Intelligent Vehicle Management Using Location-Based Control with Dispatching and Geographic Information

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Abstract: The automatic determination of vehicle operation status as well as continuous tracking of vehicle location with intelligent management is one of major elements to achieve the goals. Especially, vehicle operation status can only be analyzed in terms of expert experiences with real-time location data with scheduling information. However the scheduling information of individual vehicle is very difficult to be interpreted immediately because there are hundreds of thousand vehicles are run at the same time in the national wide range workplace. In this paper, we propose the location-based knowledge management system(LKMs) using the active trajectory analysis method with routing and scheduling information to cope with the problems. This system uses an inference technology with dispatching and geographic information to generate the logistics knowledge that can be furnished to the manager in the central vehicle monitoring and controlling center.

Keywords: GIS, LBS, Moving Object, Vehicle Operation Status Control.

1. Introduction

The database technology in most conventional vehicle tracking system has some defects when it deals with data which are continuously changed. The management of vehicles' location is one of the most representative problems. Because the exact data in the conventional databases are determined only by the update operation, the vehicle tracking system produces always invalid answer. It means the conventional vehicle tracking system based on the conventional database is unable eventually to cope with the environment that should manage the frequently changed location of vehicles.

In this paper, we propose the location-based knowledge management system(LKMs) using the active trajectory analysis method with routing and scheduling information to cope with the problems. This system uses an inference technology with dispatching and geographic information to generate the logistics knowledge that can be furnished to the manager in the central vehicle monitoring and controlling center.

Theses knowledge can not only be defined as the fact and rules, but also stored into databases so that they can be applied successfully to the vehicle operation management. The fact illustrates the object's status based on the given series of data and conditions. For examples, the *OnTime* means vehicle's operation is normal which is kept going on compared with the vehicle's location, the progress of schedule, and the road information. Generally, it is composed of name, operation, spatial and temporal predicates. The rule is one or more statement that establishes a regulation, process, method, or procedure. Commonly, it is written with simplex or complex predicates, i.e. the if-then statement, representatively.

We also have implemented the LKMs and then successfully evaluated it with practical testing scenario. The works on the development of enhan0ced LKMs with more various types of fact and rule definition adaptable to the ubiquitous environment are going on.

2. Motivation and Background

Moving objects are spatiotemporal data, which change their location or shape continuously over time. Generally if these continuously moving objects are managed by a conventional database, it is difficult to store all the location information changed over time in the database. Therefore, a time period of regular rate is determined and the location information of moving objects are discretely stored in the system for every time period. However, if the continuously moving objects are managed as discrete model, we may have problems which cannot properly answer to the query about the uncertain past and future location information. This problem is caused by the uncertain location information of the moving objects. Then a new model is required to answer properly to the location queries and to reduce the location uncertainty of the moving objects resulting from storing and managing continuously moving data in discrete model. Successful e-Logistics operation depends on the effective support of the visibility in the intelligent system.

Pfoser[8] suggested the representation of the positions of moving objects in database, a method for acquiring and representing the movements of point objects with the un-certainty, and an application scenario based on the

GPS. An integrated comprehensive framework of abstract data types for moving objects including base types, spatial types, time types, and spatiotemporal versions of them was presented in Guting's work[2]. In addition, Erwig[1] proposed an abstract and discrete modeling of spatiotemporal data types, which views moving points and regions as three-dimensional or higher-dimensional entities whose structure and behavior is captured by modeling them as abstract data types.

In modeling continuously changing moving objects, uncertainties have to be considered because of a measuring error and a sampling error. The measuring error can be produced even with very accurate measuring equipments. And the sampling error is changed by the frequency of acquiring the location samples. These uncertainties of the moving objects cause some problems such as database modeling, query processing, indexing, and incorrectness of results to the queries. Especially, the incorrectness of the answers to the queries may give wrong decision-making factors to the users. To solve these problems, Pfoser suggested the method for specifying the moving objects with a relational database and the method for measuring uncertainties with error information. In addition, in defining the location of the moving points of objects, the method to measure the non-sampled uncertain location using linear interpolation was proposed. However, it is a suggestion of the methodology, which lacks the accuracy verification through a concrete experiment.

