Map Based Information Sharing to Support Virtual Enterprise Activities

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Abstract

A virtual enterprise seems to be feasible solution which can flexibly reorganize virtual structure in order to cope with radically changing market. However, the virtual organization sometimes makes its personnel's fellowship and realistic feeling weaker than ordinary one. Even if the structure is virtual, the enterprise has connection to the real world, i.e., it is required to make products/services appear on the market and to make a deal with customers and other companies. In order to eliminate extra cost, a virtual enterprise should be aware of influence of the real world and pay much attention to geographic information provided by people who concern the enterprise. In this paper, we will discuss map based information boards through which geographically distributed people can share various kinds of information. This paper enhances the ability of co-existence relationships previously proposed by authors. By applying extended co-existence relationships, each user easily obtains arbitrary maps which satisfy his/her requirements. These tailor-made maps can support all persons who concern the virtual enterprise to share various kinds of information. The enterprise utilizes the information in order to make decisions for its strategy.

1 Introduction

With remarkable growth of broadband network and high-performance computer systems, people easily perform various economical activities on the Net, such as watching Web TV, online shopping and online banking/trading. Since an online consumer can purchase products/services from various companies worldwide without worrying about their actual location, there is no locational superiority among companies, e.g., headquarters is placed at a capital of a developed country or not. Second to company's reliability, good service with reasonable cost is one of the dominant factors by which a consumer chooses companies to make a online deal.

Products/services provided on the current e-commerce are changed frequently and drastically. In order to cope with such radical change, a company should be flexible enough to reorganize its structure. A virtual enterprise which consists of several departments/persons from different companies seems to be feasible solution in near future. Each department/individual is outstanding in its originating company and virtual structure of the enterprise can be easily reconstructed. Because the virtual enterprise can put the right department in the right mission immediately and unification of the departments can share middlemen, good services with appropriate cost can be expected.

Although enterprise's organization is virtual, the enterprise does not exist only in the virtual world, i.e., it needs connection to the real world. In case that the virtual enterprise offers products, there are various relationships with customers and existing other companies, e.g., manufacturers, transportation companies.

The virtual organization sometimes makes its personnel's fellowship and realistic feeling weaker than ordinary one. This weak fellowship often results in increasing redundancy of various resources. Different departments sporadically place orders with several factories for small quantity of a product whose number affects discount rate. In case of a global enterprise, locations of employees should be taken into account. For example, online meeting should be participated by employees whose timezones are not midnight in order to achieve high productivity,

Recently consumers do not stay their home for e-commerce anymore. In m-commerce (mobile electric commerce) environment, the consumers make deals while they are strolling around downtowns, taking trains or flying by aircraft. In such a case, location of each consumer has significant meanings for companies, e.g., to find remarkable trend of consumers' activities.

In order to cope with these problems, a virtual enterprise should not ignore the influence of the real world and thus, should pay much attention to geographic information. Computer generated maps can be considered as one of the efficient tools in order to share geographic informa-

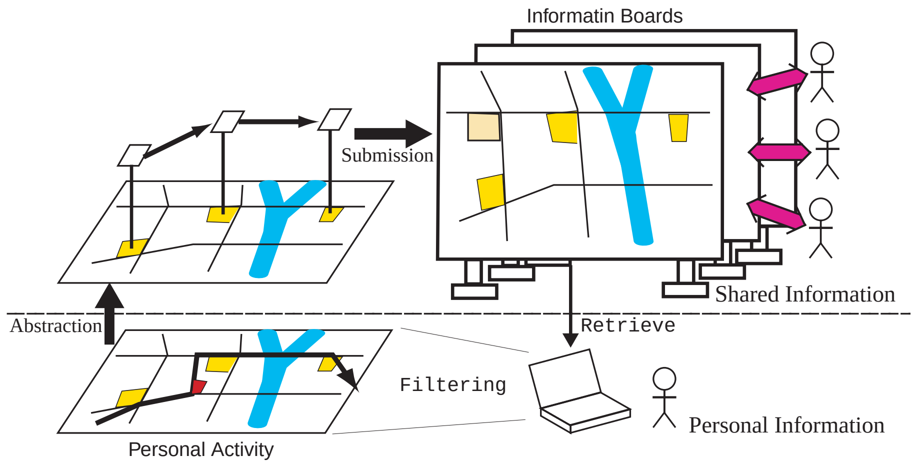

Figure 1. Basic Concept of Information Board

tion among personnel.

