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# Conception and Development of a Health Care Risk Management System

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**Abstract.** Problems related to the management of hospital sector‘risk represent without any doubt an important challenge. Nevertheless, the management of those risks for concrete applications poses many problems, among which we quote: the presence of knowledge expressed linguistically by experts, and the handling of subjective information. Thus, in this paper we propose a system based on the Fuzzy Logic approach, helping to predict and do be prepared to the occurrence of an undesirable event. Then thanks to the Fuzzy Logic, we handle problems of the interpretation of the human reasoning and vague information in the Hospital Sector.

**Key words:** Risks, Risk Management, Hospital Sector, Tension, Indicators, Decision Support System, Fuzzy Logic, Java.

## 1. Introduction

The healthcare sector has changed tremendously through recent decades. Hotly discussed issues include technological advances, biomedical innovations, information infrastructure, standards and accreditation, continuous improvement tools, healthcare financing, evidence-based medicine and value-based competition, tension between management and medical roles, tension between national policy and the realities of every-day delivery and continuity in care.

In fact, risk management is defined as the systematic process of identifying evaluating and addressing potential and actual risk [1].So, there is at present in France an emergency plan [2], which is called the “White Plan”, to face a sudden increase of the hospital activity. The “White Plan” is a specific emergency plan which is activated only in case of extreme situations. Then, activating the “White Plan” too frequently makes it incredible; so it becomes imported to minimize its use. In other words we have to minimize the frequency that the hospital is under tension, by anticipating tension cases. For these reasons hospitals show more and more a need to be assisted by Decision Support Systems in order to avoid, anticipate, and reduce risks.

## 2. Related works

Several initiatives illustrate the importance granted to the risk management in the establishments of health, so it is today asked to these establishments to be interested in the tools and the methods of risks management that have been used for several years in the industrial field and to use them in hospital field to try to reach a level of maximal safety [3]. Certain methods were already applied [4] as the method " FMECA " (Failure Modes, Effects and Criticality Analysis) and the method " PRA" (Preliminary Risk Analysis), but we sometimes note problems of compatibility during the implementation or during the follow-up due to the specificities of hospital sector. So, in order to integrate, into daily practice, the management of risks, it’s necessary to be supported by aid-decision making systems. In [5], the authors explain how the information system can contribute to identify, analyse, reduce and prevent the occurence of adverse events. On the other hand, Hospital sector depends deeply on the human reasoning and experience [6], So even Data management systems were implemented in operating room and intensive care units [7,8], systems based on the surveillance of indicators are less numerous and an understanding of the human factors is lacking. Therefore, our interest will be particularly focused on our methodology to anticipate risks in the hospital context by using the Fuzzy Logic to consider the uncertainty and the subjectivity of the information. In [9], the authors propose a system that allows healthcare professionals to define medical alerts from patient and environmental data by using fuzzy linguistic variables.

## 3. Proposed system

Our proposed system, allows taking decisions before being directly confronted with the risk by having a global view of the situation. We notice then, that it is possible to define indicators connected to factors causing tensions, and reflecting the level of tension within the hospital.So our system rely on the concepts of the Fuzzy Logic variables, based on the experts' knowledge using natural language and aims to predict the arrival of an exceptional event by the surveillance of the indicators. The surveillance will be insured by a "Watch Unit". This unit will control the evolution of a number of significant indicators already tested and selected, then, according to the evolution of indicators, will be associated, a level of tension of the hospital. In fact, Fuzzy Logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. A fuzzy logic system consists mainly on three stages[10]: Fuzzification , Inference, Defuzzyfication. So, in order to conceive our Decision Support System we have followed these steps.

### 3.1 Fuzzification

In Fuzzy Logic, we use linguistic variables to facilitate the expression of rules and facts. The Fuzzification comprises the process of transforming values into grades of membership for linguistic terms of fuzzy sets. The membership function is used to associate a grade to each linguistic term.To fuzzify variables we have defined:

- The linguistic variables : The inputs (the indicators) and the output (the decision): their numbers, names, types, and universe of discourse;
- The linguistic values:
  - Five different characteristics for the indicators, which are (Little acceptable, Acceptable, Disturbing, Very disturbing, Strictly unacceptable);
  - Three different tension levels for the decision ( T0 : Normal, T1: Disturbing, T2: High ).
- The membership functions for every input and output : trapezoidal membership functions.

