A Framework for the Search And Rescue Domain[1]

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Abstract. We describe the software environment that has been developed for the management and support of planning missions in the SAR domain. We have chosen to develop a configurable environment that simplifies the decision making process to the RCC staff. We also discuss the relation of this project with the Knowledge Management activities, especially with respect to the functions of knowledge creation, compilation, dissemination and application. We consider SARPA as a valuable tool that facilitates the organization to pursue the goals of success and efficiency.

1 Introduction

Knowledge-Based Systems (KBS) development must overcome multiple difficulties making it a high cost technology and with a (too) large number of development failures. While these *failures* were motivated by weak technology in the first-generation KBS, later, the use of naïve development methodologies were among the most recurred reasons that justified them. Currently, we can say that one of the reasons that limit the success of fielding a KBS is its o*rganizational adequacy*. It states that a KBS will only work if it is integrated into the structure and the business-process of the organization that uses it [1].

SARPA project was initially designed as a Search And Rescue (SAR) plan generator, which would act as an assistant with a high degree of initiative and independence, in the direction of the work done by Cottan in the same domain [2]. Although the initial goal was to automate a task which turned out to be too complex, we detected an important risk while executing the context analysis of the organization. The SAR organization barely meets a minimum technological ground neither in the information system nor in the personnel qualifications. This leads us to change the project objectives, so that instead of *automating a task, it would assist the user in the execution of multiple small activities*. We have deeply analysed the organization working processes in order to develop an environment which resembles

[1] This work has been partially supported by the Comisión Interministerial de Ciencia y Tecnología by means of the SARPA: Search and Rescue Planning Assistant project, number 1FD97-0612

the one used by the RCC Operator as much as possible, preserving the same flexibility that the user has when he solves the task at hand.

On the other side, each sub-task can be easily studied if we decompose the domain in many small tasks. We have used *Problem Solving Methods* (PSM) for those knowledge intensive tasks, as they were defined by McDermott [3], Chandrasekaran [4] and later integrated in KBS development methodologies as CommonKADS [5] [6], MIKE [7] or PROTÉGÉ [8].

Next sections will describe the SAR domain characteristics (Section 2) and its operation (Section 3). Sections 4 y 5 will deep into the system architecture and functionality. The relation of this project with Knowledge Management and the knowledge assets are commented in Section 6. Finally, we will raise some conclusions of this work.

2 SAR Domain

The Search and Rescue Service (SAR) is an important element of the Spanish Air Force. Its main function is to participate in any emergency situation in which it could be required. Although SAR is essentially a military organization and it was founded to rescue crashed aircrafts, actually SAR has collaboration agreements with different local governments to perform rescue missions, so most of the missions in which it participates are civilians.

The Canary Islands are situated in the Atlantic Ocean, in the North-West African Coast, with a distance of less than 100 Km. to Morocco coast. The Canarian archipelago has a rough and varied orography. The oriental islands are mountainous and with deep precipices, while the occidental islands are mostly desert and flat. Besides, the distance from the Canary Island to the Iberian Peninsula is about 2000 Km. and the distance to the Saharan fishing shoal is very short.

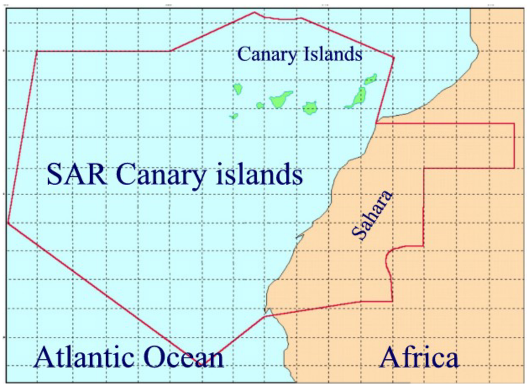

Fig. 1. SAR 802 influence area

The 802 SAR Squadron is responsible for coping with the emergencies, which could occur in our Islands. The Squadron operates over a 1.500.000 Km. zone (SAR influence zone), where 80% is sea (see Figure 1). This influence area is very important because it is a transit zone for most of the maritime routes (fishing and cargo vessels, sailing vessels) between Europe, America and Africa. Due to the particular characteristics of our Archipelago, Air Search and Rescue is the only feasible solution in most of the emergencies. There exists a great range of emergency types in which SAR participates. These types vary from rescue of a lost person in a mountain to cope with search and rescue vessels or a large air-crash. Obviously, the participation of a great number of material and human assets as well as the co-ordination with other military and civilian organizations which collaborate in rescue missions are essential.

