An Intelligent Decision Support System (IDSS) for Public Decisions Using System Dynamics and Case Based Reasoning (CBR)

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Inteligentni sistem za podporo odločanju v javnem sektorju na osnovi sistemske dinamike in študije primerov

Prispevek predstavlja snovanje in razvoj IDSS, ki omogoča odločevalcem identifikacijo ključnih dejavnikov, ki vplivajo na prihodnji razvoj družbenega sistema kot pomoč pri izboljšavi oblikovanja razvojne politike. Implementacija sistema je trenutno v teku tako, da prispevek obravnava dosedanje dosežke na tem področju. Metodološki pristop je kombinacija umetne inteligence s kvalitativnimi modeli ter simulacijo po principu sistemske dinamike. Pomemben faktor pri izbiri strategij in razvoj politike na področju kompleksnih družbenih sistemov je vpliv nabora spremenljivk, ki niso kvantificirane. Zaradi tega je bil zgrajen model, ki omogoča obravnavo tovrstnih spremenljivk. Predlagana je metodologija, ki je sestavljena iz treh faz. V prvi fazi je zgrajen model za simulacijo dinamike sistema ter oblikovanja scenarijev. Pri tem služi model ot analitično orodje. Omenjena faza omogoča določitev ključnih spremenljivk ter dejstev. Rezultati, ki so pridobljeni s pomočjo simulacije, so arhivirani v podatkovni bazi ter uporabljeni kot vhod v proces logične obravnave. Tako predstavljajo rezultati izhodiščno točko za drugo fazo. V tej fazi uporabljamo tehniko CBR (Case Based Reasoning), kjer je določen primer definiran z naborom norm oz. skupnih atributov, primerov in indeksov (atributi za diskriminacijo primerov), problema, rešitve ter razlage. Različne vrednosti omenjenih atributov predstavljajo nov primer. Zadnja faza ima za rezultat različne rešitve, ki omogočajo odločevalcu razlago o dejstvih, ki govorijo v prid ter proti posamezni alternativi. V primeru, da nobena od predlaganih alternativ ni sprejemljiva s strani uporabnikov IDSS, lahko le-ti vključijo nove rešitve, ki so po njihovem mnenju sprejemljive. Pomembno dejstvo je, da IDSS omogoča konsistentno vodenje ter spodbuja konsenz pri odločevalcih.

Ključne besede: sistem za podporo odločanju, situacijsko orientirani logični proces, odločitev, javni sektor, strateško odločanje

1 Introduction

At present, we are working on the design of an IDSS to help the strategic decision in the public sector and semi-public organizations in the Canary Islands, in order to establish a new development model. The model consolidated up to the present has serious problems to assure a sustainable and equitable development of the quality of life of the regional population. In previous works we have treated these problems (Legna 2000; 2001; 2002; Kljajic et al. 2002; 2003a; 2003b), and in this paper we are centered in the design of an intelligent tool to support Strategic Public Decisions (SPD) and the achievement of consensus between the main social actors. This paper resumes our line of researches and works with public or semi-public organizations (as Canary Islands Government, Spain European Trade Unions Confederation and Canarian Trade Unions).

The IDSS allows the representation of a large number of variables of the Canary Islands model, their interdependences and the heuristic knowledge of the processes. Also, it is useful to analyze the behavior of the social system through multiple possible scenarios, recording assumptions, decisions and results of the actions. In this way, the decision makers can see the impacts of their decisions and the IDSS can give suggestions about the best alternatives to follow.

In a DSS there are inference mechanisms (rules and ways to understand the problem) and an expert knowledge base of different solutions for the problem. Thus, it can advise decision makers about risks and advantages in particular decision situations. When it happens, the DSS is intelligent (Bhargava et al.,1999). In some situations there is more than one alternative solution for each problem, and the specialist has pre-solved similar cases, in case that it is necessary to solve new ones. Then, we can store and structure these cases in a CBR.

Pre-solved cases can be exceptions to rules in comparison with new cases. For this reason, pre-solved cases are showed as a selection of cases. In pseudo-code, the structure of a rule set (tupla) is performed as follows:

- CASE (pre-condition- data set that define the case [scenario, problem])
- A1: (alternative solution 1, explanation 1),
- A2: (alternative solution 2, explanation 2),
- ….
- An: (alternative solution n, explanation n).

Consequently, when there is not any case defined in the same circumstances like other stored case, the answer will be based in an application of a similar case. It is obtained through an inference process, called "adaptation".

