Semantic View on Trajectory Data for Ambulance Services Enhancement: Modeling, Storage, and Analysis Issues

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Abstract. Trajectory data are captured by sensors as sets of time-stamped positions that don’t carry any semantic, which harden its storage as well as its exploitation. In this paper, we reveal main semantic features of trajectory data to be covered by the target model in order to simplify further analysis. We propose two algorithms to finalize the integration of semantic information with raw spatio-temporal data, thus, building the semantic trajectory. We created customized UML profiles for an explicit representation of the semantic of trajectory data at the conceptual level in both transactional and multidimensional environments. To validate our conceptual approach, we implement an ambulance trajectory data warehouse, and we maintain OLAP analysis on the stored data in order to discover possible hidden relationships between simultaneously space, time and some issues in emergency medical services helping managers making strategic decisions in this field.

Keywords: trajectory data, semantic trajectory, UML profiles, conceptual modeling, ambulance, trajectory data warehouse, OLAP, emergency medical services.

1 Introduction

Trajectory data is an omnipresent kind of data generated by sensors and positioning technologies embedding mobile devices. It is cumulating every moment and blocking information systems of mobility-based applications which raise the challenge of efficiently store and analyze them. Indeed, there is a big need to transform trajectory data into useful knowledge helping managers making best decisions in ubiquitous applications. Nevertheless, knowledge extraction process is based on a multidimensional storage of trajectory data, thus, storage in a data warehouse. However, integrating space and time dimensions in a data warehouse is necessary but not sufficient to handle efficiently data continuously changing and transform them into meaningful information useful in a decision process. In fact, a high-level view on trajectory data, beyond its spatio-temporal nature, is required. We mean its semantic facet that should be modeled by all its features. Those later are expressed in term of geographic information specifying the space of movement, and the application-
domain information describing the context of application in which the mobile object acts. Semantic view on trajectory data allows performing more complex and meaningful analysis permitting to obtain finest and pertinent results. The following framework summarizes the issues tackled in this paper:

![Diagram](image-url)

**Fig. 1.** Semantic trajectory data modeling and analysis framework.

In this paper, we handle trajectory data generated by an important moving object, perceived as a point, namely the ambulance. We propose two algorithms to finalize the integration of semantic information, related to this application, with raw spatio-temporal data captured by sensors equipping the ambulance. We extended UML class diagram with stereotypes and expressive icons in order to explicitly represent the semantic of trajectory concepts and the constructors of multidimensional paradigm at the conceptual level. Our final goal is to facilitate and accelerate complex OLAP analysis on trajectory data in order to extract useful knowledge helping managers to make competitive decisions to ameliorate emergency medical services in general and ambulance services in particular.

The remainder of this paper is organized as follows; in section 2 we investigate trajectory data modeling field. In section 3 we describe the context of an ambulance application presented as a motivation example. In section 4, we explain the semantic view on trajectory data. In section 5 we propose a conceptual model for trajectory data rich with semantic represented explicitly and implicitly. Semantic data warehouse model is presented in section 6. Section 7 is reserved to the implementation and analysis, and finally we conclude in section 8.

## 2 State of the art

Spaccapietra and colleagues in [1] defined trajectory data as the user defined record of the evolution of the position (perceived as a point) of an object that is moving in
space during a given time interval in order to achieve a given goal. They are the first authors tackling the question of semantic and considering the trajectory for the first time as a first-class object. They performed a semantic segmentation of the spatio-temporal path into trajectories, and the trajectory into stops and moves. The semantic of trajectory is linked to BES (Begin-End-Stop) concept, move phases delimited with two stops, the network constraints, and the links to the rest of application objects. Concerning conceptual modeling, authors used MADS [2] notations in an ER like model, thus in a transactional environment. They proposed two alternative modeling approaches for trajectory data; one based on a design pattern and the other is based on dedicated data types. The Trajectory Design Pattern offers predefined sub-schema providing basic data structures for trajectory data modeling. It can be adjusted toward the application requirements and connected to the rest of its data base schema. Trajectory Data Type is the alternative solution consisting in encapsulating common components of trajectories a TrajectoryType data type and define methods enabling access to them. Both approaches may be combined to offer an efficient modeling system according to application needs. In [3] a new UML profile is performed to cope with modeling the semantic of mobile hospital trajectory data. They extended UML class diagram with stereotypes and icons to allow their model certain flexibility needed to succeed the representation of semantic aspects of trajectory object and its related concepts inspired from the work of Spaccapietra mainly stops, moves, begin, and end.