Sistla[9] proposed a method to predict the future location of moving objects based on the current location of the object, speed, and direction. The current research of DOMINO refers to the location update policy, and uncertainty of the location related to database specifying. It also suggests ways to deal with queries of tracking current and future locations. To control the uncertainty and imprecision, it suggests the extension of the MOST model and query, the response about uncertain query using the probability and the compromise between update cost and the uncertainty cost of the database, and so on. However, neither does the MOST model store history information of the un-certain past movement location of moving objects, nor does it indicate the method to predict the past location.

3. Moving Object Engine

1) Conceptual Model

The moving object can be defined as a special kind of spatio-temporal data which the location and shape changes continuously over time. There are two kinds of moving objects such as the moving point related to the change of location and moving region related to the change of shape.

In this paper, we are dealing only the moving point because the vehicles in postal logistics can be classified to the moving point [2].

[Definition 1] (Moving Point Object : MP) It stands for the special type of spatio-temporal data that changes its location over time flows. It consists of the temporal attributes(T_A), spatial attributes(S_A) and the general attributes(G_A). The conceptual structure can be described as $MP = < T_A, S_A, G_A >$. □

[Definition 2] (Temporal Attributes) It is one of elements of the moving point object(MP), and is composed of the both beginning(VT_s) and ending(VT_e) of the valid time when the object were valid at the location. Its conceptual structure is $T_A = < VT_s, VT_e >$. The VT_s and VT_e is an element of valid time domain(D_{VT}). Here the D_{VT} means the set of timestamps that is used in the real world and represented as $D_{VT} = \{t_0, t_1, t_2, ..., t_k, ..., t_{now}\}$. Each of elements in D_{VT}, there are some special characteristics as follows: $t_0 < t_1 < t_2 < ... < t_k < ... < t_{now}$, $t_k = t_{k-1} + 1$, $t_k = t_0 + k$. □

[Definition 3] (Spatial Attributes) Its conceptual structure is described as $S_A = < x, y >$. x and y is a coordinate value. □

2) System Architecture

Moving Object Engine manages the historical position data of vehicles, and handles input query related to trace, phase, geometry using historical information of vehicles. It consists of core, query processor, and data loader about the moving object.

Core has (1) main database to manage the moving historical data of vehicles in spatio-temporal database which can well express time and space changes; (2) index manager to support TB-tree algorithm for storing mass data of moving object efficiently and searching them quickly; (3) MO operators to have the operation function about the moving object data; (4) Trajectory/Geometry/Topology executor to support the operation function about position extended; (5) uncertainty processor to have the guess function for vehicle position data about time not stored from position data stored in database. Query Processor conducts SQL related to moving object query required in application system, and supports transmission/reception about the query request and the result. Data Loader has the function to convert packet transmitted from location data interface into schema data stored in database.

4. Location-based Vehicle Status Management

The Location-based Knowledge Management System infers logistics knowledge from the position data of moving vehicle. To search the position data or trajectory from moving object database, it works with the Moving Object Engine. The position data of moving objects is input periodically to the moving object management system from the detecting devices such as GPS or Beacon systems.

