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A Public Health Decision Support System Model Using Reasoning Methods

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Abstract. Problem: Public health programs must be based on the real health needs of the population. However, the design of efficient and effective public health programs is subject to availability of information that can allow users to identify, at the right time, the health issues that require special attention. Objective: The objective of this paper is to propose a case-based reasoning model for the support of decision-making in public health. Results: The model integrates a decision-making process and case-based reasoning, reusing past experiences for promptly identifying new population health priorities. A prototype implementation of the model was performed, deploying the case-based reasoning framework jColibri. Conclusions: The proposed model contributes to solve problems found today when designing public health programs in Colombia. Current programs are developed under uncertain environments, as the underlying analyses are carried out on the basis of outdated and unreliable data.

Keywords. Public health, case-based reasoning, decision-making process.

Introduction

The strategic planning of public health programs is one of the most important tasks of governmental organizations devoted to population health in Colombia in order to grant access to health services and a good life quality of the citizens [1]. Main aspects of those programs are the promotion of information and processes for disease prevention in the population, because prevention is cheaper than treatment [2]. However, when diseases appear, the programs must offer initiatives to guarantee the needed care provision to patients suffering from those diseases, especially if they are chronic or communicable [3].

Taking into account the importance of public health programs provided to the population, some tools to make decisions have been developed. These tools facilitate the data analysis and support people who are in charge of designing public health programs. The developments have been focused on providing information about the health issues to improve the quality of the decisions performed and to increase the efficiency and effectiveness of the programs designed. The existing tools for

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supporting public health decision makers do not provide the information needed for analysis, interpretation, and reasoning to detect risk factors, changes in health behavior, and outbreaks [4].

This article describes the definition of a Case-Based Reasoning Model to support the decision-making process in public health. This proposed model reuses the experience gathered in similar cases conducive to offer analytic information about a new Public Health problem to decision makers. The scheme described by the model is intended to mitigate the problems generated by the lack of experience, analysis capacity, and knowledge on the one hand, and difficulties to perform an analysis with outdated health data on the other hand.

1. Methods

In order to develop the model, the decision-making processes, as well as the personnel responsible for the definition of health priorities of the population were identified. The proposed model aims at enriching the decision-making process by reusing historical data. This way, the decision makers will be empowered to collect analytical information during their analysis for predicting future scenarios of health issues, and identifying new behavior patterns regarding population's health priorities. The proposed model defines a set of components and phases that guide decision-making in public health, starting from the analytical information that is gathered from the historical data to describe the behavior of the population.

1.1. Current Process of Decision-Making in Public Health

Currently, the organizations responsible for the protection of the population's health in Colombia work under a basic scheme of decision-making as shown in Figure 1. From source information reporting about changes in the population's behavior and the resulting effect on its health, decisions are made and interventions are applied over the population [2]. In most of the cases however, the changes in behavior are only noticed, if well-known health indicators are monitored, or if their effects raised so massively that the medical care capacity of the health centers has been exceeded. Considering this, the decision-making currently used is based on control programs and the mitigation of interventions instead of prevention programs.

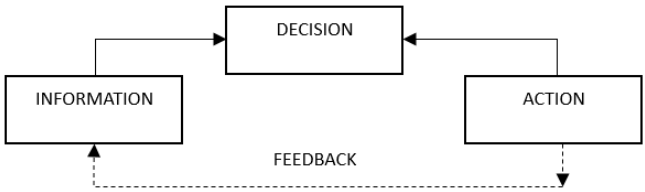

Figure 1. Decision-making process [5].

1.2. Case-Based Reasoning in Public Health

The stages of the cycle described by the Case-Based Reasoning (CBR) methodology [6] fit into the decision-making scheme Information-Decision-Action, used during the

identification of priorities of public health in Colombia. In light of the data that describe the historical behavior of health issues, the CBR cycle represented in Figure 2, allows to obtain data useful for the timely identification of behavior changes in the population. The decision makers make decisions and provide health services to the population, based on this information. Finally, this process is periodically repeated.

