On Information Science

-- An Introduction to <Principles of Information Science>

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Abstract: *As the characteristic feature and mark in science in information age, information science plays a crucial role. However, what is information and what is information science? What are the principles governing the processes of information flow? Is there any new, and meaningful methodologies supporting the study? What is the significance of the study to human society? How to promote the study of information science in the world academic community? Some of my understandings to these questions will be presented in the paper.*

Keyword: *Information; Comprehensive Information; Information Science; Principles of Information Science, Information-Knowledge-Intelligence Transformation*

1. Introduction

Different ages in human history established different kinds of sciences for marking the development of their stages. Information age has been a reality worldwide in present time. Therefore, information science needs to be established as the mark for this stage of human history.

There have been numerous works already done, or still being carried on in the globe for this purpose. It seems that it is now the right time to make a review on what has been achieved, what needs to be further dealt with and how to do it more effectively.

There are many questions, on the other hand, related to the work of reviewing. To take a few, for example, what is information and what is information science? What are the basic principles behind the processes of information? Is there any new, and also meaningful, methodologies guiding the study of information science? What is the significance of the study to human kinds? And so on, and so forth.

In response to the questions mentioned, the paper would give you a brief introduction to the book titled with <*Principles of Information Science*> [1] published in 1988 for the first edition, in 1996 the second edition, in 2002 the third edition, and in 2005 as a textbook for the use of post-graduates, all in Chinese.

Due to the limitation of the space we have had for the paper, the discussions below will be given as a number of conclusions with little explanations in detail.

2. Fundamental Concepts

For making the discussions more comfortable, it would be good to set up a number of concepts as basis.

2-1 Information Science

Due to its high complexity, there have been different understandings on the definition of information science among researchers in the world community. Here is the one cited from reference [1] in which information science has been delimited through the four criteria: the object, the content, the approach, and the goal.

It says that Information science is a trans-disciplinary science with "information" as its *object*, the "laws and principles governing the information processes" as its *content*, the "information methodology" as its *approach*, and the "strengthening the human intellectual ability" as its *goal*. The discussions given below will follow this line of thought.

2-2 Information

The first concept is Information.

Considering many different concepts of information

exist already, a proper way to make them in good order is the Level Analysis Approach. It says that the concepts may be appropriately arranged into a number of levels according to the constraints related to the concept in that level as is shown in Table 1 below.

The concept with empty constraint is the highest level which has the widest applicability while the concept with the most constraints is the lowest level which has the narrowest applicability. All other concepts are the ones in between these two.

Table 1 Level Analysis Approach

Constraint	**Concept Level**	**Applicability**
None	Highest	Widest
Least	Second Highest	Second Widest
More	Lower	Narrower
….	….	….
The Most	The Lowest	The Narrowest

In Information Science [1], the Level Analysis Approach to the concept of information can specifically be shown in Table 2.

Table 2 Level Analysis Approach to Information

Constraint	**Concept Level**	**Applicability**
None	Ontological Info	Widest
Subject	Epistemological Info	Second Widest
….	….	….

The highest level of the concept of information is termed as the ontological information which has no constraint and has thus widest applicability. The second highest level of the concept is called the epistemological information which has subject as its constraint and thus is applicable in the cases where the subject exists.

It is obvious that the ontological information is the real root of any other concepts of information whereas the epistemological information is the unique trunk of information. As the branches and leafs of the concepts of the information tree, they can all properly be derived out from these two.

The definitions on ontological and epistemological information are respectively given as follows.

Ontological information concerning any event can be defined as the event's self presentation on its states on which it may take and the manner with which the states may change from time to time, regardless whether it has been concerned by any subject.

Note that the term "event" in the concept could either be the one in physical world or in spiritual world.

The subject's epistemological information about an event is defined as the subject's description about the form, the content, and the value of "the event's states and the manner with which the states change" and is respectively named as the formal information, content information, and value information. The trinity of the three is termed as *Comprehensive Information*.

Note that the formal component of comprehensive information can be reduced to the concept of *Shannon Information* [2] when the changing manner of states is stochastic in nature.