Two main parts constitute SAR units: The Rescue Co-ordination Centre (RCC) and the Squadron itself. The RCC is in charge of the decision making about the missions planning, involved resources, search procedures to execute, co-ordination with other organizations, etc. It is responsible for generating and controlling search and rescue plans. The success of the mission depends on the right decisions made by RCC. However, the decision-making is a dynamic task and the building of a SAR plan results in a complex and difficult task. The RCC works with imprecise information like the local current information; incomplete information as could be initial data about a particular accident; erroneous information as the fact that the number of persons to rescue could be different to the number initially supposed; and fast changing data like the weather information. There are also inherent limitations with the airplanes (i.e. helicopters have less autonomy than planes, or it is difficult to operate with planes in mountain areas in land search missions). The Squadron is responsible for carrying out the search and rescue mission. They have a set of airplanes (planes and helicopters), experienced crews in search and rescue missions and qualified land staff in the maintenance and repair of aircrafts. The Canary Island 802 Squadron has three Fokker planes and four French Helicopters Superpuma.

3 RCC Operative

Figure 2 summarizes the activities carried out by the RCC. Two main modules are shown: *operation control and primitive tasks*. While the former is in charge of strategic decisions such as *what* to do and *how* to do it, the primitive task module consists of a large number of independent activities.

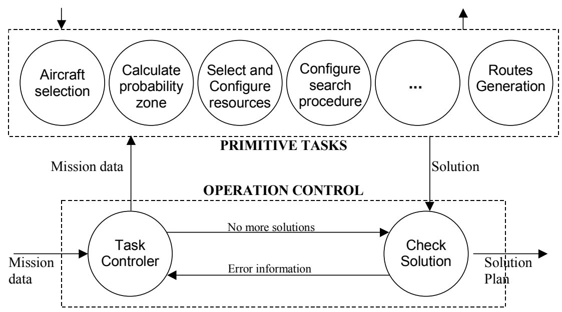

Fig. 2. RCC Tasks

3.1 Operation Control

It continuously decides what to do next and carries out an audit control over the mission evolution. Missions are composed of sessions, which are somehow similar to working journey. A session comprises all the information related to a labour journey, or stages in the case that many search procedures must be executed over the same area. Each session is built up with a set of primitive tasks, which are executed following personal criteria and expertise of the RCC Operator.

The RCC responsible must continuously evaluate or even re-evaluate the state of the primitive tasks during the mission, assimilating new information as it arrives. Each decision taken and each new received data are chronologically registered to facilitate subsequent analysis of the mission.

3.2 Primitive Tasks

We have identified over 50 primitive tasks for the Search And Rescue domain. Most of them are administrative tasks that must be completed in a certain period of time and following strict procedures. Request for using an aircraft from other organization or informing officers of some task completion are some examples. However, we have also found some knowledge intensive tasks which are not so simple to implement. These have required complex solutions, as we will describe in a later section. Some of these knowledge tasks are:

- Aircraft selection: type and number upon availability. The factors affecting this task include the mission type, the activity to be performed by the aircraft, distance to objective, response time, etc.
- Determining the maximum probability zone: we should have to first limit the operating area in the mission where you we are supposed to find something. Experience and area knowledge are critical factors affecting the efficiency of this task. There are also numerical methods that can provide us with an approximate answer when information is incomplete or personnel expertise is not high. The elapsed time, weather conditions, vessel type, maritime drifts, etc affect setting the exact situation and size of the zone.
- Selecting and configuring resources: aircraft configuration involves setting fuel, emergency material and crew each time it is used. Almost every mission data can affect this task.

Some other knowledge intensive tasks are selecting and configuring the search procedure (over a maximum probability zone) and building up a route for each aircraft.