TrDW is a very recent concept introduced by Braz and colleagues in [4] imposing the adaptation of data warehouse technology to support trajectory data. It is a challenging new area facing three main issues; one related to conceptual and logical modeling, the second related to the loading phase (ETL process) and the last to the computation of measures (aggregations of trajectory-oriented measures) for future OLAP purposes. Concerning the conceptual modeling, there is not until now considerable interest beside the importance of such phase, and designers are satisfied by only representing the TrDW by adopting the well-known relational schemes at the logical level namely star, snowflake and fact constellations and extending them with space and time dimensions. In [4], [5], and [6], authors are interested to trajectory reconstruction and ETL process. Similar work is of Marketos and his group in [7], [8], and [9] who used the classic star schema multidimensional model to design the TrDW defined with one central fact table and three dimensions (Object-Dim for the user profile, Space-Dim for the space and Time-Dim for the time), in which the authors integrate some semantic information about the specificities of space, time as well as the moving object.

Recent works handling the conceptual modeling problem and taking into account the complex structure of trajectory data and its semantic character, for instance [10]. In this later paper authors are interested to modeling herd animal movement data in a trajectory data warehouse. They adopt the idea of stop and move proper to Spaccapietra. The same idea employed to enhance the commerce investment activity in [11] by modeling trajectory data generated by a mobile information collector. Indeed, mobile professionals, communicating via mobile devices and moving in a roads network thanks to means of transport equipped with sensors, are in charge of collecting huge amounts of mobile data from planned and not planned observations. These data are modeled in a trajectory data warehouse, implemented and analyzed in
order to help investors deciding about the best investment to be made. In fact, the trajectory data warehouse was proven as a solution in many fields, therefore, it invaded all domains. In [12], the trajectory data warehouse is conceived to enhance the supply chain. The proposed model also employs the famous and successful approach of Spaccapietra to succeed the modeling of continuously changing data. The medical filed generates huge amounts of data which imposes the implementation of a data warehouse. It is necessary to enhance treatments and facilitate the detection of causes of disease as well as other scientific discoveries. In this context Akaichi et al. in [13] proposed a conceptual model for storing streams of facial nerve trajectory data in the purpose of studying the evolution of the states of patients affected by facial paralysis. This work is enhanced with a visualization algorithm of the evolution of the facial nerve’s state (FAN). Regarding the efficiency of data warehouse technology, and the tendency of moving from operational and transactional environments to multidimensional one, in [14] a system is proposed to assist users in designing a data warehouse called DWADS-Data Warehouse Assistant Design System. The system is based on the clover model and works on two steps. The first consists on choosing the schema model (star, snowflake, or constellation). The second finalizes the task. An evolved step in the world of trajectory data warehouse is tackled in [15] consists on updating the trajectory data warehouse according to structure changes in information sources (trajectory data warehouse maintenance). The proposed solution is a schema versioning approach keeping the track of TrDW evolution. In fact, authors proposed a set of algorithms handling updates for dimensions, dimension levels, and measures by always respecting integrity constraints. In [16] authors are interested to the logistic management field in particular truck delivery of goods as a very interesting branch in the economy domain. They proposed a solution for modeling and analyzing trajectory data generated by a traveling truck accomplishing its dedicated mission. Their final goal is to improve logistic management field. They consider a trajectory, at the conceptual level, as manageable and a decomposable object into meaningful events (each event is defined by begin, end and a semantic information) based on the idea of moves and stops introduced by Spaccapietra. Authors proposed a trajectory design pattern representing trajectory data using UML graphical notation and stereotype mechanism to distinguish facts from dimensions and from thematic information. They treat trajectories and events as first-class objects allowing an explicit modeling of trajectory’ geometry (TrajectoryType fact table) and its semantic facet (EventType fact table) represented with its components (moves, stops), Campora et al. in [17] adopt the same previous approach but using an ER formalism for conceptual design. In fact, they considered a trajectory as a first class semantic object having an identity, sub-components (stops, moves, and episodes) and other related thematic information. They used the Episode concept offering a high level and a more general unified representation of a trajectory element (move, stop). They developed a semantic trajectory model based on the MultiDimER notation to design their TrDW. Dimension tables are organized around a central fact table Episode. Spatial and temporal objects (dimensions), level hierarchies, measures and relationship types are expressively represented thanks to the visual icons. In [18], the MultiDimER model is adopted to conceive a public transportation application consisting on taxi travel. Writers defined a trajectory as a set of observations; each observation is the triple (location, time, semantic). They proposed two alternative modeling approaches. The
first one is based on composed multi-valued time-stamped measures in which a trajectory is considered as a measure composed of observations (stops and moves) which are themselves composed multi-valued measures, in the context of the studied application they are fill-up, pick-up and move. However, it presents some drawbacks related to aggregation functions, the relationship between time dimension and observations’ timestamps, and time consistency checks. Therefore, authors proposed a second approach which is based on composition of facts. It consists on considering each observation a separate fact relationship linked to the central fact relationship with zero-to-many relationship resulting on four fact relationships. Thus, the trajectory becomes a derived measure from the isolate fact relationships.

