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DECISION SUPPORT SYSTEM FOR FIRE SERVICE BASED ON DISTRIBUTED DATABASE AND CASE-BASED REASONING

1. Introduction

Making decisions in complex situations is extremely difficult. Short time for analysing aspects of the incident and the psychological pressure, make the case even worse. Conditions in which decisions are made are common for Rescue Services. In order to overcome these difficulties, a number of research projects have been initiated, all aimed at finding the best way of making decisions in emergency situations.

In 1989, Klein, Calderwood, and Clinton-Cirocco presented a method of making decisions in emergency situations called the Recognition-primed Decision (RPD) [1]. In RPD, the decision maker (DM) considers the particular situation's similarity to the previous ones, and then takes a course of action based on the experience learned. Despite the fact that there are no two identical incidents, DM is able to tailor the strategy through understanding the goals, cues, and expectancies acquired through experience of similar incidents. The study conducted by Klein and co-workers concludes that 80% of non-routine decisions by Incident Commanders during the rescue action are made using RPD, with the assumption that routine incidents would show an even higher percentage of RPD.

There are also weaknesses of RPD. To make a good decision, DM has to have experience. Klein's group research proved that commanders with large experience take right decision at once. On the other hand, inexperienced commanders tend to take wrong decisions using RPD [2].

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There is a wide diversity of incidents that the National Fire Service in Poland must deal with. On the global scale, the similarity among the incidents is considerably high. However, at the fire stations' level, there is a very small probability that two similar rescue situations may occur. Furthermore, there is no system that gathers the experience gained during the actions, and makes it available to the other firemen. Based on the above, it can be concluded, that no Incident Commander possesses efficient knowledge to successfully use RPD. In connection with this, mistakes made by one Commander, are repeated by others. Therefore, there is no possibility to successfully use RPD by Commanders in the National Fire Service in Poland without a special system that gathers all experience gained by Commanders and makes it available to all firemen during the rescue actions.

Artificial intelligence research brought about methods that simulate human thinking processes. The most popular technique that closely simulates the RPD method is the Case-based Reasoning (CBR) [3].

This article describes Decision Support System (DSS) for the National Fire Service of Poland. The system is based on Directory Services and Case-based Reasoning techniques. Section 2 contains Case-based Reasoning technique principles. Section 3 contains basic information about the Directory Service. In section 4, description of the proposed Decision Support System is included. Conclusions are contained in the summary at the end of the paper.

2. Case-based Reasoning principles

Case-based Reasoning is an artificial intelligence technique that simulates the process by which humans solve problems [3, 4]. It's procedure rule is very similar to RPD. CBR systems solve problems by retrieving solutions to similar problems that have been solved in the past. Next, it adapts these solutions to the new circumstances, and it teaches itself during the process.

CBR systems store information or experience in cases. Cases are individual information entities that contain a problem description and a solution. Each case is independent of other cases and can be added to, and removed from the database without affecting other cases.

Each new problem is typically represented as a case without the solution. Attributes that describe the case are compared to the cases stored in the database, and the most comparable solution is retrieved. The retrieved solution is adapted to the new circumstances and reused as a potential solution. If this adapted solution is acceptable, the problem is considered to be solved by the system. If the suggested solution needs modification, it is revised, and the appropriate solution is prepared. The next time a user requests the solution to this problem, the newly learned case is available immediately. The learning capability allows CBR systems to continuously expand their knowledge of the operating domain. The process of solving and gathering new cases is presented on figure 1.

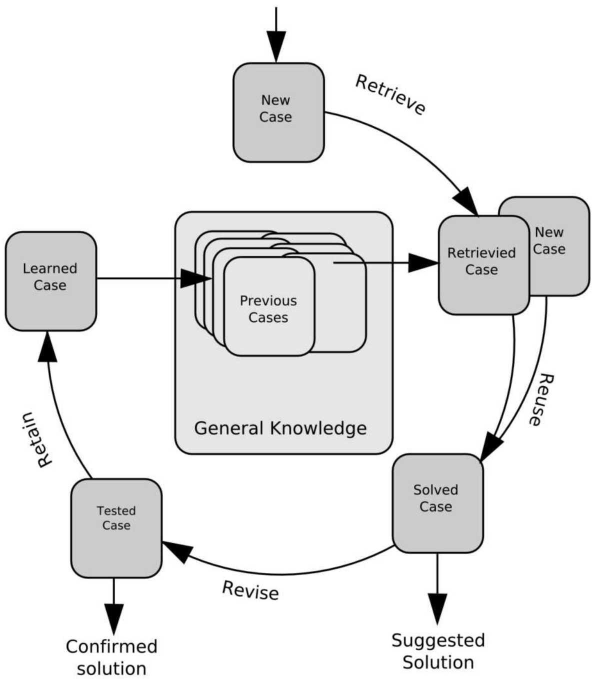

Figure 1. The Case-based Reasoning Cycle [5]