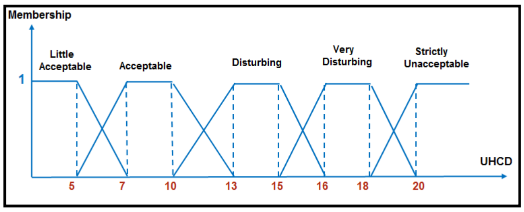



Figure 1: Membership Functions

### 3.2 Dealing with membership functions

Natural language terms are used in fuzzification, and their intervals of variation are modeled by membership functions. But, in practice, one of the problems is to define these functions since they are defined in a subjective way intended to represent expert's conception of the linguistic terms. So, in our work, defining five classes for each indicator with the maximum of precision is not an evident task even for an expert. Then, to ensure the credibility of our results, we were inspired by the Statistic Process Control (SPC), and specifically by the Control Charts to define the borders of our different classes. In fact, The Shewhart Control Chart is a graph of points representing the mean value of samples taken with a given frequency of time (every hour, three times a day, etc.). In our case, since we have the measures taken per day over all the year, we considered the day as the regular interval of measuring, and so the week as a sample, thus we have 52 samples of 7 measures for each indicator. Our Control Charts allow then to visualize the variation of the mean value of the week of the indicators.

$$\overline{\overline{X}} = \frac{1}{m}\sum_{i=1}^{m}\overline{Xi}$$

First of all, we calculate the average of the week: (1)

And the average of the extent (corresponds to the difference between the maximal and the minimal values measured in the same week i ) :

$$\overline{R} = \frac{1}{m}\sum_{i=1}^{m}Ri$$

Then, we calculate limits of control and surveillance: (2)

- Superior and Inferior Limits of control: $LCS = \overline{\overline{X}} + A_c\,\overline{R}$ (3), $LCI = \overline{\overline{X}} - A_c\,\overline{R}$ (4)
- Superior and Inforior Limits of surveillance: $LSS = \overline{\overline{X}} + A_s\,\overline{R}$ (5), $LSI = \overline{\overline{X}} - A_s\,\overline{R}$ (6)

Ac and As two coefficients depending on the samples.We obtain finally for example thi chart:

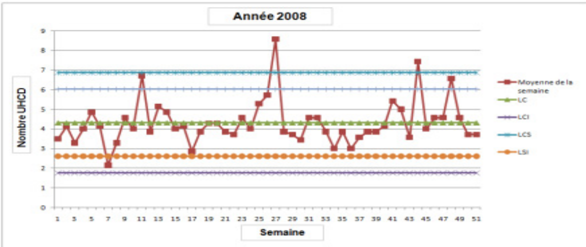



Figure 2: Control Chart

Since the limits of surveillance in the Control Chart permit to pay attention of the operator of a likely problem in the near future, and the limits of control indicate the limits beyond which the process is uncontrolled. By analogy, we defined the borders of our different classes, by using the values of these limits, naturally after the validation of the expert.

## 3.3 Fuzzy Inference

Fuzzy Inference allows calculating the fuzzy output. At first, we define the fuzzy rule base which is composed of a number of fuzzy rules, and used to produce precise output values according to actual input values. Fuzzy Rules take the form IF …THEN …, where conditions and actions are linguistic terms describing the values of input and output variables Then we defined the matrix of rules, which allows establishing the decision by taking into account correlations between indicators.

Table 1: Matrix of Rules.

| A / B | C1 | C2 | C3 | C4 | C5 |
|---|---|---|---|---|---|
| **C1** | T0 | T0 | T1 | T1 | T2 |
| **C2** | T0 | T0 | T1 | T2 | T2 |
| **C3** | T1 | T1 | T1 | T2 | T2 |
| **C4** | T1 | T2 | T2 | T2 | T2 |
| **C5** | T2 | T2 | T2 | T2 | T2 |

C1: Little Acceptable, C2: Acceptable, C3: Disturbing, C4: Very disturbing, C5: Strictly unacceptable;T0 : Normal, T1: Disturbing, T2: High ;A : Indicator 1 ; B Indicator 2.

Then, we have chosen to use the Mamdani Method for the fuzzy inference since it is the most common technique used:

$$\mu_{decision}(y)=\text{Min}\,(\mu_{premise}\,(x_0),\ \mu_{conclusion}\,(y)) \quad (7)$$

So we used the operator "MIN" for the rules conjunction, and the operator "Max" to aggregate rules for the unification of the outputs of all the rules. For this we take the membership function of the consequents and combine them into a single fuzzy set.

## 3.4 Defuzzification

At this final stage we will convert the fuzzy output into a precise numerical value.

The most popular Deffuzification Method is the Center of Gravity (COG) because its solution contains the most of the subjective information. In order to illustrate the basic concepts of our Fuzzy Logic system, we consider this simplified example: If we have :

- Indicator A : Number of the Arrivals to the Emergencies = 73;
- Indicator B : Number of short-term residential units (measured per hour) = 18,5 h.

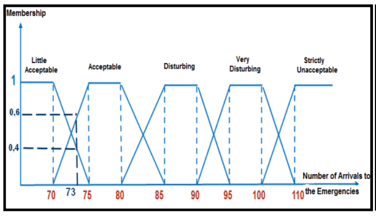


Figure 3 : Indicator (A)

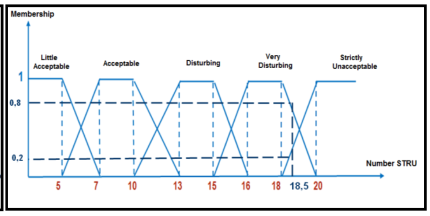


Figure 4: Indicator (B)

We get then 4 possible combinations:

- A is Little Acceptable and B is Very Disturbing ; Or
- A is Little Acceptable and B Strictly Unacceptable;Or
- A is Acceptable and B is Very Disturbing; Or
- A is Acceptable and B Strictly Unacceptable.

