



HAL
open science

A Spatial Knowledge Sharing Platform Using the Visualization Approach

Jiang-Liang Hou, Sang-Tsz Pai

► **To cite this version:**

Jiang-Liang Hou, Sang-Tsz Pai. A Spatial Knowledge Sharing Platform Using the Visualization Approach. *International Journal of Production Research*, 2008, 47 (01), pp.25-50. 10.1080/00207540601011535 . hal-00512951

HAL Id: hal-00512951

<https://hal.science/hal-00512951v1>

Submitted on 1 Sep 2010

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



A Spatial Knowledge Sharing Platform Using the Visualization Approach

Journal:	<i>International Journal of Production Research</i>
Manuscript ID:	TPRS-2006-IJPR-0366.R1
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	26-Aug-2006
Complete List of Authors:	Hou, Jiang-Liang; National Tsing Hua University, Dept of Industrial Engineering and Engineering Mgmt Pai, Sang-Tsz; National Tsing Hua University, Department of Industrial Engineering and Engineering Management
Keywords:	MANUFACTURING INFORMATION SYSTEMS, BUSINESS INFORMATION SYSTEMS
Keywords (user):	Knowledge Visualization, Knowledge Management



1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

A Spatial Knowledge Sharing Platform Using the Visualization Approach

Submitted to

International Journal of Production Research

(1st Revision)

Jiang-Liang Hou*

Associate Professor

Department of Industrial Engineering and Engineering Management

National Tsing Hua University

Hsinchu (300), Taiwan

Tel: 886-3-5742658 Fax: 886-3-5722685

adamhou@ie.nthu.edu.tw

Sang-Tsz Pai

Graduate Student

Department of Industrial Engineering and Engineering Management

National Tsing Hua University

Hsinchu (300), Taiwan

Tel: 886-3-5715131 Ext. 3981 Fax: 886-3-5722685

* Corresponding author

A Spatial Knowledge Sharing Platform Using the Visualization Approach

Abstract

Applications of information technologies have significantly improved efficiency of electronic document processing and management. The speed and amount of knowledge accumulation in the cyberspace have exceeded what common users can perceive. In order to enhance the efficiency and accuracy for knowledge receivers to acquire domain knowledge, an appropriate knowledge representation scheme is required. Most of the traditional schemes for explicit knowledge representation are text-oriented and much time is required for knowledge receivers to recognize the contents, especially for the spatial knowledge (e.g., the geographical or assembly information). This research develops a knowledge visualization methodology that computer systems can automatically convert the textual knowledge into visualized display. In addition to the proposed methodology, a Web-based prototype system is developed to support spatial knowledge sharing. In the prototype system, the free-form documents with spatial knowledge can be converted into formatted ones and the corresponding visualized display can be established based on the formatted contents. Feasibility and effectiveness of the proposed model are evaluated via a demonstration case. The goal of this research is to provide a knowledge visualization approach that can be widely applied in enterprise e-training to enhance the effectiveness of enterprise knowledge reuse.

Keywords: Knowledge Visualization, Knowledge Management, Knowledge Representation, Fragmentation, Virtual Reality Modeling Language (VRML).

1. Background

Due to the rapid accumulation of enterprise knowledge and the need for enterprise knowledge management, the traditional approach used to enhance acquisition of enterprise knowledge is teaching by domain experts (Moody et al., 1998; TerjeKarlsen and Gottschalk, 2004). However, such an approach is not cost effective since it requires professionals to extract and provide their expertise and therefore enterprises have to rely on experts for

1
2
3
4 knowledge sharing. Furthermore, in view of the space and time limitations of training, the
5 enterprise knowledge sharing model should be re-engineered (Hou and Lin, 2004).
6 Knowledge acquisition would be more efficient in speed and accuracy if the visualization
7 approach (e.g., illustration or animated simulation) can be utilized to display the knowledge
8 contents. In this way, knowledge receivers can improve their efficiency in knowledge
9 recognition and increase their willingness in knowledge acquisition (Liebowitz, J., 2004;
10 Gottschalk and Khandelwal, 2004).
11
12
13
14
15
16
17

18 The text-based knowledge and the knowledge sharing mechanism via traditional
19 education usually have the disadvantages of insufficiency and the lack of concrete expression
20 of knowledge contents. Therefore, if knowledge is presented via a visualization mechanism,
21 the spatial contents of knowledge can be illustrated. Due to the experiences of human beings,
22 the visualized representation mechanism is more direct and efficient in knowledge
23 representation and absorbing. In order achieve the above aims brought by knowledge
24 visualization, the text-based knowledge should first be analyzed and parsed based on its
25 vocabulary structure. Then the literal content should be converted into corresponding
26 illustration and orientation via visualization or simulation techniques to assist the knowledge
27 receivers in knowledge acquisition. That is, with the knowledge visualization approach,
28 knowledge expression could be more user-friendly and the knowledge acquisition and
29 application could also be more efficient. The high efficiency of self-learning successfully
30 gets rid of the deflection of space and time limitations during knowledge sharing and thus the
31 cost of knowledge sharing could be reduced.
32
33
34
35
36
37
38
39
40
41
42
43
44
45

46 Recently, the knowledge visualization concept has been applied to establish relations
47 between objects in knowledge documents by deduction principle or to represent the
48 hierarchical structure of knowledge contents. Such applications can assist document
49 receivers to explore the overall distribution and structure of knowledge documents.
50 However, in these applications, knowledge contents and meaning cannot be correctly and
51 accurately expressed. Furthermore, previous research focuses mainly on natural language
52 (NL) processing and complicated and time-consuming processes are required for knowledge
53 content analysis. Automatic and rapid identification of semantic structure of the knowledge
54 contents cannot be achieved. This research utilizes the representation and identification
55
56
57
58
59
60

1
2
3
4 methodologies of spatial knowledge and establishes the domain thesaurus, rule database and
5
6 illustration bank to automatically analyze the semantic structure of spatial knowledge within
7
8 domain documents and generate the visualized display of spatial knowledge. As a result, the
9
10 knowledge contents can be concretely and efficiently represented for the knowledge receivers.

11
12 This paper is organized as follows. In Section 2, the related studies about applications
13
14 of the visualization technology and knowledge visualization are surveyed. The algorithms
15
16 for identification and visualization of the spatial knowledge are represented in Section 3.
17
18 Section 4 introduces the web-based spatial knowledge service platform developed in this
19
20 research. Feasibility and performance of the proposed models are evaluated in Section 5.
21
22 Conclusions are given in Section 6 to show some useful extensions of the proposed model.

26 27 **2. Literature Review**

28
29 This research emphasizes application of the visualization approach on spatial knowledge
30
31 representation. Previous literature about applications of the visualization technology and
32
33 knowledge visualization is reviewed in the following subsections.

34 35 36 37 **2.1 Applications of the Visualization Technology**

38
39 With the rapid development of information technologies, the 3D image processing
40
41 technique has gradually taken the place of the traditional 2D plane technique. This trend
42
43 enables the 3D technique to be extensively applied in different applications. Recently, with
44
45 the development of multi-media technologies, virtual reality (VR) has emerged to be one of
46
47 the popular technologies. Owing to the rapid calculation, drawing, animation processing of
48
49 personal computers, the computer hardware and software can be used to simulate the real
50
51 environment or real objects and thus users can acquire the learning and training materials in
52
53 an instant and interactive environment. The characteristics (e.g., imagination, immersion
54
55 and interaction) of the visualization technology can be utilized to provide users a more
56
57 interactive channel for information sharing (Li, 2003).

58
59 Due to the great advancement of network communication bandwidth, instant and
60
visualized interaction through network has become one of the major approaches for

1
2
3
4 information transmission. The 3D visualization software is powerful in processing and
5
6 representing different types of information. Currently, the 3D software that is widely applied
7
8 in real cases is 3D Studio MAX, VRML and Java 3D:
9

- 10 ➤ 3D Studio MAX: 3D Studio MAX is developed by Autodesk for 3D animation. Its
11
12 sophisticated functions can be divided into four main modules including modeling,
13
14 compiling, scene and animation. Among the traditional researches, 3D Studio MAX
15
16 has been used as an animation platform for customized digital body (Wu, 2003) or used
17
18 to set up VR scene to simulate driving behaviors.
19
- 20 ➤ VRML: VRML refers to Virtual Reality Modeling Language. Based on the hyper-text
21
22 concept of HTML, VRML mainly defines a set of presentation standards of 3D graphs,
23
24 by which Internet users are able to browse 3D illustrations. VRML is an
25
26 object-oriented modeling language deployed with illustrations to describe 3D scenes and
27
28 to display the 3D objects. In addition, it enables instant and distant interactions among
29
30 Internet users (Wang, 2001; Chiou, 2000; Cao, 2000). VRML can also be used to
31
32 develop 3D homepage design systems and Web page designers can easily establish 3D
33
34 homepages without the knowledge of 3D language (Xue et al., 1999; Wasfy et al., 2004;
35
36 Zhang, 2001).
37
- 38 ➤ Java 3D: Java 3D is a program library that can be applied in Java platform for creating
39
40 3D objects. The library was designed based on the object-oriented concept. Java 3D
41
42 was utilized to assemble the 3D components in database and to simulate the operation of
43
44 mechanisms. The engineering information presented in a 3D simulation environment
45
46 can be served as the communication channel between enterprises and clients (Chen,
47
48 2003).
49

50 In addition, in the current 3D interactive environment, more and more applications call
51
52 for visualized presentation of instant operations. The related applications involve
53
54 educational training, medical treatment and civil engineering, etc. As the 3D representation
55
56 mechanism is applied in educational training, users can interact with each other in the virtual
57
58 environment. Previous research has indicated that users in the VR environment could
59
60 effectively and efficiently receive information (Jan, 2002) and interact with computer systems
(Erenay, Hashemipour and Kayaligil, 2002). Furthermore, dynamic materials can be

1
2
3
4 converted into 3D animation and be converted to interactive e-learning materials. With 3D
5
6 software, animation modeling could be accomplished so that users can initiatively observe
7
8 objects in any direction of a 3D space (Chu, 2002).
9

