Abstract: The integrated supply chain of business partners for e-Commerce in cyber space is defined as Logistics Chain whenever the cooperative activities are logistics-related. Logistics Chain could be managed effectively and efficiently by cooperative technologies of logistics chain execution (LCE). In this paper, we consider an uncertainty processing for the tracing of moving object to control pick-up and delivery vehicles based on GPS/GIS/ITS along with a routing and scheduling algorithm for pick-up and delivery process to minimize service time and cost in logistics chain. Uncertainty processing is required to minimize the overall cost for efficient vehicles trajectory management. Finally, we describe the Moving Object Management System with Routing and Scheduling Engine to perform plan and control activities in postal logistics environment. And we compare our result with the result of the pick-up and delivery routing plan generated manually by postmen.

Key-Words: e-Logistics, Collaborative Logistics Chain, Routes and Scheduling, Moving Object, GPS/GIS/ITS, Vehicles Tracing, Uncertainty Processing, Spatio-temporal Database

1 Introduction

The explosive increase of e-Commerce enables us to buy products without time and space limitations, and to pay a charge using secure electronic methods through network. e-Marketplace needs the cooperative works among several business partners (enterprises) in such business processes as procurement of raw materials, production, sales and order management, transportation, delivery, and customer service for cost-effective and efficient services in cyber-space. For example, there are series of cooperation processes to manage customer order (Order Management) of shopping mall (Seller), to manage stock of supplier (Warehouse Management), to distribute products to the destination by logistics service provider (Transport Management), and to deliver the products to the final customer (Buyer) through internet. These cooperative processes can be called Logistics Chain, and we define the activities performed through internet as e-Logistics.

The definition of e-Logistics is the virtual logistics business activity and service architecture among the companies based on the Internet technology. Also the e-Logistics framework which is expansion of conventional logistics framework enables the business integration among the separated information system. It supports various kinds of functions such as real-time monitoring for the logistics information flow, intelligent controlling for the unexpected logistics state, and logistic optimization for the dynamic and intelligent readjustment of logistics planning. The moving objects techniques are one of major components of e-Logistics intelligent systems which work on based on the e-Logistics integrated platform. In this paper, we consider an uncertainty processing with the pick-up and delivery routes planning in postal logistics chain for the tracing of moving object to control pick-up and delivery vehicles.

The remainder of this paper is organized as follows. In Section 2, moving object uncertainty processing with routing and scheduling component is defined. In the application area of the real world, pick-up and delivery is performed with the optimal routes and schedule obtained through the suggested algorithm. In Section 3, the implementation of the proposed model and evaluation of practical effects are given, we also implement the system and then evaluate the results after comparing them with the results of the pick-up and delivery routing plan generated manually by postmen. The related works and conclusion are summarized in Section 4 and 5, respectively.
2 Optimal Routing and Uncertainty Processing Model

2.1 Moving Object Model

A field of ongoing research in the area of spatial databases and Geographic Information Systems (GIS) involves the accurate modeling of real geographical applications, i.e., applications that involve objects whose position, shape and size change over time [1]. 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 [3, 4, 5].

[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($V_{T_b}$) and ending($V_{T_e}$) of the valid time when the object were valid at the location. Its conceptual structure is $T_A = < V_{T_b}, V_{T_e} >$. The $V_{T_b}$ and $V_{T_e}$ 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 $D_{VT} = \{ t_0, t_1, t_2, \ldots, t_k, \ldots, t_{now} \}$. Each of elements in $D_{VT}$, there are some special characteristics as follows: $t_0 < t_1 < t_2 < \ldots < t_k < \ldots < t_{now}$, $t_k = t_{k-1} + 1$, $t_k = t_0 + k$.

[Definition 3] (Spatial Attributes) It is also one of components of moving point object. Its conceptual structure is described as $S_A = < x, y >$. Here x and y is a coordinate value.

