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Decision Support System for Emergency Management

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Resumo

Pretende-se com este trabalho fornecer um contributo no âmbito do projeto THEMIS, proporcionando um sistema pericial capaz de fornecer um apoio à tomada de decisão. Tendo como base de apoio os casos passados, pretende-se inferir os meios a serem empregues para dar resposta a um certo evento.

Este trabalho foi iniciado com a realização de pesquisa bibliográfica, referente aos vários temas que englobam o apoio à tomada de decisão através de sistemas inteligentes. Desta forma, os temas compreendidos nesta tese são: gestão de crises, comando e controlo, tomada de decisão, raciocínio baseado em casos e redes neuronais.

Por forma a otimizar-se a resposta do sistema de raciocínio baseado em casos, através de redes neuronais, foi possível entender quais as variáveis que realmente influenciam a inferência dos meios a empregar na resolução dum evento. Possibilitando assim a metodologia de raciocínio baseado em casos suportar o processo da tomada de decisão com uma maior exatidão.

A analise dos resultados obtidos, referentes a um evento representativo, mostrou que as variáveis que mais influenciavam a predição do modelo são, ”Entidades Envolvidas”, ”Vitimas Civis” e ”Natureza”. Esta constatação permitiu que o sistema de raciocínio baseado em casos obtivesse resultados muito próximos das tomadas de decisão adotadas pelos comandantes.

Palavras-chave: sistema pericial, gestão de crises, comando e controlo, tomada de decisão, raciocínio baseado em casos, redes neuronais

Abstract

The intention of this work is to provide a contribution within the context of THEMIS project, providing an expert system able to provide a support for decision-making. Having as a support base past cases, it is intended to infer the means to be employed to provide a response to a certain event.

This work was initiated through bibliographic research related to different topics that encompass support to decision-making through intelligent systems. Accordingly, the topics included in this thesis are: crisis management, command and control, decision-making, case based reasoning and neural networks.

In order to optimize the case based reasoning system response through neural networks, it was possible to understand which variables really influence the inference of the means to use for the resolution of an event. Enabling the case based reasoning methodology to infer decision making with greater accuracy.

The analysis of the results, referring to a representative event, showed that the variables that most influenced the prediction model are "Entities Involved", "Civilian Casualties" and "Nature". This realization allowed the case based reasoning system to obtain results very similar to the decision-making adopted by commanders.

Keywords: intelligent systems, crisis management, command and control, decision-making, case based reasoning, neural networks

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List of Acronyms

ANN Artificial Neural Network

ANPC Autoridade Nacional de Proteção Civil

C2 Command and Control

CBR Case Based Reasoning

CRO Crisis Response Operations

MSE Mean Squared Error

NATO North Atlantic Treaty Organization

SBS Sequential Backward Selection

SFS Sequential Forward Selection

Chapter 1

Introduction

1.1 Background and Motivation

The world is increasingly confronted with instability situations caused not only by nature, but also by man, such as economic crises and ethnic conflicts. For these reasons it is of human concern not only to be ware of these types of instabilities, but also to avoid them. International organizations, such as North Atlantic Treaty Organization (NATO), have the capabilities and means to provide effective responses to these types of events. These include both structures of command and control (C2) and skilled personnel in decision making.

The commanders integrated in a mission are permanently faced with complicated situations, where lives depend on both the ability to command and the resource management skills that the commander has. Due to climate change, emerging conflicts and the growing threat of terrorism, the Armed Forces must be prepared to face the numerous disasters, natural or man-made, that may occur.

However, even in the presence of an experienced commander, derived from the human factor, there always exists the possibility of error in decision making and resource management. As a result of this error, inherent to the human condition, lives can be jeopardized.

Having realised how critical and complex the role of crisis management is to commanders and how much of a challenge this is, high command initiated several studies in the field of crisis management with the purpose of not only enabling a better understanding of the entire process, but also to evolve through the decision-making concept.

For this reason the use of technology in the fields of decision-making and resource management is increasingly required by the entities involved. Ergo relevant aspects of the crises management problem are the numerous technological developments achieved in the fields of intelligent systems, as well as communications year after year. These advances today enable automated systems to perform highly complex tasks at speed that would have been unthinkable forty years ago. Nowadays, there exists a fast and efficient communication system, not only between individuals but also between intelligent systems.

These developments allow commanders to became aware of the importance of using these technological developments in decision making, not only to provide a faster response, but to also provide more efficiency and effectiveness. Numerous studies and projects in the field of expert systems have been put in place so that the existing means regarding tactics, techniques and procedures do not fall into obsolescence.

The presence of this ideology can already be found in the Portuguese Armed Forces, where the application of this emerging field of intelligent systems in decision making, within the context of defence, specifically in support of CRO, can be central to aid commanders' decision-making in response to a situation of enormous complexity and responsibility. One of the examples of the application of this technology dates to 1995, when the expert system for the management of critical situations was used on-board vessels, in combat or emergency situations, namely Sistema Integrado para a Gestão de Prioridades e de Afectação de Recursos (SINGRAR). As a pioneer in the field, this project very quickly established itself as exhibiting a critical success factor for the performance of those ships and their garrisons.

As a consequence of these advances the project, Distributed Holistic Emergency Management Intelligent System (THEMIS) emerged, to which this project will contribute in the field of expert systems.

The THEMIS project is an emergency management distributed system demonstrator that, in a holistic way, provides situational understanding and decision support in the context of humanitarian aid operations to a community and inter-agency actors who share information and resources meant for the effective use, rational and collaborative / cooperative of available means.

Hence, this work aims to study/define integral concepts essential for crisis management, addressing in a comprehensive and consistent way concepts, from the simplest, such as the concept of ”crisis” to the most complex, such as aiming to define and explain nuclear knowledge within the field of crisis management. It is also intended to refer to the topic of crisis management in various contexts, i.e. national and NATO, so that we can understand how these different entities regard this concept. It's preponderant to realise the importance of having a back-office prepared to receive, analyse and deal with crisis events that may arise, this becomes one of the critical points in decision-making. In this way, this work will explain the influence of good preparation, not only intellectual but also the organisational/structural of C2, so that decision making can be flawless. A topic will also be assigned to decision-making, since it is seen as crucial to realise the importance of decision-making adopted by the commanders on the ground and determine which negative influences may arise due to the lack of preparation in this area.

Subsequently, one further topic related to two of the existing expert systems through the date, being the CBR and Neural Networks, will be studied. This study aims to provide THEMIS with the intelligent assessment capacity in crisis events. The intent with these topics is to explain under what methodologies these intelligent systems work and how they can be applied to crisis problems.

1.2 Objectives

This work is integrated into the THEMIS project, whose goal is to build a new intelligent system to support decision making in critical events. It is intended to contribute to a study using an expert system, able to support situational knowledge as well as command and control processes. Therefore, the intelligent system presented in this work will aim to provide intelligent features for decision making support, appropriate to the user's profile in order to assess the situation and recommend priority lines of action based on the current operating environment. The following objectives are proposed for this work:

- Show the important role of crisis management in the present day and how the result of such importance has become a major subject of study by several international entities in order to both predict events, and minimize to the extreme their damage;
- Explain how crucial it is to structure a Command and Control (C2) containing all the entities and agencies able to provide all the information, knowledge and experience to ensure the implementation of better decision-making;
- Understand how decision making influences the course of the event and see how it is articulated with the C2 systems;
- Perceive through optimization algorithms and neural networks systems how the attributes influence the intelligent model generated, making it possible to create an assignment of weights (influence) for the model to generate;
- Study the CBR system method in order to understand which is the best analysis structure to adopt, thus enabling the creation of a system based on past events model, which is able to provide a response concerning the resource management to be applied in each event;
- Define a process of response to a crisis event through determination of the descriptors that characterize a given crisis event;

1.3 Thesis Outline

Chapter 2 centrally addresses the subject of crisis management complemented with the topics of command and control and decision making. One of the objectives of this chapter ties in to demonstrate the necessity of a constant evolution and adaptation of the crisis management models in order to provide a response to global instabilities, whether caused by man or nature. It also presents the model implemented at the national level, and the model implemented by NATO. As a complement, but of no less importance, the subject of command and control is addressed. This topic was intended to demonstrate that even in the presence of a very effective crisis management model, if there is not a well-structured system of command and control in the back-office, the goal will be fulfilled efficiently. Furthermore, of the technical requirements that must support the response to a crisis, one of the decisive factors for the success of the mission relates to a decision making consciously and studied. Thus the topic of decision making was addressed in order to demonstrate the importance of a commander capable of providing the best response against a high complexity event.

Chapter 3 addresses CBR methodology, presenting at an early stage its inception and evolution and afterwards developing the topic by displaying the different existing concepts and associated terminology.

As a central topic this chapter provides CBR cycle methodology, demonstrating the overall operation inherent in each stage.

Chapter 4 addresses the subject of neural networks being, in the first instance, the inception and development of this methodology. Subsequently, some examples of structures that neural network can display and an explanation of its mode of operation are presented.

Chapter 5 presents all the methodology adopted to solve the problem. Afterwards, the treatment performed to the data provided by ANPC is demonstrated, and all the architecture adopted are later explained. In the final phase it is demonstrated how the my CBR programme is implemented and how the solution proposed by the algorithms will be evaluated.

In chapter 6 all the results obtained by different algorithms are demonstrated and analysed. In this chapter all hypotheses obtained by the algorithms will be tested giving rise to a confusion matrix, allowing the realisation of how accurate the hypothesis adopted is.

In chapter 7 the findings inherent in the work are presented, with the intention of presenting a solution to the proposed problem. In this chapter it is also the aim to present proposals for future work, with a view to improving the proposed intelligent system.

Chapter 2

Crisis management

2.1 Trichotomy Risk-Hazard-Crisis

Throughout the history of humankind there have been catastrophic events that marked societies. Therefore in order to survive, not only these types of incidents, but also for sociological reasons, Mankind has created social systems in order to develop methods of prevention and response to such events. Nowadays the role of resource management increasingly plays a key role in regard to a reliable and accurate response to a crisis event. Thus, various entities realized how crucial crisis management study is so that society can live as safe and comfortable as possible. In order to understand what behaviour to have, both in prevention and operation, society was obligated to better understand and define slightly basic concepts such as the concept of risk.

In 1990 L.Faugères, introduced during the seminar ”Risques naturels, risques technologiques. Gestion des risques, gestion des crises” the theory of risk. Noting that a crisis event is assigned to a Risk-Hazard-Crisis trichotomy and is therefore essential to define the concept of risk and the concept of hazard so that this way society can have a better understanding of what the concept of crisis is.

There are several definitions for the concept of risk, however the two most important to be considered in this work are:

- “Sistema complexo de processos cuja modificação de funcionamento é suscetível de acarretar prejuízos diretos ou indiretos (perda de recursos) a uma dada população.” (Lei no 113/91, de 29 de Agosto - Lei de Bases da Proteção Civil).
- “Degree of loss anticipated due to a certain phenomenon, taking into account the function of danger and vulnerability.” (United Nations, 1984).

Nevertheless, the most common idea of risk according to Lourenço and Tedim (2014) consists in the danger that the human being is submitted to a particular event, i.e., the risk is the probability of a hazard occurrence. In this work the risk will consist of the probability of the occurrence of a disaster, whether natural or man made. Risk, can be grouped into three groups depending on their origin:

- Natural phenomenon that produces the damage due to natural origin;

- Anthropogenic phenomenon that produces the damage due to action human;
- Mixed if the phenomenon that produces the damage has both natural as well as anthropogenic origins.

The concept of risk, as well as, the concept of hazard has obtained different definitions, depending of the author. However the definition considered more relevant to the work is, “The probability of producing, within a given time and a given area, a potentially harmful phenomenon.” (United Nations, 1984).

Considering the definition above it is understood that any hazard is defined and characterized by man-kind. Having understood this circumstances, a specific department was created to study the hazards, this new department was call cindínicas sciences.

With the knowledge referred to the concepts of Risk-Hazard, it is easy to understand the complete interconnected way between this concepts and the concept of crisis. Faugères defines crisis as ”It translates the franking normal thresholds, ie, the inability to act on the processes and the absolute uncertainty about the development of the crisis and its impacts.”(Lourenço and Tedim, 2014). With this definition and the interconnected way the concepts referred to in this work, can be understood as crisis, an event that achieves exorbitant proportions for not being controlled in a timely manner, some of the examples of such events are: floods, fires, industrial accidents, air accidents, amongst others.

With social development, the uncertainty about the emergence of crises event has increased exponentially. Today there are several factors which require a greater focus on prevention, management and evaluation of a crisis. There are factors that may be of environmental character such as, higher climacteric uncertainty that result from pollution provoked by Mankind. There are also factors of social character derived of increasingly globalized and unstable economic or political/cultural tensions. Ergo, one of the responses adopted in order to give an answer to some of the factors mentioned above is based on the controlled and organized management of the existing resources. Realizing the importance of resource management man-kind was concerned not only with studying the management of matters dealing with disasters, but also the use of new technologies, such as intelligent systems for a better resource management.

2.2 Crisis management concept

With all the experiences and lessons learned throughout history in 1978 comprehensive emergency management model made up of four steps was created, figure 2.1.

Figure 2.1: Comprehensive Emergency Management Cycle (Canton, 2007)

Though there is a hierarchy of steps in the model resolution algorithm, all stages contain the same importance with regard to effective response to the event. Thus the four steps consisting of:

1. The first step explains that after a disaster there is an initial response in order to respond to the impacts that the disaster has triggered;
2. The second step is a recovery with the aim of making society return to a normal lifestyle;
3. The third step is called the mitigation phase called an attempt to eliminate or substantially reduce the effects of the disaster;
4. The fourth step concern being prepared and ready, which aims to perform an analysis of the disaster and its resolution process, so that in the future the same disaster will not occur or if it occur allowing for a more effective response provided in a shorter time.

Bearing in mind, all that has been mentioned, in the first decade of the second millennium Canton (2007) states that emergency management is based on three very important pillars, namely: the knowledge of history, an understanding of human nature expressed in social sciences, and specialized technical expertise in response mechanisms. The author suggests that the study of past cases becomes central to a better understanding of the disaster event, enabling the preparation of an effective response to a future case. Canton (2007) claims that an understanding of human nature expressed in the social sciences aims to increase the understanding about the way human beings relate to each other and within society in order to understand why certain event happened, making it possible, not only, to predict a case but also to put aside some wrong and unfounded assumptions, that detract the performance of the authorities. The author points out a third pillar, specialized technical expertise in response mechanisms, noting that it is an extremely important study and training the of response mechanisms for these types of events, since they are a key role in the management processes both to evolve and to be more flexible in different situations that may arise.

2.2.1 National context

As mentioned above, the growing instability present in the now leads an isolated country to have tremendous difficulty in giving response to a crisis situation. Portugal understood that it would be required to look into the study of field crisis management. As such, it has become absolutely necessary to create legislation, doctrines and methods of procedure for better and more effective use of not only the public authorities but also the armed forces in a crisis situation. With this, Portugal created the *Sistema Nacional de Gestão de Crises* (SNGC) that does not constitute a new body or structure, but rather a system that provides better and effective management of resources, thus assisting the Prime Minister in decision making.

By the existing legislation through Decree-Law No. 173/2004, it was determined that the response management process to a crisis consists of three levels, namely, Decision, Implementation and Support, figure 2.2. Within the SNGC a back-office is present made up of the Crisis Office, Support Group and the Execution Entities.

Figure 2.2: Levels of response management process

The first and highest level present in SNGC is represented by the Crisis Office, whose function is to take decisions on the management of the crisis. It is so, chaired by the Prime Minister, composed of a set of ministers related to areas that involve the crisis event and the government member who coordinates the support group.

On the second level are present the entities of the National Council of Civil Emergency Planning, emergency planning committees and any other entity that is an expert in the crisis management area invited by the government of the presiding member of the support group. Under the laws of Decree-Law no 173/2004 Article 5, this level has the following functions:

- Monitor developments in the situation;
- Treat all information provided by the competent authorities;
- Prepare studies and proposals for determination of the Crisis Cabinet or on its own initiative on issues and matters relating to the management of the crisis;
- Disseminate the implementing entities issued guidelines and decisions of the Crisis Cabinet;
- Advise on matters relating to the European Union systems, the NATO, as well as with other international systems for crisis response.

In the last level present in legislation is the Execution Entities. It is expected that all departments and agencies under the direct administration of the State, are not only governed by the Crisis Office as it has a duty to collaborate with the SNGC.

Despite all this legislation relating to events that are present in the country, in the present day the threats to the creation of a crisis event are increasingly universal as a result of various human factors, such as terrorism and global warming. As a result, the civil system not always had the capacity to respond to the crisis event. In order to assist in restoring the normal functioning of society also provided for in Portuguese legislation the integration of the armed forces in aid of the treatment and resolution of the crisis event.

Through the National Defence Act (Organic Law No. 5/2014 of 29 August), the Organic Law of Bases of Organization of the Armed Forces (Organic Law No. 6/2014 of 1 September) and Organic of the General Staff of the Armed Forces (Decree Law No. 184/2014 of 29 December), the military's role is to collaborate in civil protection missions and tasks related to the satisfaction of basic needs and improving the quality of life of the population. However, due to a presence of a rigid, well-structured hierarchy, the military can not act in any way in the operation theatres. The armed forces are employed in the field if there is a crisis event, with gravity considered low level, is carried out a request to *Estado Maior General das Forças Armadas* by the ANPC so that then there is a cooperation between agencies guided by only one Command and Control system. If the crisis event prove to be a case of manifest urgency, the same application can now be made by municipal councils directly to the unit Commander in present area. In order to prevent and enable a timely and effective response by the armed forces, a readiness matrix associated with present risk level was created, figure 2.3.

