# CoMeMo: Constructing and Sharing Everyday Memory

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## Abstract

*This paper describes the CoMeMo project which aims to develop systems which articulate, organize and utilize everyday memory in a group or in a community. The basic hypothesis is that connecting information without defining the semantics using the weak information structures is effective to deal with a large amount of diverse information. The CoMeMo architecture consists of (a) CoMeMo Workbench, (b) CoMeMo Incorporator, (c) CoMeMo Mobile Terminal, (d) CoMeMo Server, (e) CoMeMo Protocol and (f) CoMeMo Agent. We have implemented the CoMeMo Workbench, the CoMeMo Incorporator and a prototype of the CoMeMo Mobile Terminal. We have developed applications based on the CoMeMo architecture: (a) Information Gathering and Reorganization from WWW pages, (b) Ontology development, (c) Education Support and (d) Conference Support.*

## 1 Introduction

Most of events in everyday life are forgotten. It is difficult to utilize ideas and thoughts which we hit on when watching TV or strolling at street corners, unless we make note of them. We call such ideas and thoughts in everyday life "everyday memory." We believe that it is significant to construct and utilize everyday memory. Everyday memory plays a critical role to facilitate human-human interaction. Sharing everyday memory and creating common background knowledge facilitates efficient message exchanges.

The CoMeMo[1] project aims to develop systems which articulate, organize and utilize everyday memory in a group or in a community. We propose the *weak information structures* to gather incomplete everyday events and gradually reorganize them. The CoMeMo project is a part of the Knowledgeable Community project[8] which aims to develop an environment of creating knowledge by humans and computers. The CoMeMo project is to assist human memory, in the light of human information processing.

There are some research topics in constructing and sharing everyday memory.

1. **Memory Representation**: how to represent memory
2. **Recall**: how to recall from clues
3. **Utilizing Memory**: how to utilize memory stored in different situations or from different viewpoints.
4. **Cooperative Construction of Memory**: how to support the process of cooperation to construct memory
5. **Presentation of Memory**: how to present memory to be comprehensible to humans

In computer knowledge sharing[8, 9, 10] which aims to implement interoperability of virtual knowledge base, the role of (1) formal common languages which define the semantics of information, (2) facilitators which mediate between agents has been emphasized. The protocol design between agents is important in multi-agent systems.

On the other hand, in order to support human interactions, we aim to make use of tacit background knowledge or contexts shared with humans. We believe it important to investigate tacit knowledge and contexts in real world problems, in the light of information science to design systems which construct and share everyday memory.

In the CoMeMo project, we attempt to explain the mechanisms of (a) interaction between tacit and explicit knowledge and (b) cognition and generation of contexts and situations by studying human interaction systems.

## 2 CoMeMo Architecture

We set a hypothesis that connecting information without defining the semantics using the weak information structures is effective to deal with a large amount of diverse information. *Associations* are one of such information representations we are investigating (Figure 1); each of which is a many-to-many mapping of memory units. Associations connect a collection of key *units* (hereafter *keys*) with a collection of units (hereafter *values*) which are normally reminded by the given keys. Units are basic entities of associations which represent concepts, texts, or image files.

We call a set of associations collected from a particular point of view *workspaces*. The CoMeMo information base is a collection of workspaces (Figure 2).

[1] "CoMeMo" represents "Common Memory", "Continuous Memory", "Computer-enhanced Memorandum", formerly called CM-2 [1, 2, 3, 4, 5, 6, 7].

