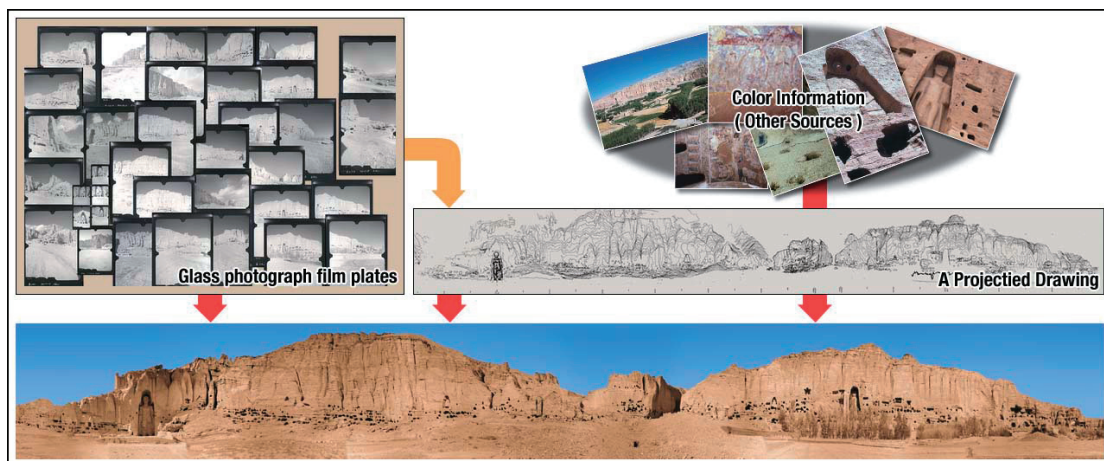


Fig. 4-5 The Complete View of the Bamiyan Remains

well as correcting for distortions caused by the curve of the domed ceiling in order to fit the contour lines of the base sketch.

Missing sections were filled in using existing photographs and the related information from available sources .

The restored image has cleaned up the picture as a whole and refined details of the painting that were difficult to grasp from the individual photographs; the central figure is now believed to be the Indian sun god Surya or the Iranian god of light Mithra on a coach-in-four .

Other figures seem to represent wind gods, winged guardian deities, kinnaras (creatures from Thai mythology) and two hamsa (geese). We aim to further collect and add more information in order to improve the quality of the restoration.

One of our immediate goals is to apply the digitally restored ceiling painting to a life-size reproduction on a ceramic board, and to realize a 3D reproduction that includes the ambience surrounding the cave. The ceramic-board recreation of the revived painting will last almost indefinitely, allowing us to exhibit it, for example at Kabul Museum and other locations, as a model of the remains.

The full-color panoramic view is another artifact of DIS, created from 30 black and white pictures that were originally taken for a geodesic survey, with color information extracted from other color photographs.

#### 4.2 DIS Technology

- The basis of the Bamiyan Virtual Museum -

DIS technology, developed over 10 years by a Hitachi research team, is used in the Bamiyan Virtual Museum.

DIS broadens the scope of imaging technology, creating images of a fineness unimaginable with conventional techniques. It represents a significant new ap-

proach towards the documentation, preservation and exhibition of valuable treasures owned by museums and libraries.

Our main focus in developing the DIS was to preserve the esthetic quality as well as the historical significance of cultural heritages materials, and to make them accessible to everyone around the world at any time. Figure 4-6 shows the configuration of the system in which all processes are conducted in digital format in order to maximize the value of information collected from the image sources.

The DIS process consists of four major steps: 1) digitization of image sources; 2) processing the artwork "as is" or enhancing it to allow researchers to test hypotheses while keeping the originals intact; 3) creation of a systematized database, including information regarding scientific analyses and the expertise of traditional artists, for effective application at later stages; and 4) output of the integrated information to an appropriate form or system. Prints are of such high quality that they will survive the test of time for the conceivable future.

DIS does more than merely create a digital reproduction of cultural properties. It conducts all the steps involved in digitization, image processing, database creation, and output in digital form; we utilize various types of scanners to first digitize the target objects. The most notable features of DIS technology are a set of software tools called DIS Filters, and technologies for their application such as the DIS Image Engine and DIS Printing.

One of the most distinctive proprietary software tools developed by Hitachi is a set of DIS Filters, which are used to manipulate the image in forms and colors of images.

DIS Filters, our revolutionary computation programs, allow us to process image files while keeping

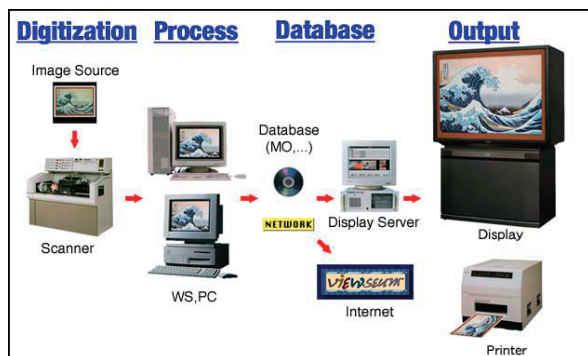


Fig. 4-6 DIS System Configuration

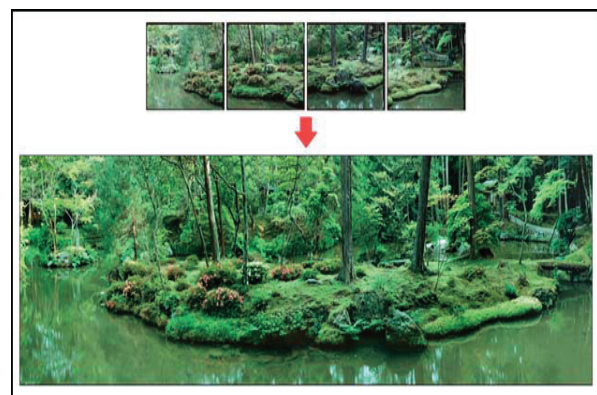


Fig. 4-7 Example of DIS Filters



the quality of the images fully intact. They can extract valuable information from color, infrared, and x-ray images, and merge them together so that they can be analyzed in scientific researches. Filters are of the following types:

De-Aging Filter - restores the colors of original works that have suffered discoloration and shade change over time.

Repairing Filter - counteracts damage such as stains, creases and scratches present in the original.



Fig. 4-8 DIS Applications

Deformation and Switching Filter - modifies the images into correct desired forms; e.g. corrects any distortion of images caused by the lens at the time of shooting; and joins multiple images taken from different angles into a single seamless picture.

Color Morphing Filter - changes the color tones to suit the intended purpose; suitable for machine adjustment of color tones among multiple images.

Re-Sizing Filter - displays magnified images in high quality.

Figure 4-7 shows an example of the capabilities of the Filters. The original materials are photographs of Moss Garden at Saiho-ji Temple in Kyoto taken from 4 angles, which unavoidably vary in color tones, and have distortions caused by the lens. Such deviations among the images were corrected and the images were synthesized into one photograph. The DIS is capable of creating a truly realistic image, which is not possible to view in the real world due to limits imposed by the angle of the human eye and the obstruction created by trees at the desired showing site.

The DIS Image Engine maximizes the quality of image and text data without sacrificing speed. This engine provides digital archive systems with a high-speed search function, visual programs, and presentation systems with high-quality images and synchronized narrations in order to enhance user-friendliness. They can all be shown on a variety of display sizes, from laptop PC screens to display panels of over 200 inches.

DIS Printing technology is capable of faithfully reconstructing the original masterpieces due to

a comprehensive examination of paint materials conducted with the aid and knowledge of experts in various fields.

This has enabled us to thoroughly reproduce the characteristics of the colors, lines, and textures of the originals, leading to an end product that is a significant improvement over conventional photographs, printings, and lithographs.

While making endeavors to enhance the DIS technology itself, we have achieved a wide variety of innovative projects, some of which are summarized in Figure 4- 8 below.

#### 4.3 Composition of the Bamiyan Virtual Museum

##### - User-Friendly Interface -

Based on the research materials at Kyoto University, accumulated information was arranged and classified, associated with spatial and geographic reference point, and stored in different levels of the database.

For example, data on the West Great Buddha, Af-

ghanistan, Bamiyan remains and the stone caves around the West Great Buddha, are all linked to each other. Data on other stone caves are stored together as a separate group.

In the museum, you can use these classification to quickly and easily, track down and select high-definition digital images .

The following is a basic description of the hardware for this museum system.

A computer is set up in the center with a touch panel that allows you to specify the section of the remains you wish to view, and a high definition display (for a clear view of the caves).

In the computer, DIS Soft Engine is loaded.

The engine carries out directions input from the touch panel, searching for pictures and displays them.

A touch panel is adopted to enable those who are not very familiar with the computer to search and retrieve information intuitively. The presence of several touchable areas on the panel improves the work efficiency. Area A shows the selected part on the map, from an overall view of the remains and, simultaneously, area E displays the Thumbnail List of research materials relevant to the selected part. If you select an image from the Thumbnail List, area A shows the magnified image with a supplementary map in area D and related information in area F. The supplementary map and Information are not displayed during the first step, the choosing of a position on the overall map, and so during that step, area A extends to cover over areas, D, E and F, to providing a larger view of the map. Area B shows the track of the retrieval track and you can return to any of the tracks you retrieved previously. Area C shows the Command buttons used to control the system itself, such as "shut down". The Command buttons change according to the contents of the other areas.

The following is an example of operation of the system.

Archived data can be selected by touching the panel, starting from the overall view of the remains as the Top Page, and gradually, focusing on a specific cave to reach the mural paintings related to that cave.

First, the upper part of the touch panel shows a full view of the caves. When you touch the part you want to examine more closely, it will be high-lighted and a magnified image of the area will be shown in the lower part of the screen.

For example, if the East Great Buddha is selected from the overall view of the remains on the upper part of the touch panel, the lower part, will display a magnified image of the East Great Buddha and its surroundings.

If you touch the East Great Buddha part within the



Fig. 4-9 Digital archive of research materials



Fig. 4-10 The basic component

<b>B</b> Retrieval tracks	<b>C</b> Command
<b>A</b> Positioning on map or Selected image	<b>D</b> Supplementary map
	<b>E</b> Thumbnail List
<b>F</b> Information	

Fig. 4-11 Allocation of touchable area

section displayed, the image will be further magnified. If you touch the East Great Buddha within the image once more, you can see the list of mural paintings, etc. relevant to the East Great Buddha cave. If you touch one of the mural paintings on the list, the selected image will be shown on both the touch panel and the large high-definition display. In the same way, other images can be selected and shown on the screen.

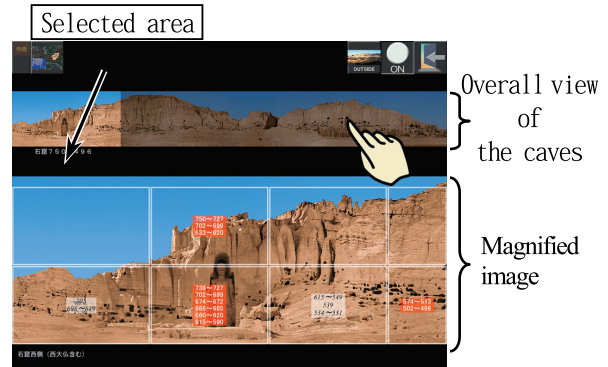


Figure 4-12 Overall view of the caves & Magnified

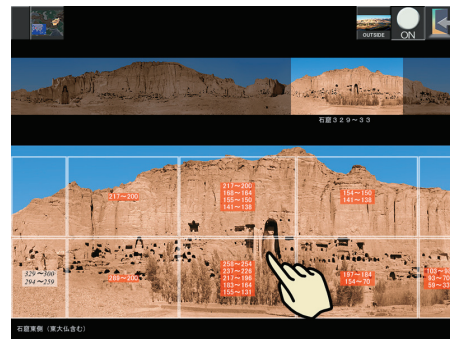


Fig. 4-13 Select the East Great Buddha

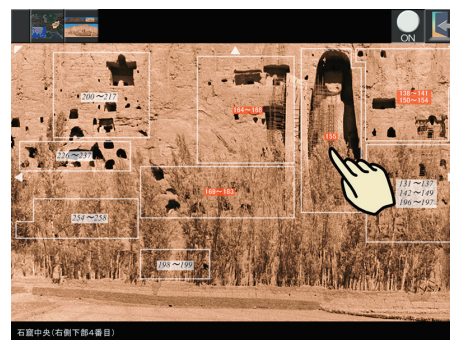


Fig. 4-14 Selecting the East Great Buddha

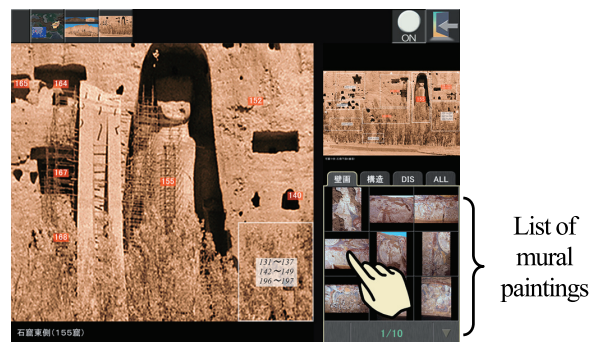


Fig. 4-15 Displaying the list of the mural paintings

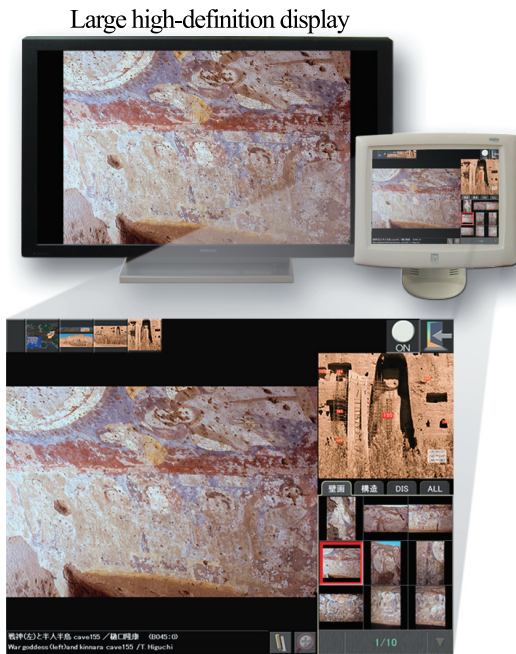


Fig. 4-16 Displaying the selected image

If you touch a part of the selected image, the display will magnify that part. You can also “drag” the image by dragging the magnified image. In such case, Area E shows the magnified image, with the dragging point highlighted in red.