This paper discusses map based information board through which consumers can exchange their information each other. By monitoring the board, the virtual enterprise can obtain various kinds of information which help to determine its future strategy. Because of different individual's preference, same representation of maps seldom suits all users' favor. Geographic information systems should provide arbitrary maps each of which is suitable for each user. Therefore, instead of digitizing ready-made maps beforehand, geographic database system stores each geographic entities, e.g., Kyoto Station, as a geographic object[2]. By applying dynamic map synthesis, the database system retrieves geographic objects which satisfy user's requirement and visualizes them with various representation methods, and finally, the user can obtain his/her tailor-made maps.

If enormous number of geographic objects are displayed on maps whose size and resolution are limited, a user feels difficultly to find out his/her aimed information. In order to control selection of geographic objects, concept of co-existence relations[6] is expanded. According to the characteristic of co-existence relations, these relations are classified into co-existence rules, sets and links.

Rest of the paper is organized as follows. Section 2 illustrates basic idea of information boards based on maps and basic concept of geographic database systems. Section 3 describes thesauruses which represent aggregation and other geographic relationship among objects. Section 4 explains co-existence relations and application control of their rules. Section 6 concludes this paper.

2 Basic Concept of Map Based Information Board

2.1 Information Sharing Based on Maps

Currently many enterprises whose employees are distributed worldwide hold meetings online or over the telephone. Even if enterprises have video meeting facilities, offline meetings are also held frequently and employees can discuss various topics, including a chat. Sharing the same time and space among employees raises their fellowship. The offline meetings can be considered as a kind of lubricant among employees.

In case of a virtual enterprise, employees belong to not only the virtual enterprise but also their originating companies and thus, it is difficult to have frequent offline meetings. The virtual enterprise sometimes makes its personnel's fellowship and realistic feeling weaker than ordinary one.

Figure 1 shows basic concept of Information Board. Every employee or consumer provides various kinds of personal information, including his/her activity, and shares the information through the boards, i.e., set of maps. Because maps can be utilized to represent complicated information as intuitively understandable forms, geographically distributed people can easily grasp overall trend of various activities.

It can be assumed that a employee may belong several departments of virtual and ordinary enterprises. Usually his/her activities are mixed with duties of different enterprises. In such a case, he/she must not disclose confidential information of a enterprise to others and thus, can represent the secret only on boards to which personnel of the enter-

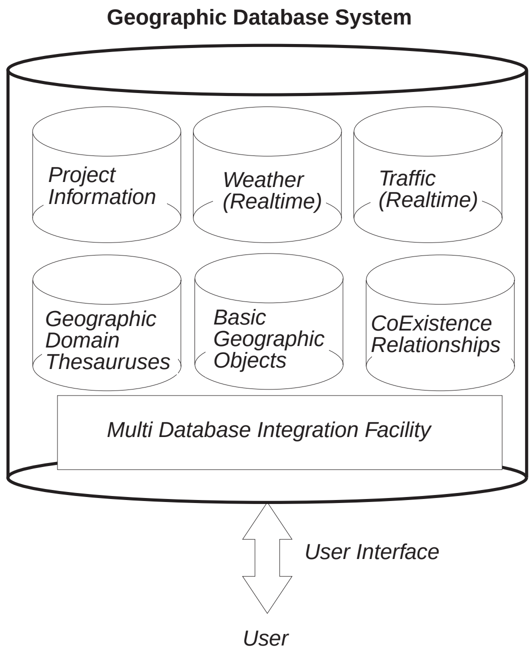

Figure 2. Overview of Geographic Database System

prise can access. Furthermore, a consumer may not want to provide all of his/her activities to Information Board in order to keep privacy.

As shown in Figure 1, a portable computer accumulates all kinds of personal information. By deleting private information such as consumer's real name, Filtering generates personal activities which can be submitted to the board. Based on his/her preference, e.g., position and mission of the enterprise, abstraction extracts activities. As an example shown in Figure 1, a black square in the "Personal Activity" is deleted, because it concerns another project which should be kept secret to others and thus, this information is not suitable to represent simultaneously with other information. Finally, these abstracted activities are submitted to Information Board.

2.2 Basic Features of Geographic Database Systems

Although the current geographic information services are mainly based on the conventional hypermedia systems, the systems are not designed for multiple purposes from the viewpoint of database systems. The conventional systems usually consist of two components: nodes which are pieces of ready-made maps and links which correspond to executions of traversing among the maps. Because of the fixed property of hypermedia systems, users cannot easily obtain any scale of the maps in combination with arbitrary geographic information.

