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An Approach to Adaptive Human Support System

K.Tsukamoto

7-1-1-1122, Aoyamadai
Tarumi,kobe,655-0873,Japan

T.Tsuji

Faculty of Engineering
Hiroshima University
1-4-1, Kagamiyama
Higashi-hiroshima,739-8527,Japan

Abstract

Mechatronics instruments and systems have to be useful for people and operate in order to support the human faculties such as intellect, action and perception. Accordingly, for the investigation of a human support system using mechatronics technology, some aspects of human behavior should be considered. The newly proposed Adaptive Human Support (AHS) system aims at providing support systems for personal use. This article discusses several approach processes to investigate AHS system which are performed with adaptive and optimum conditions for human behavior. This paper tries to suggest making a systematization of AHS system from an integrated standpoint of engineering, psychology and physiology. As the notions common to all object models, "value judgment" and "human entropy" in mental and somatic environments are introduced to design and evaluate AHS system.

1 Introduction

For the purpose of clarifying the mechatronics field within the scope of this paper, it may be classified into three types:

- Micro scale mechatronics (M mechatronics)
- Human scale mechatronics (H mechatronics)
- Large scale mechatronics (L mechatronics)

The targets of research and development in M mechatronics and L mechatronics are applications operated in such special environments as the human body, space, the ocean and large scale engineering plants. The operation base is a remote control having telecommunication existence. On the other hand, the applications of H mechatronics are applied to the instruments and systems for daily life in a life space. The purpose here is to explore a human support system for individual behavior, since the discussion is concerned with H mechatronics. The application systems of H mechatronics have been widespread for industrial and business use, but relatively few for personal use. Although only the technical difficulties requiring intelligence are indicated for personal use, another reason is that value estimation is not established compared with industrial and business use.

The core of discussion in this paper is related to the essence of human support, which is divided into two main constituents.

The first is the new concept of AHS system which is an application of intelligent H mechatronics for human support. At the outset, several notions of the elementary factor included in AHS system are defined. Here adaptability means that the most desirable support is necessary for an individual and the entire autonomous support is not always necessary. Adaptive conditions are decided from value estimation and human entropy.

The second constituent is consideration for human behavior which will be caused by value estimation except for genetic and innate factors, reflective response and unconscious behavior.

What we must consider next is to note human entropy in addition to value estimation. The increasing rate of human entropy in a human body must be suppressed more slowly to maintain sustainable evolution. Cybernetics and homeostasis are the defense systems in a human body, and human entropy is controlled by these systems. The human support system must be designed to suppress indirectly the increasing rate of human entropy as well as the defense systems in a human body. Value estimation and human entropy must deal with extensive learning fields so that systematization by interdisciplinary research is necessary for a human support system.

2 Summary of AHS system

2.1 Background

The main investigation direction of intelligent H mechatronics has been an intelligent autonomous

robot. Although a great deal of effort has been made on the development of its appliances, it remained far from practical use. The character of autonomy, self-organization, self-repair and universality are the main terms for an intelligent robot and it is very difficult to satisfy these needs on a complicated life-space. Accordingly, because of removing the difficulties of a model based robot, a behavior based robot implicated to new AI and A-Life has been proposed. [1]-[3] However, it will be necessary to break through some technical barriers in spite of many new approaches to make an intelligent autonomous robot fit for practical use.

Another direction of intelligent H mechatronics has been a human support system. Attention has been directed to practical use of medical and welfare instruments for disabled and handicapped people. For example, a rehabilitation manipulator and a wheelchair for eating, bathing, excretion and locomotion have been developed. [4]-[6] Individually speaking, there are some excellent ideas for such instruments, however, the essence of a human support for daily behavior has almost never been discussed systematically. In the last few years, the target of a human support system has been extended to daily life support for healthy elderly men and women and has attempted to raise their quality of life.

Under this situation, the concept of AHS systems has been proposed which would be more important systems in an elderly society.

2.2 Concept

The application targets of a human support system for personal use are the substitutive artificial elements for somatic functions, the instruments for daily life support, and the control of the artificial environment in a life space. After all, all of them relate to the individual supports of intellect, action and perception.

The supporting quantity is indicated by the symbol SQ:

SQ=100% : All work is achieved by substitution of an intelligent autonomous robot.

100% ≧ SQ > 0% : All work is achieved by assistance of AHS system.

SQ=0% : All work is achieved by oneself without assistance of a mechatronics system.

For definitions mentioned above, an intelligent autonomous robot is a special case of AHS systems, and cooperation between an operator and a support system will be able to remove the technical difficulties of an intelligent autonomous robot. In addition to this, through the evolution process of one generation, SQ=100% is not always favorable for a person. The details of this phenomenon are investigated in ecological psychology as the theme "Affordances and variability of actions" and in physiological anthropology as "Affordances and evolutionary influence". [7][8] The supporting quantity should be controlled adaptively from 0% to 100% in response to the personal situation and the supporting contents.

Concerning the quality of supporting quantity, the notion of positive and negative support are defined as

$$SQ = f\left(X^{+} \bigcup X^{-}\right) \tag{1}$$

$$X^{+} = g\left\{(Y_a)^{+} \bigcup (Y_p)^{+}\right\} \tag{2}$$

$$X^{-} = g\left\{(Y_a)^{-} \bigcup (Y_p)^{-}\right\} \tag{3}$$

where X^{+} and X^{-} are positive support and negative support, and Y_a and Y_p are active support and passive support. Positive support and negative support mean that supporting quantity gives positive value and negative value to an individual. Active support and passive support mean that supporting quantity acts directly and indirectly to an individual or environment.

We now consider the total value V of AHS system, which is

$$V = V(X^{+}) - V(X^{-}) \tag{4}$$

where $V(X^{+})$ and $V(X^{-})$ are the positive and negative total value, which are defined as

$$V(X^{+}) = \sum_{i=1}^{n} a_i \frac{(y^{+})_i}{(y^{+})_{i\Delta}} \Bigg/ \sum_{i=1}^{n} a_i \tag{5}$$

$$V(X^{-}) = \sum_{i=1}^{n} b_i \sqrt{\prod \left\{\frac{(y^{-})_i}{(y^{-})_{i\Delta}}\right\}^{b_i}} \tag{6}$$

where a_i and b_i are weighting coefficients for value estimation. $(y^{+})_i$ and $(y^{-})_i$ are positive and negative value estimation of each event, and $(y)_{i\Delta}$ is a criterion for normalization.

Where

$$y^{+} = g\left\{(y_a)^{+} \bigcup (y_p)^{+}\right\} \tag{7}$$

$$y^{-} = g\left\{(y_a)^{-} \bigcup (y_p)^{-}\right\} \tag{8}$$

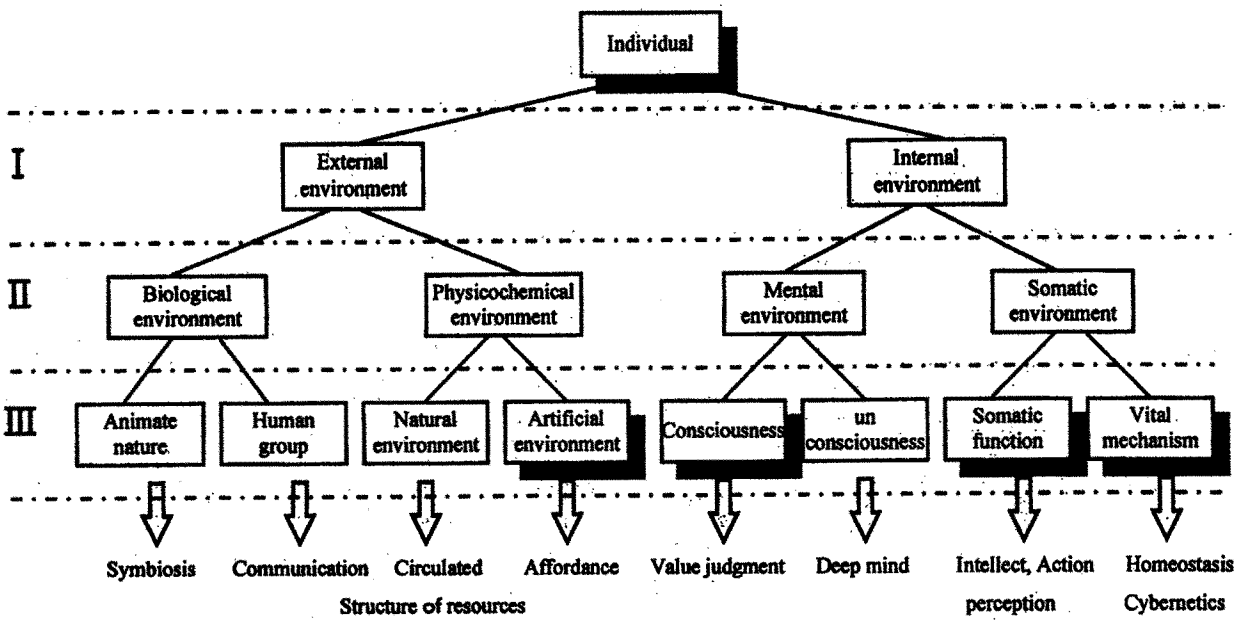

Fig. 1. Relation between individual and environment

3 Systematization

For the purpose of considering the essence of a human support for human behavior, the relation between an individual and his surrounding environment is classified into the three layers of hierarchy frame structure shown in Fig. 1. This systematization will make clear what object we should discuss for human behavior. The lower layer is more concrete than the upper layer, because the information included in the lower layer is attributed to the abstract upper layer. For an intelligent autonomous robot, the original term "individual" shown in Fig. 1 is changed to the term "robot". The locomotive behavior of such a robot is caused by getting intellect based on emergence in relation with the external environment. On the other hand, in case of a human support, individual behavior is affected by both external and internal environments.

The most representative key words extracted from the relation between an individual and each term on the third layer are added at the lowest position indicated by the arrows in Fig. 1. Although every concept should be considered to investigate AHS system, as space is limited, here we limit the discussion to a few items enclosed by a shaded rectangle. Accordingly, we must forgo genetic and inherent behavior, and behavior caused by interpersonal relations and social norms. Value judgment under consciousness is conducted for events caused by the relation between an individual and an artificial environment. This relation is discussed by the affordance theory. We must consider value judgment scientifically and seek quantitative value. The behavior based on value judgment is reflected to the somatic function and the vital mechanism. The physiological indices of the somatic functions such as intellect, action and perception are measured and analyzed for the interpretation of human behavior. Human behavior can also be regarded as the fluctuation of homeostasis in the vital mechanism. Here we introduce a new concept of human entropy for the interpretation of the vital mechanism. Value judgment and human entropy are the main problems awaiting solution for the establishment of the AHS system.

Under these conditions, the relation between AHS system and human behavior is shown in Fig. 2. The essence of a human support for human behavior is discussed from the viewpoints of psychology, physiology and engineering. The feature of Fig. 2 reveals at the standpoint that psychology and engineering pay attention to the motive factor, an individual and his behavior, while physiology takes notice of the mental and the somatic function of an individual.

The analysis of human behavior is the main theme of psychology, which deals with problems of personality and intellect caused by the dynamic interaction between an individual and his total situation. For example as the personality assessment, intellectual emotive and mental dynamic functions are examined, the following objects are their details: intelligence, temperament, character, conflict, and frustration.

The analysis of human behavior, decision making for human behavior, and value estimation for a human support are discussed from the engineering viewpoint. The analysis of human behavior is discussed in cognitive science, the pattern recognition of vision and speech systems are effective to catch up to the features of facial expression, body motion and speech expression. Decision making for human behavior in daily life is almost done by heuristics, however, a prescriptive model and a descriptive model are examined from the standpoint of value estimation to the principle of behavior. Bayesian statistics is used in decision making as a prescriptive model.

We have concentrated on the psychological approach in next chapter.

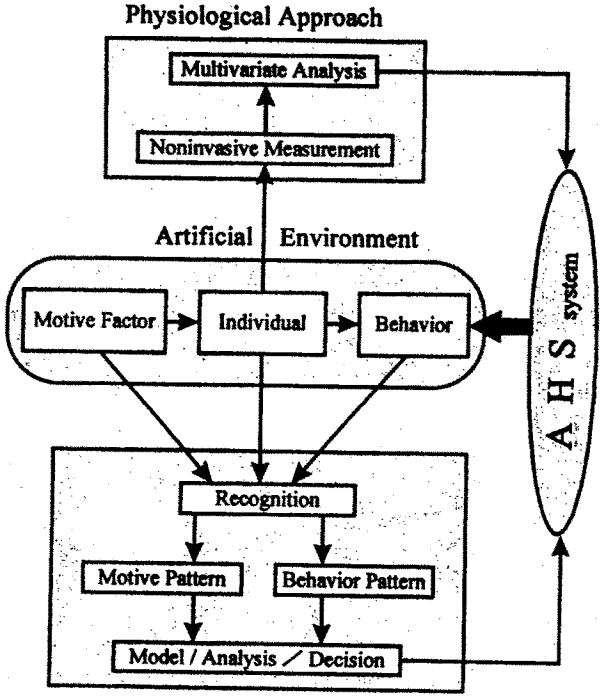

Fig. 2. Approaches from engineering, psychology and physiology

4 Approach methods

Fig. 3 shows the sequential flow of the behavior process, the somatic functions responding to the behavior process, and the measurement items. When an individual receives a stimulus, the signal is recognized and its features are extracted, then the CPG (Central Pattern Generator) is activated by a signal from the commanding neuron. A motor pattern is performed and behavior is carried out by the muscles. The somatic functions are comprised of the sensory organs, central nervous system and peripheral nervous system. Human behavior emerges as a somatic response so that the physiological indices are very effective in the analysis of human behavior. [9]-[10] Engineers are now able to acquire the data using noninvasive measurement. The measurement items practiced at each constituent are shown in Fig. 3. We can discover a great deal of knowledge from the multi-modal data through data mining technology and multivariate analysis.

As an experiment example of psychological indices, we consider various stresses that affect our daily behavior. The relation between the skin temperature and the thermal sensation under various

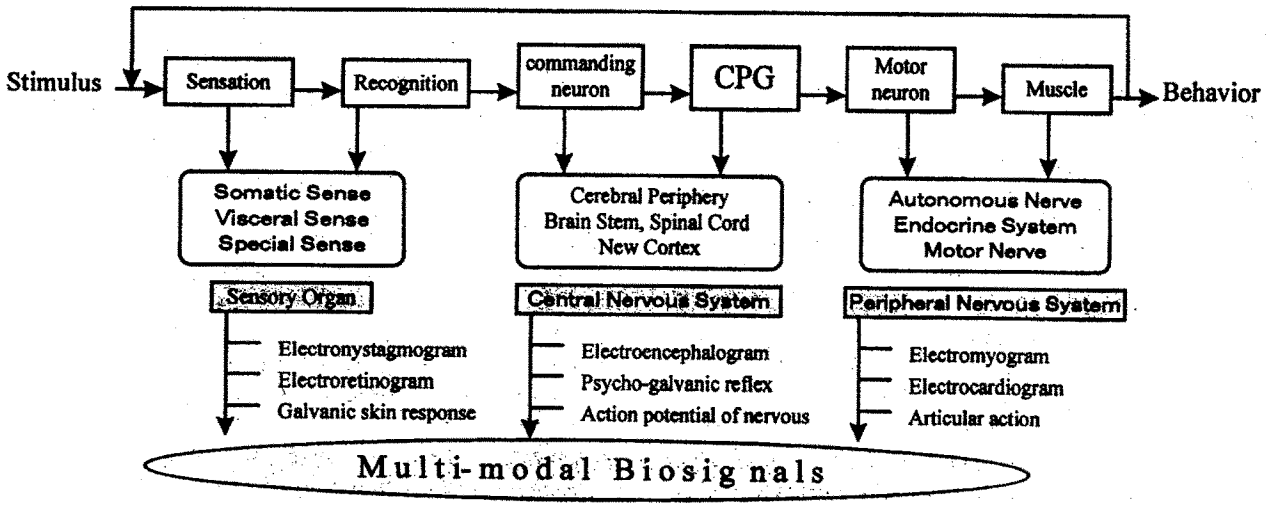

Fig. 3. Physiological indices

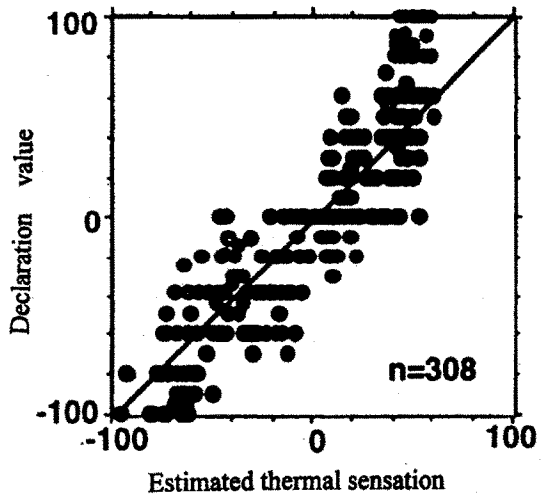

Fig. 4. Estimation of thermal sensation

types of stress is shown in Fig. 4. The thermal sensation data were acquired by a self-reporting numerical figure from a maximum hot level of +100 to a maximum cold level of -100. The inference thermal sensation is determined using facial skin temperature in a multiple regression model. At the onset of a sensation, sensory information in the brain is transmitted as an impulse to the autonomic nervous system that varies such factors as the amount of blood flow in the skin, and the amount of sweat and respiration generated. A warm environment combined with these physiological quantities forms a thermal balance of the skin temperature. We found that the thermal sensation increased while the skin decreased with stress.

When we have a more precise understanding of stress reaction, we should have a biochemical approach. Various signals caused by stress stimulus are arranged in the hypothalmus and CRE (Corticotropin Releasing Factor) hastens secretion of ACTH (AdrenoCorticoTropic Hormone) in an adenohypophysis. On the other hand, sympathomimetic action hasten secretion of adrenaline and noradrenaline so that an increase of heart rate, and a rise in blood pressure and the blood sugar are caused by the action of the cardiovascular system.

As the LCA is important in a product's life cycle, we should consider the LCA of a human life cycle which contains progressive and aging processes. Accordingly, the concept of entropy is applied to a human's life cycle just as it is to product's life cycle. There are three kinds of entropy: thermo-entropy, statistic entropy and information entropy. In isolation and non-equilibrium systems, each entropy always increases and reaches the maximum point of where the equilibrium state means death. The increase of entropy is linked to value deterioration or environmental pollution.

One of the suppression methods of thermo-entropy for a human life is the energies supplied to a human body from the environment and excreted back to the environment. For example, chemical compound such as starch, fat and protein are accepted from the outside of a body, and they are changed to waste compounds such as water, carbon dioxide, and ammonia inside of a body. The other is the homeostasis, which works to maintain the change of human entropy slowly by the following methods. At the cell level, the steady reaction by enzymes synthesis and analysis, and absorption and secretion, which work to maintain a body at a steady state. At the individual level, the phenomenon controlled by hormones, and the defense system for germs and viruses excluded by immunity.

The adaptive control in AHS systems coincides with the suppression of the increase of human entropy and a human support system should perform efficient and valuable work in the increasing process of entropy. We must newly define human entropy for human support. The factors of material, energy and information have a connection with our daily life, however, with respect to human support, the information for human behavior should be considered. Human entropy is defined as the same form with information entropy.

$$H(X) = -\lambda \sum_{i=1}^{n} p_i \log p_i \qquad (9)$$

The contents of the information X are the elements related to human behavior or product value.

5 Conclusion

Mechatronics instruments and systems have to be useful for people and operate in order to support the human faculties such as intellect, action and perception. For the application of human support, we have proposed a new concept for AHS system which is performed with adaptive and optimum conditions for human behavior. Adaptive conditions are decided from the evaluation of value judgment and human entropy introduced as the notions common to all object models. This paper does not describe the framework of AHS system so that it needs further investigation for interpretation of value judgment and human entropy from interdisciplinary research.

The advanced application level of the human support systems are arranged as follows:

1st level : An instrument is designed for the average

needs of customers. The man-machine interface is considered human-friendly in addition to providing efficient operation, but it is not always adequate for every customer.

2nd level : An instrument evolves with the learning rule in response to each user's lifestyle and behavior pattern. The evaluation base is customer satisfaction and preference, but they are not always coincident with true value for customers.

3rd level : An instrument is designed for the personal use of each customer. The personal information data of each customer is acquired by sensing from his body and life space, and used as a feedback signal to an instrument.

4th level : An instrument based on AHS system.

AHS system are a final goal for a human support system and many ideas will be performed on the way to the goal.

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