Using the Mamadani Method this combinations are transformed into:

- Min(A : Little Acceptable=0.4, B:Very Disturbing =0.8) =0.4;Or
- Min(A :Little Acceptable=0.4, B Strictly Unacceptable=0.2)=0.2;Or
- Min(A:Acceptable=0.6,B:Very Disturbing=0;8)=0.6;Or
- Min(A :Acceptable=0.6,B:Strictly Unacceptable=0.2)=0.2.

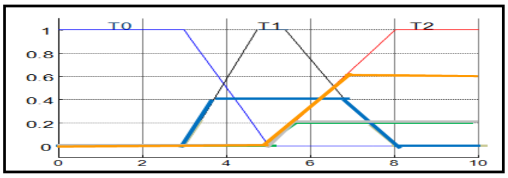


Figure 5 : Mamdani Method

Then we use the operator "MAX" to aggregate rules, and finally the defuzzification using the COG Method.

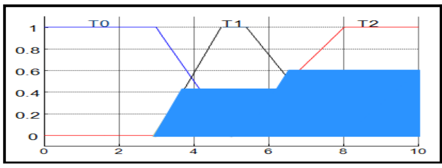


Figure 6 : Rules Aggregation

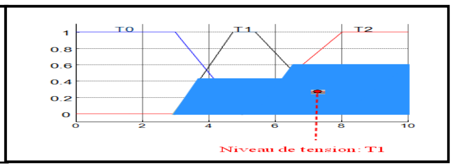


Figure 7 : COG Method

## 3.5 Simulation

The final goal is to have a graphic interface allowing visualizing the level of hospital tension by real-time alerts. We chose to develop our decision support system in language Java for its robustness, its speed, and its performance. The emergencies service of the hospital in our case, knew a state of tension on January 7th, 2009. Then, to estimate the performances of the developed system, we are going to introduce the values measured during this period and register the results and alerts given by our system. So we are going to consider two cases:

- First Case:At first we are going to consider the mean values of two indicators, measured a week before January 7th. We have then :For the first indicator "Number of the Arrivals to the Emergencies ":89.5. For the second indocator " Number of short-term residential units (measured per hour) " :7.5h.

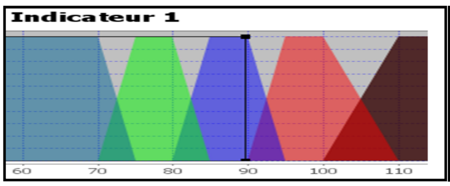


Figure 8 : 1st Case,Indicator 1

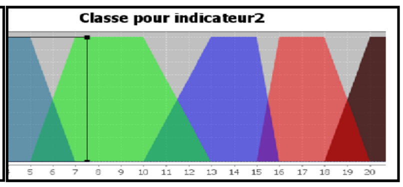
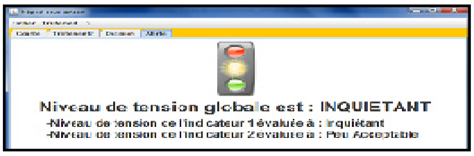


Figure 9 : 1st Case,Indicator 2

Our Decision Support System shows then an orange alert and indicates that:

- The tension level of the indicator 1 is “disturbing”;
- The tension level of the indicator 2 is “little acceptable”.




❖ **Second Case:**

Secondly we are going to test the proposed system with the measured values on the week of January 7th: 95 for the first indicator and 12 for the second indicator.

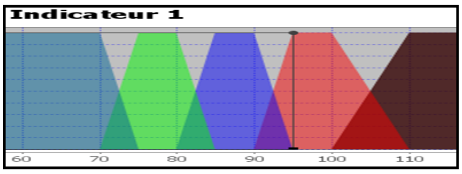



Figure 11 : 2nd Case,Indicator 1

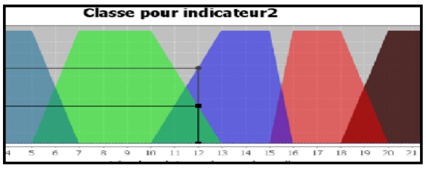



Figure 12 : 2nd Case,Indicator 2

- The first indicator “Number of the Arrivals to the Emergencies “is now in the class " Very Disturbing ".
- The second indicators “Number of short-term residential units ” moves then to the class "Disturbing". Our system shows in this 2nd case, a red alert indicating that the level of the tension within the hospital is “high”. We can conclude that our approach is validated, and that our proposed system anticipates the risks.

## 4. CONCLUSIONS

We were interested, in this work, in the problem of the risk management in hospital sectors.Our solution dedicated to hospitals; consist in creating a decision support system characterized by a big rigor in the manipulation of data to detect exceptional events in order to handle the problem of a hospital under tension.

Besides, we saw the interest of the fuzzy logic as a tool allowing to modelize phenomena approaching the human reasoning.This work opens several perspectives. Indeed it would be interesting to develop more indicators to treat all the aspects of the risks, by using methods of Data Mining to extract indications and information for the surveillance of the different services in the hospital.

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