Database systems keep all objects shared by users and only required objects are retrieved for generating view. In this paper, the concept of the database systems is applied to map generation systems in order to support activity of a virtual enterprise.

Figure 2 shows overview of a geographic database system. Computers can generate more suitable maps dynamically for a specific purpose. This paper calls this dynamic map synthesis.

Geographic database systems are usually utilized in network oriented environment where a large amount of geographic and referenced information is managed by separated databases. In order to realize efficient geographic information systems such databases should be integrated as unified one.

2.3 Geographic Databases and Objects

This paper assumes that there are two kinds of objects in geographic databases, i.e., geographic object (GO) and display object (DO). Geographic object is abstraction of entity in the real world, e.g., Kyoto University, and stored as an item of the databases. On the other hand, display object is a certain visualization method of its corresponding geographic object. In geographical databases, geographic objects are retained in a form that are independent of their visualization methods. Each geographic object can refer several display objects, e.g., a dot, an area. A dynamic map consists of various display objects. If a geographic object is updated, its corresponding display object should be refreshed to reflect the update on a map.

2.4 Virtual Hypermedia Maps

In this paper, we regard a set of display objects displayed on a screen as a view for a geographic database. Such a dynamically produced view can be regarded as a virtual node. Users' operations, such as enlargement, reduction and scroll make the view change.

The transition between virtual nodes is considered as migration of virtual link. Therefore, our map system is considered as virtual hypermedia.

2.5 Model for generating maps

Figure 3 shows a model for generating dynamic maps from geographic databases. The system selects geographic objects from geographic databases under consideration of user's purpose of map usage, geographic domain thesauruses (discussed in Section 3) and co-existence relationship (discussed in Section 4). In Figure 3, "GOs in need"

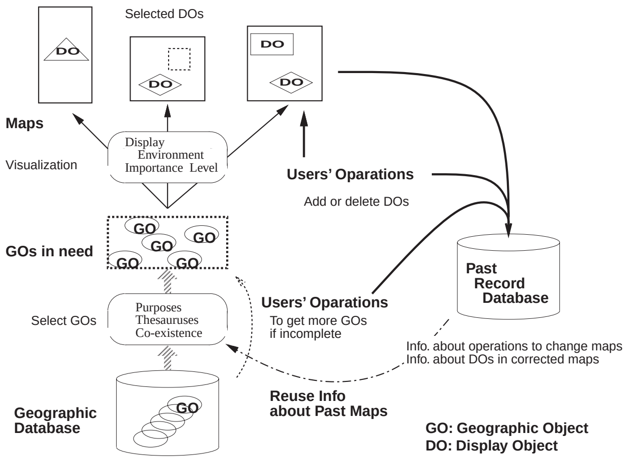

Figure 3. Dynamic Map Generation Procedure

means selected geographic objects which exist in the area of generating maps.

A user, generally, describes specifications of “Theme”, not those of “Background”. For example, if user’s query is “High School in Kyoto City”, a system regards “High School” as “Theme” and “Kyoto City” as map area. If a map shows only thematic parts, i.e., high schools, spatial relationships of geographic entities are not clearly represented. “Background” should be displayed on maps in order to understand geographic features easily.

In this example, “Background” may be city border lines, wards border lines, broad roads, rivers and so on. Both “Theme” and “Background” should be displayed on maps to understand topological relation. However, users may feel difficulties to specify background parts or other objects even if they are helpful to understand maps.

In order to reduce user’s load of operations, the system maintains his/her operations in “Past Record Database”. Assume that a user performs additional geographic operations in order to obtain more suitable map. If the resulting map satisfies the user, the system stores these operations in Past Record Database”. When another user requires similar maps, the system refers to Past Record Database and performs the additional operations to improve maps.

The rest of this paper discusses a method of object selection for generation of virtual hypermedia maps.

