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Definition of a Consensual Drug Selection Process in Hospital Universitario Virgen de la Victoria

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***Abstract*—The adequate and rational drugs selection is considered one of the main objectives in Hospital scenarios. The drugs evaluation for their inclusion in the Hospital Pharmacy 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. This paper presents a consensus decision model combining quantitative information with fuzzy multigranular linguistic information to support the selection of drugs for their inclusion in the Hospital Universitario Virgen de la Victoria from Málaga.**

Keywords-decision making; consensus process; computing with words; linguistic varables; fuzzy sets.

I. Introduction

Nowadays, drugs play a main role in health care; for this reason, the consensual drugs selection problem is considered one of the most important and complex processes in health environment. For example, in a Hospital of the importance of H. U. Virgen de la Victoria from Málaga, around 800 of the 3500 available active pharmaceutical ingredients are usually handled, choosing from over 23.000 different drugs trademarks.

This decision problem involves different criteria to be considered (pharmacotherapeutical, economics, efficiency, safety...) processing complex information to make decisions about the inclusion/exclusion of medicines in the Hospital [1, 8].

According with World Health Organization (WHO), the selection of drugs is a join, continuous and multidisciplinary process which should be based on the efficiency, safety, quality and costs of drugs to have a rational use of them [15, 16]. Based on methodology used by the WHO, hospitals have developed their own essential drug lists which are supposed to be reviewed regularly in order to improve drug supply.

In general, there are several issues involved in drugs selection. 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 products or active pharmaceutical ingredients.

Drug selection not only needs to extend the normal consensus 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 objective measure values of drugs, such as absolute risk reduction or number to treat, can be obtained from specific medical reports and cohort studies as well. To integrate exact measure values with human evaluation values can more precisely characterize a drug's medical quality.

Other issue is how to present and fuse linguistic values given by evaluators to each drug under each criterion. Evaluators may have different points of view in the area of Hospital management, different preferences for different drugs, and different feelings for the same active pharmaceutical ingredients. 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 quantitative expressions and uncertainty, inaccuracy and fuzziness of human evaluation, linguistic variables and fuzzy sets techniques are very suitable for dealing with this situation [2,10]. Therefore, based on the requirements of the hospital, the final ranking of a set of drugs can be obtained through suitable fuzzy fusion of these individuals' viewpoints for all criteria.

In this work a multicriteria fuzzy consensus model is presented to deal with quantitative and qualitative values through linguistic valuations. Also, the problem of uniformity in the criteria valuations in the drugs selection 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 scenario is defined and the hierarchical model developed in the Hospital Universitario Virgen de la Victoria is presented; in section 3 the representation of

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information system, linguistic operators and consensus control are introduced; in section 4 the new model for consensual evaluation of drugs is presented. Finally, the conclusions are exposed.

II. Drugs Selection Problem

Bodies responsible for selecting drugs for formularies or medicines lists face increasingly difficult decisions about which drugs can be funded. A variety of information about a new therapy must be evaluated in making drug selection decisions. While clinical efficacy, safety and acquisition costs are important, these are not the only factors considered by decision-making committees. Some factors may be context specific, i.e. relevant to hospital, area or national level decision-making.

In the process of evaluation of drugs, a group of evaluators provides their preferences on a set of samples of available drugs for the Hospital. The weights of all aspects and criteria are determined based on the features of the drugs and medical scenario. A weight described by a linguistic term is assigned to each evaluator. A data fusion method and consensus control will be necessary to fuse all these data to obtain a final ranking of these samples of medicaments.

A. *The Pharmacy and Therapeutics Commission*

The decision process for drug selection is developed by one of the most important clinical commission in a Hospital: the Pharmacy & Therapeutics Commission. This commission represents the set of experts involved in the consensus problem. In the Hospital Universitario Virgen de la Victoria this is composed by:

- Head of Pharmacy department.
- Medical director.
- Doctors of different departments: Oncology, Haematology, Emergency, Intensive care, Internal Medicine and Infectious Diseases.
- Pharmacist of primary care of the health area.

