Nourishing Problem Solving Skills by Performing HCI Tasks

Relationships between the Methods of Problem Solving (Retrieval, Discovery, or Search) and the Kinds of Acquired Problem Solving Skills

MUNEO KITAJIMA Nagaoka University of Technology, Japan : mkitajima@kjs.nagaokaut.ac.jp
URL http://oberon.nagaokaut.ac.jp/ktjm/organic-self-consistent-field-theory/index.html

Abstract: There are three methods for deriving a solution for a problem with which a person is facing, which are 1) retrieval of an existing solution from his/her own memory or from available external resources including human resources, digital resources, and so on, 2) clarifying the constraints to meet and discovering a solution that should satisfy them by exploring the problem space, or 3) deriving a solution by applying inference rules successively until the goal state is achieved. This paper describes the distinctive cognitive processes that respective methods should use when deriving a solution. On the assumption that the ultimately needed problem solving skill would be the one which makes a person solve any problem by himself or herself without reliance on any external resources other than himself/herself, i.e., adaptive problem solving, this paper discusses the implications of the respective methods of problem solving to acquiring the required problem solving skill.

Nourishment of Problem Solving Skills occurs while ...

Solving Problem by Inference

- PMD activated by external perceptual stimuli is used to:
  - Retrieve production rules from procedural memory in BMD
  - Retrieve factual knowledge from declarative memory in RMD
- PS activity would depend on the contents of memory and the functioning of perceptual sensors
- Influenced by the kinds of experiences one has had from his/her birth, by the culture, and the circumstances one is in in everyday life while one grows up to shape (PMD, RMD, BMD) structure
- *External environment should be of crucial importance for nourishing this kind of PS skill*

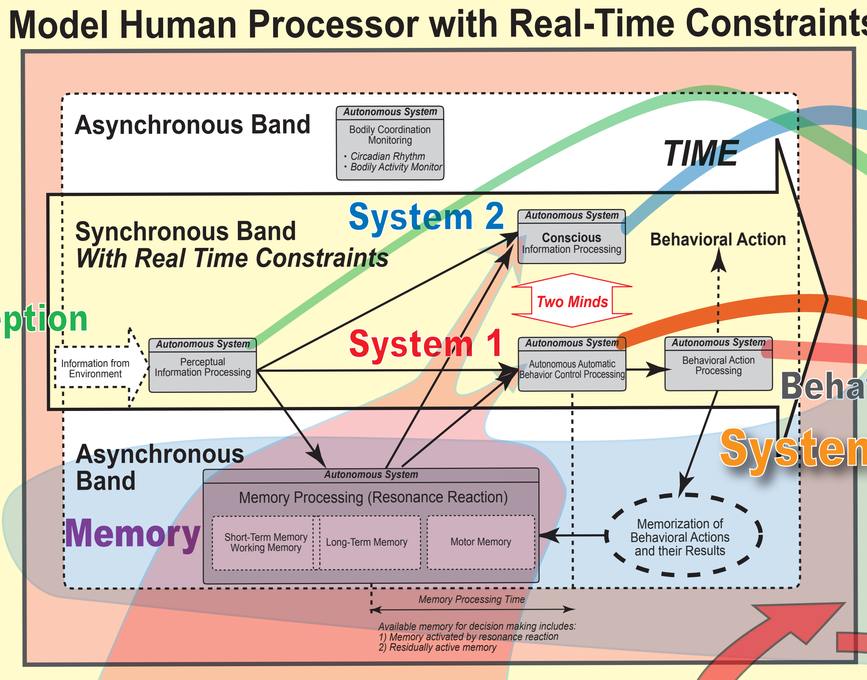
Solving Problem by Exploration

- Development of flexible and rich memory is necessary for acquiring adaptive expertise through a variety of experience with reality
- Often felt that a solution is discovered suddenly or the solution emerges spontaneously
- The critical process underlying the discovery is memory resonance
- The richness of memory should affect the possibility of successful discovery should happen
- *A variety of experience with reality is important for nourishing this problem solving skill*