In our application, we propose a methodology divided into three phases:

a) Problem definition through modeling and simulation.
b) Case base definition and representation of the reasoning process.
c) Integration of the Simulation and IA techniques to create an IDSS.

In the following sections we present the advances achieved in each phase up to the present.

2 Problem definition trough modeling and simulation

The Canarian Model was built and various scenarios were constructed using system dynamics. For the description of the model and an explanation of how it was built , see Kljajic et al. (2002). The scenarios are the following:

"Scenario 1: Non-innovative society, with population and political leaders not really concerned with the environment and the sustainable development; the importance of immigration of pensioners people; constant increase of the total population.

This scenario mixes trends of permanent population increase, decline of tourism due to the environment degradation, stagnation of the agriculture sector and persistence of non-innovative Small and Medium Enterprises (SMEs). The first scenario is not sustainable in the long term, because the crisis in tourism (and other activities boosted by it) and the degradation of the environment will reduce the immigration of pensioners. This contraction will reinforce the economic crisis and the increase of the unemployment. The economic crisis will probably be accompanied by social unrest and political troubles.

Scenario 2: Non-innovative society, with population and political leaders not really concerned with the environment and sustainable development; importance of immigration of population in working age; permanent increase of the total population.

This scenario is the same as the former, except that the projection of the aging population is lower. In this scenario the crisis will be more evident and stronger in the work market. In the medium and long term the degradation of the environment and unemployment and social unrest will feed back between them.

Scenario 3: Innovative society, with population and political leaders concerned with the environment and sustainable development; weight of pensioners in the population pyramid; permanent increase of the total population.

This scenario mixes trends of permanent population increase, slow reduction of total tourism, increase in agricultural production due to the increased productivity and augmentation of innovative SMEs. This is sustainable in the medium term, because there will not be a crisis in tourism (and the other activities boosted by it) and the environment will not be destroyed. There will be opportunities to increase the quality of employment, due to the innovative activities and the demand of elders. Nevertheless, this scenario is not sustainable in the long term, because the increase of the population can't go on indefinitely. This scenario will be transformed into another one: Number 5 or 6.

Scenario 4: Innovative society, with population and political leaders concerned with the environment and sustainable development; high weight of population at working age, due to immigration; permanent increase of the total population.

This scenario differs from the former only because the tendency of permanent population growth is replaced by a lower population ageing factor. The sustainability in the medium term depends on the equilibrium in the work market and on the profiles of the immigrants. Like the former, it is not sustainable in the long term, because the increase of the population can't go on indefinitely. So, this scenario will be transformed into another one: Number 5 or 6.

Scenario 5: Non-innovative society, with population and political leaders not concerned with the environment and sustainable development; importance of immigration of pensioners; decrease or constancy of the total population.

This scenario differs from number 1 only because the population development is stable. This is one of the worst scenarios for the long term, because the reduction in immigration will be due to the crisis in tourism (and the other activities boosted by it), the degradation of the environment and social unrest. A similar and undesirable scenario may be built on the basis of scenario 2. It is important to observe that these two scenarios are not improbable because some political leaders have emphasized the importance of economic development in the short and medium term, without considering its impact on the environment.

Scenario 6: Innovative society, with population and political leaders concerned with the environment and sustainable development; weight of population at working age, due to immigration, but rate of immigration lower than in scenario 4; decrease or constancy of the total population.

This scenario differs from number 4 in the fact that the total population does not increase indefinitely, because the immigration rate is lower. With this scenario the sustainability of improving the quality of life (that includes the increase of revenues, low unemployment rate, high wages and an enjoyable environment) is possible. It is not the only that may be built to assure the sustainable development of the quality of life. Another one may be constructed on the basis of number 3 (Kljajic et al., 2002).

The scenarios throw light on possible ways of future society development. None are pre-determined. The exact path that society will adopt will depend on external factors and, more importantly, will also depend on the behavior of its population and its leaders. To guide the Canarian social system along a certain path it will be necessary, first of all, to design and chose it (let us say, for instance, one of the possible future scenarios), and to plan and implement the appropriate strategy and policies. An example of them is presented in Kljajic et al. (2002).

At present we are working in the phases two and three. They are described in the following paragraphs.

3 Case base definition and representation of the reasoning process

Decision support systems (DSS) are interactive computer-based information systems that are designed to help human decision makers. These systems allows the processing of data and models in order to identify, structure, and solve semi-structured or unstructured problems and to make choices among different alternatives (Zolghadri et al , 2002).

