# Inference and Estimation Using Experience-Based Knowledge

Y.Sakai

Dept. of Mechanical Engineering
Yamaguchi University
Ube, Yamaguchi 755, Japan

## Abstract

In the human cognitive activity, experiencing plays a basic role. This is modeled by the idea of experience sequence here, which has been proposed by the author for the incorporation of the factor of experiencing in man-machine communication. Experience sequence is for modeling the human concept formation through experiencing. Knowledge manipulation requires concept understanding as its basis. An experience sequence deals with such a process of concept formation.

## Introduction

Experiencing is essential in skill acquisition. Through experiencing, human skill progresses and knowledge can be built in a human brain. It is expedient to incorporate this idea with those ideas surrounding it into an intelligent man-machine interface. For example, "localization" as will be described later is one of fundamental ideas for experiencing. Combining those ideas will provide a unified means in considering the problem of applying intelligence to the real systems. Human thinking seems to have various forms in execution; i.e., these can be largely broken down into something linguistic, and image manipulation. Logical things may not always take the form of language, and sometimes imagery may be an alternative form in thinking.[1] Inference in this sense can be said to be performed in both ways which seem to be equivalent each other as human internal ideas. Hence the discussion in what follows includes both aspects, though this fact may not be explicitly mentioned.

Here inference means the qualitative process in which a result is drawn:
1.through reasoning deductively,
or
2.through reasoning inductively,
or
3.through reasoning by analogy,
or
4.combining the above three procedures.
The deduction 1. is considered to be the inference in the propositional and predicate logics. The induction is the process of drawing some general conclusion from particular instances experienced. The utilization of analogy in inference is to understand an unknown situation from "similar" situations ever experienced. For reasoning by analogy, qualitative similarity sometimes plays an essential role.[2]

Although the meaning will be made clear by the idea described in the next section, inference is classified into three classes:
1.Within an ever experienced local area,
2.Using ever experienced local areas,

3.Without any experienced local areas which surround it.
Just a qualitative reasoning is available in the case of 3. In the cases of 1 and 2, more than a qualitative reasoning is available.

Here, "inference" and "estimation" are defined as follows: Inference is to draw a conclusion from thinking logically, and estimation is usually to numerically evaluate something for reasoning. Estimation is said to be the process for getting particular values required in regulating the operating situations. Estimation here will be included in inference to bring quantitativeness in inference.

## The Notion of Localization for Skill Acquisition

The author has proposed the notion of localization [3] as a necessary restriction in artificial cognitive system mimicking the human system. The notion of localization is, as can easily be imagined, the restriction of attention to a small portion in the large whole. The opposite word to "local" here is of cource "global." A global idea as the total knowledge for a particular single purpose can be called a holistic whole, because local areas which constitute the whole must be combined in some organic manner not as just an aggregation of them.

Definitions of some words used here are given below. As is described in References[3,4], a situation is understood as a local area of a manifold. Many of the objects one deals with, can be said to be the combination of the following two aspects, an operating condition and its corresponding state, especially when a part of it is considered locally.

[Definition] An operating condition of a system is a local coordinate system for a situation.

[Definition] A state is determined by the operating condition given.
[Definition] A situation is the ordered pair (an operating condition, the corresponding state).

The author's own classification of knowledge is described in Reference [5]. There, knowledge is broken down into two categories: One is just "knowledge" and another is "strategy." And "strategy" implies that it works as some sort of operator. A piece of strategy may be called a rule.[6] Here, the aspect of doing something (not just stating a fact) is emphasized in the naming of "strategy." Knowledge and strategy are descriptions with respect to a local area.

## Modeling the Process of Experiencing

The expression $C\setminus D$ denotes the difference of C from D which consists of the elements x's such that $x\in C$ and $x\notin D$.
[Proposition 1]For any $C,D\subset E$, the equation $C\cap D=C\setminus(C\setminus D)(=D\setminus(D\setminus C))$ holds.
( $C\setminus(C\setminus D) = C\cap(C\cap D^c)^c = C\cap(C^c\cup D)$
$= (C\cap C^c)\cup(C\cap D) = C\cap D$.)

Now let A be a finite set and R a partial order relation. Finiteness of A comes from the fact that experiencing by a human for a particular kind of events are always finite. For (A,R), let A be closed under the operations of union $\cup$ and difference $\setminus$. Then the set A is also closed under the operation of intersection $\cap$. For considering some measure on A (to be exact, on a Borrel set of A), closedness under the operations $\cup$, $\setminus$ is required and for introducing some topology, the closedness under the operations $\cap$ and $\cup$ is required. The above discussion shows that (A,R) satisfies the conditions necessary for introducing both measure and topology.[7,8] These two mathematical ideas are necessary for evaluating instances compared with the ever experienced examples and something organized through experiencing those real objects. In relation to this, an idea will be described later in some detail.