Status	Levels	Degree of Readiness
Ordinary	Green Low Risk	Readying forces in 72 hours
Special	Blue Moderate Risk	Readying forces in 24 hours
	Yellow high Risk	Readying forces in 6 hours
	Orange Elevated Risk	Readying forces in 2 hours
	Red Extreme Risk	Imediact readying forces

Figure 2.3: Force readiness levels (CEMGFA, uary)

However the presence of the risks and crisis events are not always occurring in said country. Nonetheless, as Portugal is integrated in organizations like NATO and the UN, it is obliged to assist in response to the international character of crises. Ergo, as a foreign policy supported in a national context, it is now present in the Portuguese Armed Forces through the Regulation Campaign Operations (Ministério do Exército, 1979), a chapter (chapter 4) responsible for CRO legislation.

Several threats considered by the Portuguese Armed Forces (Ministério do Exército, 1979) for which the CRO should address are:

- Religious, cultural and ethnic exterminations;
- Competition for vital resources and ecological disasters;
- Terrorism and proliferation of weapons of mass destruction;
- Narcotics.

Figure 2.4: CRO Spectrum (Ministério do Exército, 1979)

In order to understand more broadly crisis events and make it possible to respond to this type of event, the Portuguese Armed Forces adopted the definition of present crisis in the Generic Crisis Management Handbook, stating that the concept of crisis is to:

"Situation of National or International level that constitutes a threat to the values, interests and goals of the parties involved."(Kriendler, 1999)

The Portuguese Armed Forces found themselves still in need to establish an evaluation regarding the concept of crisis, the criteria gravity and intensity. Establishing that the gravity of an event is a relationship between effect and time, ie, a crisis is even more serious as more unacceptable are the effects and lower the term of their application on the values, interests and goals of the parties involved . And it was established that the intensity of an event is characterized by the level of violence present in the theatre.

With this, it makes sense to trace goals in which the crisis management needs to address. So the goals set by the Generic Crisis Management Handbook (Kriendler, 1999) were adopted by the Portuguese Armed Forces ,being them:

- Reduce tensions to prevent crises;

- Crisis management to avoid conflict;
- Ensuring readiness of structures;
- In the event of hostilities, control, prevent and persuade belligerents;
- Promote the return to stability.

Set out all the pillars of understanding needed to respond to a crisis event, the Portuguese Armed Forces defined the concept of CRO as: "Multifunctional operations covering political activities, military and civilian, executed according to international law, including international humanitarian law, which contribute to the prevention and resolution of conflicts and crisis management"(Ministério do Exército, 1979).

Since the crisis events have a comprehensive range of possible theatres, it became fundamental to categorize these types of operations. For depending on the theatre of present crisis, not only different modes of operation, logistics and operational, will be defined by the Armed Forces, as well as different command and control structures will be provided to C2, which requires the military flexibility in interconnection between national agencies and international. The response operations Crisis were categorized in the Operations Campaign Regulation (Ministério do Exército, 1979), the following types:

- Operations to support peace missions;
- Support Humanitarian Operations;
- Support for Disaster Assistance;
- Search and Rescue;
- Non-combatants Evacuation Operation;
- Extraction Operations;
- Support to Civil Authorities;
- Imposition of Sanctions and Embargoes.

However, despite the different theatres oblige the different types of different decision-making and organizations of C2, the general principles defined by the armed forces, in which the CRO should be based are transversal to all types of operations. Thereby allowing an established guideline is which the Crisis Management model will apply. The principles considered by the Portuguese Armed Forces (Ministério do Exército, 1979) most relevant in a matter of crisis management are:

- Command unit - requires a clear definition of authority, role and relations between actors;
- Credibility - Capacity of response with professionalism and rapidity, effectively responding to incidents;

- Flexibility - The Force should be organized and sufficiently autonomous in terms of skills, abilities, equipment and logistics;
- Promotion of cooperation and consent - requires a careful consideration and evaluation before the implementation of any military nature activity;
- Impartiality - The operations must be conducted without favouring / harm either party;
- The Use of Force - the use of force should be limited as to the degree, intensity and duration necessary to achieve the objectives;
- Mutual respect - The Joint Commander must ensure that the same principles are recognized and implemented by different contingents.

Through all of this it is possible to demonstrate a concern at the national level regarding the concept of crisis management. legislation can already be found in regards to the subject, both at a civil and military dimension. However, much still needs to be studied, ie in order that the modest crisis management model implemented at the national level gain robustness so making it possible to get a intelligent prevention and more effective acting methods. Continuous studies and projects are taken into account not only by civil authorities but also by military entities. An example of some of the successful studies are *Sistema de Apoio à Decisão Operacional* project present at the ANPC in order to assist in decision-making in a crisis event.

2.2.2 NATO context

This subtopic aims to demonstrate how NATO handles the approach to the concept of crisis management.

NATO, is an organization with the purpose of providing a collective defence system to member countries and to assist in responding to situation of crisis through political and military means. Founded on April 4, 1949 for 12 countries based in the United States in Washington DC, today it is made up of 28 member countries and is endowed with legislation to address the most difficult situations, not only conflict but also the situations of maintenance and management of peace.

Thus, only the non-Article 5 of the present legislation in the Organization has highlighted to the work, been the only article that discusses legislation to Crisis Response Operations. In the article of (NATO, 2010) are present multifunctional operations, such as the peacekeeping operations, and is the article by excellence to contribute to the prevention and resolution of conflicts, serve humanitarian and crisis management, always being in accordance with the objectives outlined by the Organization. The big difference with Article 5 for non-Article 5, is that no country is obliged to intervene in aid of others, this derivative of the type of operations are of CRO character.

Nonetheless, despite the cooperative devotion among countries in these types of operations to be more liberal, the design goals to achieve in CRO, specifically in crisis management is inevitably essential.

Therefore, this organization established objectives and basic principles in the context of crisis management, by which it is governed and that are implicit in decision making. The crisis management objectives outlined by NATO (NATO, 2010) are:

- Contribution to the effective conflicts prevention;
- Effective crisis management to prevent their escalation into conflicts;
- Ensure the readiness of civilian and military capabilities;
- Control and prevention of escalation and discouraging the aggressor from violence in the military actions;
- Crisis de-escalation after stopping violence or end of disaster.

Through the objectives outlined, are easier for member countries to adopt and evolve a structure not only conceptual, but also operational with regard to the concept of crisis management. Given this background, NATO sets out basic principles aimed at establishing the timing and agreement of member countries. This through a continuous exchange of experiences and information and a comparison between the various viewpoints of the different member countries. Allowing for a harmonization of the points of views of the various member countries in order to make possible a collectively decision-making. The basic principles assumed by NATO for crisis management are:

- Supremacy of North Atlantic Council (NAC);
- Consensus;
- Permanent Representation of NATO Nations;
- Political Control over the Military.

Thus, after the guiding lines are drawn in which crisis management should be based, a response system is then generated for crises. This system has been in constant evolution, proposing in the present day to provide required preparedness, pre-identified response measures and options and initial timely response and further organized response.

This system presents a Command and Control constituted by the NAC, Operations Policy Committee, Political and Partnerships committee, Military Committee and the Civil Emergency Planning Committee.

Thus, it is possible to understand that this is a complex system where there are several entities in very different organic and operating structures, but which, however, proves to have all the capabilities to model it to the complex crisis events of the day.

Through all this conceptual and organizational structure, based on crisis management model established generally worldwide, NATO has succours from the information already established and adapted the model to their abilities and objectives, figure 2.5. With this, NATO projects a crisis management model consisting of 6 phases (NATO, 2011).

Figure 2.5: NATO Crisis Management Model (NATO, 2011)

Phase 1: Indication and warning: According to NATO legislation (NATO, 2011), this phase is the initial phase of the entire crisis management process, where there is a guidance for the NAC about which action to be taken not only on political issues but also military. This stage is where the information systems take more relevant presence. It is an important stage for the development of the whole crisis management model does not fail the goal of resolving the crisis. Ergo it is of the most importance there exist a constant and detailed exchange of information of all the details of the crisis event by any member country or entity. The NATO information system composed of various information systems of member countries, aims not only prevent crisis situations as well as to support decision making. With this the organization can formalize various decisions depending on the case of this information, as follows (NATO, 2011):

- Organization may choose to take no consideration on the event;
- It may be deemed necessary more information and therefore increase the focus on surveillance
- They can be taken into account diplomatic and political response, including civil emergency response and be even taken into account the military implications as appropriate to the crisis event
- May decide that the crisis event is considered extremely thereby being held an enlarged review of the event, thereby pulling the process for on 2 and 3 phase.

Phase 2: Assessment: According to NATO (NATO, 2011), in this phase an assessment of the crisis event by political and military committees are carried out, providing advice on the development of the crisis event and its implications for the security of member countries to this process the organization categorized as Political-Military Estimate-PME. It is also required to the Supreme Allied Commandeer Europe to develop methods of response strategy to be adopted for the event.

Phase 3: Development response options: Base on the results provided by the process of PME, NATO is faced with a huge set of possible actions to take. In order to assist the choice of decision-making, the organization provides formal political support to NATO Military Authorities regarding the implementation of planned operations.

Phase 4: Planing: According to NATO (NATO, 2011), the entity responsible for developing the Concept of Operation and subsequently an Operation Plan is the Supreme Allied Commandeer Europe, which later submits to the military committee to give endorsement, and NAC for assessment and approval. Finishing the process step, NAC needs to formally allow the Operation Plan in order to mobilize forces.

Phase 5: Execution: At this stage NATO executes the mission and conducts a regular assessment on the state of operation in the form of reviews (Political-Military Review), in order to guarantee the result expected by the steps 3 and 4, assess the necessary military posture and evaluate its capabilities and its organizational structure. This information can generate recommendations on the implementation of the mission to be considered by the Military Committee and the NAC Council.

Phase 6: Transition: This final phase of the cycle concerns the aftermath of this situation crisis event. In an ideal situation the forces would be withdrawn and the normal functioning of the affected society would again be present. However, in some theatres a transition is implemented plans for the affected country authorities in order to the mission to be accomplished simultaneously with the gradual withdrawal of NATO forces.

It can be seen that it is a very complex and careful structure of crisis management of the model adopted by NATO, where it is possible to find a C2 composed of entities and adept institution in crisis management. Today NATO appears to be able to give an extremely accurate response with a very strong impact on society, with well defined objectives over which basic principles of operation and cooperation are based among countries and agencies.

However much remains to be solved with regard to the exchange and secrecy of information. Sometimes in some countries there are some underlying goals and interests which incurs in numerous barriers and filters to information, causing a response to the crisis event not only becomes more delayed but also less effective.

2.3 Command and Control

It is intended with this topic to demonstrate the importance of studying the C2 area, not only as a system, but also as a concept, so that there can be a more conscious and effective Decision Making.

It is stated by Alberts and Hayes (2006) that both the concept of Command and Control as the Command and Control system, were suffering numerous changes throughout history, can now be defined in a more complex and structured way. In this way, it is possible nowadays to see, a C2 system that supports the Commander involved in expert systems, which brought about changes not only to the C2 system structure that supports the Commander, as well as the process by which Command and Control is performed.

According to Alberts and Hayes (2006), all this development was triggered not only by the need of giving a better respond to the increasing diversity of crisis events, as well as derived from technological change.

So in order to more clearly understand what consists of the Command and Control system, it was sought to define the concept of Command and Control. The definition adopted for this work was, “Command and Control is the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the mission.” (Bethmann and Malloy, 1989).

After establishing the concept of Command and Control, it is then possible to define the concept of Command and Control System. Bethmann and Malloy (1989) state that the term C2 system consists in, “The facilities, equipment, communications, procedures, and personnel essential to a commander for planning, directing, and controlling operations of assigned forces pursuant to the missions assigned.”(Bethmann and Malloy, 1989).

Having presented the Command and Control concept and system it can be understood that is an interconnection between them so one could not exist without the other, figure 2.6.

Figure 2.6: Interconnection between the C2 concept and C2 system (Bethmann and Malloy, 1989)

Due to the great diversity of crisis events in present day and the stochastic course of events, it is necessary to maintain a continuous study of this C2 system. This in order to evolve the system, thus enabling a more efficient and effective response to all events. So as to ensure the optimum operation of the system, there are performed assessments to the system at the end of each mission. Alberts and Hayes (2006) states that an early stage of this C2 system, the evaluation was performed taking into account only the results of the mission, which did not allow the best judgement of system operation with regard to the mission. Therefore, a C2 system to be classified as functional, without having had no major intervention in the event. It can be stated that not always does the result of the mission reflect the performance of the C2 system. As refer by Alberts and Hayes (2006), factors such as available resources and capabilities of the adversary, are factors that do not depend on the functioning of the C2 system, but which, however, considerably influence the course of the mission.

Thus, in order to make it possible to evaluate the C2 system as to its capabilities and functioning, are enunciated several essential functions on which the C2 system should be evaluated, being them:

- Establishing intent;
- Determining roles, responsibilities, and relationships;
- Establishing rules and constraints;
- Monitoring and assessing the situation and progress;
- Inspiring, motivating, and engendering trust;
- Training and education;
- Monitoring and assessing the situation and progress.

All this knowledge can then be structured a C2 system with basic functionalities which allows for the resolution of the event quickly and effectively. Through the figure 2.7, an example scheme of the Command and Control processing algorithm can be observed. As can be seen, in this algorithm the presence of a Commander responsible for the measures adopted during the entire operation is verified which corresponds with what had already been said in relation to interconnection between C2 and C2 system. Below this level of Command and Control, follows the level responsible for handling all event information, thus providing all the information to C2 in order to enable it to adopt a decision.This second level is under the direct command of the Commander and consists of a structure composed of operating staff, equipment and infrastructure and implementing procedures inherent in the internal functioning of the C2 system.

With this, it is possible to verify the presence of a robust C2 system and studied, in order to provide the Commander all the information relating to the crisis event, enabling a more effective decision making.

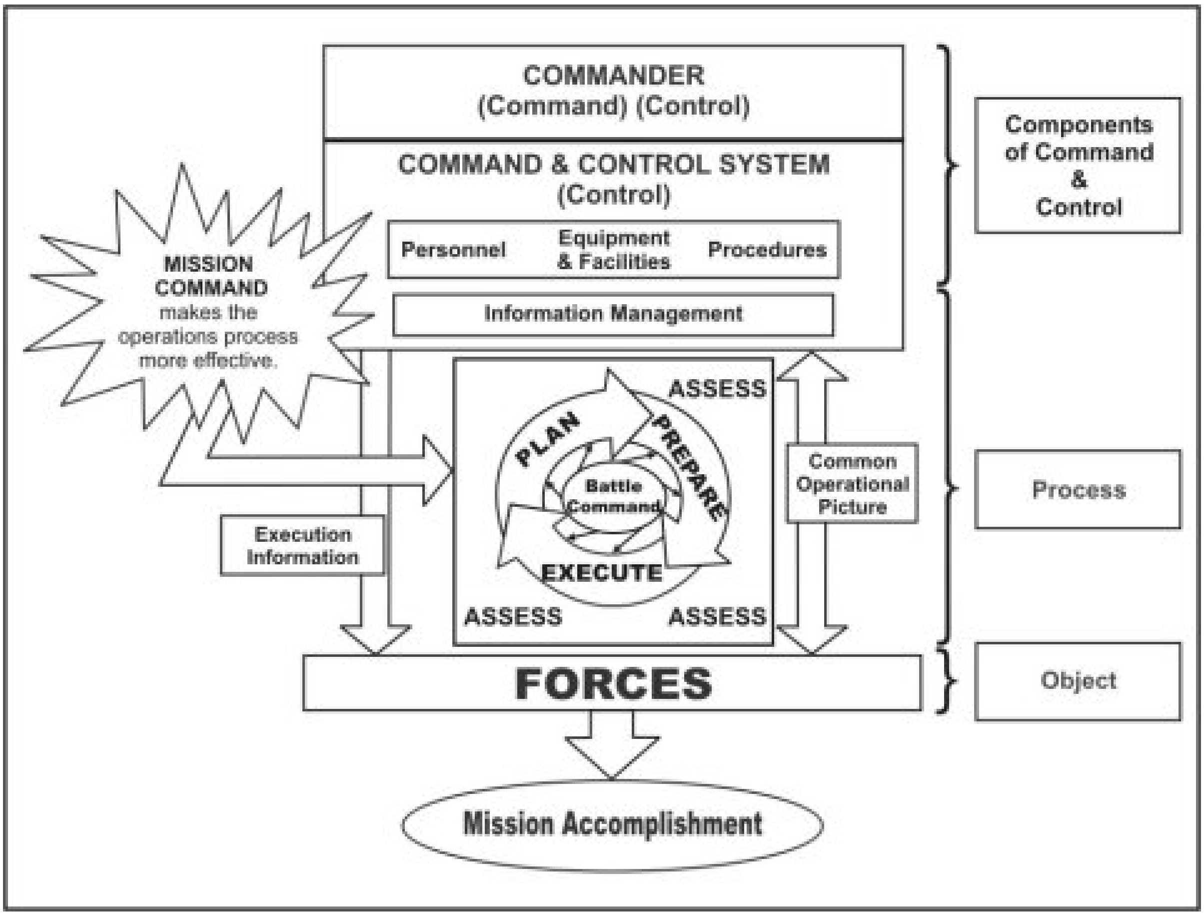


Figure 2.7: Command and Control & System (GlobalSecuruty.org, 2014)

With all this, Portugal is already aware of the importance of developing a Command and Control system to give an answer both with regard to internal crisis events as the external crisis events. However there is still much to be done, according to Ribeiro (2006), the current C2 system in use in Portugal "is a typical system of an army of the industrial age, in which some of the processes remained partially unchanged for decades."(Ribeiro, 2006). The author states that this delay is not in regard to the implementation of expert systems, but with regard to communications. Currently the Portuguese army has a C2 system called *Sistema de Comando e Controle do Exercito* , which despite being a major potential tool due to lack of updated of transmission systems, the actual capacity of the system does not are being exploited, argues Ribeiro (2006).

