

A DATA MODEL FOR OPERATIONAL AND SITUATIONAL INFORMATION IN EMERGENCY RESPONSE: THE DUTCH CASE

S. Zlatanova^a, A. Dilo^b

^a GIS Technology, OTB, TU Delft, P.O. Box 5030, 2600 GA Delft, the Netherlands – s.zlatanova@tudelft.nl

^b Pervasive Systems, EWI, Twente University, P.O. Box 217, 7500 AE Enschede, the Netherlands – a.dilo@utwente.nl

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ABSTRACT:

During emergency response a lot of dynamic information is created and needs to be studied and analysed in the decision-making process. However, this analysis of data is difficult and often not possible. A major reason for this is that a lot of information coming from the field operations is not archived in a structured way. This paper presents a data model for the management of dynamic data, which captures the situational information (incident and its effect) and the operational information (processes activated and people/departments involved). The model is derived from the emergency response procedure and structural organisation in the Netherlands.

1. INTRODUCTION

The first hours of response to a disaster are very important for saving human lives and reducing damages in public and private properties (Diehl et al, 2006, NRC 2007, Zlatanova and Fabbri 2009). In this phase, the decision-makers need not only up-to-date information, but also means to analyse the massive data flows. In the last years, many systems have been developed that provide solutions for emergency response (ER). There are software systems that provide complex analysis and predictions, but they are dedicated to specific disasters (e.g. Viking for flood, Viking 2006). The systems for sharing of operational data between the ER sectors usually provide limited possibilities for data analysis (e.g. Eagle, Geodan, 2008). One of the reasons for this is the lack of a structured way for managing dynamic information. We have extensively studied the emergency processes in the Netherlands to be able to assess what kind of dynamic information needs to be shared and is important for the decision making process.

In Netherlands, first response operations are carried out by the fire brigade, paramedics, police and municipality. Depending on the scale of the disaster other organisations, e.g. civil protection centres, defence units, Red Cross, might be involved as well. The first responders follow well-defined policies and procedures, which are described in various legislation acts and manuals (e.g. MBZ, 2003). Although very detailed, these documents give insufficient indications on the type of information that is needed during emergencies.

We have performed some investigations (Snoeren et al 2007), but still a complete inventory of the information needed during the ER is lacking. The reason behind this are: 1) the large varieties in type and scale of the disasters, and 2) the diverse views/interpretations of the different ER sectors. Dynamic data are usually stored as a collection of files without a specific structure. The structuring would facilitate a fast access to a desired piece of information, as well as the automation of data analysis, and its use in the decision-making process.

This paper presents shortly the conceptual and logical database schemas for the dynamic information created during emergency response in the Netherlands. The needs for information (with

emphasis on spatial component) were carefully analysed and translated into a conceptual data model, followed by a logical database schema for Oracle Spatial. A first version of this model was presented in (Dilo and Zlatanova, 2008) with information from fire brigade and police sectors. This paper presents further extension of the model with information important for medical services.

The paper is organised in five sections. The following section summarises the information needs for ER. Section 3 presents the extensions in the conceptual model. Section 4 discusses the logical model with respect to an Oracle Spatial implementation. The last section concludes with analysis of the development and outlines directions for further developments and research.

2. TYPES OF INFORMATION

A disaster incident in the Netherlands is managed through legally established processes (Diehl et al 2006; Dilo and Zlatanova 2008). The 25 processes define the responsibilities of the first responders. Processes are grouped into four clusters according to the ER sector that is responsible for them, i.e. fire brigade, paramedics, police or municipality. Although aimed for all kinds of disasters, the processes do not define the responsibilities of other institutions (e.g. military forces, Red Cross, etc.) that might be involved in large disasters. Each process has well-defined actors and objectives, which realisation demands certain information and often produces information during its execution.

Generally, the information needed for ER can be grouped into two large categories: static information, existing prior to disasters; and dynamic information, collected during an incident. Most of the static data (maps, registers, evacuation plans, risk maps, etc.) are commonly available in topographic, cadastre and municipality offices, as well as in private companies, ministries, public organisations or the ER sectors (e.g. fire hydrants maps are owned by the fire brigade).

Dynamic information is collected during an incident from the processes activated to manage it. We have studied the information that is collected from all processes, but we have

modelled only this information that is used/shared outside one sector, i.e. sector-specific data are not included in the model.

