# Distributed Memory System Architecture based on the Analyses of Human Brain Memory

## *The Complex System of Functional Flow Structure, Layered Structure, and Evolving Cyclic Network Structure*


***Abstract:*** A novel human memory system architecture is proposed. The memory system is an integration of three distributed memory systems associated with respective autonomous organic systems, including the perceptual system that takes care of sensory input from the environment, the conscious system that performs deliberate decision making, and the unconscious system that carries out action selections in the environment. This memory system architecture is consistent with the wide range of recent findings in the field of neurosciences. The memory system architecture works as a memory component in the comprehensive real brain model, MHP/RT, published in the Cognitive Science conferences, and the BICA conferences. MHP/RT is capable of simulating human daily behavior considering real time constraints that should define strong mutual dependencies among the three systems. With this memory system architecture, MHP/RT becomes a real brain model to be contrasted with virtual and partial models, such as ACT-R.


***Publications***


Kitajima, M., & 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, Available online 15 June 2013.

Kitajima, M., & Toyota, M. (2012). Simulating navigation behaviour based on the architecture model Model Human Processor with Real-Time Constraints (MHP/RT). *Behaviour and Information Technology*, **31**, 1, 41-58.

Kitajima, M., & Toyota, M. (2012). The Role of Memory in MHP/RT: Organization, Function and Operation. *Proceedings of ICCM 2012: 11th International Conference on Cognitive Modeling*, 291-296.



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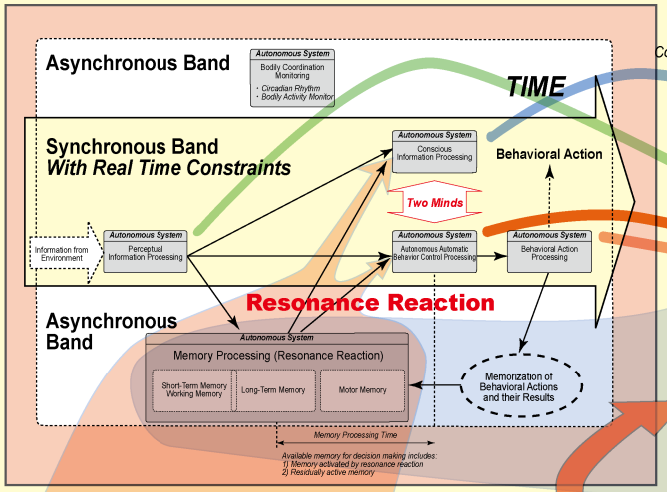
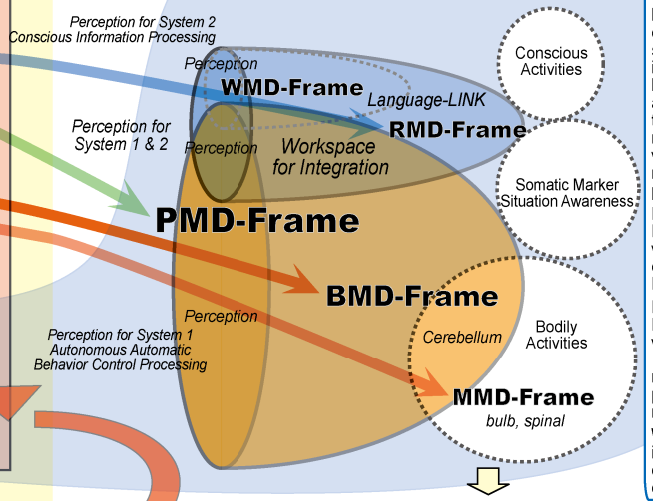
## Model Human Processor with Real-Time Constraints




## Distributed Memory System




**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.

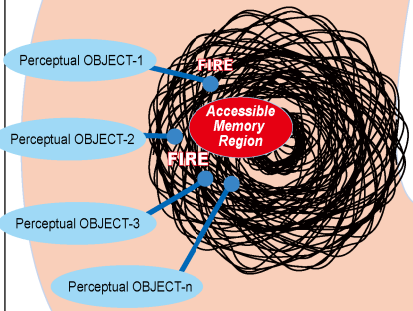
## Memory Reaction Under Realtime Constraints

Since one's birth, one continuously carries out physical behavior without any pause. This reflects on the construction of the respective memories: each constitutes a continuous cyclic network that reflects day-by-day cyclic events.

Perception plays an important role for the cyclic memory network. The memories are cross-connected each other and perceptual objects reside at the center of the cross connections. The perceptual system continuously monitors changes in the environment, and starting from the perceptual objects that are created while processing the environment, it fires the cyclic memory network. The firing continues and spreads in the network, i.e., chain-firing, as long as the perceptual objects last in the environment.

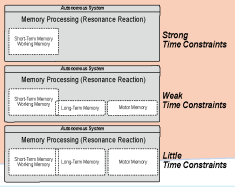
The activated region of the network finally obtained as the result of the chain-firing is "the accessible memory region" at the moment. What this process actually does is to preprocess the situation for the future by activating related memory regions beforehand.

The right figure illustrates schematically the process of chain-firing triggered by perceptual objects. The activated region would be used with a high priority in the situation with severe realtime constraints.



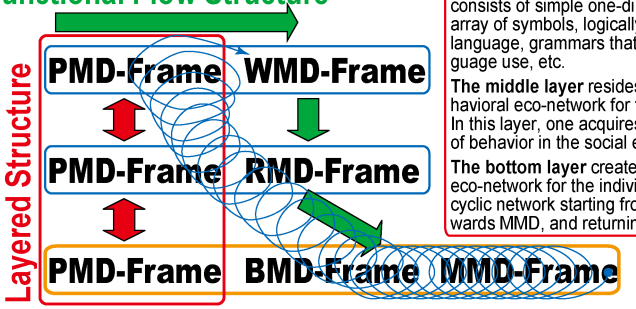

Chain-firing Triggered by Perceptual Stimuli in the Cross-Networked Memory Structure

Respective autonomous systems generate distributed memories for their use. The memories are cyclic and in effect topological, characterized by Evolving Cyclic Network Structure. They are structurally organized in three layers - Layered Structure, and at the same time they are used according to the Functional Flow Structure in the order of PMD, RMD, BMD, and finally MMD. These three features enable pipelining the processes. This cyclic connection is critical to understand the relationship between behavior and memory, which is not appropriately dealt with in the neuroscience researches.




Realtime constraints work as information filter in the time dimension with several characteristic time frames.

## Functional Flow Structure




**The top layer** is controlled by words. It consists of simple one-dimensional array of symbols, logically constructed language, grammars that specify language use, etc.

**The middle layer** resides on the behavioral eco-network for the individual. In this layer, one acquires the meaning of behavior in the social ecology.

**The bottom layer** creates a behavioral eco-network for the individual. This is a cyclic network starting from PMD towards MMD, and returning to PMD.

Evolving Cyclic Network Structure

**Functional Flow Structure, Layered Structure, and Evolving Cyclic Network Structure**