Autonomous Systems Interaction Design (ASID) based on NDHB-Model/RT

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Abstract Traditional interactive systems transform input to the systems from the environment to output in the environment by using a set of rules. However, these systems are not intelligent enough to respond to an ever-changing environment including users. There are thus cases where inputs to a system may drift too far to be treated by the set of rules, and the system might respond inappropriately. This paper proposes a new perspective on interactive system design. The key idea is to treat interactive systems as autonomous systems that interact with users that are other autonomous systems, and designing interactive systems implies designing autonomous system interactions that establish natural cooperation among them. At CogSci2007[3] and CogSci2008[1,2], we proposed an architecture model called the Nonlinear Dynamic Human Behavior Model with Real-Time Constraints, NDHB-Model/RT. We demonstrate in this paper that this architecture model provides a basis for Autonomous System Interaction Design.

Society of Autonomous Systems

Human beings interact with an environment that includes interactive systems. This section starts by describing a society of systems having the property of linearity or autonomy, followed by the needs that those systems must satisfy and the proposal of autonomous systems interaction that should meet the requirements.

Linear Systems. Behaving objects in the environment are defined in four-dimensional space-time coordinates. A human being viewed as a linear system acquires information of behaving objects via its sensory organs as two-dimensional data. The four-dimensional data are reduced to two-dimensional data in this process. The input data are then used for representing their characteristics by means of static linear functions. When an objective of behavior is given, the linear system will behave by deriving static solutions by using the linear functions that best match the current situation.

Figure 1 illustrates a society of linear systems managing various situations by tuning the relationships among the constituent systems. However, there are situations where the current organization of the systems causes a large amount of stress in spite of efforts made to resolve the situations and they cannot behave properly. In these situations, the systems have to change themselves. However, the change may or may not produce good results. In the worst cases, the change may cause a rapid increase of stress and crash the system.

Autonomous Systems. Human beings viewed as autonomous systems represent behaving objects in the four-dimensional space-time environment via sensory organs. For example, the sense of taste is represented by six-dimensional data and the sense of sight is represented by four-dimensional data. The input data are processed mainly by the A^2BC-layer (Autonomous-Automatic Behavior Control layer) and the B-layer (Bodily state layer), and by *optionally* by the C-layer (Conscious state layer) in the brain, and used to define functions that work in SMT [2] and MSA [3] with the real-time constraints defined by BIH [1]. The functions accumulate personal four-dimensional experience continuously. When an objective of behavior is given, the autonomous system will behave by deriving effective regions so that the self will behave properly by using the functions.

When an autonomous system communicates with another one, it uses the effective region at each moment. This assures less stressful communication among autonomous systems than among linear systems (Fig. 1).

Needs that a Society of Information Systems Must Meet

This paper suggests that autonomy of systems is necessary for establishing an effective society of interactive systems because the current society has become rich and has to satisfy each individual's diverse needs. The needs of the society include the following.

Need for efficiency, effectivity and low price. This is satisfied by developing high-performance systems with integrated functionalities. However, it is important to match the performance of the systems with the performance of brain functioning by considering the characteristics of human beings based on NDHB-Model/RT.

Need for ease of use. This depends on an individual's knowledge and its use. This need has priority over the need for efficiency, effectivity and low price. The use of knowledge is mainly defined by SMT.

Need for satisfaction. This need depends on an individual's experience. This is satisfied by developing an autonomous systems society that can deal with diversity in the evaluation criteria and their temporal changes.

Outline of Autonomous System Interaction (ASI)

The current social system is built on the traditional interaction model that assumes linearity of the society. As described above, there are serious limitations in linear systems when trying to satisfy diverse individuals' needs. In the following, this paper outlines autonomous systems interaction that should satisfy the above-mentioned needs for a society of information systems.

An autonomous system monitors its environment continuously and initiates communication with the other autonomous systems when needed. There are three purposes of ASI.

1) It helps enhance the autonomy of human beings.
2) It adds autonomy to devices.
3) It helps maintain harmony of the entire society.

In order to achieve these purposes, autonomous system interaction includes the following characteristics:

1) request for information,
2) support for help, or
3) guide for action.

Initiation of communication includes such activities as 1) direct the other party's attention to the initiator and 2) synchronize activities among the participants. An autonomous system takes the initiative in order to maintain communication.

There are two types of information in ASI. One is static information that is used for the analysis of objectives and evaluation. The other is dynamic information that is used for organizing future courses of behavior.

The static information is acquired either by

monitoring without notice, which means that the system does not notice that it is monitored, or

monitoring with notice, in which the monitored system knows that it is being monitored.

