Formal modelling of processes and tasks to support use and search of geo-information in emergency response

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Abstract
Many Command& Control or Early warning systems have been developed providing access to large amounts of data (and metadata) via geo-portals, or by accessing predefined data sets relaying on Spatial Data Infrastructure. However, the users involved in emergency response are usually not geo-information specialists and they lack deep understanding about the spatial data structures and corresponding terminology. Semantic web and knowledge engineering approaches applied to geo-data can bring significant improvements in these directions. This paper presents a formal modeling for the emergency management as performed in the Netherlands. Having the tasks of the actors well specified, it is possible to define the geo-information needed for completing the task.

1 Introduction

Emergency response procedures may significantly differ per country because they reflect the vulnerability and preparedness of the country for disasters. The organizational structure for response to disasters may also differ. Some countries are exposed to earthquakes, others to flood and fires; fire brigade and police might be the primarily responders in some countries, while in others civil protection centres or other governmental institutions may take the lead. However, all governments have legislations that prescribe work-flows and procedure for emergency response. Using these documents and analyzing the work of the emergency responders, it is possible to specify what kind of data might be of primarily interest when performing a certain tasks.

Such an approach will help in filtering (reducing) the information flows to only those pieces needed for the specific task and thus will avoid the information overflow (which is often quoted as a problem in emergency management). This is especially critical for geo-information, since the emergency responders are not geo-specialist and have difficulties in reading and perceiving maps. The geo-information used in emergencies is quite diverse ranging from topographic maps to specialized cadastre, soil, utility, road, etc. maps. All these data sets may use the specific terminology of a domain, which may complicate the work of non-geoinformation specialists in situations under pressure and stress.

A conceptualisation is required to make the knowledge (or to establish the relations) between the tasks of the actors and the data (and information) explicit and usable. Different conceptualization approaches can be used to formally express this knowledge, e.g. descriptive logic, ontology, object-oriented modelling (Baader et al 2005, Zlatanova et al 2006, Xu and Zlatanova 2007, Pund 2008). Thought all of them have advantages and disadvantages (e.g. Xu et al 2008). In this paper, an object-oriented modelling is applied and more specifically the Unified Modelling Language (UML). UML is used to represent application structures, behaviours, architecture, business process and data structures (www.uml.org). There are nine types of UML diagrams, but for the scope of this paper only the class diagram (Bell 2004) is used. A class diagram gives an overview of a system by showing its classes and the relations among them and as such it is static.

This paper presents our approach for formal modelling of emergency response processes and tasks in Netherlands in order to define the data (information) needs per task. The study is concentrated on geo-information, but some non-geographical data are used as well. The next section presents briefly the conceptualisation of the emergency response processes in Netherlands. Section 3 presents in detail the formal modelling of actors, tasks and information in two processes and analyzes the results. Section 4 addresses next steps and shortcoming developments.

2 Formalisation of emergency response

The Netherlands has well-defined procedures for emergency response that have been presented in various papers (Borkulo et al 2005, Diehl et al 2006, Neuvel and Zlatanova 2006, Snoeren et al 2007, Xu and Zlatanova 2007, Dilo and Zlatanova 2008). They will be therefore not discussed here. Xu et al, 2008 have presented the *process*, *tasks*, *sector*, *actor* and *information* (data) as the most important concepts in the emergency process in the Netherlands (Figure 1). The conceptualisation is done with respect to development of a system that will serve management and sharing of information during emergency response (Scholten et al 2008).

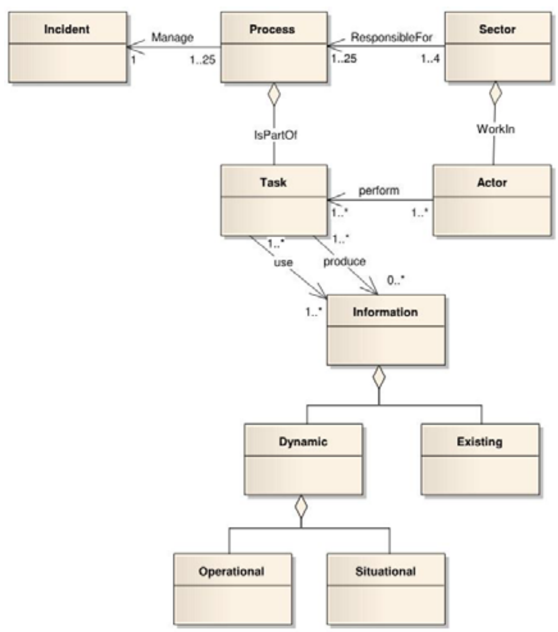

Figure 1: Top-level classes representing the relationships between process, sectors, task, actor and information, which are needed to manage an incident.

