# AN EVALUATION SYSTEM FOR HUMAN INFORMATION PROCESSING

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## ABSTRACT

Information Processing (IP) is a key link in the decision-making process. In this paper the characteristics of the IP process are analyzed and the fuzzy evaluation models are presented to describe this process. By using the descriptions the analysis of the IP abilities for a decisionmaker and a decision team (a group of decisionmakers) are given in a quantitative way.

## INTRODUCTION

Informltion Processing (IP) has been a prosperous field of information science with tremendous applications for many years. The huge number of techniques in information processing implied the maturity of this field of science. However, the studies in the evaluation of IP are seldom seen let alone the studies aided by Fuzzy Sets Theory.

A method is developed here to obtain the models of the information processing in various decisionmaking situations. The models are derived by considering the three fundamental factors in IP process of decisionmakers, i.e., the quantity, the quality, and the time used in the process. The concepts of the Truth and the Originality, related to the quality of the IP, are discussed to measure the abilities of IP for the decisionmakers. An optimization problem of fuzzy information partition for a decision team is proposed by means of these concepts. Using the quantitative definitions of the quantity, the quality, and the rate of IP, the rules of the measurements of IP both for a decisiommaker and a decision team (a group of decisionmakers ) are presented.

## QUANTITY AND QUALITY OF INFORMATION PROCESSING

### 1.The Quantity of IP

Usually information is considered to be related to uncertaity and the gain of the information can reduce the uncertainty of the system considered. The relationship between information and uncertainty is well discussed by G. J. Klir and J. A. Folger (1987).

Consider a set of messages $X=\{x1,x2,\dots,xn\}$ (or called the useful information set) and their probabilities $P=\{p(x1),p(x2),\dots,p(xn)\}$, which form an information flow. The amount of information we get by processing the information flow can be measured in several different ways. The mostly often used measures are Hartley information $I(xi)=\log(1/p(xi))$ (bits) and Shannon entropy $H(X)=-\sum_i p(xi)\log p(xi)$ (bits/message). In the sections below we denote Qn as the amount of information or the quantity of IP.

2. The Quality of IP

The quality of IP is defined as the quality of the conclusions obtained from processing the useful information, and it is associated with every item of the information set X. The quality can be considered as a function of the Truth and the Originality of the conclusions. The truth of a conclusion means the correctness of the comprehension about the information, and it is the level of the comformity between the conclusions and the information processed. The originality means the level that the conclusions involve new ideas, which are hidden in the original information and not easy to be revealed.

DEFINITION 1. Let X be the universe, $T:X\rightarrow[0,1]$, $O:X\rightarrow[0,1]$, T and O define two fuzzy subsets T and O, T and O are called the fuzzy subsets of the truth and the originality respectively.

DEFINITION 2. Let X be the universe, $Q:X\rightarrow[0,1]$, and $Q=T*O$, i.e.,$x\in X$, $Q(x)=T(x)*O(x)$. Q is called the quality of IP in X.

From the relationship between the algebra sum $\hat{+}$ and the algebra product $*$ in the fuzzy sets theory (D. Dubois and H. Prade, 1980), $Q=T*O$, the reduction of the quality of IP is subject to the algebra sum of the untruth and the triviality of IP. The quantitative expression is $\bar{Q}(x)=\bar{T}(x)+\bar{O}(x)-\bar{T}(x)*\bar{O}(x), \forall x\in X$.

## DESCRIPTIONS OF INFORMATION PROCESSING

1. The Concept of IP

DEFINITION 3. An IP is such a six-tuple $\{x, Qn(x), T(x), O(x), Q(x), t\}$, where x is an information signal (a piece of message); and $Qn(x)$ denotes the amount of information of x; $T(x)$, $O(x)$ and $Q(x)$ are the grade of memberships for the truth, the originality and the quality of the IP respectively; and t is the time used in processing x.

In fact an IP can be simplified as a four-tuple $\{x, Qn(x), Q(x), t\}$ from the relationship amony the three fuzzy sets T, O, and Q. If $u(x)=Qn(x)/t$ is defined as the rate of IP, it can further be simplified to a couple $\{u(x), Q(x)\}$. The above three representations are the same in meaning and reflect the key aspects of a IP.

2. The Oedering Relations amony IPs

A. The Ordering of single IPs

DEFINITION 4. Assume a and b are two IPs, X is the information set, $x0\in X$. For the same processing time t0, if $Oa(x0)\geqslant Ob(x0)$, then a is more creative than b with respect to x0, denoted by $a(x0)\geqslant_O b(x0)$; if $Ta(x0)\geqslant Tb(x0)$, then a is truer than b, denoted by $a(x0)\geqslant_T b(x0)$; if $Qa(x0)\geqslant Qb(x0)$, then a is of higher quality than b, denoted by $a(x0)\geqslant b(x0)$.

PROPOSITION 1. For $x0\in X$, if $a(x0)\geqslant_O b(x0)$ and $a(x0)\geqslant_T b(x0)$, then $a(x0)\geqslant b(x0)$.

DEFINITION 5. If $a(x0)\geqslant b(x0)$ and $b(x0)\geqslant a(x0)$, say that a and b are equavelent with respect to x0.