The quality of the case-based solution depends on four main factors:
- The representation of the domain;
- The similarity calculation;
- The adaptation capability;
- The quality of the cases.

Typical application areas of CBR include [5]:
- Troubleshooting and diagnosis of technical equipment;
- Customer support and help-desk;
- Engineering and design;
- Medical applications.

3. Directory Service principles

Directory Service is a simplified database [6]. Usually, it does not have typical database mechanisms, like transactions support or recovery protocol. Directories allow for both read and write operations, but are intended primarily for high-volume, efficient read operations by clients.

Lightweight Directory Access Protocol (LDAP) is a distributed directory service protocol. LDAP is based on a client-server model and runs over TCP/IP. It can be used to access stand-alone directory servers or X.500 directories [7].

Information is stored in the LDAP directory in the form of entries arranged in hierarchical tree-like structure. An LDAP entry is a collection of attributes. Entries are a representation of the real world object. For example, an entry can represent a person. Attributes that describe such an object could be: name, surname, email address. Each attribute has a name and one or many values. For example the attribute *email address* has a name *mail.* Attribute value *mail* could be *foo@foo.com.* An exemplary entry is presented on figure 2.

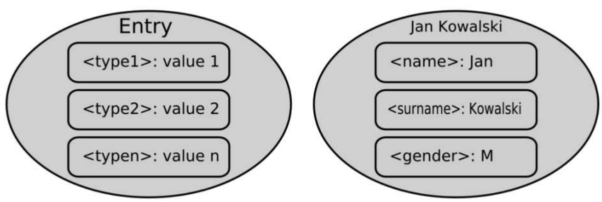

Figure 2. The idea and representation of an entry

LDAP defines operations for querying and updating a directory. There are operations provided for adding and deleting entries from the directory, changing the value of an existing entry, or changing the name of an entry. However, LDAP is mostly used to search for information in a directory. The LDAP search operation allows some portion of the directory to be searched for entries that match some criteria specified by the search filter. Information can be requested from each entry that matches the criteria.

4. Decision Support System for Fire Service

CBR technique was used by the author to create Decision Support System (DSS) for the State Fire Service in Poland. The CBR technique is based on descriptions of rescue actions called cases. Cases are created by defining special attribute types. The set of attributes depends on rescue actions kind. The cases are arranged in groups, creating a tree-like structure. All groups are stored in the Directory Service.

According to regulation [8], rescue actions can be divided into three main categories: fires, local threats, and false alarms. Each of these categories contains subcategory according to the type of fires or incidents. For example, fire category contains among others: woodland fires, house fires, and industrial fires. All the entries within the category use the same set of attributes that describes a rescue action. The set of attributes among categories is different.

The entries categorization described above was the base for creating directories in the Directory Service. Root directory contains three contexts called: fires, local threats, and false alarms. They were created as an object container in the directory name space. All of these containers have subcontainers for accidents types described by the regulation [8]. The fires group includes example subcategories:

- Entertainment buildings fires
- Residential building fires
- Transport fires
- Woodland fires

The local threats group includes example subcategories:

- Chemical accidents
- Ecological accidents
- Building collapse
- Road traffic accidents

The false alarm group contains among others:

- Detected by people
- From automatic fire detection system

Figure 3 illustrates structure of entry categorization.

All containers and subcontainers must have the attribute *name* defined. The corresponding value of the attribute must be one of the categories, presented on the figure 3, e.g. *name = Natural Calamity*.

Described subcontainers contain entries that represent real rescue actions. The selection of the attributes depends on the accident type. The attributes used and their values are the key to the efficiency of the CBR technique. It is very important to set accurate attributes. The sets of attributes currently used in the research are based on the regulation [8] and interviews with firemen who have taken part in rescue actions.