In the form of (A,R), a single relation is introduced in the ordering. If, multiple relations such as $(A, R_1, R_2, \ldots, R_r)$, are utilized, then a more complex evaluation system can be built. Vectorized relation is assumed in this type of ordering. There are two cases:

1.No priority is assumed among $R_1, R_2, \ldots, R_r$.

2.Some priority is assumed between at least two of $R_1, R_2, \ldots, R_r$.

A vectorized relation can be broken down into the following cases:

1)Vectorized relation without priority --- For two elements $a,b \in A$, a is said to be stronger than b with respect to $(R_1, R_2, \ldots, R_r)$ if $aR_ib$ holds more often than $bR_ia$, $i=1,\ldots,r$. For some $R_i$'s, none of $aR_ib$ and $bR_ia$ may hold. If this is the case in every $R_i$ and also if $aR_ib$ and $bR_ia$ for an equal number of $R_i$'s, then the elements a and b are said to be uncomparable with each other.

2)Vectorized relation with priority --- In the same manner as above, "stronger than" and "uncomparable" can be defined, with the only difference that comparison is made with some weighting corresponding to the degree of priority of each $R_i$. The type of ordering without priority is included in the case where some priority is introduced. That is, the special condition for the case with priority is eliminated in the case of non-priored ordering, comparing any two elements of the set A. So it can be said that a vectorized relation without priority is simpler than the one with priority. Thus $(A, R_1, R_2, \ldots, R_r)$ can be written as just (A,R) for a partial order relation. And in what follows, a vectorized relation will not be distinguished in symbol from a single case.

Order relations to be considered for (re-)organizing pieces of experience ever obtained may be like the ones given below.

i) Dimensions
(Examples): length, width, height, depth

ii) Count

iii)Time
latest, new, old, modern

iv) Volume

v) Weight
weight, specific weight, density

vi) Color
wave length(spectrum), brightness

vii)Surface conditions
roughness, luster, flatness

Since the set A is finite, A can be written as:

$A=\{a_1, a_2, \ldots, a_n\}$,

where n indicates the number of pieces of past experience. Now (A,R) can be written as a sequence so as to express $a_{i+1}Ra_i$, $i=1,2,\ldots,n-1$, as follows:

$a_1, a_2, \ldots, a_n$,

where some succesive elements may be uncomparable. Letting $B_1=A$, pick all the elements b's of $B_1$ which satisfies the property $bRa_1$. And let such elements constitute the set $B_2$. In like manner, let the upper bound of the local minimum $b_i$ of $B_i$ be the elements of $B_{i+1}$. The family of sets thus formed $\{B_i\}$ will be called the filter base of a particular experience sequence concerned.

The notion of filter base can be used for evaluation. This will be described below, for obtaining the feelings of "big," "medium," and "small." "Big" and "small" can be defined as the inverse relation of each other, since they are the antonym of each other as a concept. When an experience sequence is formed under any one of these relations, then the "inverse" experience sequence is also formed automatically. That is,

[Definition] When the filter base of an experience sequence "big" is given, then the filter base of "small" can be formed by taking the lower bound of each of the elements ($B_i$'s) of the filter base "big," and vice versa.

Now that "big" and "small" are given, the secondary concept "medium" of them can be defined. "Medium" means that it is as far as possible from each of "big" and "small," including the problem of measure. This meaning of "medium" sounds contradictory, but "medium" is such a concept. Anyway, the numbers of elements of the filter bases of both "big" and "small." Thus, "medium" can be defined as follows.

[Definition] The filter base of "medium" can be given as the family of sets each of which is the intersection of particular elements ranked in the same rank choosing one from every filter base.

To be concrete, let $\{A_K\}$ and $\{B_K\}$, $k = 1, 2, \ldots, m$, $m \leqq n$, be the filter bases of "big" and "small." Then by the sets $C_j$'s, $C_j = A_{K-r} \cap B_{K-r}$,

$j = 1,2,\ldots,m-r+1$, $k = r+1, r+2, \ldots, m$, the filter base of "medium" can be constituted, where r is the minimum k which satisfies the condition,

$$A_K \cap B_K \neq \emptyset.$$

Numerically evaluable concepts like "big and small" and "high and low," etc. are not the only concepts of which the filter base can be formed. More general concepts may be the objects to be dealt with within the above framework. The filter bases of a partial order relation R and its inverse relation $R^{-1}$ are constituted by the same single experience sequence, as the negation of the other, in the same manner as the above. Thus the "medium" in an abstract sense can also be formed in like manner:

[Definition] (the extension of the concept of "medium" in the ordinary sense;i.e., "Does not belong to any one of the experience sequences for R and $R^{-1}$.") Let the filter bases for R and $R^{-1}$ be $\{A_K\}$ and $\{B_K\}$, $k = 1, 2, \ldots, m$, $m \leqq n$, respectively. Then, "neither R nor $R^{-1}$" can be evaluated by the filter base $\{C_j\}$ where

$$C_j = A_{K-r} \cap B_{K-r},$$
$$j = 1,2,\ldots,m-r+1,$$
$$k = r+1, r+2, \ldots, m.$$

As is dealt with in References [4,5,6,8], knowledge and strategy are expressed in IF~THEN~ form. There, premises and consequents are stated in a (natural) language. So in this sense the style of evaluation described above is fundamental for inference. That is, a human classifies rather roughly in evaluation and hence the idea fits such human cognitive activities. Now the fundamental ideas for inference and estimation is provided in the above. Fig.1 shows the roles played by each idea in the whole and the relationships held between those.