DEFINITION 6. For an IP f={x,Qn(x), Q(x),t0}, if any one of the elements amony Qn(x), Q(x) and t0 is zero, then f is called a nil IP, denoted by f={nil}. If x does not belong to the useful information set X, f is called a null IP, denoted by f={nul}.

DEFINITION 7. Let f1={x, Qn(x), Q1(x), t1}, f2={x,Qn(x), Q2(x),t2}, the combined optimal IP of f1 and f2 is defined as f=f1*f2={x,Qn(x), max(Q1(x),Q2(x)),min(t1,t2)}.

B. The Ordering of IP series

DEFINITION 8. Let the information set is X={x1,...,xn}, and the two processing sequence are F={f1,...,fn}, G={g1,...,gn}, if we have $\sum_i$ Qfi(xi) $\geqslant$ $\sum_i$ Qgi(xi) for the same time t0, then we say that the IP series F is superior to G, denoted by F(X) $\geqslant$ G(X). If Qfi(xi) $\geqslant$ Qgi(xi) ($\forall$xi$\in$X), the IP series F is called absolutely superior to G. Notice that the t0 here corresponds to the time used in processing the whole set X.

DEFINITION 9. If F(X) $\geqslant$ G(X) and G(X) $\geqslant$ F(X), then we say F(X) and G(X) are equvelent IP series, denoted by F(X) $\cong$ G(X).

## INFORMATION ABILITIES OF HUMAN

1.The Implication of Human IP

The process of human infomation processing can be viewed as an IP sequence on a message flow. Each processing action is an above defined six-tuple {x, Qn(x), T(x), O(x), Q(x),t}. The whole processing process on the information flow X={x1,...,xn} can be simlified to a triple {X, u(X), Q(X)}, where u(X) is the processing rate, and Q(X) is the overall quality of IP series. The basic characteristics of human information processing process can be well reflected by the triple.

2. The Evaluation of Single Person's IP

DEFINITION 10. Let two persons a and b do the processing on the same information set X. If $\sum_i$ Oa(xi) > $\sum_i$ Ob(xi), then the say that a is more original than b with respect to X, denoted by a(X) $\geqslant_O$ b(X); if $\sum_i$ Ta(xi) $\geqslant$ $\sum_i$ Tb(xi), then say that a is steadier than b, denoted by a(X) $\geqslant_T$ b(X); and if $\sum_i$ Qa(xi) > $\sum_i$ Qb(xi), then say that the IP quality of a is higher than that of b, denoted by a(X) $\geqslant$ b(X).

DEFINITION 11. If Ta(xi) $\geqslant$ Tb(xi) for any xi in X, then say that a is absolutely steadier than b, and the concepts of "absolutly original" and "the absolutely higher quality" can be defined in the same way.

PROPOSITION 2. If a is absolutely steadier and absolutely more original than b, then the IP quality of a is absolutely higher than that of b.

DEFINITION 12. If a(X) $\geqslant$ b(X) and b(X) $\geqslant$ a(X), then say that the IP quality of a is equavelent to that of b.

If the information sets are two different sets Xa and Xb, Qn(Xa) and

Qn(Xb) maybe different and so are the time ta and tb. The rate of IP must be considered under this situation. Let the IP rate $u(X)=Qn(X)/t$.

DEFINITION 13. Let $f:[0,1]\rightarrow R+$, and f satisfies (a) $f(0)=0$; (b) $f(1)=+\infty$; (c) for $\forall x1,x2\in[0,1]$, if $x1\geqslant x2$, then $f(x1)\geqslant f(x2)$. f is called the quality transformation function and $q=f(Q(X))$ is called the quality index.

DEFINITION 14. Assume a person processes an information set X, his IP rate is $u(X)=Qn(X)/t$, his IP ability is defined as $A(X)=c*u(X)+(1-c)*f(Q(X))= c*u(X)+(1-c)*q$, where $c\in[0,1]$ is the weight.

## INFORMATION PROCESSING ABILITIES OF DECISION TEAMS

1.The Concepts of IP Quantity and Quality for Decision Teams

A decision team usually consists more than two members. While processing infomation each member takes charge of one or more aspects of the information. Here the same member-level decision teams are considered, and in this type of teams no member can command the others. We make a fuzzy partition for the information set, i.e., there exist $Ai\in F(X)$ which satify $Ai\neq\phi$, $Ai\neq X$, and $\sum_{i\in I} Ai(x)=1$ ($i\in I$, $x\in X$), $Ai(i\in I)$ is called a fuzzy partition on X. Let each Ai represents an aspect of information.

DEFINITION 15. Assume a same member-level decision team T has m members, T={p1,...,pm}, each of them processes one aspects of information. Let pi processes Ai, the quantity of his IP is

$$Qn(Ai)=\sum_{x\in X} Ai(x)\log(1/p(x)).$$

For the limited universe X, if $A\in F(X)$, let $||A||=\sum_{x\in X} A(x)$ is the cardinality of A.