2.4 Decision Making

As mentioned earlier, Commanders today with respect to a crisis event, are exposed to situations of extreme stress and responsibility and need to make quick and effective decision facing a huge amount of available information.

Having realized the need to study the decision-making process, in conjunction with the great technological evolution, it has now become possible not only to identify the parameters that affect the decision making, but also monitor the situation in real time, without Commander being present, thus allowing a faster and more conscious decision-making.

With regard to the conceptual level, it was initially defined by Simon (1991) the concept of decision-making as ”the process of choosing Among alternative courses of action for the purpose of Attaining a goal or goals.”(Simon, 1991). Decision making is one of the core activities with regard to the management, so as to provide the best possible management has become essential to understand the entire the decision making process.

After the creation of decision-making concept in conjunction with technological developments, it has created the first Decision Support System. Later, with the arising of expert systems, a new human-machine interaction arises, now being possible the Commander be advised through intelligent systems with regard to decision-making. Later, through Holsapple even more advanced and complex system has been created known for Knowledge-Base Decision Support System. Forgionne et al. (2003) state that the following characteristics can be found in this system:

- It contains various types of knowledge that described selected aspects of the decision-makers world;
- It has the ability to acquire and maintain descriptive knowledge such as record keeping and other types of knowledge as well;
- It can produce and present knowledge in various ways;
- It can select knowledge to present or derive new knowledge;
- It can interact directly with the decision maker.

Even more complex systems can be found today , able to provide more capabilities to the Commander in decision making, these intelligent systems are called Intelligent Decision Making Support System. The most popular model is the model composed of three phases (Intelligence Design Choice), however since the model does not consider learning after application of the decision nor consider the results of the implementation of the decision, two new phases years later by Mora were added(Implementation, Learning), figure 2.8.

Figure 2.8: Decision Making process steps

According to Forgionne (2003), during the intelligence phase, the Commander looks at reality, acquires fundamental knowledge of the event and all your information. In the second phase of the model, the Commander develops a method that aims to examine in a systematic way the event. In phase Choice are evaluated in a logical way, all the possibilities generated to resolve the event and subsequently generated recommended actions. In the fourth phase of the model, the Commander ponders the analyses and recommendations, weighs the consequences, develops an implementation plan, secures needed financial, human and material resources, and puts the plan into action. After the final decision has been implemented, the Commander observes the new reality and verifies if the result was the desired one, thus being able to learn and adapt its decision-making to a new case.

All this decision making process is repeated iteratively through feedback cycles in order to be implemented in the best hypothesis generated and to enable that the knowledge generated, by the decision making is identified and recorded for future events .

2.4.1 Military Decision Process

With regard to the Portuguese reality, the most accepted decision-making model is the OODA loop model, figure 2.9. The OODA-loop model is based on the fundamental principle that, if the commander can observe, orient, decide and act faster than his opponent, he can increase his probability of success.

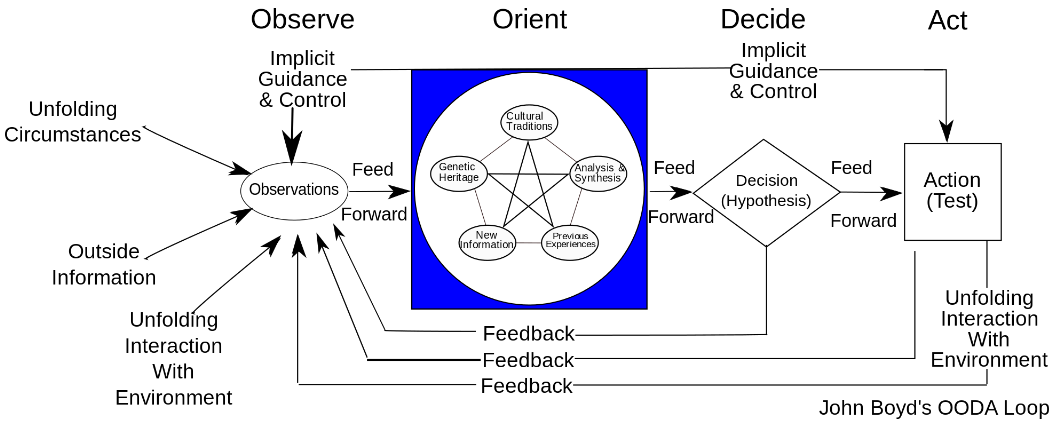


Figure 2.9: OODA-loop model (Boyd, 1976)

As can be seen in the figure 2.9, the decision-making cycle starts by the observe step, which is the step responsible for acquiring all the information not only is regard to the event but also of the entire environment that surrounds. However, if the C2 structures are not prepared to support, with regard to the acquisition of information, it will be very difficult to formulate an effective decision-making. In this way, should be a concern of the Commander to seek as much information as possible in order to provide an answer effectively. At the orientation phase, Individuals apply context to the data collected, which creates situational awareness. However, Boyd (1976) states that this assignment situational depends much on the human factor which can lead to an incorrect perception of the event, and hence to adopt the wrong decision making. For this reason many technologies, not only cognitive analysis, but also of surveillance were adopted, thus assisting the commander in real time to realize all contexts related to the event. In the third phase of the cycle the assessment of possible hypotheses is performed to be applied to the resolution of the event. However, this step is dependent not only on the Commander experience, but also in the way he perceives the event. Thus, assist the Commander in decision making intelligent systems are used not only in order to generate a prioritization of actions to be taken in response to the event, as well as, predict the resulting result of the implementation of a decision. After developing and assessing multiple options, the decision is put into action.

Chapter 3

Case Based Reasoning

3.1 Background

Case Based Reasoning-CBR is a methodology that aims at reproducing human learning capabilities and improving knowledge through experience, Riesbeck and Schank (1989) state that, “a case-based reasoner solves new problems by adapting solutions that we reused to solve old problems”.

CBR saw a major advance in 1977 through the work carried out by Watson (1995), with regard to the creation of the knowledge and storage of lived experience. According to this author, “our general knowledge about situations is recorded as scripts that allow us to set up expectations and perform inferences”, (Watson, 1995).

Some advances with regard to dynamic memory, the importance of storage of experiences and organization of the stored experiences in the form of memories for the resolution of new problems and self-learning were introduced by Riesbeck and Schank (1989). Further studies were conducted (Michalski et al., 1986) with regard to learning by analogy and generalizing concepts.

Based on the work done by Schank (1983) on dynamic memory and Memory Organization Packets and a year later by Janet Kolodner at Yale University, emerged the first CBR system called CYRUS. This was a very simple system, basically task-response, that helps to better schedule meetings. This system was the basis for many other CBR systems that followed.

In 1989, Bruce Porter and his work-group at the University of Texas came up with a new CBR system called PROTOS. This system already contained a more complex knowledge structure, because by integrating common knowledge and knowledge of the case itself, this system internally generated a memory representation after solving the problem.

In the same year, Phyllis Koton at the Massachusetts Institute of Technology studied the use of CBR in order to optimize a system referent to cardiac arrests, resulting in the CASEY system, thus integrating for the first time a CBR system in the area of healthcare. Given the success of this type of system applied to sensitive areas such as healthcare, a system similar to PROTOS, yet more robust in order to be applied in the field of Law, was developed by Branting in 1991.

Through all this background, Seyedhosseini et al. (2011) state that most studies are carried out about “including cognitive psychology, pattern recognition, machine learning, cognitive science, information retrieval, statistics/robotics, structures date, software engineering, and process planning”, (Seyedhosseini et al., 2011). Even with all the progress made in the CBR methodology up to the present day, progress made in regard to support strategic decision making is still under development.

Based on this knowledge, this work will aim to use this methodology to infer which material and human resources can be applied in response to a crisis event. In this way, the use of the methodology will constitute the final step in the whole process defined in this work.

3.2 Methodology

All technology is based on functioning in way very similar to how human beings work and store knowledge. Like the human cognitive system it is intended that the machine is able to interpret and work with generic and specific knowledge in order to be able to formulate a coherent decision concerning the problem in question. The CBR system, as already mentioned, works based on past cases, cases that allow the system to analyse the possibilities of an answer to a certain problem thus enabling a coherent response to the case in question. This system also demonstrates capabilities to allow analysis of our own behaviour at the time of the response formulation and an analysis in the implementation of the proposed solution, thus enabling this system not only to become faster in the formulation of the solution, but also make the solution yet more accurate than the last time it was applied.

Janet L. Kolodner was one of the scientists at the beginning of the 80s that most contributed to the development of intelligent CBR system. Bergmann et al. (2005) proposed several advantages and disadvantages associated with this methodology.

Advantages:

1. It provides quick fixes and avoids time losses related to its development without any starting point;
2. It provides solutions in areas not fully perceived by the user;
3. Gives forms for evaluation algorithm when no solutions are available for this purpose;
4. Provides support to the interpretation of open areas or poorly structured concepts;
5. Avoids past mistakes and prospective future results;
6. Allows approaches according to different views of the same situation and focuses or widens the perspectives of these approaches.

Inconveniences:

1. The creation in the user undue reliance on past experiences, which lead to not validate the solutions in the new situation;
2. The emergence of trends that restricts the originality in the creation of new solutions;

3. The use of past experiences less appropriate to the situation in question.

Watson (1995) states that this methodology is not necessarily an explicit modelling of the domains relating to any instance of the cycle. He argues that the application of this system should rely solely on the identification of the attributes that best describe a given situation. Watson (1995) further claim that the CBR has the ability to handle large amounts of information using standard techniques of database management, providing to the system the ability to learn and retain knowledge of a simple and efficient manner.

Yet today, even with all the technological advances, there are many obstacles to building a fully capable machine to perform autonomously, such as, a thought of abstract sense, followed by a proposal for action, reliable and accurate, ending with a positive lesson for future cases. These obstacles make room for evolution in several fields, such as engineering, mathematics, psychology, medicine, and many others.

3.3 Definitions

According to Witten and Frank (2005), for every event available in the case base, the name of instances is given, and these will be classified, associated, or clustered. To each instance introduced in the system is also associated a corresponding solution; this output is called ‘class’. There are some situations which are not associated classes to the instances, in these cases, in a general way, the learning method used is clustering. These instances consist of attributes or features that according to (Aamodt and Plaza, 1994) are described in very basic forms, such as feature vectors.

Different levels of measurement can be assigned to these attributes, depending on the type of information to be represented, four levels of distance measures can be considered (Witten and Frank, 2005): nominal, ordinal, interval, and ratio.

According to Witten and Frank (2005) nominal attributes can also be referred to as categorical, discrete or enumerated. These types of attributes are used to represent symbols or words and generally do not establish a relationship of quantity between the different attributes. A particularity of these types of attributes are the dichotomy presence in certain situations where the classification can only be considered as true or false. To this particular group of attributes the name ‘Boolean attribute’ is given. The ordinal attributes may also be referred to as continuous. These types of attributes are used to establish a relationship of quantity between the different attributes. Through this characteristic it is possible to establish an ordination of words without any sense of distance, for example: hot $>$ mild $>$ cold. The interval attributes assign an ordinance and allow a measurement. These types of attributes are used to represent temperature ranges or dates. Finally, ratio attributes are used to represent measurements, such as the distance between two objects, of which inherently the centre of the referential is already defined.

3.4 Approaches

When reference to the CBR system is made in a generalized form, it is directly associated with a type of approach, however, there are several approaches associated with CBR which often causes confusion on the subject. Nonetheless, they all work on the same paradigm. According to Aamodt and Plaza (1994) the following approaches can be identified:

Exemplar based reasoning: This approach it is characterized by defining the concepts of an extensive/generalized form, storing all existing information on the examples provided for training (Clark, 1990). In this approach the method used for classification is performed by calculating a metric distance between the concepts present in the memory with a new concept. The most common method used is known as the Nearest Neighbour, which is attributed to the concept analysed, the class of the stored concept that is closest. This method will be explained later in this work.

However, there are situations where the creation of concepts, do not represent reality. This happens because a clearly defined manner of mapping of instances, does not exist. Thus, as the comparison between cases is based on the calculation of a distance and, as mentioned above, the best mapping of instances does not always exist, and at the end of inference between cases a wrong result may be obtained. Other works by Salzberg (1991) and Aamodt and Plaza (1994) were developed to improve this approach.

Instance based reasoning: This approach is normally used as a tool to study machine learning without interference by a user, and can be viewed as a derivation of the EBR approach. However, Witten and Frank (2005) states that this approach does not make the classification in the creation of rules, but rather directly on the set of instances provided as an example to analyse, this method of analysis is called 'instance based learning'. This approach, unlike the EBR approach, does not have a structure under a generalized form or an extensive set of events in its memory, that is, a previous construction of concepts do not exist. According to Witten and Frank (2005) the major difference of this approach is that unlike all others, the learning process is performed at the time that the classification between two instances is required. That is, instead of being previously performed, a learning with instances, stored and subsequently made the classification on the occurrence of a new event, in this process of learning this approach is only performed when the classification of a new instance is required. The concepts are only generated at the time the classification is required between the present instances. Note that the learning process typically used for the generation of concepts is 'clustering'. Yet the learning process used to classify a new event is typically performed using a Nearest Neighbour method. This method will be explained later in the work.

Memory based reasoning: The Memory based reasoning approach, such as the IBR approach, also works the CBR in a purely syntactic form. However, this approach differs from others by the huge memory capacity that it provides and the research processes. Due to the amount of data, this approach places a huge importance on the internal organization of the data in order to reduce the computational effort. Another very specific and fundamental characteristic of this approach, due to the amount of data, is the use of parallel processing states Aamodt and Plaza (1994). Parallel processing is a form of information processing in which two or more processors together with some form of inter-processor communications system, co-operate on the solution of a problem (Tylavsky et al., 1992).

Analogy based reasoning: This approach, according to Aamodt and Plaza (1994), is often used to characterize the methods used to solve new problems based on past cases. Therefore, this approach differs greatly from approaches that store the cases and subsequently, through intelligent algorithms, seek similarities between the stored case and a new situation. According to Voskoglou and Salem (2014), many experts in the field believe that all acts of learning involve an analogy processes, however this statement is still under discussion and it could be said that that much of the cognitive activity is intrinsically linked to the reasoning ability of analogy. Aamodt and Plaza (1994) also mention that the main focus of studies in the field of ABR is based on the reuse of a past event, which is called a mapping problem. The process of mapping the solution of a situation identified as analogous is called 'source' and the situation in question is called 'target' (Aamodt and Plaza, 1994).

Several studies have been conducted by many experts, such as Smith and Medin (1981) and Gentner (1983), in order to generate more reliable models, with regard to the comparison by analogy, therefore improving the mapping process.

In the work of Voskoglou and Salem (2014), they claim that the issues that experts are more engaged in were: representation of the target problem, search-retrieval of the analogous problem, mapping of the representations of the target and the possible analogous problem and adaptation of the solution of the analogous problem for use with the target problem.

