
Mesosopic approach of the traffic for safety of navigation within the Mediterranean region

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RÉSUMÉ. Le niveau de détail des données géographiques est un critère fondamental en ce qui concerne l'analyse et la visualisation. Pour les trajectoires, l'information est souvent disponible sous la forme d'enquêtes origine-destination. Une analyse locale des différents types de trafics et de leur densité demande de désagréger cette information. Ainsi, pour les trajectoires s'appuyant sur des réseaux, cette opération est fondée sur le calcul du plus court chemin entre l'origine et la destination. Par contre, pour les trajectoires d'objets se déplaçant dans des espaces semi-ouverts (les océans, le ciel ou les espaces piétonniers, par exemple) cette approche est inadaptée. Ce papier présente une méthode qui permet l'analyse et la visualisation des déplacements d'objets mobiles à un niveau mesoscopique. Cette méthode est appliquée dans le cadre du projet SAFEMED qui recense plus de 600 000 déplacements de navires de commerce en méditerranéen.

ABSTRACT. To realize a suitable visualization or analysis, the selection of level of detail for geographic data is fundamental. For trajectory data, origin-destination survey is often the information input. Local traffic analyses require desegregation process. If mobile objects use a network, this process is based on the computation of shortest paths from origin to destination. On the other hand, for mobile objects such as vessels, plane or pedestrians, this approach is unsuitable. This paper presents a mesoscopic approach for analysis and visualization of this kind of mobile objects. The SAFEMED project, with more than 600 000 vessel trajectories, illustrates this method.

MOTS-CLÉS: objets mobiles, visualisation mesoscopique, trafic maritime.

KEYWORDS: mobile objects, mesoscopic approach, maritime traffic.

1. Introduction

The SAFEMED Project¹ is a response to the interest of the European Union (EU) to develop Euro-Mediterranean cooperation in the field of maritime safety and security and prevention of pollution from ships. This project addresses the safety of navigation within the Mediterranean region through the promotion and development of Vessels Traffic Monitoring Systems within the Mediterranean Partners. Task 2.3 O of this Activity aims at studying maritime traffic flows within the Mediterranean Sea. Sub-action 3 of this Task aims at developing a web Geographical Information System (GIS) on maritime traffic flows and related risks in the Mediterranean. Web GIS is the process of generating and delivering maps on the World Wide Web. These maps are created on demand each time the user reloads the web pages, often from dynamic data sources, such as databases. The webserver generates the map using a web map server or self-written software. Web GIS allows the map user to apply his own data filtering, selective content and the application of personal styling and map symbolization (legend). For the SAFEMED project, Web GIS allows partners to increase their risk analysis capabilities. Web GIS provide users with a tool allowing them to carry out their own analysis of risks related to maritime traffic within the Mediterranean from database. Expected results are varied, but one example would be helping the decision-making processes involved in the location of anti-pollution resources. This is only an illustrative example, the GIS itself being designed primarily for the display of results of database queries.

To design this prototype, we had a set of data about the traffic: Origin-Destination Survey (ODS). This survey includes 63 448 distinct pairs of ports which are used by the 608 473 voyages. There are 8 310 distinct ports of which 735 are inside Mediterranean Sea. Unfortunately, this survey doesn't include the vessels' routes.

The main objective of this paper is to define a mesoscopic approach for analysis and visualization of this kind of mobile objects. To set up this approach, we conceived an abstract network in accordance with the maritime constraints which represents the Mediterranean Sea. This abstract network provides a schematic representation of vessels' voyages. Finally, to experiment the feasibility of this project and to visualize the results, we used Google Earth, to display geographical information.

The outline of this paper is as follows. First, in Section 2, we present microscopic and macroscopic approaches of the traffic representation. In Section 3, we introduce the mesoscopic approach. Section 4 describes how to convert macroscopic data to mesoscopic data. In Section 5, one query on mesoscopic databases and their visualization are presented. Finally, in Section 6, we conclude.