4 Environment and Architecture.

An important part of the analysis efforts has been devoted to build a mission classification and to the development of a basic structure for each type of mission. In this structure the subset of primitive activities that should be carried out are specified, as well as the order in which they could be executed. We have had to integrate operation procedures coming from fully heterogeneous sources, as the normalized operative procedures from OACI, internal documents from the squadron, chronology of already developed missions, and mainly, the expertise and experience of the RCC staff.

The user is forced neither to follow the specified order, nor to execute an activity that seems irrelevant for the mission being carried out. If any activity is knowledge intensive, the RCC operator can either automate the task or perform it manually, or he can even modify the result provided by the automated task.

The architecture of the software solution is presented in Figure 3. We have also developed an information system which consists of a set of supporting utilities aimed at providing the RCC with a complete working environment. In general, the RCC operator interacts with the software tool, although the RCC Coordinator has the final responsibility for the recorded information about the mission.

Figure 3 follows the same policy that has been described in the previous section. Now, we will focus on some details about the implemented solution.

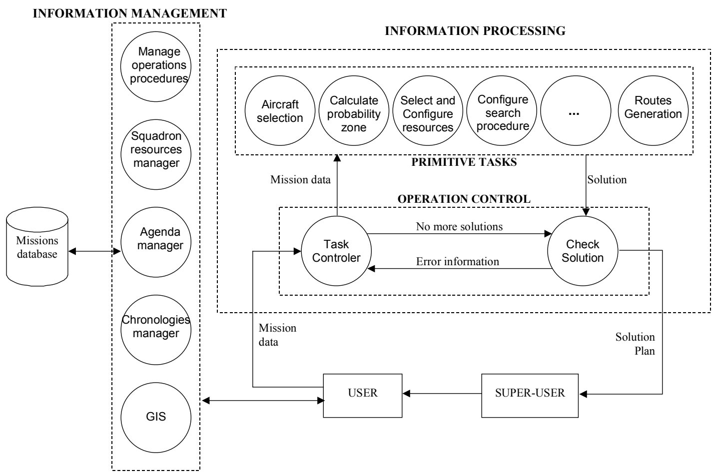

Fig. 3. SARPA Software Architecture

4.1 Information Processing.

The information processing is responsible for both, the decision and planning processes. It consists of the operation control and the primitive tasks.

The operation control is responsible for building and maintaining the structure of the current mission. For every new mission it settles the environment by initialising the set of activities that must be carried out starting from the information about the new mission. The user can modify the environment by either including new activities or deleting some existing ones. The operator can check the current state of each outstanding activity by means of visual flags.

The primitive tasks have been modelled using independent forms, such that, on one hand the operator can easily visualize the information needed for the execution of the task, and on the other hand he can also complete the information by introducing additional information. The knowledge intensive tasks have been modelled independently using specific PSM. Table I summarizes the type of PSM that has been used for the implemented knowledge intensive tasks. In the task of "*determining the search zone*" we have used numerical methods where some parameters have been settled according to the local experience of the RCC staff. For a detailed description about the PSMs that have been used, refer to Romero-Castro and Rodríguez-Rodríguez [9][10].

Table 1. Task name and type of PSM that has been used for the knowledge intensive tasks.

Task Name	PSM types
Aircraft Selection	Assessment, adapted from [1]
Select and configure the search procedure	Assessment [1]
Select and configure resources	Configuration design
Build the route	Planning [10]

In Figure 4, we present a view of the interface in the developed software. The figure shows an example mission: on the left, the primitive tasks tree, and on the right, the form associated with the task of selecting and configuring the search procedure (pattern) over a certain search area.