Action Selection and Merorization Processes

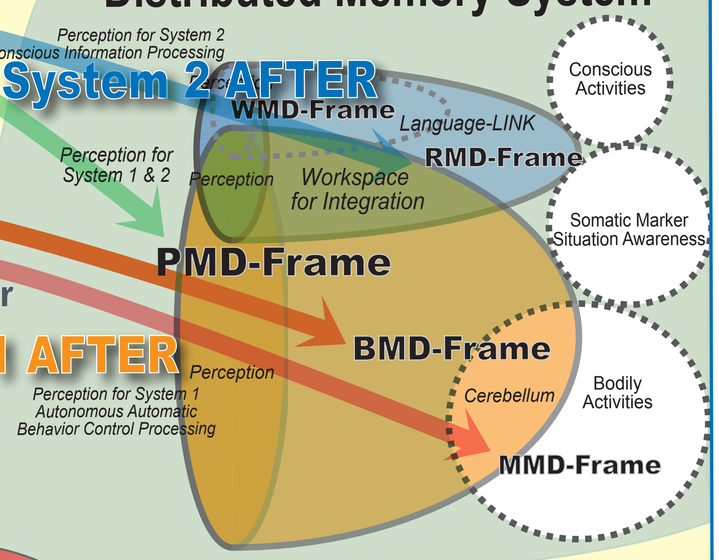
Kitajima, M. (2016). *Memory and Action Selection in Human-Machine Interaction*. Wiley-ISTE.
Kitajima, M. and Toyota, M. (2012). Simulating navigation behaviour based on the architecture model Model Human Processor with Real-Time Constraints (MHP/RT). *Behaviour & Information Technology*, 31(1):41–58.
Kita jima, M. and Toyota, M. (2013). Decision- making and action selection in Two Minds: An analysis based on Model Human Processor with Realtime Constraints (MHP/RT). *Biologically Inspired Cognitive Architectures*, 5:82–93.

Model Human Processor with Real-Time Constraints

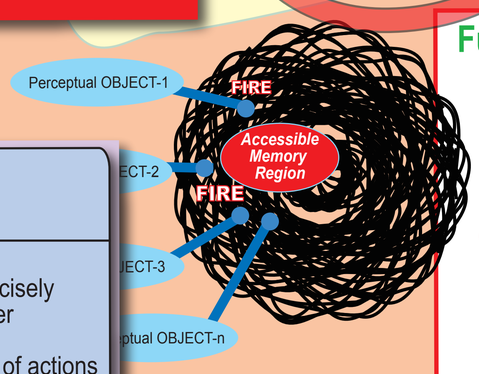


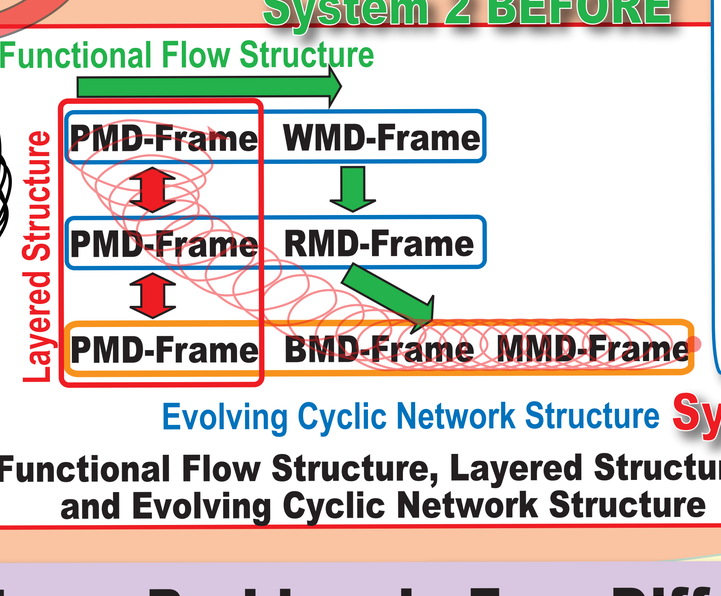
Memorization

Distributed Memory System



Action Selection





PMD (Perceptual Multi-Dimensional) Frame constitutes perceptual memory as a relational matrix structure. It collects information from external objects followed by separating it into a variety of perceptual information, and re-collects the same information in the other situations, accumulating the information from the objects via a variety of different processes. PMD incrementally grows as it creates memory from the input information and matches it against the past memory in parallel.

MMD (Motion Multi-Dimensional) Frame constitutes behavioral memory as a matrix structure. The behavioral action processing starts when unconscious autonomous behavior shows after one's birth. It gathers a variety of perceptual information as well to connect muscles with nerves using spinals as a reflection point. In accordance with one's physical growth, it widens the range of activities the behavioral action processing can cover autonomously.