¹ <http://www.safemed-project.org>

2. Microscopic and macroscopic approaches of the traffic representation

2.1. Microscopic approach of the traffic

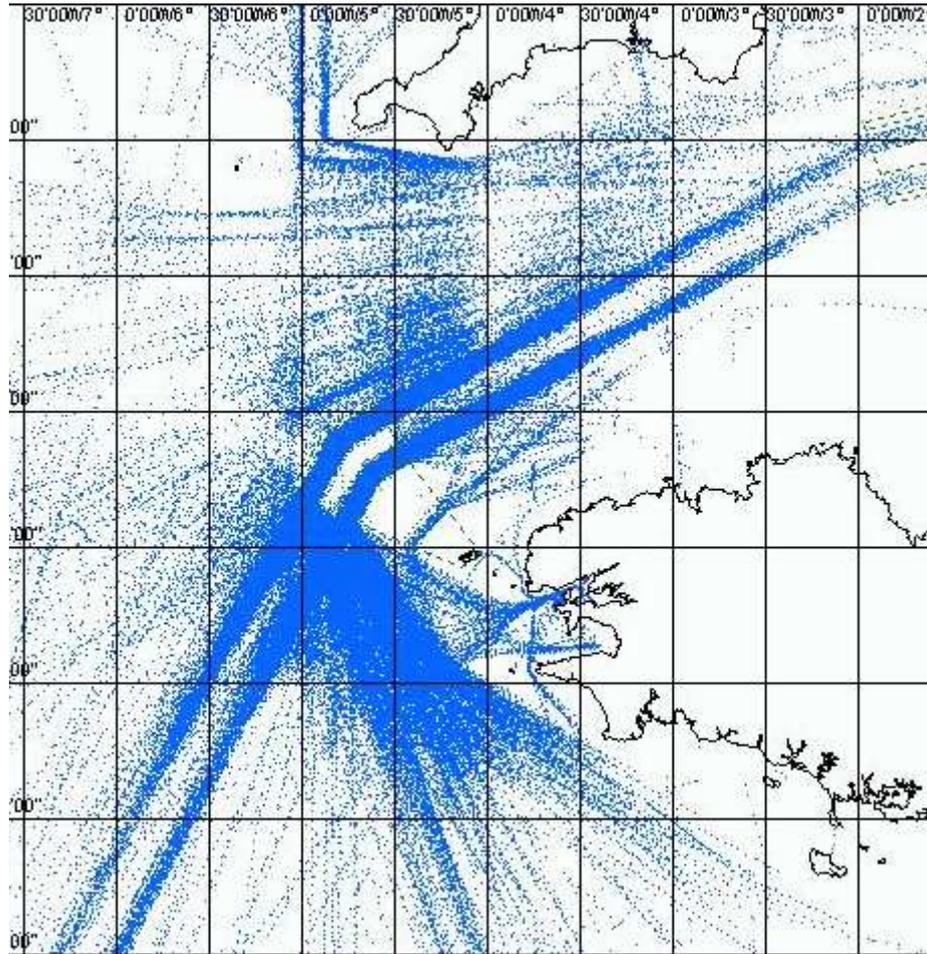


Figure 1: AIS paths on the separation traffic schema of Ouessant in May 2005 (CETMEF 2005)

The Microscopic approach displays the traffic with a high level of precision and is the most accurate since each vessel path is represented. Furthermore, this representation is in accordance with the reality of the traffic and with the maritime constraints. Nevertheless, it does not allow us to get a good representation of the traffic, because it is too detailed. If we use it, we will obtain a concentration of

aggregated paths without the possibilities to distinguish between two paths (see figure 1).

This figure was obtained with Automatic Identification System (AIS) data. This system provides information about identification, position, course, speed and cargo of merchant vessels. Mesoscopic approach is adequate to monitor in real-time a small area (Krauss et al. 1997, Peytchev and Claramunt 2001, Bertrand et al. 2007) and avoid collisions between vessels but it cannot be used in order to display the traffic extracted from a database.

As a consequence, we have to find a representation of the traffic more legible for a user and less detailed in order to be able to aggregate on paths the data of these voyages.

2.2. Macroscopic approach of the traffic

The macroscopic approach considers the traffic in its entirety. Only origin and destination of each voyage are considered. The most important is not the vessel paths as in the previous approach but the origin and the destination of these paths. This Origin-Destination Survey (ODS) is adequate to manage data from a database since we just have to store, for a vessel voyage, the origin port, the destination port and additional information about the voyage such as departure date, arrival date at destination, cargo and its tonnage. For the SAFEMED project, the REMPEC² (Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea) has licensed a database from the Lloyd's Maritime Intelligence Unit (LMIU). The LMIU is the world's largest provider of maritime data (Lloyd 2003). This database includes data on the movements of all merchant vessels for a period starting on 01\01\2004 and ending on 31\12\2005, which represented 608 437 voyages in the Mediterranean Sea. REMPEC has also its own database on accidents which happened within the Mediterranean Sea. Around 500 accidents are listed in this database.

Nevertheless, this approach does not allow us to display properly the traffic within the Mediterranean Sea. With this representation of the traffic we can not identify the areas where the traffic is most concentrated. For example, if a user wants to display the traffic at departure from Marseilles, he will obtain a series of paths from Marseilles to the other ports (see figure 2).

² <http://www.rempec.org/>

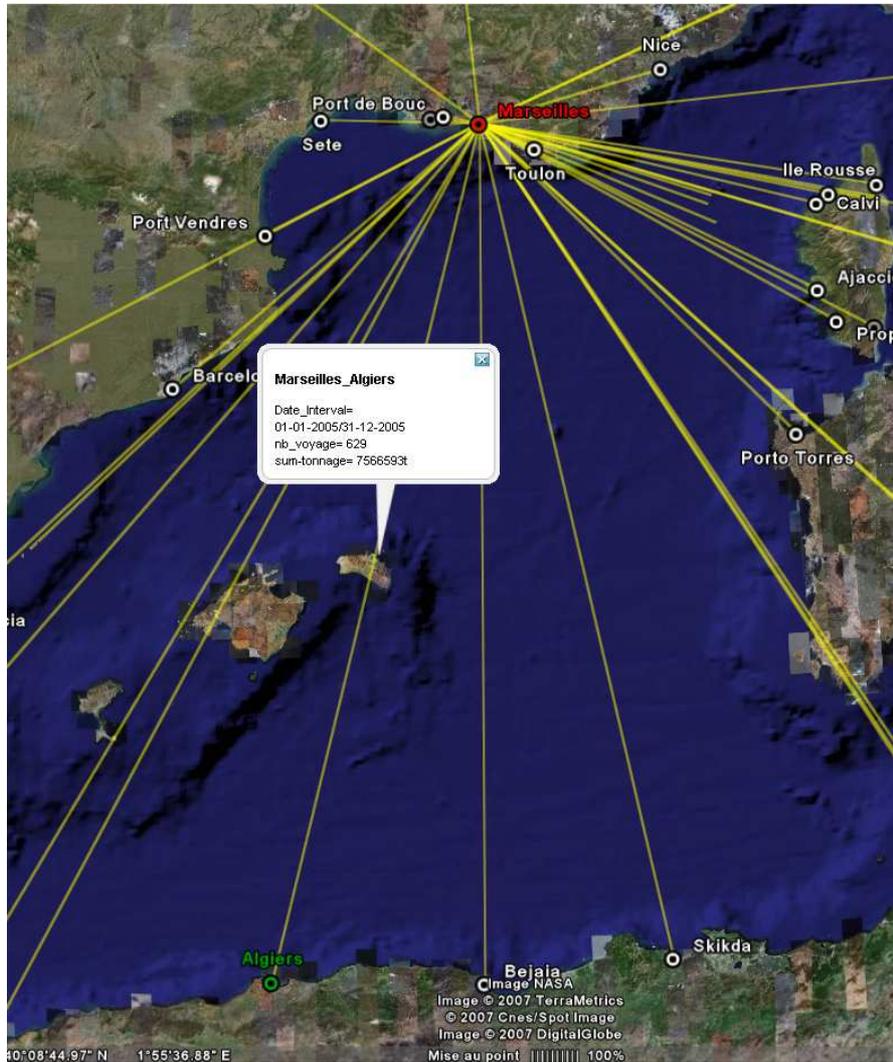


Figure 2: Traffic flows at departure from Marseilles

This representation is not realistic and not in accordance with the reality of the traffic. Furthermore, it does not help the user in assessing the traffic within the Mediterranean.

Therefore, we have to find an intermediate approach between the microscopic and the macroscopic approach in order to display properly the traffic and identify the areas where the traffic is concentrated.

3. Mesoscopic approach

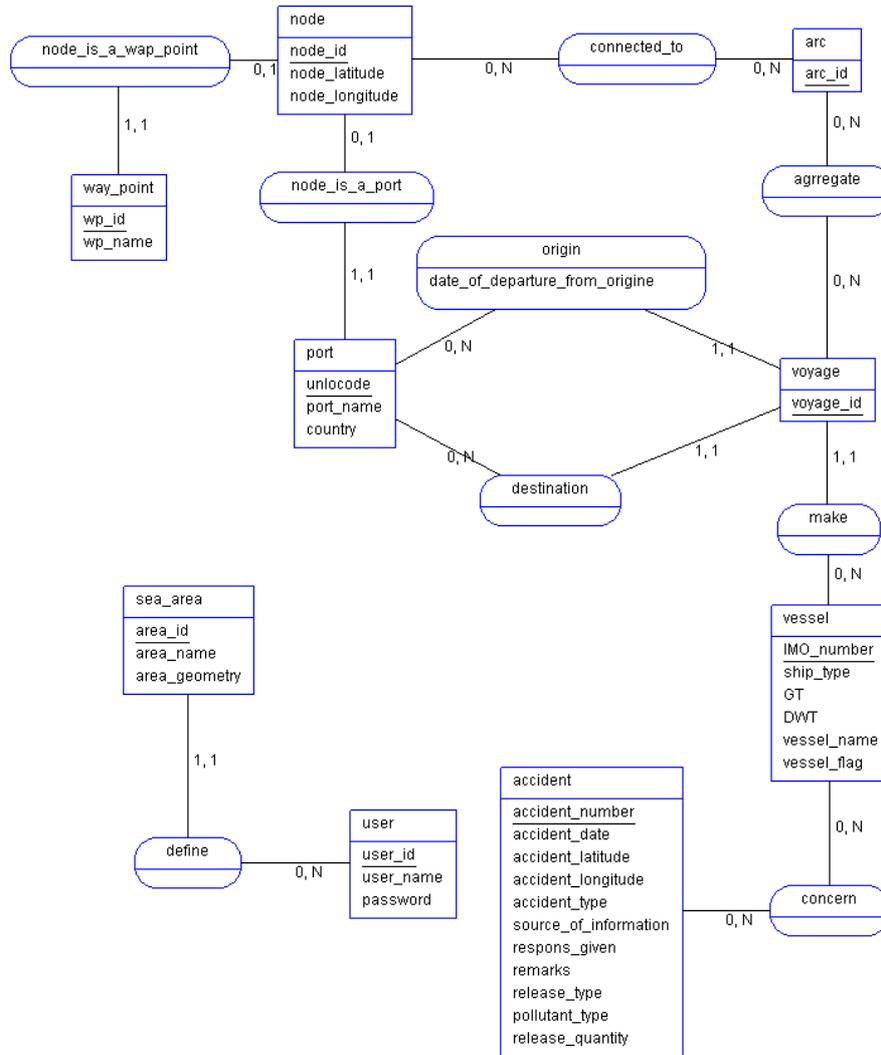


Figure 3: Conceptual data model for Mesoscopic approach

The mesoscopic approach has to display a schematic representation of the traffic with a level of detail which allows us to identify the area where the traffic is concentrated and to display the 63 448 distinct pair of ports which are used by the 608 473 voyages stored in the database. Furthermore, the abstract route representation must respect maritime rules. The abstract network must be in

accordance with the maritime constraints which represents the Mediterranean Sea. The user, however, will have to be made aware that actual routes followed by vessels cannot be displayed within the system due to lack of available data. This limitation is acceptable considering that only aggregated data will be displayed. Thus; the objective is to represent the Mediterranean Sea by an abstract network which links all the Mediterranean ports together and in accordance with the reality of the traffic. This abstract network is closed to real network. It can be used to aggregate data for the traffic density visualization but this abstract network is unsuitable to define the real road of vessels. Help to this network density

This approach is based on the new conceptual data model, includes new tables and reduces redundancies (see figure 3). This model includes nodes and arcs. Ports and way points are nodes. Way points define important points of shipping routes such as straits or channels. 2 kinds of way points are distinguished:

- Internal way point. For example, a strait between two Mediterranean islands or Mediterranean countries, such as the Strait of Messina, between Sicily and the toe of Italy.

- Connection to other seas: the Strait of Gibraltar, Bosphorus, Suez Canal.

Way point constraints are identified in (UKHO 2004).

4. How to convert macroscopic data to Mesoscopic data

The conversion of macroscopic data to Mesoscopic data is common. For example, (Thériault et al. 1999) convert very large data bank on commuting trips recorded in an Origin-Destination (OD) survey to find the optimal route for each OD trip (mainly the shortest Path procedure) on urban network. For Mediterranean Sea, vessel path are not well-known. For example, figure 4 represent the main routes for the west part of Mediterranean Sea. These routes don't link each port. Only main ports and way points are connected.

As a consequence, we have to create a new abstract network. Thus, we have, in a first step, to define the structure of our graph and its level of detail. In a second step, we have to disaggregate the data about the voyages, included in the database of REMPEC, in order to display all the voyages. In a final step, we need to aggregate the data from the different voyages with the arcs of our graph.

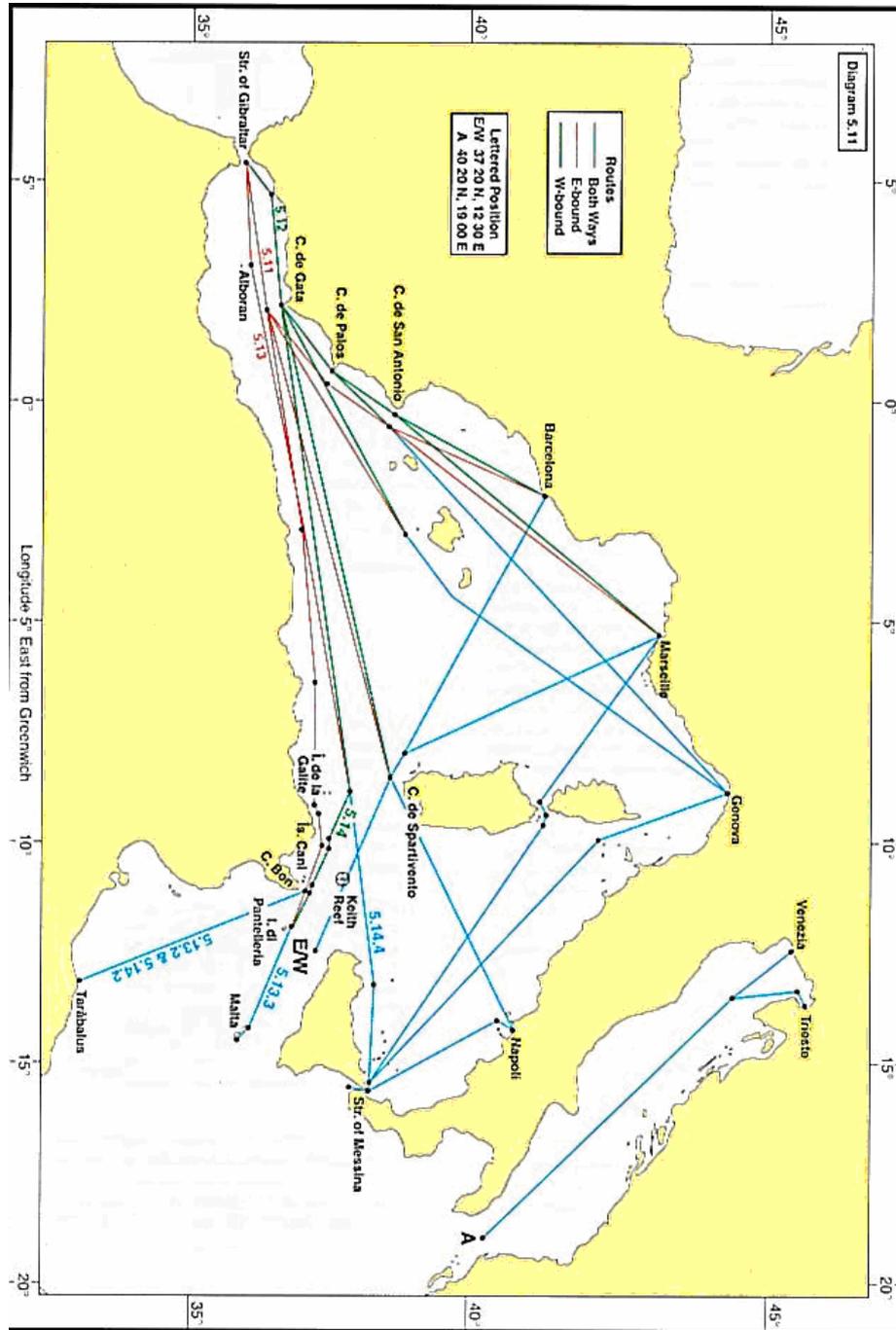


Figure 4: West Part of Mediterranean Sea with main shipping routes (UKHO 2004)

4.1. Graph design

The objective is to represent the Mediterranean Sea as a network which links all the Mediterranean ports together while remaining close to the reality of the traffic. As a consequence we will use a grid of points. We shall proceed with a step-by-step approach.

- First step: we have to find a stitch at our grid which offers us enough possibilities to properly display all paths. A stitch of 30 nautical miles (about 55 km) is a compromise between a schematic representation of the traffic which allows us for providing a good analysis of the traffic and a number of arcs and nodes not too large in order to not decrease the performance of the application. Nevertheless, the stitch will have to be adapted with the scale of the map chosen for the project.

- Second step: we have to adapt our grid to the topography of the Mediterranean Sea and to find its optimal resolution. Furthermore our grid has to be accurate, as it cannot cross through an island or a continent.

- Third step: our grid has to take into account

- The Mediterranean shipping routes (see figure 4),

- The internal way points at the following locations: the Strait of Messina between Sicily and the toe of Italy, the Corsica channel between Corsica and Italy, the strait of Bonifacio between Sardinia and Corsica, the strait of Otranto between Italy and Albania.

- The connection to other seas: the strait of Gibraltar, Bosporus, Suez Canal.

- Fourth step: our grid has to link each 735 Mediterranean ports to the shortest nodes together. For example, Ibiza is linked with point 14 (see figure 5).

- Fifth step: Ports outside Mediterranean Sea must be associated with one of the connections to other seas.

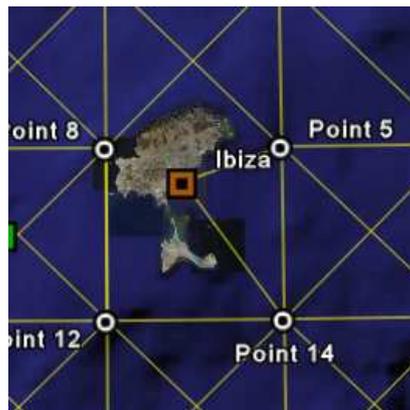


Figure 5: Grid around Ibiza

4.2. How to generate path from Origin-Destination data?

A voyage is an ordered set of arcs between two ports or straits. An arc is the link between two nodes. As a consequence, we have to find all the sets which represent the voyages included in the database. the REMPEC database takes into account 63 448 distinct paths. Furthermore, the sets have to be realistic and in accordance with the maritime traffic within the Mediterranean Sea. In order to display properly the voyages and to find the set of arcs for each voyage, we will use the shortest path algorithm since the best way between two ports, and the most profitable for the ship-owners, so the most taken, is the shortest. in order to solve the shortest path problem, Dijkstra algorithm (Dijkstra 59) is used. In our case, this algorithm computes the shortest path between two ports (or connections to other seas) which are linked to the grid.