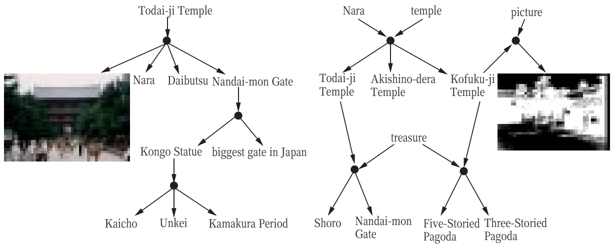



Figure 1: Example Associations

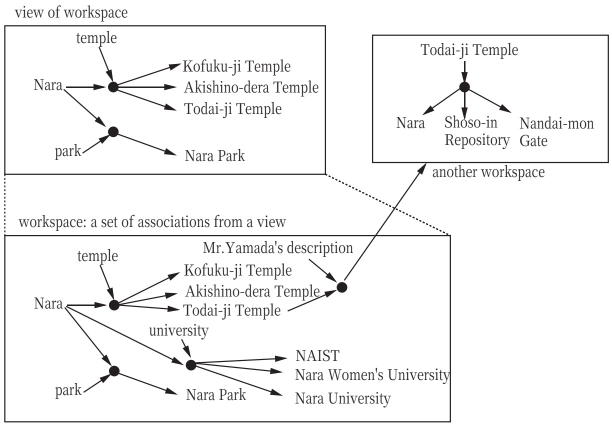



Figure 2: Workspaces

In our approach, the semantics of the associations is not defined rigorously. Instead, we leave the interpretation of the semantics to tacit human background knowledge. This facilitates information acquisition from a variety of data (e.g. images, texts, ideas, memoranda). The CoMeMo architecture helps sharing and reuse of fragmented information.

The CoMeMo architecture consists of following components (Figure 3).

1. **CoMeMo Workbench** helps users explore, browse and edit associations in the CoMeMo information bases.

2. **CoMeMo Incorporator** gathers and converts a wide variety of information into information representations which CoMeMo can deal with.

3. **CoMeMo Mobile Terminal** enables users ubiquitous use of CoMeMo information.

4. **CoMeMo Server** articulates and serves associations on demand, and mediates between information users and developers.

5. **CoMeMo Protocol** exchanges information between each component.

6. **CoMeMo Agent** (a) executes user tasks, (b) negotiates common problems with other agents or humans, and (c) presents the contents of CoMeMo information bases to users.

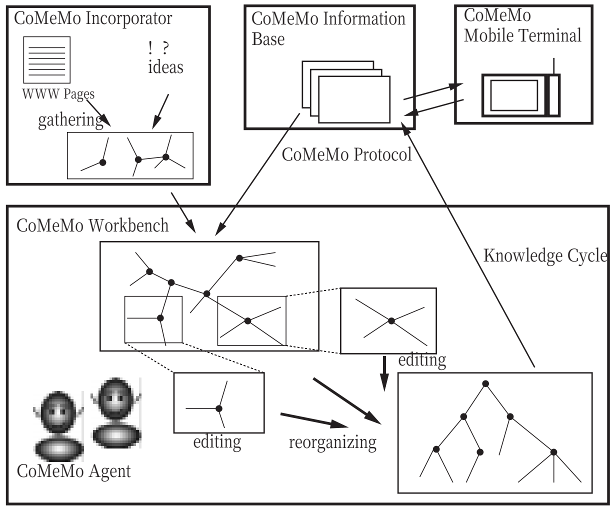



Figure 3: CoMeMo Architecture

We have implemented the CoMeMo Workbench and the CoMeMo Incorporator. We have implemented a prototype of the CoMeMo Mobile Terminal. The CoMeMo Server, the CoMeMo Protocol and the CoMeMo Agent are under construction. We will describe the CoMeMo Workbench and the CoMeMo Incorporator in next two sections.

## 3 CoMeMo Workbench

The CoMeMo Workbench helps users explore, browse and edit associations in the CoMeMo information bases.

### 3.1 Information Exploration

In addition to basic input, edit functions, following functions help users to edit and reorganize information bases.

1. **Focus**: to hide units which are unrelated to selected units

2. **Neighbor Search**: to display units which are linked to selected units

3. **Path Finding**: to display relations between selected units

4. **Unit Search**: to display units by keyword search

In what follows, we concentrate on the path finding. Path finding is based on the idea of "spreading activation" on semantic networks [11]. Path finding with distance $n$ searches a set of units which are linked by associations with distance $n$. Distance 1 denotes an extent between keys and values. Figure 4 illustrates how the algorithm works to answer a question;

> "Is there any temple related to Prince Shotoku?"