1) Concepts

The vehicle operation status monitoring and controlling is the most suitable practical domains for the LKMs which deals the real-time location of vehicles with the dispatching and road information. In order to determine efficiently the status of vehicle operation, the construction of expert's knowledge which is generally understood should be constructed. Theses knowledge can not only be defined as the fact and rules, but also stored into databases so that they can be applied successfully to the vehicle operation management. The *fact* illustrates the object's status based on the given series of data and conditions. For examples, the *OnTime* means vehicle's operation is normal which is kept going on compared with the vehicle's location, the progress of schedule, and the road information. There are several typical fact names such as *Ahead*, *Behind*, *Stoppage*, and *Secession*, and so on. Generally, it is composed of name, operation, spatial and temporal predicates. The *rule* is one or more statement that establishes a regulation, process, method, or procedure. Commonly, it is written with simplex or complex predicates, i.e. the if-then statement, representatively. The *event* is a system internal tag which inform the happens of facts or triggering of rules to the LKMs. Whenever location data is entered from the vehicle location detecting device, the LKMs check whether there is any *event* or not. It also avoids the duplicated runs of rules by checking the sequence of them.

2) System Architecture

The LKMs consists of two modules, i.e. intelligent application and inference engine as shown in Fig. 1.

- **User interface:** The moving object data have to be filtered because inference cost is too expensive to execute about all data. In user interface, user is able to set up a preference of the LKM. The elements of the preference are inference period set up, SMS manager, fact/rule definition, vehicle id set up.
- **Decision Maker:** The final result of inference is control messages. The knowledge generated from inference engine can request optional actions to another system by logistics manager's decision. Decision maker writes control message and transmits this message another system.
- **Moving object routing and scheduling loader:** The routing and scheduling plan is major basis data for analysis moving object data. This plan is saved in routing and scheduling (R&S) database not moving object database. This loader calls the suitable routing and scheduling plan for analyzed data.
- **Movement pattern loader/selector:** In spite of routing and schedule plan, detailed route between delivery points is decided by vehicle driver. Movement pattern loader/selector calls general movement pattern of vehicle from past data.
- **Fact generator:** Facts are generated from the moving object data. Moving pattern loader/selector calls movement pattern and scheduling loader call routing and scheduling plan about the target data of inference. Fact generator makes a factor to be fact using these data and judges this factor can be a fact or not.
- **Rule scheduler:** A fact can use the event of a rule or rules. Also, a rule can use the event of a rule or rules. Rule scheduler calls the rule IDs selected by fact and make an execution list.
- **Rule executor:** Rule executor includes not only rules but also action module. In LKM, rule executor have SMS sender. If necessary, we can design additional action module.

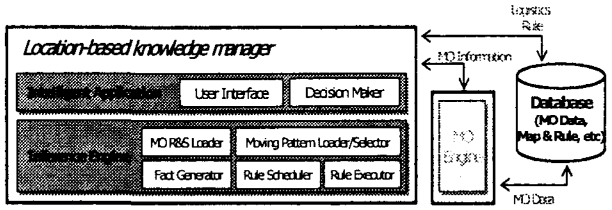


Fig. 1. LKMs Architecture

The data flow in the LKM is depicted in Fig. 2. The input data of the LKM is the current position of moving vehicle and the output data is inferred result. The SMS message is sent by transport manager's decision.

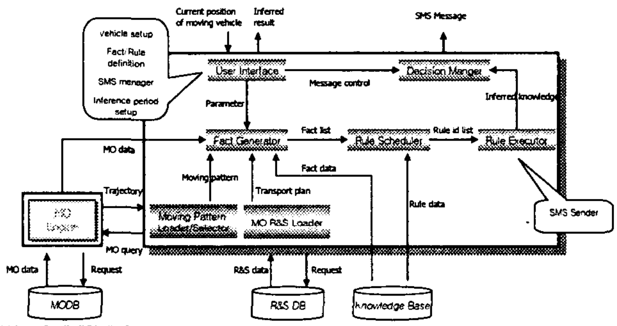


Fig. 2. LKM data flow diagram

3) Schema and Function

The knowledge base has the *fact*, *rule* and *event* schema like below table 2. The *DiffTime* is a function to define the fact. The result of *DiffTime* is the status of moving object and it is computed with the functions defined in the PREDICATE attribute. The *MoreThan*(-20) *AND LessThan*(-40) means that the position of the moving object delayed more than 20 and less than 40 as compared with schedule.