Semantic trajectory data was largely explained in [19], [20], and [21] who proposed two modeling approaches. The first approach is an ontological framework composed of three ontologies; the geographic ontology, the application-domain ontology and the geometric trajectory ontology. The second is an hybrid spatio-semantic model which consists on three levels of abstraction of trajectory data offering a comprehensive description for mobility data in any application. His approaches are based on the concepts of stops and moves introduced in [22] and generalized with the episode concept offering more flexibility for semantic segmentation of trajectory data.

3 Motivation Example: Ambulance Travel

The ambulance service is indispensable since it assure non programmed interventions in urgent cases to support a patient or an injury or a parturient woman until reaching the nearest medical institution. It is a very important service in which the time counts and the quality of service also. Therefore, it is a sector that should be supervised and well studied to be ameliorated in the purpose to succeed complex interventions and save the patients lives. The ambulance is a specific vehicle equipped with sophisticated materials and first aid drugs. It has an associated crew composed of a medical staff, an assistant and naturally a driver. The medical staff could include a doctor or not, and a nurse or more depending on the incident. Since it is a very important vehicle, it should be tracked everywhere to know its position. This is performed thanks to GPS-receiver implanted in the ambulance vehicle. The ambulance is equipped also with a GSM-modem assuring real-time transmission of trajectory data to the server managed by an ambulance manager. This device enables also vocal communication between the assistant and the distant manager as well as the exchange of other data necessary to successfully accomplish the mission. The ambulance trajectory begins in the ambulance service center or in the owner medical institution until an urgent call comes. When this later event happens, a crew is affected to the available ambulance, and it moves to the location of incident. The ambulance takes the shortest and less congested routes to reach its destination, and don’t stop in traffic lights, it stops only in the location of accident, in its home destination or in a medical institution, except unexpected break down. A call in an anxious situation requires the intervention in the subsequent 30 minutes no more, since the time between the call and the arrival of the ambulance could make the difference between death and life.
While moving, sensors embedding the ambulance capture huge amounts of spatio-temporal records (longitude, latitude, timestamp). They are ambulance trajectory data that should be efficiently stored and exploited in order to extract the useful information helping to push this important service. Ambulance movement data analysis requires information about the trajectory (stops, moves, speed, and duration of stop or move, direction, the location of incident, regions of move or stop, roads followed). Other information is related to the mission, object of an ambulance intervention (activity achieved during a stop, the type of incident, the state of the patient, the specialty of the medical staff…). This information enables formulating more complex and significant queries as well as extracting explaining behavioral patterns, which is impossible by only considering the spatio-temporal view of a trajectory consisting on a set of time-stamped locations (x, y, t). Indeed, more semantic information is required for meaningful interpretation of the movement behavior, for facilitating as well as accelerating the analysis process.