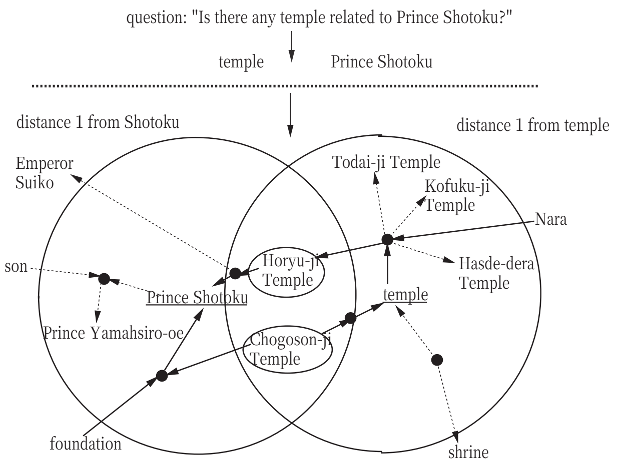



Figure 4: Path Finding

Table 1: Experimental Results of Path Finding

| Distance | Precision | Recall |
|---|---|---|
| Distance 1 | 64% | 64% |
| Distance 1 + 2 | 76% | 92% |

Precision: $\frac{answers\ whose\ results\ are\ all\ appropriate}{qyestions} \times 100\ (\%)$

Recall: $\frac{answers\ which\ contain\ appropriate\ results}{questions} \times 100\ (\%)$

As preliminary experiments (10 questions) had shown that (a) when appropriate answers are obtained by nearest path, far more search is in vain and (b) many unnecessary answers are obtained in distance 3 search, we decided to evaluate distance 1 search and distance 1 + 2 search. Distance 1 +2 search means that if no answers are obtained in distance 1 search, distance 2 search is performed.

We manually constructed an information base referring a sightseeing guidebook of Nara. It contains 1,286 units and 862 associations. We tested path finding against this information base. We obtained appropriate 38 answers out of 50 queries (76% at precision rate, distance 1 + 2; See Table.1). In distance 1 + 2 search, units which cannot be found in distance 1 are found. This is why it improves both of precision and recall rate.

### 3.2 Information Unification

Information unification unifies various associations such as generated from WWW pages and those created by humans into new associations and remove unnecessary associations using heuristics.

Figure 5 shows an example of information unification: information in the right 2 workspaces are unified onto the left workspace.

This facility helps users to utilize information bases possessed by himself/herself or other members in his/her small group. When it is used in bigger societies, ontology and background knowledge bases may be necessary to supply the deficit of the contexts.

Another example is shown in Figure 6. Members of our lab have constructed information bases of slides, survey and so on. User A wrote a plot to write a paper

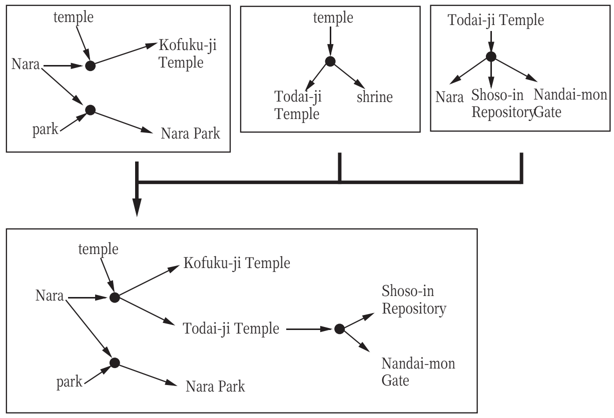



Figure 5: An Example of Information Unification

Table 2: Experimental Results of the CoMeMo Incorporator

| Information Sources | Test | Precision | Recall |
|---|---|---|---|
| Nara Sightseeing Guidebook | $Test1$ | 92% | – |
| | $Test2$ | 86% | – |
| Nikkei Newspaper Full-text Database | $Test1$ | 63% | 91% |
| | $Test2$ | 83% | 71% |
| HTML Documents on WWW | $Test1$ | 90% | 83% |
| | $Test2$ | 68% | 73% |