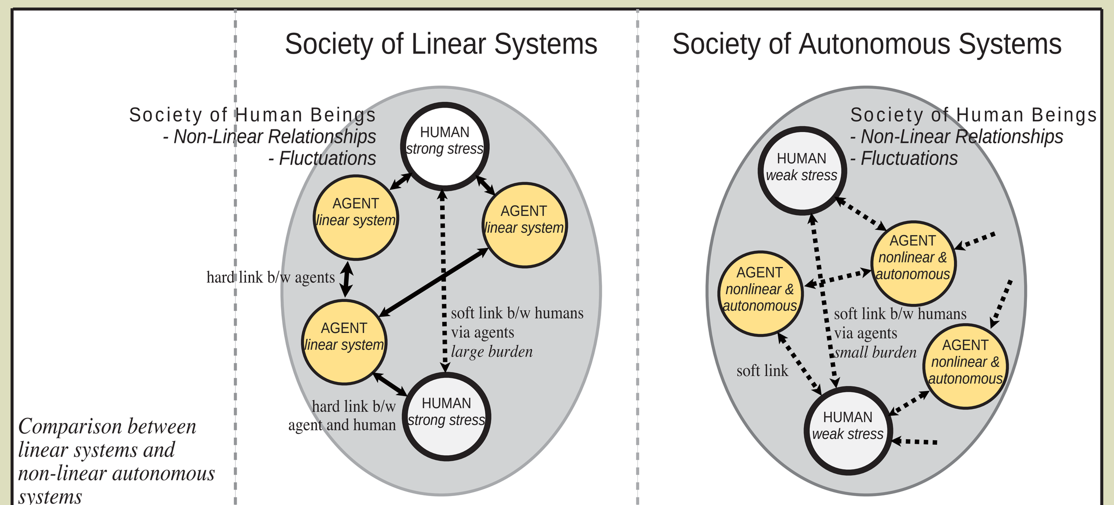
The dynamic information is used for emergency control, supportive control, or full control.

In summary, consciousness and emotion function jointly for determining communication behavior. Figure 2 depicts an example of a society that is designed by means of autonomous system interaction (ASI).

Conclusion

This paper proposed a concept of autonomous system interaction design that is most suitable for constructing a society of interactive systems including human beings. All the constituent systems are modeled and designed as autonomous systems, and thus interactions among them are symmetric. Coordination of systems in pursuit of satisfying the current objectives is achieved through participation of all the systems: each system behaves autonomously for achieving the objectives. Autonomous systems are designed by assuming that human beings behave according to the NDHB-Model/RT.

A society of systems that consists of personal decision support systems, operation support systems, mobile communication support systems, and public support systems would be a typical organization of autonomous system interaction as depicted in Fig. 2. Each autonomous system has its characteristic regions in the spatial-temporal and information dimensions, and it decides what to do next by using a decision-making algorithm that is specific to the system. When deciding, the system monitors the other systems that are relevant to the current decision making and requests information when necessary in order to make better decisions by considering the other systems' behavior. The systems iterate this fundamental coordination process to achieve a stable and effective solution for the current objectives.



Dimensionality:	All systems are 4 dimensional systems	Each system has its own cognitive dimensions
Communication Method:	Synchronization	Cooperative autonomous synchronization
Coordination Method:	Reconstruction of the entire systems	Autonomous coordination by each system
Number of Systems:	Small number of systems acceptable	Large number of sysytems can participate
Soft Link b/w Humans:	Large burden	Small burden

Figure 1: Society of linear systems and society of autonomous systems.