4 Semantic view on trajectory data

Inspired from the hybrid spatio-semantic trajectory model of Yan [19], we consider that a trajectory could be seen in levels, each level allows explicitly the detection of features to be covered by the target conceptual model. This representation gives a clear and comprehensive description for trajectory data:
Fig. 3. Trajectory levels representation.

**Raw level.** It is the lower level of abstraction where the trajectory is in its raw nature, thus, the set of GPS positions (x,y,t) received by a sensor technology used by the object in motion.

**Structured level.** This level is the bridge between the geometric view still considered in moving objects data modeling attempts, and the semantic view always searched. It facilitates the task of integrating what ever semantic required by the application to the trajectory.

**Semantic level.** At this level, we reach the physical trajectory. In fact, we reveal semantic information to be integrated with each episode such as the specification of the space, the specification of time, the objects involved by the application with which interacts the moving one, the activities achieved… Consequently, we reach the definition of a new concept recently introduced [16] and [19] namely ‘semantic trajectory’.

### 4.1 Stop, move, episode

Spaccapietra [1] introduced the concepts of stop and move generalized by Yan in [19] by proposing a unified concept *episode*. The semantic segmentation of a trajectory into stops and moves gives a structured view on trajectory data. In the following, we propose an algorithm consisting on detecting stops and moves based on the speed indicator. The algorithm takes as input the set of GPS positions denoted RT for raw trajectory. It compares the speed at each point and feed the stop list if it corresponds to stop or the move list if it corresponds to move. Both lists are returned in output:

```
algorithm StructuredTrajectory_Construction
INPUT: RT:<P₁,...,Pn> with Pᵢ: <x,y,t>
  S: Speed
  STH: Speed Threshold
OUTPUT: Stop: <S₁,...,Sₘ>: list of stops;
             Move: <M₁,...,Mₖ>: list of moves;
```
with \( S_i = M_i = \langle X, Y, t_b, t_e \rangle \) and \( X \): set of \( x \), \( Y \): set of \( y \), and \( t_b \): time begin and \( t_e \): time end

\[
\begin{align*}
\text{begin} \quad i \leftarrow 1, j \leftarrow 1, t \leftarrow 1; S_i.t_b \leftarrow P_i.t; \\
\text{WHILE (} i \leq \text{RT.Length) DO} \\
\text{WHILE (} S \leq \text{STH) DO} \\
\text{IF (} i \leq \text{RT.length) } S_j.X &.add(P_i.x); \ S_j.Y &.add(P_i.y); \ i++; \\
\text{END IF} \\
\text{END WHILE} \\
\text{S}_j.t_e \leftarrow P_{i-1}.t; \ M_t.t_e \leftarrow S_j.t_e; \ j++; \\
\text{WHILE (} S \geq \text{STH) DO} \\
\text{IF (} i \leq \text{RT.Length) } M_t.X &.add(P_i.x); \ M_t.Y &.add(P_i.y); \ i++; \\
\text{END IF} \\
\text{END WHILE} \\
\text{M}_t.t_e \leftarrow P_{i-1}.t; \ S_j.t_b \leftarrow M_t.t_e; \ t++; \\
\text{END WHILE} \\
\text{end.}
\end{align*}
\]

4.2 Geographic information

We divide the space of movement into points of interest forming the stop episodes, lines of interest object of move episodes and regions of interest to which belong segments of trajectories:

**Points of Interest.** The geographic label of stop episodes. In our ambulance application, they are medical institutions kind of hospital, clinic, or specialized health care unit which could be of type private or public, location of incident (Home, hotel, school, restaurant, factory, street, airport, market, station, museum, university, sea, football stadium...). Finally, the ambulance services center. Traffic lights don’t concern ambulance vehicles since it is an emergency service. However, break down points are of interest since further decisions should be taken to save the case.

**Lines of Interest.** The geographic label of move episodes, thus, the segments of roads followed by the object in motion to displace from one point of interest to another. Lines of interest are represented with the object roads network having significant properties (road_name, road_type: highway, pathway, road, bridge...).

