# Transforming Information to Knowledge and Intelligence*

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**Abstract:** Intelligence is regarded as the most precious wealth among all kinds of capabilities. It would be of great interest and significance if the formation mechanism of intelligence could be understood. It is our discovery that intelligence is activated from knowledge and the latter in turn is refined from information and the transformations of information to knowledge and further to intelligence and that is the secrets of intelligence formation. These discoveries will be reported in the article as what could be followed for building intelligent machine. As an interesting by-product, the three existing approaches to AI research have also been unified in the article.

**Key Words:** Information, Knowledge, Intelligence, Transformation from Information to Knowledge and to Intelligence

## 1, Introduction

As the most attractive, powerful, and unique attributes to human beings, intelligence has been received more and more attentions from scientific circles. It would be a great scientific breakthrough in history if human intelligence, or even part of it, can steadily be transferred to machines.

What is the essence of intelligence we should understand in the context? What is the technically feasible mechanism for intelligence formation? Would it be really possible for humans to make machines intelligent? How to make machines intelligent, if possible? And what if intelligent humans can eventually utilize and manage the intelligent machines?

Based on the observations and results accumulated during his research, the author of the article would like to give some of the answers toward the questions above. Due to the space limitation we have for the article, the answers will be concise and brief.

## 2, Model of Human Intelligence Process

To begin with, a model of intelligence process performed by humans is necessarily given as a basis of the discussions that will be carried on in the article. In Fig.1 below shows a model of human intelligence process in the boxes of which are human organs (the sensors, nerve system, brain and actuators) while outside the boxes are the functions the organs perform (information acquisition, information transferring, information cognition & decision

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making, and strategy execution) and alongside

The model tells how human beings solve the problems they face in the real world and how the intelligent strategies and accordingly the intelligent actions are produced from knowledge and information.

### 3, The Transformations

The mechanisms embedded in the process of intelligence formation consist of a number of transformations that will be explained in the following sub-sections. Due to the limitation of the space we have for the paper, only the nucleus, the transformations of information to knowledge and then to intelligence are dealt with in the paper.

### 3-1 The Transformation: from Information to Knowledge

The first step is to deal with the transformation from information to knowledge and here the information is the so-called epistemological information as is shown in Fig.1. The related concepts can be given below.

$$K \Leftarrow \bigcap\{I_E\} \qquad (1)$$

where the symbol ∩ in (1) stands for induction operator; $\{I_E\}$ the sample set of the epistemological information; and $K$ the knowledge produced by $\{I_E\}$. In some cases, there may need some iterations between induction and deduction and the deduction itself can be expressed as

$$K_{new} \Leftarrow \Re\{K_{old}, C\} \qquad (2)$$

where C stands for the constraint for deduction. Fig.3 shows the general process of transformation from epistemological information to knowledge.

**Definition 1 Epistemological Information** *of an object is a description, given by the subject (observer or user), concerning the object's states and the manner including their forms, meanings and utilities and are respectively termed as the Syntactical Information, Semantic Information and Pragmatic Information,* see [1].

**Definition 2 Knowledge:** *Knowledge concerning a category of objects is the description, made by subjects, on various aspects of the states at which the objects may stay and the law with which the states may vary. The first aspect is the form of the states and law and that is termed the formal knowledge, the second aspect is the meaning of the states and law that is termed the content knowledge and the third aspect is the value of the states and law with respect to the subject that is termed the value knowledge. All the latter three aspects constitute a trinity of knowledge* [2].

The definitions 1 and 2 indicate that the transformation from epistemological information to knowledge can be implemented through inductive algorithms:

More specifically, the formal knowledge can be refined from syntactic information, content knowledge can be refined by semantic information, and utility knowledge can be refined by pragmatic information through induction/deduction as indicated below:

$$K_F \Leftarrow \bigcap\{I_{sy}\} \qquad (3)$$

$$K_V \Leftarrow \bigcap\{I_{pr}\} \qquad (4)$$

$$K_C \Leftarrow \bigcap\{\Re(I_y, I_{pr}, C)\} \qquad (5)$$

where the symbols $K_F$ , $K_V$ and $K_C$ respectively stand for formal, content and value knowledge while $I_{sy}$ and $I_{pr}$ for syntactic

and pragmatic information. The general algorithms related to （3）,（4）and（5）can be referred to [2].

Knowledge, in accordance with its maturity in the process of growth, can roughly be further classified into three categories: the experiential knowledge, the regular knowledge and the knowledge in common sense.

**Definition 4 Empirical Knowledge:** *The knowledge produced by induction yet without verification is named the empirical knowledge. It may also be called the potential knowledge, or pre-knowledge, sometimes.*

**Definition 5 Regular Knowledge:** *The regular knowledge can be defined as matured knowledge. It is the normal stage of knowledge growth.*

**Definition 6 Knowledge in Common Sense:** *There exist two sub-categories: axiom and reflection with or without conditions. Learning and reasoning process are not needed in the category. Knowledge can also be called the popular knowledge.*

**3-2 Transformation: from Knowledge to Intelligence**

The task for decision-making in Fig.1 is to create an intelligent strategy, based on the knowledge and information, as the guidelines for problem solving intelligently. The strategy is the embodiment of the related intelligence.

**Definition 7 Strategy:** *A Strategy for problem solving is sort of procedure, produced based on the related knowledge and information, along which the given problem could be satisfactorily solved, meeting the constraints and reaching the goal. It is the embodiment of intelligence and is therefore also called intelligent strategy.*

The transformation from knowledge and information to strategy can be expressed as

$$I_S : (P, E, G; K) \mapsto S \tag{6}$$

where $I_S$ denotes the strategy, $P$ the problem to be solved, $E$ the constraints given by environment, $G$ the goal of problem solving, $K$ the knowledge related to the problem solving and $S$ the space of strategies. Theoretically speaking, for any reasonably given $P$, $E$, $G$ and $K$, there must exist a group of strategies such that the problem can be solved satisfactorily and among the strategies there will be at least an optimal one guaranteeing the optimal solution.