This information consists of *situational information* about the incident and its effect, and *operational information* about the processes activated to handle an incident, responsible departments/persons and their roles (Figure 1). Situational information covers type, scale, and affected area of an incident; casualties (trapped, missing, injured people), measurements (in case of detection of dangerous substances in the air, water or in the ground). Operational information is related to teams, involved in the ER, teams performing measurements, process started to handle a disaster and involved departments. As the investigations have shown (Snoeren et al 2007) much of this information is common for all the ER processes.

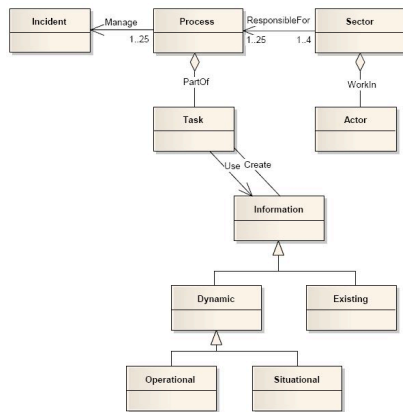


Figure 1: Top-classes for ER in the Netherlands

The dynamic data have a temporal aspect, i.e. we need to keep track of changes. The temporal aspect can be at different layers. Time might be related to start/end of incident, process, individual task in a process, or a piece of data (measurement, report, etc.). The data model captures this temporal nature with the new data types that it creates.

The model that is described in this paper is restricted to information collected by the actors of the four sectors. To manage an incident, various pieces of dynamic information might be important and not all of them are gathered by the first responders. For example in case of flood – velocity and water depth and flood prediction; in case of incident with ships – ship type, numbers of people on board, owner and other ships in the surroundings; in case of aircraft incident – type of plane, function (cargo /military /civilian), number of people on board, type of fuel and volume. Such dynamic data are to be obtained from other organisations/institutions. For example, information about the actual water levels and the likelihood of a flood are to be received from the Ministry transport, public works and water management.

3. CONCEPTUAL DATA MODEL

An incident can be hypothetical (a forthcoming large concert or important football match), or a real (traffic, industrial, or humanitarian accident, or natural disaster). The virtual incident is not directly related to the processes, but much of the operational data (sectors, actors, vehicles) are known and available for response.

A real incident starts with a call to the call centre. Based on the type of the incident, several processes are activated, each process being responsibility of one more departments in sector.

All processes require information (existing and dynamic data) to complete the tasks within one process. Many processes produce data related to the incident description and its effects, locations of rescue teams, measurements of dangerous substances, number of injured people, damaged property, etc. The information is reported either as a free text (e.g. numbers of injured people) or via filling out templates. For example, when the incident involves release of dangerous substances, a template for measurements is in use.

The way that information is reported is not of critical importance for the model. However, if templates are used, the intention is to preserve the structure of the template. Additionally, only measurements performed by the emergency responders are considered. For example, data from optical (images and video), range (laser scan data), or chemical sensors are not modelled. As mentioned above they are to be collected from the institutions responsible for them.

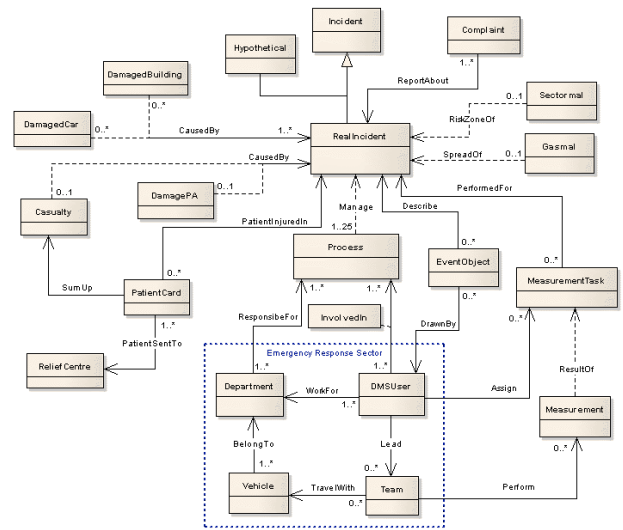


Figure 2. Conceptual schema for dynamic data

Figure 2 shows the UML diagram of the conceptual data model for ER dynamic data. Central to the model is the incident and the processes. An Incident can be a RealIncident or Hypothetical. When incident is reported (via call recorded in Complaints), a template is used to make first estimates about the affected area. This first estimates are recorded in the class Sector mal. The information from Sector mal is also used to determine locations for measurements (if needed for some of the processes). The result of a measurement task is stored in Measurement and is used to define more precisely the gas plume (i.e. class Gasmal).