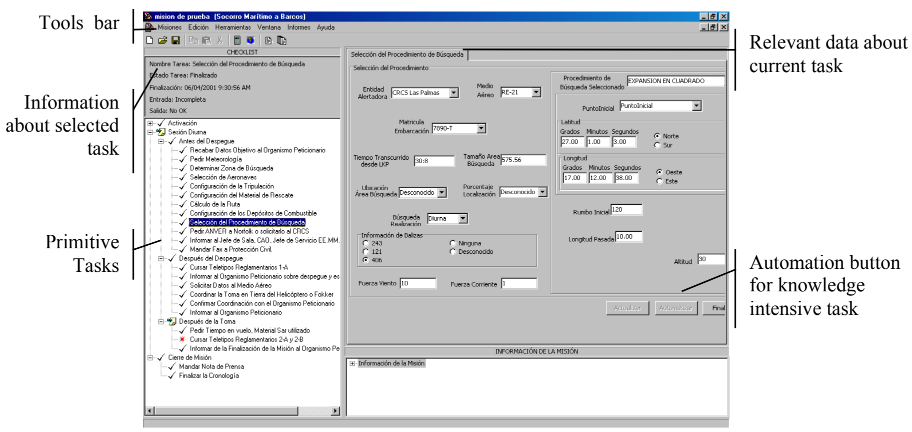

Fig. 4. SARPA main GUI snapshot

4.2 Information Management.

This module implements the following functions:

The manager for the operative procedures: we define here the mission types and the set of primitive tasks which provides us with the basic structure for each mission type.

The resources manager: it allows creating new resources, for example, aircrafts, or modifying their properties.

The entities and contacts agenda: It is an agenda which compiles all the relevant information about any organization and staff that can be useful for carrying out any step in a mission. This function is integrated in the primitive activities, where it is expected to be used. It is supplied with default queries that accelerate the location of the adequate contacts.

The manager of the chronology reports: it allows generating all the documents associated to a mission in order to be analysed later. In Figure 5, an example of this utility is presented.

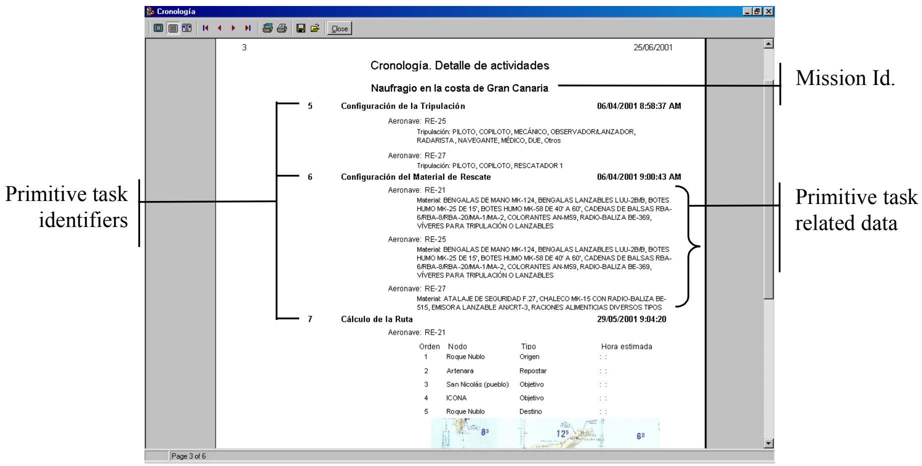

Fig. 5. Report generation utility

The Geographical Information System (see Figure 6): Visual references are a key factor in the decision making process. This tool provides us with a set of functions that speeds up the decision making process. Its functions are:

- Cartographical integration at different scales.
- Cartography geographically referenced.
- Conversions between geographical coordinates and UTM.
- Measure of geographical distances.
- Visualization of relevant nodes, like hospitals, airports, etc..
- Calculation and visualization of routes, searching areas, and searching procedures already performed.

The user interface, the general control of the application, and a big part of the information management module have been developed in Delphi 5 from Borland Corp. Knowledge based modules, except for the calculation of the searching area, have been implemented using MindBox's ART*Enterprise (versions 2.5 and 3.1). The database that has been used is Microsoft Access 2000.