The Moving objects database based on the spatio-temporal databases technique is composed of two major tables to store sampled location data of moving objects. The detailed scheme structure for each of them has the following schema:

<table>
<thead>
<tr>
<th>Table 1. Moving Object Databases Schema</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VehicleID</strong></td>
</tr>
<tr>
<td>VarChar2(10)</td>
</tr>
<tr>
<td>(a) VehicleInfo_T</td>
</tr>
<tr>
<td><strong>VehicleID</strong></td>
</tr>
<tr>
<td>VarChar2(10)</td>
</tr>
<tr>
<td>(b) VehicleOperation_T</td>
</tr>
</tbody>
</table>

In VehicleInfo_T table, the VehicleID and DriverName is the key value as an identifier of the moving object. The Type, CellularPhone, Depot, Etc are for the properties of each object including non-spatial information. Movement information table, i.e. VehicleOperation_T, stores historical information regarding sampled time and location of the object. In VehicleOperation_T table, the set of VehicleID, VF(Valid From), and VT(Valid To) is the key value. And the XS, YS, XE, YE specifies sampled time point and location coordinate values. Finally, the Velocity and Direction attributes are the additional information calculated directly from the location detecting devices.

2.2 Uncertainty Processing Model

There are generally four sorts of reasons that give rise to happen uncertainty of moving object such as (1) the inadequate time interval which gathers location data, (2) the errors in telecommunication and databases(physical layer), (3) the illegal road and traffic information(logical layer), (4) the unexpected events in applications. The uncertainty concepts are bringing into relief when users request the locations at some time for the moving objects. Usually the temporal management is always included into the moving object techniques. Intuitively, there are two kinds of query types in uncertainty processing which can be handed in the users to the system. On the basis of current time, (1) the retro-active uncertainty queries request the locations that can be estimated among the past locations, on the other hand (2) the pro-active uncertainty queries demand the future location which means the location where should be calculated in terms of time, i.e. immediately after of current time. There is a representative operator, i.e, AtTime, which is one of typical moving object operators and is related directly to the uncertainty processing. The AtTime operator searches the point included in the
There are also several kinds of method to estimate the location of uncertain time. (1) Nearest value method determine the nearest location from the two or three locations which were stored in the database and is nearest to the estimated location, (2) Linear interpolation method estimates the uncertain location where is one location exist in the line which stems from two locations with simple equation, (3) Spline interpolation method differs from the linear interpolation, and uses two locations and additional location with spline equation.

The moving object uncertainty processing system adopts a linear interpolation method for uncertainty processing. The detailed processing algorithm is can be described as below:

**[Basic Processing Step]**
- Get the query time \( t \) and probability \( p_r \), and search location \( p_s \); If found return with \( p_s \);
- Retrieve two locations \( (p_1, p_2) \) which are corresponding the timestamps \( (t_1, t_2) \) contains user’s query time \( t \);
- Calculates the location \( p_u \) using the linear interpolation method. Here the location \( p_u \) can be defined with the ratio of query time \( t \) from the locations \( (p_1, p_2) \);
- Computes the uncertainty boundary of \( p_u \), based on the input probability \( p_r \).

**[Additional Processing Step]**
- If there is any planning route data \( p' \) corresponding to \( p_h \) at query time \( t \), \( p_h \) should be revised to \( p' \). \( p' \) also should be exist within the uncertain boundary;
- In order to set \( p_h \) to the real world value, there is also additional processing such as map matching process;

### 2.3 Optimal Routing Model

The routing and scheduling problem considered in this paper includes more realistic restrictions.

The details of major constraints are as follows:

- **Multiple types of vehicles**: The classes of vehicle can be heterogeneous. Each vehicle has a distinct capacity.
- **Pick-up and deliveries with time windows**: Vehicles can deliver and pick-up product within a designated time window.
- **Time dependent travel times**: The travel time between two locations can depend on not only the distance (static view) but also the traffic volume (dynamic view) of the day.
- **Compatibility and precedence constraints**: Customer-vehicle compatibility constraints can restrict the set of customers that a vehicle can service. Depot-customer compatibility constraints can restrict the set of customers that a depot can service. Customer-customer precedence constraints can impose a partial ordering on the customer sequence.
- **Route constraints**: The total time duration or the total distance of a route or the number of customers serviced by a route can be constrained.

