A Multigranular Hierarchical Linguistic Model for Pharmacy and Therapeutics Committee

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Abstract

The pharmacy and therapeutics committee is one of the most important clinical commissions in Hospital environments. Its main function is the selection and evaluation of medicaments and therapies that should shape the hospital's pharmaceutical guide according with World Health Organization recommendations. These decision problems requires considering multiple evaluation aspects and criteria where different people are involved with different roles, valuations and preferences with the aim of analyzing a great number of factors and characteristics from a huge number of resources with imprecise assessments. We propose to manage this evaluation environment a multigranular hierarchical linguistic model to help the pharmacy and therapeutics committee in its decision problems.

Keywords: Group decision making, medical decision support systems, linguistic approach, multigranular information, majority operators.

1 INTRODUCTION

The decision process for therapies and drug selection is developed by one of the most important clinical commission in a Hospital: the pharmacy and therapeutics committee. Usually, this committee is composed by the pharmacy department head, the medical director, doctors of different departments (Oncology, Haematology, Emergency, Intensive care, Internal Medicine and Infectious Diseases), and primary care pharmacist of the health area. This commission represents a set of experts involved in decision problems to develop the management health strategy of a hospital area. This decision making considers different criteria as pharmacotherapeutical, economics, efficiency and safety; processing complex information to make decisions about the inclusion/exclusion of therapies and drugs in a Hospital [1, 9].

According to World Health Organization (WHO), the pharmacy and therapeutics committee works in an environment which is a continuous and multidisciplinary process which should be based on the efficiency, safety, quality and costs to have a rational use of the health resources [15, 16]. Based on methodology used by the WHO, hospitals have developed their own essential drug lists, available therapies and health strategic which are supposed to be reviewed regularly in order to improve services quality and health resources.

In general, there are several issues involved in these decision problems. The first is the determination of evaluation aspects/criteria and their degrees of importance. This problem often needs to consider multiple evaluation criteria that are in a hierarchy. These evaluation criteria may also have different weights for different situations or medical scenarios. These problems need to extend the normal decision methods to deal with a hierarchical evaluation model with dynamic weights assigned, but also needs to consider the level of evaluators' experience and knowledge in dealing with the model.

Furthermore, some quantitative values can be obtained from specific medical reports and cohort studies as well. To integrate numerical values and linguistic evaluations can more precisely characterize medical quality.

Other issue is how to present and fuse linguistic values given by evaluators to each option under each criterion.

Evaluators may have different points of view about Hospital management, different preferences for different options, and different feelings for the same solution. These differences will directly impact on the final evaluation results. It is very hard to describe the feelings and preferences of evaluators by numbers, since they are often expressed in linguistic terms. Linguistic terms reflect conventional qualitative expressions and uncertainty, inaccuracy and fuzziness of human evaluation, linguistic variables and fuzzy sets techniques are very suitable for dealing with this situation [3, 10]. Therefore, based on the requirements of the hospital, the final ranking can be obtained through suitable fuzzy fusion of these individuals' viewpoints for all criteria.

In this work a multigranular hierarchical decision model is presented to deal with quantitative and qualitative values through linguistic valuations. Also, the problem of uniformity in the criteria valuations is solved using the 2-tuple fuzzy linguistic representation model for computing with words.

The paper is structured as follows: in section 2 the decision environment is determined, the hierarchical model is defined and the representation of information system is introduced; in section 4 the new decision model is presented. Finally, the conclusions are exposed.

2 DEFINITON OF DECISION ENVIROMENT

The process by which health policy, therapies and drugs are selected is critical. It provides a framework within which the activities of the hospital area can be coordinated and it should be developed through a systematic process of consultation with all interested parties. In this process the objectives must be defined, priorities must be set, strategies must be developed and commitment must be built. An essential requirements list that is imposed from above will not reflect the needs of the users or be accepted by them.

It is therefore very important that:

i. the process is consultative and transparent;
ii. the selection criteria are explicit;
iii. selection of the therapies and drugs are linked to evidence-based clinical guidelines;
iv. and the clinical guidelines are divided into levels of care, and are regularly reviewed and updated.

This scenario is considered a very complex decision problem, where different people are involved with different roles, valuations and preferences with the aim of analyzing a great number of factors and characteristics from a huge number of resources with imprecise assessments [4, 9, 14].

In these conditions, the information should be easy to obtain, so there must be established mechanisms to express their opinion in terms or expressions more usual to them, avoiding any imposition neither in the way of expression nor the number of values to be used to express themselves.

This brings a double necessity, on the one hand, to establish tools in the decision process that allow operating with the linguistic information, and, on the other hand, to use a methodology able to make a fusion process with information represented in different expression scales (multigranular linguistic information).