Table 2. Fact-Rule-Event Schema

RuleName	PredicateF	PredicateV	Action	ValidFrom	ValidTo
CHAR(64)	CHAR(128)	CHAR(10)	CHAR(128)	CHAR(8)	CHAR(8)

FactName	Item	Predicate	ValidFrom	ValidTo
CHAR(64)	CHAR(64)	CHAR(128)	CHAR(8)	CHAR(8)

EventTime	Week	CarNum	LinkID	FactID	RuleID
CHAR(12)	CHAR(1)	CHAR(10)	CHAR(12)	CHAR(9)	CHAR(9)

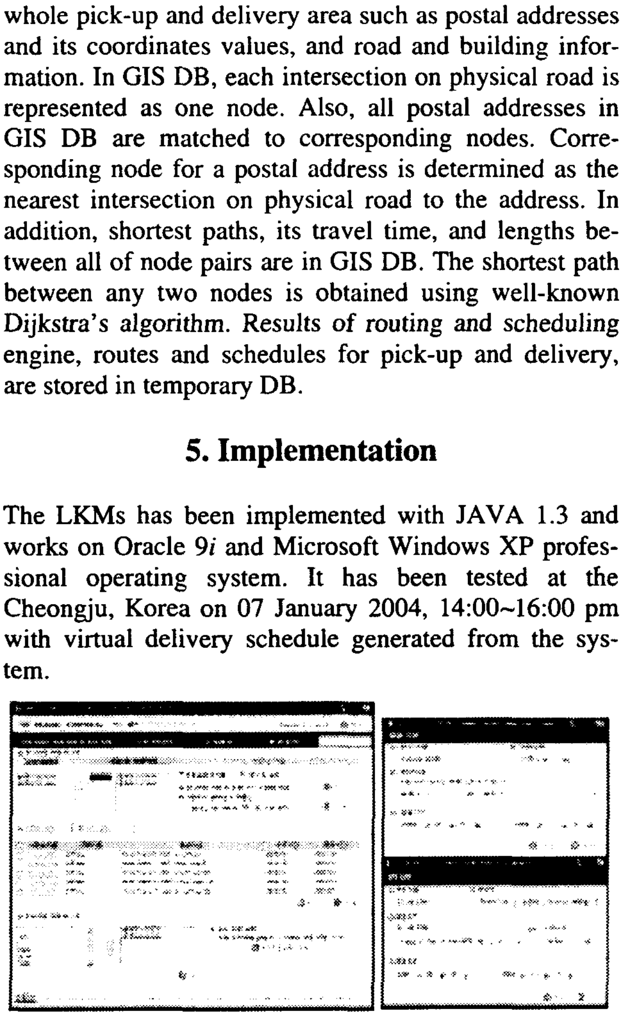
In the table 2, the ACTION attribute is the function to be executed lastly. In the case, the *SMS* function send 'delay warning' message to driver. The rule is executed by satisfying two condition; PREDICATEFACT and PREDICATEVEHICLE. Additionally, the fact and rule have a period of validity. If the period of validity is completed, than the fact or rule is not executed any more.

4) Dispatching Information

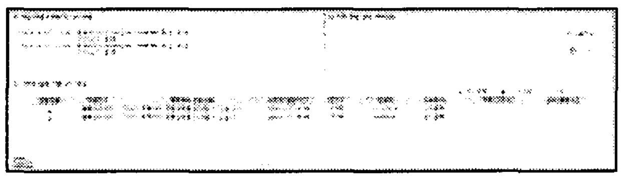
Routing and Scheduling Engine are used to generate the optimized route for the pick-up and delivery of parcel service. Temporary DB includes information about sender and receiver of parcel such as postal address, requested time, and name and phone number, while GIS DB in GIS tool includes geographical information of whole pick-up and delivery area such as postal addresses and its coordinates values, and road and building information. In GIS DB, each intersection on physical road is represented as one node. Also, all postal addresses in GIS DB are matched to corresponding nodes. Corresponding node for a postal address is determined as the nearest intersection on physical road to the address. In addition, shortest paths, its travel time, and lengths between all of node pairs are in GIS DB. The shortest path between any two nodes is obtained using well-known Dijkstra's algorithm. Results of routing and scheduling engine, routes and schedules for pick-up and delivery, are stored in temporary DB.