B. *Decision Hierarchy*

The hierarchical model developed for drugs evaluation in the Hospital Universitario Virgen de la Victoria is based in two levels. The first level represents four main abstract attributes of the drugs: efficiency, adequacy, clinical efficacy, and safety. The second level represents the decomposition results of related aspect of the previous level: Cost, budget impact, and incremental cost-effective; dosage forms and drug administration; adverse events, watching drug, contraindications and interactions; absolute risk reduction and number to treat. These criteria are more concrete evaluation attributes of drugs and are determined by pharmacy and therapeutics commission according to quality standards and norms of national health organization and WHO.

In figure 1 the hierarchy developed for the decision model is shown for standard evaluation.

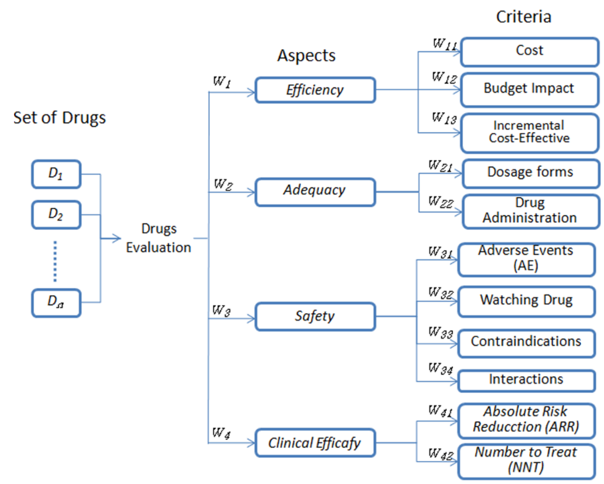

Figure 1. The hierarchical model for drugs evaluation.

III. Decision Tools

The drug evaluation 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 [3, 8, 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 one hand, to establish tools in the decision process that allow to operate with the linguistic information, and, on the other hand, to use a methodology able to make a consensus process with information represented in different expression scales (multigranular linguistic information).

A. *Information Representation. Linguistic Variables*

Actually the concept of linguistic variables is widely used in those decision making problems with imprecise assessments given in a linguistic way for some of its elements [4, 7, 10]. In that case a better approach may be to use linguistic assessments instead of numerical values [7, 9, 17]. The fuzzy linguistic approach represents qualitative aspects as linguistic values by means of linguistic variable.

To work with multigranular information the 2-tuple fuzzy linguistic representation model was presented in [5, 6], 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 [5, 6].

Let $s_i \in S$ be a linguistic term, then its equivalent 2-tuple representation is obtained by means of the function θ as:

$$\theta : S \rightarrow (S \times [-0.5, 0.5)) \quad (1)$$

$$\theta(s_i) = (s_i, 0) / s_i \in S \quad (2)$$

Let $\beta \in [0, g]$ be a value supporting the result of a symbolic aggregation operation, then the 2-tuple that expresses the equivalent information to β is obtained with the following function:

$$\Delta : [0, g] \rightarrow S \times ([-0.5, 0.5)) \quad (3)$$

$$\Delta(\beta) = \begin{cases} s_i & i = round(\beta) \\ \alpha = \beta - i & \alpha \in [-0.5, 0.5) \end{cases} \quad (4)$$

where round is the usual operation, s_i has the closest index label to β and α is the value of the symbolic translation.

There is always a Δ^{-1} function, such that, from a 2-tuple it returns its equivalent numerical value $\beta \in [0,g]$.

$$\Delta^{-1} : S \times [-0.5, 0.5) \rightarrow [0, g] \quad (5)$$

$$\Delta^{-1}(s_i, \alpha) = i + \alpha = \beta \quad (6)$$

The multigranular information is represented through the linguistic hierarchical structures which are able to transform linguistic terms with different granularity of uncertainty and/or semantics into the same domain expression without missing of information. These linguistic structures allow us to improve the precision in the aggregation processes of multigranular linguistic information.