2-3. Model of Information Processes

Another concept, which is as important as the concept of information in information science, is the *Model of information Processes.*

In terms of the functionality that information process performs, the model of the processes can be expressed in Fig.1, in which the problems and constraints in real world serve as the sources of information; and then the processes of information acquisition, transferring and processing are followed to prepare the information for easy use; further, the processes of knowledge extraction and strategy creation are required to successively converse the information processed to *knowledge* and converse the knowledge to *strategy*; finally, the strategy is passed on to the unit of strategy execution where the strategy is conversed to the *action* through which the problem will be solved.

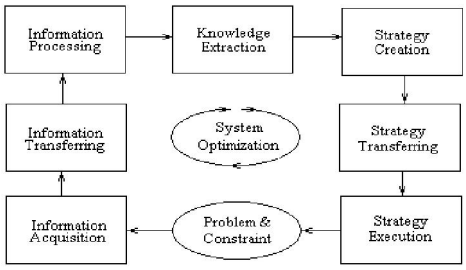

Fig.1 Model of Information Processes

2-4 Intelligence

For any given problem, constraint, and the goal in real world, the *intelligence* is defined as the ability to understand and further to solve the problem, meeting the goal under the constraint given.

Interesting enough, the information processes in Fig.1 is exactly the model of intelligence formation: acquiring the information about the problem, constraint and goal; extracting knowledge from the information; creating the strategy from the knowledge extracted; and conversing the strategy to action, thus solving the problem.

It is noted that the strategy can be regarded as the major embodiment of intelligence. Thus, it is reasonable to call the strategy as the intelligence (in narrow sense).

In other words, "intelligence" is normally supported by the entirety of information processes in which the "*Information-Knowledge-Intelligence conversion*" is the soul and the mechanism of intelligence formation.

2-5. Information Methodology

Because of the fact that information is different from matter, information science needs its own approach to the study in addition to the use of traditional one.

The Information Methodology has three components as a whole, namely (1) the information approach for information system *analysis*, (2) information approach for information system *synthesis* and designing, and (3) information approach for information system *evolution*.

2-6 Possible Taxonomy for the Study

Because of the multi-facets of information, there have been many groups of researchers dedicating in the study, related to information but yet from different angles, typically such as philosophic, scientific, technological, economic, and sociological study.

As for the information study within the category of natural science, it may be rational to classify the study into some interrelated branches according to the levels of the concept on which the branches are standing.

Having indicated in Table 2, the branch that stands on the highest level, the ontological level, could reasonably be named as *Theoretical Study of Information Science*, or briefly Theoretical Informatics; the branch that stands on the second highest level, the epistemological level, could named the *General Study of information Science*, or briefly General Informatics; and the branches that stand on other levels below the two mentioned above could named *Applied Study of Information Science in certain areas*. As the results, we may have the taxonomy of information science studies as shown in Table 3.

Table 3 Taxonomy of Info Studies

Concept Level	**Taxonomy of the Studies**
Ontological Level	Theoretical Study of IS
Epistemological Level	General Study of IS
More Specific Level	Applied Study of IS in Area

3. Major Principles of Information Science

Referred to the model of information processes in Fig.1, the principles governing the processes can briefly be summarized as the followings.

3-1. General Principles of Information

(1) Information is a kind of existence at any locations in both space and time domain and therefore cannot be isolated from, and ignored by, humans.

(2) Information has close relation to, and yet has great difference from, matter and energy and thus cannot be simply regarded as a part belonging to, or completely separated it from, the matter and energy completely.

(3) Information is a kind of important resources from which both knowledge and intelligence can be produced as vital products to human society.

(4) Information can be qualitatively understood and quantitatively measured as the science and mathematics develop forward continuously.

(5) The highest level of information is the ontological one and the second highest level is epistemological one. The former is the root and origin of information and the latter is the common trunk and main stream. Other levels of information can all be derived from these two fundamental levels.

(6) The central elements of information in definition, both ontological and epistemological, are the "states on which the event may take and the manner with which the states may vary from time to time". Therefore,

information must have a carrier for its presentation. It is important to note, on the other hand, that although the "states" and the "manner" of an event are produced from that event, but they are not the same as the event itself. Rather, once "the states and manner" of an event is produced, it can also be presented by other carriers, or media. This is bases of why information can be copied, transferred, stored and manipulated without loss of its properties in general.