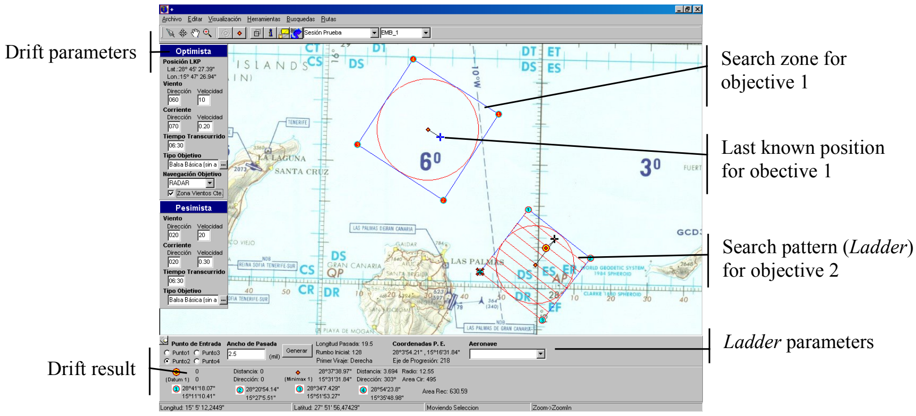

Fig. 6. GIS with some search areas activated

5 Knowledge Assets and Management Benefits

The Tool captures most of the organization knowledge needed for performing and controlling SAR missions. These knowledge assets are distributed all over the software functionality. It is on the definitions of the missions' templates where we find the most valuable knowledge that we have elicited, both in the primitive activity definitions and in their organization. Providing a user with a checking list of the actions and activities that he should carry out during the mission operation is not trivial. These checking lists capture the expertise of people doing this kind of work for about 20 years. If the RCC operator has confidence on these lists, he can concentrate on solving specific tasks instead of deciding what could be done. For example, a mission activity may consist in alerting a certain hospital of the imminent arrival of a helicopter with injured people. The RCC operator does not have to realize that he is responsible for the execution of that action, so he can focus on solving more knowledge intensive tasks. Similarly, we can consider all the relevant data and information for completing a primitive task. The RCC operator can access, with just one look, all the relevant information needed to make the right decision since we have designed a specific form for each primitive task

Knowledge is also captured in the implementation of multiple KBSs, which automates small portions of the global plan scheduling (selecting aircraft, configuring emergency resources, calculating maritime drift and aircraft route building). These *smart tools* allow the users to confront their own opinions and experiences with those given by the KBS. Afterwards, they can disregard or adapt the solution given by the System. It is important to notice that SARPA project neither builds a global plan on its own, nor substitute the role of the human user. It simply provides him with a set of *tools* on which he can rely whenever he wants.

Finally, the whole application design replicates the environment in which the RCC Operator works, including most of the resources that should be needed during the mission.

The development of KBSs is a valuable tool that can participate in most of the functions of Knowledge Management (KM) [11]. So, from this point of view, this project is concerned with most of the functions assigned to KM as described in Wiig [12]: *knowledge creation, compilation, dissemination and application*.

Knowledge *Creation* refers to learning and assembling knowledge from external and internal sources (i.e. Experts). While the final product is not able to *learn* new situations by itself, the assembling capability has been achieved through an engineering process. We used CommonKADS methodology to elicit and combine knowledge from heterogeneous sources.

Knowledge *Compilation* applies to combining, organizing and holding knowledge in memory. Undoubtedly, the most important achievement of this project was not the software product, but the Organization and Context analysis. We carried out an extensive analysis of the Organization modus operandi, which results in a set of documents describing detailed actuation procedures and work categorization. Now, the SAR personnel have now the same opinion, though they were initially sceptical because they used to argue that there are not two similar missions and resolution processes are different from one mission to another.

Knowledge compilation is also related to building a unified view of the Organization world, so that all people can refer to the same thing using the same terms. By using this tool, users normalise the expressions and the vocabulary used during the project. We have worked to eliminate ambiguous expressions that may have fatal consequences in real world situations (terms as *long, near, wide, many, etc.*). The ontology generated also simplifies the de-briefing activities which take place when a mission is finished and a global analysis is made with rescue team members.

Knowledge dissemination means distributing the knowledge to where it is needed, allowing people to access and use it. This is especially important in organizations as the air force, where personnel promotions and destinations complicate the possibility of keeping a corporate knowledge. We also allow people to access, analyse and learn about past missions by systematically archiving all the relevant information, and enforcing the users to use the system by simulating emergencies, and contrasting both responses.