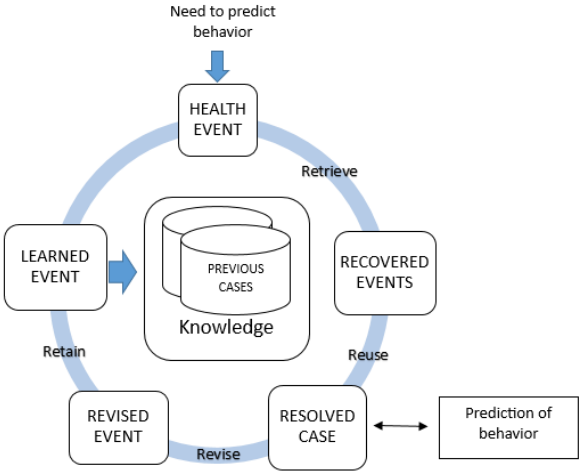

Figure 2. CBR in Public Health

2. Proposed Case-Based Reasoning Model

Figure 3 describes the proposed Case-Based Reasoning Model.

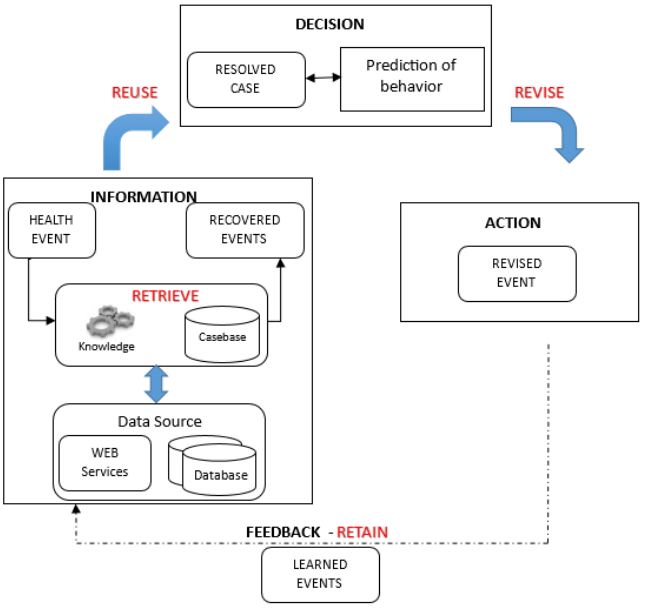

Figure 3. CBR model

The model strengthens the scheme of decision-making that is currently followed through analytic information generated from historical data that describe the behavior of health issues. In addition, the model considers the integration of alternate data sources that contribute to describing the behavior of a health issue in a better way (e.g. socioeconomic, climatic, and geographic location data). These sources are currently not taken into account by the decision makers since the available computing tools do not support their integration into processes of search and analysis. The different components of the model are described in Section 2.1. Following, in Section 2.2, a prototype implementation of the model is described.

2.1. Model Components

2.1.1. Information

The effectiveness of the decision-making model Information-Decision-Action is related to the quantity and quality of information available during the decision-making process. As it has been shown however, the current decision-making process in public health realized in Colombia is supported by limited computing tools that impede personnel to get the most from the historical data of health issues in order to provide useful and timely information [4]. Taking into account the aforementioned considerations, the model specifies a set of elements to strengthen the information component within the decision-making process in public health.

Now, considering that the decision-making process in public health requires the association of different contexts in order to understand the behavior of health issues, this model defines a case structure for health issues from a set of values that can be associated to instances of an ontology, as shown in Figure 4.