DEFINITION 16. The IP quality for fuzzy information Ai is defined as

$$Q(Ai)=(1/||X||)\sum_{x\in X} Ai(x)\cdot Qpi(x).$$

PROPOSITION 3. For any fuzzy partition $Ai(i\in I)$ the total amount of information of $Ai(i\in I)$ is the same as that of X.

PROOF Let $Ai(i\in I)$ be a fuzzy partition of

$$\sum_{i\in I} Qn(Ai)=\sum_{i\in I}(\sum_{x\in X} Ai(x)\log(1/p(x)))$$
$$=\sum_{x\in X}(\sum_{i\in I} Ai(x)\log(1/p(x)))$$
$$=\sum_{x\in X}(\log(1/p(x))\sum_{i\in I} Ai(x))$$
$$=\sum_{x\in X}(\log(1/p(x))=Qn(X)$$

PROPOSITION 4. The sum of the cardinality of any fuzzy partition $Ai(i\in I)$ on X equals to the number of the elements in X.

PROOF
$$\sum_{i\in I}||Ai||=\sum_{i\in I}(\sum_{x\in X} Ai(x))=\sum_{x\in X}(\sum_{i\in I} Ai(x))$$
$$=\sum_{x\in X} 1= \text{the number of elements in X.}$$

The IP quality of a decision team can be measured from synthesizing the IP qualities of all the aspects of the information. According to the different importance for different aspects of information in a certain decision problem the concept of the importance index is thus introduced below.

DEFINITION 17. Let $z:F(X)\longrightarrow[0,1]$. If for any fuzzy partition $Ai(i\in I)$ for X, we have $\sum_{i\in I} z(Ai)=1$, then $z(Ai)$ is the importance index of fuzzy sets $Ai(i\in I)$.

DEFINITION 18. The overall IP quality of a decision team T can be calculated as follow

$$Q[T,Ai(i\in I)] = (\sum_{i\in I} Q(Ai)*z(Ai))/I$$

2.The IP Ability of a Decision Team

It is difficult to compare the IP abilities between different decision teams, because their structures and the number of members maybe not the same, and the information partitions for them would be quite different. But we can make the comparasion possible for some decision teams with particular structures or with similar structures by using the concepts defined above. First we will consider the decision teams with same the structure, the same information source and the same information partition, then consider the same member-level teams with different numbers of members.

DEFINITION 19. Assume that two decision teams T1 and T2 have the same number of members, the same structure and the same information source and partition. If within the same processing time t0 we have $Q[T1,Ai(i\in I)] > Q[T2,Ai(i\in I)]$, then the IP ability of T1 is higher than that of T2, denoted by $T1(X)\geqslant T2(X)$.

DEFINITION 20. Assume that two decision team T1 and T2 are the same member-level teams, but their numbers of members are not the same. For the same information source their information partition are $Ai(i\in I)$ and $Bj(j\in J)$ respectively. If within the same processing time t0 we have $Q[T1,Ai(i\in I)] > Q[T2,Bj(j\in J)]$, then the IP ability of T1 is higher than that of T2, denoted by $T1(X)\geqslant T2(X)$.

3. The Optimal Information Partition for Decision Teams

How do we assign the information to each member of the decision team in order to make its overall IP performance best? For the teams with the same member-level the problem can be focused on the fuzzy information partitions of the information set. In order to describe this problem, we must know what "the best performance" is at first. There need some rules for the effectiveness. Here two points are considered: (1) all the members of the team must finish the IP process at the same time; (2) The partition of the information set must make the overall IP quality of the team highiest. The former assures that all the members work in the no-leisure state, and the later assures that the assignment of the information to each member makes the overall IP quality of the team best. The quantitative representations of the rules are given below.

[The Principles of Optimal Information Partition for Decision Teams]

Assume that a same member-level team has m members $T=(p1,...,pm)$, the optimal information partition $Ai(i\in I)$ of the information set X must satisfies the following equations:

(1). $\forall i,j \in M$, ti=tj, i.e., t1=t2=...=tm, where ti is the time the ith member pi spends in processing Ai. From the relation upi(Ai)=Qn(Ai)/ti, the above equation can be rewritten as

$$Qn(Ai)/upi(Ai)= Qn(Aj)/upj(Aj) \quad (\forall i,j \in M)$$

or

$$[\sum_{x\in X}( Ai(x)\log(1/p(x)))]/upi(Ai)=[\sum_{x\in X}( Aj(x)\log(1/p(x)))]/upj(Aj)$$

(2).
$$Q[T,Ai(i\in M)] = \max_{Ai(i\in M)}\{\sum_{i\in M}(Q(Ai)z(Ai))\}$$
$$= \max_{Ai(i\in M)}\{\sum_{i\in M}[(1/||Ai||)\sum_{x\in X}( Ai(x)\cdot Qpi(x))]*z(Ai)\}$$

## CONCLUSIONS

The theory of IP evaluations proposed here has been applied to an experiment about single person's information processing so as to determine the form of human information processing channel under some work situations involving uncertainty. Another application is in the measurement of the effectiveness for military command and decision in C3I systems. Details about the theory and its applications can be found in references [3-9]. The work also provide a new way to understand the relationships between information and decisions.

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