10 In the fields related to medical treatment, the 3D VR technique with 3D medical video
11 and medical raster display can be brought into telemedicine systems (Chang, 1999). In
12 addition, the virtual reality technique can be used to develop a computer-aided simulation
13 system for intravenous injection and the operators can efficiently learn and practice the related
14 procedure for intravenous injection (Hsiao, 2001).
15
16
17
18
19

20 As to civil engineering, after selection and analysis of the project blueprints, a 3D VR
21 structure model proportional to the real one can be produced and users can quickly acquire the
22 related information of the construction projects through the visualized interface (Hong, 2002;
23 Yan, 2001).
24
25
26
27
28
29

30 **2.2 Knowledge Visualization**

31
32 Previous studies about knowledge management focus mainly on knowledge discovery
33 (Neaga and Harding, 2005), knowledge extraction (Hou, Chuo, and Sun, 2003) and
34 knowledge reuse (Shaw and Edwards, 2006). Concerning the knowledge sharing issues, the
35 visualized display of information or knowledge can bring users into image and enhance their
36 comprehension and cognition about the aim of learning. The traditional approach of
37 representing the knowledge in text or in plane illustration has the defecion of information
38 insufficiency. With the 3D visualized simulation technique, knowledge can be represented
39 via the visualization mechanism. Due to the similar experience in visualization of human
40 beings, visualized knowledge representation is more direct and efficient for users to acquire
41 knowledge. The visualized knowledge representation mechanisms can be divided into
42 knowledge map representation and knowledge level representation. With The knowledge
43 map representation mechanism, the knowledge contents and their corresponding relationship
44 can be depicted via the landscape map. In the knowledge level representation mechanism,
45 the relationship of knowledge contents can be represented via directories or a hierarchical
46 tree.
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4 A knowledge map displays the knowledge structure in the form of map to show the
5 relevance of knowledge. Knowledge maps can be classified into three sub-categories (Tsai,
6 2002):
7
8

- 9
- 10 ➤ Conception knowledge map: Characterizing of the themes and conceptions of knowledge
- 11
- 12 ➤ Workflow knowledge map: Composed of a series of activities
- 13
- 14 ➤ Ability knowledge map: Used to explore relation between knowledge and human beings
- 15

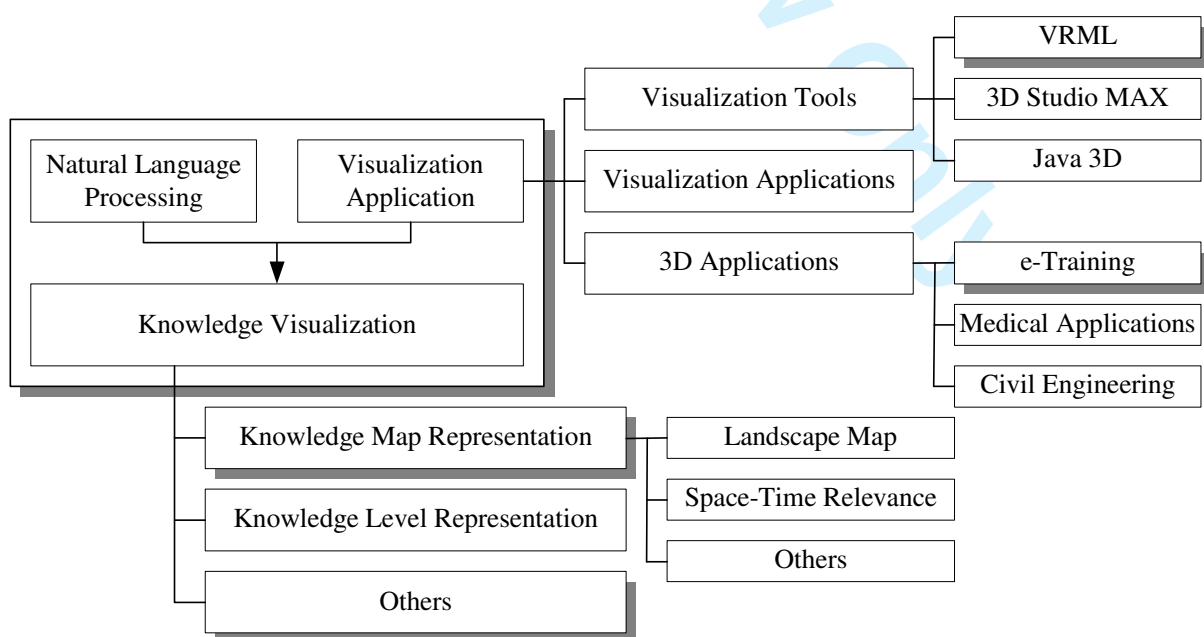
16 The display methodologies of knowledge maps can be divided into landscape map and
17 visualization of space-time relevance. The landscape map shows the knowledge and concept
18 structure in the form of map or graph (Hadley, 1996). Large amount of knowledge is
19 marked according to its characteristics and information and knowledge with high correlation
20 is clustered and linked. The marked and linked information will be presented visually on the
21 map. The structural map expression makes it easier for users to be acquainted with the
22 complicated relevance and meanings of knowledge (Chen and Paul, 2001; Morris et al., 2002;
23 Yeap et al., 2003). With a 3D space composed of longitude, latitude and time, visualization
24 of space-time relevance is a special model showing the relation between time and space
25 information in the documents (Hewagamage and Hirakawa, 2001; Yost et al., 1997).
26
27

28 Knowledge level representation categorizes the disordered information according to its
29 attributes in order to obtain the visualized hierarchical structure of information. Lou et al.
30 (2000) categorize information visualization into three levels namely basic visualization,
31 conceptual visualization and evolutionary visualization and propose different process models
32 for distinct information visualization levels. Kanno et al. (1999) establish a visualized
33 e-training support system and present a four-level knowledge model (i.e., configuration,
34 causality, state and goal) to describe the domain knowledge. Ohwada and Mizoguchi (2003)
35 utilize the information visualization and retrieval techniques in Internet knowledge searching.
36 A 3D hyperbolic tree is used to reveal the linkage structure of Web pages and user preferences
37 for the Web pages. In addition to exploring the level relation of knowledge, the Web pages
38 that do not meet user preferences can be filtered out to enhance accuracy of information
39 retrieval. Other knowledge visualization concepts include the visualized teaching algorithm
40 (Hanson et al., 2002), knowledge-based multimedia medical distributed database system
41 KmeD (Chu et al., 1995) and the integrated knowledge visualization scheme with three
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

fundamental views (i.e., knowledge type, recipient type and visualization type) (Burkhard, 2004).

In general, compared with the previous research, the achievements of this research can be shown in Figure 1. Those with shaded areas are the topics (i.e., knowledge content analysis and visualization) emphasized in this paper. Previous studies focus mainly on natural language processing for knowledge content analysis. The knowledge visualization concept has been applied to establish relations between objects in knowledge documents by deduction principle or to represent the hierarchical structure of knowledge contents. Such applications can simply assist document receivers to explore the overall distribution and structure of knowledge documents. However, in these applications, knowledge contents and meaning cannot be correctly and accurately expressed. In this research, the knowledge contents and meaning are taken into consideration for visualization. As a result, the knowledge receiver can more accurately recognize the knowledge contents.

On the other hand, the visual display has many advantages for learning and applied commonly in software learning/help applications. However, different from the other studies, this research recognizes the advantages of visual display and thus proposes a model to automatically convert the text-based contents into visualized display. As a result, rely on domain experts for generating the visual display can be reduced



1
2
3
4 Figure 1. The research roadmap about knowledge visualization
5
6
7

8 **3. Visualization Model for Spatial Knowledge** 9

10 As shown in Section 2, in most of the previous research, the clusters or structural relation
11 is presented in the form of graphs or hierarchical structure via the knowledge visualization
12 technique. However, few papers are concentrated on the visualization of spatial knowledge
13 contents. Therefore, in this research, the Cartesian coordinates are used to visualize the
14 spatial knowledge represented in text. The visualization model for spatial knowledge first
15 explores the standardized format for spatial knowledge expression (Pai and Hou, 2005). The
16 standardized format can be represented as a geographic information matrix M:
17
18
19
20
21
22
23
24
25

$$26 M=[\text{Object point, Reference point, Position, Proportion, Distance}]$$

27
28
29
30

31 Taking the sentence “A is on the right of B, 10 meters away” for example, the free form
32 sentence can be converted into a geographic information matrix with the object point (A),
33 reference point (B), position (right), proportion (meter) and distance (10):
34
35
36
37
38

$$39 M=[A, B, \text{right, meter, } 10]$$

40
41
42

43 Based on the derived information matrix, an attribute comparison procedure for
44 information visualization can be carried out and the visualized display of knowledge contents
45 can be obtained. The procedure for knowledge visualization can be illustrated via Figure 2.
46 The free-form documents should first be converted into the formatted information matrix via
47 knowledge structure analysis (Pai and Hou, 2005). First, a thesaurus containing three
48 predefined tables (object, position and unit tables) and a rule database are established to
49 denote the domain terms and semantic rules for expressing spatial knowledge. Then
50 contents of a free-form document are fragmented into meaning units via a document
51 fragmentation algorithm (Hou and Lin, 2005). The fragmented meaning units of each
52 sentence are compared with the predefined thesaurus and rule to identify roles of the meaning
53
54
55
56
57
58
59
60

units in a sentence and thus a geographic information matrix can be established for each sentence containing spatial knowledge. For instance, "Proportion" in the geographic information matrix M denotes the unit (e.g., meter) used in the target sentence and can be automatically extracted by looking up a predefined unit table. Since the distance between the object and reference points is usually expressed via a numeric value followed by a unit, Distance in the geographic information matrix M can be automatically obtained by extracting the numeric value followed by a unit.

The formatted contents can be further converted into visualized display by looking up predefined tables, e.g., Object Relation Table, Direction Definition Table, Object Definition Table and Unit Conversion Table (details about these tables are provided in the following).