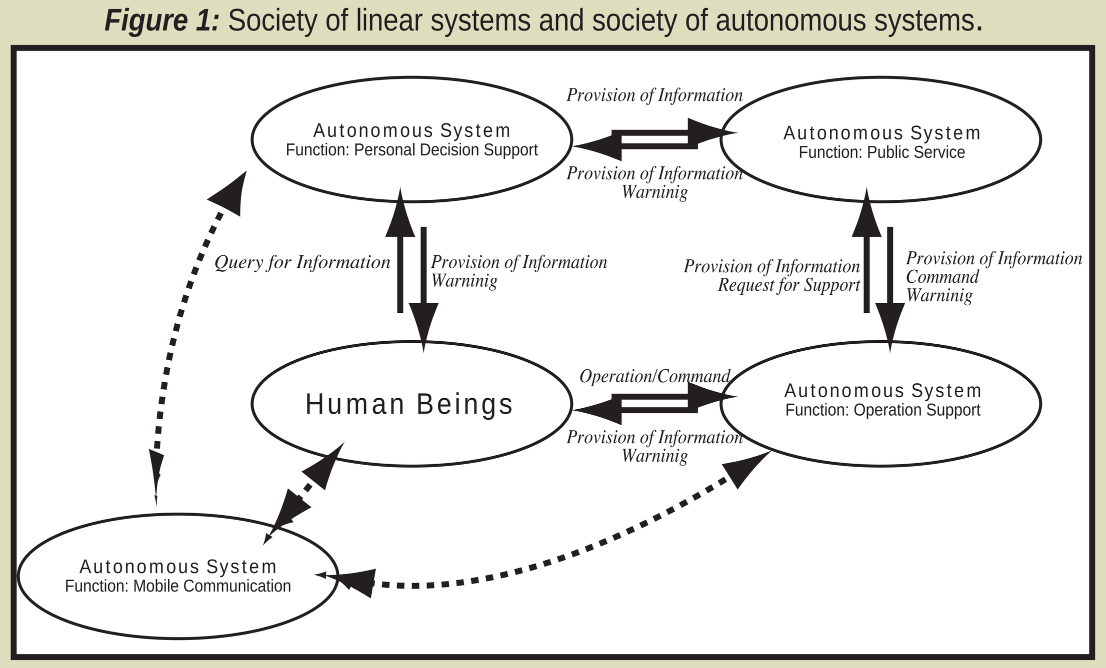


Figure 2: An example of society composed of autonomous systems interaction (AIS).

Nonlinear Dynamic Human Behavior Model with Real-Time Constraints (NDHB-Model /RT)

Living organisms, including human beings, act autonomously. The living environment on the Earth is a field constructed through interactions among the living organisms in a variety of ways. The Earth's environment changes continuously in a one-year fundamental cycle. In order to attain stability in the ever-changing environment, which incorporates the Earth and the other living organisms, living organisms have developed their own autonomous control systems.

The whole universe of complexly interconnected living organisms thus constructed can be called "an organic self-consistent field." Figure A depicts such a field from the viewpoint of the information structure. The autonomous living organisms act by mapping the information structure shown in Fig. A onto their brains in their evolution. The nonlinear dynamic human behavior model with real-time constraints represents an organic self-consistent field as a model.

It consists of three fundamental nonlinear constructs that correspond to the information structure of Fig. A.

1. **Brain Information Hydrodynamics (BIH):** BIH deals with information flow in the brain and its characteristics in the time dimension (see [1] for detail).
2. **Structured Meme Theory (SMT):** SMT deals with empirical effectiveness of information and its range (see [2] for detail).
3. **Maximum Satisfaction Architecture (MSA):** MSA deals with how autonomous systems achieve goals under constraints (see [3] for detail).

BIH, SMT, and MSA jointly define constraints for actions as follows. The phenomena that emerge in the human society are the results of the actions that each human's autonomous system takes in order to maximize satisfaction and happiness (MSA) under the constraints defined by BIH and SMT. Figure B depicts the brain mechanism according to the proposed model. The brain consists of memory that functions as an autonomous organ and bodily activity control that functions as a somatic organ.

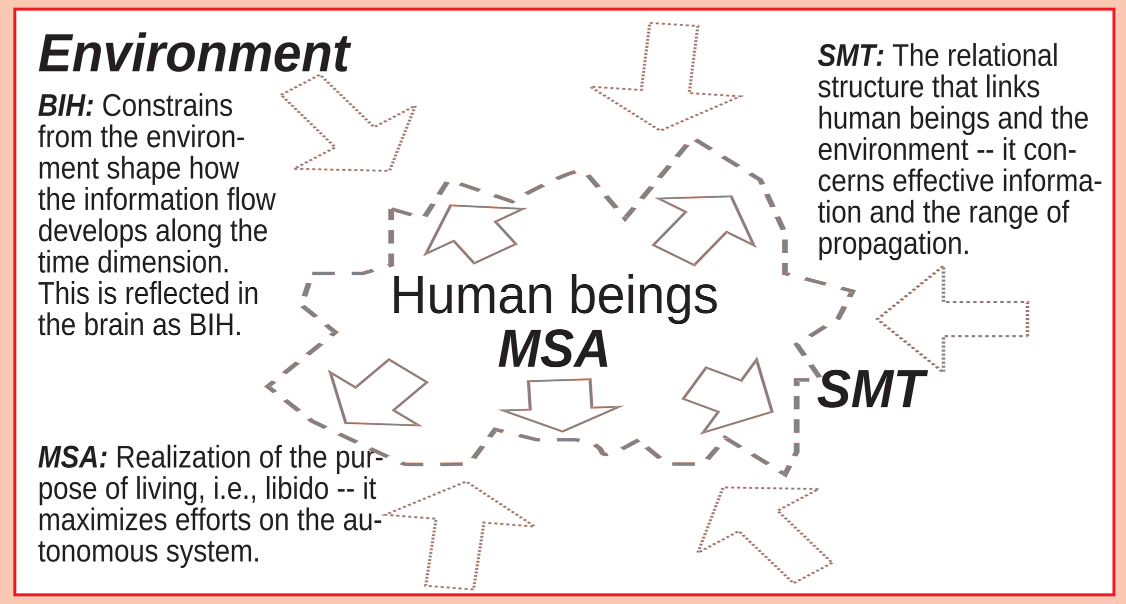


Figure A: Three fundamental constructs that define the nonlinear dynamic human behavior model with real-time constraints.