The retrieval tracks listed in the top left section allows you to return to previous information you have retrieved, and to start a new search from there if you wish.

#### 4.4 Expansion of the system to cover other Silk Roads regions

We plan to extend the Bamiyan Virtual Museum to cover the entire remains of Bamiyan artifacts scattered throughout Silk Road countries, and to make it available to more people via expanded network access, enabling researchers worldwide to exchange information through, and add information to the system. The archiving and sharing of such research results will help advance study of the Silk Roads regions.

### 5 The Design of the DSR Portal

#### 5.1 Overview

The portal site of the DSR (Digital Silk Roads) project (<http://dsr.nii.ac.jp/>) serves a repository of digital resources, the main contents of which are digital archives of rare books and endangered cultural heritage materials [16,21]. The purposes of the portal are to distribute research findings and to motivate informa-



Fig. 4-17 Magnification of the selected image

tion exchange among researchers and non-experts alike, with its end goal being the creation of a comprehensive resource on the Silk Roads that is accessible from anywhere in the world via the Internet. To realize this goal, we have developed the portal based on standard technologies that do not require proprietary tools for development or viewing, and made it available to the public free of charge. This section introduces the contents of the DSR portal, how we are building the system, and the direction of future system development.

#### 5.2 The Contents of the DSR Portal

##### 5.2.1 General Information

General information (Figure 5-1) introduces project information, an overview of the DSR project, and summaries of the DSR symposiums held in Tokyo in 2001 and Nara in 2003. This page is also a portal to other contents such as:

- Digital Archive of Toyo Bunko Rare Books (Section 5.2.2)
- The Citadel of Bam, Iran: Keeping Memories and Gathering Information for Post-earthquake Reconstruction (Section 5.2.3)
- Bamiyan Virtual Museum (Section 4)
- Advanced Scientific Portal for International Cooperation on Digital Silk Roads (Chapter 6)

##### 5.2.2. Digital Archive of Toyo Bunko Rare Books

“Digital Archive of Toyo Bunko Rare Books” (Toyo Bunko Web) (<http://dsr.nii.ac.jp/toyobunko/>) is a portal site of rare books about the Silk Roads (Figure 5-2). This is a collaborative project with Toyo Bunko (Oriental Library), the detail of which was addressed in Section 3. The design philosophy of Toyo Bunko Web is to improve accessibility to both the textual and image contents of their books through digitization and information extraction from books for navigation and in-



Fig. 5-1 Digital Silk Roads Web site.

dexing. Technical detail will be explained in Section 5.4.

### 5.2.3. The Citadel of Bam, Iran: Keeping Memories and Gathering Information for Post-earthquake Reconstruction

“The Citadel of Bam, Iran: Keeping Memories and Gathering Information for Post-earthquake Reconstruction” (Bam Web) (<http://dsr.nii.ac.jp/bam/>) is a portal started as a quick response to aid the destruction of cultural heritages of Bam (Figure 5-3). More than 70 percent of the historical district of Bam was destroyed by an earthquake on the morning of Friday 26, December 2003, and this Web site was opened to the public on December 31, 2003, just a few days after the earthquake. The purpose of the Web site can be summarized as follows.

- To keep the memory of the great monument and city of Bam.
- To gather data from around the world related to Bam and its remains.
- To provide a forum for collecting digitized data from all over the world.
- To allow people from all over the world to share visual and/or textual data of Bam and the Great Citadel.
- To provide a foundation for the documentation and further reconstruction and restoration of Bam.

This Web site consists of a collection of photographs

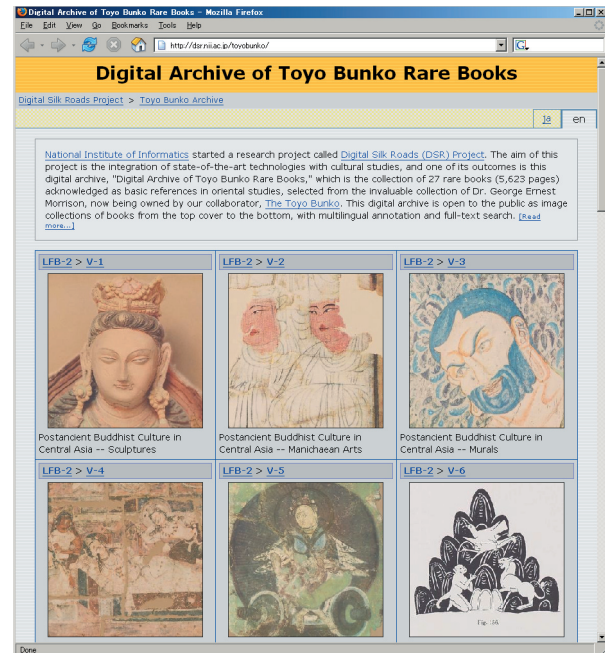


Fig. 5-2 Toyo Bunko Rare Books Web site.

and videos, contributed by various people who agreed to share their data on this Web site with other people around the world. Our appeal for the contribution of data attracted a number of contributors from locations all around the globe, ranging from Iran, Japan, and Germany, to the Czech Republic. As of January 2005, we have received more than 100 pictures and 1 video from about 10 contributors around the world, who generously submitted their photographs and videos to aid in the reconstruction of Bam. The collected data, along with other related data of Bam recorded before its destruction, will be used in the future for the reconstruction of Bam, both physically and virtually. Results of reconstruction will also be presented on this Web site to show the progress of reconstruction effort.

### 5.2.4 Advanced Scientific Portal for International Cooperation on Digital Silk Roads

“Advanced Scientific Portal for International Cooperation on Digital Silk Roads” (ASPICO-DSR) is the portal site of the Digital Silk Roads Initiative Framework (DSRIF), which is the international research collaboration between National Institute of Informatics (NII) and UNESCO explained in Section 1.2. This Web site is designed to be a common access point for international researchers and experts to share information and their knowledge about cultural heritages across a variety of disciplines.

The ASPICO-DSR portal addresses two separate

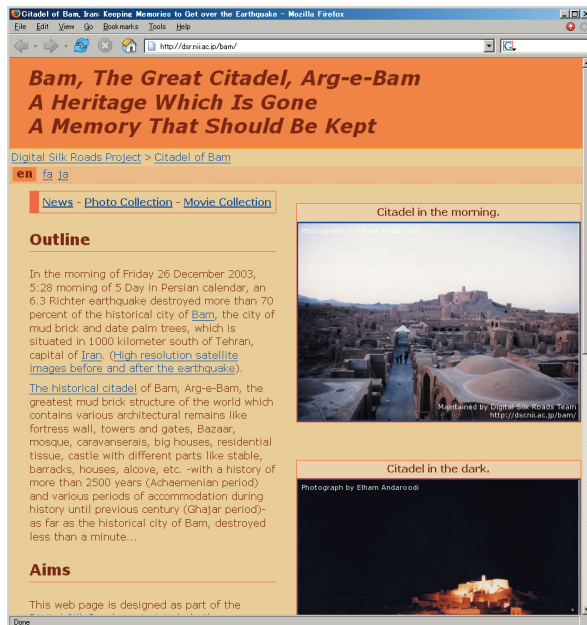


Fig. 5-3 Citadel of Bam Web site.

ways to view its cultural contents (Figure 5-4). First, the Member Area provides researchers and experts with a work environment, named Work Space, in order to allow them to create contents and offer their expertise by writing interpretations and comments. On the other hand, the Public Area lets anyone world-wide accessing available cultural contents from member works, through a category-based search engine that uses comments to index resources.

### 5.3 Content Management System

#### 5.3.1 Design Policy of DSR-CMS

All the contents, except for ASPICO-DSR, are maintained by a full-fledged content management system (CMS) developed by us for the DSR portal (hereafter called DSR-CMS). DSR-CMS was designed to reduce the overhead of content management while giving a uniform appearance to DSR contents. The DSR-CMS design policy has three main components - static generation, multilingual access, and awareness of information design.

##### 1) Static generation

Static Web pages are generated in advance to avoid the dynamic generation of Web pages on request. This policy has two advantages. The first is the reduction of load on the web server, while the second is an organization that is friendly for search engine robots. The latter refers to the fact that static Web pages without troublesome URLs are preferred by search engine robots, hence those pages are more likely to be indexed

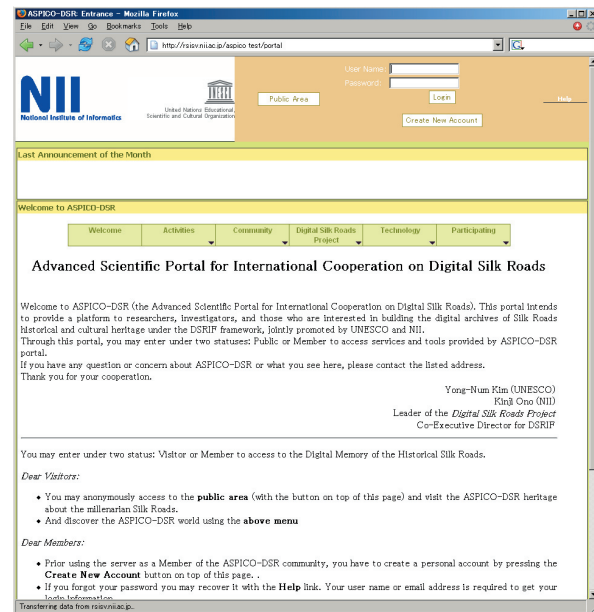


Fig. 5-4 ASPICO-DSR Web site.

and searched on major search engines, such as Google.

##### 2) Multilingual access

All Web pages can be accessed at least in two languages, namely Japanese and English. Bam Web even provides contents in three languages, Japanese, English and Farsi (Iranian). The most reliable method for switching languages is through content negotiation, which is a function of HTTP (HyperText Transfer Protocol), by switching the language preference on the user agent (Web browser). Another convenient way to switch languages is to use the language links shown at the top of the page.

##### 3) Awareness of information design

Usability is directly linked with the information design of Web pages. Many users nowadays have considerable experience using other Web sites, so following typical design rules can minimize users' overhead for learning how to use the DSR portal. We generally follow the best practices of information design which users are anticipated to be familiar with. One example of this is the breadcrumbs list, or topic path, we use to express the user's current location within the Web site.

#### 5.3.2 Languages

The DSR-CMS uses the following five languages for content management.

- XML (eXtensible Markup Language) for content description.
- XSLT (XSL Transformation) for content transformation.

- Perl programming language for content processing.
- HTML (HyperText Markup Language) for content delivery.
- CSS (Cascading Style Sheets) for content rendering.

All contents are currently edited using standard text editors, as an integrated environment for content editing has not yet been developed. All the software, including the server software, is based on open source software, so extension of DSR-CMS can be done without restrictions.

### 5.3.3 Content Description

First, we identify the basic elements of information design. At present we still do not have a ready-made convenient standard for representing the information elements necessary for DSR-CMS, or for document structure generally, so we employ a bottom-up approach - identify important information elements through experience. An example of an information element is a page title, a section and its title, a paragraph, a list, and so on.

Second, we define an appropriate XML tag for information elements. For example, we use `<section>` for sections, `<list>` and `<item>` for lists and items, respectively. Sometimes we need to make decision as to whether to use a tag or an attribute for an information element, or how to define a hierarchy of information elements. At some point during development, we would like to identify the essential information elements and organize a more systematic definition of information elements using DTD (Document Type Definition) or XML Schema.

### 5.3.4 Content Transformation

The purpose of content transformation is to transform XML documents, which are best suited for content description, into HTML documents, which are ideal for content delivery.

Unfortunately, HTML has only a fixed set of tags, which specify the basic logical design of the Web page. We have hence decided to embed context-dependent information into the class attribute of each tag. For example, we transform the XML tag `<section>` into the HTML tag `<h2 class="section">` to specify that it is not only a level-2 header, but also specified as a section in the original XML document.

### 5.3.5 Content Rendering

Content rendering uses information in CSS format. We define CSS properties for HTML tags with class information to change the appearance of tags in a context-dependent manner. For example, we define both the CSS for the h2 tag, and the h2 tag having the attribute "class" as "section." In this way, we can differen-

tiate the visual design of identical tags in an HTML document in accordance with the original intention represented in the XML document. Moreover, CSS is used extensively within the DSR portal to apply a uniform appearance to the whole site.

## 5.4 Navigational Aids

### 5.4.1 Problems of Conventional Navigational Aids

This section deals with the design of basic navigational aids for the DSR portal. Here we take Toyo Bunko Web as a case study, but the same design philosophy applies to other contents of the DSR portal.

Navigational aids are so important because they are the key point determining the usability of the system. To help users reach information that meets their needs, we need navigational aids appropriately designed for the digital archive. Cultural digital archives with poorly designed navigational aids are unfortunately common.

A typical example of a problematic navigational aid is one where users are requested to input appropriate keywords into multiple text input boxes associated with metadata, such as creator, title, and subject. Users can also select some choices from pull-down menus, on which are usually lists of highly technical terms. Then users can find information that exactly satisfies their needs, as long as they carefully specify all criteria. This method, however, expects users to input the right words into the right text box to match both their information needs and the system's vocabulary.

This interface has several drawbacks, two of which are summarized as follows:

- 1) If the user is unfamiliar with appropriate keywords for the particular digital archive, the user sees only "not-found" messages and is unable to interact with the system. This drawback is especially apparent for non-experts or for first-time users of a Web site.
- 2) Users tend to search by a single criterion, not by multiple criteria. Hence the interface for setting multiple criteria is usually meaningless, since most users are interested in only a single criterion. As Google-style full-text search engines became popular, users are accustomed to work with a single text input box that accepts any kind of keywords, irrespective of the classification of metadata, such as the creator, title and subject.