The last KM area covered by this project focuses on applying the knowledge assets described at the beginning of the section. The overall performance of the RCC organization will increase through the use of SARPA system. In summary, if we consider this project as a KM action, then we can say that the goal of *making the organization act as intelligently as possible to secure its overall success is enforced [11]*.

6 Conclusions

We have described the software environment that has been developed for the management and support of planning missions in the SAR domain. We have chosen to develop a configurable environment that simplifies the decision making process to the RCC staff, instead of developing a global planner. The global planner would probably not be used by the RCC staff because of the difficulties in technology transfer, the inherent complexity and dynamism of the domain, and the low previous technological background of the organization.

This setting out has made us modify some of the initial goals. We have evolved towards the development of a modular system in which the steps that the user is forced to follow (for example, the execution of non desirable tasks) is almost null. The final product provides with a working environment in which the user feels comfortable, thus guaranteeing the success of the global development.

We have been able to analyse the SAR domain, build a mission classification and extract a set of primitive tasks, starting from heterogeneous knowledge sources, as international norms, internal documents and mainly from the expertise of the RCC staff. Regardless of the value of the software that has been developed, the RCC staff thinks about it as a success that justifies the project development itself.

The modularity that has been used during the tool development eases the evolution and improving processes. These improvements may consist in including new mission types, redefining the existing ones, including new primitive tasks, optimising some knowledge intensive processes without jeopardizing the rest of the working environment, etc. Modularity has also eased the knowledge modelling task, by designing a specific PSM for each task where it is needed.

We have also discussed the relation of this project with the Knowledge Management activities, especially with respect to the functions of knowledge creation, compilation, dissemination and application. We consider SARPA as a valuable tool that facilitates the organization to pursue the goals of success and efficiency.

The system is currently being tested by the RCC and we think that it will be fully operative by October 2001.

References

1. Schreiber, Akkermans, Anjewierden, de Hoog, Shadbolt, Van de Velde, Wielinga. Knowledge Engineering and Management. The CommonKADS Methodology. The MIT Press. 1999.
2. Cottam, H., Shadbolt, N., Kingston, J., Beck, H., Tate, A. Knowledge Level Planning in the Search and Rescue Domain. In Research and development in expert systems XII edited by M. A. Bramer, J. L. Nealon and R. Milne, Information Press Ltd, Oxford, England, 1995. pp.309-325. ISBN-1-899621-04-0. 1995.
3. McDermott, J.: Preliminary Steps towards a taxonomy of problem-solving methods. In S. Marcus (ed.). Automating Knowledge Acquisition for Expert Systems. 1988; 225-256
4. Chandrasekaran, B. Generic Tasks in Knowledge-based reasoning: High level building blocks for system design. IEEE expert 1986; 1(3): 23-30.
5. Wielinga, B.J., A.Th. Schreiber, J.A. Breuker; KADS: A Modelling Approach to Knowledge Engineering. Knowledge Acquisition, Special issue "The KADS Approach to Knowledge Engineering", 4, 1, 1992.
6. Breuker, J., Van de Velde, W. CommonKADS Library for Expertise Modelling. IOS Press, Amsterdam, 1994.
7. Angele, J.; Fensel, D.; Studer, R. Domain and Task Modelling in MIKE. In Suthliffe, A et al. (eds). Domain Knowledge for interactive system design. Chapman & Hall. 1996

8. Eriksson, H, Shahar, Y; Tu, S.; Puerta, A.; Musen, M. Task Modelling with reusable problem-solving methods. In Artificial Intelligence 1995; 79 (2): 293-326.
9. Romero, M.; Rodríguez, A., Then Analysis of a Planning Task. In Knowledge-based software engineering. Hruska and Hashimoto (eds.). IOS Press, 2000
10. Romero, M.; Teruel, A.; Rodríguez, A., Multi-Layered PSM for planning. In Research and Development in Intelligent Systems XVII. Bramer, Preece and Coenen (Eds). Springer-Verlag, 2001.
11. Tiwana, A. The knowledge Management toolkit. Prentice Hall PTR. 2000.
12. Wiig, K. Roles of knowledge-based systems in support of knowledge management. In Knowledge Management and Its Integrative Elements. Jay Liebowits (ed.). CRC Press. 1997.