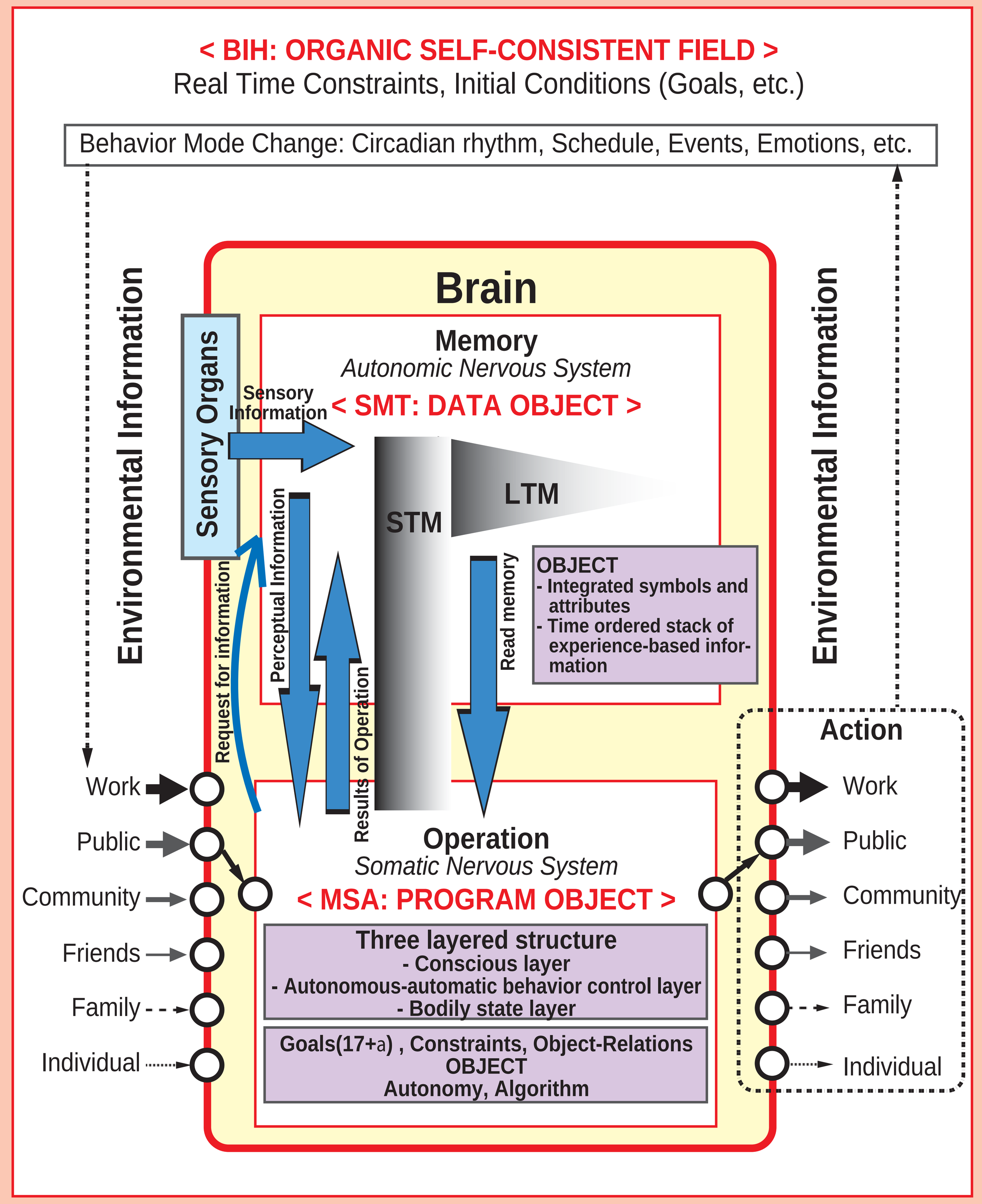


Figure B: Mechanism of the brain explained by the NDHB-Model/RT.

References

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