The specific form of the transformation will be dependent on the properties of the problem faced and the knowledge possessed. For empirical knowledge, the form of the transformation can obviously be implemented via learning/training and testing. In fact, this is the mechanism of neural network's learning [3].

As for the regular knowledge, the transformation can be implemented via a series of logic inferences. More specifically, for the given problem, constraints, goal and the related knowledge, it is possible to form a tentative strategy for the selection of rules for applying to the problem and producing a new state of the problem. Diagnosing the new state by comparing it with the goal and making analysis based on the related knowledge, the tentative strategy can thus be improved or maintained. A new rule can then be selected to apply to the new state and new progress may be made. This process will be continued until the goal is reached, the constraints are met. In the meantime, the strategy is also formed.

Evidently, this is the mechanism of strategy formation in the so-called Expert System [4].

In the case of common-sense knowledge, the mechanism of intelligent strategy formation can be implemented by directly linking the input pattern and the strategies. As long as the input pattern is recognized the strategy for control can immediately be determined based on the common-sense knowledge direct related to the problem without any inferences needed. This is the typical feature of strategy formation sensor-motor category [5].

**Summary:** *As it is indicated in Fig.1, there are four categories of functional units in the entire information process (also intelligence process). The units of information acquisition and execution are two kinds of interface between intelligent system and the external world: the former acquires the ontological information from the external world while the latter exert strategic information to the external world. On the other hand, the units of information cognition and decision-making are the two kinds of inner core of the intelligent system: the former create knowledge from information and the latter produce strategy from the knowledge. Only by the synergetic collaboration among all the four functions could make intelligence practical.*

## 4. Unified Theory of Intelligence: A By-Product

It is interesting to note that in a long history of Artificial Intelligence development there have been three strong approaches to the research in literature, the structuralism also called as connectionism, the functionalism also termed as symbolism, and the behaviorism or senor-motor approach, that seem distinctive to each other.

As is seen in last section, however, all the three approaches have well been unified into one same mechanism of intelligence formation, that is, the transformations from information to knowledge and further to intelligence. In views of the mechanism of intelligence formation, there is a unified theory of intelligence, realizing the unification among the three approaches. This is shown in Fig.2.

It is clearly enough to see from Fig.2 that the real difference among the three traditional approaches lies only on the categories of knowledge in use while the core mechanisms of cognition and decision-making are always necessary.

As stated in section 3-2 and shown in Fig.2, if the knowledge to be used must be refined from information directly and instantly (this is the first category of knowledge, or experiential knowledge), the implementation of cognition and decision-making will have to employ the training and testing procedure by using, for example, the artificial neural networks approach. This is so-called Structuralism because Artificial Neural Networks are designed by following the Biological Neural Networks in principle.

If the knowledge to be used can be obtained from somewhere and not necessary to be refined from information (this is the second category of knowledge, or regular knowledge), the cognition is simply be performed by the system designers while the decision-making can be implemented via logic inference. This is the approach emphasizing on the functions of the system without considering the structure.

When the knowledge to be used is the third category, the common sense knowledge about

the relationships between the input patterns and output actions, there is of course no need for else knowledge. This is behaviorism approach.

*After all, the three approaches in Artificial Intelligence research are by no means in contradiction. They, Artificial Neural Networks Approach, Expert Systems Approach, and Senor-Motor Approach, are well complementary to each other and no one can take the other's place.*

This, the author believes, is an important conclusion resulted from the studies in the core transformations in intelligence creation.

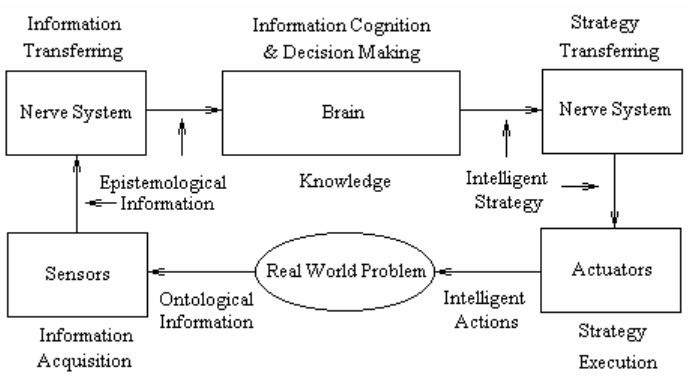


Fig.1 Model of Human Intelligence Process

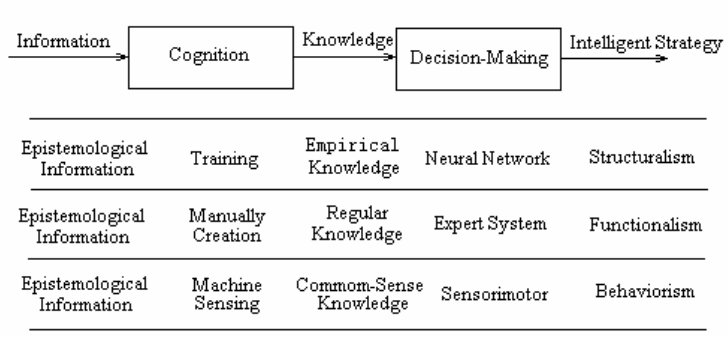


Fig.2 Intelligence Theory Unification

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