We proposed the tabu search based algorithm that has route construction phase and route improvement phase.

In route construction phase, we find initial feasible solution by using simple heuristic methods. In route improvement phase, we find better solution than the obtained initial solution.

In the phase, we use tabu search. The tabu search moves from the current solution to its best neighbor at each iteration, not necessarily less than the cost (travel time or length of tour in our problem) of the current solution, until a stopping criterion is satisfied. In order to prevent cycling, solutions that have been examined before are forbidden and inserted in a tabu list. The tabu list records the iteration number at which a customer is removed from a route.

#### 2.3.1 Route construction phase

The route construction procedure is composed of three steps: customer assignment, saving heuristic, and multi-trip creation. (1) In case of multi-depot, initially each customer is assigned to its nearest depot. If there are depot-customer compatibility constraint between a customer and a depot, the customer is assigned to one of the other depots. Two customers who must be serviced by the same vehicle on the same route are assigned to the same depot. If there is only one depot, this procedure is omitted.
(2) The savings heuristic is applied to the customer set. In case of multi-depot, the heuristic is applied to the customer set of each depot. The method starts with vehicle routes containing the depot and one other customer. At each step, two routes are merged according to the largest saving that can be generated. Two routes containing customers which must be serviced by the same vehicle on the same route are merged first of all.

(3) If multi-trip for a vehicle is allowed, multi-trip is created by using a bin packing algorithm. All routes are sorted in non-increasing order of the time duration of a route and assigned to the lowest indexed initialized bin (multi-trip) into which it fits. When the current route cannot fit into any initialized multi-trip, a new multi-trip is introduced. This heuristic is referred to as First-Fit Decreasing (FFD). If there is any time window constraints, multi-trip is created with consideration of start time and end time of a route.

2.3.2 Route improvement (Tabu search)
Tabu search moves from the current solution to its best neighbor at each iteration, not necessarily less than the cost of the current solution, until a stopping criterion is satisfied. To avoid cycling, a move is considered as tabu if it tries to reinsert customers removed in one of the previous moves. The algorithm can be summarized as follows:

[Step 1] Create an initial solution \( x \) by the route construction phase. Set the tabu list \( T = \phi \).
[Step 2] Generate a neighborhood set \( N(x) \) of \( x \). If \( N(x) \setminus T = \phi \), go to Step 3 Otherwise, identify a least cost solution \( y \) in \( N(x) \setminus T \) and set \( x = y \). Update the best known solution.
[Step 3] If the stopping criterion is satisfied, stop. Otherwise, update \( T \) and go to Step 2.

In Step 1, an initial solution is created by the route construction procedure. The tabu list records the iteration number at which a customer is removed from a route.

In Step 2, to generate a neighborhood set, we use simple neighborhoods based on arc exchanges or customer movements, such as two-opt, insertion, or-exchange, and swap-exchange in this tabu search. The two-opt procedure breaks two routes by deleting one link in each route, and then the first customers on the first route are linked to the last customers on the second route, and the first customers on the second route are linked to the last customers on the first route.

The insertion procedure removes a customer from its current position and reinserts it in a different position in other routes. The or-exchange considers the insertion of two consecutive customers. Finally, in the swap-exchange two customers in different routes are exchanged. In order to reduce the computing time of neighborhood exploration, a sparse graph that includes short arcs as well as important arcs is used. One of the four neighborhood generation method is selected randomly each iteration. By adding the penalty terms about the route constraints, such as the total time duration, the total distance of a route, and the number of customers which can be serviced by a route, the visit of infeasible solutions is allowed.

In Step 3, if the maximum number of iterations since the last update has been reached, the algorithm is stopped. Otherwise update the tabu list and go on searching.