Precision: $\frac{appropriate\ units}{generated\ units} \times 100\ (\%)$

Recall: $\frac{appropriate\ units}{units\ which\ should\ be\ extracted} \times 100\ (\%)$

(Figure 6(a)) and then unified information bases in the lab. As a result, a piece of slides or papers contained in User B's survey information base and User A's slide information base are integrated through the workspace (Figure 6(b)).

## 4 CoMeMo Incorporator

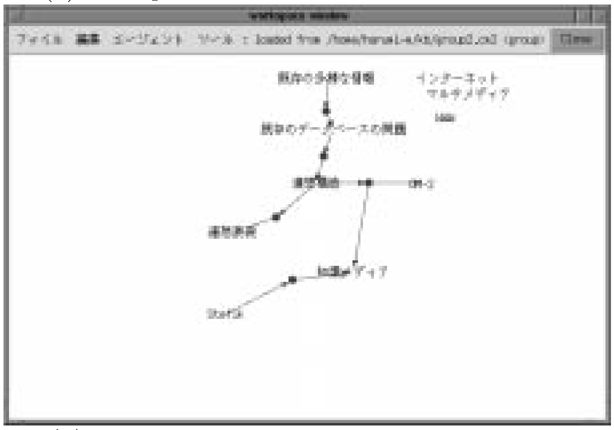
The CoMeMo Incorporator gathers and converts a wide variety of information into information representations which CoMeMo can deal with. For example, information is gathered from HTML documents on WWW and newspaper databases[2, 3, 4, 5]. The current algorithm is quite simple; extracting keywords by morphological analysis[12] and generating associations by analyzing HTML structures (Figure 7). Figure 8 shows an example of associations generated from WWW Pages concerning Kyoto sightseeing information.

To evaluate the effectiveness of the methods, we tested several cases to generate associations from full-text newspaper database, HTML documents and so on. The number of units was around 1000 – 2000. Table 2 shows the results. See [2, 3, 4, 5] for details.

## 5 Applications

We have developed some applications based on the CoMeMo Architecture. The first three systems con-

