Automation of the Moving Objects Movement Prediction Process

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ABSTRACT

Whereas research on moving objects is involved in a variety of different application areas, models and methods for movement prediction are often tailored to the specific type of moving objects. In this paper, we presented a conceptual model for movement prediction independent on an application area. Related work is critically evaluated, addressing advantages, possible problems and places for improvement. Generic model is proposed, based on an idea to encompass missing pieces in related work and to make the model as general as possible.

Key Words: moving object, spatiotemporal data, movement prediction, generic model for movement prediction

1. Introduction

Recent wide-ranging usage of Global Positioning System (GPS) devices and wireless communication devices, together with enhancements of supportive technology, induced the expansion of the research on moving objects. By modelling and analyzing moving objects data, we learn about the moving objects behaviour and even become able to predict their future locations.

All moving objects in the real world comprise time and space attributes simultaneously, with characteristic of having changeable location or shape through the time [2]. In many applications, knowing moving objects locations in advance can be substantial. Discovery of behavioural patterns and prediction of future movement can greatly influence different fields. Examples are the analysis of the wild animals' movement in order to predict their migrations, monitoring and analysis of vehicle movement in order to predict traffic congestions, mobile user movement and access point availability prediction in order to assure the requested level of quality of service in wireless networks or analysis and prediction of the movement of an aircraft in combat in order to develop defending strategies. There are also situations in which the exact position of a moving object cannot be determined, for example when the moving object enters a shadow area of GPS and the estimation of future location by tracking the previous ones that were provided in visible regions becomes necessary.

As technology advances, more available data about moving objects is encountered, thus increasing ability to mine spatiotemporal data [3]. In [13], authors found out that human movement shows a high degree of temporal and spatial regularity. Froehlich and Krumm [8] show that a large portion of a typical driver's routes are repeated. It is thus reasonable to expect to extract that regularity, describe it and use it to predict future movement.

Different data mining techniques can be used to extract behavioural patterns from moving objects data, several prediction techniques can be used to model and predict moving object's future location, such as neural networks, Markov models, and specific types of dynamic Bayesian networks like hidden Markov models or Kalman filter. Still, all aforementioned methods have to be adapted to deal with moving object’s data. Furthermore, the most of them focus on managing historical and current movement data of moving objects and only a few of them have been proposed to deal with moving object’s future movement prediction [15].

2. Related Work

Considerable research on moving objects has been done in various application areas so far. J.Froehlich and J.Krumm [8] predict the route of a vehicle. They claim prediction is the missing piece in several proposed ideas for intelligent vehicles. Prediction is useful for giving warnings about upcoming traffic hazards or giving information about upcoming points of interest, including advertising, to the driver. C.S. Jensen et al. [9] track a population of vehicles. They list a range of applications that may utilize this kind of tracking, such as mobile services in relation to traffic monitoring, collective transport, and the management of fleets, (e.g. of emergency vehicles, police cars, delivery trucks, and vehicles carrying dangerous or valuable cargo). In [14] authors present methods for person motion prediction in order to enable a mobile robot to keep track of people in its environment and to improve its behaviour. They state that robots operating in populated environments can improve their service if they react appropriately to the activities of the people in their surrounding and in the same time not interfering with them.

J. Petzold [11] presents context prediction evaluated by the people walking through the office building, recording their movements on PDA.

G. Yavas et al. [6] consider mobility prediction a hot topic in management research field. J.M. François et al. [7] claim that prediction can be particularly useful to assure the given level of quality of service despite the typically large jitter and error rates in wireless networks.

D.W.Sims et al. [10] analyse large amount of data representing displacements of diverse marine predators – sharks, bony fishes, sea turtles and penguins, while A. Franke et al. [5] encapsulate movement and kill-site behaviour in three wolf packs.

Furthermore, J. Krumm and E. Horvitz [4] mention usefulness of next location prediction in ubiquitous computing research. As they claim, beyond current object location, location-based services can be developed by taking into account object future locations, providing more efficient service.

Some work has been done concerning moving objects in general [3][12]. It is also worth to mention a recent database research on moving objects [1][2], where important issues are development of spatiotemporal databases to support moving objects, efficient indexing techniques and efficient extraction of spatiotemporal data.

3. Automation of the Modelling process and Prediction

3.1. Objectives

Shortcoming of related work is in most cases considering only location and time as attributes of moving object’s movement. We believe that considering geospatial conditions (e.g. type of a habitat, climate, and various object vicinity) that pertain to the location and temporal conditions (e.g. season, time of the day) leads to a more accurate description of moving objects behaviour and prediction of their future movement. The most of additional attributes can be extracted from coordinates and time attributes. Knowing space coordinates, attributes such as vegetation, altitude or type of road can be scanned from geospatial maps. Similarly, knowing time attribute, attributes such as season, temperature or rainfall can be get from historical data collected by weather stations.