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.

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

$$LH = \bigcup_t l(t, n(t)) \quad (7)$$

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 $n(t)$.

$$S^{n(t)} = \left\{ s_0^{n(t)}, \ldots, s_{n(t)-1}^{n(t)} \right\} \quad (8)$$

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

$$L(t, n(t)) \rightarrow L(t+1, 2 \cdot n(t) - 1) \quad (9)$$

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

$$TF_{t'}^{t}(s_i^{n(t)}, \alpha^{n(t)}) = \Delta\left(\frac{\Delta^{-1}(s_i^{n(t)}, \alpha^{n(t)}) \cdot (n(t') - 1)}{n(t) - 1} \right) \quad (10)$$

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

B. *The Linguistic Aggregation Operator*

To solve the aggregation problem in the drugs selection, 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 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 semantics of majority [11, 12, 13].

The LAMA operator is a mapping function $F : R^n \rightarrow R$ that has associated a weighting vector $W = [w_1, w_2, \ldots, w_n]^T$ where and $\sum_{i=1}^{n} w_i = 1$.

$$LAMA(a_1, a_2, \ldots, a_n) = b_1 \otimes w_1 \oplus b_2 \otimes w_2 \oplus \ldots \oplus b_n \otimes w_n \quad (11)$$

with b_j is the j^{th} 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].

$$w_i = f_i(b_1,\ldots,b_n) = \frac{\gamma_i^{\delta_{\min}}}{\theta_{\delta_{\max}} \cdot \ldots \cdot \theta_{\delta_{\min}}} + \ldots + \frac{\gamma_i^{\delta_{\max}}}{\theta_{\delta_{\max}}} \quad (12)$$

where

$$\gamma_i^k = \begin{cases} 1 & if\ \delta_i \geq k \\ 0 & otherwise \end{cases} \quad (13)$$

and

$$\theta_i = \begin{cases} (number\ of\ item\ with\ \delta \geq i) + 1 & if\ i \neq \delta_{\min} \\ number\ of\ item\ with\ \delta \geq i & otherwise \end{cases} \quad (14)$$

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.

C. Consensus Control

The consensus process is defined as a dynamic and iterative group discussion process, coordinated by a moderator helping experts to bring their opinions closer. If the consensus level is lower than a specified threshold the moderator would urge experts to discuss their opinions further in an effort to bring them closer. Otherwise, the moderator would apply the selection process which consists in obtaining the final solution to the problem from the opinions expressed by the experts. As part of the consensus model, a feedback mechanism substituting the figure of the moderator is given to help experts change their opinions on the alternatives in order to obtain the highest degree of consensus possible. It consists of simple and easy rules generating recommendations in the discussion process [4].

The consensus model develops its activity in three phases: computing consensus degrees, controlling the consensus state and feedback mechanism.

1) Computing consensus degree

The consensus degrees are used to measure the current level of consensus in the decision process. This computation is carried out as follows:

i. For each pair of experts, e_i, e_j ($i < j$), a similarity vector, $SV_{ij} = (sv_{ij}^l)$, is defined where

$$sv_{ij}^l = 1 - \frac{\left|\Delta_{t'}^{-1}(TF_{t'}^t(p_i^l) - \Delta_{t'}^{-1}(TF_{t'}^t(p_j^l)\right|}{n(t')-1} \quad (15)$$

being p_i^l and p_j^l the linguistic valuations of experts *i* and *j* for the option *l*.

ii. A consensus vector, *CV*, is calculated by aggregating all the similarity vectors using the arithmetic mean as the aggregation function

$$cv^l = \phi(sv_{ij}^l) \quad (16)$$

This vector measures the agreement on each alternative amongst all the experts, and cv^l represents the consensus degree on alternatives.

iii. A consensus degree amongst the experts opinion is calculated:

$$cd = \frac{\sum_{l=1}^{n} cv^l}{n} \quad (17)$$

2) Controlling the consensus state

To control the consensus state a minimum consensus threshold, $\gamma \in [0, 1]$, is fixed before applying the consensus model. When the consensus measure, *cd*, satisfies this value, the consensus model finishes. Otherwise, the feedback mechanism is applied. To avoid the lack of convergence in the consensus process, a maximum number of consensus rounds is incorporated.