3-2 Principles of Information Acquisition

(1) Information, defined as "the states on which the event may take and the manner with which the states change from time to time", can in principle be sensed by human sensing organs in some cases and by various artificial sensors in other cases. This is because of the fact that any change of the state and manner of an event will certainly produce specific kinds of the effects to other events via the interactions. If there is some kind of event sensible to the effects, the change in state/manner, i.e., information, will then be received by that event.

(2) It is obvious that only the ontological information as well as the formal component of the comprehensive information can be sensed by either human organs or artificial sensors whereas both the content and value components of comprehensive information cannot be so in the same way.

(3) For acquiring the value and content components of comprehensive information, the processes of learning and reasoning, which are much more complicated than sensing, are needed.

(4) Information, with "the states on which the event may take and the manner with which the states may change from time to time" as its feature, can also be differentiated from one another based on the differences in their features. This is really the foundation of Pattern Recognition.

(5) Information can be represented in different means, carriers or media, as long as the major part of its feature is maintained satisfactorily.

(6) There may be many sources of information closely related to the same event. For getting to know the entire facet of the event, the process called "fusion" of the information from all related sources will be needed in these cases. Information fusion is a kind of intelligent processing of information.

3-3 Principles of Information Transferring

(1) Defined as "the states on which the event may take and the manner with which the states may change from time to time", information can be transferred from one point to another, in both time (storage) and space (communication) domain, as long as the major part of its feature is well maintained.

(3) What needs to be considered in the transferring of information is the formal component of comprehensive information as the sensing system can only provided the formal information which is carried by waveform of the signals.

(2) The basic criteria for satisfactory transferring of information (or equivalently named information sharing) include such performances as efficiency, reliability, and security in signal transmission.

(4) The performances in information transferring will be greatly improved if comprehensive information can fully be utilized. But this is the story that could be told in the future.

3-4 Principles of Information Processing

(1) As a kind of resources meaningful to humans, the raw information is usually inconvenience to use. Thus, some manipulations must be employed before the use.

(2) Any kinds of operations exerted to information for the purpose of making it becoming the information more conveniently to be used are termed as information processing. But, any operations exerted to information for the purpose of producing knowledge, or for the purpose of producing intelligence, will be classified as "knowledge extraction from information" and "strategy creation from knowledge" respectively. They will no longer be classified as information processing

(3) There may be many kinds, uncountable in practice, of operations that are used for information processing according to specific needs and purposes.

(4) All kinds of information processing will be able to make the information more conveniently to use, but can never increase the amount of information it contains.

(5) Information is currently processed only based on

the formal component of comprehensive information. It will be able to gain more if comprehensive information is effectively utilized.

3-5 Principles of Knowledge Extraction

(1) The ontological information as well as the formal component of comprehensive information, even the one after processing, are the phenomena in nature and can only provide to humans with the shallow understanding of the event.

(2) Ontological information can well be conversed, through the support from either the intelligent beings or intelligent systems, to the epistemological information, or the comprehensive information, including the formal (also named the *Syntactic* information), the content (the *Semantic* information), and the value (the *pragmatic* information) component.

(3) As the raw resource, however, information can be refined, through various kinds of inductive algorithms and more often via the combinations of inductive and deductive algorithms, to the knowledge that is able to provide to humans with deep understanding about, or the essence of, the events.

(4) The conversion from information to knowledge, which is termed as Cognition, is the one of the central process in the entire processes of information. The quality of the conversion is mainly determined by the quality as well as the quantity of the comprehensive information provided and also by the appropriateness of the methods used in conversion. This explains the reason of why the task of knowledge extract from information can only be performed by human beings, or intelligent systems.

3-6 Principles of Strategy Creation

(1) Knowledge provides with the deep understanding over the event in consideration and therefore it is very much important. However, successfully dealing with the event, i.e., solving problem faced, is the basic interest for, and thus even more important to, humans.

(2) The process of conversing knowledge to strategy for problem solving is the natural step. This is named the strategy creation which is another central process in the entirety of information processes.

(3) To properly converse knowledge to strategy, it needs the guidance from the goal for problem solving given beforehand.

(4) The process of conversing knowledge to strategy needs comprehensive information as the strategy created should be able to achieve the maximum benefit (or the minimum loss) that needs, of course, the support from vale (pragmatic) and content (semantic) information.

(4) The process of strategy creation is not a straight way as the information and knowledge obtained may not be sufficient and the goal given before may not be fully reasonable. Moreover, the methodology for creating the strategy may not as proper as it needs to be.