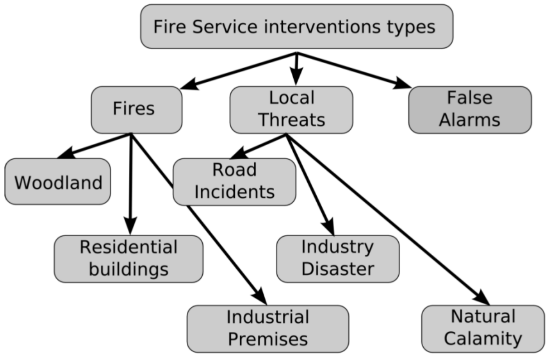

Figure 3. Incidents categorization tree

The abstract class *case* was created to represent object accident, as the effect of this study. The class includes three main attributes:

- Object type – identifies the type of an object in the accident. In the case of fires, the attribute values could be one of: hotels, industrial units, cars, etc. The list of valid values are defined by regulation [8];
- Accident size – identifies the size of an accident. The possible attribute values are: small, local, medium, large, very large. The classification of accidents is described in the regulation;
- Solution – contains a short and structured description of how the problem was fixed. This attribute contains the key information which is needed to manage the accident properly.

The abstract class *case* is extended by an inherited class which describes detailed type of the accident. For example, class *home_fire_case* describes home fires accidents and extends the abstract class *case*. This class includes a special type attributes, e.g.:

- Hazard category – danger category to which the object belongs;
- Water supply – type of water supply that the object contains. The possible values are: drencher, sprinklers, internal hydrant system;
- External hydrant system;
- Water storage tank;
- Object area;
- Cubic measure;
- Storeys number;
- Number of building's entries;
- Number of staircases;
- Exposed building;
- Fire zone;

- Largest fire zone;
- Electric system;
- Gas system;
- Building structure;
- Roof construction;
- Wall construction;
- Rescue equipment;
- etc.

The remaining special classes extend abstract class *case* analogically, defining the set of special attributes. The classification method and the list of obligatory attributes which belong to the detailed class are included in [9].

The structure described is a data deploying schema in the Directory Service. However, for better performance, LDAP is not a standalone service. Containers and included entities are distributed across nodes. The network architecture is composed of servers located in fire stations. The server located in the Headquarters of the State Fire Service contains RootDSE and three main contexts. Those are: fires, local threats, and false alarms. Containers which represent contexts, include objects of the class *referral* which are pointers to subcontainers stored on the servers located in the Districts Headquarters. Each server in the Districts Headquarters, stores two containers with detailed sets of accidents. For better reliability, each of the nodes is replicated by it's slave node.

The network architecture of distributed directory is presented on figure 4.

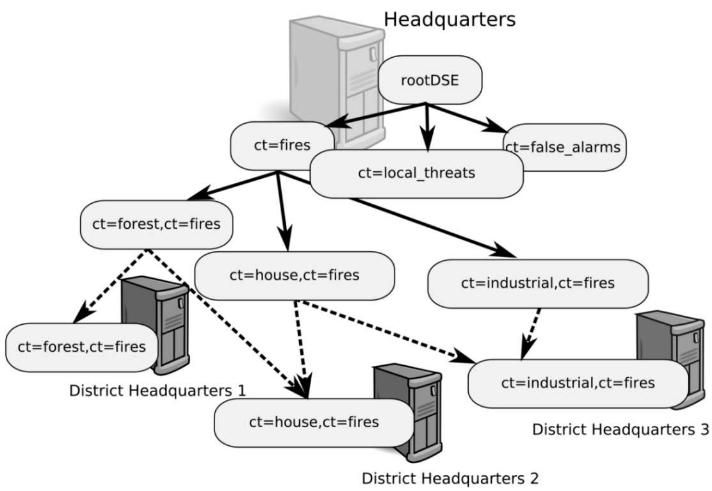

Figure 4. Proposed distributed database architecture for DSS

This solution has many advantages, such as:

- Data distribution causes that nodes have less amounts of data to process. That results in shorter response time;
- Increasing number of processors in the system shortens the response time;
- Data replication increases the reliability of the system.