3) Feedback mechanism

The feedback mechanism provides recommendations to support the experts in changing their opinions.

First we need to obtain proximity measures through the collective linguistic preference relation *Pc*, proximity vector, *Pv*, and proximity global degree, *pd*.

Pc is calculated by means of the aggregation of the set of individual linguistic valuations using the LAMA operator with $\delta_i = 1$(arithmetic mean):

$$pc^l = \underset{i}{LAMA}(p_i^l) \quad (18)$$

PV_i is calculated

$$pv_i^l = 1 - \frac{\left|\Delta_{t'}^{-1}(TF_{t'}^t(p^l) - \Delta_{t'}^{-1}(TF_{t'}^t(pc^l)\right|}{n(t')-1} \quad (19)$$

where pv_i^l measures the proximity between the preferences on each alternatives , of the expert, e_i, and the group.

And the global proximity degree is

$$pd = \frac{\sum_{l=1}^{n} pv^l}{n} \quad (20)$$

Secondly, the production of advice to achieve a solution with the highest degree of consensus possible is carried out in the following steps.

- Identify the experts and alternatives (*FBA*) that are contributing less to reach a high degree of consensus and, therefore, should participate in the change process.

$$FBA = \{p_i^l \mid pv_i^l < \gamma \text{ and } pd_i < \gamma\} \qquad (21)$$

- Determine the direction of change to be applied to the preference assessment:

$p_i^l > pv_i^l \rightarrow e_i$ should decrease the assessment associated to the alternative l.

$p_i^l < pv_i^l \rightarrow e_i$ should increase the assessment associated to the alternative l.

IV. Decision Model for Consensual Selection of Drugs

To handle the above decision problem, this paper proposes a fuzzy multi-criteria consensus model. This method applies fuzzy sets techniques to deal with linguistic terms used in the weights of aspects and criteria, the weights of evaluators and the evaluation scores given by evaluators. It can integrate human linguistic values with quantitative measure parameters to calculate the relevance degrees of drugs. Finally a consensus and aggregation techniques are applied to rank all options of drugs.

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

Level 1: Determine the decision scenario.

i) Determine the expression of evaluators and linguistic hierarchies.

ii) Determine the consensus degree γ and maximum number of rounds.

iii) Determine importance degrees of evaluators.

iv) Determine weights of evaluation aspects/criteria and the relevance degree of each drug on each criterion.

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

For objective measurement, the relevance degree is obtained using a transformation from numeric values into linguistic terms.

Level 2: Consensus and Aggregation Process

v) Individual evaluation

The criteria 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 δ_i of the majority process.

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 drug.

vi) Consensus Control

The individual evaluation is computed using the consensus control defined in the section 3. While the consensus degree is not accomplished the feedback mechanism indicates the expert's evaluation to change. When the consensus level satisfies the threshold γ, the system goes to next step.

vii) Group evaluation

The group value is obtained through the majority process and the information of the previous step. The aggregation process applies the OWA operator using the importance degree of evaluators of step 2 as majority importance function.

At the end of the process all drugs are ordered by the evaluation value and can be considered for their inclusion in the pharmacy of the hospital.

V. Conclusions

A consensus support system is presented in this paper and implemented to deal with the drugs selection problem. A hierarchy for decision is proposed and a new approach for drugs evaluation is presented. To solve the problem of multigranular information representation the 2-tuples linguistic model is used and the majority OWA operator LAMA is proposed to aggregate the values. Additionally, an advanced approaches allowing to generate recommendations to help experts is described in order to increase the agreement and to reduce the number of experts' preferences that should be changed after each consensus round.

This consensus process can effectively support pharmacy and therapeutics commission in the selecting drugs problems in the Hospital Universitario Virgen de la Victoria from Malaga.

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