(a)Workspace Before Information Unification



(b)Workspace After Information Unification

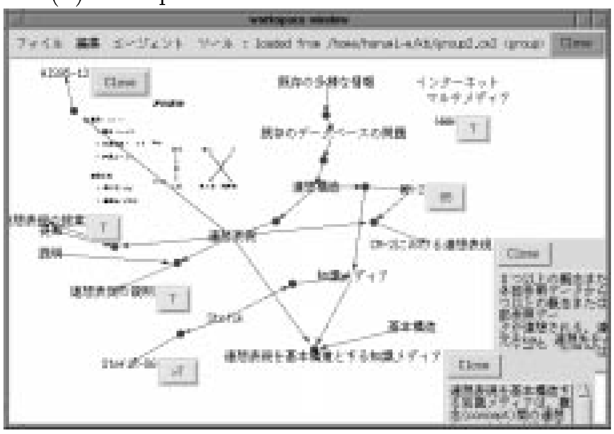


Figure 6: Unifying CoMeMo Information Bases

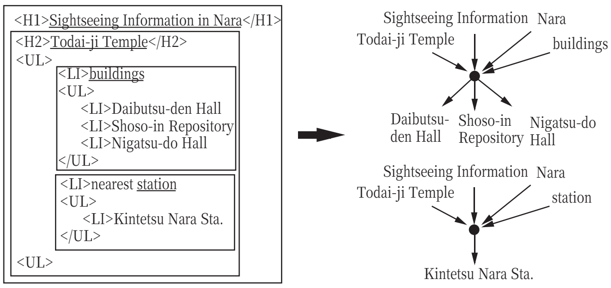
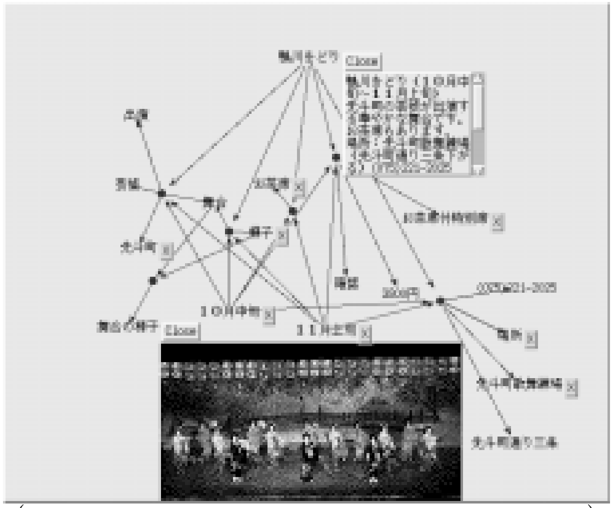



Figure 7: Generating Associations from Mark-up Documents



(http://www.notredame.ac.jp/Other/Kyoto/matsuri/kamo-odori-j.html)

Figure 8: An Example of Associations Generated from WWW Pages

cerns the CoMeMo Workbench and Incorporator, and the last one is a prototype of the CoMeMo Mobile Terminal.

## 5.1 Information Gathering and Reorganization from WWW Pages

Recently the World Wide Web has become very popular for human information sharing. Although a number of search tools available, it is difficult to extract useful information and reorganize it according to user's point of view.

We have developed an application to gather WWW pages, extract information and reorganize it according to user's input.

We gave 100 WWW pages concerning AI researchers to CoMeMo Incorporator for organizing AI directories. The CoMeMo Incorporator extracted units about 7 classes (researchers, projects, e-mail, topics, universities, departments and laboratories), and generated associations. It then reorganized these units and associations to display various lists according to user's input.

The overview of the process is illustrated in Figure 9. The algorithm is as follows; (1) to generate units and associations by morphological analysis and analyzing HTML structure, (2) to identify class of the generated units using heuristics, (3) to unify units and associations using heuristics, and (4) to reorganize associations by path-finding according to user's input.

Figure 9(a) shows an example result when a user input "reasoning","researcher","e-mail","project" and "university". For example, researchers such as Adam Farquhar, Alon Levy, Edward Feigenbaum and James Allen are extracted first, because the word "reasoning" and their names are written near in WWW pages, and then their related information is reorganized. The experimental results are shown in Table 2. See [3, 4] for details.