Figure 1 shows the process, a group of evaluators provides their opinions on a set of options using a hierarchical model. The weights of all aspects and criteria are determined based on the features of the available therapies, drugs, and medical scenarios. A weight described by a linguistic term is assigned to each evaluator. A data fusion method will be necessary to fuse all these data from decision hierarchy to obtain a final ranking.

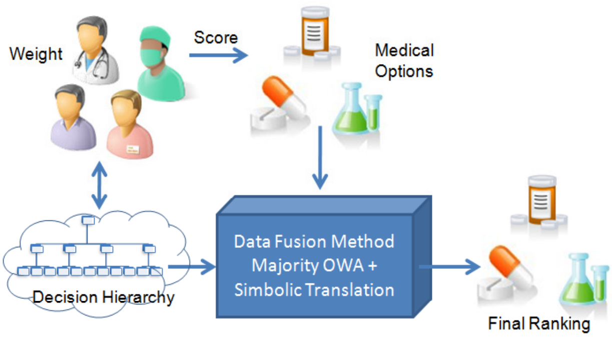

Figure 1: Representation of the decision environment.

2.1. MODEL SCHEME

The hierarchical model structure developed for the decision and evaluation problem in the pharmacy and therapeutics committee is based on two levels:

I. The first level represents four main abstract attributes based on methodology used by the WHO; e.g. efficiency, adequacy, clinical efficacy, and safety.

II. The second level represents the decomposition results of related aspect of the previous level, e.g. cost, budget impact, incremental cost-effective, etc. These criteria are more concrete evaluation attributes of each option and are determined by Pharmacy and Therapeutics commission according to quality standards and norms of national health organization.

In Figure 2 the hierarchy developed for the decision model is shown for standard evaluation.

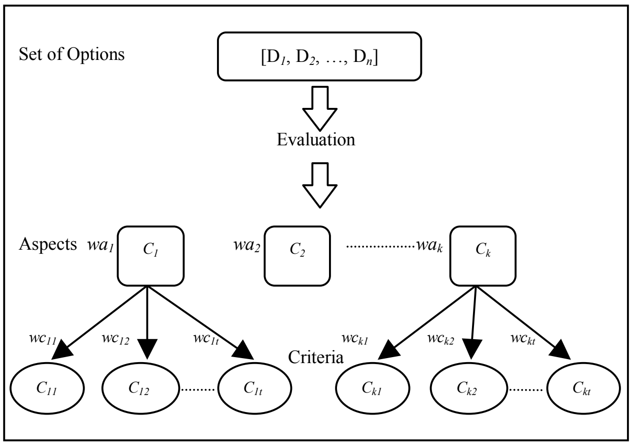

Figure 2. The hierarchical model.

2.2. USE OF MULTIGRANULAR LINGUISTIC INFORMATION

The main aim of establishing the linguistic descriptors of a linguistic variable is to supply the user with a few words by which he can express his information needs [8, 10, 17]. Hence the burden of qualifying a qualitative concept is eliminated. The fuzzy linguistic approach represents qualitative aspects as linguistic values by means of linguistic variable [5, 8, 10].

In order to accomplish this objective an important aspect to analyze is the "granularity of uncertainty", i.e. the level of discrimination among different counts of uncertainty. The cardinality of this term set must be small enough so that it does not impose useless precision on the users and it must be rich enough in order to allow a discrimination of the assessments in a limited number of grades. Typical values of cardinality used in the linguistic models are odd ones such as 7 or 9 with an upper limit of granularity 11 or no more than 13 where the mid term represents an assessment of "approximately 0.5" and with the rest of the terms being placed symmetrically around it [2].

In the pharmacy and therapeutics committee the decision makers must be able to make their evaluation using their own expression domain for the weights and evaluation values. It is needed to determine the level of fuzziness, that is, the granularity of the labels, and to establish the semantic for the linguistic values.

To work with multigranular information the 2-tuple fuzzy linguistic representation model was presented in [6, 7], where different advantages of this approach are shown to represent the linguistic information over classical models.

The linguistic information is represented by means of 2-tuples (r_i, α_i), $r_i \in S$ and $\alpha_i \in [-0.5, 0.5)$. S is the set of linguistic terms, r_i represents the linguistic label centre of the information and α_i is a numerical value that represents the translation from the original result β to the closest index label in the linguistic term set (r_i), i.e., the symbolic translation. This linguistic representation model defines a set of functions to make transformations among linguistic terms, 2-tuples and numerical values [6, 7].

A linguistic hierarchy is a set of levels, where each level is a linguistic term set with different granularity to the rest of levels of the hierarchy. Each level belonging to a linguistic hierarchy is denoted as $L(t, n(t))$, where t is a number that indicates the level of the hierarchy and $n(t)$ is the granularity of the linguistic term set of the level t. The levels belonging to a linguistic hierarchy are ordered according to their granularity. A graphical example of a linguistic hierarchy is shown in Figure 3.