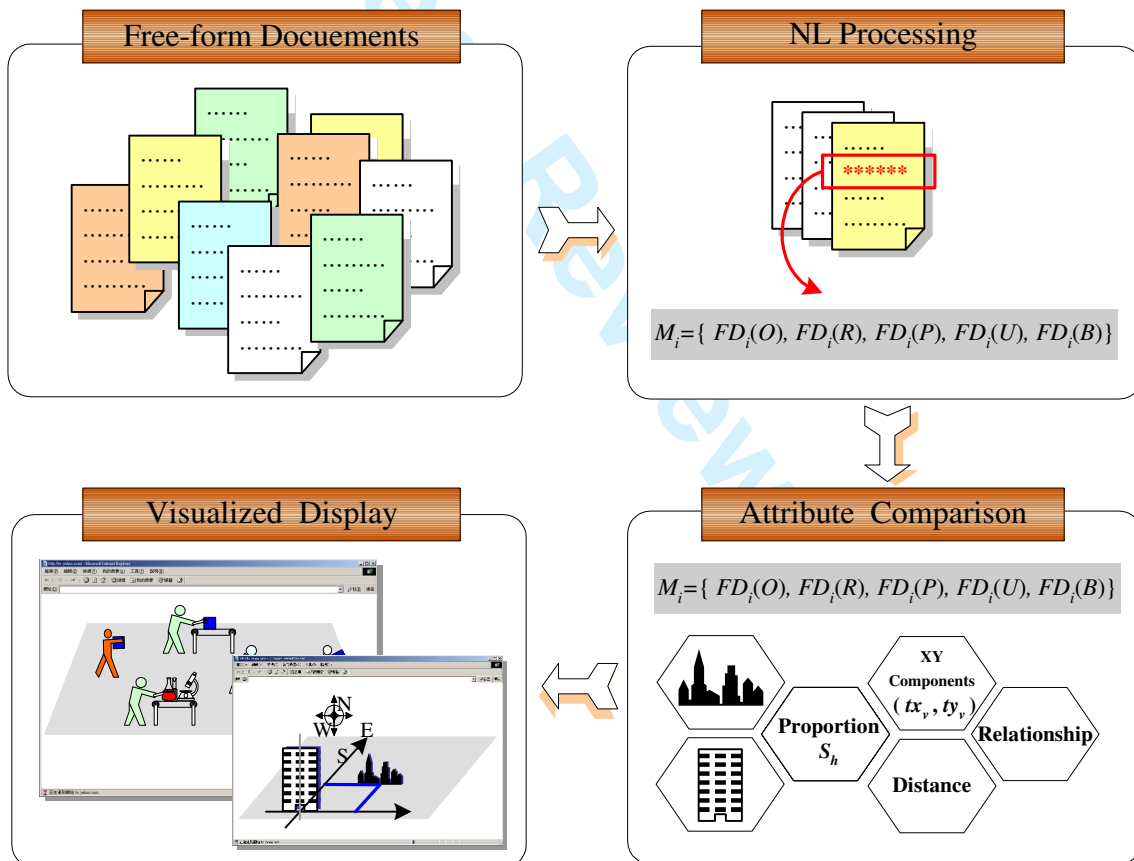


Figure 2. Procedure for knowledge visualization

Before discussing details of the knowledge visualization procedure, the symbols used in the proposed methodology are defined as follows:

A_m	The region attribute of the m'th relation rule INC_R_m in Object Relation Table
B_i	The distance attribute in the i'th information matrix M_i of the target document
INC_R_m	The m'th relation rule in Object Relation Table
L_m	The location attribute of the m'th relation rule INC_R_m in Object Relation Table
O_i	The object point in the i'th information matrix M_i of the target document
P_i	The position attribute in the i'th information matrix M_i of the target document
R_i	The reference point in the i'th information matrix M_i of the target document
S_h	The conversion ratio of U_h with respect to meter
T_v	The v'th direction described in Direction Definition Table
tx_v	The X component of T_v
ty_v	The Y component of T_v
UC_h	The h'th unit defined in Unit Conversion Table
U_i	The unit attribute in the i'th information matrix M_i of the target document

Since some critical information including distance, object illustration, unit conversion is required for spatial knowledge visualization, four fundamental tables namely Object Relation Table, Direction Definition Table, Object Definition Table and Unit Conversion Table are established for mapping visualization information:

- Object Relation Table defines the relation between regions and sub-regions. As shown in Table 1, the relation rule INC_R_i defines that sub-region L_i is included in region A_i . That is, the object relation rules can be used to identify if two regions have subordination relation.

Table 1. Object Relation Table

	Rule ID	Region	Sub-region
1	INC_R_1	A_1	L_1
2	INC_R_2	A_2	L_2
...
i	INC_R_i	A_i	L_i
...

- Direction Definition Table can be used to define the direction P_i in information matrix M_i (as shown in Table 2). After looking up the table, the corresponding unit vector t_v of direction P_i can be applied to identify the relative position of objects in the information matrix for knowledge visualization.
- Object Definition Table can be used to map the object point O_i or the reference point R_i in the information matrix M_i to the corresponding path and file name PN_l of the visualized illustration C_l (as shown in Table 3).
- Unit Conversion Table can be used to convert the unit UC_h in the information matrix M_i into standard unit (i.e., meter) (as shown in Table 4). That is, the table lists the conversion ratios between the commonly used units and the standard unit.

The knowledge visualization methodology proposed in this research focuses on mapping the attributes in the information matrix to the related visualization parameters, including the subordination relation of objects and geographic definition of positions and directions. Details of the corresponding procedure are as follows.

Table 2. Direction Definition Table

	Direction ID	X Component	Y Component
1	T_1	tx_1	ty_1
2	T_2	tx_2	ty_2
...
v	T_v	tx_v	ty_v
...

Table 3. Object Definition Table

	Object Illustration	Path and File Name
1	C_1	PN_1
2	C_2	PN_2
...
l	C_l	PN_l
...

Table 4. Unit Conversion Table

	Unit	Conversion Ratio
1	UC_1	S_1
2	UC_2	S_2
...
h	UC_h	S_h
...

Step (A1): Determine the subordination relation

In the attribute mapping procedure, the attributes in the information matrix are converted into illustrations. First the subordination relation of the object point and reference point (i.e., O_i and R_i) should be determined via the rules in Object Relation Table (L_m). The concept can be expressed as follows:

If there exists INC_R_m that $O_i \in L_m$ and $R_i \in A_m$

Then O_i is in R_i (1)

Otherwise O_i and R_i are exclusive (2)

In case (1), there exists subordination relation between R_i and O_i , and O_i is contained in R_i . In case (2), R_i and O_i are mutually exclusive. The procedure for determining the subordination relation between the object point and reference point is shown in Figure 2.

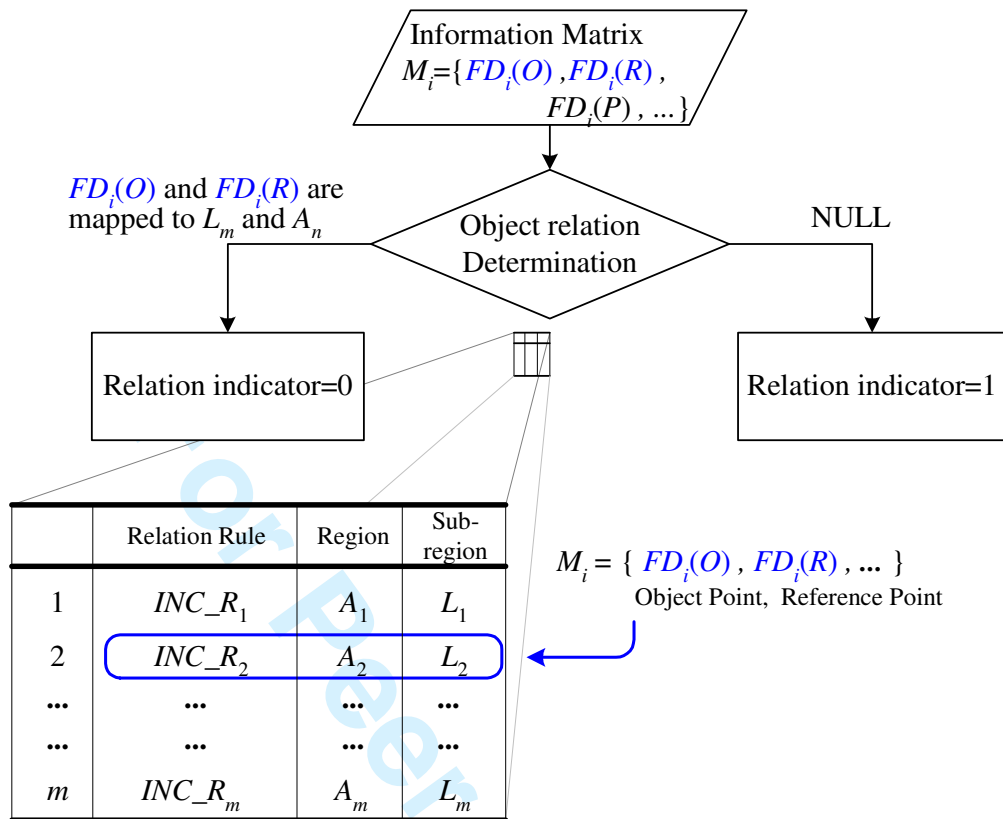


Figure 2. Procedure for subordination relation determination

Step (A2): Determine the respective direction of objects

After determining the subordination relation between the object point and reference point in Step (A1), the position attribute P_i in information matrix M_i should be mapped to the related direction T_v in Direction Definition Table. As a result, a unit vector (tx_v, ty_v) indicating the respective direction of the object point and reference point can be obtained (as shown in Figure 3).