In this category of applications, experts must evaluate and make decisions with the data showed by analysis tools. One way to create a useful tool is to represent the reasoning process in a form of rules and build an expert knowledge based system. But knowledge based systems have several problems related with the process of extraction and representation of expert knowledge. Therefore, generally these systems are slow and usually can not access to huge amount of information. That is why we propose a case based reasoning method, that allows the resolution of new problems through the adaptation of past solutions used to solve similar problems (Riesbeck & Schank, 1989).

One advantage of this type of techniques is that it doesn't require an explicit knowledge of the domain. The extraction process is reduced to collect historic cases and to identify relevant attributes to describe the cases. We plan to start with a small amount of cases, then eliminate cases that are not useful, and add new ones. In addition, we can give explanations, use techniques of database to administrate a large amount of information, and the best advantage, the system can learn, acquiring new knowledge as cases. All these features makes the system easy to maintain and reuse.

In our application we define each case as a set formed by [(scenario, problem), (solution, explanation)]. Initially, we define cases for proposed scenarios, but the system is not limited to these ones, because it can learn and add to the database news scenarios and new solutions suggested by the user.

The simulation module gives facts that define an actual case. This case will be processed by the Inference Engine module. The CBR Cycle of work is the following (figure 1) (Aamodt & Plaza, 1994):

1. Similar case retrieval (a new problem is matched with similar cases stored in case data base);
2. Re-use proposed solutions in cases to try to solve the problem;
3. Revise proposed solution (in case it is necessary);
4. Retain the new solution as part of a new case.

The cycle is completed with user intervention.

The information stored for each case is related to:

1. The conditions that defines the scenario;
2. The problem, that emerges from the particular conditions of the scenario;
3. A description of the solution found for the problem and the decisions made;
4. A result describing the state of the system after the application of actions suggested.

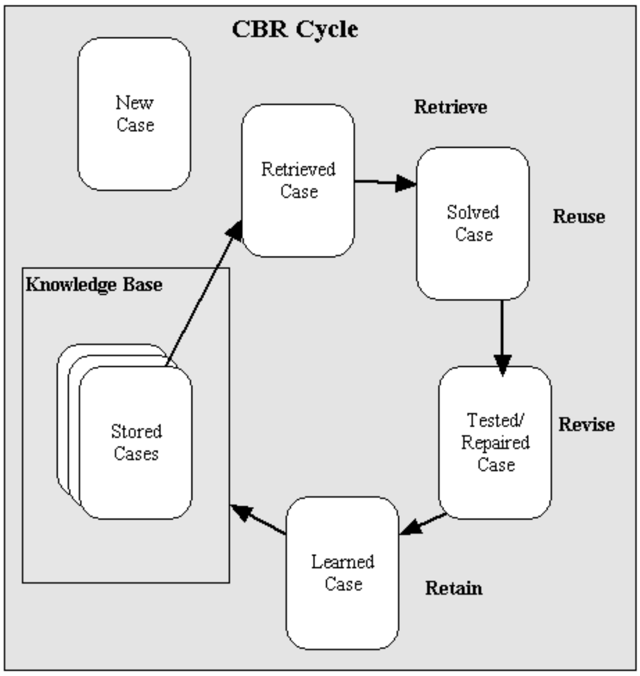

Figure 1: CBR life cycle

If one scenario has more than one problem, it is a new case for the case data base. In other words, (scenario1, problem1) <> (scenario1, problem2) <>…<> (scenario1, problem n).

To define a case and establish differences with others, we consider information regarding to: (i) functionality and (ii) easy acquisition of information represented in the case.

Concerning to cases recovery, we assign indexes for each case, and select an indexation method based on similarity. This method generates a set of indexes for abstract cases created with cases that share common attributes. Attributes not shared are used as indexes in original cases.

In relation with a case memory model, we use one called category-exemplar (Bareiss, 1989). In this model, cases are called exemplars and are organized in a semantic net of categories, semantic relations, cases and indexes. Each case is associated with a category. Case attributes have different weights; these weights indicate if they match up or not with a category.

There are three indexes that indicate:

- Attributes (descriptors of cases -scenario, problem- of cases or categories);
- Categories with their associated cases;
- Categories with neighbor cases which are differenced with a small number of attributes.

An exemplar is stored according to the level of similarity to a prototype category. A new case with small differences to another one is not stored.