**Regions of Interest.** We consider the finest and most important granularity of space, the zone which could be of a specific type such as rural zone belonging to a city< a municipality< a regional government< a country. The type of zone is crucial in elaborating precise and meaningful analysis in order to obtain precise and pertinent results for decision making purposes. Thus, the attribute zone_type has the following values: industrial zone, campus, residence zone, touristic zone, leisure zone, woody zone, rural zone, sea zone, commercial zone, other (for non specific zones).
4.3 Application-domain information

Modeling such information consists on establishing semantic links between the moving object and the rest of application objects from the one hand, and integrating thematic information from the other hand.

**Application objects.** Patient, ambulance, crew (driver, assistant), ambulance manager, techno-graphic object (GPS-receiver, GSM Modem), medical staff (doctor, nurse):

**Thematic information.** Stop-reason, speed and direction, demographic information: gender, age, function, The specialty of the doctor affected to the ambulance; type of the ambulance (A, C, D), type of incident requiring the intervention (auto accident, boat and water accident, train and plane accidents, work accident, animal accident (horse, dog...), food poisoning, sport injury, home accident, parturient woman, heart attack, serious injury...), cause of break down, cause of unexpected stops, the specialty of the medical staff...

**Semantic links.** Meaningful relationships of the trajectory with the rest of application objects, either the moving one, via the moving object, such as system users, crew of the moving vehicle. Here we profit from the powerful semantic relationship types of UML (association, generalization/specialization, composition, aggregation) with adequate multiplicities (many-to-many, many-to-one...).

4.4 Semantic trajectory

By integrating the geographic and application-domain information with the raw trajectory we obtain a semantic trajectory. We define a semantic trajectory (SmT) with: SmT=<E₁,...,Eₙ> with (Eᵢ) an Event: <sp, tᵢ, te, si> such that:

- sp: semantic position; the geographic label of the raw position, in short the point (P) or line (L) of interest with the associated region (R) to which belong those later: sp:(P/L, R);
- tᵢ: beginning instant of the event;
- te: ending instant of the event;
- si: semantic information derived from the domain of application.

The following algorithm consists on building the semantic trajectory:

```plaintext
algorithm SemanticTrajectory_Construction
INPUT: Stop: <S₁,...,Sₙ>
Move: <M₁,...,Mₘ>
P: <P₁,...,Pₙ>; List of points of interest;
L: <L₁,...,Lₙ>; List of lines of interest;
R: <R₁,...,Rₖ>; List of regions of interest;
OUTPUT: SmT:<E₁,...,Eₙ>; List of Events
with E:<sp, tᵢ, te, si>
begin
  k<1;
  FOR each Sᵢ in Stop DO
    i<Get application-domain information();
```
FOR each $R_t$ in $R$ DO
IF ($R_t$.include ($P_j$)) THEN
$E_k$.sp$\leftarrow$Sannotate ($R_t$, $P_j$) END IF
END FOR
$E_k$.t$b$$\leftarrow$S$t_b$; $E_k$.t$e$$\leftarrow$S$t_e$ ; $E_k$.s$I$$\leftarrow$I;
SmT.add($E_k$); j++; $K$$\leftarrow$$K$+2;
END FOR

$K$$\leftarrow$2
FOR each $M_i$ in Move DO
I$\leftarrow$Get application-domain information();
FOR each $R_t$ in $R$ DO
IF ($R_t$.include ($L_j$)) THEN
$E_k$.sp$\leftarrow$Mannotate ($R_t$, $L_j$) END IF
END FOR
$E_k$.t$b$$\leftarrow$M$t_b$; $E_k$.t$e$$\leftarrow$M$t_e$ ; $E_k$.s$I$$\leftarrow$I;
SmT.add($E_k$); j++; $K$$\leftarrow$$K$+2;
END FOR

end.

5 Ambulance trajectory data conceptual modeling

In this section, we propose a semantic-rich conceptual model for a comprehensive representation of ambulance trajectory data. We used UML class diagram extended with stereotypes and icons addressing the challenge of semantic representation of trajectory data at the conceptual level, for geographic objects representation we employ icons adopted from MADS approach [2]. The model is designed in StarUML 5.0 open source platform enabling creating customized UML profiles. Indeed, we created a new UML profile personalized to support trajectory data modeling.