Step (A3): Convert the unit

In this step, the unit attribute U_i in the information matrix M_i should be mapped to UC_h defined in Unit Conversion Table which denotes the ratio between the target and default units. That is, according to the unit used in the target sentence and the default unit (i.e., meter), the ratio used to determine size of the visualized display can be determined by looking up the table. As a result, the unit conversion ratio S_h can be obtained for determining the respective position of the object point O_i and reference point R_i (Figure 6).

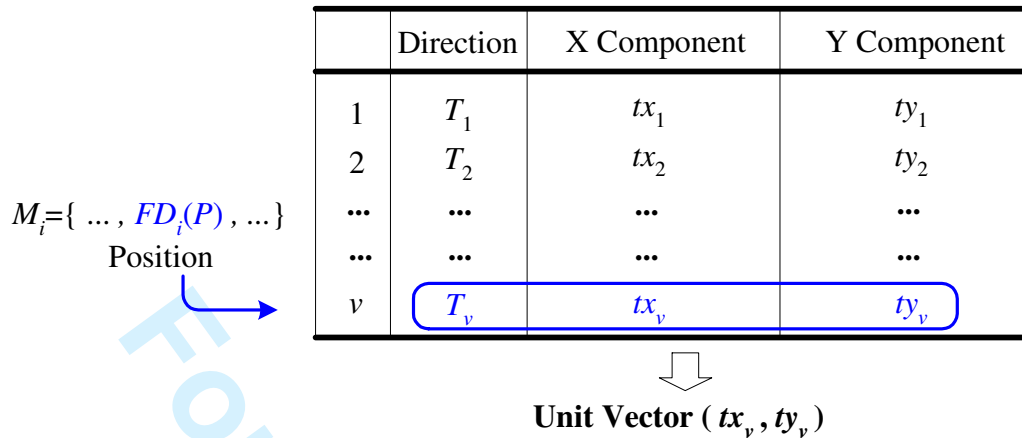


Figure 3. Respective position determination

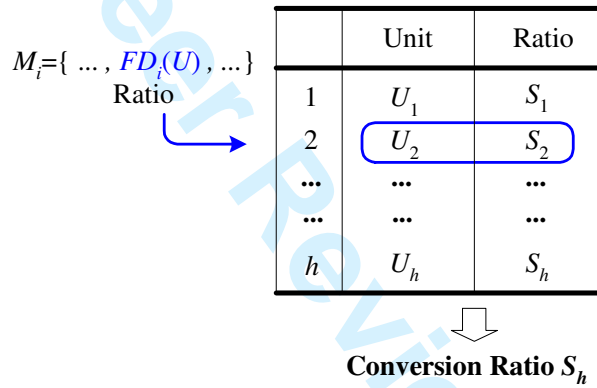


Figure 4. Illustration of Unit Conversion

Step (A4): Visualize knowledge contents

In this step, the related illustrations for knowledge visualization can be obtained after mapping the object point O_i and reference point R_i to Object Definition Table. The unit vector (tx_v, ty_v) and the conversion ratio S_h derived in Steps (A2) and (A3) can be used to generate the visualized display according to the subordination relation or exclusive relation determined in Step (A1). Without loss of generality, center of the illustration of the reference point is defined as the origin in the Cartesian coordinate and center of the object point is positioned on the $(B_i \times tx_v \times S_h, B_i \times ty_v \times S_h)$. The visualization process for the two distinct subordination relations is illustrated in Figure 5.

The entire procedure for knowledge visualization is revealed in Figure 6. After the

above knowledge visualization procedure, the corresponding visualized display of the information matrix M_i can be generated. The proposed methodology provides a systematic procedure for spatial knowledge visualization via looking up the domain thesaurus. Owing to the user-friendliness and easiness of the visualized display, the knowledge contents can be efficiently captured by users. On the other hand, the traditional knowledge visualization mechanism that simply presents the information hierarchy is unable to accurately show the knowledge contents. Via the proposed approach in this research, the Cartesian coordinate as well as the predefined illustrations can be used to visualize the spatial knowledge expressed in text. Through knowledge visualization, users can efficiently and accurately acquire spatial knowledge.

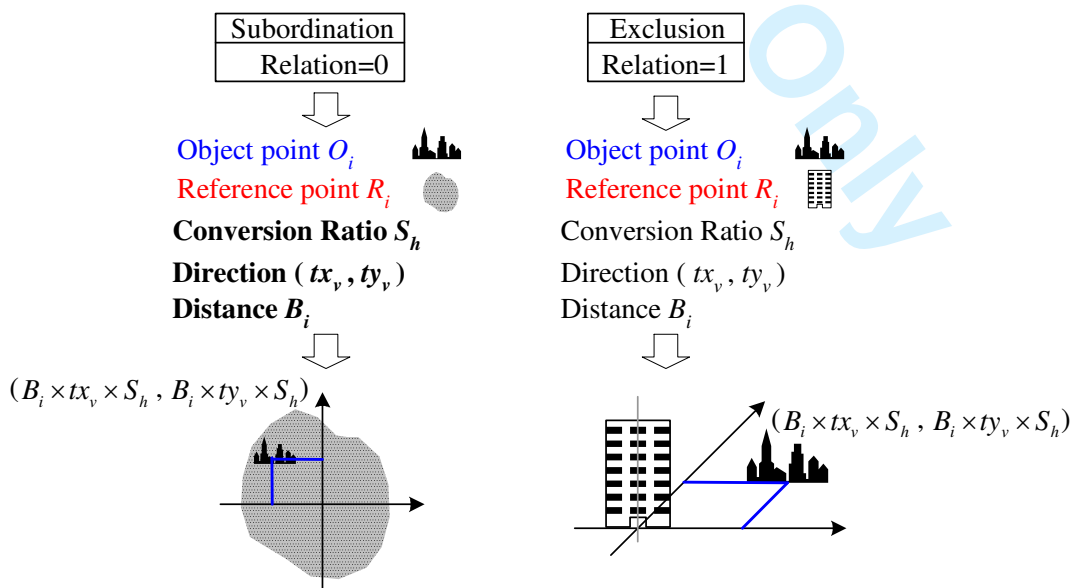
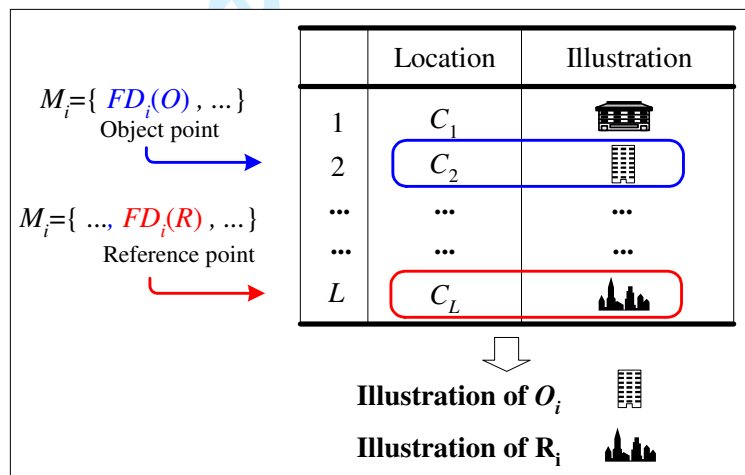


Figure 5. Knowledge visualization procedure for distinct subordination relation

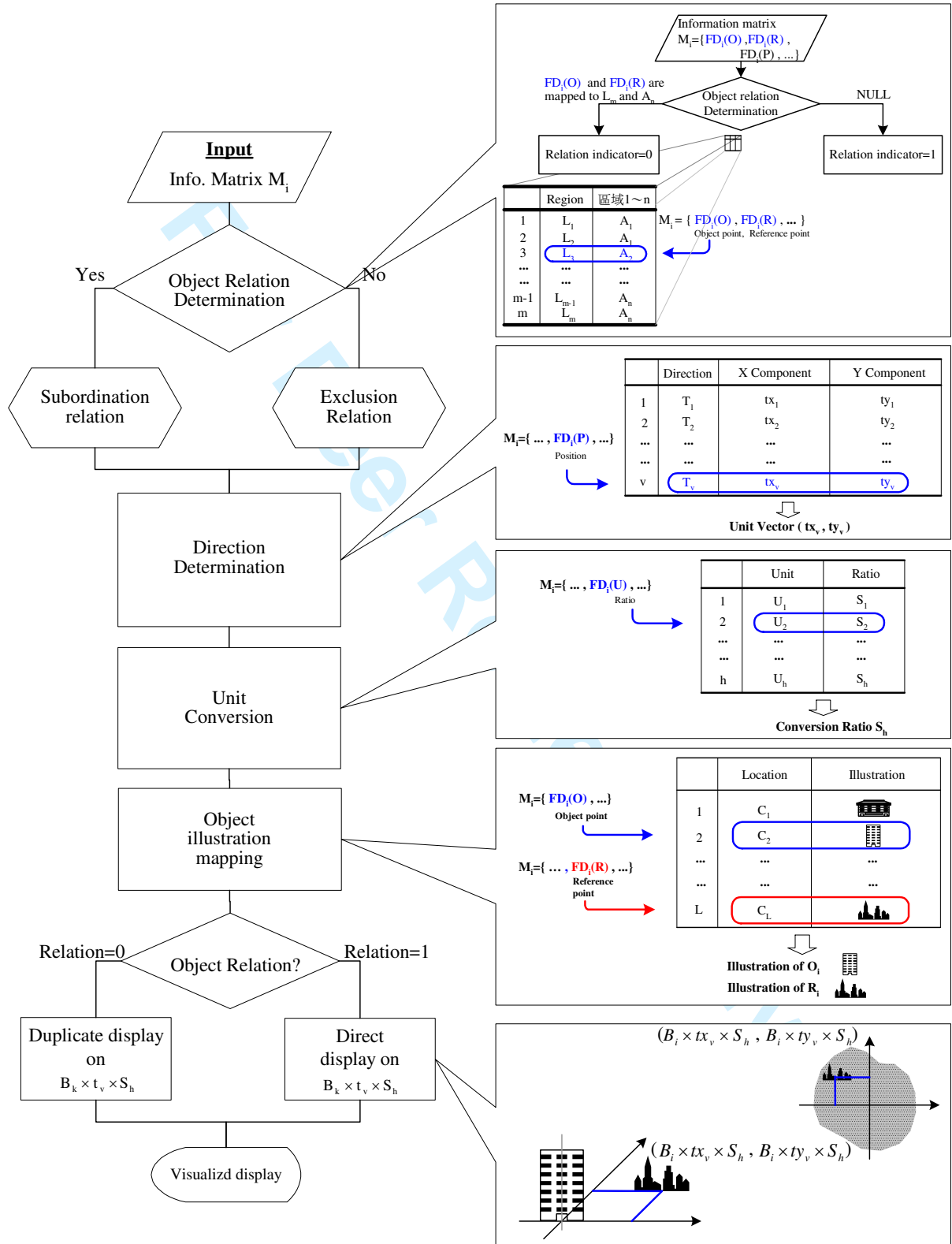


Figure 6. Knowledge visualization process

4. Spatial Knowledge Service Platform

In addition to the knowledge visualization algorithm, another purpose of this research is to develop a spatial knowledge service platform over the Internet. In the service platform, a semantic analysis module is developed to acquire and analyze the spatial knowledge in the free-form documents. On the other hand, a visualization module is developed for spatial knowledge visualization and presentation. Users can access the spatial knowledge service platform via the browser to share and manage the knowledge for visualization. There are five main modules namely Document Import Module, Domain Thesaurus Maintenance Module, Visualized Illustrations/Information Maintenance Module, User Management Module and System Setting Module. The relationship of the modules and information access mechanism are illustrated in Figure 7.

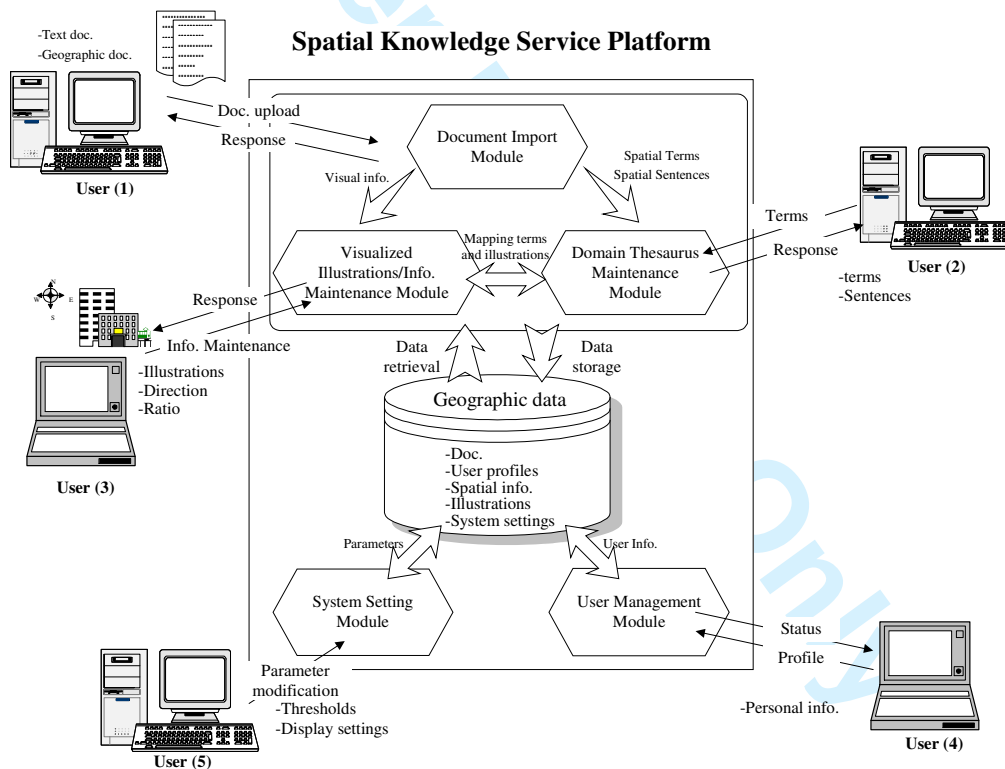


Figure 7. Operation framework of spatial knowledge service platform

In this section, the manual for PC component assembly is taken as a demonstration case to show the knowledge visualization capability of the proposed system. For a PC retailer,

1
2
3
4 most employees are temporary staff (or self-supporting students) of short work term and high
5 mobility. It usually costs the employers a lot of time and efforts to train the employees about
6 PC component assembly. However, once the employees quit or newcomers are recruited,
7 such time-consuming and costly training programs have to be resumed. It rather difficult for
8 the staff to get acquainted with the assembly processes of all types of computers. As the
9 knowledge visualization platform is applied in this domain, the technical personnel can equip
10 the system with manuals and illustrations about PC component assembly in advance.
11 Newcomers can acquire knowledge about PC component assembly by themselves and the
12 cost of human resources and time devoted in repetitive training can be reduced. Furthermore,
13 the system can facilitate staff's autonomous learning without limitations on time and space
14 and risk of expertise loss can be reduced. Functions of the platform for two distinct roles,
15 i.e., the knowledge provider (computer technicians) and the knowledge demander (new
16 employees), will be introduced in the following.

(A) Knowledge providers (computer technicians)

34 For a PC retailer, the computer technicians are the providers of PC component assembly
35 knowledge. The technicians are responsible for importing the manuals and illustrations of
36 PC components onto the system so that the knowledge demanders can acquire related
37 knowledge online. The technicians should maintain the following data:

- 38 ➤ Thesaurus about PC component assembly: Computer technicians can input the domain
39 vocabulary related to PC component assembly into the system via Domain Thesaurus
40 Maintenance Module (Figure 8) including IDs of computer components (e.g., "RAM" and
41 "CPU"), behaviors (e.g., "Install to", "Insert in" and "Link with") and location
42 descriptions (e.g., "Below" and "Above").
- 43 ➤ Illustrations of PC components: Illustrations of PC components can be maintained in the
44 system for visualized presentation of text-based descriptions. In addition, subordination
45 relation between components should also be identified to ensure correct visualization
46 (Figure 9).
- 47 ➤ Manuals for PC component assembly: As the manuals about PC component assembly are
48
49
50
51
52
53
54
55
56
57
58
59
60

imported onto the system via Document Import Module, the system will automatically analyze the uploaded files to identify the target sentences about assembly knowledge that can be represented visually. The target sentences are segmented and tagged to generate geographic information matrices. After mapping the information matrices with the domain thesaurus and illustrations, the related visual representation of the extracted target sentences can be displayed on the user interface and stored in the system database for the other employees to access. In addition, other materials about software and driver installation can be available to the staff as well (Figures 10 and 11).

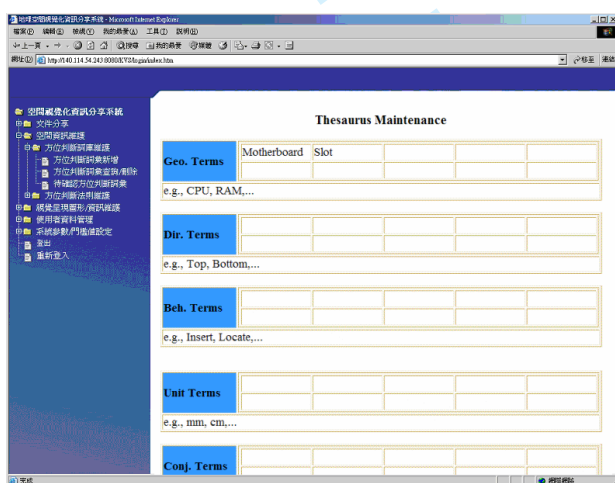


Figure 8. Thesaurus maintenance

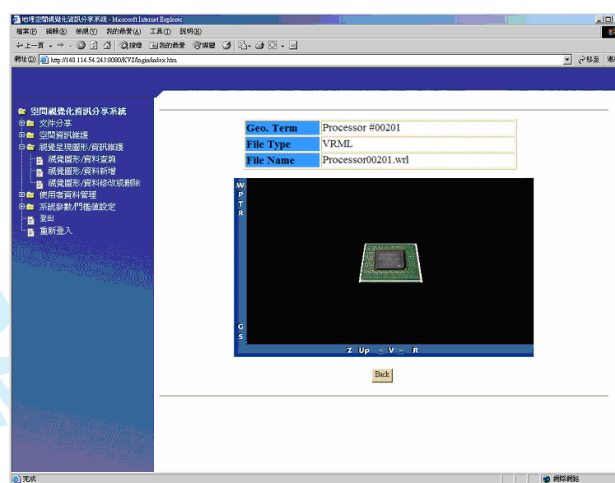


Figure 9. Illustrations maintenance

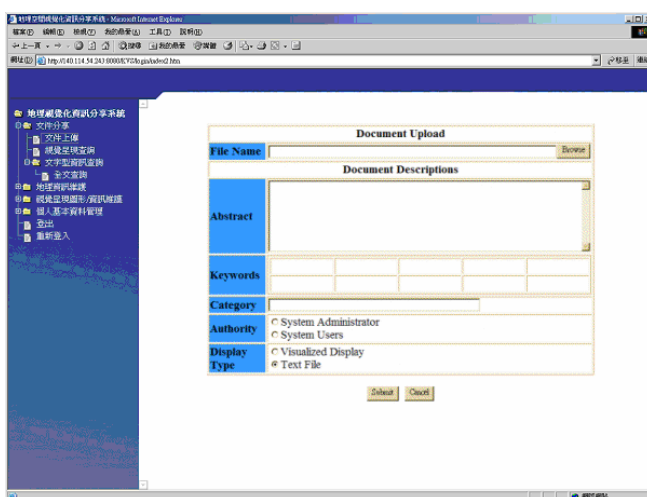


Figure 10. Domain document upload

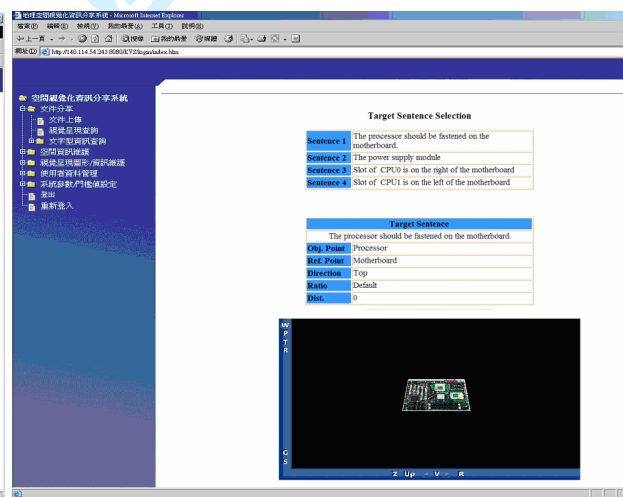


Figure 11. Target sentence identification

(B) Knowledge Demanders (new employees)

With assistance of the system, new employees can examine the outlooks of various PC

components in order to get familiar with the visual instructions about PC component assembly.

Three types of information available to knowledge demanders are as follows:

- Assembly information: New employees can realize the outlooks of all the PC components in the backend database via Visualized illustrations/Information Maintenance Module. As a result, new employees will not select the incorrect components during hardware installation (Figures 9 and 12).
- Text-based/visualized documents: New employees can acquire the documents uploaded by computer technicians via Visualized illustrations/Information Maintenance Module and learn PC assembly know-how by going over the illustrations. The non-spatial documents (e.g., installation instructions or notes) in pure text format are also available online (Figures 11 and 13).
- Documents for visualization: New employees can upload component assembly manuals by themselves through Document Import Module of the system. Contents of the manuals will automatically be analyzed and the corresponding visualized presentations can be generated for the other staff to browse. On the other hand, employees can also upload the visual illustrations of components to the database for more accurate visual display.

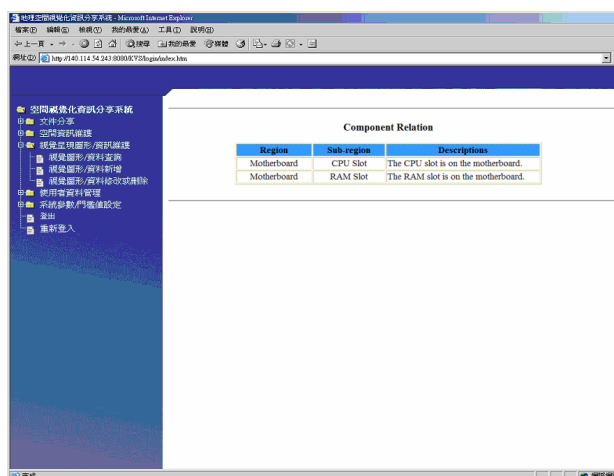


Figure 12. Component relation search

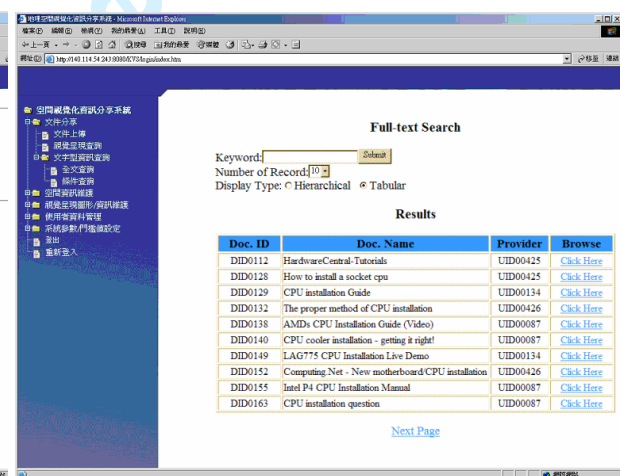


Figure 13. Full-text search

In summary, the thesaurus and illustrations used for spatial knowledge identification and visualization should be maintained in the platform via the interfaces of Figure 8 to Figure 9

1
2
3
4 respectively. Based on the predefined thesaurus and illustrations, the target document
5
6 uploaded onto the platform (via the interface of Figure 10) can be analyzed to extract and
7
8 visualize the spatial knowledge (via the interface of Figure 11).
9

10 11 12 **5. Performance Evaluation**

13
14 In order to evaluate the effectiveness of knowledge content analysis and visualized
15
16 presentation, visualization of the PC component assembly knowledge is selected for
17
18 demonstration.
19

20 21 22 **Evaluation Scenario**

23
24 At first, 62 manuals about PC component assembly are selected. The target sentences
25
26 describing the spatial knowledge are also identified from the manuals and 159 sentences are
27
28 selected for visualized presentation. Furthermore, the target sentences are segmented into
29
30 meaningful units and each segment is marked with appropriate tag to denote its role in the
31
32 geographic information matrix (i.e., object point, reference point, position, proportion or
33
34 distance). The analysis procedure is revealed in Figure 14. Among the 62 manuals, 10
35
36 manuals and 10 target sentences are randomly selected to test the reasoning accuracy of the
37
38 proposed methodology. In order to explore the learning capability of the proposed
39
40 methodology, eight test stages with different numbers of training sentences (i.e., 20, 40, 60, 80,
41
42 100, 120, 140 and 159 sentences) are carried out.
43
44

45 46 47 **Performance Indices**

48
49 In this research, six quantitative indices for target sentence identification, sentence
50
51 fragmentation and tagging, and information matrix generation are employed to evaluate the
52
53 performance of the proposed methodology.
54
55

56 57 (A) Target sentence identification

58
59 In a free-from document, the target sentences that express spatial knowledge will be
60
extracted and visualized. In the developed platform, a sentence with the attributes of “object

point”, “reference point” and “position” is regarded as a target sentence. That is, “proportion” and “distance” are considered as the required attributes for spatial knowledge representation and default values of “proportion” and “distance” are assigned to the target sentence without the two optional attributes. The parameters used to derived the recall rate and accuracy of target sentence identification are defined as follows:

- $R_S(Doc)$ Recall rate of target sentence identification
- $A_S(Doc)$ Accuracy of target sentence identification
- $N_{RS}(Doc)$ Number of nominal sentences for visual presentation
- $N_{TS}(Doc)$ Number of reasoned sentences for visual presentation
- $N_{CS}(Doc)$ Number of sentences in the intersection set of $N_{RS}(Doc)$ and $N_{TS}(Doc)$

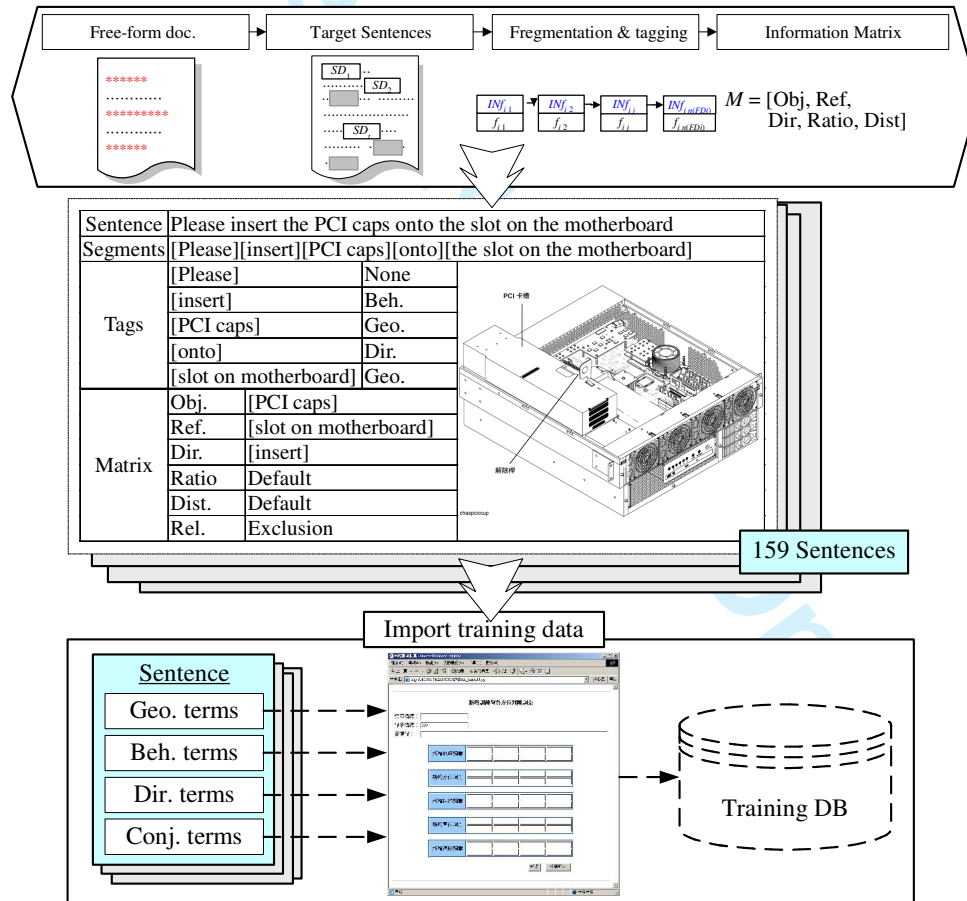


Figure 14. Target sentence identification and segmentation

The recall rate of target sentence identification ($R_S(Doc)$) denotes the system

performance in capturing the right target sentences. The accuracy of target sentence identification ($A_s(Doc)$) denotes correctness of the target sentences acquired. These two indices can be obtained as follows:

$$R_s(Doc) = \frac{N_{CS}(Doc)}{N_{RS}(Doc)}$$

$$A_s(Doc) = \frac{N_{CS}(Doc)}{N_{TS}(Doc)}$$

(B) Sentence fragmentation and tagging

The parameters used to derived the recall rate and accuracy of sentence fragmentation and tagging are defined as follows:

$R_M(SD)$	Recall rate of sentence fragmentation and tagging
$A_M(SD)$	Accuracy of sentence fragmentation and tagging
$N_{RM}(SD)$	Number of nominal segments to be fragmented and tagged in the target sentences
$N_{TM}(SD)$	Number of reasoned segments in the target sentences
$N_{CM}(SD)$	Number of segments correctly tagged

The recall rate of sentence fragmentation and tagging ($R_M(SD)$) represents capability of the system in fragmenting the target sentences into segments. The accuracy of sentence fragmentation and tagging ($A_M(SD)$) refers to correctness of the system in fragmenting the target sentences into segments. These two indices can be determined via the following equations:

$$R_M(SD) = \frac{N_{CM}(SD)}{N_{RM}(SD)}$$

$$A_M(SD) = \frac{N_{CM}(SD)}{N_{TM}(SD)}$$

➤ Information matrix generation

The parameters used to derived the recall rate and accuracy of information matrix generation are defined as follows:

$R_E(SD)$	Recall rate of information matrix generation
$A_E(SD)$	Accuracy of information matrix generation
$N_{RE}(SD)$	Number of nominal matrix elements corresponding to the target sentences
$N_{TE}(SD)$	Number of reasoned matrix elements corresponding to the target sentences
$N_{CE}(SD)$	Number of elements in the intersection set of $N_{RE}(SD)$ and $N_{TE}(SD)$

The recall rate of information matrix generation ($R_E(SD)$) refers to the system capability in parsing the target sentences into matrix elements. The accuracy of information matrix generation ($A_E(SD)$) represents correctness of the system in parsing the target sentences into matrix elements. These indices can be calculated as follows:

$$R_E(SD) = \frac{N_{CE}(SD)}{N_{RE}(SD)}$$

$$A_E(SD) = \frac{N_{CE}(SD)}{N_{TE}(SD)}$$

The above indices can be used in the eight test stages to evaluate performance of the developed system in spatial knowledge identification and visualization.

Result Analysis

(A) Target sentences Identification

As shown in Table 5 and Figure 15, the recall rate of target sentence identification is at the lowest (44.76%) at the first stage (with 20 training sentences) and climbs up with increase of training sentences (amount to 159 sentences) to reach the peak (96.67%; the corresponding standard deviation is 0.105). Except that the recall rate at the fourth stage (with 80 training sentences) is equivalent to that at the fifth stage (with 100 training sentences), the recall rates at all stages feature an upward trend, which reveals the learning capacity of the target sentence identification.

1
2
3
4 The accuracy of target sentence identification with 20, 40 and 60 training sentences
5 grows upward from 60.0%, 64.84% to 66.0%, while decreases by 11.33% to 54.67% with 80
6 training sentences. It indicates that the system performs poor in target sentence
7 identification at the early stages (with fewer predefined domain terms). The accuracy grows
8 slightly by 6.14% from the fourth stage to the eighth stage and it can be concluded that the
9 accuracy of target sentence identification features the learning capacity. Higher accuracy
10 can be achieved if the threshold value for target sentence identification can be adjusted with
11 respect to the number of predefined domain terms.
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 5. Performance of target sentences identification indices

Target sentence identification		Number of training sentences at each stage							
		20	40	60	80	100	120	140	159
Recall rate	Average	44.76%	69.29%	78.33%	78.33%	78.33%	86.67%	93.33%	96.67%
	Std. Dev.	0.363	0.363	0.295	0.295	0.295	0.233	0.141	0.105
Accuracy	Average	60.00%	64.83%	66.00%	54.67%	54.67%	56.71%	59.38%	60.81%
	Std. Dev.	0.446	0.371	0.281	0.306	0.306	0.280	0.268	0.253

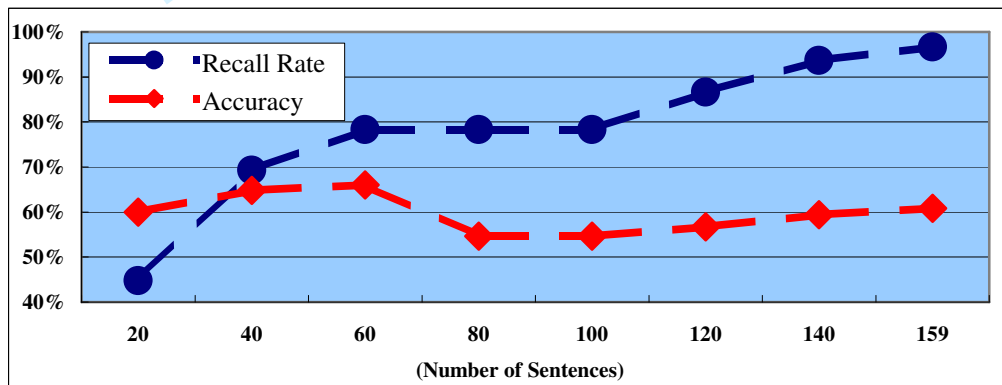


Figure 15. Performance tendency of target sentence identification

(B) Sentence fragmentation and tagging

According to Table 6 and Figure 16, the recall rate of sentence fragmentation and tagging strikes the lowest at 66.55% (with a standard deviation of 0.255) at the first stage and ascends rapidly to the highest of 93.24% (with the lowest standard deviation of 0.118) at the third stage. The accuracy is at the lowest of 53.57% (with a standard deviation 0.260) at the first stage and increases to the highest of 87.38% at the third stage. It indicates that the recall rate and accuracy of sentence fragmentation and tagging feature learning capability. Moreover, small-scale application domains with limited domain knowledge or domain terms require less training stages for more reliable sentence identification, fragmentation and tagging.

(C) Information matrix generation

Based on Table 7 and Figure 17, the recall rate of information matrix generation hits the lowest at 33.33% (with a standard deviation of 0.471) at the first stage and climbs up quickly to 100% at the third stage. The accuracy is at the lowest of 33.33% (with a standard

deviation of 0.471) at the first stage and rises rapidly to 100% at the third stage. Information matrix generation relies much on the accuracy of sentence fragmentation and tagging. Therefore, as the recall rate and accuracy of sentence fragmentation and tagging reach the peak at the third stage, the performance of information matrix generation also strikes the highest.

Table 6. Performance of sentence fragmentation and tagging indices

Sentence fragmentation and tagging		Number of training sentences at each stage							
		20	40	60	80	100	120	140	159
Recall rate	Average	60.55%	75.90%	93.24%	93.24%	93.24%	93.24%	93.24%	93.24%
	Std. Dev.	0.255	0.215	0.118	0.118	0.118	0.118	0.118	0.118
Accuracy	Average	53.57%	67.38%	87.38%	87.38%	87.38%	87.38%	87.38%	87.38%
	Std. Dev.	0.260	0.243	0.207	0.207	0.207	0.207	0.207	0.207

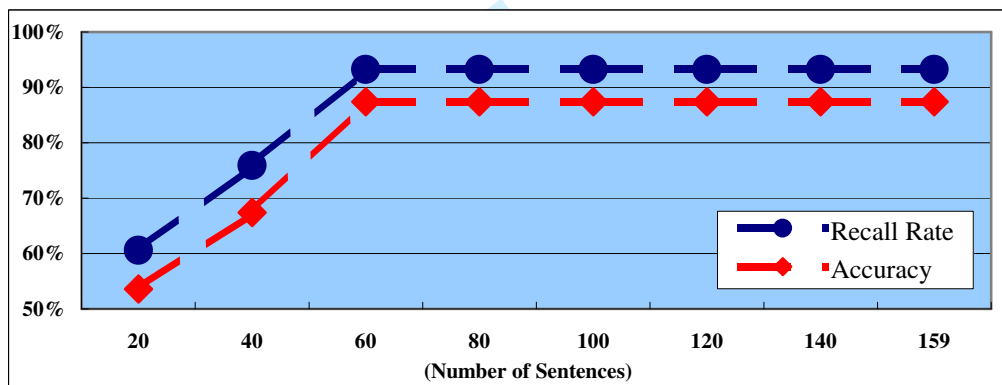


Figure 16. Performance tendency of sentence fragmentation and tagging

Table 7. Performance of information matrix generation indices

Information matrix generation		Number of training sentences at each stage							
		20	40	60	80	100	120	140	159
Recall rate	Average	33.33%	58.33%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	Std. Dev.	0.471	0.467	0	0	0	0	0	0
Accuracy	Average	33.33%	58.33%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	Std. Dev.	0.471	0.467	0	0	0	0	0	0

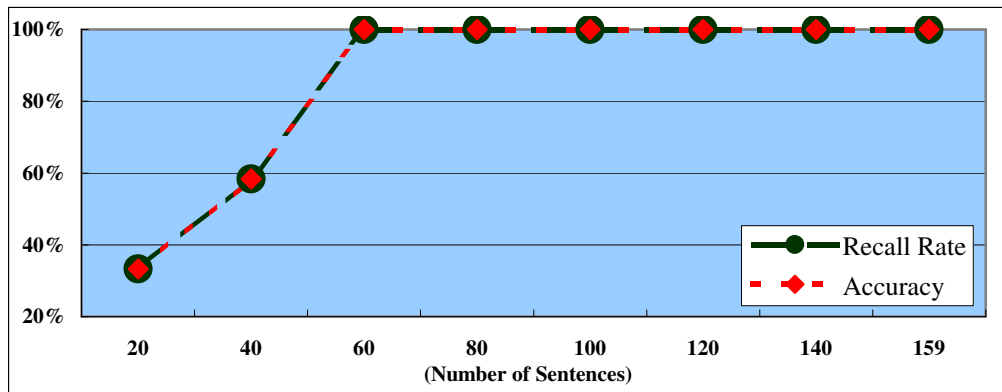


Figure 17. Performance tendency of information matrix generation

The summarized results and the tendency graphs above reveal the learning capability of the system. As more domain terms are maintained in the system, the recall rate and accuracy of each type of performance indices can be enhanced. For domain knowledge with limited domain terms, less training stages are required for high effectiveness. Thus the proposed methodology and system can be applied to application domains with spatial terms in order to visually present domain knowledge.

On the other hand, comparing the engineer exploded map with the proposed methodology, the engineer exploded map accurately reveals the relationship of components of the target object. The exploded map is usually established by domain experts. This research develops an algorithm and a platform to automatically convert the text-based contents into visualized display (ideally the engineer exploded map). Based on the proposed methodology, rely on domain experts to establish the exploded map can be reduced. However, the shortcoming of this methodology is that accuracy of the visualized display generated via the proposed methodology cannot totally be guaranteed.

6. Conclusions

This research is dedicated to visual representation of spatial knowledge. At first, this study explores the spatial knowledge acquisition and presentation models for automatic structure analysis of spatial knowledge. Based on spatial information glossary and rule base, accurate visual representation of spatial knowledge contents can be generated. A Web-based system is developed to facilitate knowledge receivers to study the visualized domain

1
2
3
4 knowledge through highly user-friendly interface. Based on a demonstration case of PC
5 component assembly, the proposed system is verified to effectively identify spatial knowledge
6 and visually display the knowledge contents as an appropriate number of terms are
7 maintained in the system. By application of the system, organizations can more effectively
8 manage and share domain knowledge and the staff can more efficiently capture domain
9 expertise through the knowledge visualization mechanism. In the future, the text-to-speech
10 (TTS) technology can be integrated into the system to enhance the comprehensive
11 interpretation and representation of spatial and non-spatial knowledge.
12
13
14
15
16
17
18
19

20 References

- 21
22 1. Burkhard, R. A., 2004, "Learning from architects: The difference between knowledge
23 visualization and information visualization," *The Eighth International Conference on*
24 *Information Visualization*, pp. 519-524.
25
26
- 27
28 2. Cao, C.-H., 2000, "Web-based cooperative virtual reality design system," *Master Thesis,*
29 *Department of Computer Science, National Chiao-Tung University.*
30
31
- 32
33 3. Chang, C.-R., 1999, "Study and application of 3D medical image model restructuring
34 technology based on VRML components," *Master Thesis, Department of Electrical*
35 *Engineering, National Cheng Kung University.*
36
37
- 38
39 4. Chen, C. and Paul, R. J., 2001, "Visualizing a knowledge domain's intellectual structure,"
40 *Computer*, Vol. 34, No. 3, pp. 65-71.
41
42
- 43
44 5. Chen, C.-L., 2003, "Remote rapid prototyping and knowledge engineering management in
45 network design and manufacturing," *Master Thesis, Department of Automation*
46 *Engineering, Da-Yeh University.*
47
48
- 49
50 6. Chiou, H.-J., 2000, "Distributed virtual reality system with multiple interactions," *Masters*
51 *Thesis, Department of Computer Science, National Chiao Tung University.*
52
53
- 54
55 7. Chu, F.-J., 2002, "Teaching materials for Web3D CAL of Martial Arts Zhongyi Boxing,"
56 *Master Thesis, Graduate Institute of Sports Science, National College of Physical*
57 *Education and Sports.*
58
- 59
60 8. Chu, W. W., Cardenas, A. F. and Taira, R. K., 1995, "KMeD: A knowledge-based
multimedia medical distributed database system," *Information Systems*, Vol. 20, No. 2, pp.

- 1
2
3
4 75-96.
5
6 9. Erenay, O., Hashemipour, M. and Kayaligil, S., 2002, "Virtual reality in requirement
7 analysis for CIM system development suitable for SMEs," *International Journal of*
8 *Production Research*, Vol. 40, No. 15, pp. 3693-3708.
9
10 10. Gottschalk, P. and Khandelwal, V. K., 2004, "Stages of growth for knowledge
11 management technology in law firms," *Journal of Computer Information Systems*, Vol. 44,
12 No. 4, pp. 111-124.
13
14 11. Hadley, S. W., 1996, "Finding part-machine families using graph partitioning techniques,"
15 *International Journal of Production Research*, Vol. 34, No. 8, pp. 1821-1840.
16
17 12. Hanson, S., Narayanan, N. H. and Hegarty, M., 2002, "Designing educationally effective
18 algorithm visualizations," *Journal of Visual Languages & Computing*, Vol. 13, No. 3, pp.
19 291-317.
20
21 13. Hewagamage, K. P. and Hirakawa, M., 2001, "An interactive visual language for
22 spatiotemporal patterns," *Journal of Visual Languages & Computing*, Vol. 12, No. 3, pp.
23 325-349.
24
25 14. Hong, H.-F., 2002, "Application of VRML visual environment in reinforced concrete bar
26 design," *Master Thesis, Department of Architecture, Tam Kang University*.
27
28 15. Hou, J.-L., Chuo, H.-C. and Sun, M.-T., 2003, "Heuristic and integrated approach for
29 technical document authority and authentication sequence determination," *International*
30 *Journal of Production Research*, Vol. 42, No. 9, pp.1747-1768.
31
32 16. Hou, J.-L. and Lin, F.-H., 2004, "A document and user matching model via document
33 keyword analysis," *Journal of Computer Information Systems*, Vol. 44, No. 4, pp. 1-15.
34
35 17. Hou, J.-L. and Lin, R.-K., 2005, "Knowledge component analysis for RDF-oriented
36 knowledge representation," *The Sixth Asia Pacific Industrial Engineering and*
37 *Management Conference*, Paper ID: 1229.
38
39 18. Hsiao, C.-J., 2001, "Virtual reality systems for intravenous injection," *Master Thesis,*
40 *Graduate Institute of Mechanical Engineering, National Central University*.
41
42 19. Jan, D.-Y., 2002, "Application basis of virtual reality in cooperative group learning",
43 *Master Thesis, Department of Information and Computer Engineering, Chung Yuan*
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Christian University.

20. Kanno, T., Furuta, K. and Yoshikawa, S., 1999, "Support system for profound understanding of plant operation by visualization of relevant knowledge," *IEEE International Conference on Systems, Man, and Cybernetics*, Vol. 3, pp. 681-686.
21. Li, Y.-F., 2003, "Network-based virtual interior design system," *Master Thesis, Department of Electronic Engineering, National Taiwan University of Science and Technology.*
22. Liebowitz, J., 2004, "A knowledge management strategy for the Jason organization: A case study," *Journal of Computer Information Systems*, Vol. 44, No. 2, pp. 1-15.
23. Lou, W., Kong, F. and Cao, Y., 2000, "Data visualization and knowledge visualization," *Proceedings of the 3rd World Congress on Intelligent Control and Automation*, Vol. 4, pp. 2523-2525.
24. Moody, J. W., Blanton, J. E. and Will, R. P., 1998, "Capturing expertise from experts: The need to match knowledge elicitation technologies with expert system types," *Journal of Computer Information Systems*, Vol. 39, No. 2, pp. 89-95.
25. Morris, S., DeYong, C., Wu, Z., Salman, S. and Yemenu, D., 2002, "Diva: A visualization system for exploring document databases for technology forecasting," *Computers and Industrial Engineering*, Vol. 43, No. 4, pp. 841-862.
26. Neaga, E. I. and Harding, J. A., 2005, "An enterprise modeling and integration framework based on knowledge discovery and data mining," *International Journal of Production Research*, Vol. 43, No. 6, pp. 1089-1108.
27. Ohwada, H. and Mizoguchi, F., 2003, "Integrating information visualization and retrieval for WWW information discovery," *Theoretical Computer Science*, Vol. 292, No. 2, pp. 547-571.
28. Pai, S.-T. and Hou, J.-L., 2005, "Architecture and concepts for knowledge visualization: Spatial knowledge analysis," *Industry Forum*, Vol. 7, No. 2, pp. 1-26.
29. Shaw, D. and Edwards, J. S., 2006, "Manufacturing knowledge management strategy," *International Journal of Production Research*, Vol. 44, No. 10, pp. 1907-1925.
30. TerjeKarlsen, J. and Gottschalk, P., 2004, "An empirical evaluation of knowledge transfer

- 1
2
3
4 mechanisms for IT projects,” *Journal of Computer Information Systems*, Vol. 44, No. 1,
5 pp. 112-123.
6
7
8 31. Wang, Y.-H., 2001, “Study and production of XML-based virtual reality documents,”
9 *Master Thesis, Department of Engineering Science, National Cheng Kung University*.
10
11 32. Wasfy, H. M., Wasfy, T. M. and Noor, A. K., 2004, “An interrogative visualization
12 environment for large-scale engineering simulations,” *Advances in Engineering Software*,
13 Vol. 35, pp. 805-813.
14
15
16 33. Wu, Y.-H., 2003, “Construction of 3D human phantoms with 2D images,” *Master Thesis*,
17 *Department of Industrial Engineering & Engineering Management, National Tsing Hua*
18 *University*.
19
20 34. Xue, K., Cheng, J., He, P. and Zheng, J., 1999, “A 3D visualization tool for landmark
21 allocation,” *Engineering in Medicine and Biology*, Vol. 1, pp.651.
22
23
24 35. Yan, T.-H., 2001, “Preliminary study on integrating global infrastructure and visualized
25 environment into building construction design platform,” *Master Thesis, Graduate*
26 *Institute of Civil Engineering, National Chiao-Tung University*.
27
28
29 36. Yeap, T., Loo, G. H. and Pang, S., 2003, “Computational patent mapping: Intelligent
30 agents for nanotechnology,” *International Conference on MEMS, NANO and Smart*
31 *Systems*, pp. 274-278.
32
33
34 37. Yost, J., Varecka, A. F. and Marefat, M. M., 1997, “Content-based visualization for
35 intelligent problem-solving environments,” *International Journal of Human-Computer*
36 *Studies*, Vol. 46, No. 4, pp. 409-441.
37
38
39 38. Zhang, J., 2001, “TOFIR: A tool of facilitating information retrieval-introduce a visual
40 retrieval model,” *Information Processing and Management*, Vol. 37, pp. 639-657.
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60