The problem of finding the best case involves heuristic methods to limit/guide the search. Heuristics must allow making partial matches. We use a method based on templates, like SQL queries, where all cases that satisfy certain parameters are retrieved. Then we apply an inductive technique, that let us determine which attributes differences better the cases and to generate a decision tree, to organize the case in memory.

4 Integration of the Simulation and IA techniques to create a IDSS

Our system is based on a new approach including both simulation and intelligent analysis techniques.

Initially, dynamics of the system are modeled and the results of the simulations are stored in a database. This is the first step in the reasoning process. Then, the inference engine module identifies the case, selecting the case by similarity using templates and inductive techniques and predictions are performed. Finally, the solutions are showed to user with explanations of the consequences of the application of different possible solutions. If the results and the explanations do not satisfy the user, it is possible to introduce new ones. Thus, the system can be validated and can learn new solutions from the user.

For carry out the execution of our IDSS we have designed 4 main modules:

- Problem Definition, Modelling and Simulation Module;

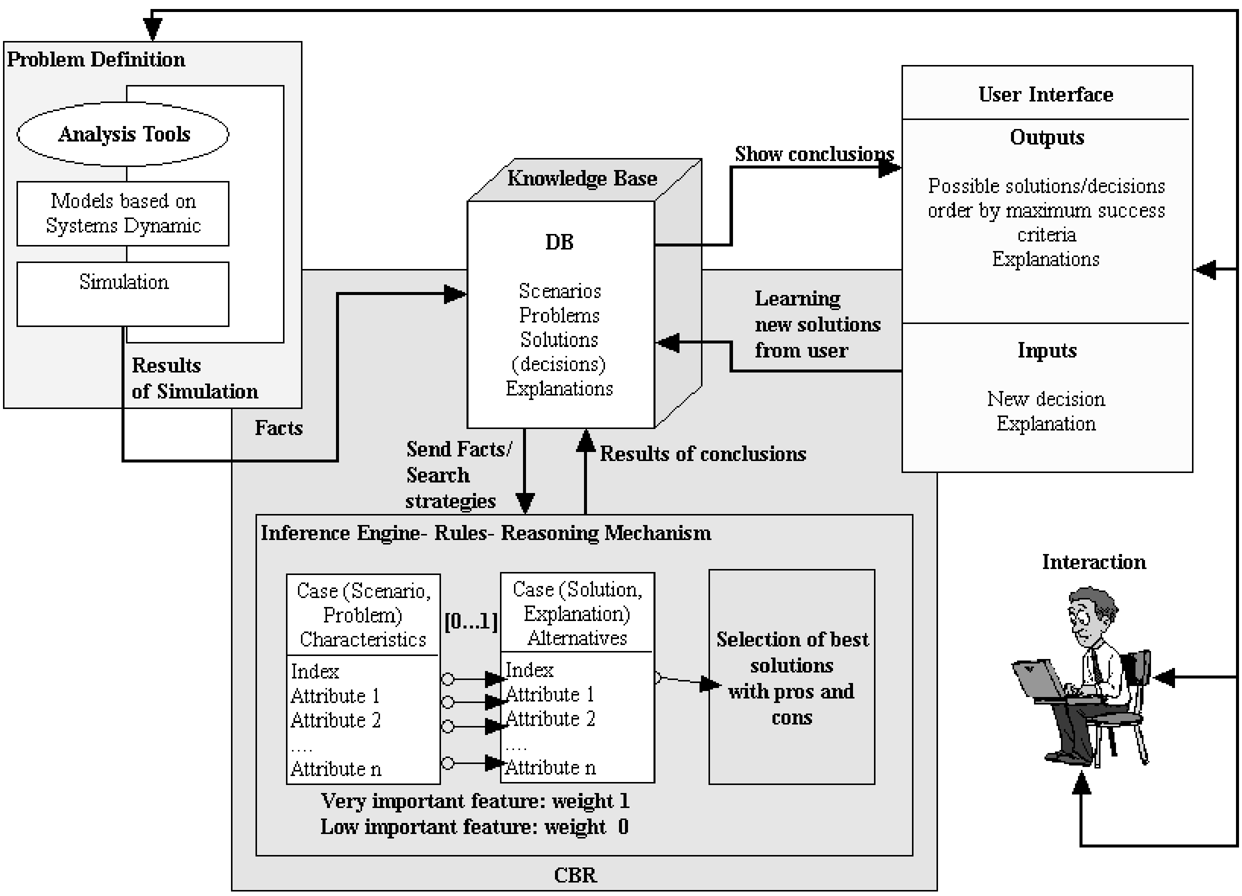

Figure 2. Architecture of IDSS-Canary Islands

- Knowledge Base Module, a DB with information of cases.
- Inference Engine Module, formed by representations of heuristic methods and case selection. It carries out the reasoning process.
- User Interface, that produces the best choices and the solutions for each case. It develops the learning and validation process trough feedback with the system.