The disaster (called also *Incident*) in the Netherlands is managed by connected activities, which are indicated as *Process*. There are 25 types of processes defined in the Netherlands (Diehl et al 2006). There are four primarily emergency response *Sectors*: municipality, fire brigade, police and paramedics (GHOR, Medical Assistance in case of Accidents and Disasters). Each sector is responsible for a group of processes. For instance, the fire brigade is responsible for seven processes such as fire fighting, rescuing and technical assistance, decontaminating people and animals, measurements and observations and so on. *Actors* are all the users that work with the system and they can play different roles and perform different operations. These operations are considered as *Task*. Every process consists of a set of tasks, which are performed by actors (individuals or teams). The team reacts as one unit as the team leader performs the communication to the other actors in the process or with other actors. Therefore a team is also referred as to an actor. Each actor needs data to complete the task and can deliver data (measurements, number injured people, number damaged infrastructure, etc.) to the system. The data that are therefore either *used* or *created* by an actor is indicated as *Information*. The information could be existing information and dynamic information (operational and situational). *Process*, *Sector*, *Actor*, *Task*, *Information (Existing and Dynamic) and Incident* constitute the top-level classes in the model (see Figure 1).

To be able to identify the information that is needed, a two step approach has been followed. First, the data needed for/created by a process are specified and, second, the information needed for an actor/task in a process is identified. While identifying the manner of working and the needed information, it is very important to cooperate closely with the emergency responders by organising interviews, filling out questionnaires, open discussions, participating in training, studying organisational instructions, etc. Many of these activities have been reported elsewhere (Neuvel and Zlatanova 2006, Snoeren et al 2007, Zlatanova 2008). It should be noticed that the obtained results may vary per administrative region (safety region, municipality or province). Some regions may have better organisation, more advanced software systems or may have more elaborated preparation plans. As result particular emergency responders could have better (worse) knowledge on understanding and using geo-spatial data. This can affect the scope of information that is used.

The information flows in Netherlands were investigated in one safety region (consisting of several municipalities). The 25 processes were studied in detail and formally modelled in UML, using use case and activity diagrams. This effort resulted in the specification of actors, the communication between those actors and the required (existing/static and newly created/dynamic) data sets per process (Snoeren, 2006). The dynamic information required for all processes was further organised in dynamic data model (Dilo and Zlatanova 2008) to be used for an emergency response system (Scholten et al 2008). Next section will demonstrate the modelling of information required for the tasks in two processes.

3 Modelling of tasks

The actors and tasks within a process depend on goal of the process but also on the complexity of the incident. The complexity of incident is measured by the effects and the area it covers. More actors are getting involved in a process if the incident affects the territory of more than one municipality. In this case a special Regional Operational Team (ROT) will be formed, which will take the lead for managing the emergency. The complexity of the incidents is reflected in the GRIP levels (Coordinated Regional Incident Suppression Procedure, MBZ,2003), which are discussed in (Borkulo et al, 2005). While levels 1-3 are managed by the four emergency response sectors, levels 3-4 require establishment of provincial or national coordination centers. So far, the modeling of dynamic information and actors has considered only the GRIP 1-3.