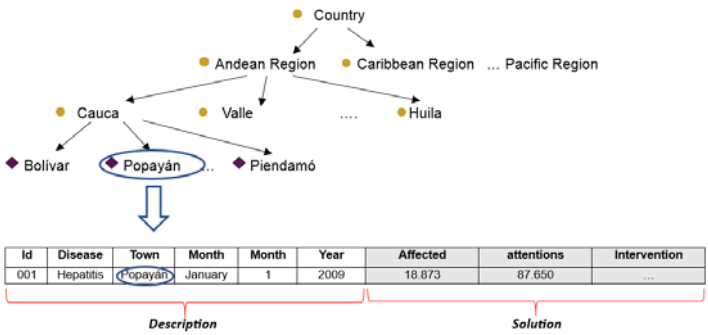

Figure 4. Example of case representation

2.1.1.1. Case Representation

The representation of each case uses the information that describes the occurrence of the health issue. Each case is stored in a case base, following the structure: Case = Problem Description + Solution. The feature vector stores the values associated to the Problem Description (D) and the Solution (S). Each characteristic considered in D is a variable that describes the problem and is stored in the feature vector. The elements of S represent the solution to the problem, in this case the incidence of the health issue and the number of visits. It can also include a field to recommend health interventions for the given behavior. Thus, it will be able to predict a behavior and obtain suggestions to solve the problem.

The selected features to describe the description of cases are: ID, Disease, Month, Consecutive Month and Year. The characteristics that describe the solution are: ID, number of affected, number of attentions and Interventions.

2.1.1.2. Recovery Phase

For the recovery phase, the model proposes the use of a similarity function that allows users to search in the case base for those cases that might show a high degree of similarity with the health issue under consultation.

k-Nearest Neighbors Algorithm (KNN)

The KNN algorithm allows users to search in the case base the K cases that can be more similar to the new case. In order to do so, it uses the similarity function with the aim of assessing the differentiations of the new cases and all the cases existing in the case base. The k case that could be more similar will be used to solve the new case.

Given that the features used to describe cases can be instances of ontologies, the similarity function defines a function to compare each feature according to content. Therefore, the sum of the differences of all the features represents similarity function.

2.1.1.3. Data Source

The module data source integrates data from external sources and own databases to feeding and/or updating the case base and the knowledge base (from which projection of health issues are searched). For the definition of this module, the specification of web services was considered to search data from external or own sources. By that way, the complexity produced during the communication of data from systems which have been designed using different technologies and security protocols can be reduced.

2.1.2. Decision

In the decision component, the decision makers use the solution generated to determine the priority of the health issue and the interventions that have to be applied over the population. This allows individuals to reuse historical data that describe the behavior of the health issues when solving of new problems.

2.1.2.1. Reuse Phase

In the reuse phase, the solution for a new problem is built. Here, the projection of a health issue from which its future behavior is required to anticipate is calculated. The solution uses the outcome of recovered cases in the component information in order to generate the solution for the new problem (the behavior that needs to be known). By an adaptation function, the remembered solutions of similar cases are adjusted to solve the new problem.

Adaptation Function

The adaptation function, in charge of solving the new case by using the remembered solutions of similar cases, is based on the degree of similarity between the new case and the recovered cases. That way a weighting factor is created that allows individuals to give more importance to the solution of similar cases. Since the recovered k cases considered for the creation of a solution to the new problem exhibit different weighting factors, some recovered cases are closer to the new case and others are away because of the mechanisms exploited by the KNN algorithm. The adaptation function is defined by the Formula 1.

$$Solution = similarity_1 * Affected + similarity_2 * Affected + \cdots + similarity_k * Affected \quad (1)$$

2.1.3. Action

The action component is in charge of applying the decisions that have been defined in the decision component. The component describes the way the decisions applied in population health will be documented for being considered in future recommendations. This is due to the fact that the Information-Decision-Action model considers that the actions applied can generate feedback, which in turn becomes new information that will serve to support the new decisions.

The feedback process specified within the proposed model gets an input defined by the actions or interventions of public health that will be applied. Once they are applied, results will be generated to become the output of the process. The analysis of the results obtained after the application of actions carried out by the decision makers allows to learn from failures or successes after the decisions have been made. So, those mistakes won't be repeated in the future; on the contrary, right decisions will be reused.