3.5 Cycle

The CBR process aims, as stated above, to predict a response taking into account past cases. According to Seyedhosseini et al. (2011), this process can be described through a cycle composed of 5 stages, figure 3.1

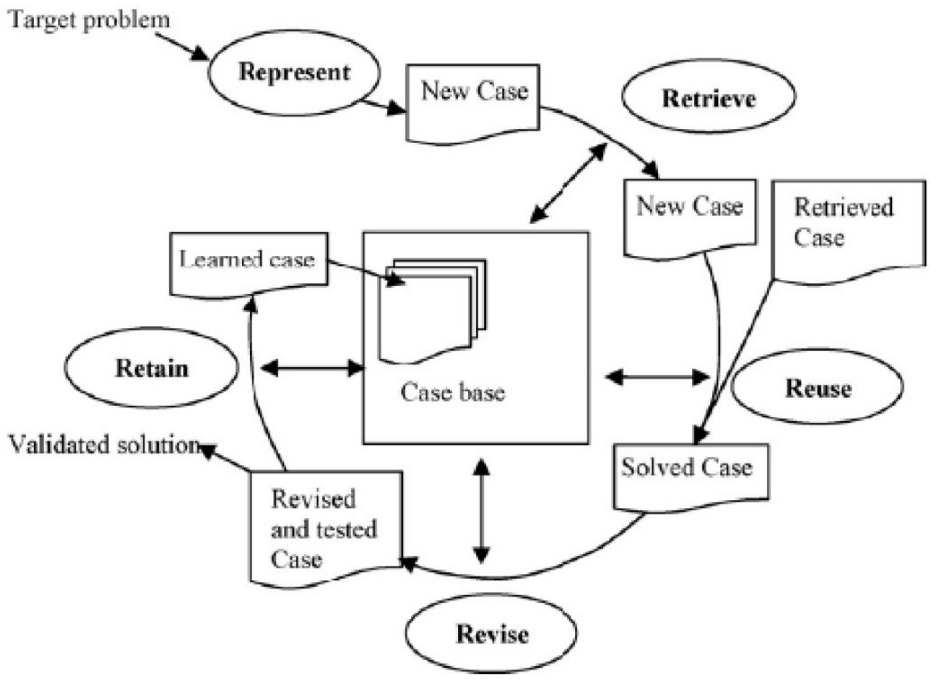


Figure 3.1: Case Based Reasoning cicle (Seyedhosseini et al., 2011)

Represent Phase: This phase consists of a representation of past cases in memory for future analysis. There are several forms of representation, however, the most common representation is through feature vectors. Subsequently, all cases being introduced, analysis by experts is carried out in order to understand which features, pertaining to the case, are relevant.

Retrieve Phase: With regard to the type of attributes that constitute a case, within this phase different evaluation algorithms can be found. Miles et al. (1998) states that some of these algorithms are:

1. **Nearest Neighbour:**

   This method aims to assign a similarity factor between attributes of different cases through a metric. There are different forms of this factor of similarity to be calculated, the most common ways are the Euclidean distance and by weighted Sum.

   - Euclidean Distance

$$\text{DIS}_{xy} = \sqrt[2]{\sum_{i=1}^{n}(p_{x_i} - p_{y_i})^2} \tag{3.1}$$

$$\text{SM}_{xy} = \frac{1}{1 + DIS_{xy}} \tag{3.2}$$

   Equation 3.1 shows the distance DIS_{xy} between between two events, where p_x represents an event stored in the case base, p_y the new event and n is the number of attributes in the feature vector.

After being calculated the value of distance between two events a calculation fraction is performed for the purpose of generating a similarity factor directly influenced by the previously calculated distance between two cases, equation 3.2.

In order to obtain a result, where the importance of each feature that characterizes a event is taken into account, a weight w_i is associated to compute the distance between two features, equation 3.3.

- Weighted Sum

$$\text{DIS}_{xy} = \sqrt[2]{\sum_{i=1}^{n} w_i(p_{x_i} - p_{y_i})^2} \tag{3.3}$$

$$\text{SM}_{xy} = \frac{1}{1 + DIS_{xy}} \tag{3.4}$$

In a similar way to the calculation performed for the Euclidean distance a calculation of a similarity factor is subsequently performed, equation 3.4.

However, there are some negative factors to this method, such as, the determination of the weights to assign nominal attributes and the computational effort required by a database that presents cases with many attributes. According to Witten and Frank (2005), the problem of assigning importance to nominal attributes is exposed. The example given by Witten and Frank was, "what is the distance between the colours red and red and red and green?" (Witten and Frank, 2005). As expected the distance between the same color is zero and between different colors is one. As stated by Witten and Frank, such assignment is too vague and the need to use a more robust method is essential to the situation in which two similar colors to be compared have a different distance than in comparing two completely different colors.

Regarding the computational effort, the system response time increases linearly with the number of stored experiences, thus the more robust and accurate the database is, as a result of a high number of stored cases, the greater the computational effort will be (Watson, 1995).

2. **Induction:**

The induction methods cannot always be performed from derived information present in the experiments, that is, if a case is not associated with a class of binary type (True/False, Played/Not Played, died/survived), it is extremely difficult to apply the induction methods with some logical sense. Induction methods are usually applied to the Exemplar based reasoning and Instance based reasoning approaches, where according to Miles et al. (1998) patterns in this method are identified among the instances and through these are created clusters, generating concepts based on attributes found in instances.

There are various classification algorithms that work the generated clusters, two of the most known are, the Divide and Conquer algorithm and the Naive Bayes algorithm. Despite the differences between the two algorithms, the objective will always be to predict the outcome taking into account the presence of certain parameters in the existing attributes.

- Divide and Conquer algorithm

  Considering an example, such as fire, the goal will be to know, towards the means available and the circumstances presented, if it is possible to extinguish the fire. This algorithm will then apply the database available so that the new situation can be interpreted according to past cases, this generates a Cause Induction in Discrimination Tree, also known as decision tree.

  At an early stage an attribute is selected and divided into subsets. Subsequently recorded is how many times the fire was controlled or not, both in attribute as well as to the existing subsets. According to Witten and Frank (2005), when a subset has only one type of solution , whether it is controlled or not, it is called " pure set". The purpose in this phase of the algorithm is to divide subsets till they become pure, so that it can characterize the fire as controlled or uncontrolled, figure 3.2.

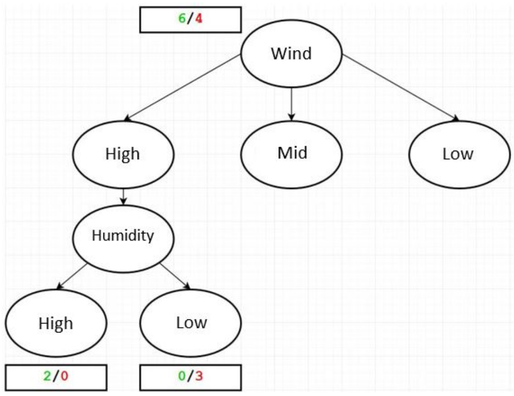


Figure 3.2: Cause Induction in Discrimination Tree

It is important to note that after all subsets become pure, it does not only register if the fire was controlled or not, but it must also record the amount of times that the answer was obtained. Ergo, it becomes possible not only to predict a solution but also to calculate a confidence level of the solution. It is important to note that the choice of attribute to the root of the Cause Induction in Discrimination Tree, according to which all others will branch, is not performed at random, but according to a criterion. This choice is very important because for a situation where the number of attributes is high and the training set contains many objects, it is fundamental to perform this choice in order to save computational effort.

The considered algorithm for this method is ID3, presented by Quinlan (1993). Thus, approached through ID3 algorithm, the method used to calculate the root attribute is based on the calculation of uncertainty, and one way to represent the uncertainty according to (Witten and Frank, 2005), is by entropy. This calculation of entropy will tell how pure one subset is. The adopted formula for calculating the entropy is present in the equation 3.5.

$$I_{(p,n)} = -\frac{p}{p+n}\log_2\left(\frac{p}{p+n}\right) - \frac{n}{p+n}\log_2\left(\frac{n}{p+n}\right) \tag{3.5}$$

Wherein I is the entropy of the subset, this is how pure the subset is, p is all the cases positive subset and n all the negatives of a subset. This measure has the unit ”bits”, if they are pure subsets I is zero, otherwise the values are compromise between zero and one. After calculated entropy is calculated the gain of information of the attribute. This procedure is performed recursively for all attributes. The formula for calculating the gain adopted is present in the equation 3.6.

$$E_{(A)} = I_{p,n} - \sum_{i=1}^{V} \frac{p_i + n_i}{p + n} I_{(p_i,n_i)} \tag{3.6}$$

Wherein E represents the gain of the attribute information as the root, p_i represents positive cases of a given subset, n_i represents negative cases of a given subset. The summation in the formula provides a weight measurement of the subset, providing information on how many instances are present in the subset.

Yet, despite all the work in trying to find the best match of two events, there are factors that may induce error in the analysis. One of these factors is the noise, according to Witten and Frank (2005), in this context noise is considered as the existence of two events that have associated different classes, but which, however, are constituted of the same parameters. This event may have been caused by human error, in the introduction of the event, or whether such an event actually happened. It is important to have present the allocation of parameters, which is often performed subjectively so the data that cause these malfunctions should be ignored. The existence of noise in the decision tree may lead to some attributes that at the time were not dispensable but now are, promoting the complexity of the tree.

Having knowledge of this problem, Quinlan (1993) suggested two ways to solve the problem.

(a) Evaluate if the branches generated in the attribute will considerably improve accuracy, preventing that in the phase test the noise spread and deteriorate the result. The fact of dividing the subsets in order to make the subset pure and thus increase the accuracy may prove not to be rewarding. One solution is to assign an absolute or percentage value, threshold, relatively to the gain information to the fact of having divided the subset.

(b) The algorithm must be able to work with dispensable attributes , because noise can cause the most significant attribute which may seem dispensable. One way to solve the problem is to consider class in a generalized way, $p/(p+n)$, now being characterized between zero and one. It may be interpreted as a probability of belonging to a certain subset to a class. This method works by minimizing the sum of squares of the error on the existing objects in a given subset. Other ways to solve the problem are to assign the class, more present in the subset, as the representative class of the subset, i.e. if a given subset shows six positive results and two negative results, positive class is attributed to this subset. In the opposite case, there are two positive results and six negative results, or in the situation of positive cases and negative cases existing in the same number, the assigned class is negative. This method works by minimizing the absolute error of the objects present in a given subset.

- Naive Bayes algorithm

  Witten and Frank (2005) state that the Naive Bayes method belongs to a family of probabilistic classifiers, where independence between features in relation to the class is assumed. Although this algorithm provide a fairly simple equation, where the results obtained by this method compete with the results obtained by more elaborate and sophisticated methods, such as support vector machines. This method has been studied quite extensively since 1950, and nowadays can be found in medical applications, such as in automatic medical diagnosis. In an analogous manner, (Witten and Frank, 2005) adopted the equation 3.7 as the equation to predict the class of a new case.

  $$P(c|x) = \frac{P(x|c)P(c)}{P(x)} \tag{3.7}$$

  Where $P(c|x)$ is the conditional probability of c (class) occur x (attribute), also referred to as a posteriori probability, $P(x|c)$ is the conditional probability of x occurs in c, also referred to as likelihood, $P(c)$ represents the probability of c and $P(x)$ represents the probability of x. However since the value of the denominator have constant character, for purposes of comparing the probabilities obtained this value is dispensable, thus resulting in the equation 3.8.

  $$P(c|X) = P(x_1|c) \times P(x_2|c) \times ... \times P(x_n|c) \times P(c) \tag{3.8}$$

  In this equation, 3.8, X is the set of attributes and n the total number of attributes.

  In order to facilitate the calculation of the probabilities, frequency tables are created and thereafter created a likelihood table. The class that present the largest posteriori probability is the response predict by the method for the new case.

3. **Knowledge Guided Induction:**

   Knowledge Guided Induction is yet another indexing mechanism that combines knowledge based indexing with induction methods. Pure induction methods do not take into account the specific domain knowledge stored inside the expert's head. According to Barletta and Mark (1988), in this method is manually identified the domain of the features that belong to the case. As this is a manual assignment of the domain, one of the disadvantages of this method, derived of a very extensive database and as a result numerous features, caused by lack of understanding of the case, unknowing the essential features of the domain case. Thus this method is used in conjunction with other indexing techniques.

4. **Template retrieval:**

   Russell and Norvig (2003) state that this method is similar to SQL-like queries. In this method parameters are specified and only the cases that are delimited by these parameters are retrieved.

This method is used in a general way before other methods, to limit the search space for a relevant space within the case base.

Reuse Phase: Aamodt and Plaza (1994), states that the reuse of the solution obtained in the retrieve phase is based on two important points. The first point concerns the differences between the new case and the case associated to the solution recommended by the system, the second point is based on how much the obtained solution can be implemented as a solution to the new case.

In situations where the CBR systems see the problem as a simple classification problem, as in the Exemplar based reasoning approach, the differences between the cases are not taken into account, only their similarities are considered relevant. In these situations the resulting solution of the retrieve phase is instantly used for the new case. However, there are other types of CBR systems that take into account both the differences and the similarities between the cases under review. In these CBR systems, Aamodt and Plaza (1994) state that, the system should be able to verify that, sometimes, the solution obtained in the retrieve phase, can not be applied in its entirety as a solution to the new case, but rather has to be adapted to the characteristics of the new case. According to (Aamodt and Plaza, 1994), there are two ways of adapting the solution subsequently obtained in the cycle:

1. Transformational reuse, also referred by Watson (1995) and other authors as structural adaptation. With this type of adaptation what happens is that the solution resulting from the retrieve phase is not, as previously mentioned, directly applied to the new case. Watson (1995) indicates that the most common way is by substituting a retrieve phase component solution with a value provided by another knowledge source. Aamodt and Plaza (1994) propose that this knowledge is presented in the form of {T} operators, that when applied to the solution previously obtained generate a new solution, with application sense to the new case. The author also proposed to organize the {T} operators by indexing them coupled to the detected differences between the stored case and the new case. Thus it is clear that this method relies heavily on knowledge not only of the concept/domain involved but also of the organizational structure of {T} operators.

2. Derivational reuse, is a method which according to Watson (1995) uses the algorithms adopted in the retrieve phase, that generated the original solution, to the same case but with different parameters, producing a new solution. Aamodt and Plaza (1994) state that in this type of adaptation, the resulting solution of the retrieve phase is stored together with all the information of the calculation process, such as justifications for the adopted solution, sub-goals considered, alternative generated solutions, fails, among many other parameters. It can be concluded, that it is necessary to have a perfect and complete understanding of the case.

Revise Phase: Aamodt and Plaza (1994) said that the fact that the previous phase fails, provide the CBR system with, a good opportunity of learning. the author also states that there are two tasks associated with this stage, the first task concerns to the evaluation of the solution generated by the reuse phase and the second task is to retain or repair the evaluation that was classified as positive or negative. Generally the assessment of the proposed solution is carried out by a user. If the applied solution was assessed by the user, as negative, a repair is performed by the system. This repair consists of identifying the current solution errors adopted and generate explanations to justify the failure. Aamodt and Plaza (1994) states that there is an previous attempt to put knowledge a posteriori, specifically in the reuse phase, so that at this stage not only is an explanation of why certain goals of the solution were not reached generated, but also predict possible shortcomings of plans.

Retain Phase: This is the phase where all the elapsed process to date in the cycle is stored as knowledge. According to Aamodt and Plaza (1994), the learning success or failure, of the proposed solution, is triggered by the assessment carried out. It involves selecting which case information should be retained, in what form, how to index the case for future reuse and how to integrate the case in the memory structure. If the CBR approatch is consider, where the vast majority of system learning is done automatically, the system will be updated whether the problem is classified as well resolved as unsolved, otherwise only an expert in the event situation, may approve the integration of the case on the case-base. In this phase it is important not only to add the descriptors and the solution of the case, but also the justification of why the solution adopted is the best solution to the case. It is referred by Aamodt and Plaza (1994), that this attitude considerably improves the speed of response and the computational effort, since only a part of the domain database will be considered for analysis of the problem. The presence of justification for a case that has been classified as negative, can remember the system of a situation and even assist the system in a better understanding of why the solution was classified as negative.

For this work ABR methodology was adopted, allowing not only the attribution of the solution of the event with the closest characteristics but also the perception of how similar the inferred cases are.

Chapter 4

Decision support systems

The increased complexity of crisis events lead the commanders to feel the necessity to be supported on technology in order to give the most effective response possible.

This necessity triggered the development of intelligent systems such as artificial neural networks and fuzzy logic, that provide the ability to solve some problems, such as classification problems and regression problems.

Besides the development of new intelligent systems, new algorithms and new tools have been developed in order to complement and assist the function of these systems. Some examples are the feature selection tool and optimization algorithms, like genetic algorithms. These tools and algorithms allow a better understanding of how the features influence the problem.

In this work, the neuronal networks will be approached only with the aim of serving as a cost function for both feature selection and genetic algorithm. This provides the possibility to obtain results, both by the feature selection tool and the genetic algorithm with a higher level of accuracy, thus increasing the reliability of the two processes.

4.1 Neural Networks

4.1.1 Background

(Mcculloch and Pitts, 1943), a neurophysiologist and a mathematician, made a number of advances in the understanding of how nerve cells (neurons) work. These two researchers modelled a simple neural network using electrical circuits to show their idea of how neurons work.

In 1949, (Hebb, 2005), a psychologist at Harvard University in the United States released, new ideas about how our neuronal system evolves through learning. In his work he describes that the recurrent use of the same neuronal pathway, within a network, to solve the problem will make the neural pathway stronger and preferential, since it is the neuronal pathway for which the best answer to the problem is obtained, "*When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased*", (Palm and Aertsen, 2012).

Initially only simple logic functions were processed, but later on in 1957, Frank Rosenblatt came up with the first concrete neuronal model called perceptron. (Widrow and Hoff, 1962), devised a new learning system called Supervised Learning. This system consisted of a logic change in the weight of each single neuron of the neural network. The weight of each neuron will alter depending on the result achieved in each particular case, "*this learning method essentially uses a gradient descent technique, and the change ΔWij is proportional to ΔE / ΔWij, where E represents the error measure.*" (Widrow and Hoff, 1962), and "Wij" represents the weight of with neuron.