3.1 Process 1: Fire fighting

This process belongs to the group of processes of the fire brigade sector. It is one of the primarily processes, activated immediately with the reporting of an incident. The goal of the process is to fight a fire, prevent further damages on property and limit emission of dangerous substances in the air. This process aims to serve all types of fires such as natural (e.g. forest fire), industrial (chemical based), fires on ship, airplanes, trains and in houses. The workflow does not change much in the different cases: a call for fire initiates the process; the call centre registers the incident and informs the responsive fire brigade unit (in particular, the officer on duty and the fire brigade trucks leader). The officer in duty and the FB-leader move to the area of the fire. On the way to the fire they request various pieces of information: different topographic maps, locations of water resources (open water and hydrants), the optimal route to the area, vulnerable objects in the area (available on risk maps), information about citizens, etc. If the size of the fire is relatively big and cannot be localised fast, ROT might need to be formed and take over the coordination. If this happens, several other processes most probably will be started such as process 11 'clearance and evacuation' (performed by the police) and process 5 'measurements and observations' (performed by the fire brigade).

The actors in this process 1 are specified as *CallCentre, FBleader, OfficerDuty* and *ROT.* The tasks that have been identified as important for providing/recording information are *RegisterInsident, FightFire, Report, OperationalLead and TacticalLead* (Figure2). The task of the call centre is to register the incident and inform the fire brigade sector. FB-leader has to fight the fire and take case of the consequences. The officer on duty performs the overall operational lead on the filed. The two actors report to the ROT.