Table 1. Extensions for semantic representation of trajectory oriented concepts.

<table>
<thead>
<tr>
<th>Element</th>
<th>Stereotype</th>
<th>Icon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trajectory</td>
<td>&lt;&lt;Trajectory&gt;&gt;</td>
<td><img src="image1" alt="Trajectory Icon" /></td>
</tr>
<tr>
<td>Episode</td>
<td>&lt;&lt;Episode&gt;&gt;</td>
<td><img src="image2" alt="Episode Icon" /></td>
</tr>
<tr>
<td>Stop</td>
<td>&lt;&lt;Stop&gt;&gt;</td>
<td><img src="image3" alt="Stop Icon" /></td>
</tr>
<tr>
<td>Move</td>
<td>&lt;&lt;Move&gt;&gt;</td>
<td><img src="image4" alt="Move Icon" /></td>
</tr>
<tr>
<td>Region</td>
<td>&lt;&lt;RegionOfInterest&gt;&gt;</td>
<td><img src="image5" alt="Region Icon" /></td>
</tr>
<tr>
<td>Medical institution, Breakdown point, Location of incident, Amb_service center</td>
<td>&lt;&lt;PointOfInterest&gt;&gt;</td>
<td><img src="image6" alt="PointOfInterest Icon" /></td>
</tr>
<tr>
<td>Roads network</td>
<td>&lt;&lt;LineOfInterest&gt;&gt;</td>
<td><img src="image7" alt="Roads Network Icon" /></td>
</tr>
</tbody>
</table>
Fig. 4. Ambulance Trajectory Data Conceptual Model.
6 Trajectory data warehouse modeling

The data warehouse is the core of decision support systems based on a multidimensional structure. This later is defined with a star-like model having a central table called fact surrounded with other tables called dimensions, and implemented typically in a star, snowflake or a constellation schema depending on application requirements and designer choices.

6.1 Semantic trajectory data warehouse

We adopt the idea of Trujillo and colleagues in [23] proposing to design a data warehouse with a central composite fact class in a shared aggregation relationship with n dimension classes. Our proposed model is based on the star schema, seeking for minimum number of tables, designed with UML class diagram enriched with stereotypes and icons in order to capture, at the conceptual level, the semantic of trajectory data on the one hand, and the constructors of multidimensional paradigm on the other hand. We used also StarUML platform.

Table 2. Extensions for semantic representation of trajectory fact and associated dimensions.

<table>
<thead>
<tr>
<th>Element</th>
<th>Stereotype</th>
<th>Icon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trajectory</td>
<td>&lt;&lt;Trajectory_Fact&gt;&gt;</td>
<td></td>
</tr>
<tr>
<td>Ambulance</td>
<td>&lt;&lt;Moving_Object_Dim&gt;&gt;</td>
<td></td>
</tr>
<tr>
<td>Episode</td>
<td>&lt;&lt;Episode_Dim&gt;&gt;</td>
<td></td>
</tr>
<tr>
<td>Stop</td>
<td>&lt;&lt;Stop_Dim&gt;&gt;</td>
<td></td>
</tr>
<tr>
<td>Move</td>
<td>&lt;&lt;Move_Dim&gt;&gt;</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>&lt;&lt;Time_Dim&gt;&gt;</td>
<td></td>
</tr>
<tr>
<td>Patient, Doctor, Nurse</td>
<td>&lt;&lt;Actor_Dim&gt;&gt;</td>
<td></td>
</tr>
<tr>
<td>Point of interest, Medical institution,</td>
<td>&lt;&lt;PoinOfInterest_Dim&gt;&gt;</td>
<td></td>
</tr>
<tr>
<td>Break-down point, Amb_services center,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location of incident</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roads Network</td>
<td>&lt;&lt;LineOfInterest_Dim&gt;&gt;</td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td>&lt;&lt;RegionOfInterest_Dim&gt;&gt;</td>
<td></td>
</tr>
<tr>
<td>Crew, Medical staff,</td>
<td>&lt;&lt;Dimension&gt;&gt;</td>
<td></td>
</tr>
</tbody>
</table>