3 Implementation
3.1 System Architecture
The system to grasp operating situation about pick-up and delivery of these post offices is the vehicles tracking subsystem of LCE system, and the system to devise pick-up and delivery plan and to respond to real-time order of customer is the routing and scheduling subsystem as shown in Fig 1.
Moving Object Engine of layer 2 is the subsystem to manage the historical position data of vehicles using database, and to handle query related to trace, phase, geometry using historical position data of vehicles. It consists of core, query processor, and data loader about the moving object.

The moving object uncertainty processing system consists of three kinds of sub-modules, (1) The uncertainty boundary calculation module calculates the boundaries where the moving objects is expected to be there by means of the user’s expected probability value and additional information of moving object such as velocity and directions. (2) The moving object location interpolation module generates the continuous set of location, i.e. trajectory, defined within the uncertainty boundary. (3) The moving object location matching module reforms the location using the difference between the estimated location and the historical location of the moving object.

Routing and Scheduling Engine of layer 3 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.

3.2 Scenario in Postal Logistics
As discuss above, there are representatively two kinds of query type in the moving object uncertainty. The detailed query type and their respective processing sequence are described below:

- Query Example: Display the location of vehicle (SL81Ba3578) at 2003-2-7 17:00 with probability 50%.
- Processing Example: Estimate the location of vehicle as below:
  - Search location for the vehicle with exact matching of vehicle number and time, i.e. SL81Ba3578 at 2003-2-7 17:00
  - If there is no match location data but given probability is not 0%, retrieve two locations which timestamp contains the input timestamp, i.e., 2003-2-7 16:59 and 17:01
  - Calculates the uncertainty boundary from the location where is expected to be from the input timestamp using the input probability (50%)
  - Check the planned route within uncertainty boundary
    - None → Return the location calculated with linear interpolation method
    - Otherwise → Return the location retrieved from the R&S system

The system mentioned above was implemented in Java. We tested the algorithm on several instances from the literature with up to 100 customers and the test was run on a Pentium 1.7 GHz PC.

Fig 2. Uncertainty Processor Architecture

Fig 3. GUI of LCE
In order to service the pick-up demand of 24 customers which is managed by a postman in one day, sum of operated distance and disturbance time is 35.21 km and the 336 minutes, respectively. On the other hand, the routing path which was generated from the routing and the scheduling engine of the proposed system improve overall complexity of the routing route. Also the total operated distance is 20.85 km and, the disturbance time is 245 minutes. Through the uncertainty processing, we regulate the collection of GPS location data without failure of vehicles tracking from 10 second units to 60 second interval, it will be able to attain the reducing of frequency in telecommunication and DB updating as one to six.

4 Related and Previous Works
The studies on the management of the moving object have been increasingly focused in the spatiotemporal research area. Pfoser[1] suggested the representation of the positions of moving objects in database, a method for acquiring and representing the movements of point objects with the uncertainty, and an application scenario based on the GPS(Global Positioning System). 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[3] 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.

Pfoser[5] suggested the method for specifying the moving objects with a relational database and the method for measuring uncertainties with error information. When it expresses the continuous movement of the moving object drawn as a curve by the polyline of the discrete form, the uncertainty occurrence factors of the moving objects were classified into the measured errors and the sampling errors. Sistla and Wolfson proposed a method to predict the future location of moving objects based on the current location of the object, speed, and direction. 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 uncertain past movement location of moving objects, nor does it indicate the method to predict the past location.

5 Conclusions
In this paper, we proposed an uncertainty processing with the pick-up and delivery routes planning in postal logistics chain for the tracing of moving object to control pick-up and delivery vehicles. Pretest results of the tabu search algorithm for the vehicle routing and scheduling problem show that the algorithm generates acceptable solutions within a reasonable time. Currently the suggested system suggested in this paper is in the field still going on test for the door-to-door parcel service. In the future, the algorithm is to be updated so that it will apply multi-typed business model for e-logistics companies.

References: