Moving Objects Management

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Moving Objects Management

Models, Techniques and Applications

Second Edition

With 105 Figures

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Preface

The widespread use of mobile positioning tools like GPS and smart mobile phones nowadays has aroused great interests in location-based services (LBS) that have to store and manage continuously changing positions of moving objects. This book gives a comprehensive and complete view of a moving objects database and introduces how it is used in LBS and transportation applications. It aims at moving objects management, from the location management perspective to analyze how the continually changing locations affect the traditional database and data mining technology. Specifically, the book describes the cutting edge technologies related to topics like moving objects modeling and location tracking, indexing and querying, trajectory prediction, location uncertainty, traffic flow analysis, objects clustering, traffic aware navigation and privacy issues as well as their application to intelligent transportation systems.

Previous studies mostly focused on moving objects database in free space. They assumed that the movement of the objects is unconstrained and based on Euclidean spaces. However, in the real world, objects usually move within spatially constrained networks, e.g., vehicles move on road networks. Overlooking this reality often leads to unrealistic data modeling and inaccurate query results. The content in this book focuses mainly on the moving objects within spatial networks, which is more practical. By exploiting the network feature of spatial networks, this book introduces models, techniques, and applications of moving objects management in a spatial network.

This book is intended to help readers understand the main technologies in moving object management and apply them to LBS and transportation applications. Compared with the first edition, this book particularly focuses on the constrained network environments, and it has made substantial changes to each chapter so that the cutting edge techniques in this field are included. With its accessible style and emphasis on practicality, the book presents new concepts and techniques for managing continuously moving objects. Database management systems developers,

mobile applications developers, and applied R&D researchers will find the study an essential companion for new concepts, development strategies, and application models associated with this kind of changing location data. The book:

- Presents a comprehensive architecture of moving object management, which includes not only basic theories and new concepts but also practical technologies and applications
- Describes a set of new database techniques in modeling, tracking, indexing, querying of moving objects, traffic flow analysis, as well as data mining techniques in clustering analysis of moving objects
- Introduces some new research issues in location privacy and uncertainty management of moving objects, which are topics of major interest in this field
- Provides typical applications of moving objects management in intelligent transportation systems

Organization of the Book

This book contains 12 chapters, which describe the problems, models, techniques, and applications of moving objects management. It is organized as follows:

In Chap. 1, we introduce some background of moving objects management, including its concept and applications. Finally we present the main content: key technologies of moving objects databases and our focus in this book.

In Chap. 2, we introduce some underlying modeling methods and present two moving object models that can reflect real-time traffic conditions of the road network. The first one is the DTNMOM, which considers the dynamics of underlying road network. And for the second model called ARS-DTNMOM, we introduce the concept of atomic route section and define its corresponding data types and operations in database.

In Chap. 3, we introduce a few underlying methods on moving object tracking. Then, we describe three representative network-constrained location update strategies (Net-LUM, ANLUM, and EuNetMOD), which can achieve better performances in terms of communication costs and location tracking accuracy.

In Chap. 4, we first introduce a few of the underlying spatial index structures including the R-tree, TPR-tree, spatio-temporal R-tree, trajectory-bundle tree, and MON-tree. Then, we propose two new index methods that are used for indexing frequently updated trajectories of network constrained moving objects and indexing the whole trajectories with historical, current, and near future positions, respectively.

In Chap. 5, we classify the basic querying types for moving objects according to spatial predicates, temporal predicates, and moving spaces. Then, we introduce how to process a range query and a kNN query in a spatial network, based on the Euclidean restriction and network expansion frameworks.

In Chap. 6, we introduce advanced querying for moving objects including similar trajectory queries and density queries for moving objects in a spatial network. We first present how to process the snapshot density queries. Then, we introduce some efficient methods based on the safe interval to continuously monitor dense regions for moving objects.

In Chap. 7, we first review some linear prediction methods and analyze their limitations in handling moving objects in spatial networks, then present the simulation-based prediction methods: fast-slow bounds prediction and time-segment prediction, and finally present an uncertain path prediction method which can predict future trajectories based on the uncertain historic trajectories of moving objects in spatial networks.

In Chap. 8, we study the uncertainty management problem for moving objects databases with a few uncertainty models. Then we introduce a novel framework that can manage uncertainty trajectory effectively and answer queries about them accurately; particularly, we focus on the key technical issues like uncertain trajectory modeling, database operations, and query processing of uncertainty management.

In Chap. 9, we study the underlying researches and inherent problems in traffic behavior analysis based on moving object trajectories. Then we firstly propose a new model for objects moving on dynamic transportation networks (MODTN), based on which we introduce a real-time traffic flow statistical analysis method (NMOD-TFSA).