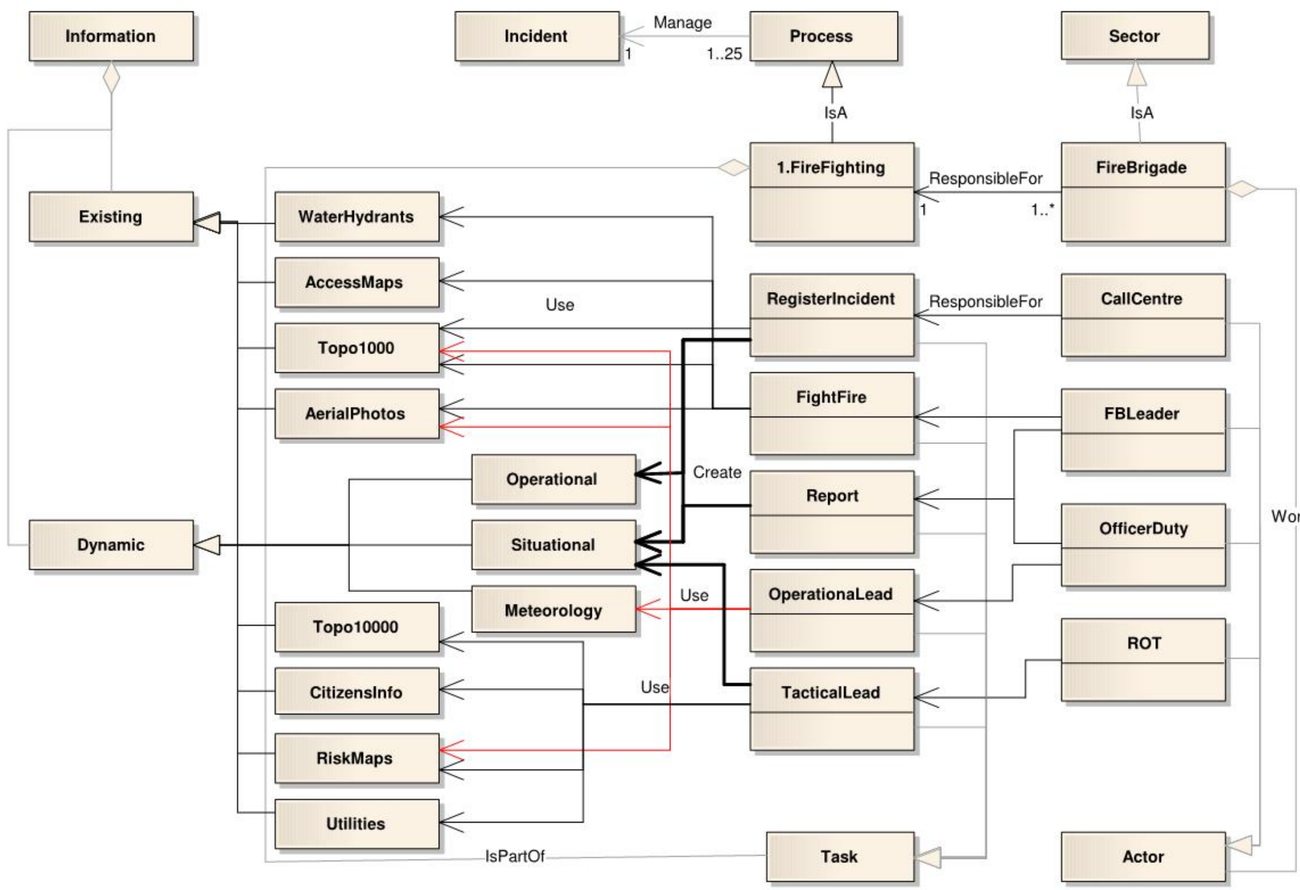

Figure 2: Tasks, actor and information in the process Fire Fighting.

The information that is needed at first instance for this process slightly differs with respect to the actors. The registration of the incident and the actors that are on the field (FB-leader&teams and the officer in duty) need large scale topographic maps (i.e. Topo1000, scale 1:1000). ROT (positioned in the command centre in the safety region or municipality) requires small-scale map (Topo10000, scale 1:10000) and information about citizens, vulnerable objects (available through Risk Maps) and often utility maps (e.g. gas-pipe lines). Essential for the FB-lead is the information in the access maps (representing entrances of public buildings and industrial establishments). Some of the actors have more than one task, for example FB-leader and officer of duty have to report about the situation in addition their major responsibilities. The reports are recorded in the spatio-temporal data model (Dilo and Zlatanova 2008).

3.2 Process 11: Clearance and evacuation

This process is responsibility of the sector Police and it is a very good example of a secondary process, i.e. it is activated after an incident is registered. It concerns all the activities that are required to clear (or evacuate) certain area. There is no clear border between clearance and evacuation. A certain area might be declared a limited-access area to facilitate the work of the emergency responders (usually referred as clearance). In other cases the citizens are requested to leave the area due to some treats (flood, dyke break, etc.), which is regarded as evacuation. Large evacuations are managed by another process, which is responsibility of the municipality and the police has a supporting role only. In this process 11, the police units are leading and have two major tasks: 1) to prepare a plan for transportation providing directions and capacity of roads and 2) to guard the cleared area. This process is likely to be initiated after the process 1 as explained above.