Inter-relations among modules can be observed in Figure 2.

Simulation module gives facts that define the actual case. This case will be processed by de Inference Engine module. Initially, we start defining cases for proposed scenarios, but the system can learn on new scenarios and new solutions, adding to the database news scenarios created by modelling and simulation tools and new solutions suggested by the user.

In order to give a solution to the user for a specific problem in one scenario the following sequence of actions is carried out (figure 3).

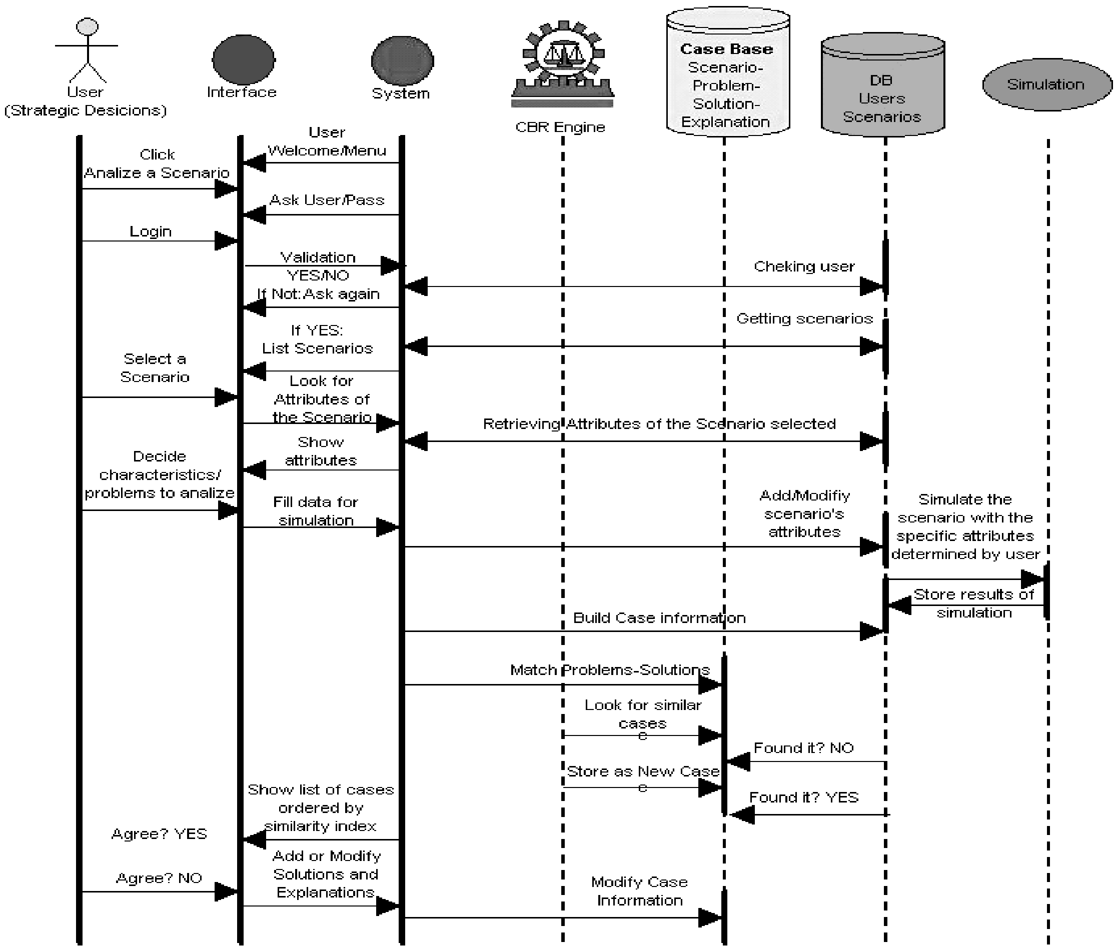

Figure 3. Sequence Diagram. Giving solutions for a scenario/problem.

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