Furthermore, the prediction (in the way it is handled in previous work) assumes dispose of an amount of training data concerning observed area, i.e. area in which prediction has to be made. It means that we are not able to predict the object movement in areas where the object has never been before. We propose adaption of existing methods in

Table 1 Comparison of movement prediction methods

Moving objects	Application area	Method	Technology[1]	Advantages	Limitations
Mobile users (walking or driving)	Predicting the next router that a host will be linked to in order to assure high quality of service level [7]	Hidden Markov model (HMM)	GPS or antenna	Non-similar patterns distinction; Model states are not predefined (they depend on the data)	Number of models grows as the number of neighbour access points squared; Impossible to predict future locations in new areas
Vehicles	Predicting end-to-end route of a vehicle [8]	Clustering, similarity measuring	GPS	Predicting driver's entire route, not only destination; Independence of map matching	Assuming to have been given driver's historical data; Impossibility to predict future locations in new areas
Vehicles	Tracking populations of vehicles and predicting their movement [9]	Tracking techniques (point-, vector- and segment-based)	GPS (INFATI data [18])	The tracking component can be used in a variety of applications; Combining different prediction techniques into a single robust tracking technique	Very naive and simple short-term prediction algorithm
Vehicles	Predicting a driver’s near-term future path for giving the warnings about upcoming road situations [17]	Markov model	GPS	Simple and accurate algorithm; Prediction is based on only a single previous observation of a few road segments	Short-term route predictions; Impossible to predict future locations in new areas
People	Predicting the indoor movement, i.e. the next room a user will enter in office building [11]	Artificial Neural Networks	Manual location recording on PDAs	Comparison of several prediction techniques; Predicting not only future locations, but the duration of stay at and the locations and the time of the location change	Manual location recording; Impossible to predict future locations in new areas; Applicable solely on indoor places or other places with the clear space division
General	Any, but tested on data about vehicles movement data [3]	Clustering, similarity measuring	GPS (INFATI data)	Using clusters instead of raw data (which is cheaper to mine); Exceptional points removal	Assuming periodic movement (the same for each object’s data); Impossibility to predict future locations in new areas
People	Improving robot’s behaviour in populated environments by keeping track of people and predicting their movement [14]	HMM, Clustering	Laser-range finders	Long-term prediction; Maintaining and estimating positions of multiple persons; Complete solution (from data collection to prediction)	Clustering depends on trajectory length; Impossible to predict future locations in new areas
Animals	Prediction of wolf kill-sites for gaining insight into predator-prey dynamics [5]	HMM	GPS (collars and manual recorded from aircraft)	Examining interaction between predator and prey; Exact location independence (measuring distance, angle and travel rate instead of solely coordinates)	Predicting only kill-sites, not future locations; Manual prey location recording

[1] used to get test data

order to predict movement in the new areas. Problem could be modelled considering the analogous areas as the same, thus allowing the data collected at one area to be used as training data for other areas.

Another possible improvement could be in supplementing prediction process with expert knowledge about particular moving object characteristics and behaviour.

In Table 1, comparison of some aforementioned works is given.

3.2. Generic model for moving objects' movement prediction

The schema of prediction process that consists of creating the model, learning and finally predicting the movement is given in Figure 1 [15]. "The model" here refers to the prediction model constructed using different prediction techniques and adaptable to the given data about moving objects (e.g. historical data, expert knowledge data, geographical data).

In the first phase, with a help from experts in an application domain, the problem is modelled (for example space partition and/or expert movement rules are defined). The gathered historical data is prepared (using for example clustering techniques, with additional removing of outliers, errors in data or random movement). They are eventually used to define model structure as well (using for example clustering methods to extract interesting places and then to define the parts of model). The historical data is (iteratively) used to estimate the model parameters. Further on, additional information such as terrain or climate characteristics is included in modelling and/or data preparation. The result of the first phase is a model, automatically adapted to the application domain, i.e. to the given data and knowledge representing certain class of moving objects.

