Patient Trajectory Modeling and Analysis

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Abstract. In the last decade, several and different trajectory data warehouses have been proposed, as an extension of traditional ones to take into account mobility data provided by ubiquitous systems. As a new paradigm, it was adopted by users in various applications such as patient trajectory in the field of health care systems. However, the proposed conceptual models suffer from dispersed points of view that have to be unified in order to offer generic conceptual support for experts and ordinary users. The goal of this work is to propose a unified conceptual model able to unify different points of view through a generic description of facts on one hand and dimensions of analysis such as patient and medical organism well adapted to new concepts imposed by the emergence of pervasive systems. In addition, we illustrate our work on a health care case study involving the modeling and the analysis of patients trajectories describing actions performed by medical actors in order to take care of patients' needs and to offer new means to decision makers to improve health care services quality.

Keywords: Patient trajectory, trajectory data warehouse, unified model

1 Introduction

Recently, the modeling and the analysis of data out coming from moving objects activities such as stream nerve in the case of facial paralysis has attracted a particular interest which is motivated by the development of pervasive systems and/or positioning technologies. Moving objects activities generate a huge volume of data which permits the emergence of a new concept called trajectory data. Indeed, according to authors in [1] trajectory data is the record of the evolution of the position of a moving object traveling in space during a time interval in order to achieve a given goal. For analysis purposes, trajectory data have to be extracted, transformed and loaded into a new comer, in the decision making field, called Trajectory Data Warehouse (TDW). TDW takes birth by integrating spatio-temporal data related to objects motion and activities into a unique repository useful for analysis and/or mining. In fact, classical Data Warehouses (DWs)[2] have shown their little support for managing data generated by moving object. Following these purposes, classical DWs have to be extended to be able to support the data warehousing changing from the representation till querying

of data related to moving objects and their trajectories in order to extract knowledge from raw data captured by mobile devices. Whatever the type of the DW, classical, spatial, temporal, spatio-temporal, or trajectory, the design of these DWs remains a difficult task that have to be performed by experts. However, it would be motivating to allow experts and ordinary users to define and to build themselves their model through a simple and flexible process. Traditionally, the design of a DW is based on an adequate representation of facts such as patient test on one hand and dimensions of analysis such as physician, hospital, etc. In [3], the author has shown, through a proposition leaning on a graphical representation offering a visual help to the user, that a unified representation can be envisioned. We think that the model proposed in [3] is very interesting. However, it does not take into account the new requirement of mobile object imposed by the emergence of trajectory data and warehouse. In fact, classical DWs do not allow the analysis of the moving object and its trajectory. Various TDW models oriented applications were proposed such as those related to marketing, agriculture, health care, etc. Nonetheless, at the best of our knowledge there is no consensus on methodologies proposed for TDW modeling. After a survey related to trajectory data warehouse models , we propose a unified model representing the basic structure of a TDW which can be used to apprehend the modeling of facts and dimensions in a unified way.
We also illustrate our work on a health care case study involving the modeling and the analysis of patients trajectories describing actions performed by medical actors in order to take care of patients' needs. In fact patients move to reach health care institutions dispersed along the territory and leave digital traces either in their ways or into targeted institutions. In these, actions, most of the time, involve mobility that have to be tracked. Getting these traces, thanks to pervasive systems either medical or ambient, and collecting them into TDW will offer new means to decision makers to improve health care services quality.
The remainder of this paper is organized as follow. The next section presents a scenario of patient trajectory. Section 3 highlights the structure of the unified model. Finally, we conclude and we propose future works.

2 A scenario

TDW can be applied in many contexts. We consider the patient as a moving object which traverses several trajectories leading to points of interest which are medical institutions. Moreover, a patient trajectory is the series of events that entail the patient with the health care system. In fact, the patient visits many health care institutions where he has to do different tests and clinical exams in order to have an idea about his disease evolution. In each health care institution there are several specialized services such as cardiology or emergency. each service has a medical staff which is composed of physicians, anesthetist and nurses. Adding to that, we find specialized health care equipments and devices such as scanner, mammography, probe, and stent.
Besides, data resulting from all diagnostics and grading medical systems pro-

posed in [4] [5] [6] [7] [8][9] constitute valuable information for curing patients and for learning more about the disease. All of this generated data are dispersed into many medical organisms' information sources such as the doctor offices, hospitals and physiotherapy organisms. This raises the need to integrate them into a TDW able to handle moving objects, and to enhance collaboration between physicians and scientists.

3 The Unified Model

TDW design process consists in different steps. Moreover, for the case study of patient trajectory, we create the fact table which is trajectory and/or clinical test almost the time. Then, we define different dimensions such as medical organisms, patient, and physicians. The design of the TDW can be finished at this step and we get a *star schema* for this TDW. Furthermore, we can also make hierarchies for the dimensions by defining the members. It can be the case of making hierarchies to medical organisms like hospitals and materials. This step results another type of structure which is the *snowflake schema*. In addition, we can add one or many facts like tests, and we get a *constellation schema*.

3.1 Modeling facts

A fact table is the primary table in a dimensional model which contains measures corresponding to an event or a situation. In our example the trajectory is the fact, showing the trajectory toward several criteria like date and point of interest. In fact, measures can be obtained by the intersection of different criteria called dimensions. A TDW should include a spatial, a temporal, and a moving object dimension. A fact has the following structure: fact−name[(T),(fact−key), (temporal−reference−attributes), (spatial−reference−attributes), (moving−object−reference−attributes), (accurate−fact−attributes), (holistic−fact−attributes)] where:

- fact−name: is the name of the type
- T: is a mark for the trajectory fact type
- fact−key: is the concatenation of the values of temporal−reference−attributes, spatial−reference−attributes and moving−object−reference−attributes.
- temporal−reference−attributes: is a list of attribute names, each attribute is a reference to a member instance in a time dimension.
- spatial−reference−attributes: is a list of attribute names, each attribute is a reference to a member instance in a space dimension.
- moving−object−attributes: is a list of attribute names different from spatial or temporal attribute names, each attribute is a reference to a member instance in object dimension.
- accurate−fact−attributes: is a list of attribute names including distributive and algebraic measures.
- holistic−fact−attributes: is a list of attribute names including holistic measures.

3.2 Modeling dimensions

Information connected to facts can be analyzed in terms of entities. These entities called dimensions. Dimensions and dimension members have the same structure: member−name[(M), (member−key),(list−of−reference−attributes), (list−of−property−attributes)] where:

- member−name: is the name of the member
- M: is a mark for the member
- member−key: is a list of attribute names, the concatenation of these attributes identifies each instance of the type
- reference−attributes: is a list of attribute names where each attribute is a reference to the dimension member.
- property−attributes: is a list of attribute names where each attribute is a property for the member. Only the member−key is mandatory.

4 Conclusion

In this paper, we proposed a unified modeling for TDW design model. This general representation offers a unified way for modeling facts, dimensions, and members. Nerveless, it takes into consideration requirements for modeling and analysis of patient trajectory. Through a motivating example for health care field, we prove the validity of the proposed consensus methodology. As future work, we suggest to add a rear layer of patient trajectory ontology that allow our model to automatically generate a patient trajectory TDW specific to users requirements.

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