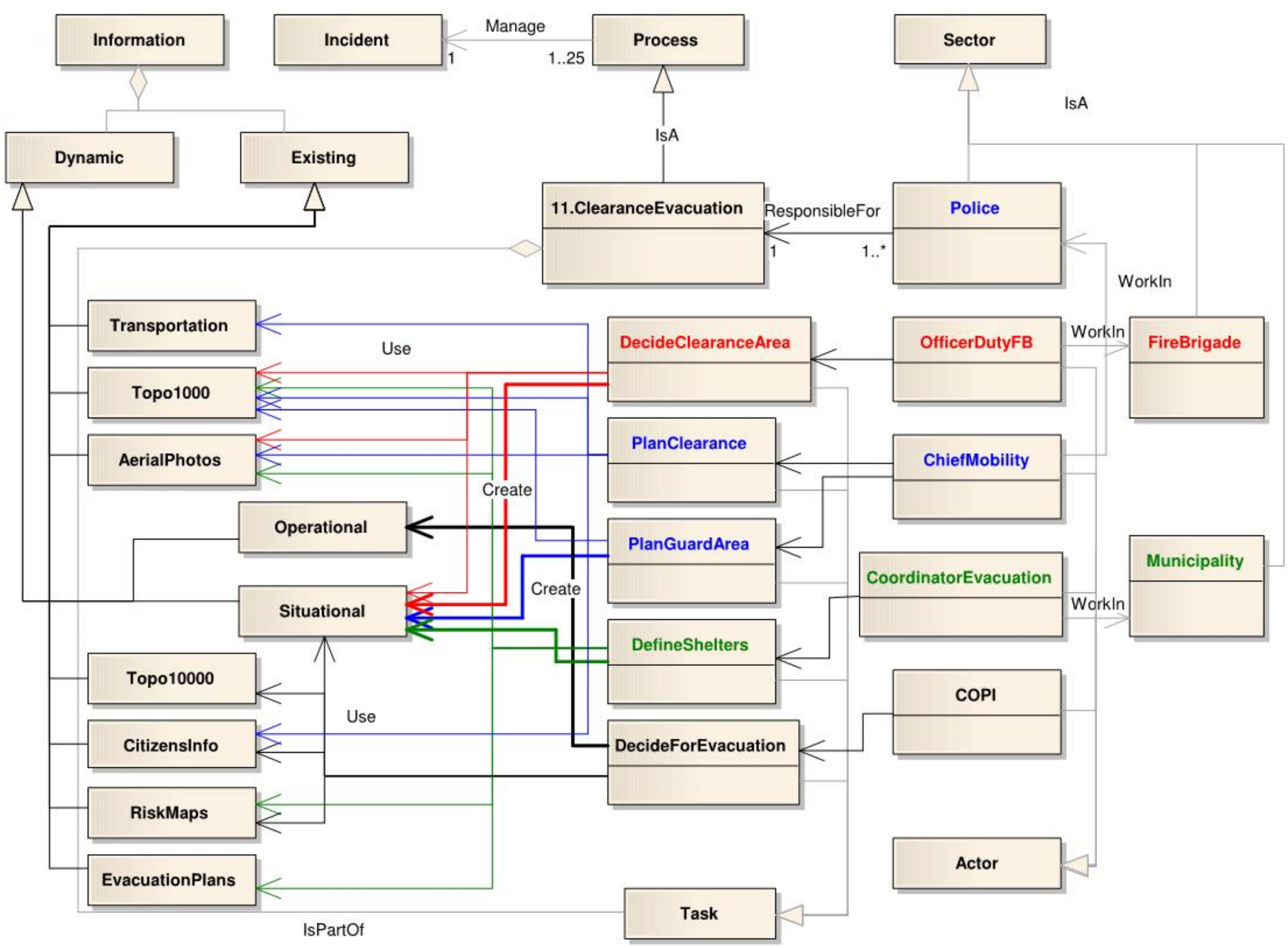

Figure 3: Tasks, actor and information in the process Clearance and Evacuation.

Although the process is coordinated by the police the municipality and the fire brigade are also involved. The tasks and the actors of different sectors are therefore given with different colours in the

UML diagram (Figure 3). The relationships with tick line between task and data indicate that the task create information. The major actors in this process are the *OfficerDutyFB, ChiefMobility, CoordinatorEvacuation and COPI.* COPI is abbreviation of a special coordination team composed by representatives of all the sectors that are present at the filed. COPI takes a decision whether an evacuation of citizens is required.

COPI takes this decision using all the situational information (available for the moment) and several existing sources most essential of which are topographic maps (usually small scale), information about citizens and risk maps. COPI might also decided whether the evacuation should be leaded by the municipality (which will introduce changes in the dynamic operational information). The officer of duty from the FB defines the area that has to be kept clear (or evacuated) and indicates it in the situational section of the dynamic information. The municipality coordinator decided which shelters/intake locations (available in the evacuation plan) have to be used in the current incident and locates them in the spatio-temporal data model (class *EventObject,* Dilo and Zlatanova, 2008). The chief mobility has to deliver a plan for the evacuation and guarding of the area. These plans are based on the situational information, information about citizens and transportation models (software available at the office of the police). Similar to the previous process some of the tasks use information (e.g. *PlanClearance*), others create information.

Compared with the first example, the information flow is much more complex. The tasks are dependend on each other, i.e. some of the tasks have to wait for certain information to be created (e.g. clearance area). The importance of order of tasks is observed also in other processes, e.g. process 5 'measurements and observations'.

3.3 Discussion

This modelling of tasks revealed that the information can be further specialised with respect to the actors. For example, most of the tasks require use of topographic maps and aerial images as background information to get a better orientation. However, the scale of the maps differs per task/actor. Actors on the place of incident (as officer duty FB, FB Leader, chief mobility) perform their work on large scale maps, while ROT prefer small-scale, more generalised maps, which give better overview on a larger area. This was not obvious from the first step, i.e. the information modelling per process. In contrary, it looked as most of the processes require the same set of data.