Two decades later, in 1974, studies by (Werbos, 1974), (Anderson, 1972) present the first Backpropagation Learning algorithm. With this algorithm emerges a new neural network model composed of three layers of neurons rather than one, reviving interest in this area.

Since 1990s, this new tool has been successfully applied in various fields such as medicine and marketing, amongst others.

To this day, other types of learning beyond supervised learning have emerged and many advances have been made regarding the way how the weights are processed, that is, they tried to look for an activate function that provides the ideal result.

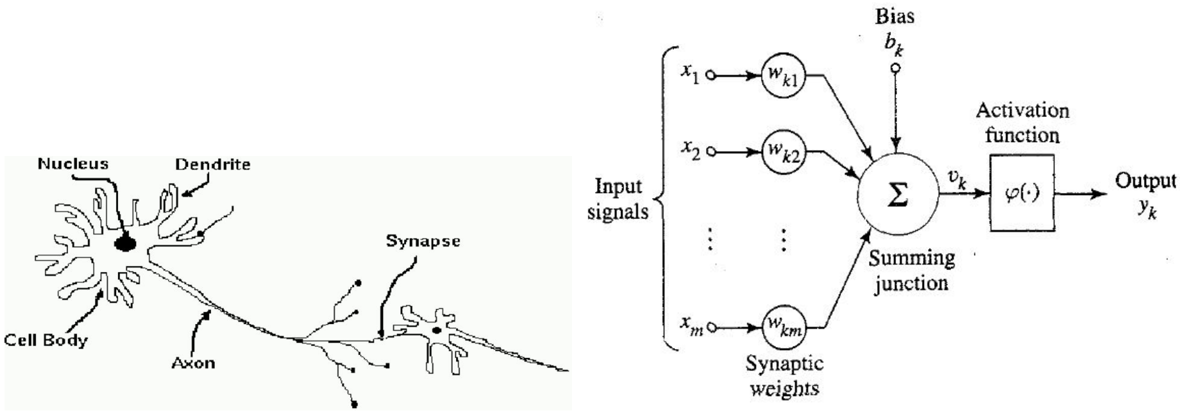
Despite all of the technological development, the base structure of the neural network has remained essentially the same since 1974, known as a multi-layer perceptron. However, despite all of the developments at both the theoretical and the technological level, today it is still not possible to create a system capable of subjugating the human brain in all aspects. According to (Kriesel, 2007), despite the fact that today these machines are faster systems in processing, regarding the amount of processes processed simultaneously, machines still fall somewhat short compared to the human brain.

4.1.2 Methodology

The functioning of the human brain is based on synapses between neurons. This is a massive processor of parallel processing, containing over 10 billion neurons. Electrical signals transmitted between neurons are called 'synapse', performed by chemical processes called neurotransmitters. The neurons send electrical signals from their axons to the dendrite of one or more linked neurons, and these may be connected to more than 10.000 neurons, figure 4.1(a).

$$u_k = \sum_{i=1}^{n} w_{ki} x_i$$
$$v_k = u_k + b_k \tag{4.1}$$
$$y_k = \psi(v_k)$$

In a similar way an artificial model of mathematical processing was built, called Perceptron, in order to solve problems similarly to the human brain. This system is composed by, inputs x_i, entries that are associated to a weight value w_i, figure 4.1(b). The weighted sum of the entries has an associated bias, b_k, thus providing the possibility of being assigned an extra weight in situations where inputs have constant values. However, it is common to associate this variable to the zero value in order to simplify



(a) Biological nerve cell (Engelbrecht, 2007)

(b) Artificial nerve cell (Perceptron) (Haykin, 1998)

Figure 4.1: Adaptation of a biological nerve cell to a artificial nerve cell

the problem, causing the output v_k to be a sum of inputs. The activation function ψ_v is dependent of the sum of the entries and are often limited in the intrevals $[0, 1]$ or $[-1, 1]$. According to (Engelbrecht, 2007), the activation function can have various forms, but the most common forms are, sigmoidal and tangent hyperbolic functions.

By combining several single units, illustrated in figure 4.1(b), it becomes possible to build artificial neural network capable of solving simple problems such as pattern recognition. It can be said that an artificial neural network is composed of a set of simple processing units, which communicate by sending signals between artificial neurons over a large number of weighted connections. Similarly to the biological neural networks, the exchange of information between neurons in the artificial neural networks is performed by electric pulses called spikes. Today artificial neural networks are more sophisticated, allowing a structural composition of several layers with various possible activation functions, enabling the solution of increasingly complex problems. A common structure of ANN found today is Multi Layer Perceptron.

With the need to solve more complex problems several neural networks structures have been created. Some examples are Feedforward Neural Networks and Simple Recurrent Neural Networks.

In this work only the case of Feedforward Neural Networks will be considered. These networks are structured by an input layer, one or more hidden layers and an output layer. In this structure the information flows only in one direction, from the inputs through the hidden layers to the output, figure 4.2.

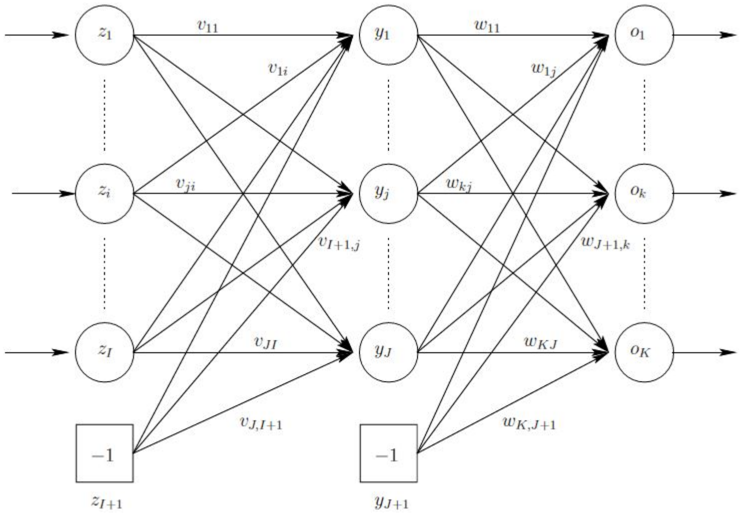


Figure 4.2: Feedforward Neural Networks (Engelbrecht, 2007)

These networks are actually a static mapping between the inputs and outputs which can be simple linear relations or highly non-linear. According to (Engelbrecht, 2007) the equation that describes the output is given by,

$$o_k = f_{o_k}\left(\sum_{j=1}^{J+1} w_{kj} f_{y_j} + \left(\sum_{i=1}^{I+1} v_{ji} z_i\right)\right) \tag{4.2}$$

Where o_k represents the output unit, f_{o_k} and f_{y_j} are respectively the activation functions for output unit o_k and y_j represent the perceptron allocated on the hidden layer . The value w_{kj} represent the weight between $o_{k,p}$ and y_j and z_i represent the input values.

Observing the structure present in figure 4.2, only to a very simple problem with low complexity, it would be possible that the neural networks establish the optimal weights and bias at a first attempt. As such a situation is unlikely to occur, neural networks need to be trained, which means adjusting the weights and bias. Some learning algorithms are Gradient Descendent, Levenberg-Marquardt backpropagation and Bayesian Regression. The error can be computed using by several methods as, Mean Squared Error (MSE) equation 4.3 and Root Mean Squared Error equation (RMSE) 4.4.

$$\text{MSE} = \frac{\sum_{i=1}^{epochs} \left(y_{i_{target}} - y_{i_{test}}\right)}{n} \tag{4.3}$$

$$\text{RMSE} = \sqrt[2]{\text{MSE}} \tag{4.4}$$

Where $y_{i_{target}}$ represents the desired output to obtain and the $y_{i_{test}}$ represents the output obtained by the method.

(Dreiseitl and Machado, 2002) point out some advantages and disadvantages of Artificial neural

Networks.

Advantages:

1. Neural network models require less formal statistical training to develop;
2. Neural network models can implicitly detect complex non-linear relationships between independent and dependent variables;
3. Neural network models have the ability to detect all possible interactions between predictor variables;
4. Neural networks can be developed using multiple different training algorithm.

Disadvantages:

1. Neural networks are a “black box” and have limited ability to explicitly identify possible causal relationships;
2. Neural networks models may be more difficult to use in the field;
3. Neural network modelling requires greater computational resources;
4. Neural network models are prone to over fitting;
5. Neural network model development is empirical, and many methodological issues remain to be solved.

4.2 Feature Selection

The Feature Selection methodology aims at improving the computational efficiency and reduce the generalization error of the model by removing irrelevant features. This methodology identifies features that are less relevant or even redundant and has the ability to establish a rank of features that characterize the case. Can be concluded that Feature Selection aids in a better understanding of the feature domain that actually affect the result. According to (Hossain et al., 2013), Feature Selection methods may be classified into two groups based on the objective functions: Wrapper methods and Filter methods. The aim is to achieve an optimal feature subset for the model.

According to (Hossain et al., 2013), the Wrapper methods use inductive algorithms, such as Naive Bayes Algorithm or Neural Networks, to evaluate the accuracy of the generated subset, and thus realize which subset best describes the model.

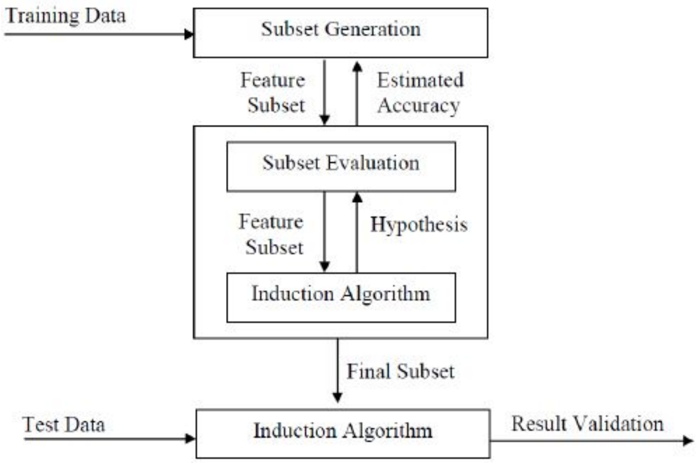


Figure 4.3: Wrapper method flowchart(Hossain et al., 2013)

Two searching techniques commonly used are: Sequential Forward Selection (SFS) and Sequential Backward Selection (SBS). SFS starts the analysis with just one feature and then adding feature by feature until it is no longer possible to increase the accuracy of the model.

This process starts by calculating the error, through neural networks, between $y_{i_{target}}$ and $y_{i_{test}}$. Having obtained the error, the process of evaluation of influence of features is initiated in the model. As noted above, the process starts without selecting any of the features. After selecting the first feature, the subset is evaluated by maximizing a cost function. If the error obtained by the generated subset is equal to the error initially calculated, the feature is attached to the subset. If the error is lower than the error initially calculated, the feature is not selected to be part of the subset.

SBS presents a very similar process to the one presented by searching technique SFS, differing from searching technique SFS by starting with all the features and subsequently remove feature by feature until it is not possible to Increase the accuracy of the model.

A limitation of the SBS method is its inability to re-evaluate the usefulness of a feature after it has been discarded.

This method presents a good performance, if compared to the Filter method, however it requires a large computational effort and if the number of cases in the dataset is insufficient, over-fitting may occur.

According to (Kumari and Swarnkar, 2011), Filter Methods measure the model accuracy differently to the Wrapper methods.

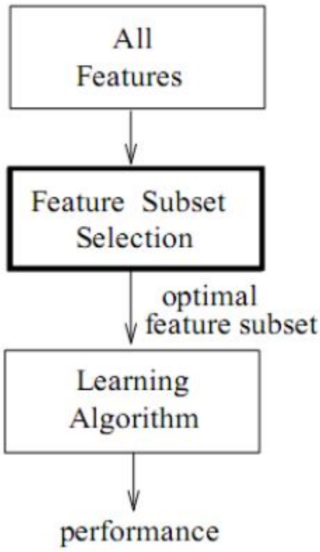


Figure 4.4: Filter method flowchart (Hossain et al., 2013)

This method filters the features through an analysis between features establishing a rank, which is established by the weight that the feature have in the dataset. According to (Kumari and Swarnkar, 2011) the features can be evaluated according to various methods, such us, the assessment of intrinsic parameters of the dataset, through the euclidean distance or even through the Nearest Neighbour method. After this analysis, the user will choose the features that have the highest weights and omit the features that have the smallest weights. Then a classification method is used, such as Naive Bayes, in order to evaluate the accuracy obtained by the model after removing the features selected as useless.

Unlike the Wrapper method, the Filter Method is not dependent on a classifier provides to provide a lower computational effort resulting in a faster method. However, if the classifier is somehow not in tune with the rank algorithm, with respect to assigning weights to the features there is the possibility of over-fitting. One of the ways of solving this problem is to observe the learning curves and check where the common minimum is, thus enabling it to realize the minimum number of features needed to increase accuracy.

This method is often used on Data-mining problems since this type of problems present a high number of features. Ergo, this type of algorithm is ideal for reducing the number of features to a necessary minimum.

In this work, the wrapper method will be used, since the purpose is to evaluate the accuracy of the model through the features subset generated, thus allowing identification of the features/descriptors that most influence the characterization of a crisis event.

Chapter 5

Implementation

5.1 Dataset of events

The aim of this work is to design and implement a DSS to assist the commander in assigning resources to respond to crisis events. Therefore, establishing not only a better management of resources, as well as, an awareness of what and how many means should exist in that unit.

The database used for the study was provided by the Portuguese Authority that manages fire-fighting operations. The database consists of 3207 events and is categorized into nine fields, with each field being assigned a data-type:

1. Council

   For the study in question the string type was assigned to this field, allowing a search procedure through comparison between words.

2. Nature

   In order to be able to characterize an event, a classification list was provided with an taxonomy of occurrences. So when an event occurs, this event is identified according to the type of occurrence identified in the list. Thus, the format that is suitable to apply to this field is the string type, allowing a search by comparison between words.

3. Duration

   This field was represented on the dataset in minutes and seconds, however it was decide to convert this field to minutes. Since this is a numeric field, the integer type was assigned and then the minimum unit is the minute. This field represents the duration of the occurrence starting with the reporting event until its resolution.

4. Entities Involved

   This field relates to the number of entities that were called to the scene to solve or assist the resolution of the occurrence. Ergo, the integer type was assigned to this field.

5. Casualties of Civil Protection

   This field represents the number of victims from civil protection that were involved throughout the course of occurrence and thus is represented by an integer variable.

6. Civilian Casualties

   This field represents the civilian victims involved throughout the course of occurrence, therefore it is represented by an integer variable.

7. Hectares Burned

   Since this is a variable that represents the quantity of burned area, the type float was assigned to this field.

8. Material resources

   This field relates to material resources, such as land and air vehicles, used to respond to the event, thus the integer type was assigned to the field. This is one of the two problem targets, i.e. fields to be inferred by the DSS, used in this work.

9. Operational resources

   This field relates to human resources which have intervened in response to the incident, therefore the integer type was assigned to this field. This is the other target to be inferred by the DSS proposed in this work.

The objective of the DSS, which is proposed in this work based on the use of CBR methodology, is to infer suitable values for *Material Resources* and *Operational Resources* (problem targets) based on a subset of the first seven database fields (input descriptors).

Concelho	Natureza	Duração	ET# entidades envolvidas	VA# vítimas proteção civil	VO# vítimas civis	HA# hectares ardidos	VC# Meios	OP# Operacionais
SANTA MARIA DA FEIRA	Protecção e Assistência a Pessoas e Bens - Trauma	1438	1	0	0	0	1	5
ARRAIOLOS	Protecção e Assistência a Pessoas e Bens - Doença	1420	1	0	0	0	1	5
CASTELO BRANCO	Protecção e Assistência a Pessoas e Bens - Doença	1397	1	0	1	0	1	2
MAFRA	Protecção e Assistência a Pessoas e Bens - Doença	1360	1	0	0	0	1	2
ELVAS	Protecção e Assistência a Pessoas e Bens - Doença	1309	1	0	1	0	1	3
VILA NOVA DE FAMALICÃO	Operações e Estados de Alerta - Deslocações em Formação	1225	1	0	0	0	1	2
PALMELA	Protecção e Assistência a Pessoas e Bens - Doença	1215	2	0	1	0	2	5
MACEDO DE CAVALEIROS	Protecção e Assistência a Pessoas e Bens - Doença	1195	1	0	0	0	1	4
MAÇÃO	Protecção e Assistência a Pessoas e Bens - Doença	1169	1	0	0	0	3	11
CASTELO BRANCO	Protecção e Assistência a Pessoas e Bens - Doença	1158	1	0	1	0	1	2
ALTER DO CHÃO	Protecção e Assistência a Pessoas e Bens - Doença	1155	1	0	1	0	1	2
CUBA	Protecção e Assistência a Pessoas e Bens - Doença	1136	1	0	1	0	1	2
ALTER DO CHÃO	Protecção e Assistência a Pessoas e Bens - Doença	1116	1	0	1	0	1	2
CONDEIXA-A-NOVA	Protecção e Assistência a Pessoas e Bens - Doença	1068	1	0	0	0	2	4
MOURA	Protecção e Assistência a Pessoas e Bens - Doença	1062	2	0	1	0	2	4
TORRES VEDRAS	Protecção e Assistência a Pessoas e Bens - Transporte Extra SIEM	992	1	0	0	0	1	2
MIRANDELA	Protecção e Assistência a Pessoas e Bens - Doença	977	1	0	0	0	1	3
PALMELA	Protecção e Assistência a Pessoas e Bens - Doença	976	1	0	1	0	1	3
AGUIAR DA BEIRA	Protecção e Assistência a Pessoas e Bens - Queimadura	963	2	0	1	0	2	4
VILA NOVA DE GAIA	Protecção e Assistência a Pessoas e Bens - Transporte de Doentes entre Unidades de Saúde	957	1	0	0	0	2	4
BEJA	Protecção e Assistência a Pessoas e Bens - Doença	941	1	0	0	0	1	2
LISBOA	Protecção e Assistência a Pessoas e Bens - Doença	920	1	0	0	0	1	2
VILA VERDE	Protecção e Assistência a Pessoas e Bens - Transporte Extra SIEM	918	1	0	0	0	1	2
CASTELO BRANCO	Protecção e Assistência a Pessoas e Bens - Doença	911	1	0	1	0	1	2
ABRANTES	Protecção e Assistência a Pessoas e Bens - Doença	905	1	0	1	0	1	2
VENDAS NOVAS	Operações e Estados de Alerta - Deslocações em Formação	898	1	0	0	0	1	1
MANGUALDE	Protecção e Assistência a Pessoas e Bens - Doença	867	1	0	0	0	1	1
PONTE DE LIMA	Protecção e Assistência a Pessoas e Bens - Doença	863	1	0	0	0	3	11

Figure 5.1: Data Base

However, the initial database was reduced since evidence of missing data for some events was identified. In order to solve the problem the events that presents this missing data were eliminated, resulting in a dataset with 3202 occurrences. This database are constituted by nine fields, where seven are input variables marked with blue in table 5.1 and two are target (output) variables marked with orange in table 5.1.