In Chap. 10, we introduce the clustering analysis of moving objects in spatial networks. After that, we introduce two new static clustering algorithms, which use the information of nodes and edges in the network to improve the clustering efficiency and accuracy. Then, we introduce the notion of cluster block (CB) as the underlying clustering unit and propose a unified framework of clustering moving objects in spatial network (CMON), which improves the dynamic clustering performance of moving objects and supports different clustering criteria. Finally, we introduce two trajectory clustering algorithms which use the partition-and-group framework for clustering trajectories and a filter-refinement framework for hot region discovery, respectively.

In Chap. 11, we present another application, traffic aware route navigation, with a new traffic aware route planning model based on incremental planning method introduced. By selecting intermediate destinations, a partial path rather than whole path is planned each time for long distance queries. In this way, route planning is more efficient because it is carried out in a much smaller region, and unnecessary re-calculations caused by the dynamic road conditions can be avoided.

In Chap. 12, we introduce location privacy, and analyze the challenges of preserving location. Then, we provide an analysis of the current studies including the system architecture, location anonymity, and query processing.

As shown in Fig. 1, the contents of the whole book construct a comprehensive moving object management and application system. Figure 1 also shows the relationship of each component in the system.

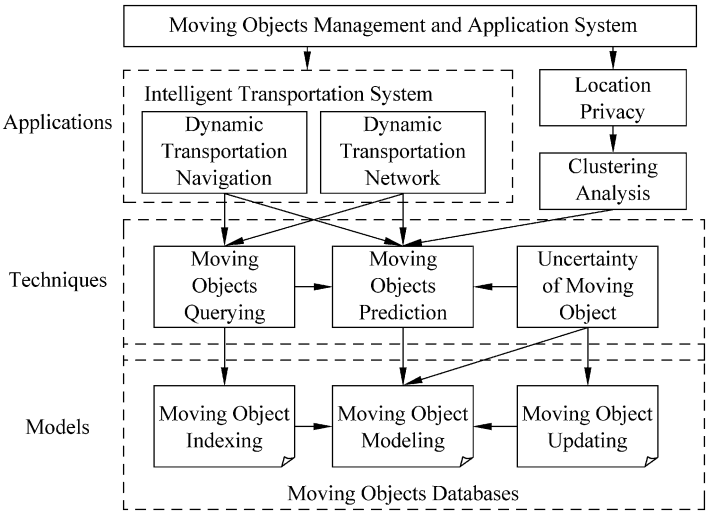

Fig. 1 Organization of the book

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This book is based on the research work of the authors for over 15 years. The book integrates the collective intelligence from the mobile group of the WAMDM Lab (Lab of Web and Mobile Data Management) at Renmin University of China, and the database group of NFS Center (The National Engineering Research Center of Fundamental Software) at Institute of Software, Chinese Academy of Sciences. The authors would like to express their great thanks to all the people who contributed to this book, including Dr. Jidong Chen, Dr. Xiao Pan, Dr. Limin Guo, Dr. Kuien Liu, Dr. Haoming Guo, Xing Hao, Zhen Xiao, and Rui Ding. In particular, the authors wish to thank Dr. Jidong Chen, Dr. Xiao Pan, and Dr. Limin Guo for their valuable efforts on this book.

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Contents

Acronyms

ADT	Abstract data type
ANN	Aggregate nearest neighbor
AU	Adaptive unit
CA	Cellular automaton
CN	Cluster node
CU	Cluster unit
DS	Dense segment
DSS	Dense segment set
DTTLU	Distance-threshold triggered location update
DyNSA	Dynamic navigation system based on moving objects stream aggregation
GCA	Graph of cellular automata
GPS	Global positioning system
HAT	Hierarchy aggregation tree
IER	Incremental Euclidean restriction
INE	Incremental network expansion
ITLU	ID-triggered location update
LBS	Location-based service
LP	Linear prediction
MBR	Minimum bounding rectangle
MO	Moving object
MOD	Moving objects databases
MODTN	Moving objects on dynamic transportation networks
MOST	Moving objects spatio-temporal
MRM	Mobile resource management
NN	Nearest neighbor
PDQ	Period density queries
PTSS	Prediction with time-segmented
QoS	Quality of service
RER	Range Euclidean restriction
RNE	Range network expansion

RNN	Reverse nearest neighbor
SDQ	Snap-shot density queries
SP	Simulation-based prediction
STTLU	Speed-threshold triggered location update
UT-Unit	Uncertain trajectory unit
UTR-Tree	Uncertain trajectory R-tree