A RealIncident is managed by one or more Processes (at most 25). As soon as an incident is initiated, the departments involved in it will be specified. Their number increases as new processes are started. This data are maintained in class Department. The association ResponsibleFor keeps track of the responsible departments for each process. Class Vehicle keeps information about vehicles, and BelongTo takes care of the ownership. Class DMSUser contains information about the system actors, i.e. actors that are users of the ER system. A system user might be involved in different processes of one or even different incidents at different times. For example the advisor dangerous substances can consult several incidents. The association InvolvedIn contains the duration of such

involvements. The class Team has information about teams, which might be created during emergencies. Usually, the team leader has access to the system and coordinate access to the needed information. The information about the ER sector (classes within the dashed-line box in Figure 2) together with processes and their associations constitute the operational information.

Several new classes reflect the work of the paramedics. The class PatientCard holds the information of the (analogue) patient card. Various new data types are created to reflect the complexity of this information. On the basis of the work of medical units Casualties and damaged people and animals (DamagedPA) are derived. The class ReliefCentre contains data about the type of the centre (hospital, field hospital, other public buildings to be used as shelters/intake locations), the capacity and the location of the centre, etc.

4. LOGICAL DATA MODEL

A critical question for an emergency response application is how to store the dynamic information. A spatial Database Management System (DBMS) could be a very appropriate solution, since it ensures standard and consistent management of data. DBMS-based solution is usually very flexible, because it permits a variety of approaches to access the information. Important aspects to be considered while selecting a DBMS are the support for different spatial data models and spatial data types, spatial operators and functions, the support for the temporal component, extendibility with new types and functions, commercial or freeware type of the database, etc.

In our investigations we have considered Oracle Spatial and PostGIS. Both DBMS have support of spatial data types and extended set of spatial functions. PostGIS spatial data types and functions are compliant with the OGC specifications. The choice between open source and commercial DBMS is often driven from pragmatic reasons. On the one hand, a freeware DBMS (or open source) such as PostGIS may have benefits in large area devastating disasters (similar to East Asia Tsunami or the hurricane Katrina) when existing infrastructure is destroyed and a command centre has to be set up in few hours. On the other hand, many organisations in the Netherlands have already commercial DBMS. Oracle Spatial and PostGIS offer the most from the functionality we need, but we have decided to use Oracle Spatial. Many units from the emergency sector, e.g., municipalities, have already their data in Oracle Spatial.

The conceptual model described in Section 3 is translated to a logical database schema for Oracle Spatial, followed by another translation to DDL (Data Definition Language) scripts for creating the actual tables in Oracle Spatial. We used Enterprise Architect to create the data model(s), and to perform automatically some of the translations. Both translations needed manual modifications afterwards to represent correctly the data model. Figure 3 shows a part of the logical database schema. Generally, for each class in the conceptual level there is a corresponding table at the logical level. All the one-to-one and one-to-many associations are resolved by primary key-foreign key relations; a new table is created for the many-to-many associations.

The automatic translation, does not resolve correctly dependencies, associations with attributes, some data types, and identifiers in some specific cases. For example, Casualty and Process that are dependent on RealIncident are created as separate tables with their own identifier and no relation to the

RealIncident. The association InvolvedIn between DMSUser and Process is translated to a new table resolving the many-to-many association and another separate table for the attributes with no relations to any other table.

Data types like integer, date, timestamp (not shown in Figure 2) are not translated to any Oracle data type. For example the spatial types are changed to `MDSYS.SDO_GEOMETRY`, which is the spatial type of Oracle Spatial for all points, lines, and polygons. The enumeration types are changed to `NUMBER()`; the numeric values are used as codes that refer to values in the enumeration list. The boolean types are changed to `CHAR(1)` and a check constraint is added to restrict values to true (Y) and false (N).