3-7 Principles of Strategy Execution

(1) The strategy created and expressed in an abstract form can in principle be conversed to the corresponding sequence of actions through certain mechanism.

(2) The sequence of actions can then be exerted on the event/problem in consideration so that the state of the event could be regulated in accordance with the strategy created.

(3) The prescribed goal, if reasonable enough, will be reached if the strategy (and the related knowledge and information) are proper sufficiently.

3-8 Principle of Information System Optimization

(1) Due to the uncertainties existed in many ways and many forms, the information acquired, the knowledge extracted, and the strategy created during the above processes may have deficits which will be resulted in certain error in the process of goal seeking.

(2) The error happened can serve as a new kind of information for problem solving and goal seeking which should be fed-back to the input of the processes for optimizing the information acquisition, knowledge extraction, and strategy creation so that the process of problem solving will be improved and the goal will eventually be reached.

(3) If the prescribed goal cannot be reached after all possible measures of optimization described above, this may mean that the goal prescribed for problem solving is not reasonable and thus should be reset.

Having discussed the major principles governing the processes of information flow, it is emphasized that the nucleus of the all principles should be the one which says that "*information could be conversed to knowledge and further be conversed to intelligence*" which can be termed as the *Principle of Information Conversion*.

As is widely accepted that having information you will be able to know what it is, having knowledge you will be able to know why it is so whereas having intelligence you will be able to know how it does. So, Information is fundamental and Knowledge is more important than information while Intelligence is the most meaningful among the three.

The principle of information conversion is by all means the lifeline of information science. This is because of the fact that the purpose of studying on information is not merely for getting to know the information itself, but rather, and more importantly, is for improving the living standards and further development for human society. Therefore, intelligence and knowledge are more significant than information.

Generally speaking, information is a kind of valuable resource and knowledge and intelligence are products produced from information. Consequently, there would be no knowledge and intelligence if there were no information. From the point of view, however, of social development, knowledge, particularly intelligence, will play more important role. Therefore, information may not make much sense if it cannot be conversed to knowledge and intelligence although all of the three are indispensable to humans in information age.

This leads the discussions to the next, and a relatively new and relatively more interesting, topic, the topic that we term it as Advanced Intelligence.

4. Advanced Intelligence

As is mentioned above that the major principle of information science is *the conversions from information to knowledge and further to intelligence*, it is necessary to have a brief investigation on the study of intelligence and knowledge. Note that the discussions in this section will often be referred to the Reference [3].

4-1. Brief Introduction to Intelligence Study

The study of intelligence consists of two branches, which are the natural intelligence study and the artificial intelligence study. The task for the former branch is to explore, and understand, as much as it could the secrets of natural intelligence, the secret of human thinking in particular. Neurological science and cognitive science are its representatives in this field. The task for the latter branch, the Artificial Intelligence, is to create machine as intelligent as it could, based on the understanding about the secrets of natural intelligence. Therefore, the two branches should closely interact to each other.

During the past decades, both the studies have made good progresses but at the same time faced a number of problems and challenges too. For the information about the progress made in neurology and cognitive science, please see the reference [4] and for the detailed progress in artificial intelligence, please refer to the reference [5].

The problem and challenge that the study of natural intelligence is facing now is the great gap between the neurology science and cognitive science. It is still a big mystery on how intelligence is generated from brain and how intelligence makes influences on the evolution process of the brain.

As for the major problem and challenge that the study of artificial intelligence confronts is that there have been three schools carrying on the same study with different approaches, namely the structuralism approach (neural network systems), the functionalism approach (expert systems), and the behaviorism approach (sensor-motor systems), and never cooperate to each others. There has no unified theory in the field so far. Moreover, none of the three schools have paid necessary attentions to such issues as consciousness, emotion and cognition that are extremely fundamental to the study of intelligence. In the meantime, there is little cooperation with the study of natural intelligence.

An even bigger problem existed in the fields of intelligence study, also in other fields of course, is the methodological issue. Researchers have been used to the traditional methodology called "divide and conquer". They divided the study of intelligence into different respects (the structural respect, the functional respect, and the behavior respect) and carried on the research

within the limit of each respects of intelligence. As results, each of them cannot get the global picture of the intelligence and cannot accept the progress made from other respects. This is the basic cause of why they failed to have a unified theory of intelligence among the three schools.