3 Geographic Domain Thesaurus

In order to support activities of the virtual enterprise, geographic database systems should generate any scales of maps where arbitrary kinds of geographic information are displayed. Since it is difficult to specify a query exactly,

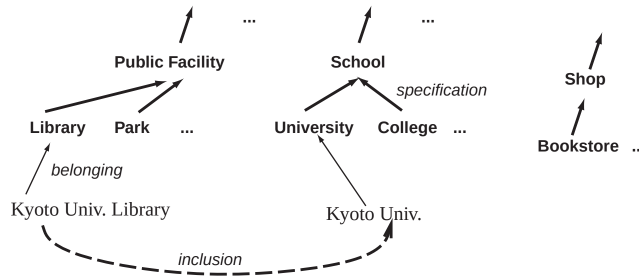

Figure 4. Examples of Geographic Domain Thesauruses

the system should automatically compensate missing information or find errors in the specification. For the purpose we use geographic domain thesaurus which contains aggregation and other geographic relationship as well as conventional thesaurus hierarchy.

3.1 Basic Concept of Geographic Domain Thesaurus

A geographic domain thesauruse reflects knowledge of geography such as geographic terminology. The thesaurus describes relationships among classes or instances as shown in Figure 4 and is represented by utilizing graphs(C, L). C and L denote a set of nodes and a set of directed links between two nodes respectively. Here we explain classification of the nodes and links.

[nodes]

`class`: Each geographic object is classified into a class, e.g., School, Park.

`instance`: Each geographic object is a instance of a class, e.g., Kyoto University is an instance of class “University”.

[links]

`specification` (bold line): If attributes of class c_1 inherit all attributes of class c_2, c_1 is a specification class of c_2. For example, "Park" is a specification class of "Public Facility".

`belonging` (thin line): If i is an instance of class c, i belongs to c. For example, "Kyoto University" belongs to "University".

`inclusion` (broken line): If instance i_1 is geographically included by instance i_2, i_1 is inclusion instance of i_2. For example, "Kyoto University Library" is included by "Kyoto University".

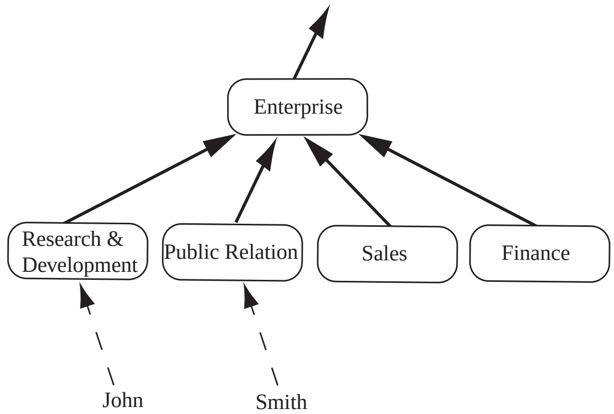

Figure 5. An Example of Enterprise Hierarchy

In this paper, "display a class" defines that all instances in the class are displayed on a map. For example, "display School" extracts its all subclasses and displays their instances. By the definition above, our system can treat classes and instances without distinction. Therefore, rest of this paper describes them as geographic objects and they are denoted as o_i $(i = 1, 2, \cdots)$.

By utilizing the thesaurus, a user can obtain understandable maps. Assume that a user requires "generate a map concerning Kyoto University Library". As a matter of course, a geographic database system generates a map where theme object "Kyoto University Library" is displayed. Since the user cannot understand the map which describes no information, except the theme object, other geographic objects should be displayed on the map for user's readability.

If the map has enough space to display other geographic objects, the system starts from the theme object and follows the directed links of the geographic domain thesaurus. It is considered that the number of links followed represents relevance to the theme object and thus, geographic objects with small number of links are displayed with emphasized representation, e.g., large font, bright color. As the results, the system puts other libraries, buildings of Kyoto University on the map.

3.2 Extension of Geographic Domain Thesaurus

As shown if Figure 5, organization of typical enterprise is hierarchical. The enterprise has similar structures to geographic domain thesaurus. In this paper, therefore, each instance and class in the enterprise hierarchy are treated as geographic instance and class respectively. Relationship between classes (instances) is also expressed by directed link.

4 Co-Existence Relationships

As discussed in previous section, the geographic domain thesauruses represent only geographical facts. Even if the geographic domain thesauruses have no relationship among geographic objects, quite a few practical applications require to define some kind of relationship to them and display them on maps simultaneously. For the purpose, other mechanisms which define semantical relationships between user's theme and geographic objects are required.