Table 5.1: Case format example

County	Nature	Duration	Entities involved	Casualties of civil Protection	Civilian casualties	Hectares burned	Material resources	Operational resources
VALONGO	Protection and Assistance to People and Goods - Trauma	205	6	0	0	4	11	42
VILA VERDE	Protection and Assistance to People and Goods - Disease	464	8	0	0	2	11	37

With this, the CBR methodology will be used, so that through the inference between the cases stored in the database, and a new case, can be obtained a plausible response to taken into account. Thus, ABR approach was adopted this because since it was not necessary to generate a concept, as the case base providing the nature of the event, the approach that makes it more practical sense to be applied is ABR.

5.2 Assignment of weights through Feature Selection

After the handling of the database and the approach that which will face the whole problem be establish, the correct assignment of weights to the existing descriptors is now performed. This step can be considered the most critical step in the implementation issue, this because the whole inference between cases will be based on the importance assigned to each descriptor. For such purpose two methods will be adopted for the analysis, Feature Selection and Genetic Algorithms, allowing validate the solution obtained through the different results obtained. In other words, it is intended that through these two methods predict the output variables, Materials resources and Operational resources, that best suited the resolution of the event.

The tool adopted to apply the methods of analysis was the Matlab software, this software it was adopted not only for providing packages of intelligent algorithms capable of analysing the influence of features in the generated model, such as Feature Selection and Genetic Algorithms, as well as due to greater ease of programming since it was the programming software most used during the course.

Therefore, it was decided to start the study of the analysis of the descriptors by using the Feature Selection algorithm on the Wrapper method instead of the Filter method since the desired objective is to realize the influence that each of the features has on the model. As the number of input variables present is reduced, only seven, it is not necessary to make a pre filtering, because the recovered computational effort would be negligible.

Since the method of analysis of accuracy of the model used by the Feature Selection method through the neural networks, it is necessary à priori to study what is the best structure for the neural network. So in order to know the best values of neurons and layers that should constitute the neuronal network, it will be performed a test using the Monte Carlo method.

In an initial phase, it was established a neuronal network structure with 70% of the data for training, 15% for validation, and 15% for the test. This choice was made with the criterion of only provide the sufficient amount of data to the neural network learn, so that exist a good number of elements to test. Having a considerable number of cases for testing, the network will be subject to a wider range of tests, which provides a result of more robust prediction. However, if the number of samples is not high enough, it could occur that the neural network was not a sufficient data to provide a reliable result. In this work that problem should not exist since the case base is composed with 3202 samples.

After the neural network data structure has been established, an analysis will be performed using the Monte Carlo method. This method consist of performing the analysis 50 times in order to performed in the end, an average of correlation and MSE values between the output data and data target obtained for each neuron. The training of the neural network will be performed for 100 epochs, with a variation of neurons between 1 and 15. This way it can be checked the number of neurons that most often presents better accuracy values of the generated model. This process is repeated for a range of 1 to 8 layers, was considered a maximum of 8 layers since only an extremely complex problem would plausible consider an analysis for a greater range of layers.

The established method for training the neural network, in order to solve a regression problem, was Levenberg-Marquardt backpropagation.

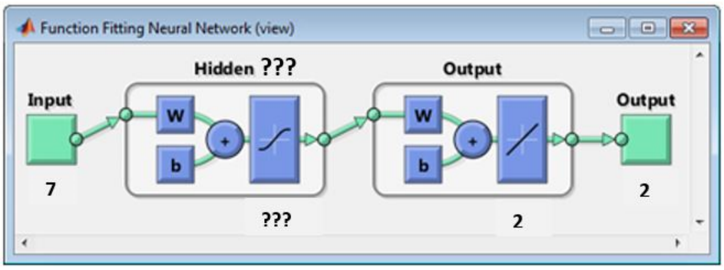


Figure 5.2: Computation for the number of Layers and the number of Neurons

Having opted for the Wrapper method for the above reasons, the Matlab software used a function called *sequentialfs*. This function starts by calling another function called *featureImp*, in order to evaluate the accuracy obtained by the model, through the use of neural networks. After established the evaluation method of accuracy obtained by the model is then through the function *sequentialfs* analysed the influence of each descriptor in the model. Taking into account that the neural networks do a random pre-selection of the data for the training and test groups, it is necessary to carry out this experiment under Monte Carlo method. Through the analysis by the the Monte Carlo method, it will be possible check which features are more often integrated in the subsets proposed, thus establishing a ranking of the features.

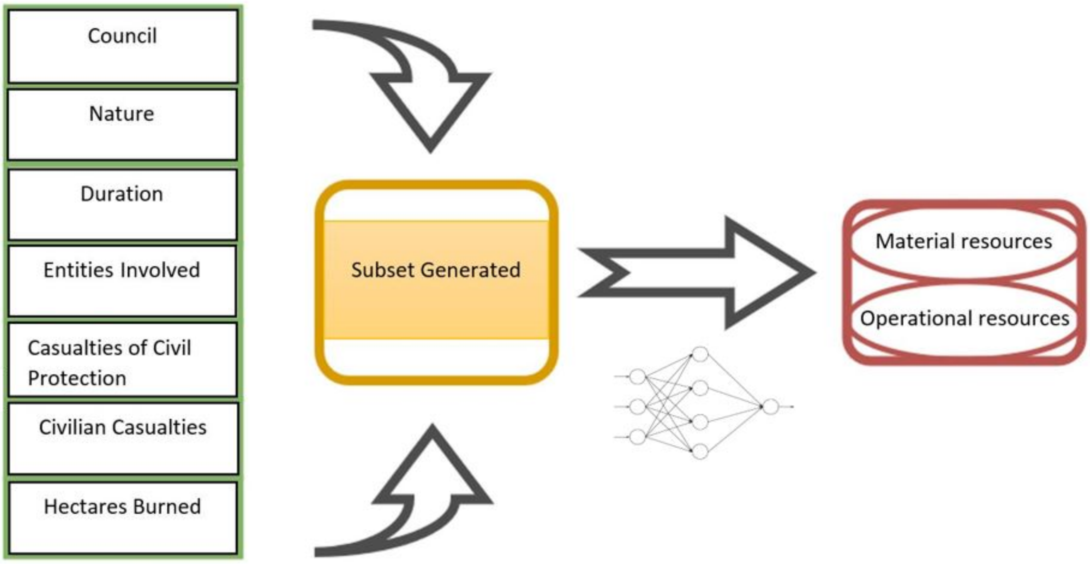


Figure 5.3: Creation of the optimal subset

As mentioned in chapter 4, subchapter 3, the adopted Wrapper method will have the function of analysing which of all the possible subsets of features being generated has the best accuracy for the generation of the model. Since the Matlab software is an already evolved tool, this software provides, within the function *sequentialfs*, the ability to allow the two forms of analysis inherent to the method. That is, the software has both the ability to parse through SFS and through SBS. Ergo, carried out at the analysis by the two algorithms in order to obtain a wider range of results and understand whether there was any discrepancy derived from the chosen selection method.

5.3 Computational Implementation with the myCBR Workbench

The CBR software adopted for the analysis was the myCBR workbench. Workbench which is an open-source similarity-based retrieval tool and Software Development Kit. The criterion for choosing myCBR was:

- it allows modelling and testing knowledge-intensive similarity measures;
- it provides a user-friendly graphical user interfaces for modelling various kinds of attribute-specific similarity measures and for evaluating the resulting retrieval quality;
- it has been adopted by several software platforms, which facilitates the search for an open source platform able to allow its use.

The myCBR software in the form of a plug-in for the Protégé editor, figure 5.4 shows the Graphical User Interface on which the problem will be implemented.

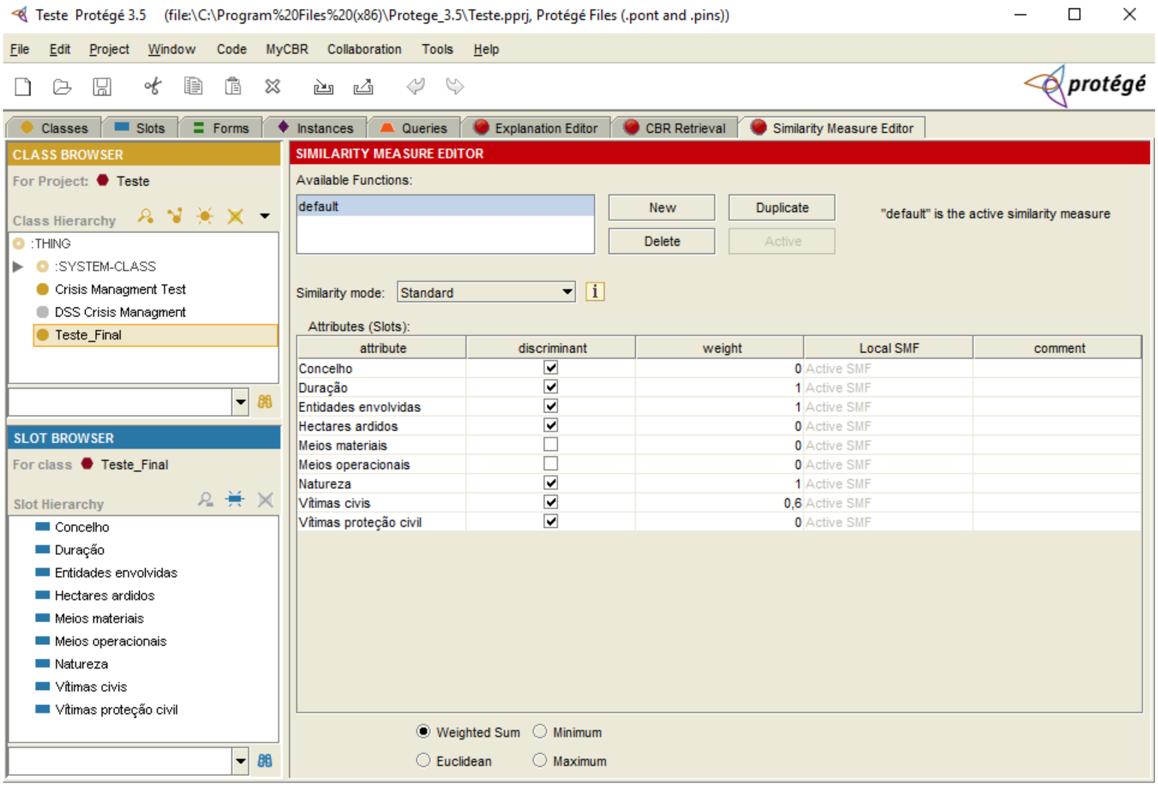


Figure 5.4: The CBR Graphical User Interface provided by the myCBR plugin for Protégé

The initial steps of the process entail the upload of the available *database*, which from this point on will be identified as *case base*, to the myCBR environment. This means that both input descriptors and targets will be formatted so that the decision support for new cases can be realized with logical sense. The framework myCBR supports the description of cases with various attributes such as numeric, string and character, logical, among others. Figure 5.5 shows the configuration for a descriptor of string type, e.g County. As shown in figure 5.5, the inference method consists of a comparison between words using method maximal trigram. This method allows for some flexibility during the inference step, not just with respect to writing errors, but as well as, case sensitivity (i.e. upper or lower case writing).

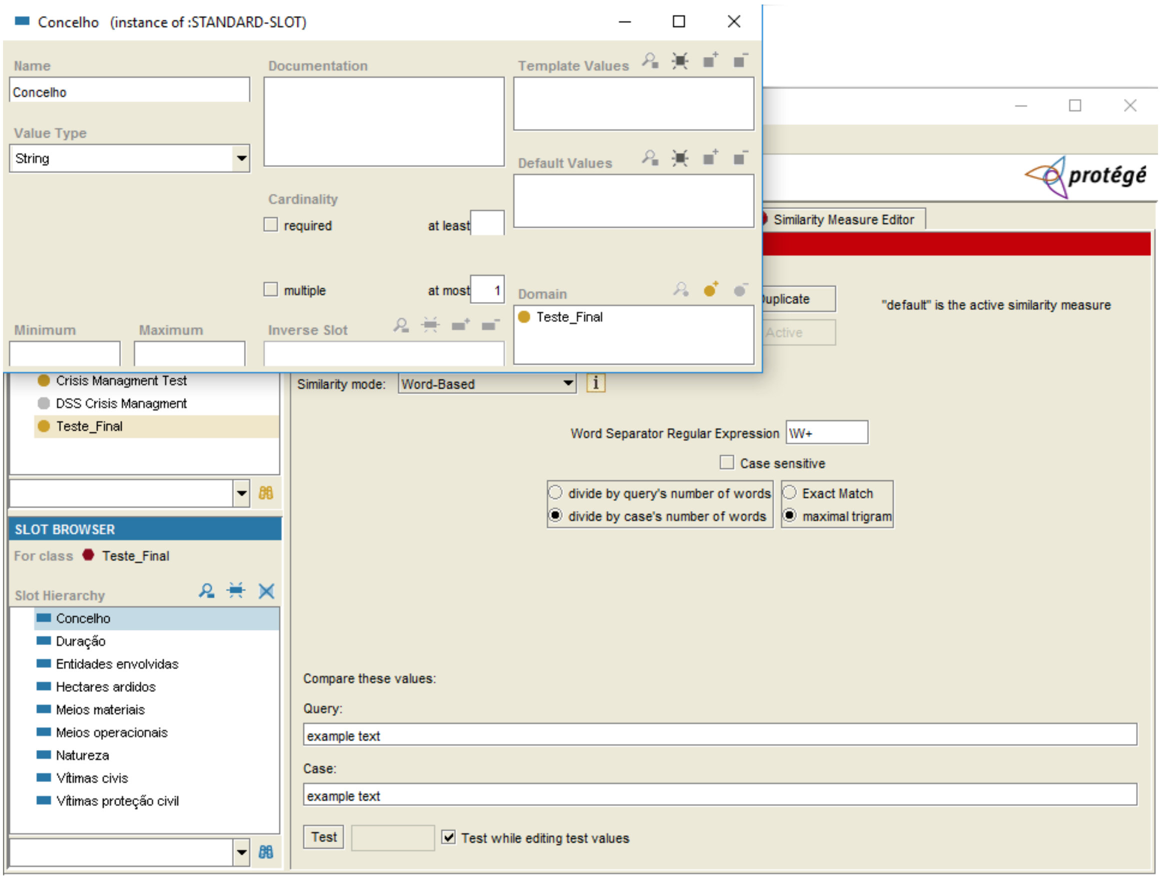


Figure 5.5: Design of a similaritiy measure for descriptor County

Figure 5.6 shows the assignment of the integer data type to descriptor County. In this type of variable the inference is performed through a kind of fuzzification method. The shape of this membership function will be designed with the aid of field experts in crisis management, who have the right knowledge and experience.