### 5.4.2 Link-Centered Design

To solve the problems inherent in the text-input-box interface, we propose that Web pages provide enough information for users to choose the desired direction when navigating through the Web site. This leads to the idea of a link-centered design built around the idea that, as far as possible, it is better to provide a variety

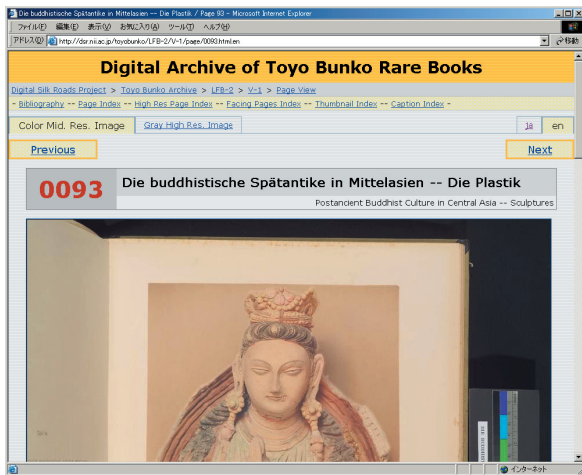


Figure 5-5 Navigational links on a Toyo Bunko Web

of links, with each link representing a distinct navigational path through the Web site. Here a set of links shows a list of system's vocabulary, and each link serves as narrowing down the database by a single criterion.

Let's look at a page of the site, as shown in Figure 5-5. At the top part of the page, links for navigation within books, such as "Previous" and "Next," and other links leading to the index pages, are listed. At the top we put a breadcrumbs list to show the current location within the Web site, as well as a few links to index pages of the contents that will be introduced in the next subsection. Below the breadcrumbs list and index links we put other navigational links for switching the format of images and for switching languages. Then we placed page links allowing the user to move to either the previous or the next page, and put additional page links at the bottom part of the page (not shown in Figure 5-5) for jumping directly to distant pages. Other links are also provided to further assist navigation through the Web site.

In the near future, we plan to give more advanced links semi-automatically to technical terms in the text that jump directly to entries of related terms and documents. With the help of dictionaries and ontologies that will be explained in Section 5.5, we can improve upon how users navigate through information within the portal. Such navigational aid can be easily implemented on the DSR portal via the modification of DSR-CMS. As we add more contents, we will need to implement more navigational aids within DSR-CMS,

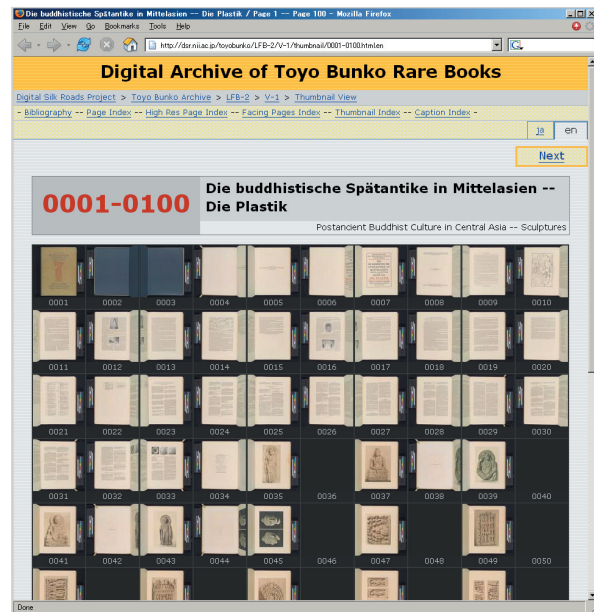


Figure 5-6 Index page for thumbnail

and the link-centered design based on the CMS may be the biggest difference between ours and other digital archives.

#### 5.4.3 Index Pages

The presence of many links to jump to various pages facilitates users' navigation through the pages of a book. But, as users sometimes get lost in the web of hyperlinks, we need to introduce other navigational aids capable of showing the overall structure of the Web site at a glance. Index pages are designed for that purpose.

Figure 5-6 shows an index page that summarizes 100 pages in one table by using thumbnail images of each page. This index page is useful for searching pages with photographs, illustrations and drawings, because those pages can be easily identified via visual browsing of thumbnail images. Other types of index pages include those with book pages, book facing pages, high resolution images, and book captions. In the near future we also plan to have a table of contents that shows the logical structure of books, such as chapters and sections.

#### 5.4.4 Full-text Search

A full-text search, which is a typical navigational aid for conventional cultural digital archives, is also provided on the DSR portal, as the only text input box interface left on the system. The search engine we use is called GETA.<sup>1</sup> It was developed by National Institute of Informatics and other organizations with support



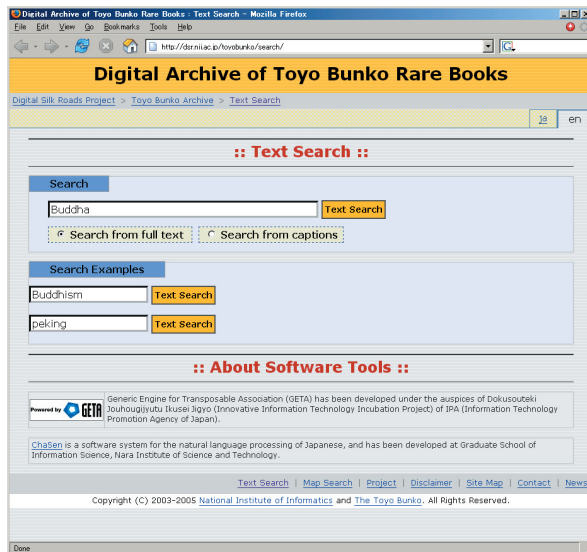


Fig. 5-7 Full-text search interface.

from IPA (information technology promotion agency).

Figure 5-7 shows the interface for the keyword search. This interface supports exact-match-based full-text search only. A user first chooses the search target; either full-text or captions only. The latter is especially useful for searching images, illustrations and tables with keywords. Figure 5-7 shows an example when a user inputs the word “Buddha” to search for documents containing that word.

Figure 5-8 shows the results of a full-text search for the word “Buddha.” The left panel of the screen shows the list of documents containing the word; this result also supports KWIC (Keyword-in-Context) by showing the text around the searched-for keywords. The system shows three occurrences of the keywords starting from the first instance, so users can understand the context in which search keywords are being used.

In the top right panel of Figure 5-8, keywords translated into other languages are shown, along with the number of documents containing the translated keywords. This translation is carried out by MASS (Multilingual Annotation Support System), introduced previously in Section 3. If search keywords match one of the records in MASS, the system applies a query expansion for multilingual search. Thanks to this method, users are only required to input keywords in a language they are familiar with, while still being able to search for documents written in languages they cannot write simply by following links provided.

Finally the bottom right panel of Figure 5-8 shows the list of keywords related to the list of documents in

1 <http://geta.ex.nii.ac.jp/>

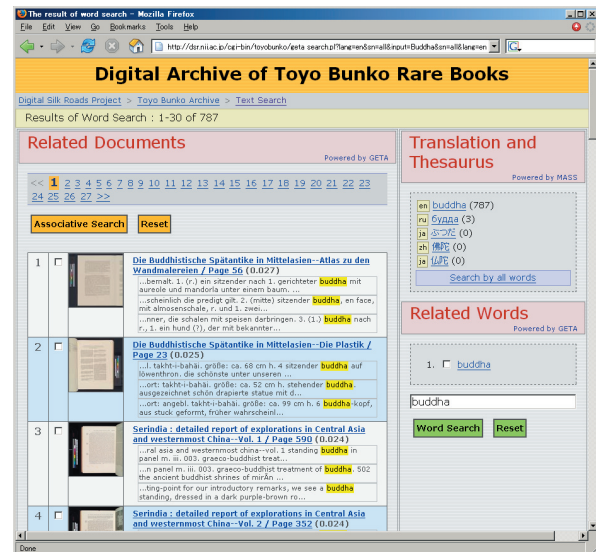


Fig. 5-8 Results of a full-text search.

the left panel. The usefulness of this feature is explained in Section 5.4.5.

Referring back to the left panel of Figure 5-8, clicking one of links takes you to the page containing the keywords, as shown in Figure 5-9. This page shows the image of the original book at 900x900 pixels, and below the image it shows the OCR (optical character recognition) text extracted from the image. When users reach this page through the full-text search, they will find that search keywords are highlighted on the OCR text as shown in Figure 5-10. From a practical viewpoint, this highlighting function significantly reduces users’ burden in locating keywords within OCR text.

This search system also supports basic stemming and stop-word elimination. For Japanese language in particular, a morphological analysis tool called ChaSen<sup>2</sup> is used for splitting words into meaningful segments in standard word form. Indexing of documents is done in Unicode (UTF-8) for all languages in order to generate a single index for all documents.

#### 5.4.5 Associative Search

The uniqueness of GETA search engine is better demonstrated by the “associative search” for searching documents similar to the queried documents. The advantage of an associative search is that users do not have to input keywords, instead simply picking documents for which to find similar documents based on similarities between word frequency statistics. Figure 5-11 shows an example list of associated documents

2 <http://chasen.aist-nara.ac.jp/>

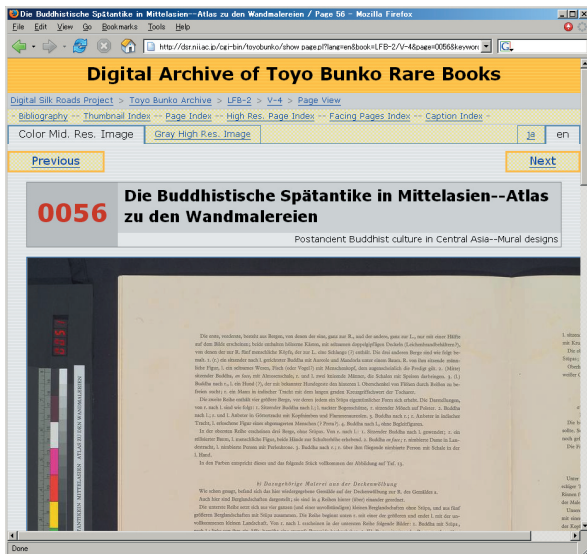


Fig. 5-9 Page view of full-text search

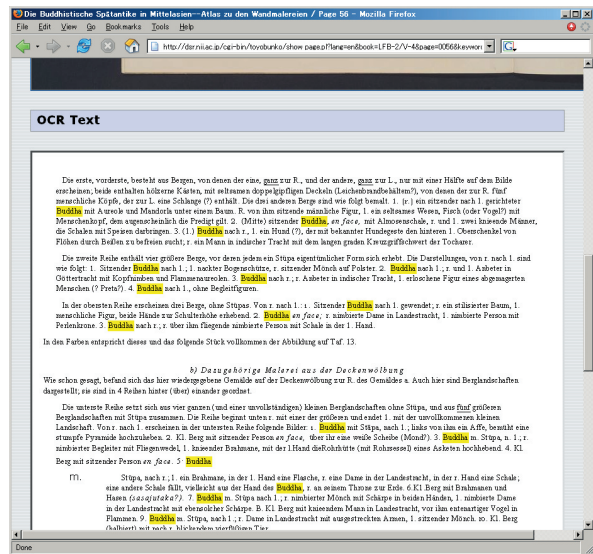


Fig. 5-10 Page view of full-text search (OCR)

and important keywords automatically chosen for searching associated documents. Note that similar documents are chosen from multiple books. Following those links, users can navigate across books for related information.

5.5 Knowledge Representation  
5.5.1 Metadata

The metadata used in the DSR portal includes basic information such as title, creator, description, publisher, date, format, identifier and language. Those elements are taken from the Dublin Core Metadata Element (DCME) Set<sup>3</sup>, which is used as the de facto standard for representing basic bibliographic metadata. The extension of DCMS is also required on the DSR portal, however, in terms of multilingual metadata and domain-specific metadata. One metadata that cannot be ignored for the digital archiving of rare books is the binding information of the book. Western books have bindings opposite those of Chinese books. Other page numbering features also vary by book, so we need a metadata to describe such information. These metadata are described in XML with standard metadata tags as well as special tags defined by us. Then those metadata are processed on DSR-CMS in order to process HTML documents embedded with metadata.

5.5.2 Ontology

Ontology is used to represent the relationship of concepts in a hierarchy, thesaurus and other forms

3 <http://dublincore.org/documents/dces/>

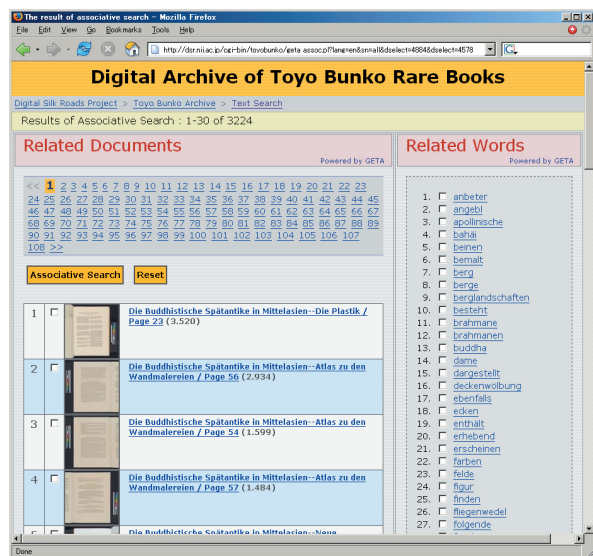


Fig. 5-11 Results of an associative search.

[22]. It is a key concept for the semantic management of contents, because it can be used to create relationships between cultural resources on a conceptual level. Concepts and relationships between concepts, however, vary by domain. Hence it is important for the DSR portal to have good ontologies in the related domains of the natural sciences and the humanities. Good ontologies have already built in some areas, but in most areas there are no such ontologies so we need to develop them ourselves. The building of ontology is not a trivial task, so we start with a simple ontology for a restricted domain, and build up a large ontology combin-

ing multiple smaller ontologies. We are also building special tools, called Open Ontology Forge (OOF), to support the management of ontologies.

### 5.5.3 Combining Knowledge with Search

Knowledge represented in the way above can be integrated into advanced search mechanism. One example is a concept-based navigation and multilingual search. The former is related to an ontology, while the latter is linked to a multilingual dictionary. As illustrated in Figure 5-8, a basic form of multilingual search has already implemented - a searching mechanism indispensable for cultural digital archives that straddle multiple languages and periods.