The key issue in the Decision Support System is finding the solution for a new problem. The CBR technique is used for describing DSS. As mentioned above, the CBR finds solutions by comparing cases stored in the database, with the new case. In the proposed Decision Support System, the cases are described by the sets of attributes. The comparing algorithm proposed by Cortes is involved [5]. The similarity between a query (Q) and a case (C) is determined by calculating the weighted sum of the similarities between the values for each attribute.

$$\mathrm{SIM}(Q, C) = \frac{\sum_{i=1}^{n} w_i \,\mathrm{sim}_i(Q_i, C_i)}{n}$$

In the formula given above:

- Q is the query or the set of attributes describing a new case,
- C is the case stored in the directory,
- $\mathrm{SIM}(Q, C)$ is overall similarity between the query and the case,
- n is the number of attributes,
- w_i is the weighting factor for the attribute,
- i and sim_i is the similarity measure for the attribute i of the query and the case.

It is worth noticing, that to compare a query and a case, the weighted mean is used. On account of that, the detailed attributes have different influence for successfully solving the problem. For example, in the case of house fire where no external hydrant system is available, the key issue to fix the problem is the appropriately organized water supply. In the case an external hydrants system is present, the water supply organization is less important.

The presented formula for comparing queries and cases is of a general form. Depending on the situation, the particular algorithm should be involved. For example, during a traffic accident, a tank containing an explosive liquid was destroyed. One of the describing attributes of such an accident is *substance concentration*. Electronic detector indicated that the concentration is above lower explosion limit (LEL). The weight of the attribute *concentration* in the comparison algorithm is significant. There are two cases in the database that describe a similar situation. In the first case, the difference between the query and the case is very small but *concentration* is under LEL. In the second case the difference is significant, but the concentration is above LEL. It is obvious, that a better solution and possible danger are better described in the second case.

The example mentioned reveals that comparison of cases is not simple in some situations. The algorithms for such cases should be determined after detailed research, which have not been conducted. At the current stage of the study only a general comparison algorithm was tested.

Another relevant CBR issue is solution adaptation. At the current stage of research the adaptation is calculated by the Incident Commander. He receives only the solution and plausible dangers included in the most similar case from the database. Based on this and on the incident observation he adapts the solution.

The system works according to the following scenario:

The Control Room Commander (CRC) receives an emergency call about a fire or another accident. Information received from the caller is entered to the system via special forms. These forms allow for searching for the cases against the database. It allows for pre-selection of the cases stored in the database. For example, category *fires* → *woodland fires*. Hierarchical structure of the directory database narrows the number of directories being searched, and speeds up the response. The CRC next sends an appliance crew into the accident ground. After arriving at the fire ground, the Incident Commander sends a report to the CRC about the situation. It is a base for the CRC to look for a similar case in the database. The system finds the most similar case, then it shows the solution and plausible dangers on the screen based on the algorithms described above. The CRC sends this information to the Incident Commander. The Incident Commander using the proposed solution and it's own accident valuation, adapts the solution to the case.

The situation may change throughout the rescue action. Every time the Incident Commander sends the details of the action to the CRC, the CRC can search for new solutions.

After fixing the problem, attributes of the accident and the solution are entered to the database, and a new case is created.

The system will become useful in real rescue actions, as soon as the database is complemented with a considerable number of consecutive cases. At the final stage of the process, the cases are being gathered directly from the Incident Commanders reports. To start the system, a minimal number of cases in the database is needed. In order to overcome this difficulty, a special module has been created. The aim of this module is to fill the database with rescue actions from the past. The data will be acquired from the filing system EWID, and from text documents called Accident Analyses.

EWID provides the basic information, e.g.: category of the accident, object type, and its size. The rest of the attributes and solutions will be gathered from Accident Analyses. Accident Analyses are unstructured text documents. Special methodology, like text mining is necessary to create high quality information. The methodology of the data acquisition is described in [10].

5. Summary

According to Klein's group research, RPD is the most optimal way for taking decisions in emergency situations. CBR is a technique for simulating RPD in computers systems. The basis for CBR is a special database containing cases. In the proposed Decision Support System, these cases are the representations of real rescue actions. Cases are described by special type attributes, grouped in sets which depend on the type of the accident. The cases also contain solutions to the described problems. All the cases are divided into special groups which form a hierarchical structure. This structure is the base for the creation of the directory information tree in the Directory Service. The Directory Service is extremely efficient in data searching. To find the solution for a new accident, attributes of the accidents are compared against cases stored in databases. Special comparing algorithms are involved. The solution found is sent to the Incident Commander on the fire ground. Using this information and the Incident Commander's own situation evaluation, he adapts a solution to given conditions. Successful solution and the accident attributes are entered to the database, which results in creating a new case.

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