## Conclusion

"Localization," as has been discussed in the present paper and the previous papers by the author, seems to play a fundamental role in human cognitive activities. Concept understanding, especially in acquiring expertise, always needs experiencing. Experiencing is defined, in the above papers, as obtaining (partial) order relations necessary to accept instances of a particular concept. In this sense, experiencing is to obtain the feeling of some distance as a (sometimes weighted) distance from representatives in some sense. (Weighting is available if equipped with a measure.[7]) The discussion in the present paper is being implemented by the concrete ideas described in References [9,10,11,12].

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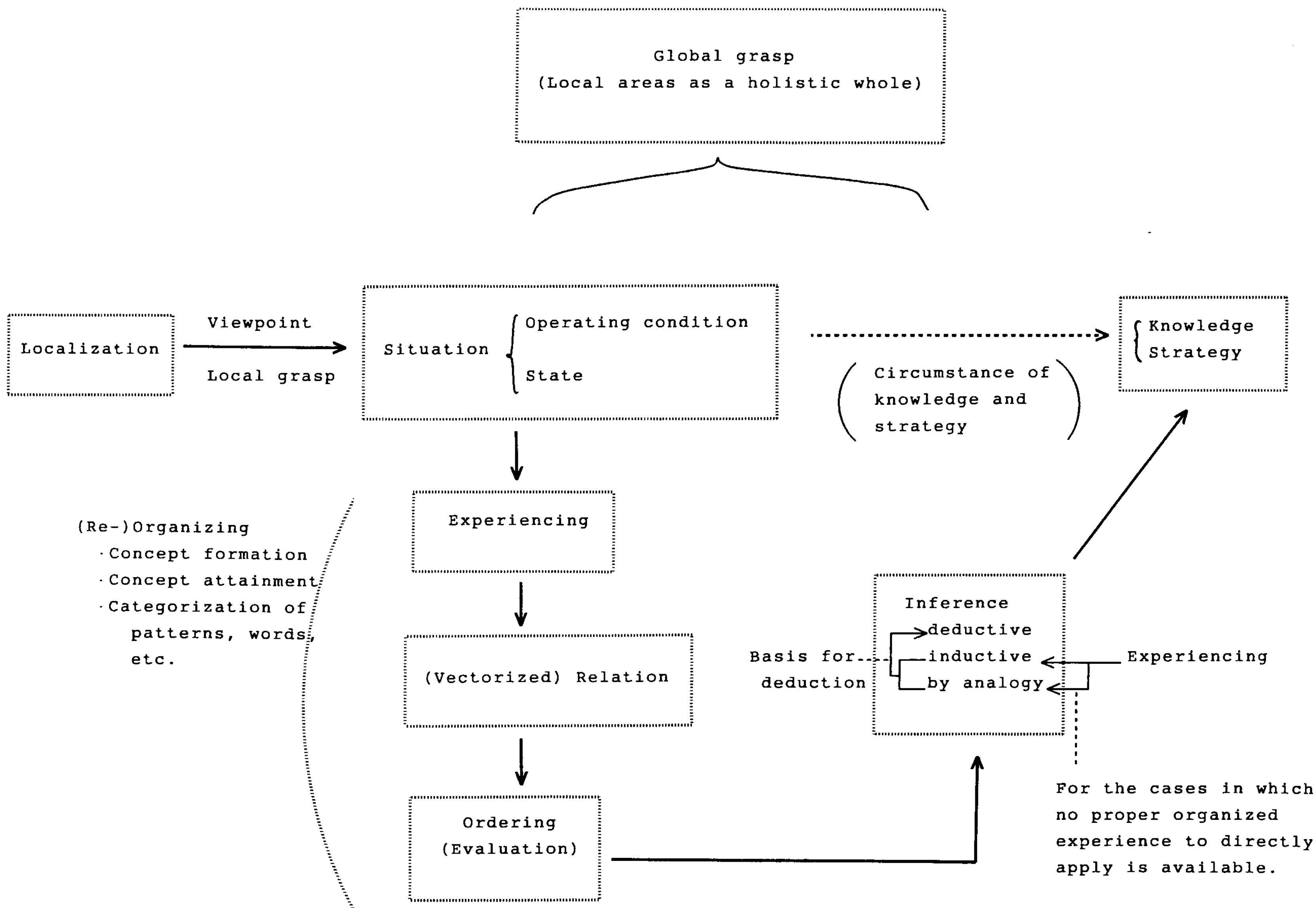


Fig.1 Schematic overall view of the ideas here

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