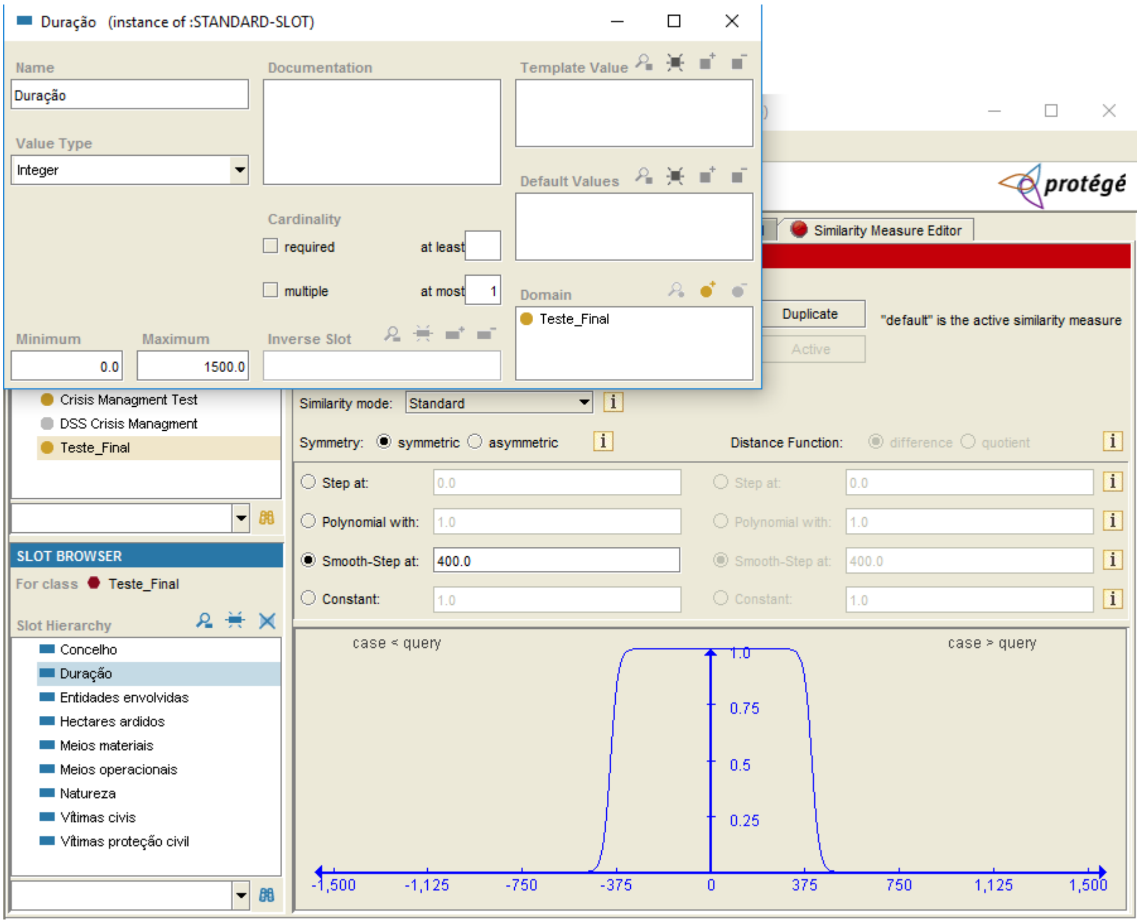


Figure 5.6: Design of a similaritiy measure for descriptor Duration

Upon completion of descriptor design, the weights assigned to each feature will be assigned, so that the inference of the resources be affected by the importance of each feature. Figure 5.7 shows the graphical environment under which the association of weights to descriptors was carried out. This inference is performed by the Nearest Neighbour method described in section 3.5. It can be seen at the bottom of figure 5.7 the possibilities of distance metrics provided by the myCBR plug-in:

- Euclidean distance;
- Weight Sum distance;
- Maximum distance;
- Minimum distance.

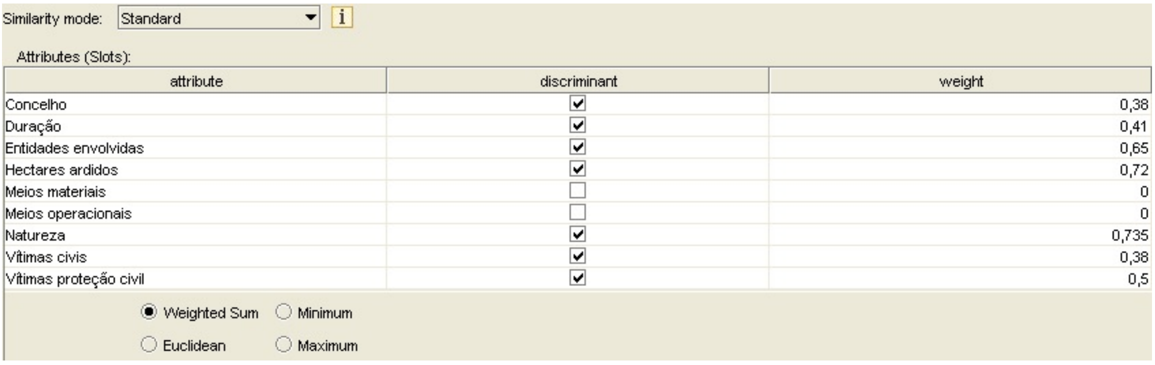


Figure 5.7: Assignment of descriptor weights and global weighted distance

Figure 5.8 shows a sample representation of a new case according to which the search for similarities will be applied. The search is then performed in the case base for the purpose of being found the most similar case, taking into account the weights assigned to each of the features.

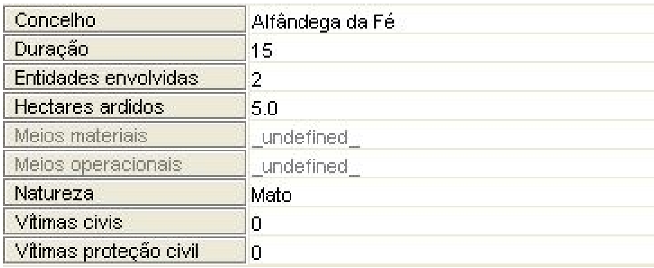


Figure 5.8: Interface used for the retrieval of new cases

The events presented in table 5.2 were randomly selected to validate and verify the performance obtained using the CBR implementation described in this section and assess if the outcome corresponds to the decision-making that was performed by the expert.

Table 5.2: Events chosen to assess the performance for the CBR implementation

Council	Nature	Duration	Entities Involved	Casualties of civil Protection	Civilian Casualties	Hectares burned	Material resources	Operational resources
ABRANTES	Protecção e Assistência a Pessoas e Bens - Prevenção a actividades de lazer	633	1	0	0	0	2	4
PORTO	Riscos Mistos - Inundação de estruturas por água canalizada	68	1	0	0	0	1	3
SINES	Riscos Tecnológicos - Despiste	107	1	0	1	0	1	3

Chapter 6

Results

6.1 Selection of problem descriptors

This section presents an analysis to identify which descriptors contribute the most to justify a given target.

6.1.1 Artificial Neural Networks Architecture

With the percentage of data defined for training, validation and testing datasets, an initial study was conducted to identify the suitable number of neurons and layers for the ANN used in this work. This analysis was done hundred times to obtain results with acceptable levels of confidence, resulting in the averages present in table 6.1.

Table 6.1: Evolution of Correlation factor and MSE parameters with neurons

	Number of Neurons														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Avarege of Train data correlation	0,8619	0,8916	0,9108	0,9184	0,9193	0,9233	0,9234	0,9259	0,9262	0,9251	0,9263	0,9250	0,9243	0,9228	0,9260
Avarege of Test data correlation	0,6674	0,7213	0,7536	0,7387	0,7363	0,7331	0,7955	0,7745	0,7832	0,7816	0,7853	0,8015	0,7976	0,8255	0,8143
Average of Correlation (70%Train+30%Test)	0,8035	0,8405	0,8636	0,8645	0,8644	0,8663	0,8850	0,8805	0,8833	0,8821	0,8840	0,8880	0,8863	0,8936	0,8925
MSE	3,5580	2,8948	2,3966	2,2239	2,1352	2,0920	2,0344	2,0340	2,0223	2,0204	2,0010	1,9972	1,9946	2,0217	2,0055

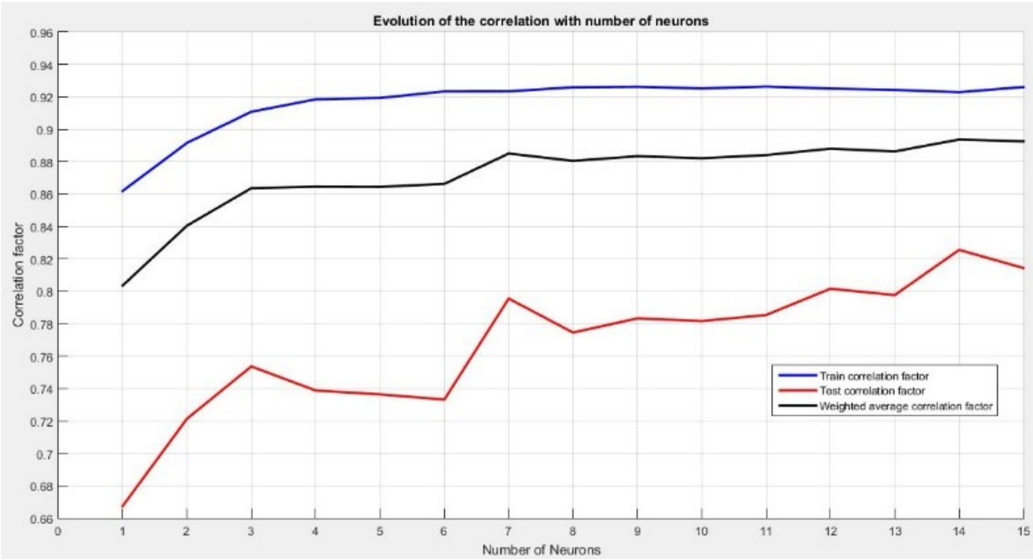


Figure 6.1: Evolution of the correlation factor, with the number of neurons

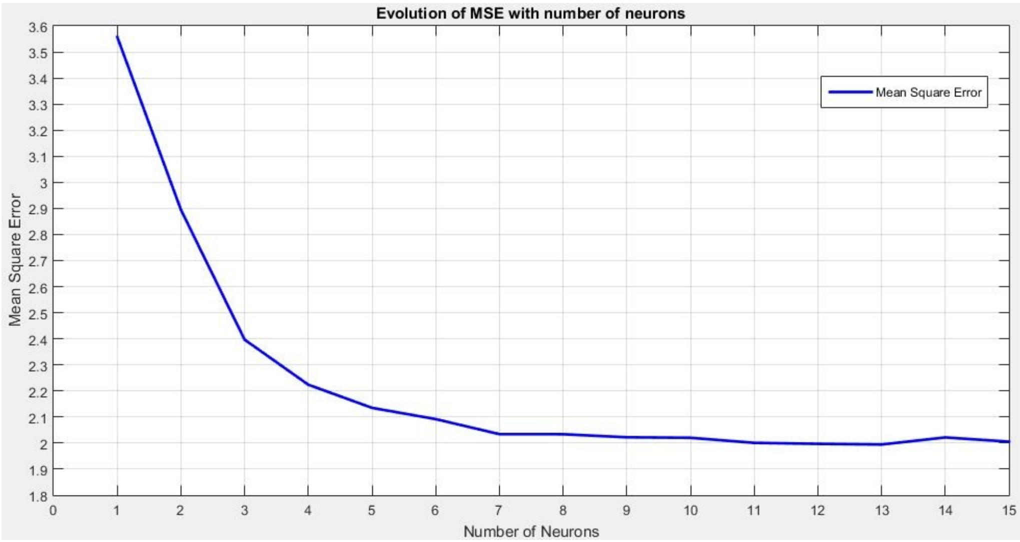


Figure 6.2: Evolution of the MSE parameter, with the number of neurons

It is possible to verify that the best values of correlation obtained using training datasets correspond to an amount of eleven neurons, the best value of correlation obtained using test datasets correspond to fourteen neurons and the best weighted average corresponds to fourteen neurons. It is also possible to observe that the best MSE value corresponds to thirteen neurons.

However, it appears that for a structure of a seven-layer neurons correlation values and MSE are very close with their respective maximums. It is noted that for seven neurons, the MSE value has a difference of 0.0398, the training correlation value has a difference of 0.0029, the test correlation value has a difference of 0.03 and the weighted average correlation value presents a difference of 0.0086. For these reasons the number of seven neurons was adopted as the ideal number of neurons for the ANN structure, as is the value that as a whole provides a good result and at the same time it is possible to be spared computational effort.

After selecting the number of neurons, the study of the ideal number of layers that the structure should have was initiated. The results obtained for each number of layers is present in table 6.2.

Table 6.2: Evolution of Correlation factor and MSE parameters with layers

	Number of Layers					
	1	2	3	4	5	6
Avarege of Train data correlation	0,9239	0,9297	0,9330	0,7970	0,7912	0,7388
Avarege of Test data correlation	0,7672	0,7968	0,7883	0,6863	0,6512	0,6349
Average of Correlation (70%Train+30%Test)	0,8755	0,8891	0,8828	0,7625	0,7492	0,7077
MSE	2,0585	1,9302	1,8784	4,1828	4,7944	5,7076

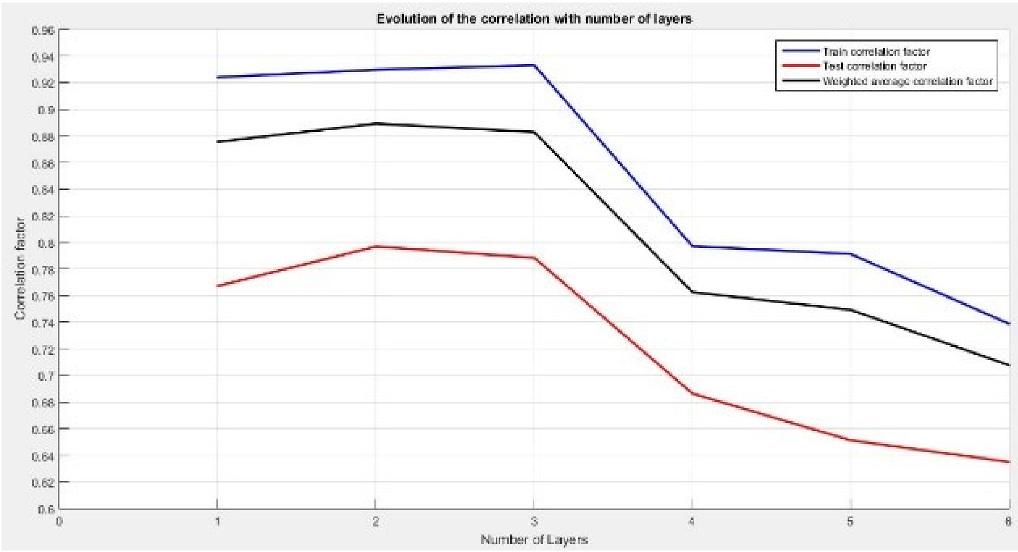


Figure 6.3: Developments of the correlation factor, with the number of layers

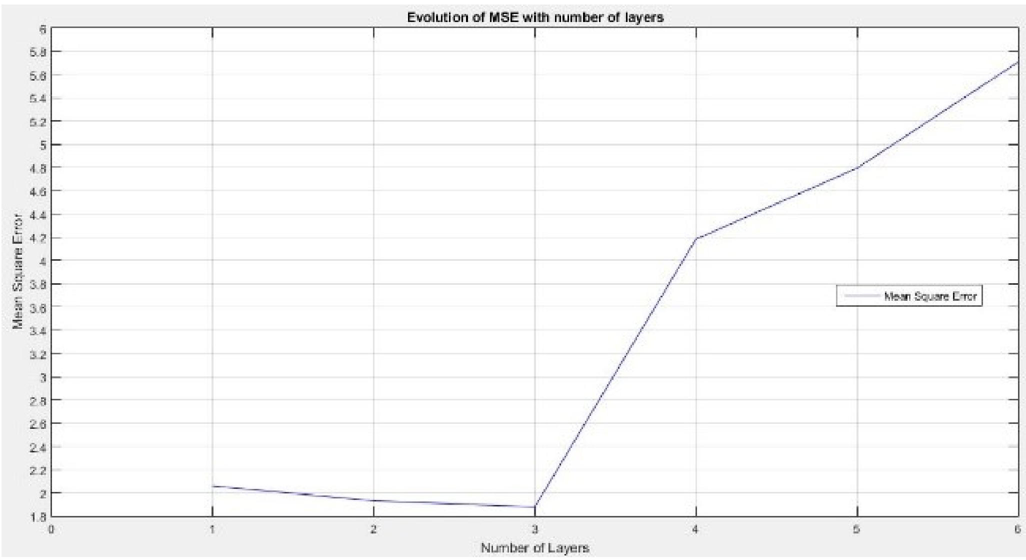


Figure 6.4: Developments of the MSE parameter, with the number of layers

As can be seen in figures 6.3 and 6.4, to a structure with four layers the correlation factor value begins to descend and the MSE value begins to increase. For this reason the analysis was limited to six layers, being this way possible to save computational effort since the number of layers are no longer affecting the performance of the result.

The best result presented with respect to MSE corresponds to a structure of three layers each with seven neurons. However, it is possible to adopt a structure with only two layers, since the penalty MSE is just 0.0518 and the correlation values displayed for two layers are very close or even better that a structure with three layers.

Having adopted a structure with two layers was found that the best amount of neurons, is presented to a range of seven to six neurons per layer, table 6.3. As can be seen in figures 6.5 and 6.6, despite the lowest MSE value correspond to seven neurons per layer it is possible to adopt an amount of five neurons per layer and does not significantly penalize the values of correlation and MSE. Thus, it is possible to lower the computational effort at the same time continuing to justify the response obtained with correlation and MSE values very acceptable.