The spatial dimension is not a unique condensed entity anymore, but it is broken down into three entities or dimensions (point, line, and region). Such granulation facilitates and accelerates the query formulation task, and allows elaborating more precise, meaningful analysis permitting to obtain the finest results at the reasonable time. This territorial subdivision offers also a precise geo-localization of the source of a given problem enabling making the precise decision at the right time.
Time dimension contains the instants of begin and end of a trajectory, the period of day (morning, evening, afternoon) and other specificities of time following an ascendant hierarchy (day, month, quarter, year). Measures are the duration of the travel, the traveled distance, the number of stops, number of moves, number of episodes, max speed, min speed, and average speed. In addition to other application-dependent measures namely number of patients supported, number of doctors and nurses intervened, number of break downs of the ambulance and number of deaths that could occur in an intervention.

**Fig. 5.** Ambulance trajectory data warehouse semantic model (STrDW).

### 7 Implementation, analysis and visualization

Ambulance services are indispensable in our life, and their qualities are constrained with the response time, skills of the medial staff, and the efficiency of the medical equipments. Insufficiency in one of the above constraints could cause the death of a patient or non desirable effects. Therefore, there is still a big need to check weaknesses and ameliorate this important emergency medical service. Ambulance trajectory data storage and analysis could lead to pertinent results to enhance this field. In this section, we implement an ambulance trajectory data warehouse in order to store ambulance trajectory data. We formulate OLAP queries where the answer could be the buried information making visible the hidden relationships between variables, which is necessary for making strategic decision in this domain, such as imposing new considerations in the ambulance
training, increasing the number of ambulances in zones where the range of incidents is high, enhancing the skills of the associated medical staff or of the whole crew to handle specific, particular or frequent incidents, augmenting the number of ambulances in a given place for a given period, adopting ambulance equipments to specific incidents…

7.1 Implementation

The first step is the implementation of our cube of data in order to store trajectory data. We use the relational DBMS SQL Server 2005 development environment.

![Image of Ambulance trajectory data warehouse relational model (star schema).](image)

**Fig. 6.** Ambulance trajectory data warehouse relational model (star schema).

7.2 Olap on-line analytical processing and visualization

In this section, we carry out ROLAP analysis on ambulance trajectory data. With ROLAP technology, OLAP operations (slice, dice, rollup, drill down) are traduced in SQL-Structured Query Language. However aggregations with SQL are possible using Group BY operation which is costing, thus we reformulate queries in MDX-MultiDimensional eXpressions, which is a language dedicated to query multidimensional data. We used OlapCube tool in order to restitute visual results of formulated queries.

**Query.** Which are the zones responsible of major types of incidents in summer?

This query makes in correspondence space, time and the type of incident. From such query, we aim to discover the role of space and time in explaining the cause of some incidents. The decision made on the light of this query could be increasing the number of ambulances in the zone where there is high number of accidents as well as adopt the medical staff skills and quality of medical equipment to save patients’ lives:

**SQL Query.**

```
SELECT SUM(nb_patient), zone_type, typeOfincident
FROM Trajectory T, Patient P, Region R, Date
WHERE T.id-patient = P.id-patient
```
And T.id-region = R.id-region And T.id-date=D.id-date And D.Quarter="3"
GROUP BY zone_type, type-of-incident.

MDX Reformulation. SELECT {([Measures].[Nb Patient], [Patient].[Type-of-incident].children)} ON COLUMNS, {([Region].[zone_type].children) ON ROWS FROM [Amb Traj DB] WHERE ([Date].[Quarter].&[3]).

Fig. 7. Visualization in OlapCube Reader.

8 Conclusion

Along this work, we detected semantic features of an ambulance trajectory, and we proposed two algorithms finalizing the task of attaching them with the raw spatio-temporal data. We implemented an ambulance trajectory data warehouse and we maintained some OLAP operations on the stored data using SQL and MDX. However no one of the used languages is adopted to explore adequately trajectory data as well as its deep semantic, which is the motivation of our future work.

9 References

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