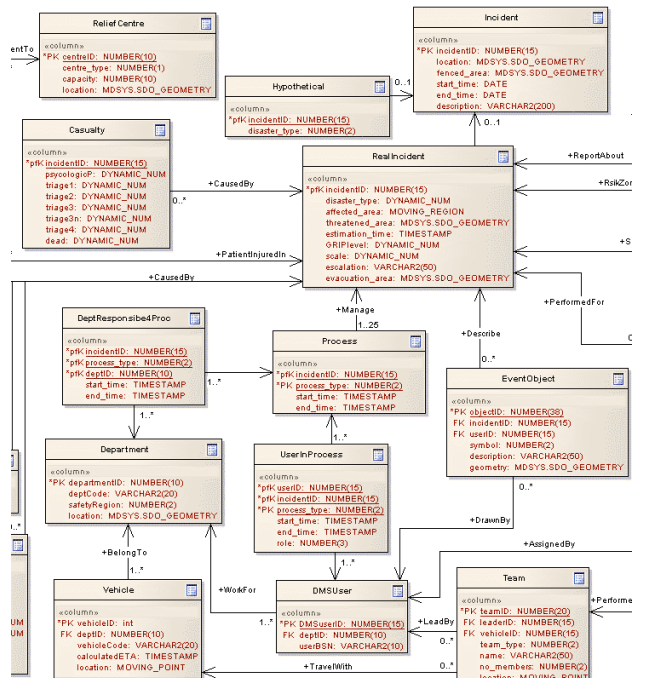


Figure 3: Part of Oracle Spatial tables and relationships

Very important for our model are the temporal and spatio-temporal data types: `DYNAMIC_NUM` for dynamics counts (e.g. number of missing people), `MOVING_POINT` for dynamic points (e.g. position of a team in the field) and `MOVING_REGION` (e.g. gas plume). The general approach for temporal data in DBMS is use of timestamps (e.g. the time fact become valid). Timestamps are added at the record (instance) level, or at the attribute level. Some pieces of data have a period of time they might be valid (as process) and this is indicated with begin- and end-timestamp. Classical research on spatiotemporal databases has focused on discrete changes (e.g. Zaniolo et al 1997, Güting et al 2005: sporadic events (volcano eruptions, earthquakes), stepwise constant changes (headquarter of field operational team); later research concentrates on continuous changes and uses the term moving objects.

In this implementation we follow this latest approach. A `MOVING_POINT` is stored as a sequence of pairs (point, time), and a `MOVING_REGION` as a sequence of pairs (polygon, time). Different interpolation techniques can be used for calculating point position and polygon shape for any moment of time (e.g. Meratnia 2005). The newly designed data types are defined by *nested tables*. Nested tables are preferred (to *varrays*), because they offer more flexibility for search and query, when individual values of the new data types have to be used.

This spatiotemporal data model can be used for various analyses, in order to help the decision-making during emergencies. This analysis usually requires a combination of existing data and dynamic data, which in turn requires integration of spatial functionality (on static data) with spatiotemporal functionality (on dynamic data). The list of queries to be performed on the model is very long but some examples could be: find police vehicles that are in a radius of 5km from the incident; which car is the closest to the incident? (dynamic routing); calculate the speed of expansion of the gas plume; evaluate the evacuation area for the next 8 hours from the area covered by the current gas plume and the prediction; calculate a route, which does not overlap with the gas plume; find the location of all the fire brigade teams; give the locations of the measurement teams; give information that has been available 2 hours after the incident has taken place; when the fire brigade/ambulance arrived at the place of incident?; what is the size of the affected area?; give number of injuries/damages/... 4 hours after the incident has taken place; how many people of the police sector are involved? and so on.

5. DISCUSSION

This paper briefly presents a spatiotemporal model to maintain operational and situational information in ER. Compared to previous editions of the model, several new classes are introduced such as ReliefCentre, PatientCard, DamagedCar, DamagedBuilding, DamagedPA, etc, which reflect the work of paramedics. More extensions are foreseen, however.

Some of the municipality processes require further attention. For example, Process 23 deals with the registration of damages and destructions (usually in large disasters). When this process is activated, a special centre is established. The work of the centre is quite complex and requires an overall view on the damages on buildings, infrastructure, cars, data (e.g. cadastre data and other registers), claims from citizens and companies etc. Parts of this information can be found in currently available classes DamagedCar, DamagedPA and DamagedBuilding, but we expect that the model needs to be extended to serve this process.

A further extension of the model is needed towards considering higher emergency levels, which practically means involvement of more organisations, more actors (i.e. people with specific tasks) and wider range of information.

The model is currently tested for the management of spatiotemporal data as being the most challenging. Further experiments are needed to validate all the developments and especially the digital replacements of the templates used by the fire brigade and the paramedics. Appropriate digital templates and interfaces (on mobile devices) are needed as well.

This model is derived from the organization of ER in the Netherlands and many of the attributes represent pieces of information, which are currently collected in analogue way (paper templates) and via telephone. Despite these specifics, the model is a very good example of a spatiotemporal data that can be tested in other countries. It captures the type of disaster, the involvement of response sectors (allowing registering of their locations), consequences of the disaster for people, animals and infrastructure, and captures other significant objects.

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