### 5.6 Current Status

The number of accesses to this Web site is measured by the number of page views for the top page, excluding internal and erroneous accesses. As of January 2005, the page view of the DSR top page has reached about 38,000 (since December 2003), the Toyo Bunko Web top page, 20,600 (since April 2004), and the Bam Web top page, 12,400 (since January 2004). The number of actual page views by visitors is difficult to measure, because a considerable number of accesses are from search engine robots, which are not meaningful as user-request statistics.

### 5.7 Future Directions

#### 5.7.1 Challenges

The DSR portal is not yet fully developed; we need to solve the following challenges to make the DSR portal more powerful for researchers and non-experts alike.

#### 1) A steady increase in the amount of digital cultural resources

The first challenge is to increase the amount and variety of digital cultural resources available. Variety is especially important because an integrated information resource like the DSR portal has more value when connected to information from multiple sources, such as books, papers and photographs.

#### 2) Effective integration of multiple resources

An increased variety of cultural resources will require effective linking across cultural resources. Knowledge representation such as ontology can be used as glue to connect multiple resources. Another possibility is to use research papers as a hub for linking multiple cultural resources with academic descriptions.

#### 3) Sustainable evolution of databases and users

We need to have a strategy for the evolution of the digital archive. This means that knowledge collected in the digital archive should not be static but should be

dynamically evolved via collaborative work by a variety of experts and non-experts. One way is to collect opinions, comments, and follow-ups on cultural resources from motivated individuals; we are planning to set up another portal for this purpose. This kind of collaborative work is necessary for the sustainable evolution of digital archives, and we hope that motivated individuals can also learn from participatory collaborative work.

As stated, it is important for the DSR portal to increase the amount and variety of contents; we plan to include the following two resources into the DSR portal in the near future.

#### 5.7.2 The Global Database of Buddhist Caves

“The Global Database of Buddhist Caves” will be an integrated multimedia database with information on Buddhist caves around the world. The purpose of this database is to build a portal site for Buddhist caves that provides textual information about the caves as well as related information such as research papers and photographs. Ontology may be especially important in the creation of this database. The structure of the different cave sections - walls, ceiling, statues, and murals - follows the concepts of Buddhism, so the representation of the structure requires a systematic knowledge representation method. Hence domain ontologies are required for a number of academic fields, such as archaeology, art, history, and architecture. This database is expected to allow researchers to compare caves across different sites and countries, studying them to discover commonalities and differences between them.

#### 5.7.3 The Database of Silk Road Studies

“The Database of Silk Roads Studies” will be a collection of research papers, academic reports, and other research references related to Silk Roads Studies. This is in some sense an extension of Toyo Bunko Web, which archive only books. Research papers and academic reports provide detailed descriptions of specific topics, and add a good deal of knowledge that cannot be found in books. The design of this database will allow users to search papers that are related to a cultural resource, or cultural resources that are related to a paper. In this sense, papers can be used as a hub to connect multiple cultural resources. Those resources can also be linked with ontologies and dictionaries to support instant lookup of important technical terms on the DSR portal.

## 6 ASPICO Portal for International Collaboration

### 6.1 Overview

This chapter describes ASPICO-DSR (Advanced Scientific Portal for International Cooperation on Digital Silk Roads), a Web-based portal that aims at hosting international and multidisciplinary experts to create a digitized cultural heritage of the Silk Roads. This solution features services through a standard Web browser to collect or upload multimedia resources, comment them (metadata), and search them such that resources provided by members are, finally, viewable by the public. In addition, ASPICO-DSR eases and fosters members' collaborative studies by providing communication tools and shared workspaces.[15][16]

### 6.2 ASPICO-DSR: Architecture and Metadata Management

DSR was established to protect the heritage of the Silk Road by utilizing the raft of new technologies being developed within numerous fields of research. NII and UNESCO pledged to support this tremendous work via a development of the ASPICO-DSR Web-

based portal .

#### 1) Architecture

The functional architecture of ASPICO-DSR is laid out in Figure 6-1. The portal entrance leads to one of two different areas depending on the status of the users, namely whether the user is a visitor or a member.

The Public Area is freely accessible by visitors interested in the Silk Roads. Users can first browse pages about various topics, ranging from the ASPICO-DSR project to underlying technologies and partner initiatives. Users can also search for multimedia resources available from the Digital Silk Roads Database through the portal, and view the comment from Silk Roads experts accompanying along these resources.

The Member Area relies on workspaces to encourage collaboration among expert members and allow members to manage cultural resources. Each member can access a private domain, namely called 'My Workspace,' to manage his/her own resources and work. Ad-

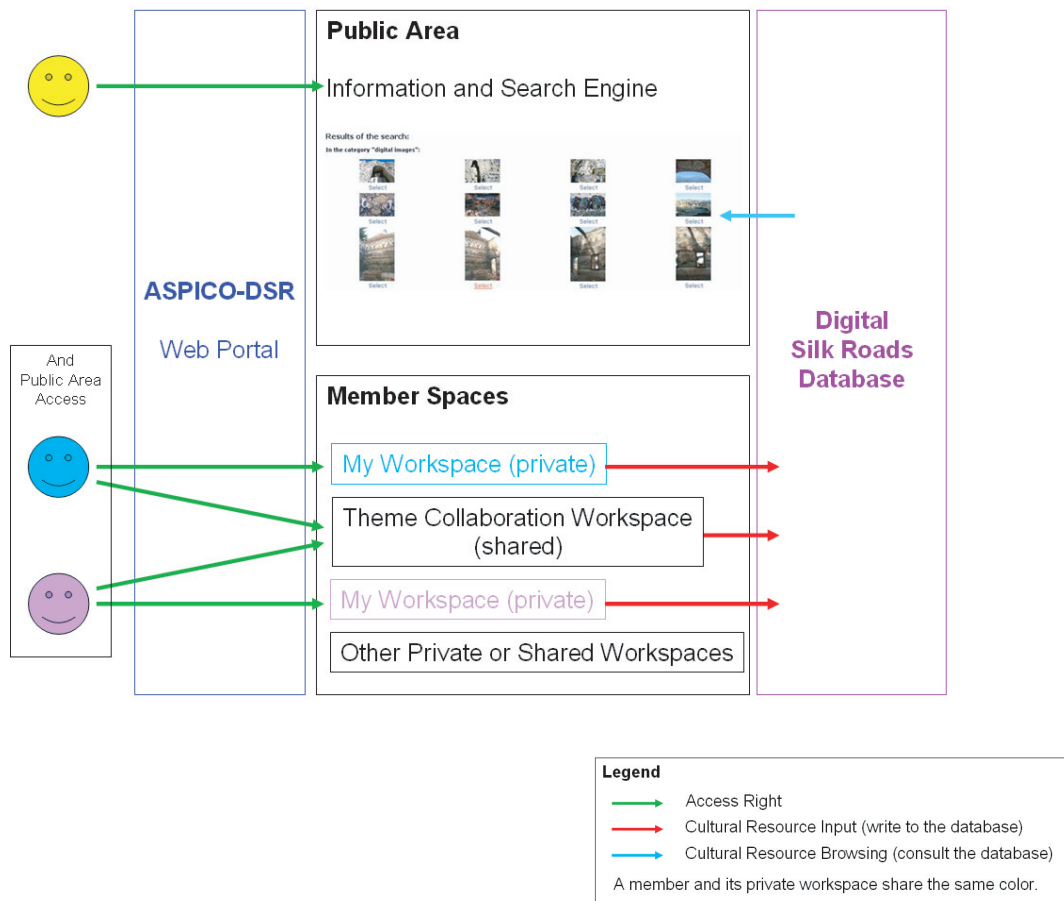


Fig. 6-1 Functional Architecture of ASPICO-DSR

ditionally, members may freely join work groups that share a ‘Collaboration Workspace.’ In this space, members can manage common resources, work, and also collaborate with others in the work space via the available communication tools.

The Public and Member Areas rely on mostly multi-lingual interfaces in order to foster international cooperation among members. In the end, the overall work and data from member studies is stored in the the Digital Silk Roads Database to serve the Public Area and support ongoing endeavors to build and improve the contents of the portal.

## 2) Metadata Management

The central function of this architecture is the management of resources and their comments. Comments are provided to visitors along with resources, and they are categorized as metadata for those resources. This second point of reference allows resources to be directly searched by means of their comments, as shown in Figure 6-2.

In this example, the search request is the keyword ‘Buddha’. The engine retrieves a set of results that includes the image in Figure 6-2, since its comments include a reference to the keyword. Requests 2 and 3 will also retrieve this resource, but the other resources in their respective result sets will differ from those for Request 1.

The current metadata schema of ASPICO-DSR for classification of resources relies on four separate standards to create the base of its cultural heritage ontology model. Those standards are Dublin Core (DC), Ob-

ject ID, the Categories for the Description of Works of Art (CDWA), and Visual Resources Association (VRA). ASPICO-DSR builds its schema from them by exploiting their standard vocabulary. The following Tree 1 shows a part of the current structure of the schema.

Terminal leaves of the tree are categories that can be selected as the final classification point for resources (for instance, videotapes, or post-cards). Branch nodes can be customized through ASPICO-DSR to dynamically represent new categories.

Beyond the creation of metadata, management includes ensuring the quality and correctness of comments that become available in the Public Area. In this regard, the design specifies three states for resources, temporary, clean, and validated, which are assigned on the status and quality of the corresponding metadata, as shown on Figure 6-3.

Temporary Resources are isolated files without any associated metadata. They require comments from Silk Roads experts for further exploitation (discussion and publication). Such data is only accessible from Private or Shared Work Spaces. Clean, or Commented Resources consist of sets of data with associated comments. Such Resources must be reviewed by the committee before being open to the public. They are still only accessible via member’s Private or Shared Work Space. Finally, a Validated Resource is one which has been reviewed by the ASPICO-DSR quality committee and is available in the Public Area.

This three step process ensures a collegial decision and validates the quality and relevance of submitted

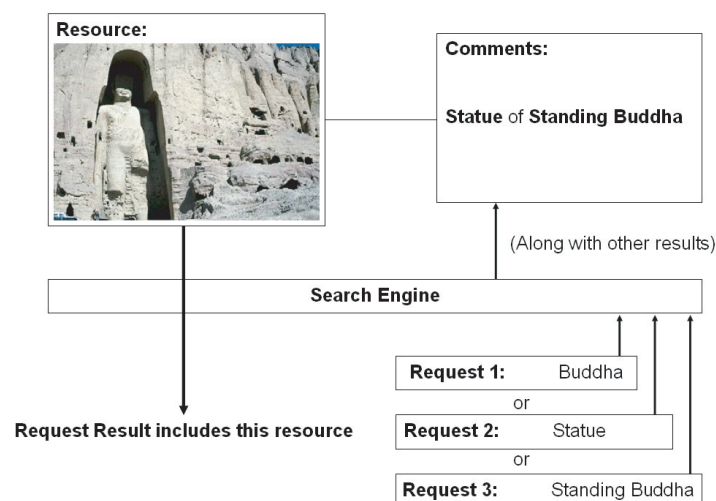
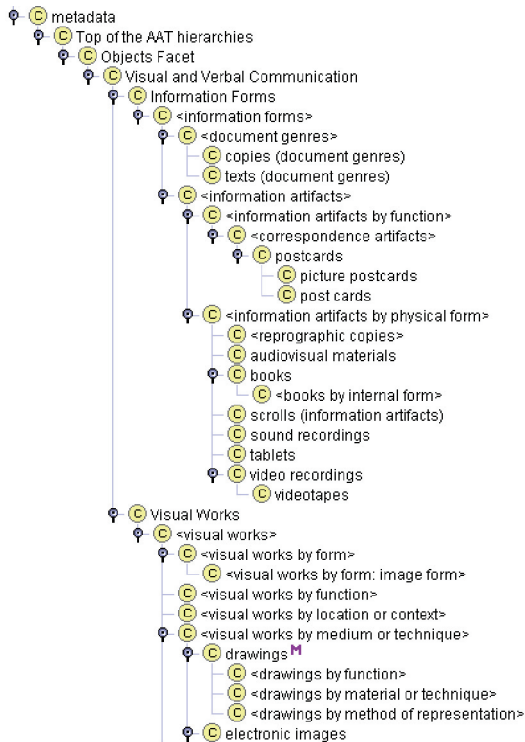


Fig. 6-2 Comments are also search keywords (image from the Bamiyan Collection)



Tree 1 Partial Metadata

resources before they reach the Public Area.

### 6.3 Description of the ASPICO-DSR

The current implementation of the ASPICO portal relies on open-source software and is built on top of the Comprehensive Collaboration Framework (CHEF) from the University of Michigan running in Java[41]. This section describes the main tools of ASPICO-DSR, namely the primary simple search engine, work

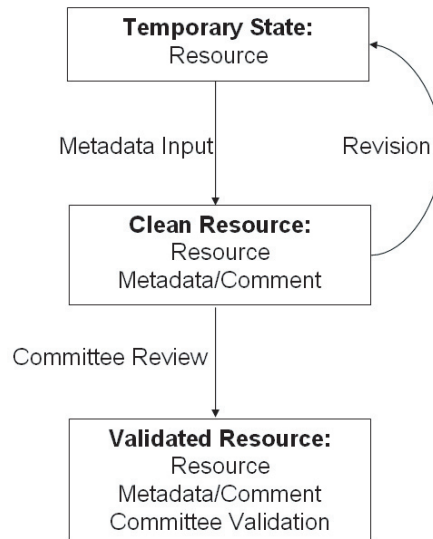


Fig. 6-3 -Resource States

space, communication and collaboration tools, the metadata editors, and the quality committee function.

#### 1) Basic Search Engine

On the entrance page of ASPICO-DSR, detailed information about the project, related technologies and related activities is accessible through the front menu. At the top of the page, shown in Figure 6-4, the 'Public Area' button leads to the Silk Roads digital heritage search engine.

The current search engine provides for only basic operation; after it is proven to be conceptually sound, additional function will be added. At present, searches may only be performed by categories of resources (media type, object type), such as paintings or books.