2.2. Case Based Reasoning System to Define Priorities of Public Health

According to the defined model, a prototype was created by using the case-based reasoning framework jColibri [7]. The prototype grants users to search the behavior of health issues in a given time period. They also permit them to update the case base and knowledge base. Throughout the framework the structure and case base are described and implemented. In addition, the mechanisms used to revise and retain the cases in the case base are described and implemented. Figure 5 presents the system architecture of the prototype.

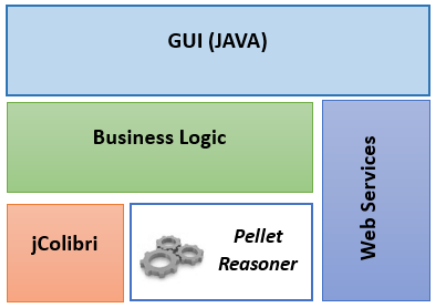

Figure 5. System architecture.

Figure 6 demonstrates a screenshot of the application, showing how the system is able to predict the future behavior of an event in the genitourinary system, based on previously retrieved cases.

```
Retrieved cases:
[Description: [2010 , CIE10_E1 , caso208 , 24 , Colombia$Pais , 12]][Solution: [46225 , 151745 , caso208]]
[Description: [2010 , CIE10_E2 , caso199 , 23 , Colombia$Pais , 11]][Solution: [61682 , 172809 , caso199]]
[Description: [2010 , CIE10_E3 , caso190 , 22 , Colombia$Pais , 10]][Solution: [85912 , 219171 , caso190]]
_____
CIE10 DISEASES OF THE GENITOURANRIO SYSTEM
SOLUTION: Affected population: 64606.333333333336
SOLUTION: Amount of attention: 185968.67067183324
```

Figure 6. Example of a cases prediction.

A dataset was selected to test the system's accuracy in predicting health events behaviors. The data set was used to apply n-folds cross validation. The evaluation performed determined an 88.09% accuracy. The data used in the evaluation were

extracted from the Data Warehouse SISPRO according to case representation. SISPRO is used by the Ministry of Social Protection of Colombia to store and publish historical data of the events of Health.

3. Discussion

Decision making is a task influenced by the capacity of analysis and the knowledge of the individual who singles out the best choice, because it includes the selection of an alternative among different options [8]. In public health, this process is exposed to the subjectivity of the person in charge of making decisions. In several cases and due to the lack of updated and reliable information, the decisions are made intuitively either according to the experience or based on personal opinions. Considering the importance of right decisions in public health for the care of the population, the current process must be strengthened with the purpose of increasing the amount of analytical information that describes priorities for population health. Today, some information systems support analysis tasks during decision making processes [4]. However, these systems have not been developed according to the real needs of users. Moreover, some works can be found in the literature on systems that support decision making for specific health events; however these have not been tested in a real context [9][10][11].

In summary, a case-based reasoning model is proposed to support the decision making of public health. By using the principles of the CBR methodology, the decision makers will be empowered to perform analysis about the data associated to the problems they have to solve, and to use the experience acquired in order to structure the solution to solve other similar problems. Thus, the implementation of the prototype developed in a real environment will allow users to have timely information for early detection of health risks of the population. It will also empower personnel with little experience and knowledge to make decisions about the health of the people.

4. Conclusions

The case-based reasoning model integrates knowledge and analytical information to the process of decision making in public health from different data sources. The integration of the different data sources and knowledge enriches, and increases the reliability of, the analytical information gathered since generally relevant data about events of Health and behavior are not considered by the difficulty of processing and analysis that it represents for decision makers.

By the proposed model, the limitations identified in the current process of decision making in public health are mitigated. The availability of analytical information will increase the probability of success of the decisions made in an environment with outdated information about health issues, unreliable data and analysis, little experience, and low analysis capacity of decision makers.

The article describes in detail how the CBR model supports the timely identification of health needs of the population through the reuse of data that describe the historical behavior of health issues. This is a significant contribution to the design and planning of public health programs, as health care and life quality of the population depend on the success of the health interventions applied. As a further study, we plan to

evaluate the impact of prototypes for the identification of health needs of the population.

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