In the second phase, the prediction is done based on the given test data by using prepared model and appropriate algorithms. Test data is the part of the historical data, not included in building the model, left to test model accuracy. As well as historical data, it

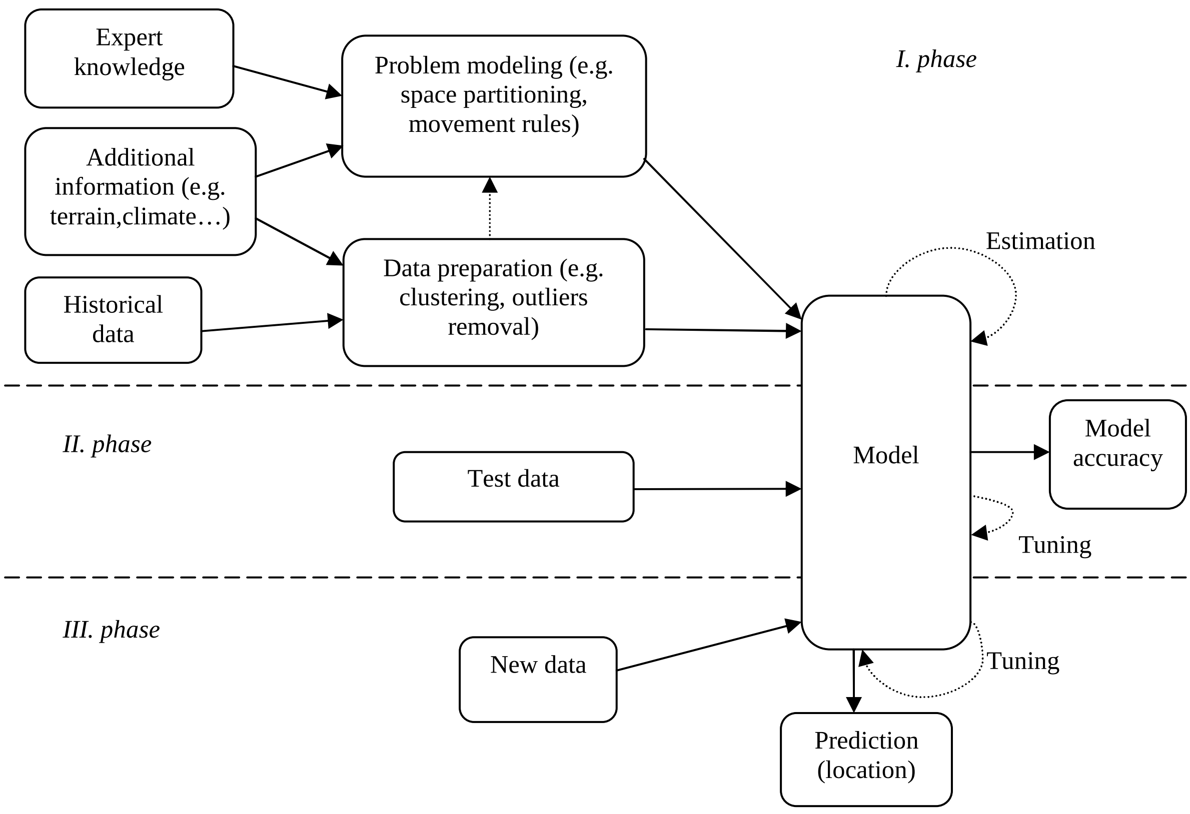

Figure 1 A generic model for prediction of moving object's future location

is prepared to fit the model input. Predicted locations are compared to actual locations stored in test data and model accuracy and statistics is calculated. Test data can be used to tune model parameters.

In the third phase, the prediction is done for given new data using the prepared model and appropriate algorithms, Information about accuracy (calculated in the previous phase) is provided to the user. New data can be used to tune model parameters. Presence of particular process elements differs for various applications. For example, expert knowledge or additional information could be included just to formulate problem or it could be used in an iterative process of parameters estimation. They don't have to be included at all, but that will lead to the loss of model completeness and model accuracy.

The main idea is to automate this process, which encompasses automated fetch of additional information using different services, discovery of expert knowledge from additional data sets (e.g. rule mining), embedding expert knowledge without model perturbation and the independence of application area.

4. Conclusion

Knowing moving objects' behaviour and predicting moving objects' future locations can be very useful in many application areas. Beside analysis which we could perform to extract some regularity in the movements and get better insight into moving objects' behaviour, the great issue is to predict moving object's next position.

Short overview and comparison of related work is given, in order to encompass main characteristics of moving objects and to address present problems. Conceptual model for moving objects movement prediction is presented. The directions for future work are to include the knowledge about the type of a habitat that pertains to the location and the knowledge about moving objects' behaviour. The main goal of our future work is to suggest mechanisms to incorporate those elements to a proposed generic prediction model.

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