Fig. 6-4 Top of the entrance page

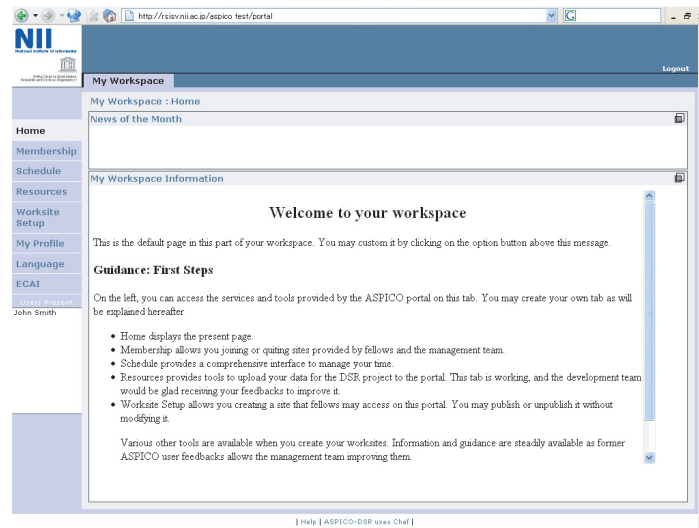


Fig. 6-5 My Workspace (private area)

For instance, only request 2 ('statue') from Figure 6-2 is currently supported as a mean to search for resources.

When a category is selected, the corresponding available resource list is displayed and visitors are able to choose objects of interest. When an element is clicked on, it is magnified and information provided by experts appears alongside it. Comments are mostly descriptive, and situate the resource in time and space when possible (Title, Location, Era, Comments, Dimensions, Relation to the Silk Roads, etc). All authoring information presented conforms to the UNESCO policy on ASPICO-DSR contents.

## 2) Workspaces

ASPICO-DSR divides workspaces into two types to allow members to make full use of the services available in each. This infrastructure relies directly on the CHEF model and exploits its capabilities within the context of the Silk Roads.

Each member receives a private workspace upon creating an account. Figure 6-5 shows a typical workspace area. This home page allows each member to manage personal information such as their profile, membership status in shared spaces, and schedule, and engage in resource and metadata management.

At the top of the page, tabs may be available for swapping among spaces. The default tab is always set

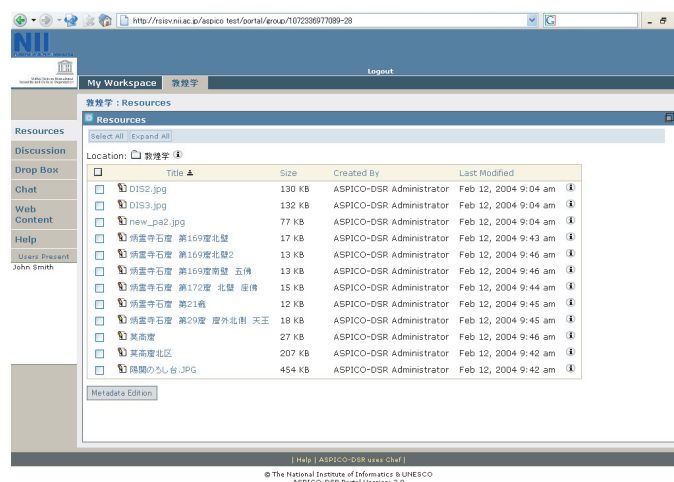


Fig. 6-6 Shared Workspace example

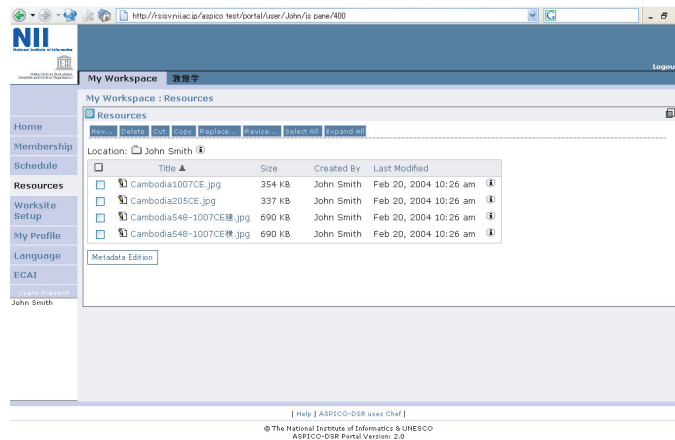


Fig. 6-7 Resource Management and Metadata Creation

to the private ‘My Workspace,’ and, after entering a working group by applying using the ‘Membership’ tool (on the main menu to the left), a new tabs becomes visible at the top to represent the workgroup. In the example in Figure 6-6, two work groups are presented, ‘Silk Weaving’ and the Japanese ‘敦煌学’.

Figure 6-6 shows an example of one of these shared spaces, with the Japanese ‘敦煌学’ tab selected.

The layout is similar to ‘My Workspace,’ so members should be familiar with the interface. However, the left menu and colors can vary depending on the creation options.

To create and control shared spaces, the left menu in ‘My Workspace’ has a button named ‘Worksite Setup.’ The creator is the owner of this shared space, and may

choose to grant any simple access or full maintenance rights to all who request it, or manually select members to allow to participate. Furthermore, as shown in Figure 6-6, the owner may freely modify colors and menus to suit the purpose of workgroup. The ‘Help’ link at the bottom of the portal page details the sequence to create and customize a complete workspace.

The main advantage of these shared workspaces is the ability to share resources and communicate directly with fellows and peers. The following section describes these optional communication and collaboration tools.

### 3) Communication and Collaboration Tools

In shared workspaces, members may exploit ASPI-

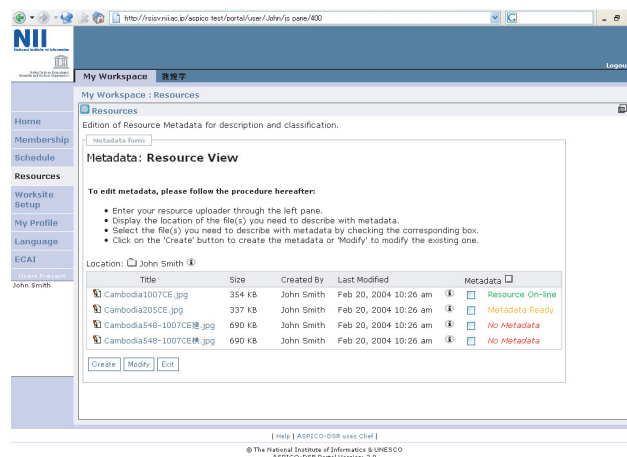


Fig. 6-8 Metadata Editing Tool



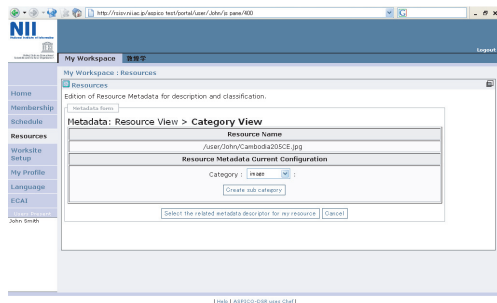


Fig. 6-9 Metadata Class Selection (category)

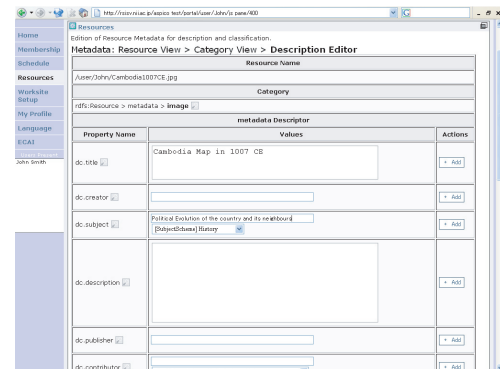


Fig. 6-10 Properties list for the selected category

CO-DSR communication and collaboration tools. From the original CHEF platform, the portal provides a discussion forum, integrated instant messaging (chat), and a drop box, i.e., access to personal folders for peer to peer file exchanges. A tool is available in a shared workspace when its name appears in the menu at the left. Members may submit request to the administrator of the space for access to tools dynamically using the 'Worksite Setup' function.

The discussion forum uses a format similar to most systems widely available on the Internet. Members can create new discussion threads and messages or reply to posts from fellow workspace members. Similarly, the integrated instant messaging system (chat) closely resembles popular versions of such tools used on the Internet. As users chatting in several workspaces simultaneously may lose the thread of some conversations and not be able to participate meaningfully, the chat program is only permitted to be open in one workspace at any given time. Finally, the drop box is aimed mainly at allowing members to exchange working documents from person to person through the portal. This system has two main advantages: first, it avoids a problem common in email, where a large file attachment causes an email to be rejected and go undelivered—there are no restrictions on file size for the drop box: second, privacy is ensured, as the data never leaves the ASPICO-DSR servers .

#### 4) Metadata Editing Tool

The main tool for ASPICO-DSR is that used for managing and commenting resources provided by members. In technical terms, this means it uploads data and creates associated metadata along the ASPICO-DSR cultural heritage logics (a proper schema relying on standards such as Dublin Core). On member spaces, the 'Resource' button on the left menu leads to the screen in Figure 6-7.

The initial screen shows the current list of resources

provided by the member. The top menu of the central panel in Figure 6-7 contains a row of buttons that group together the most often used resource management functions, such as new resource, deletion, and copy and paste options. These buttons lead to separate screens to complete the desired function and return to the screen shown in Figure 6-7 after completion of the function. The creation of a new resource requires a file name and the acceptance of one UNESCO license, either for full donation to UNESCO, or for limited rights (under definition).

At the bottom of the central panel in Figure 6-7, the 'Metadata Editing' button leads to the metadata management tool, the typical layout of which appears in Figure 6-8.

The list of available files is displayed once more displayed, together with metadata related information. A color code is employed as an easy way to show the status of resources, with red, orange, and green corresponding to temporary, clean and validated states respectively. The green state means the resource is online and available in the Public Area, whereas red and orange states are still local to members.

To create comments, members select one or more resources (in the latter case, all resources have the same metadata) and start the process. First a category is required (metadata class), as shown in Figure 6-9, and then the corresponding properties can be filled in to describe and comment the resource, as shown in Figure 6-10.

The Figure 6-9 also makes apparent the possibility of creating a subcategory before selecting a category selection. Indeed, members may not find an appropriate classification in the list. As Silk Roads experts, members can add one or more subcategory in their field of interest and then select the one appropriate for the described resource. For example, one root category is 'Books Containing Illustrations,' which may seem too abstract to properly describe a member's book about

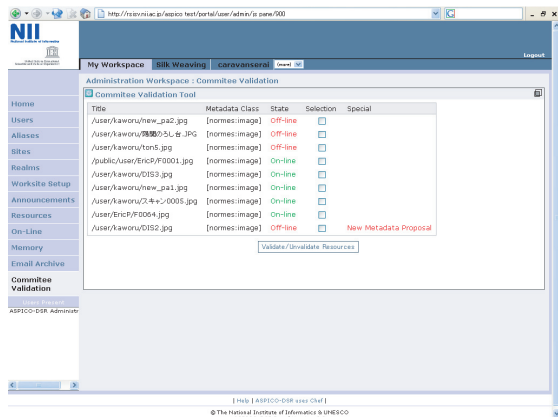


Fig. 6-11 Committee Validation List

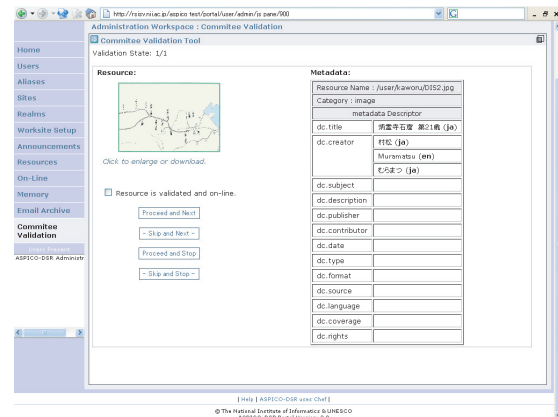


Fig. 6-12 One resource and comments

pottery. The member can then create a subcategory ‘Pottery along the Silk Roads’ that will then serve all books on the subject.

On completion of the creation process, the resource change status, switching from red state to orange. Modification processes can then be applied to revise or complete the input information. From the orange state (clean), one additional step is required to publish the resource in the Public Area and make it accessible by the search engine. This step is only able to be carried out by the ASPICO-DSR committee, in order to ensure the quality and correctness of contents.

5) Content Quality Tool: Metadata Validation by the

ASPICO-DSR Committee

The ASPICO-DSR Committee is in charge of the portal to ensure that the information available in the Public Area is of a high level of quality. Elected members have access to a special tool in the left menu of their personal workspace. The current implementation only allows the portal leader to access this tool. Figures 6-11 and 6-12 show this tool and its functions.

Resources of either a clean or validated states are shown in the list on Figure 6-11. The color code is simpler here as only two states are used: red means the information is offline and green means the information is online. The committee member can select resources to review. Special warnings appear when online re-

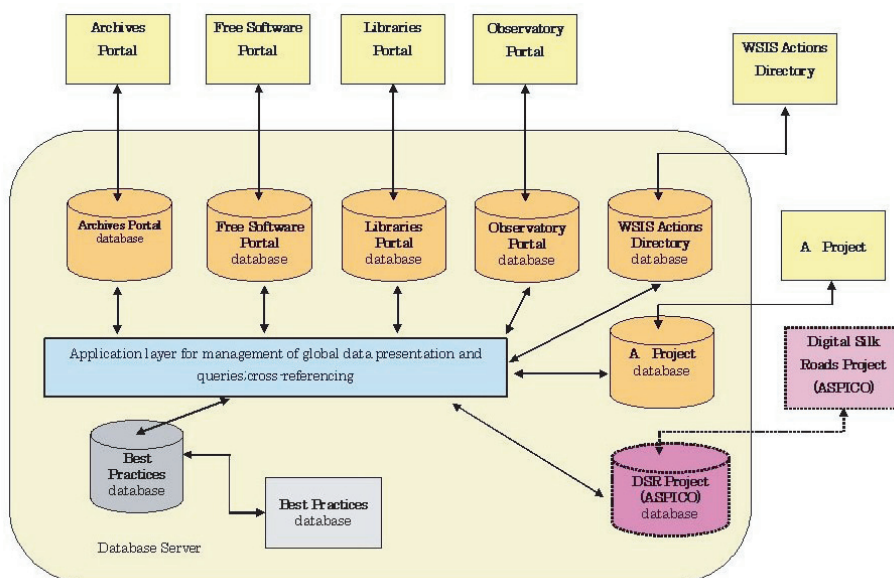


Fig. 6-13 Possible Integration of ASPICO with the UNESCO Web Portal

sources are modified by their original creator, usually to make improvements or suggestions.

Figure 6-12 shows the typical reviewing screen when resources are selected. The resources displayed are accessible by simply clicking on them. Comments are compiled in the table on the right, and buttons provide options for validating or canceling the process. Once validated, updated resources are searchable through the engine in the Public Area.

#### 6) Integration of ASPICO with the UNESCO Web Portal

ASPICO-DSR will be open not only to the Silk Roads community but also to the public, via the Internet. To harness ASPICO as the DSR community's tool for daily cooperation and assistance as well as a platform for information dissemination, we are trying to integrate ASPICO with the UNESCO Web Portal.

Figure 6-13 shows a possible method of integration.

#### 6.4 Conclusion

This chapter presents ASPICO-DSR in its current state of implementation, and describes future developments that are being pursued with a view toward its evolution. The architecture of the system fulfills the requirements for support of the international Silk Roads community set forth by UNESCO via a set of services allowing for the upload and commenting of multimedia resources before publication in the Public Area. After publication, it makes the resources accessible by anyone around the globe with a standard Web browser.

ASPICO-DSR presently fulfills the initial requirements set forth in DSR project. This first version, however, needs improvements to meet member needs in a real-life usage environment. For this reason, we are considering implementing an advanced resource interface to ease resource and metadata management.

For the future, we are also discussing interlinking different systems around the world to build a comprehensive set of independent cultural heritage databases. ASPICO-DSR allows these databases to be searched individually or collectively from a common portal.

## 7 Annotation and Knowledge Management of Cultural Resources

### 7.1 Introduction

In this report, we present the latest development of an open-source collaboration tool dedicated to semantic management of cultural content, a new type of WWW-based collaboratory for cultural heritage information sharing and cooperative exchange for research and education purposes. Professional domain experts are able to use the system to analyze, evaluate, and

collaborate on the interpretation and indexing/annotation of multimedia documents. The metadata hereby provided are managed via an advanced XML-based content manager and an intelligent content- and context-based retrieval system.

The ASPICO system not only provides the functions of a traditional digital library, but on top of that it employs a comprehensive approach as an aid in the development to collaborative knowledge derived from cultural sources, i.e. supporting users in their analysis, interpretation, and evaluation of the sources as well as the creation of new knowledge as a result of this work with the material. Therefore, the system and its components are adaptable to heterogeneous cultural domains.

From the ASPICO Approach to a Scoper-based Approach

Designed as a content- and context-based knowledge work environment for distributed user groups, the initial system, called "ASPICO" (Advanced Scientific Portal for International COoperations), supports both individual work and collaboration among domain experts who are analyzing, evaluating, indexing, and annotating the material in the multimedia data repository. It continuously integrates the user knowledge thus derived into its metadata repositories, and on this basis can offer improved content-based retrieval functionalities within the information system. Users can therefore both access and create valuable knowledge about various cultural contexts, which in turn allows other end-users to better retrieve, compare, and interpret the materials. The two major features of the ASPICO system are:

- (1) Direct access to cultural heritage knowledge is provided by a content-centric, user-driven information system and collaborative working environment over the internet.
- (2) Feedbacks of the professionals' actual usage of the collaboratory are analyzed and documented for different tasks and user groups so as to implement new user requirements and improve the system functionalities. The usages from various cultural cooperations strongly influence the evolution as an, iterative, dynamic platform.

The first prototype of the ASPICO system was provided at the end of March 2004 under the Digital Silk Roads project[1][2][15], allowing for formal cataloguing, content-based indexing and annotation of digitized text documents, and document exchanges. A newer version called "myscoper" incorporates advanced document preprocessing modules for automatic metadata analysis and indexing of multimedia data in collaborative scopes and points of views, and especially more support of collaboration between users

based on a collaborative and point-of-view based task model. As a prerequisite for collaborative work, any digital material is analyzed, indexed, preliminarily translated, annotated, and interlinked by experts. “myscoper” provides them with appropriate task-based interfaces for in-depth indexing/annotation and other tasks as well as with supporting knowledge management tools (indexing aids and special control vocabulary lists). End-users can input valuable information through annotations. In this way, a growing body of metadata is emerging over time. The system exploits the digital nature of the data by employing advanced XML-based content management and advanced retrieval methods. The online version of “myscoper” will integrate cutting-edge document processing and management facilities, e.g., XML-based document handling, digital watermarking, and semi-automatic segmentation, categorization, and indexing of digitalized contents.

By combining the results from the manual and automatic indexing procedures, elaborate content-based retrieval mechanisms can be applied. This helps users find what they are actually looking for according to various points of views.

## 7.2 The Platform Architecture

The “myscoper” system introduces the following innovative features:

- practicable methods of content and knowledge processing for isolated document collections
- a new concept of content-based organization, handling, and presentation of historical materials
- a user-friendly online working environment to share the expert knowledge of professionals via annotations.

The dynamic accumulation of annotations requires new data structures to be both scaleable and extensible. In order to capture these dynamics we chose XML as a de facto standard for the encoding of generic documents and metadata representation schemata. The use of XML guarantees the interoperability, since these schemata can then be enriched and tailored to additional sources and knowledge incorporated into our system without any need for re-modeling the whole system. In addition, XML allows the integration of knowledge processing methodology and retrieval functionality within the system. Therefore as a result, the system is capable of capturing the dynamics of collaboration without neglecting the necessary flexibility of scaleable and extensible representation schemata.

The platform architecture (see Figure 7-1) is based on open-source components including a storage layer (Dspace<sup>1</sup>), an ontology-based metadata management

program, query interface and resource entry services, and a multi-resolution resource viewing tool. The storage layer can support various types of digital data, ranging from scanned-in text documents to multimedia data and the accumulated annotations related to one or more of these original data sources. The system limits the access to data according to the users’ rights set to indoor users (Intranet), outdoor users (Extranet), and to the Web users. The Collaborative Task Layer allows a wide variety of user types to access, manipulate, and annotate the digitized material. Some of these tasks can be performed collaboratively, e.g., collaborative inspection and interpretation of source materials. A collaboration model has been developed and offers context-dependent interface functions for collaboration between users.

Support of collaborative work goes beyond contemporary groupware products, offering innovative functions such as:

- collaborative interpretation of sources, e.g., tagging, annotating document sources and annotations made by other colleagues
- support of specific tasks in scholarly work where individuals or groups contribute to a common information space

### 7.2.1 Ontology-based Metadata Management

In order to organize the stored data in a way that supports the complex knowledge-intensive tasks users perform, suitable tools for metadata management are being provided. The knowledge structures, which are represented by specific XML schemata, constitute the Domain Model. These knowledge structures, a key feature of our system, are managed as multilingual ontology-based metadata support. Our platform follows a promising research approach based on the usage of metadata and ontologies. Metadata is any information which characterizes instance data, and which describes relationship between those instance data. Metadata is used to provide an effective use of data, in order to facilitate any data management, any data access, and data analysis[43].

An ontology is an explicit specification of the conceptualization of a domain[44]. Ontologies enable domain experts to create an agreed-upon vocabulary and semantic structure for exchanging information about that domain. Ontologies facilitate the cataloguing and sharing of knowledge, as domain experts are able to contribute to a shared, worldwide, but well-organized knowledge base of technical information. We considered a metadata management architecture and designed multi-layer ontologies to classify and describe

<sup>1</sup> MIT’s Dspace: <http://www.dspace.org>

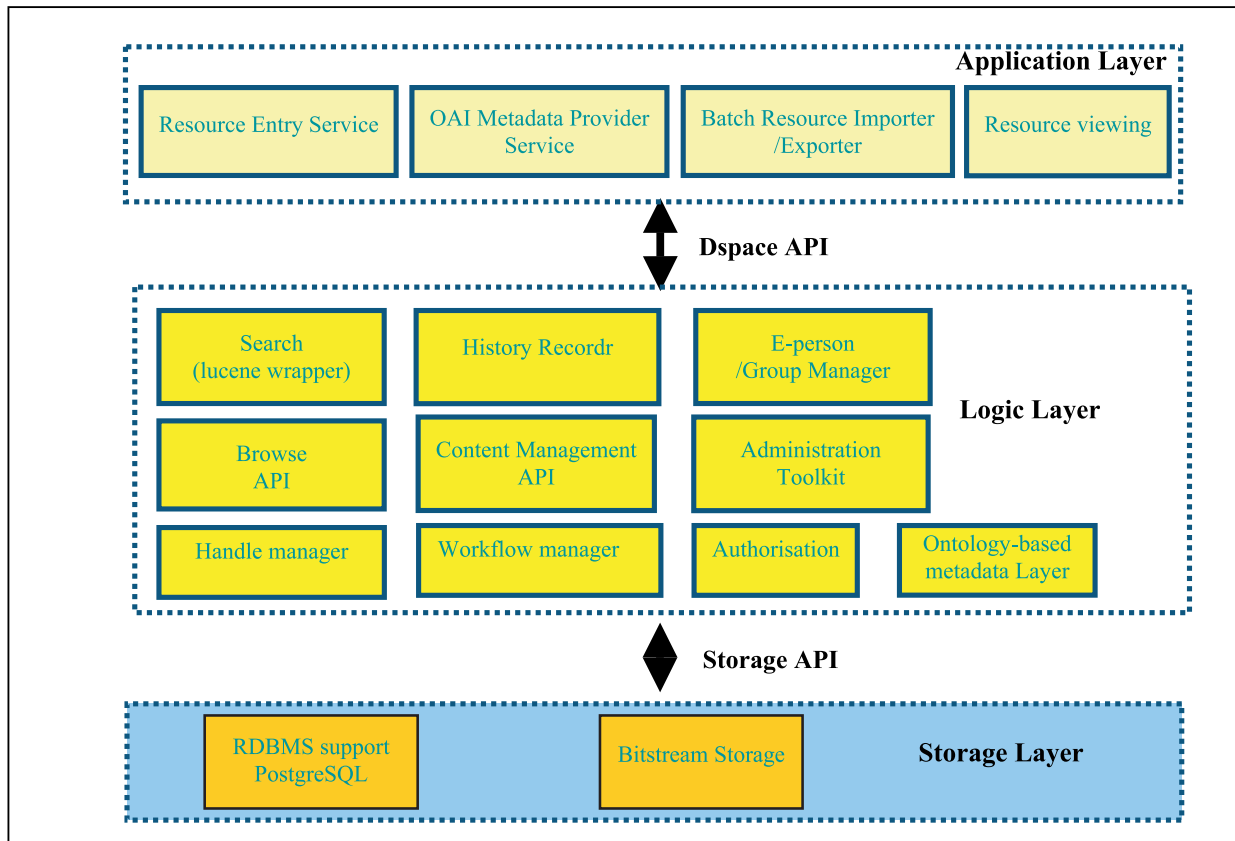


Fig. 7-1 Architecture of the myscope platform

resources. It is based on Protégé 2000 where each ontology is related to one field such as history, geography, architecture, and art, etc... However, the system included the possibility for overlappings, as different ontologies may have equivalent concepts, or may contain subsets of separate ontologies within themselves.

This problem of ontology integration has been solved by classifying and reorganizing ontologies in a logical and semantic sense according to metadata. Our approach points to a need for a formal model for ontology-based metadata management. Ontology is the formal and explicit conceptualization of a particular domain. It includes a set of concepts and their relationships. Based on Protégé 2000, we defined our ontology structure as a 6-tuple:

$$O := \{C, P, A, H^c, prop, att\}$$

where  $C$  represents a domain-based set of concepts,  $P$  a set of relation identifiers, and  $A$  a set of attribute-value relations.  $H^c$  is a *Hierarchy of Concepts* that are linked together through relations (e.g. specialization, generalization).  $H^c$  is a directed transitive relation  $H^c \subseteq C \times C$  called *concept taxonomy*; function  $prop$ :  $P \rightarrow C \times C$  relates two concepts non-taxonomically; function  $att$ :

$A \rightarrow C$  introduces the relationship between concepts and literal values.

Example. Let us consider a subset of our ontology structure related to spirituality

$C := \{\text{SPIRITUALITY, RELIGION, LANGUAGE, OBJECT, LANGUE, BOUDDHISME}\}$ ,

$P := \{\text{EXPRESS, CREATE}\}$ , and  $A$  defines the relations  $\text{EXPRESS}(\text{RELIGION, LANGUAGE})$  and  $\text{CREATE}(\text{RELIGION, OBJECT})$ .

### 7.2.2 Resource Entry

Resource entry is also performed via a Web browser interface similar to that used for querying. Users who wish to enter some resources first need to log on. Write, modification, and suppression rights can be assigned and controlled by the system administrator for each user; the availability of some predefined types of users provides community and group management abilities.

Information such as the identification profile of the user and the date of the entry are automatically filled in by the system. To maintain the integrity of the resource being entered into the system, the controlled

lists of relevant vocabulary within the thesaurus are used for each translatable field. When uploading a resource via the web interface, users are required to enter some preliminary metadata related to the resource. When a resource is saved in the main database, the metadata is translated into a language-independent code representation. The creation of the metadata profile is done according to some metadata categories such as structural metadata, content metadata and contextual metadata to avoid overlaps between attribute sets,

### 7.2.3 Query Interface

Queries are performed via a web browser-based interface. New interfaces for simple or advanced queries can be easily created and the fields to be included and customized by the system administrator. In addition, date or numeric size fields can be searched by specifying a range of dates or sizes between which searches are to be performed. Users are able to select the working language and the domain of interest as well as the number of results to be returned and whether resource results are shown. The interface is divided into three parts:

- 1- Historical and material resources related to artifacts;
- 2- Technical or management information related to photographic resources;
- 3- Technical or management information related to document resources;

Where applicable, the user can choose technical terms from a list of relevant terms ordered alphabetically, the user can type something in his own search terms. Ontologies in 21 languages will be able to be consulted online. Full-text searches can be made within each domain.

The format for display or the output format of the results (e.g., HTML, XML, plain text, formatted tabular, list of images, graphical or statistical analyses, etc.) is independent of the storage structure in order to optimize the delivery process. The format generation typically follows a methodology based on context-dependent cultural resource accesses [25].

### 7.2.4 Multi-Resolution Resource Viewing

Another key component of the resource management system is the capability to remotely view multi-resolution resources, including high-resolution images of both 2D paintings and 3D objects. Each image resource is stored as both a JPEG thumbnail for rapid previewing and in tiled pyramidal TIFF format for high-resolution viewing. A java applet acting as an interface for the storage layer permits multi-resolution viewing. This viewing system is based on the Internet

Imaging Protocol. The viewer works by requesting only the tiles at the appropriate resolution required for viewing a particular part of the image. The requested tiles are then dynamically JPEG encoded by the server and sent to the applet. In this way, images of any size can be viewed quickly across Internet.

### 7.2.5 Multilingual Ontology-based metadata

Multilingual support is becoming of critical importance in the cultural domain. This can be accounted for by: (1) the increasing amount of cultural contents accessed over the Internet, (2) efforts to develop standards for cultural data from diverse fields for the purpose of digital archiving and research sharing, and (3) the increase in the use of tools to extract semantic data from cultural digital data. Furthermore, a multi-lingual Ontology-based metadata approach enables searching by both semantic and by contextual content, as it relies on multi-lingual annotated documents and features extraction processes. Each set of ontologies is based on object-identifier bridge between mono-lingual Unicode (UTF-8) encoding ontologies.

Controlled lists of technical terms (e.g., Art and Architecture Thesaurus AAT, Library of Congress Authorities) from each ontology as well as the free text information fields (such as the titles) have been translated with the support of domain experts. Providing content- and context-based access to the data repository is a crucial feature of "*myscoper*". "*myscoper*"'s users directly enrich the document repository through new sources and successive annotations and indexation. Annotation as a multifunctional means of in-depth analysis can be done individually but also collaboratively, for example in the form of annotations of annotations, or collaborative comparisons of documents. As a result, a large amount of value-added information is provided in addition to the digitized documents.

### 7.3 Ontology-based metadata compliant to the Open Archives Initiative Metadata harvesting Protocol

The Open Archives Initiative (OAI) consortium is dedicated to solving problems of digital archive interoperability via the establishment of standard protocols. A major accomplishment of this consortium is the definition of a protocol for metadata harvesting (OAI-PMH). This is a protocol to transfer metadata from one archive to another. "Data Providers" refers to entities that possess data/metadata and are willing to share this data/metadata with others (internally or externally) via well-defined OAI protocols (i.e., Any WWW-based system that can be accessed through the well-defined interface of the Open Archives).

Table 7-1 Dublin Core Elements

No	Element	Description
1	Title	Name of the object
2	Creator	Author(s) of the written document
3	Publisher	The agent or agency responsible for making the object
4	Subject	The topic addressed by the work
5	Description	The contents of the resource
6	Type	The genre of the document (such as novel, poem, etc.)
7	Format	Electronic format
8	Identifier	String or number used to uniquely identify the object
9	Source	Information about a second resource
10	Language	Language of the intellectual content
11	Relation	Relationships to other objects
12	Coverage	The Spatial location and temporal duration
13	Rights	The management, statement for the resource
14	Contributor	Any entities responsible for making contributions to the contents of the resource
15	Date	The date of publication

Table 7-2 ECAI-Specific Metadata Elements

No	Element	Description
16	ECAI.Team	The ECAI team responsible for collecting the dataset or overseeing its incorporation into ECAI.
17	ECAI.Theme	The thematic domain(s) covered by the dataset.
18	ECAI.Notes	Additional information about the resource being described.
19	ECAI.UseRestrictions	Defines the level of access permitted to the data through the ECAI data browser
20	ECAI.Content	Describes the nature of the material available in the dataset.
21	ECAI.Expert.Commentary ECAI.Expert.InternalNotes	Authoritative comments for public viewing written by the ECAI team editor or other ECAI expert on the quality, validity, usefulness, etc. of the resource. Authoritative notes from the ECAI team editor or other ECAI expert on the quality, validity, usefulness, etc. of the resource. For internal use only.

### 7.3.1 The OAI Data Provider Service

Our digital archive is composed of many separate collections. Each collection has records in different metadata formats. We have developed tools for displaying collections based on the metadata formats of the records contained in those collections. The Collections include metadata contents organized as XML files and database files. All the metadata required for a particular format is in the database.

Our OAI Data Provider is based on OAICAT provided by OCLC. OAICat is a Java Servlet web application providing an OAI-PMH v2.0 repository framework. The framework has been customized to work with arbitrary data repositories by implementing some Java interfaces. Multilingual support has been added to

the `oai.properties` file. All the implementation aspects of the Data Provider that deal with the database are captured in this file. Using the software requires familiarity with writing SQL queries and java. This software is currently undergoing testing.

### 7.3.2 OAI Metadata Support

Our implementation of the OAI protocol uses unqualified Dublin Core (DC) with the metadata prefix `oai_dc`. The Dublin Core Metadata Element Set contains 15 attributes, shown in Table 7-1.

Moreover, the OAI-PMH has changed the current status of unqualified Dublin Core from *mandatory* to *recommended*. As such, we have implemented a richer metadata protocol using the ontology-based metadata

hierarchy of metadata sets.

### 7.3.3 OAI Extended to support ECAI

The Electronic Cultural Atlas Initiative (so called ECAI) Metadata is an extension of Dublin Core (DC). It includes data which catalogues the content and spatial and temporal ranges of datasets. ECAI has added custom ECAI extensions that enable access to the data resource via software such as TimeMap. The metadata focus on the data collection as a whole rather than the individual items in the collection. The TimeMap metadata extensions describe attributes such as

- a) where the data is located on the network and
- b) where the spatial and temporal information is stored within the data.

For example, ECAI metadata requires that the extent of the resource or dataset be defined by a bounding box (or “space-time cube”) consisting of minimum and maximum longitude (x) and latitude (y) values, and a minimum and maximum time/date (t).

The core-based implementation of OAI has been extended based on the metadata prefix `oai_dc.ecai`.

The ECAI-Specific Metadata Elements are given in table 7-2.

### 7.4 Conclusion

The *myscoper* system is a scientific and education portal collaborative tool supporting exchanges of cultural document information between users via innovative task-based interfaces for content indexing and annotation.

## 8 Spatial-Lexical Knowledge Model for the Silk Roads caravanserais -Multilingual Domain Ontology for Advanced Systematic Classification-

### 8.1 Motivation

Management of cultural heritage information systems especially those dealing with Silk Roads content will face the sheer volume and variety of the multidisciplinary databases of both tangible and intangible heritage.

The main challenge is how best to represent and share such large databases of cultural heritage systematically while bridging the knowledge gap between info-base providers and users accessing the system via the Internet (Fig.8-1).

Implementation of a separate knowledge model for each homogeneous field is of key importance in the conceptualization of the content, and representation of technical domain knowledge. Such models need to follow relevant standards to allow data interoperability between different information systems and communities, and to facilitate information gathering, integra-

tion, and distribution over networks.

In a general schema it can be noticed that such a knowledge model is the core of data management for advanced digital documentation of cultural heritage especially in a collaborative way, with contributions from domain experts like architects, historians, archeologists, etc. and computer scientists and IT experts, through related Web sites and portals; such kind of model is one of the targets of the Digital Silk Roads.

### 8.2 Statement of Problem

As a subset of the cultural heritage of the Silk Roads, information on architectural assets - as well as our case study, Caravanserais of the Silk Roads - reflects the main characteristics of historical buildings, the three-dimensional forms and spatial organization of it as a whole, which varied during different historical periods. A technical domain-based knowledge model including spatial dimensions is required to efficiently manage such visual 3D information and related annotations.

A new question arises here: What are the theoretical studies on the development of such knowledge models for the selected corpus of historical architecture within the described general schema (such as the Digital Silk Roads project)? Which technologies should be implemented? How can the proper theory, concept and technology be implemented using new information and communication technologies and how can the knowledge in the domain, i.e., architectural science, be supported by such a knowledge model?

To propose of some solutions for the above-stated problems, this research, as part of a multidisciplinary Ph.D. study in informatics with an architectural engineering backdrop, focused on a Spatial - Lexical Knowledge Model for Caravanserais of Silk Roads, Multilingual Domain Ontology for Advanced Systematic Classification<sup>1</sup>.

The following parts of this paper contain discussion on selected corpus and objectives of this knowledge model, development of domain ontology of selected corpus, design process and enhancement of available methods and the tool and software support. Finally, it concludes with the future plan of the study to reach to innovative knowledge model and cover the spatial attributes of architectural content of caravanserais.

### 8.3 The Focused Corpus and Objectives

Due to the varied content of information within the domain - as reflected in typological differences based

<sup>1</sup> The supporting projects for this research, which is done in cooperation with Ecole d' Architecture Paris Val de Seine (EAPVS) in France, are “Digital Silk Roads Initiative Framework” (DSRIF) from NII and UNESCO, and “Inventory of Caravanserais,” from EAPVS and UNESCO.





Fig. 8-1 A graph showing examples of cultural heritage data over vast scope like Silk Roads and challenge for data management

on time, environment, and space - it is necessary to choose a special corpus of architectural heritage of the Silk Roads to be able to focus on its characteristics, i.e., information management, semantic annotation, and data access, and understand it as a system.

The corpus is an important subset of the cultural heritage of the Silk Roads, caravanserais<sup>2</sup>. Their main function was to support caravans during their journey [27]. Caravanserais were built in a chain in such a way that, as Robert Hillenbrand said, "They punctuated the major historic overland routes at intervals of a day's journey" [28]. Caravanserais of the Silk Roads are spread almost all throughout these historical roads - in the East, through China and India; in the Middle East, from Iran westward to Europe; in Venice; and even in North Africa and the Sahel. But within this general area, they are concentrated mainly in three countries: Iran, Turkey, and Syria [30].

Based on the available researches, especially the UNESCO project on caravanserais<sup>3</sup>, Iran is considered to be the mother country of caravanserais, with more than thousand samples of different typologies. In accordance with this huge number of cases and based on background research on caravanserais [46], the area of

this research focused on caravanserais of east-west Silk Roads in Iran, excluding samples of city typology.

The information of this corpus contains different types of visual information reflecting characteristics of this typology of historical buildings, based on various features such as location, style, historical period, and environment (Fig 8-2).

The objectives of this research focusing on the selected corpus are as follows:

(1) To define a method for advanced knowledge-based management and systematic documentation of data on the cultural heritage of the Silk Roads involved in a case study of caravanserais using NTIC, with architectural science support.

(2) To create a spatial-lexical model in order to conceptualize and to represent the knowledge of historical architecture found in the corpus of caravanserais. From this step, an advanced systematic classification system may be created.

(3) To scientifically recognize caravanserais through an analytic study of their components and relationships between components used to form the architectural space as a whole.

(4) To study and develop domain ontology for enhanced semantic access to visual data, especially via the Internet.

(5) To propose a cooperative joint research to cover the multilingual needs of users of the corpus of Silk Roads by extending the content to other languages<sup>4</sup>

<sup>2</sup> The supporting projects for this research show the important role of caravanserais in studies along the Silk Roads

<sup>3</sup> The UNESCO project is entitled "Inventory of Caravanserais," with participation by 9 countries in Central Asia and under the general coordination of Professor Pierre Lebigre from EAPVS

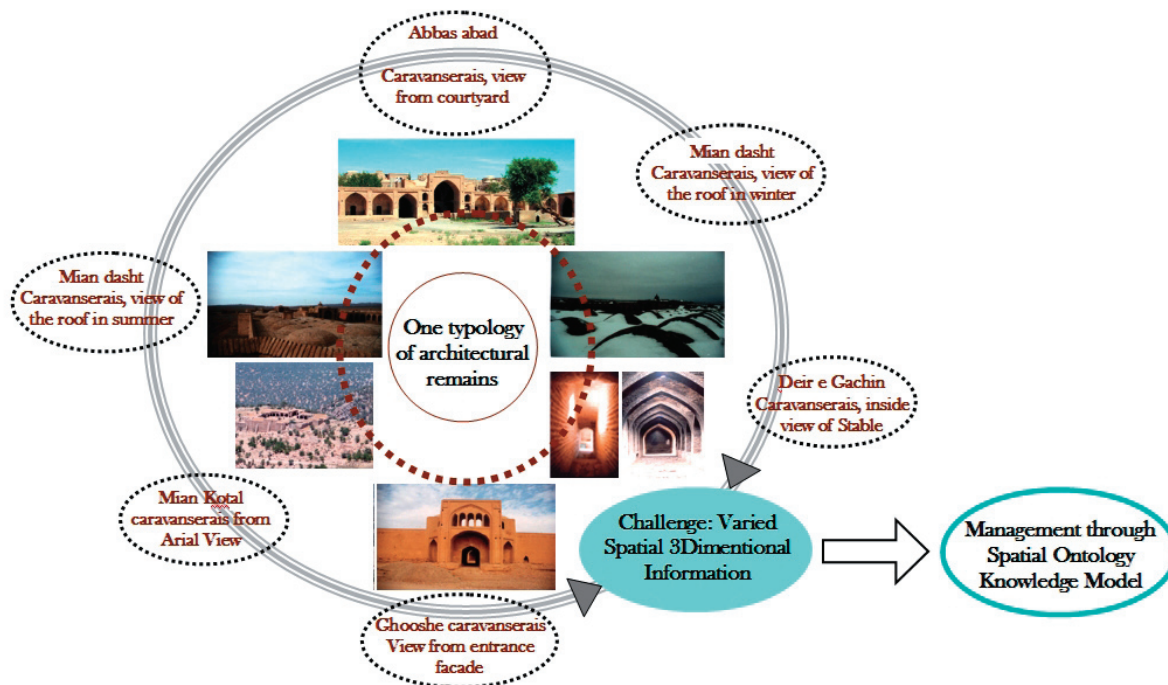


Fig. 8-2 Different typologies of caravanserais of Silk Roads in Iran and challenges ahead the management of their databases.