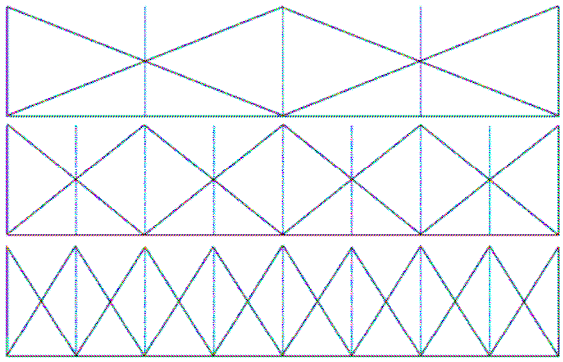

Figure 3. Linguistic hierarchy of 3, 5 and 9 labels.

From the above concepts, we shall define a linguistic hierarchy (LH) as the union of all levels t.

$$LH = \bigcup_t l(t, n(t)) \qquad (1)$$

To build a linguistic hierarchy it must be taken into account that its hierarchical order is given by the increase of the granularity of the linguistic term sets in each level. Then the definition of S is extended to a set of linguistic term sets, $S_n(t)$, each term set belongs to a level of the hierarchy and has a granularity of uncertainty $n(t)$.

$$S^{n(t)} = \left\{ s_0^{n(t)}, \ldots, s_{n(t)-1}^{n(t)} \right\} \qquad (2)$$

Generically, the linguistic term set of level $t + 1$ is obtained from its predecessor as

$$L(t,n(t)) \rightarrow L(t+1, 2\cdot n(t)-1) \qquad (3)$$

The main problem for aggregating multigranular linguistic information is the loss of information produced in the normalization process. To avoid this problem, we shall use linguistic hierarchies term sets as multigranular linguistic contexts, but also we need transformation functions among the linguistic terms of the linguistic hierarchy term sets that carry out these transformation processes without loss of information.

The transformation function from a linguistic label in level t to a label in level $t + 1$, satisfying the linguistic hierarchy basic rules, is defined as

$$TF_{t'}^{t}(s_i^{n(t)}, \alpha^{n(t)}) = \Delta\left(\frac{\Delta^{-1}(s_i^{n(t)}, \alpha^{n(t)})\cdot(n(t')-1)}{n(t)-1}\right) \qquad (4)$$

The combination of 2-tuples and linguistics hierarchies allow us to fusion information without loss of information working with different expression domain.

2.3. LINGUISTIC OPERATOR

To solve the aggregation problem the operator must be capable of computing with words in the decision making process. Also, it must work with vague evaluations moved from the natural language to fuzzy terms or linguistic variables.

In order to add the information in the evaluation process the linguistic majority OWA operator LAMA will be used, because this operator is adapted for computing with words and is able to synthesize linguistic information in decision making environments producing results with a semantic of majority [11, 12, 13].

The LAMA operator is a mapping function $F : R^n \rightarrow R$ that has associated a weighting vector $W = [w_1, w_2, \ldots, w_n]$.

Where $w_i \in [0,1]$ and $\sum_{i=1}^{n} w_i = 1$.

$$LAMA(a_1, a_2, \ldots, a_n) = b_1 \otimes w_1 \oplus b_2 \otimes w_2 \oplus \ldots \oplus b_n \otimes w_n \qquad (5)$$

with b_j is the *jth* largest element of the a_i, $\oplus$ is the sum of labels and $\otimes$ is the product of a label by a positive real.

The weight used in the LAMA operator is usually calculated from the majority process and importance function described in [12].

$$w_i = f_i(b_1, \ldots, b_n) = \frac{\gamma_i^{\delta_{\min}}}{\theta_{\delta_{\max}} \cdot \ldots \cdot \theta_{\delta_{\min}}} + \ldots + \frac{\gamma_i^{\delta_{\max}}}{\theta_{\delta_{\max}}} \qquad (6)$$

where

$$\gamma_i^k = \begin{cases} 1 & \text{if } \delta_i \geq k \\ 0 & \text{otherwise} \end{cases} \qquad (7)$$

and

$$\theta_i = \begin{cases} (\text{number of item with } \delta \geq i) + 1 & \text{if } i \neq \delta_{\min} \\ \text{number of item with } \delta \geq i & \text{otherwise} \end{cases} \qquad (8)$$

The majority operators aggregate in function of δ_i that generally represents the importance of the element *i*. The calculation method for the value δ_i is independent from the definition of the majority operators.