Before this computation, a voyage was represented only as the following table “voyage” (see table 1):

Voyage_Id	Place_Name_Origin	Departure_Date	Place_Name_Destination	Arrival_Date
20769	Arzew	2004-05-05	Algiers	2004-05-05

Table 1: Former representation of a voyage

We had no information about the path of this voyage. As a consequence, we were not able to display properly this voyage. Now, with the new conceptual data model and the computation of shortest path, a new table “aggregate” is managed (see table 2). Tuples in this table link voyages with Arcs. Help to this table, information from voyage can be disaggregated. Table 3 joins the information about voyage and information from the table “aggregate”.

Arc_Id	Voyage_Id
1	20769
2	20769
3	20769
4	20769
5	20769
6	20769
7	20769

Table 2: The new table aggregate

Arc_Id	Voyage_Id	Place_Name_Origin	Departure_Date	Place_Name_Destination	Arrival_Date
1	20769	Arzew	2004-05-05	Algiers	2004-05-05
2	20769	Arzew	2004-05-05	Algiers	2004-05-05

3	20769	Arzew	2004-05-05	Algiers	2004-05-05
4	20769	Arzew	2004-05-05	Algiers	2004-05-05
5	20769	Arzew	2004-05-05	Algiers	2004-05-05
6	20769	Arzew	2004-05-05	Algiers	2004-05-05
7	20769	Arzew	2004-05-05	Algiers	2004-05-05

Table 3: Representation of a voyage with the new conceptual data model

5. Visualization of query results

To illustrate the result of mesoscopic visualisation, we define this Query: “Display the path from Arzew to one of these 3 ports: Castellon, Valencia, and Algiers”. Some temporal predicates could be also used. In the same way, some other attributes as “vessel type” or “vessel flag” could also be included in predicates. Finally, some way points could also be included in query. For this example, the legend is defined according to the number of voyages that arcs included.

5.1. Aggregation

To answer this query, Voyage_Id where the value of origin port is “Arzew” and the value of destination port is “Castellon”, “Valencia” or “Algiers” is selected. In the table “aggregate”, where the value of attribute Voyage_Id is one of the selected values, the Arc_Id is selected. Finally, for each selected Arc, the sum of selected voyage is computed. So, we obtain as result table with two attributes: Arc identifier and sum of selected voyages.

5.2. Visualization

We use Google Earth in order to display the answer to the query. Google Earth is an example of web application able to display geographic information. This web application is useful for this prototype. Unfortunately, Google Earth is unsuitable for SAFEMED project. Indeed, Google Earth internet data flow is too important for several south Mediterranean partners.



Figure 6: Query visualisation on Google Earth

The result table is employed to generate one KML (Keyhole Markup Language) file. KML is an XML-based language schema for expressing geographic annotation and visualization on web GIS. For each arc of result table, colour and width are defined according the number of voyages associated with this arc. In the same way, nodes including ports, linked by selected arcs are added to the KML files. This file is displayed on Google Earth (see figure 6). KML files can also be used by other web GIS.

6. Conclusion

Mesoscopic approach is common for traffic databases and real networks. Our prototype allows a user to compute and display all the queries which can be computed from the ODS REMPEC database. It provides a useful analysis of the traffic and risks related to this traffic. To set up this approach, we conceived an abstract network in accordance with the maritime constraints which represents the Mediterranean Sea. This abstract network provides a schematic representation of vessel's voyages. Finally, to experiment the feasibility of this project and to visualize the results, we used Google Earth, to display geographical information.

However, the chain stage is not yet automated; some steps have to be done manually for the moment. Nevertheless, all the steps which have been done manually can be automated. In the same way, this Mediterranean abstract network must be improved. Our grid are too regular, several points must be moved. For example, some axial adjustments with capes are required. To improve this network, we must first display different wide areas with all vessels' voyages.

Finally, this mesoscopic approach with abstract network can be useful for other mobile objects analysis as pedestrian or plane.

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