#### 8.4 Study, Design and Implementation of the Selected Concept, Domain Ontology

This research focuses on ontology as a proper model to visualize and to represent spatial data of the selected corpus through study on theory and development of a spatial-lexical multilingual specification of caravanserais.

Ontology is originated from philosophy and is the study of the kinds of things that exist. However, the definition given by Gruber to ontology, "as a specification of a conceptualization" [31] focuses on its role in knowledge management. It represents a declarative model of the terms and relationships in a domain<sup>5</sup> and provides a lexical knowledge-base. Domain ontology focuses on the conceptualization of specific domain data, like the selected corpus of this research.

This research started with the study of visual modeling technologies related to knowledge management - mostly with a focus on ontology as the selected concept - and the available state-of-Art, domain knowledge models and ontologies, especially those in the field of cultural heritage [32][33], in a comparative

way and study of their shortcoming. Furthermore it focused on studying the theory and implementation of new methodologies, using domain knowledge and architectural science to enrich the ontology (as compared with the studied samples) and to create a new, compatible systematic knowledge model to ensure that a common semantic understanding of spatial information was shared among multilingual users.

As a practical implementation, a prototype of an ontology model for caravanserais was developed. One typical application of ontology models which is to help solve stated problems, especially those involving semantic data access, search and retrieval of visual data of the selected corpus over the Internet is going to be reviewed (in a parallel research) and tested as part of the Layout Learning Ontology tool.

#### 8.5 The Process and Innovative Enhancement

The main interest of this research is to cover the spatial features of the corpus in order to conceptualize the semantic structure of the content, developing multilingual domain ontology through the following processes:

(1) Designing a lexical model through:

(a) Data acquisition, component-recognition, and completion of a multilingual term-set of technical components of caravanserais (Fig.8- 3) [12]

<sup>4</sup> Part of this multilingual support is provided by a UNESCO expert team in the field of Silk Roads field

<sup>5</sup> Poli-Roberto, Framing ontology-second part  
[http://www.formalontology.it/Framing\\_second.htm](http://www.formalontology.it/Framing_second.htm)

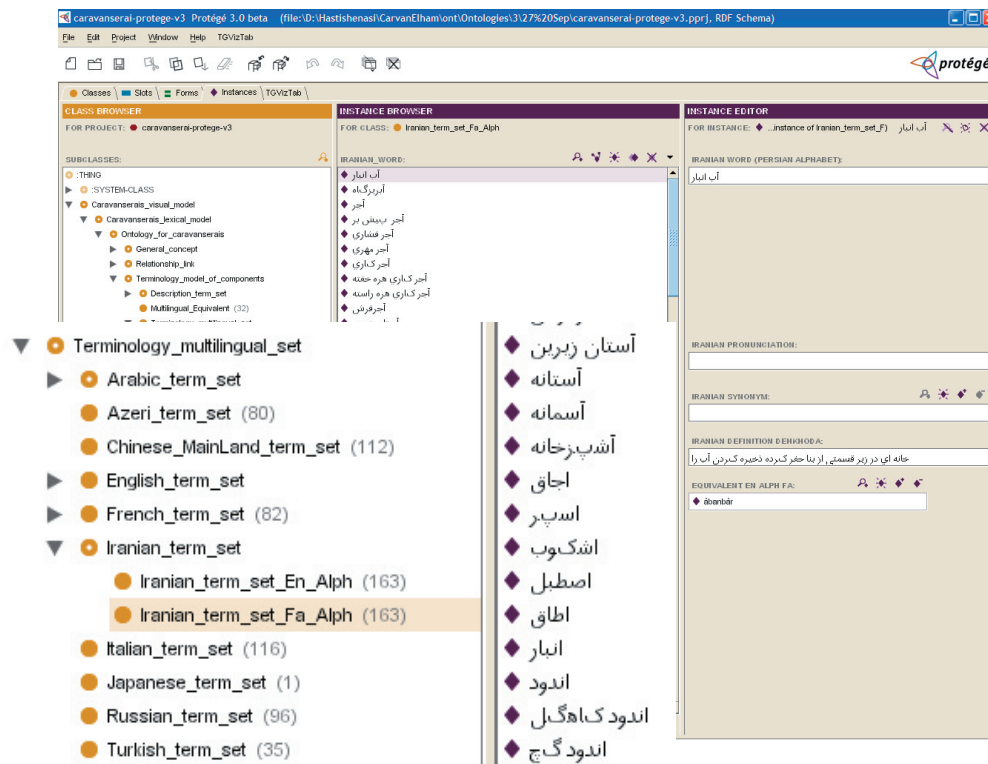


Fig. 8-3 A snapshot of multilingual terminology designed in Prot\_g\_ tool for caravanserais and Iranian term-set

(b) Designing a lexical terminology model including both lexical and linguistic data by mapping from available lexical databases or dictionaries such as Oxford [34], WordNet [35], Pappillon [36], and General Ontology for Linguistic Description (GOLD) [47].

(c) Designing a taxonomic lexical model mapped with each monolingual term-set using thesauri, such as Art and Architecture Thesaurus for the English term-set (Fig8- 4) [37].

→ This lexical model helps in conceptualizing the evolution of technical architectural vocabularies through time. It also disambiguates the function of spaces within the hierarchical structure of the thesaurus. The main challenge of this process was to design the lexical model, with lots of interrelated information, in a clean way compatible with the languages and tools of ontology development (protégé, and RDFS), with classes, subclasses, and properties of classes as slots and instances of each class having a mono-linked ID.

(2) Adding relationships between terms based on the spatial organization or structural features of components within the overall architectural concept of caravanserais (Fig.8-5).

Parts of these relationships are mapped from the available domains, such as upper-level relationships

(like generalization or specialization) [38] or distance, orientation, and topology relationships provided by systems of qualitative representation of space [39] or part-whole relationships defined in mereology [48]. Finally, new relationships based on architectural characteristics were added.

→ This process represents an innovative enhancement of available ontology models, using architectural domain science to cover spatial attributes and their development through time in historical architecture.

(3) Defining a shape grammar for developing spatial model of components based on their form, shape, and location within the space of a caravanserai and its dimensions. Such models are mainly based on algorithms that understand and create designs directly through computation of shapes, rather than indirectly through computation of text or symbols [40].

→ Shape grammar provides a shape-based knowledge representation and attempts to define the scale, proportion, and spatial organization of a three-dimensional space. Here architectural science tries to enrich domain ontology by covering the gap between the verbal description of a space and the formal representation of it in visual tools.

(4) Adding domain knowledge to the software application process of Layout Learning Ontology as part of

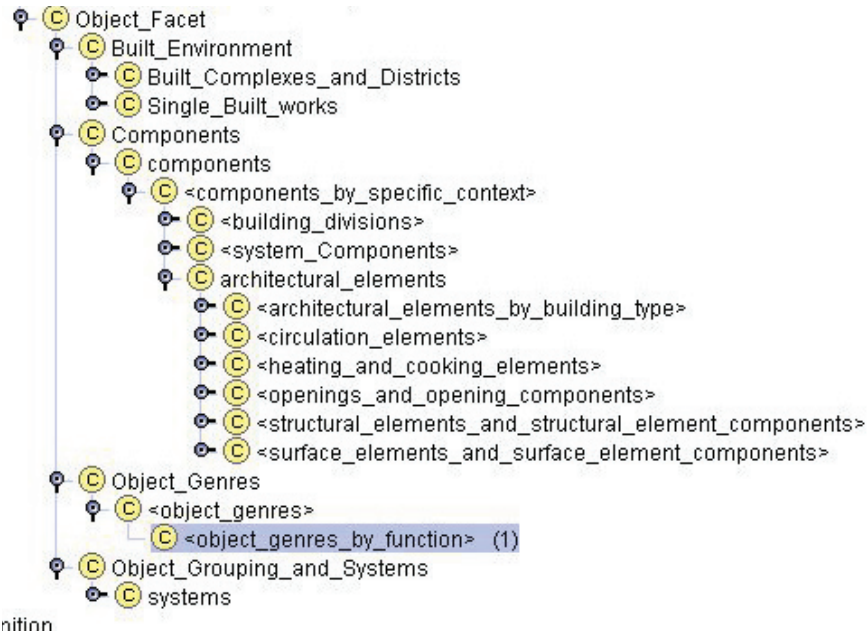


Fig. 8-4 A snapshot of hierarchical structure given to English term-set by using Art and Architecture Thesaurus

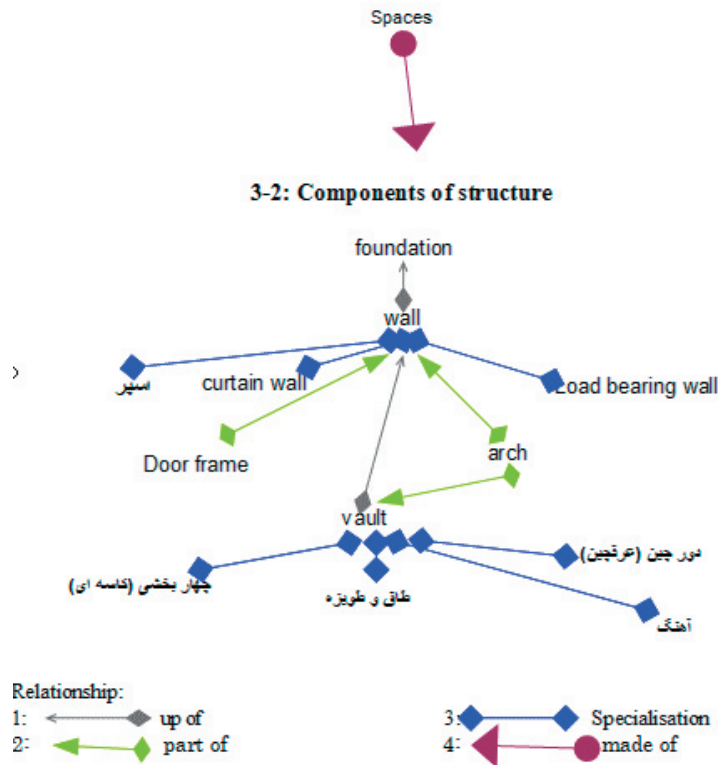


Fig. 8-5 A sketch of visual model of terms and their relationship, an example of defining relationship to complete the model caravanserai components

semantic access and distribution of data via the Internet.

#### 8.6 The Tool and Software Supports

Protégé, a knowledge-base editing environment, was used to develop the ontology which has enabled us to combine a multi-lingual multimedia ontology with Web standards for knowledge representation, as required by semantic webs such as RDFS and OWL.

Protégé supports construction of ontologies in a frame-like fashion, using classes and slots [49]. Classes can define hierarchies - which are term-set, AAT hierarchies and relationships set in our ontology - and slots can contain values or information for each instance of a special class.

#### 8.7 Conclusion

Cultural heritage information deals with multi-disciplinary, multilingual content of various technical specifications. Architectural heritage adds the three-dimensional properties of historical buildings to info bases with spatial ambiguity in how data is accessed, especially knowledge-level semantic annotation and retrieval. This research focuses on the conception and development of a knowledge model through domain ontology, enhancing available methodologies through the use of architectural science. This paper presented a general overview of the spatial-lexical knowledge model and multilingual ontology, focusing on the caravanserais along the Silk Roads in Iran, excluding typology of city samples, as a case study.

Within the proposed research plan the following tasks have been achieved:

- (1) Reviewing the state of Art in knowledge management-ontology applications;
- (2) Completing the multilingual terminology for caravanserais;
- (3) Study and design of a lexical description model proper for historical architecture terminology;
- (4) Study and definition of relationship links based on properties of historical architecture.

The future plan of this research and expected results are as follows:

- (1) Formalization of content-base and constraint-base relationships for architectural properties within a caravanserai by moving from RDFS language to OWL;
- (2) Study and definition of Shape Grammar Language for selected corpus with IT input tool;
- (3) Discussing with domain experts regarding the completed prototype of ontology in collaborative work over the Internet to reach a consensus among the network of experts of supporting projects.

(4) Supporting the parallel research on testing the application's ontology in the Layout Learning tool;

(5) Studying the possibility of generalizing the research to other typologies of architectural remains or cultural properties.

## 9 Conclusion

This article reported the progress of the Digital Silk Roads project, being conducted at NII in cooperation with UNESCO, over the past 4 years.

The main objectives of the project are to develop a virtual museum or library of Silk Roads cultural and historical heritage and to provide a uniform platform for international and multidisciplinary collaboration.

New technology should be utilized so that it will bring the maximum benefit to mankind, not only in terms of the economy but also in terms of enriching our lives and cultures. We believe that utilizing advanced information technology to preserve historical and cultural heritage will certainly serve this goal.

Digital archiving technology, for example, allows heritage materials and sites thought to be beyond saving to be restored, enabling us to pass on such assets to the future generations. The Digital Silk Roads project will provide us with a new paradigm of collaboration in the digital age, establishing a rout for digital information exchange among the countries along the Silk Road and encouraging the creation of a new cultural form, just as the Silk Road did throughout their history.

The DSR project will enable people to freely explore and experience some of the world's greatest cultural assets without actually visiting them, which had been merely a dream for many centuries. There is no doubt that the DSR project will have a significant impact on the enhancement of cultural diversity around the world.

We plan to make the entire system accessible via the Internet, so that users around the world can share and utilize these precious cultural resources. Furthermore, we are currently working to develop a system to store related information and documents together with the images and videos so that such information can be referred to quickly and easily. This will allow researchers to fully share available resources, which seems sure to lead to further development of the Silk Road studies.

At the moment, the most urgent task is to resolve intellectual property rights issues and accumulate cultural heritage contents. In an effort to obtain appropriate contents, the project will make the most of the Digital Silk Roads Initiative Framework (DSRIF) under the

MOU between UNESCO and NII. Researchers and experts from around the world are expected to contribute to the development of the Digital Silk Roads on their own initiative through the network collaboration system: ASPICO-DSR.

We believe that our effort will set a new direction for study of the Silk Road in the 21st century

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