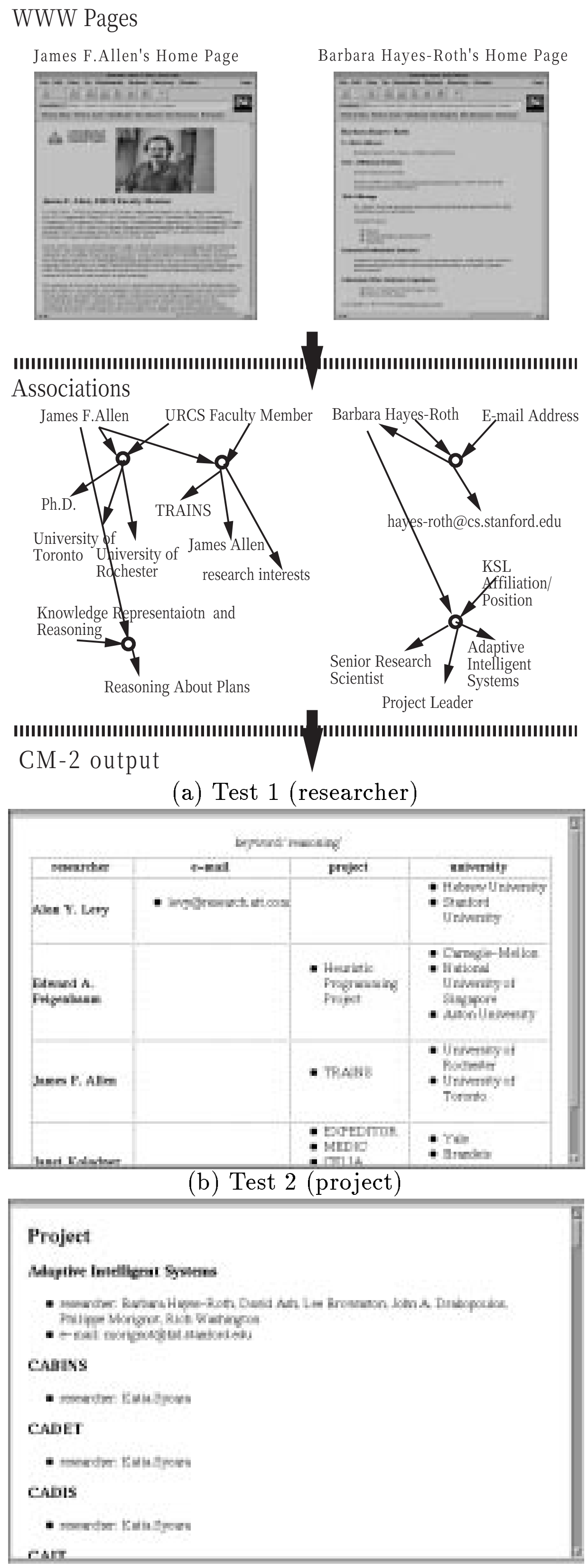



Figure 9: Information Gathering and Reorganization from WWW Pages

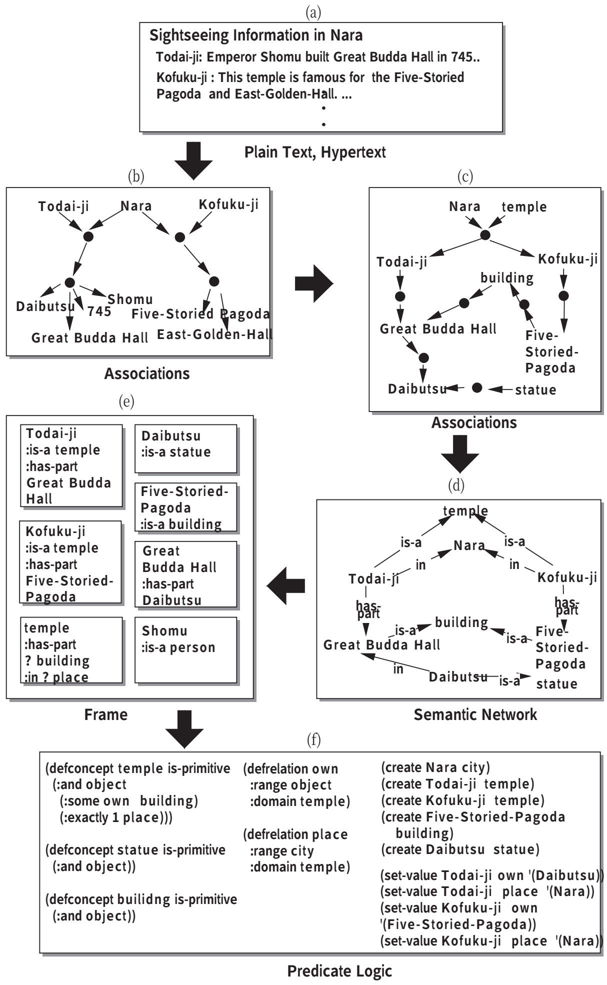



Figure 10: Ontology Development

## 5.2 Ontology Development

Ontology plays a central role in achieving large scale knowledge sharing. Unfortunately, development of ontology is often a quite painstaking and time consuming task, because it needs much effort to collect and select terms through task analysis. We have applied our approach based on the weak information structures to ontology development. It allows for data-driven ontology development, by accumulating raw data and incrementally creating the structure of concepts through human-computer collaboration (raw data → associations → refined associations → semantic networks → frames → predicate logic) . The overall process of our approach is shown in Figure 10.