Table 6.3: Evolution of correlation and MSE parameters with neurons of the ideal layer

	Number of Neurons for 2 Layers						
	1	2	3	4	5	6	7
Avarege of Train data correlation	0,8605	0,9009	0,9184	0,9240	0,9272	0,9297	0,9283
Avarege of Test data correlation	0,7183	0,7326	0,7585	0,7816	0,7894	0,7942	0,7968
Average of Correlation (70%Train+30%Test)	0,8178	0,8504	0,8704	0,8813	0,8859	0,8891	0,8889
MSE	3,5970	2,6858	2,2456	2,0617	1,9515	1,9361	1,9302

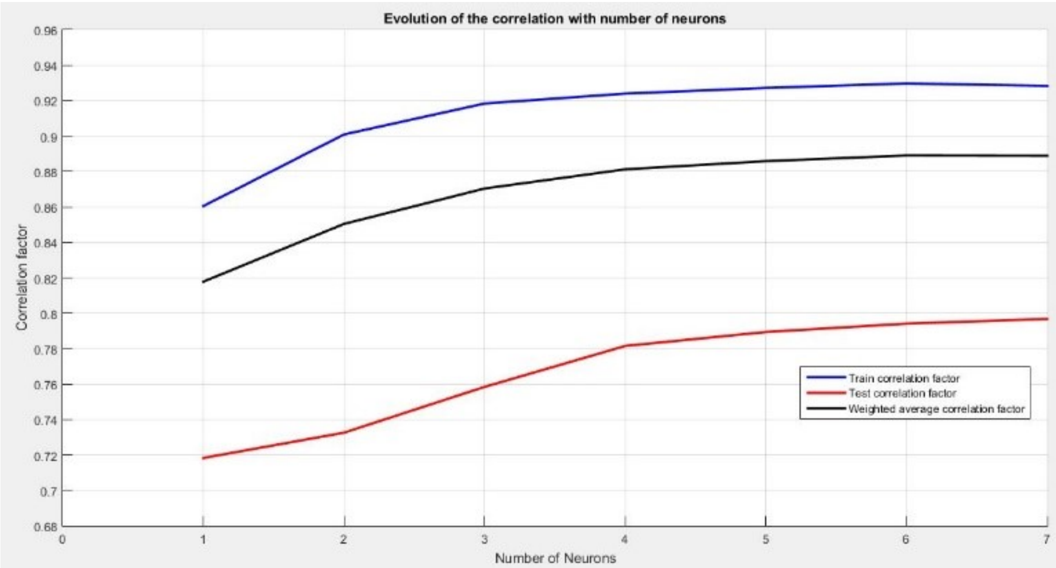


Figure 6.5: Developments of the correlation factor, with the number of neurons of the ideal layer

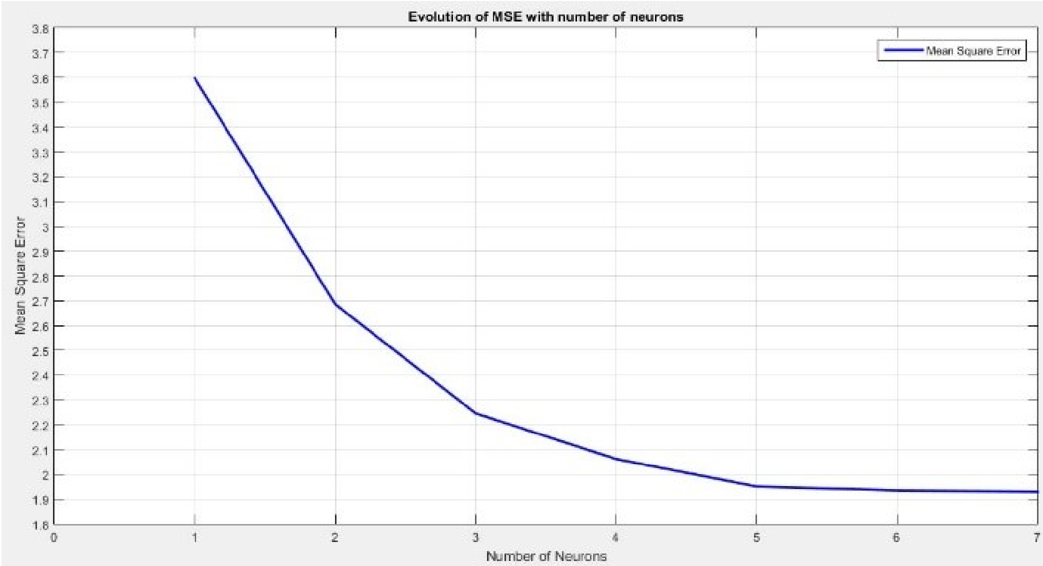


Figure 6.6: Developments of the MSE parameter, with the number of neurons of the ideal layer

It was concluded that the best amount of layers and the best number of neurons to be adopted corresponding to two layers composed of five neurons each, with a weighted correlation of 0.8813 and an MSE value of 1.9515.

6.1.2 Feature Selection

With the structure of neural network defined, were conducted tests using the SFS and SBS algorithms, with MSE stop criterion. The obtained data can be viewed in table 6.4.

Table 6.4: Results obtained to SFS and SBS algorithms

	Features						
	Council	Nature	Duration	Entities Involved	Casualties of Civil Protection	Civilian Casualties	Hectares Burned
SFS	0	6	1	47	7	12	4
SBS	35	44	50	50	32	40	28

It can be seen from figure 6.4, that some problem descriptors have been selected more often than others to characterize the event, thereby verifying that there are features with a stronger influence than others in the event characterization.

It is verified that descriptor Council, for both the SFS and SBS algorithms, shows little importance, establishing a concordance in the influence of the feature to characterize the event. However it is also possible to verify that the importance attributed to features Casualties of Civil Protection and Civilian Casualties differ greatly between the two algorithms.

Thus, since there is no complete agreement on the choice of the descriptors weights, through the results obtained by myCBR, will be made an evaluation of the results provided by all the methods, making it possible to evaluate which of the algorithms provides better results.

Based on the number of times that each feature was selected to be part of the model, a weight was established. Since the analysis has been performed fifty times, the weight of each feature is represented by the equation 6.1.

$$F_i = \frac{n_i}{N} \tag{6.1}$$

Wherein $"F"$ represents the weight of the descriptor $"i"$, $"n"$ is the number of times that a feature was selected and $"N"$ represent the number of iterations.

The result the weights presented are presented in table 6.5.

Table 6.5: Weights obtained from SFS and SBS algorithms

	Features						
	Council	Nature	Duration	Entities Involved	Casualties of Civil Protection	Civilian Casualties	Hectares Burned
SFS weights	0,00	0,12	0,02	0,94	0,14	0,24	0,08
SBS weights	0,70	0,88	1,00	1,00	0,64	0,80	0,56

6.2 Inference events

The following section has the objective of assessing model performance with each set of weights from previous section. Tests were performed in order to check if after all this analysis the calculated weights generate a good model to infer the means to a certain event.

Initially weights calculated by the Feature Selection algorithm using the SFS method were implemented, figure 6.7. Later weights derived from Feature Selection algorithm by SBS method were implemented, figure 6.8.

attribute	discriminant	weight
Concelho	☑	0
Duração	☑	0,02
Entidades envolvidas	☑	0,94
Hectares ardidos	☑	0,08
Meios materiais	☐	0
Meios operacionais	☐	0
Natureza	☑	0,12
Vítimas civis	☑	0,24
Vítimas proteção civil	☑	0,5

Figure 6.7: Weights assigned by the Feature Selection algorithm through the SFS method

attribute	discriminant	weight
Concelho	☑	0,7
Duração	☑	1
Entidades envolvidas	☑	1
Hectares ardidos	☑	0,53
Meios materiais	☐	0
Meios operacionais	☐	0
Natureza	☑	0,88
Vítimas civis	☑	0,8
Vítimas proteção civil	☑	0,5

Figure 6.8: Weights assigned by the Feature Selection algorithm through the SBS method

As mentioned in the previous chapter, three events were used to test, the results obtained by the CBR system, table 6.6.

Table 6.6: Test Events

Evests	Council	Nature	Duration	Entities Involved	Casualties of civil Protection	Civilian Casualties	Hectares burned	Material resources	Operational resources
A	ABRANTES	Protecção e Assistência a Pessoas e Bens - Prevenção a actividades de lazer	633	1	0	0	0	2	4
B	PORTO	Riscos Mistos - Inundação de estruturas por água canalizada	68	1	0	0	0	1	3
C	SINES	Riscos Tecnológicos - Despiste	107	1	0	1	0	1	3

6.2.1 Results obtained by applying the weights obtained using the Feature Selection algorithm through the SFS method

Event A: Applied the weights shown in figure 6.7, were originated 11 results with the largest similarity factor, table 6.7. As can be seen the values of the variable Material resources for the 11 events do not vary significantly, with an average of 1.1 elements and a standard deviation of only 0.3 elements. However, with regard to the Operational resources variable the value recorded for past events show a high variation, with an average of 2.8 elements with a standard deviation of 2 elements.

In this way CBR system presents to the variable Material resources the answer set of {1,2} elements and the variable Operational resources presents the answer set of {1,2,3,4,5} elements.

Table 6.7: Events inferred to the event test A from the SFS method

Events	Similarity Factor	Material resources	Operational resources
1	0,96	1	2
2		1	1
3		1	2
4		1	1
5		1	3
6		1	6
7		2	7
8		1	4
9		1	2
10		1	2
11		1	1
	Average	1,1	2,8
	Standard deviation	0,3	2,0

Event B: Applied weights of figure 6.7, were originated 3 results with the largest similarity factor, table 6.8. As can been observe the variable values of Material resources for 3 events does not vary, presenting an average of elements equal to the value registered for the 3 events and as a result a zero standard deviation. However, with regard to the Operational resources variable the value recorded by past events has a small variation, with an average of 2.3 elements and a standard deviation of 0.6 elements.

In this way CBR system presents the variable Material resources the answer set of {1} elements and the variable Operational resources presents the answer set of {2,3} elements.

Table 6.8: Events inferred to the event test B from the SFS method

Events	Similarity Factor	Material resources	Operational resources
1	0,98	1	3
2		1	2
3		1	2
	Average	1,0	2,3
	Standard deviation	0,0	0,6

Event C: Applied the weights of figure 6.7, were originated 4 results with the largest similarity factor, 6.9. It is possible to observe in this event that so much to the values of the variable material resources, as to the values of Operational variable resources, the values recorded in all past events are equal. As a consequence the value of the average of corresponding elements of the two variables is equal to the value of the variables recorded for past events and the standard deviation value is therefore zero.

In this way CBR system presents the variable Material resources the answer set of {1} elements and the variable Operational resources presents the answer set of {2} elements.

Table 6.9: Events inferred to the event test C from the SFS method

Events	Similarity Factor	Material resources	Operational resources
1	0,95	1	2
2		1	2
3		1	2
4		1	2
	Average	1,0	2,0
	Standard deviation	0,0	0,0

It can be seen in the results inferred by the CBR system for test events A and B, the existence of only a past event with the same answer that the selected event to test.

However although the CBR system response was not exactly the same as the test event response, it can be said that for cases B and C, the answer provided by the intelligent system is not very different from that adopted in the response test event. Assuming that the response adopted in the test event is correct, it can be said that the intelligent system provides an important aid in decision making.

6.2.2 Results obtained by applying the weights obtained using the Feature Selection algorithm through the SBS method

Event A: Applied the weights shown in figure 6.8, it can be seen that there is only an event with a higher similarity factor, table 6.10. It is also evident that the value of the variables recorded by the last event do not match the value of the variables of the test event.

In this way CBR system presents the variable Material resources the answer set of {1} elements and the variable Operational resources presents the answer set of {2} elements.

Table 6.10: Events inferred to the event test A from the SBS method

Events	Similarity Factor	Material resources	Operational resources
1	0,89	1	2

Event B: Applied weights of figure 6.8, originated 2 results with the largest similarity factor, table 6.11. As can be observed the variable values of Material resources for 2 events does not vary, presenting an average of elements equal to the value registered for the 2 events and as a result a zero standard deviation. However, with regard to the Operational resources variable the value recorded by past events has a small variation, with an average of 2.5 elements and a standard deviation of 0.7 elements.

In this way CBR system presents the variable Material resources the answer set of {1} elements and the variable Operational resources presents the answer set of {2,3,4} elements.

Table 6.11: Events inferred to the event test B from the SBS method

Events	Similarity Factor	Material resources	Operational resources
1	0,87	1	3
2		1	2
	Average	1,0	2,5
	Standard deviation	0,0	0,7

Event C: Applied weights of figure 6.8, were originated 5 results with the largest similarity factor, table 6.12. As can be observe the variable values of Material resources for 5 events does not vary, presenting an average of elements equal to the value registered for the 5 events and as a result a zero standard deviation. However, with regard to the Operational resources variable the value recorded by past events has a small variation, with an average of 2.2 elements and a standard deviation of 0.4 elements.

In this way CBR system presents the variable Material resources the answer set of {1} elements and the variable Operational resources presents the answer set of {2,3} elements.

Table 6.12: Events inferred to the event test C from the SBS method

Events	Similarity Factor	Material resources	Operational resources
1	0,84	1	2
2		1	2
3		1	3
4		1	2
5		1	2
	Average	1,0	2,2
	Standard deviation	0,0	0,4

It is possible to observe the results inferred by the CBR system to test events B and C, the existence of only one past event with the same response of the selected event for testing.

However although the CBR system response was not exactly the same as the test event response, it can be stated that in events B and C the answer provided by the intelligent system is not very different from the response adopted in the test event. Assuming that the response adopted in the test event is correct, it can be said that the intelligent system provides an important aid in decision making.

6.2.3 Comparison of results

Table 6.13: Results obtained through the methods of inference

Event A				Event B				Event C			
Output variables	Material resources	Operational resources	Similarity factor	Output variables	Material resources	Operational resources	Similarity factor	Output variables	Material resources	Operational resources	Similarity factor
SFS	{1,2}	{1,2,3,4,5}	0,96	SFS	1	{2,3}	0,98	SFS	1	2	0,95
SBS	1	2	0,89	SBS	1	{1,2,3,4}	0,87	SBS	1	{2,3}	0,84
Test event	2	4		Test event	1	3		Test event	1	3	

It is possible to observe that none of the algorithms implements a unique solution exactly equal to the solution adopted by the commander. As stated above it must be taken into account that the case base on which the algorithms analysed, has not been previously filtered. As a result, there are present redundant cases and cases associated with bad decision making, causing that the inferences cases can not provide just one solution as an ideal solution.

As it turned out by the sensitivity analysis of the ANN, the MSE value approximates to 2, showing that the error made by the algorithms are not significant to the point of not being able to accept your answer. Through the table 6.13 can be seen that approximately 90% of the responses obtained by the different algorithms of the intelligent system incorporates the commander's decision-making, this way reinforcing the credibility of the results.

By doing an analysis of the results of the methods, it is possible to conclude an optimal decision making for each event, table 6.14.

Table 6.14: Solution proposed by the inference data

Event A		Event B		Event C	
Material resources	Operational resources	Material resources	Operational resources	Material resources	Operational resources
1	2	1	2	1	2

The table 6.14 can confirm that none of the events was the right decision-making, ergo proving the high need of decision-making support system so they can not only be managed all resources effectively, but also to the risk of victims is reduced as much as possible.

Chapter 7

Conclusions

The existence of a decision support system is helpful to support the command exercise, allowing the commander to adopt the best decision, saving resources and allowing for a greater mission success rate.

However, it is possible to verify that the results obtained have an error value. This error may be due to several factors: the case base provided not having been previously filtered by experts and as such introduce human error, the decision-making held in the test event might not have been the most accurate or the assignment of weights to each feature may not be the most accurate. It is possible to affirm that the retrieve method used, Nearest Neighbor, is not the most accurate method, and it can also be one of the factors for the existing error value.

To apply a decision support system on management of the resources of a crisis event, it is important to have a comprehensive knowledge of the concepts that incorporate the crisis management issue, because without this knowledge is difficult to know which features should be treated.

It is important not only at a national level, but also international, to generate studies regarding the CBR system. This is because the methodology allows work with features, not only numerical format but also string format. Besides this, the methodology also allows integrate justification of the cicle process, allowing the system to be more accurate to a response of a peculiar event. It is therefore concluded that although the intelligent system CBR, is a promising system, it is necessary to carry over some progress with regard to algorithms that incorporate all phases of the CBR cycle.

The ideal process of the methodology is purely automated. Despite this type of process not existing today, with the help of ANN and some tools, it is possible to obtain results with very satisfactory performances as regards the resolution of problems of classification, regression, among others.

7.1 Future Work

In future works a database with all descriptors that an event presents should be implemented. By working with all the descriptors it is avoidable to eliminate some important descriptor that in a first evaluation by the expert could appear to redundant. In addition, the application of induction methods in order to provide a comparison with the nearest neighbour method with weight average applied in this work, thus enabling it to realize not only the best method to be applied, but also the features relationship through its internal organization.

It is of the utmost importance that all new work should be supported on a database reviewed by experts, not only to save on computational effort, since simulations last more than 18 hours, but also to obtain outcomes with more accuracy.

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