FUZZY MEASURE ANALYSIS OF PUBLIC ATTITUDE TOWARDS THE USE OF NUCLEAR ENERGY

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(1) INTRODUCTION

It is important to identify the structure of public acceptance or rejection when new technologies are developed and implemented. The structure of attitudes should have the essential attributes and their interrelation. In such a structural analysis the attitudes need to be decomposed into meaningful attributes by a suitable model. However, the data obtained in this type of study may be more or less subjective and fuzzy, and the following problems may be pointed out:

(1) A man does not always have an additive measure such as probability to evaluate fuzzy objects.
(2) The attributes of an object in his evaluation process are not always independent of each other.

In either case a linear model may not be applicable.

This paper is concerned with applying fuzzy measures and fuzzy integrals to analyze public attitude towards the use of nuclear energy.

Probability theory deals with the definition and description of models involving the probability concept. Probability judgements are concerned with repetitive events which have basic similarity. Most applications of probability theory may be interpreted as special cases of random processes. If, as in many games of chance, equal probabilities are assigned to each of the simple events of a given finite fundamental probability set, then the probability of realizing a compound event (success) defined as the union of specified simple events ('favourable' simple events) can be computed as the ratio of the number of favourable simple events to the total number of simple events. It is on the basis of these considerations that probability is deduced by resolving the various outcomes into a number of equipossible alternatives. However, when we apply the term probability to a non-repetitive event or an isolated case, for example, probability of 'Julius Caesar's visit to Great Britain', or probability of a certain country secretly producing nuclear weapons, it is impossible, at any rate in any obvious way, to generate a sequence of trials and thus measure the probability of its occurrence by means of a frequency ratio. We have, therefore, to estimate it by a more or less subjective intuitive appraisal of such evidence as we may have. Since in such cases a universally acceptable quantitative estimate of the degree of our confidence in the statement cannot be given, probability when used in this sense cannot form a part of a scientific assertion in the conventional sense.

To avoid confusion, it is, therefore, better to restrict the use of probability in a scientific sense to repetitive events only and to use the term 'possibility' when we wish to speak of our expectations of non-repetitive events, as suggested in fuzzy set theory. In addition to the probability and possibility measures, belief, credibility, certainty, necessity, plausibility measures, etc. are also introduced as special cases of fuzzy measures.

(2) FUZZY MEASURES

A fuzzy measure of Sugeno is an extended probability measure in one sense, which assumes, in general, only monotonicity without additivity.

Let X be a universal set and $\mathscr{B}$ be a Borel field. Then a set function g defined on $\mathscr{B}$ with the following properties is called a fuzzy measure.

(i) $g(\emptyset) = 0, g(X) = 1$ (boundedness)

(ii) If $A, B \in \mathscr{B}$ and $A \subset B$, then $g(A) \leqslant g(B)$ (monotonicity)

(iii) If $F_n \in \mathscr{B}$ for $1 \leqslant n < \infty$ and a sequence $\{F_n\}$ is monotone (in the sense of inclusion), then $\lim_{n\to\infty} g(F_n) = g(\lim_{n\to\infty} F_n)$ (continuity)

A triplet $(X, \mathscr{B}, g)$ is called a fuzzy measure space, and g is called a fuzzy measure of $(X, \mathscr{B})$.

For applications, it is enough to consider a finite case. Let K be a finite set $K = \{s_1, s_2, ..., s_n\}$ and P(K) be a class of all the subset of K. Then a fuzzy measure g of (K, P(K)) is characterized by the first two properties since the third one implies continuity.

In particular, $g(\{s_i\})$ for a subset with a single element s_i is called a fuzzy density like a probability density. We denote $g^i = g(\{s_i\})$. As a special form, g_λ fuzzy measures have the following characteristics:

$$A \cap B = \emptyset \Rightarrow g_\lambda(A \cup B) = g_\lambda(A) + g_\lambda(B) + \lambda g_\lambda(A) g_\lambda(B) \quad (-1 < \lambda < \infty)$$

When the fuzziness coefficient $\lambda = 0$, λ-fuzzy measures are probability measures. $\lambda > 0$, belief measures; $-1 < \lambda < 0$ plausibility measure.

(3) FUZZY INTEGRAL

Let h be a measurable function from X to [0, 1]. Then the fuzzy integral of h over A with respect to g is defined as

$$\int_A h(x) \circ g = \sup_{\alpha \in [0,1]} [\alpha \wedge g(A \cap F_\alpha)]$$

where $F_\alpha = \{x, h(x) \geqslant \alpha\}$ and $\wedge$ stands for minimum.

In the above definition , A is the domain of a fuzzy integral which is omitted if A is X.

Now let us see how to calculate a fuzzy integral. For simplicity, consider a fuzzy measure g of (K, P(K)) where K is a finite set previously defined.

Let $h : K \rightarrow [0, 1]$ and assume without loss of generality that $h(s_1) \geqslant h(s_2) \geqslant \ldots \geqslant h(s_n)$. Renumber the elements of K, if not in descending order. Then we have

$$\int h(s) \circ g = \bigvee_{i=1}^{n} [h(s_i) \wedge g(K_i)]$$

where $K_i \triangleq \{s_1, s_2, \ldots, s_i\}$ and $\vee$ stands for maximum.

A fuzzy integral can be used as a model of subjective evaluation of fuzzy objects where the attributes of an object are measured by a fuzzy measure and the characteristic function of an object is integrated with respect to a fuzzy measure. In the example about the nuclear power plant let h : K [0,1] be the characteristic function of the plant, i.e. the function expressing the characteristics of the plant. For example, we set h ('output'), h ('safety'), h ('price') etc. Then the overall evaluation of the plant is given by the fuzzy integral of h with respect to g, i.e. the grade of subjective importance of each attribute. As is clear from the definition of a fuzzy measure, a fuzzy measure is not only a subjective scale for guessing whether an a priori non-located element in X, a universe, belongs to a subset A of X, but also concerned with such cases as the grade of subjective importance of an attribute referred to in the foregoing from a practical point of view. The fuzzy integral model is applicable to non-linear cases, where one does not have to assume independence of one attribute from another. In the example given it is highly possible that there is a certain dependence between 'safety' and 'price'. If this is the case, we cannot use a linear model as far as we regard 'safety' and 'price' as the attributes of the plant.

We have to consider the dependence of attributes from two points of view. One is objective dependence such as between 'safety' and 'price', and the other is subjective dependence. Even if an attribute seems physically independent of another, one may consider that they are subjectively dependent in some cases.

The uncertainties involved in human judgement are usually non-additive and fuzzy, and therefore could be treated more adequately with the fuzzy theory.

(4) CONCLUSION

We applied the fuzzy measures and fuzzy integrals to analyze public attitude towards the use of nuclear energy by distributing questionnaires to about 100 students of engineering department of Kinki University, Higashi-Osaka, Osaka, Japan. Before and after the Chernobyl Accident we noticed a distinct difference in mental structure. Before the accident, the students of pro-nuclear group were whole-heartedly in favour of the use of nuclear energy, based on fringe benefits, impacts on society and economic progress, but after the accident they showed a favourable attitude towards the use of nuclear energy based on economic progress, but with some reservation because of the potential threats.

This calculation was conducted by Mr. Sen'ichi Mokuya in Master's Program of Science and Engineering, Tsukuba University, Japan.

References

[1] K. Ishii, M. Sugeno: A model of Human Evaluation Process Using Fuzzy Measures, International Journal of Man-Machine Studies 22(1985) 19-38

[2] M. Sugeno: Theory of Fuzzy Integrals and its Applications, Dr. thesis, Tokyo Institute of Technology (1974)