5. Implementation

The LKMs has been implemented with JAVA 1.3 and works on Oracle 9*i* and Microsoft Windows XP professional operating system. It has been tested at the Cheongju, Korea on 07 January 2004, 14:00~16:00 pm with virtual delivery schedule generated from the system.



(a) Fact and Rule Managing Interface



(b) Vehicle Operation Status Monitoring
Fig.3 LKMs Execution Snapshot

The vehicles which are to be traced can be selected as shown in the Fig.3(a). And the detailed matters of fact and rule definition with temporal predicates is described in the Fig.3(a). In the Fig.3 (b), the practical vehicle operation status was shown. It can detect various types of vehicle operation status in the pertinent situation automatically. However, the possible execution restriction of the LKMs is if routing and scheduling data is defective, then the LKMs is able to generate the wrong vehicle operation status.

6. Conclusions

The moving objects technology not only makes possible to overcome the problems in conventional vehicle management, but also gives additional information that are required to efficient decision making.
The LKMs suggested in this paper can define the logistics expert knowledge in form of fact and rules concepts. It adopted inference engine that generates fact from the position data of the moving vehicle. It detects automatically the vehicle operation status in the setting mode so that it helps drivers to finish their jobs as on time as possible. We have implemented the LKMs and then successfully evaluated it with practical testing scenario.
The works on the development of enhanced LKMs with more various types of fact and rule definition adaptable to the ubiquitous environment are going on.

References

[1] Erwig, M., R. Güting, M. Schneider, and M. Vazirgiannis 1999, Spatio-Temporal Data Types: An Approach to Modeling and Querying Moving Objects in Databases, GeoInformatica 3(3), 269-296.

[2] Guting, R., M. Bohlen, M. Erwig, C. Jensen, N. Lorentzos, M. Schneider, and M. Vazirgiannis, 2000, A Foundation for Representinf and Querying Moving Objects, ACM Transactions on Database Systems, 25(1).

[3] Kim, D.H., J.S. Kim, and K.H. Ryu, 2002, Moving Objects Technology in Postal Application Domain, Proceedings of the International Conference on Communications in Computing(CIC '02).

[4] Kim, D.H, H.A. Lee, J.S. Kim, Y.A. Ahn, and K.H. Ryu, 2002, Moving Objects Relational Model and Design for e-Logistics Applications, Proceedings of the 1st International Conference on Information Technology & Applications.

[5] Lee, H.A., H.J. Lee, D.H. Kim, and J.S. Kim, 2003, Moving Object Query Language Design for Moving Object Management System, Proceedings of the 30th Conference 30(2), Korea Information Science Society.

[6] Micucci, D., 2002, Exploiting the Kaleidoscope architecture in an industrial environmental monitoring system with heterogeneous devices and a knowledge-based supervisor", Proceedings of the 14th international conference on Software engineering and knowledge engineering. 685-688.

[7] Pal, K. and J. Campbell, 1997, An Application of Rule-Based and Case-Based Reasoning within a Single Legal Knowledge-based System, ACM SIGMIS Database, 28(4), 48-63.

[8] Pfoser, D., et al, 1999, Capturing the Uncertainty of Moving-Object Representations, Proceedings of the International Symposium on Spatial Databases.

[9] Sistla, P., O. Wolfson, S. Chamberlain, and S. Dao, 1998, Querying the Uncertain Position of Moving Objects, Springer-Verlag Lecture Notes in Computer Science number 1399, 310-337.