Conceptual Model and Design of Semantic Trajectory Data Warehouse

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ABSTRACT

The trajectory patterns of a moving object in a spatio-temporal domain offers varied information in terms of the management of the data generated from the movement. The query results of trajectory objects from the data warehouse are usually not enough to answer certain trend behaviours and meaningful inferences without the associated semantic information of the trajectory object or the geospatial environment within a specified purpose or context. This article formulates and designs a generic ontology modelling framework that serves as the background model platform for the design of a semantic data warehouse for trajectories. The methodology underpins on higher granularity of data as a result of pre-processed and extract-transformed-load (ETL) data so as to offer efficient semantic inference to the underlying trajectory data. Moreover, the modelling approach outlines the thematic dimensions that offer a design platform for predictive trend analysis and knowledge discovery in the trajectory dynamics and data processing for moving objects.

KEYWORDS

Generic Trajectory Ontology, Multidimensional Entity Relationship, Semantic Annotations, Semantic Trajectory Data Warehouse, Spatio-Temporal Data Modelling

INTRODUCTION

The trajectory of an object is the sequence of ordered points of a path or route followed by the moving object in a defined geographical space, and mostly within a specified temporal function. Objects could be classified as humans, animals, or vehicles within a geographic context. The trajectories of these objects could be affected or informed by varied factors, such as, weather changes (for example, rain precipitation, and snow falls), gravity, geographic surfaces, and events, amongst others.

Over the years, tracking of the trajectory movement of these objects has been done with the aid of devices, such as, Global Positioning Systems (GPSs), smart phones, geo-sensors, surveillance cameras, and Radio-Frequency Identification (RFID) tags, amongst others. Trajectory data captured by these devices and the subsequent processing by Geographical Information Systems (GIS) have increased the amount of movement data for future trend analysis (Rigaux et al., 2001, pp. 2). Moreover, recent application of satellite devices has been adopted in capturing the trajectory of moving objects, as has been in the case of vehicular movements (Bodur & Mehrolhassani, 2015). The concept of trajectories has received quite an appreciable amount of study in the literature. The information

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gathered from specific trajectories has become useful in varied application domains. The collected data are valuable in the detection of informed and uninformed trends in trajectory movements, and critical in decision-making for these application domains, such as, tourism management, and animal migration, amongst others.

A semantic trajectory data warehouse (DW) is a data repository that stores the semantic information of a trajectory object and the associated spatial objects within a period of temporal instance to achieve a particular goal or purpose. In analyzing the semantic information of a trajectory object, the stop and move activity of the object at any temporal instance is determined by the goal. This goal can be classified as being a personal goal, an activity object goal, or a movement objective, for the activity in view (Da Silva et al., 2015; Parent et al., 2013). Some of the semantic information are annotations of semantic objects, events and activities, behavioral data, and the data of the spatio-temporal objects, amongst others.

Modelling and designing a trajectory data warehouse for analysis and predictive inferences have been addressed by varied researchers. The need to understand the rare semantics of trajectory stops, moves, velocity rates, and movement pattern, amongst others, still remain a challenge. Additionally, the characteristic attributes of trajectory objects and the semantic annotations associated with events and activities that the objects participate in draw out vital information that most trajectory data warehouses are not able to address.

In this paper, a framework model for the modelling and design of a semantic data warehouse for a trajectory object in a spatio-temporal paradigm is formulated. The novel proposition is to gather all relevant semantic data of objects and events related to the trajectory object, as well as, the trajectory object itself and its movement dynamics. The researcher introduces an approach that defines and outlines a generic ontology model for handling the varied semantic characteristics of trajectory objects, events and activities, environmental considerations, as well as, social media interaction. Hence, the main contribution in this paper is to present a generic modelling approach for the design of semantic data warehouses for trajectories. To this end, the researcher focuses on an approach based on the higher granularity level of preprocessed and transformed trajectory data, being an output of Extract-Transform-Load (ETL) procedures. This is necessary because of aggregated data item elements in the fact or dimension repositories.

The merits of the methodology approach are:

1. An expressive generic ontology model for trajectory objects, geographic environments, events and activities, and social media interaction;
2. A comprehensive trajectory data warehouse for efficient, scalable, and optimized query processing;
3. Maximum semantic annotation enrichment for every aspect of the trajectory of a moving object.

The technical contributions are summarized, as follows:

- To formulate a generic ontology for the modelling of semantic trajectory of moving objects which extends to different application domains;
- To instantiate the constructs of the formulated generic ontologies to design a semantic data warehouse model for the trajectory data of moving objects;
- To outline the thematic dimensions, the fact information, and the attribute and measure data for the trajectory data warehouse; which will serve as data modelling entities for semantic trajectory of moving objects;
- To utilize the semantic data warehouse instances as a platform for the predictive trend analysis and knowledge discovery of the trajectory of moving objects in a spatio-temporal application domain.
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