3 A MULTIGRANULAR HIERARCHICAL LINGUISTIC MODEL FOR PHARMACY AND THERAPEUTICS COMMITTEE

To handle the above decision problem this paper defines a multigranular hierarchical linguistic model. This method applies fuzzy sets techniques to deal with linguistic terms used in the weights of aspects and criteria, the weights of experts and the evaluation scores given by evaluators. It can integrate human linguistics values with quantitative parameters to calculate the relevance degrees. Finally a fusion technique is applied to rank all options.

The evaluation model is composed of five steps on two levels.

Level 1: Determine the decision scenario.

1. *Determine the expression of evaluators and linguistic hierarchies.*

   Suppose an evaluation group with m (m >= 1) evaluators:

   $$E = \{e_1, e_2, \ldots e_m\}$$

   A set of n (n >= 1) samples to evaluate:

   $$D = \{D_1, D_2, \ldots, D_n\}$$

Also, a two-level evaluation model, as shown in Figure 2, has k aspects and k_t criteria.

$$C = \{C_1, C_2, \ldots, C_k\}$$

$$C_k = \{C_{k1}, C_{k2}, \ldots, C_{kt}\}$$

2. *Determine importance degrees of evaluators.*

Evaluators play different roles in the pharmacy and therapeutic commission and have different degrees of influence on the ranking of a set of drugs. The weights are determined through discussions in the group or assigned by a higher management level before the evaluation process.

$$We = \{we_1, \ldots, we_m\}$$

3. *Determine the weights of evaluation aspects and criteria for each expert.*

Let $WA = \{wa_1, wa_2, \ldots, wa_k\}$ be the weights of the aspects in the evaluation model. For each aspect C_k, let $WC_k = \{wc_{k1}, wc_{k2}, \ldots, wc_{kt}\}$, be the weights for the set of criteria on level 2 of Figure 2.

In this level all weights are described by a set of linguistic terms. The evaluators can use their own expression granularity through the 2-tuple linguistic model and the symbolic translation.

At the end of this step a set of individual weighted hierarchy for each expert is obtained.

$$H = \{H_1, \ldots, H_m\}$$

Level 2: Aggregation of values

4. *Individual evaluation.*

The relevance degree of each option on each criterion is set up based on two different kinds of evaluations, i.e. the subjective evaluations and objective values. Subjective evaluations are obtained from human evaluators; while objective values are collected through specific medical reports and/or cohort studies.

For objective values, the relevance degree is obtained using a transformation from numeric values into linguistic terms through 2-tuples functions.

The opinion values are aggregated for each evaluation aspect using the LAMA operator. In this case, the weight of each criterion represents the value of the importance function of the majority process [6, 7].

Following the aspects are aggregated in the same way with the OWA operator. Finally the obtained result represents the individual evaluation of each expert over each item.

$$IV_m = (IV_1^m, IV_2^m, \ldots, IV_n^m)$$

5. *Group evaluation.*

The final group value is obtained through the majority process and the information of the individual evaluation.

The aggregation process applies the OWA operator using the importance degree of evaluators of step 2 as majority importance function.

$$GV_n = LAMA(IV_n^1, IV_n^2, \ldots, IV_n^m) \quad (9)$$

At the end of the process all options are ordered by the linguistic aggregation value and can be considered for the final committee decision in the particular medical scenario.

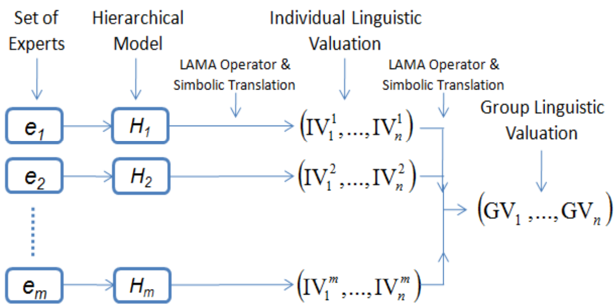

Figure 4. Representation of decision model.

4 CONCUSIONS

The pharmacy and therapeutics committee makes important issues in Hospital management. This commission is involved in complex decision situation in which criteria are within a hierarchy structure and both subjective and objective data are considered. In particular, these data are often vague rather than in crisp numbers and in different dimensions.

We have presented a multigranular linguistic decision model to help the pharmacy and therapeutics committee in management problems. A decision hierarchy have been developed for health environments using two levels which join the WHO and national health organization recommendations. This model uses the advantages of the 2-tuples fuzzy linguistic representation model and majority OWA operator to improve a natural language system to experts. It can integrate human linguistics values with quantitative parameters to calculate the relevance degrees of solutions and help and support the pharmacy and therapeutics committee decisions.

This decision system is being tested in the Hospital Universitario Virgen de la Victoria from Málaga, Spain.

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