As can be easily realised, the actors and the tasks could result in a quite large (but finite) number, which might be difficult to handle. Furthermore, many of the relationships between tasks and actor are 1:1, which raises the question whether the modelling of the tasks can be avoided. Theoretically relationships could be established between the actors and the information they need. Currently, we prefer to keep this separation since some tasks can be repeated in the processes (e.g. *Report*) and some actors can have several roles in different processes (e.g. *OfficerDutyFB* and *CoordinatorEvacuation*), which may require different information. As soon as all the tasks are modelled, it will be investigated whether they can be further aggregated to a smaller generic set of tasks. The actors and the generic tasks can be then used to specify the needed information (by creating rules). For example, several actors could make a decision about the area to be evacuated (e.g. *OfficerDutyFB*, *CoordinatorEvacuation*, *ROT* or even GHOR actors). The task then will be only *DecideClearanceArea*, but it will be performed by the different actors.

Such modelling of actors, tasks and corresponding information allows for providing the most relevant data sets as soon as the actor logs-in in a system to perform a certain task. The data sets can be readily available on the server of the corresponding safety region or accessed remotely via services (Scholten et al 2008). In this respect, the data must be seen as a default data set that will be immediately available for use, which is expected to safe time and efforts. As soon as an actor needs further information, it can be obtained by browsing geo-portals or predefined data sets. The data sets considered in this model are as general as possible, and are applicable for the most common experienced incidents. Specific disaster will definitely require additional information. For example fire in on a ship (tanker, cruiser) will require information about the cargo or the number of people on board. This information can be further requested by the actors.

It should be noticed that this approach is still insufficient in resolving vocabulary problems and lack of knowledge about content of different data sets. The emergency responders still have to learn how to read and interpreted utility or cadastral maps, i.e. to understand their semantics (meaning). Furthermore, the data sets may still contain too much information which is not required for completing a specific task. For example, a FB-leader needs generally buildings, roads and fire hydrants to fight a fire. Looking at the digital Dutch large-scale topographic map, one will notice two problems: first there is much more information than needed and second the buildings and roads are spread over several different layers (having distinct names). In this case, a mechanism will be needed to map the terms ‘building’ and ‘road’ used by the firemen to the much richer classification of buildings and roads available in the data set.

To resolve semantic interoperability and especially to apply reasoning (i.e. search according to a rule), descriptive logic (ontology) approaches are needed. After the ontologies for data sets and the actors are built, it will be possible to access/search information with respect to the specific terminology used by the actors. Search of additional information will be facilitated as well. Some initial ideas about use of ontology in emergency response are presented in Xu and Zlatanova, 2007 and Xu et al 2008. The modelling of tasks completed so far can be further extended and linked with the ontologies developed for actors and information.

4 Conclusions

This paper presented an approach for formalising emergency response tasks and actors in the Netherlands. The approach relies heavily on the legislation for emergency response in the Netherlands. The procedures are derived from the daily routines of the primarily responders and their need to cooperate and communicate in any kind of incident (and middle-scale disasters). The modelling, however, can be applied for other counties and even for specific types of disasters. The top-classes in our model are very generic as well as many of the actors and the specified tasks. Naturally new tasks and data sets would be identified. Future work will concentrate completing the identification of generic tasks and performing tests with several processes.

UML is quite appropriate for modelling tasks and actors, since it gives a good overview of the classes (actors and tasks) and their relationships. It is also well-suited for describing attributes of the classes (not shown here) and their mapping to logical models (i.e. spatial schemas in database management systems). However, the language provides insufficient tools for reasoning, which would be needed to establish rules between general tasks and actors in different processes. For instance, if one wants to derive the relation between the actor and the information, he/she needs to specify a rule like ‘use (*Task*, *Information*) Λ responsible (*Actor*, *Task*) => use (*Actor*, *Information*). Similar rules can ensure the correct order of tasks is a process as well. This inference can be accomplished only through ontology modelling and reasoners, which is yet another topic to be address in near future.

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