We gave 30 WWW pages concerning ARPA Intelligent Integration of Information (I3) Initiative [2] to CoMeMo Incorporator. Each page contains overview of projects which belong to the I3 Initiative. The CoMeMo Incorporator generated associations. Generated associations themselves are incoherent and can-

[2] http://dc.isx.com/I3/

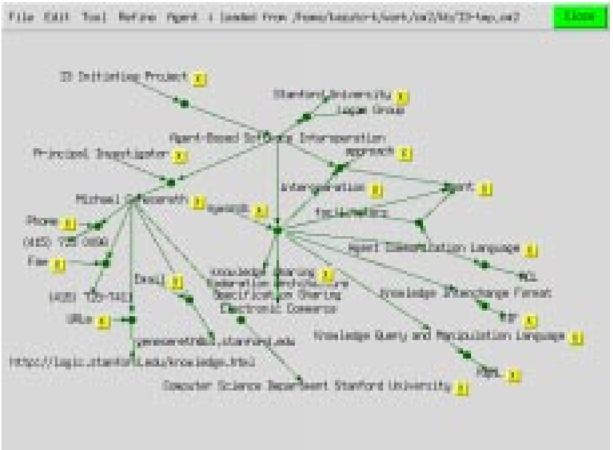


Figure 11: An Example Result of Refined Associations

not be used as ontology as they are. Users and computers collaborated to form these associations into more coherent structure on the CoMeMo Workbench. Figure 11 shows an example result of refined associations concerning the project "Agent-Based Software Interoperation". It corresponds to level c ontology (refined associations) in Figure 10. See [6] for details.

### 5.3 Education Support

A high school teacher Mr.Moriyama has developed a system called CALON based on the CoMeMo Workbench which helps high school students learn Japanese history. He used the system at the classroom for one year and evaluated it.

CALON allows teachers to express their knowledge and students to access the contents of textbooks.

He evaluated how students understand the semantics of associations written by himself. He created associations from historical facts. 41 students tried to convert these associations into natural language texts. He found that 90% students could do the above tasks.

Next, he examined how students create associations from natural language texts in textbooks. From this experiment, he found how students understand the historical facts. See [7] for details.

### 5.4 Conference Support

We have implemented a shared-card information system to support community information sharing called InfoCommon, which is a prototype of the CoMeMo Mobile Terminal.

We evaluated the usefulness of InfoCommon at the ICMAS'96 (Second International Conference on Multiagent Systems) Mobile Assistant Project[13], which is the world first experiment in applying mobile computing systems to community support. 100 personal intelligent communicators with handy phones were loaned to conference participants to actually try out the system. Figure 12 is a photo taken in the Nara Park where an excursion was held, which shows how a user actually used InfoCommon.

Figure 12: InfoCommon in Use

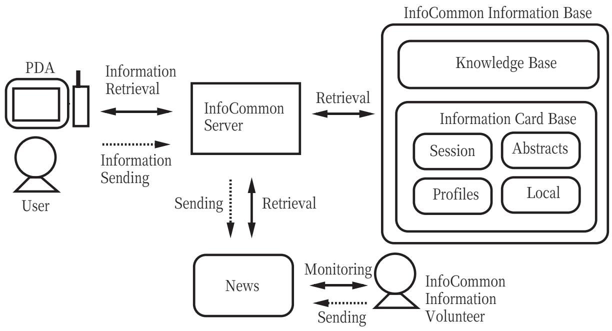



Figure 13: Overview of InfoCommon

InfoCommon provides visual interface for retrieving and sending information cards. Figure 14 shows a screen image of InfoCommon. The relation between two information cards is displayed by a link. InfoCommon information base consists of (a) a knowledge base which links keywords and information cards using the weak information structure and (b) an information card base as shown in Figure 13.

InfoCommon information bases store static information such as abstracts of papers, session, local information and profiles to share information among participants.