It is worth of mentioning that the methodology of "divide and conquer" has made great contributions to the modern science but it is not quite sufficient for the study of information science. Because of the limitation of the space for this paper, we will not discuss this issue in detail and will do it later.

4-2. Advanced Intelligence: Recent Progresses

One of the progresses in artificial intelligence study achieved in the year of 2006 when the 50th anniversary celebration was held at the International Conference on Artificial Intelligence in Beijing [6], that is the program of Advanced Intelligence proposed by the delegate from Chinese Association for Artificial Intelligence (CAAI) and approved by the representatives of the participants of the Conference.

The major concepts of the program, also the major contributions the program have made, can be briefly summarized as follows.

(1) The Program strongly requests a unified theory for artificial intelligence study, making effort to end the situation of "separation among the three schools";

(2) The Program calls for the interactions between the studies of artificial and that of natural intelligence, making any possible efforts to end up the separation between the two;

(3) The Program places the emphasis on the study of fundamentals e.g., emotion, consciousness, cognition and their unification, instead of dodging the issues.

It is believed by the participants that the Program of Advanced Intelligence gave a guideline far reaching for the study of intelligence in the future and thus asked CAAI to organize the serial "International Conference on Advanced Intelligence, ICAI" once each two years from 2008.

Accepted the response, CAAI set up a networking organization, "International Academy for Advanced Intelligence, IAAI" in 2007, then cooperated with the European Coordination Committee on AI, organized the first ICAI in 2008 with great success. Further more, an International Journal on Advanced Intelligence, IJAI, also published in 2009. And now we are joining in the second ICAI in 2010.

It is interesting to note that, under the guidance of the Advanced Intelligence Program and also based on the Principle of Information Conversion, good progresses have been made recently in the study of knowledge and intelligence. Knowledge Ecology has been discovered and the Unified Theory of Artificial Intelligence has been established, see [3].

All the events, IAAI in 2007, ICAI in 2008, IJAI in 2009, ICAI in 2010, and the unified theory of artificial intelligence indicate the facts that the Program of Advanced Program has clearly shown its strong vitality in guiding the study of intelligence science, has been well accepted by the researchers in the world, and has also been successfully implemented very well during the past years. It is well believed that the Program of Advanced Intelligence will have even brighter future in the years to come.

5. Concluding Remarks

A brief outline on Information Science and Advanced Intelligence, based on the references [1] and [2], has been introduced in the paper. What we would like to emphasize here include the following.

(1) Considering the facts that the advancement of information science will certainly lead the development of information technology and the latter in turn will push the growth and maturity of information/knowledge economy and the related society, that is the big law of "*Science-Technology-Economy-Society Reaction Chain*", the high importance of the science of information and intelligence to the prosperity of the human society for both developed and developing countries worldwide can never be overestimated in Information Age, compared with the matter science in Industrial Age.

(2) In view of the progresses in Information Science achieved so far, however, it needs still greater efforts for further advancement in the study. Hence, it is apparently

necessary for researchers in this field in the globe to take more active and more effective steps for better cooperation in research and exchange.

(3) We may have different points of view and different understanding over the concept of Information and Information Science due to many factors. This diversity is absolutely normal and natural and not bad thing. Instead, it is a good thing. The difference will make people to have rethinking in somewhat different way and therefore will become the real source from which deeper understandings and better progresses may be produced. Contrarily, if there is no difference among people, it would be useless for idea exchange.

(4) Therefore, forming an international organization dedicating to the scientific research and exchange on Information Science and Advanced Intelligence seems to be needed and feasible as well.

(5) It may be necessary to mention once again that the relative completeness of the scope and the systematic structure of the study in Information Science will be of importance. The reason for this consideration is that many deep laws and principles of Information Science may not be discovered if the study has only parts of its scope. It is therefore suggested that the entire process of the *Information-Knowledge-Intelligence Conversion* be regarded as the baseline of Information Science study, containing the theoretical study, general study, as well as applied study as its major branches.

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Note that the word "COGNETICS" was coined by the author to express the concept of "Cognition and Cybernetics", in which the term of *Cognition* represents the process of conversing information to knowledge while the term of *Cybernetics* represents the process of conversing knowledge to intelligent strategy and action.