BMD (Behavior Multi-Dimensional) Frame is the memory structure associated with the autonomous automatic behavior control processing. It combines a set of MMD frames into a manipulable unit.

RMD (Relation Multi-Dimensional) Frame is the memory structure associated with the conscious information processing. It combines a set of BMD frames into a manipulable unit. The role BMD frames play for RMD frame is equivalent to the role MMD frames play for BMD frame.

WMD (Word Multi-Dimensional) Frame is the memory structure for language. It is constructed on a very simple one-dimensional array.

Solving a Problem in Four Different Modes

1) Solving a Problem by Retrieval

Solving a well-defined problem

Preparation
- Goal and initial states are represented unambiguously and precisely
- Able to retrieve the description of action sequences from his/her memory that should intervene the both ends of the states
- System 2 Before Mode is used when retrieving the sequences of actions

Execution
- Carry out the retrieved sequence of actions
- *Hill climbing*
- System 1 Before Mode is used to solve the problem (PMD, BMD)

Memorization
- Strengthen the retrieved memory trace that connects the representation of the initial state and the goal state
- System 1 or System 2 After Mode strengthen the memory that has used in the activity (PMD, BMD)
- *Learns from the PS practice to strengthen the memory traces of successful performance; connection (PMD, BMD) might be strengthened.*

2) Solving a Problem by Retrieval

Problem solved without problem solving activities

Preparation
- Goal and initial states represented unambiguously and precisely
- The description of the problem statement is used literally as it is
- Expects to reach any "solutions" someone has created for the problem
- *Retrieve solutions using external memory to internal (PMD, WMD)*

Execution
- Follow consciously the sequences of actions as the solution specifies, i.e., *the problem has solved by borrowing the others' thinking*
- Perceives the state of the problem and moves eyeballs and hands as the description of what to do in the perceived situation (PMD, WMD, MMD)

Memorization
- Could use System 1 After Mode for tuning neural networks to just finished activities, MMD
- Could use System 2 After Mode for reflection (PMD, WMD, MMD)
- Memorizes the episode, *"the problem was given, and successfully solved by retrieving solutions from the Web" (PMD, WMD)*
- Link between the problem and the solution may or may not be established, i.e., RMD may not be created
- *Learning is very limited*

3) Solving a Problem by Inference

Preparation
- Goal and initial states represented unambiguously and precisely
- Retrieve inference rules, i.e., *procedural knowledge*, to carry out the necessary state transitions
- *Equipped with procedural memory, which connects PMD and BMD with the help of RMD*

Execution
- Inference rules are successively applied to transform the current state to the next until the goal state is achieved
- System 2 Before Mode is used for planning (PMD, RMD)
- System 1 Before Mode is used to execute individual production rules (PMD, BMD, MMD)

Memorization
- System 1 After Mode is used to strengthen the successfully applied production rules in BMD and declarative memory in RMD
- System 2 After Mode might be used to create a new set of production rules that are expected to function more efficiently for the kinds of situations defined by the just solved problem

*Ultimately, the person will have the ability to carry out the same task more and more efficiently, very fast without error, i.e., has acquired **Routine Expertise** for the kinds of tasks executable by applying well-learned procedural knowledge, BMD.*

4) Solving a Problem by Exploration

Preparation
- Can only represent both the goal state and the initial state vaguely
- Not possible to retrieve anything directly relevant to solve the problem
- *Needs needs to create effective retrieval cues to find any action that should move the current state to another along the unknown successful path to the goal*

Execution
- Memory system receives input from the autonomous perceptual system
- Chain-firing starts from PMD, followed by activation of WMD, RMD, BMD, and MMD, makes the memories available to System 1 and 2
- System 2 Before Mode and System 1 Before Mode use resonance to select the most appropriate next action in BMD

Memorization
- The processes are totally exploratory but the memory traces of the executed actions will be created with the flag of success or failure
- The memory trace with successful performance (PMD, BMD, RMD, and WMD) will be strengthened because it is associated with reward

*Ultimately, the person will have the ability to handle the same situation flexibly with less ineffective search; it is said that he/she has acquired **Adaptive Expertise** for the kinds of ill-defined tasks with a variety of well-developed BMD available through chain firing initiated from PMD.*

HUCAPP 2018 - 2nd International Conference on Human Computer Interaction Theory and Applications