MODELLING RAILWAY PASSENGER ACTIVITY IN TOKYO

Movement Simulation and Analysis

In a world where everyone is constantly on the move, simulation and analysis of characteristics of the movement of objects is increasingly important, not only for behaviour forecast and policy/decision-making but also for monitoring and accident prevention. The authors developed key techniques for modelling large-scale moving objects and applied the system in movement simulation and pattern analysis of railway station passengers in Tokyo.

Technology push and application pull are leading to increasing study of simulation and analysis of the spatial and temporal behaviour of large-scale moving objects such as pedestrians, cars, buses and trains. The technology push results mainly from advances in positioning systems, in particular GPS, and wireless communication. These rapidly developing technologies enable continuous tracking and recording positions of moving objects. The application pull comes from demands for services which require (1) information on the flow density of potential visitors, (2) tracking and visualising the actual movement of objects and (3) behaviour understanding and forecast, and policy formulation.

System Architecture

A three-level system architecture is proposed. At Database level the data includes boundary partition, map data, travel data and attributes of moving objects. The data is stored and managed in Oracle. At Model level a kernel of class hierarchies in Java, called Moving Objects Model Library, has been developed. The kernel encloses all capabilities for modelling, querying and visualising spatio-temporal data and information to support moving-objects applications. It includes spatial schema, temporal schema and spatio-temporal schema, query processing and indexing, and movement-simulation model. Figure 2 shows a UML class-diagram of the spatio-temporal schema and simulation model. At Application level user requests are translated into basic functions corresponding to special services such as:

- background network display
- movement query, performing queries on objects and spatial, temporal and spatio-temporal behaviour, visualisation of query results enabling analysis of patterns of movement
- movement simulation for tracking and visualising the whole evolution of movement over time
- movement analysis on flow density and characteristics and movement patterns.

Spatio-temporal Model

Space and time are two properties inherent to any moving object. We use an object-based approach to model such moving objects and their behaviour. Each object encapsulates its spatial dimension, temporal dimension, attribute characteristic, corresponding behaviour operation and interaction with the environment. Our spatio-temporal data model, includes:

- abstract data type and process to support data representation and data manipulation
- representation of dynamic attributes
- spatio-temporal relationship for representing interaction between moving objects and their environment
- spatio-temporal operations for query processing.

Movement Query

On the basis of the above conceptual spatio-temporal data model, various application queries have been developed to capture movement characteristics. Specialised spatio-temporal operations and efficient indexing have also been developed for fast access. The index structure is based on an improved R-Tree mechanism called ST R-Tree, which considers time as another spatial dimension in 2D and uses an integrated 3D spatio-temporal index. Further, the ST R-Tree improves the efficiency of R-Tree by indexing line segments as part of trajectories, enabling special queries such as determination of the trajectory of a moving object. Our system handles four basic types of query: spatial, temporal, spatio-temporal and object-related. Spatial queries, which are formulated in terms of spatial operations, return spatial attributes; since no temporal information is used, the query covers the whole time axis. Temporal queries, which are formulated in terms of temporal operations, deal with temporal relationships between objects and with the valid time of an object; since no spatial

information is used, the query covers the whole space. Spatio-temporal queries return spatial components or values at a specific time, or valid time of spatio-temporal relationships. Object queries are a special spatio-temporal type of query, which extracts information on object trajectory by selecting a spatial and temporal range.

Movement Simulation

Movement can be represented as a spatio-temporal relationship among moving objects. A movement-simulation model is applied for representing spatial and temporal characteristics of moving objects and for analysing the patterns of motion of a moving object, which includes four components:

- trajectory interpolation: the position of the moving object is sampled in time and its trajectory represented as a series of straight lines connecting successive positions
- motion parameter computation in the simulation model is done using higher-level parameters such as speed, direction, and acceleration and travelled range
- transaction-time definition: the history of database activity of moving objects is recorded rather than real-world history; this maintains the entire temporal behaviour of moving objects; the valid period of transaction restricts the time of existence or validity of the object in the temporal world
- data structure and indexing: these have been designed for large-scale simulator, including data structure of trip, indexing structure of starting time and indexing structure of ending time.

Case Studies

We applied the approach to movement simulation and pattern analysis of 10,000 passengers of East Japan Railway Company in JR railway stations in Tokyo. The railway network under consideration here is located within a radius of about 70km2 of Tokyo and comprises 32 major railway lines. Information about the rail travel of each passenger was recorded by questionnaire. Application queries on passenger movement included the number of movements in one day (see for an example Figure 3), the number of movements within a specific station and movements on a selected railway line.

Further Reading

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- ISO/TC 211 Secretariat, 2000, ISO/TC 211 Geographic information/Geomatics 19108 Geographic information â€“ Temporal schema.
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