4.1 Co-Existence Objects

Assume that "$o_1, o_2, \cdots$" is a set of selected geographic objects and that "$o_i, o_j, \cdots$" has no geographical relationship to the set. If the addition of "$o_i, o_j, \cdots$" to the set is suitable for users' purposes, "$o_i, o_j, \cdots$" should be displayed together with the set in order to generate more understandable maps. This paper denotes such relationship as "co-existence". In this section, we introduce co-existence relationships which enhance ability of geographic database systems

Similar to the geographic domain thesauruses, co-existence relationships are defined as follows,

> **`co-existence`**: Assume that objects $o_1, o_2, \cdots, o_i$ are included in the set of selected geographic objects for generating a map and that o_j has no geographic relationships to the set. If o_j has semantical relationship to the set, o_j should be added to the set as its co-existence object.

According to the characteristic of co-existence relationships, they are classified into the following three types and stored in co-existence database.

1. Co-existence rules among geographic objects which belong to different classes in the thesaurus.
2. Co-existence sets among geographic objects which belong to same class.
3. Co-existence links among instances.

4.2 Co-Existence Rules among Different Classes

Each rule is described as the following example. Here, O denotes a set of selected geographic objects.

$$
\begin{array}{lll}
Rule_1\textbf{:} & (o_1, o_2 \in O) \quad ? & (O \leftarrow O \cup o_3) \\
Rule_2\textbf{:} & (o_2 \in O) \quad ? & (O \leftarrow O \cup o_4) \\
 & \vdots & \\
Rule_N\textbf{:} & (o_j \in O) \quad ? & (O \leftarrow O \cup o_k)
\end{array}
$$

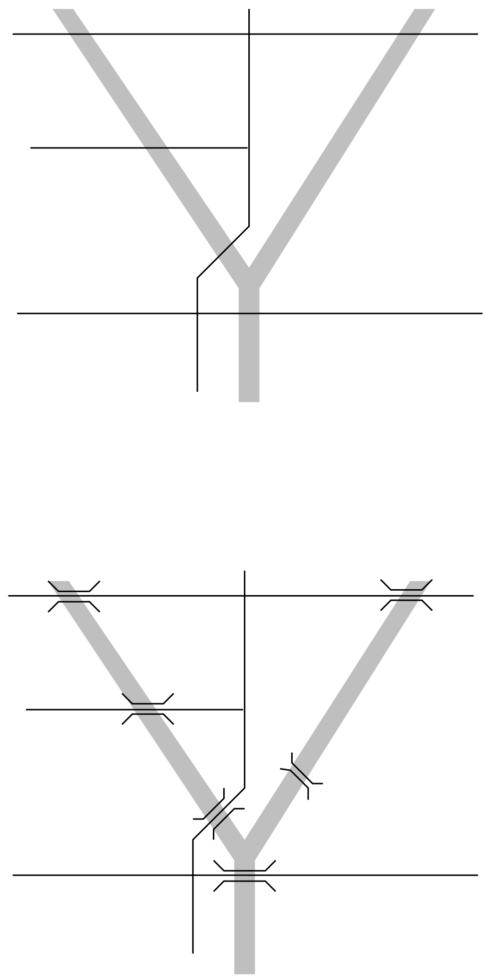

Figure 6. Co-existence rules

In the rule, left side of the operator "?" is a condition. If the condition is satisfied, right side is performed as an action. For example, the first rule means that if o_1 and o_2 are elements of O, then the system adds o_3 to O.

Assume that classes River and Road are included in the set of selected geographic objects, and that both roads cross over the river. In this case, Bridge$_i (i = 1, 2, \cdots)$ across the river are additionally selected as co-existent object(s) (Figure 6).

4.3 Co-existence Set among the Same Class

The following co-existence sets define co-existence relationships among objects which belong to the same class in the geographic domain thesauruses.

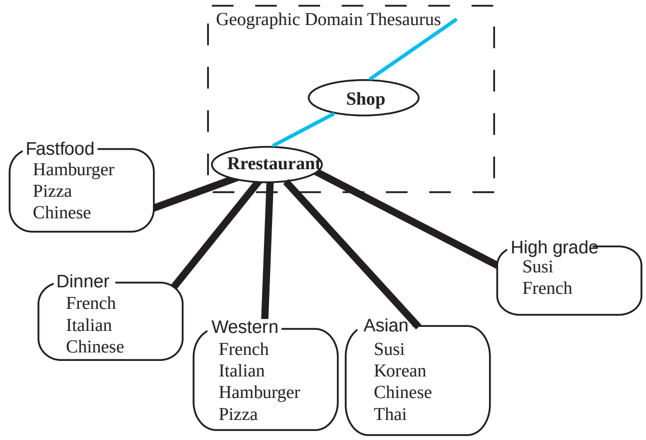

Figure 7. Co-Existence Set

$$
\begin{array}{ll}
Set_1\textbf{:} & \{\text{Set Name 1} \mid o_1,\ o_2,\ o_3\} \\
Set_2\textbf{:} & \{\text{Set Name 2} \mid o_2,\ o_4\} \\
 & \vdots \\
Set_N\textbf{:} & \{\text{Set Name N} \mid o_j,\ o_k\}
\end{array}
$$

The first set defines that there is some semantic relationship among geographic objects o_1, o_2, o_3. As an example above, each geographic object can belong to several sets.

As shown in Figure 7, "Hamburger", "Pizza" and "Chinese" can be classified into set "Fastfood". Assume that a user requires a map with displaying pizza shops. If the map has enough free space, Hamburger and Chinese Food shops are also displayed on the map.

As shown in Figure 7, each co-existence set consists of set of classes and a link to its parent class of the geographic domain thesaurus. Each parent class maintains its corresponding co-existence sets by their IDs.

As similar to geographic objects, structure of a virtual enterprise is defined by utilizing co-existence sets. For example, assume that virtual enterprise ZZZ consists of sales department of ABC Bookstore, accounting department of OQP Insurance and public relation department of XYZ Foods. This relation is described as follows,

$$
\begin{array}{ll}
Set\ j\textbf{:} & \{\text{Virtual enterprise ZZZ} \mid \\
 & o_{\text{sales department of ABC Bookstore}}, \\
 & o_{\text{accounting department of OQP Insurance}}, \\
 & o_{\text{public relation department of XYZ Foods}}\}
\end{array}
$$

If a user requires a map with displaying virtual enterprise ZZZ, all departments which are defined by the set above are represented on the map. In case that the sales department is too busy to handle all deals of the virtual enterprise, other departments which are retrieved by utilizing co-existence sets and geographic domain thesauruses are displayed on maps, e.g., sales department of XYZ Foods.

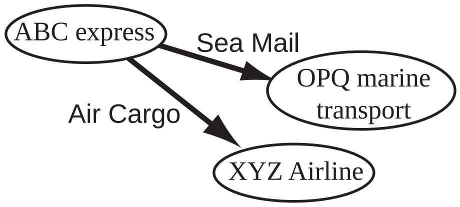

Figure 8. Co-Existence Links

4.4 Co-existence Links among Instances

Co-existence relationships among instances are described as co-existence links.

Link$_1$: $o_1 \to o_2$
Link$_2$: $o_1 \to o_3$
$\vdots$
Link$_N$: $\{o_1, o_3\} \to o_N$

First two links represent instance o_1 has semantic relations to o_2 and o_3. An example shown in Figure 8 represents that "ABC Express" has alignments with "OPQ Marine Transport" and "XYZ Airline".

Last link defines similar relationship to a co-existence rule. For example, a relationship that John and Smith belong to customer support department is represented as follows,

$$Link_k\text{:}\ \{o_{\text{John}}, o_{\text{Smith}}\} \to o_{\text{Customer Support}}$$

In practical applications, it is difficult to make strict distinction between a class and an instance. For example, a department has both propeties of a class and an instance. As we discussed in Section 3, our system treats classes and instances without distinction and thus, such ambiguous objects can be managed without any modification.

Since co-existence links represent specific relationships among instances, these links cannot to be utilized for the definition of general relatoinships. An instance which exists on the left side of the expression maintains link ID.

If several instances which belong to the same class have similar links, the links are treated as co-existence link or co-existence rule.

5 Multiple Application of Co-Existence Relationships

If there is no limitation on the application of co-existence relationships, the relationships are recursively applied and, in the worst case, all objects in geographic databases are selected. If too many co-existence geographic objects are visualized on maps, it might be difficult for users to find out important information, such as theme. The system is, therefore, required to control application of co-existence relationships.

5.1 Application Control of Co-Existence Relationships

In order to identify user's requirement of maps, typical purposes of map usage are prepared and stored in purpose database in advance. As the following example, each purpose is defined by utilizing the set of co-existence relationships and their weight.

$$P_1 = [(R_3, w_{R_3,1}), (R_7, w_{R_7,1})]$$

Here, $0 \le w_{R_3,1} \le 1$, $0 \le w_{R_7,1} \le 1$, $w_{R_3,1} + w_{R_7,1} = 1$.

A user selects several purposes from the purpose database in order to satisfy his/her purpose of map usage. For each purpose P_j, the user defines similarity $S(P_j)$ $(0 \le S(P_j) \le 1,\ \sum_j S(P_j) = 1)$. $S(P_j)$ expresses the ratio of each purpose to all selected purposes. Given $S(P_j)$, the system obtains relationship R_i's weight $w(R_i)$:

$$w(R_i) = \sum_j w_{R_i,j} * S(P_j)$$

For example, a user wants a map with the purpose — "Project A:4 Project B:1". Each similarity is normalized as follows,

- Relationships for the purpose of only Project A: $S(P_{ProjectA}) = 0.8$
- Relationships for the purpose of only Project B $S(P_{ProjectB}) = 0.2$

Then, weight for relationship R_i is calculated as follows,

$$w(R_i) = 0.8 \cdot w_{R_i,A} + 0.2 \cdot w_{R_i,B}$$

According to the calculation of $w(R_i)$, the relationship with large weight is assigned high priority and co-existence rules, sets and links are applied as described in the following sections.

5.2 Application Control of Co-existence Rules

Co-existence rules among different classes are controlled as follows.

Threshold weight W_r:
The system defines threshold weight W_r $(0 \le W_r \le 1)$ in advance. Assume that rule R_1 is applied first. Rule R_1 has its original weight $w(R_1)$. If rule R_2 is invoked by R_1, its weight is modified to $w^*(R_2) = w(R_1) *$

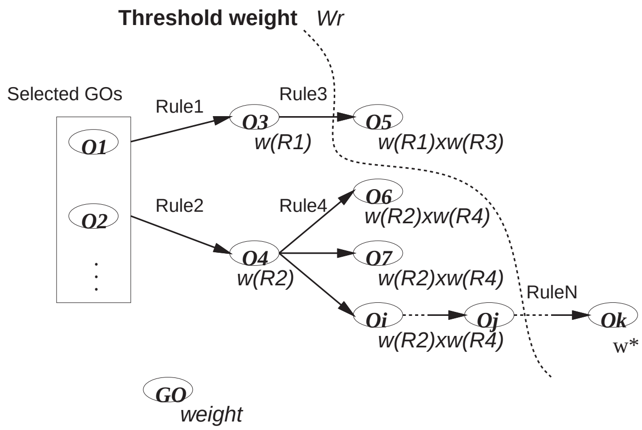

Figure 9. Co-Existence Rules and Threshold Weights

$w(R_2)$. Likewise, rules R_i invoked after applying other rules has weight $w^*(R_i) = \Pi_{k=1}^{i} w(R_k)$. If $w^*(R_i)$ is smaller than W_r, the rule is rejected (Figure 9).

Maximum ratio Ra_r of co-existence objects: The system calculates total number of co-existence objects and that of initially selected ones. If the ratio of co-existence objects to initially selected ones is larger than Ra_r, the system terminates rule applications.

Maximum number N_r of co-existence rule applications: The system applies co-existence rules less than N_r times. Usually application of rules should be terminated by the limitations above. However, in a particular case that every weight equals to 1, rules are applied many times. Obviously huge number of geographic objects are selected and users cannot understand the generated maps. This limitation is, therefore, prepared for such unusual cases.

It may occur that the same rule is invoked by a large number of distinct rules. In such case, the system assigns much larger weight to the rule.

5.3 Application Control of Co-existence Sets

Generally co-existence set can have more than two entities. For simplicity, however, this paper assumes that every co-existence set consists of only two geographic objects.

Here, $Set_{i,j}$ denotes co-existence set whose elements are o_i and o_j. $o_i \underset{Set_{i,j}}{\longrightarrow} o_j$ represents that o_i is selected first and then o_j is selected by $Set_{i,j}$. For simplicity, multiple application of the following co-existence sets,

$$o_1 \underset{Set_{1,2}}{\longrightarrow} o_2,\ o_2 \underset{Set_{2,5}}{\longrightarrow} o_5,\ \cdots,\ o_i \underset{Set_{i,j}}{\longrightarrow} o_j$$

is abbreviated to,

$$Set_{1,2}\ Set_{2,5}\ \cdots\ Set_{i,j}$$

This section defines Set Similarity $Sim_{Set_{i,j}}$ $(0 \leq Sim_{Set_{i,j}} \leq 1)$ in order to control application of Co-existence sets. Assume that Go represents set of geographic objects which are selected by the theme and thesauruses, and that $Num()$ denotes a function to obtain the number of elements of a set. Then, Set Similarity is expressed as follows

$$Sim_{Set_{i,j}} = \frac{Num(\{o | o \in Set_{i,j} \cap o \in Go\})}{Num(\{o | o \in Set_{i,j}\})}$$

Application of co-existence sets is controlled by examining the product of Set Similarity. Here, N_s (> 0) denotes threshold value of multiple application of co-existence set. It is assumed that series of co-existence sets

$$Set_{1,2}\ Set_{2,5}\ \cdots\ Set_{i,j}$$

is allowed to be applied. In order to apply co-existence set $o_j \underset{Set_{j,k}}{\longrightarrow} o_k$ to the series, the following condition must be satisfied.

$$Sim_{Set_{1,2}} \cdot Sim_{Set_{2,5}} \cdots Sim_{Set_{i,j}} \cdot Sim_{Set_{j,k}} \geq N_s$$

Geographic objects which are retrieved by co-existence set with large product have high priority and are displayed on a map with emphasized representation.

5.4 Application Control of Co-existence Links

Compared to co-existence rules and sets, a co-existence link among instances does not represent general geographic information. Therefore, a co-existence link is applied only when a user requires to display linked objects or when a map is considered to have enough free space to display them.

5.5 Visualization of Co-Existence Relationships

The system reflects the number of application of co-existence relationship to the visualization method of co-existence objects. If a co-existence object is selected after co-existence relationships are applied n_i $(n_i > 0)$ times, the importance level $I(n_i)$ of the geographic object are reduced as follows:

$$I(n_i) = C * \frac{I(n_1)}{n_i} \quad (C : const.)$$

$I(n_1)$ is an initial importance level of the geographic object.

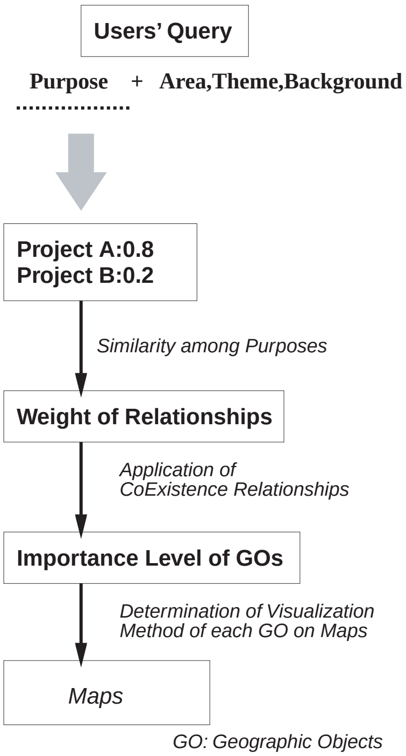

Figure 10. Outline of Application of Co-Existence Rules and Visualization Method

The outline of applying co-existence relationships and the method of visualization are illustrated in Figure 10. Geographic objects that have weaker relationship to theme will be omitted, or displayed by abbreviation or popup menu. By reducing importance levels, users will not acquire maps on which huge number of co-existence objects are visualized.

6 Conclusion

This paper discussed methods of object selection to generate virtual hypermedia maps which support activities of a virtual enterprise. Based on geographic domain thesauruses, geographic objects which have geographic relationships to user's theme are also displayed on maps. The user can obtain his/her suitable maps with the additional information.

Even if some geographic object does not have any relations to theme in the thesauruses, displaying the object with the theme might make maps more readable than original one. It may be considered that there are semantical relationships between theme and the object. In order to enhance the ability of geographic domain thesauruses, co-existence relationships are utilized. Co-existence geographic objects retrieved from geographic databases are helpful to understand generated maps. According to the characteristic of co-existence relationships, these relationships are classified into co-existence rules, sets and links.

By utilizing the maps as shared information boards, geographically distributed workers and consumers of a virtual enterprise can exchange their information and the enterprise can decide its management strategy and eliminate extra cost.

Our system unifies geographic database systems and supplementary data, e.g., thesauruses and co-existence, as extended geographic database systems. Although this approach cannot be acceptable to all architectures of geographic database systems, proposed map systems are much more flexible than conventional layer-based map systems.

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