InfoCommon supports the following functions.

**Content-based Information Retrieval** Given a set of keywords, InfoCommon will respond with the set of information cards connected to the keywords. The result of retrieval is stored in the user's local information base where the user can re-arrange the collection of information cards, and add/remove nodes/links as desired.

**Information Sending (Posting News)** InfoCommon is built on a conventional News service. Users can add information cards on their local information base and send them to a News server.

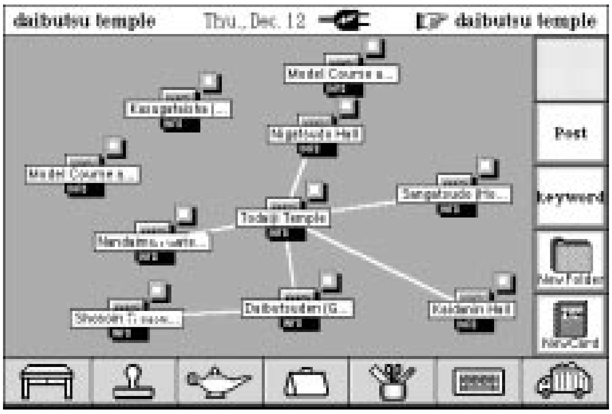



Figure 14: Screen Image of InfoCommon

The following results indicate the system's usefulness for information sharing in community: (a) 51% of users were satisfied of the system, (b) 81% felt search results were fine and (c) 55% answered that the system was useful for getting information they need. We consider the results are supporting evidence of the effectiveness of the weak information structure for information sharing in community. See [14] for details.

## 6 Related Work

Our work is related to recent work on information gathering from heterogeneous sources on Internet ([16],[17],[18],[19],[20]). Instead of focusing on the strategies and heuristics for information gathering, we concentrate on how to classify information obtained from multiple information sources and integrate it into personal information spaces.

CYC[21] and ARPA Knowledge Sharing Effort[10] have made a significant contribution in the sense they shed light on the importance of knowledge and information sharing and that they have presented a self-completed computational model. Their approach orients computer information sharing while ours is for human information sharing.

Gaines uses semantic networks as information representation for group knowledge sharing[22]. Our approach is based on much weaker information representation than semantic networks.

Kautz studied the use of agents in assisting and simplifying person-to-person communication for information gathering tasks[23]. They focus on the use of a software agent. We concentrate on the process of how humans create knowledge and information.

Sumi[24], Hori[25] and Kunifuji claim the importance of knowledge and information in the field of creative thinking support.

The basic recognition behind this research is a trade-off between the benefit from conceptually well-structured information representation and the cost for organizing information space. The more well-structured information representation becomes, the more useful it is for computational manipulation, however, the more expensive the cost of information acquisition and integration becomes.

Our approach is to provide a framework of collaborations between humans and computers to construct and share everyday memory with a low structural facilities and to facilitate raw information from vast information sources to be incorporated without much labor and gradually refined and elaborated as more insights are obtained.

## 7 Future Work

As information systems spread into human societies, supporting human interaction in community becomes more important. We think that one direction of future work is to support communication directly, such as matchmaking proposed by Ishida[26]. Other direction may be indirect support based on information sharing to find people who has information one needs.

The CoMeMo architecture supports to send and receive information produced in everyday life. We attempt to study knowledge creation on social networks which is proposed by Imai, Nonaka[27], and Hori[25] and so on.

## 8 Concluding Remarks

We described the CoMeMo project for constructing and sharing everyday memory in a group or in a community. The basic hypothesis is that connecting information without defining the semantics using the weak information structures is effective to deal with a large amount of diverse information. We implemented the CoMeMo Workbench, the CoMeMo Incorporator and a prototype of the CoMeMo Mobile Terminal. We evaluated applications based on the CoMeMo architecture.

In addition to experiments stated in this paper, we are currently investigating cognitive modeling on how humans create the weak information structures and how humans understand the semantics of the weak information structures using their tacit knowledge.

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