Briefing of AMAM

H.Kimura[1], H.Witte[2] and G.Taga[3]

[1]Univ. of Electro-Comm., Tokyo, hiroshi@kimura.is.uec.ac.jp

[2]Friedrich-Schiller-Universitat Jena, witte@pan.zoo.uni-jena.de

[3]Univ. of Tokyo & PRESTO, JST, Tokyo, taga@complex.c.u-tokyo.ac.jp

Abstract

In this symposium, several functions of skeletal systems (mechanisms), muscles (actuators) and nervous systems (control) in adaptive motion will be discussed. In addition, relations and coupling between them should become important issues for discussion. In vertebrates, the nervous system as the control instance allows to separate into low level (generation and control at spinal cord), medium level (adaptation at cerebellum), and high level (adaptation at cerebrum) control. In invertebrates, on a first glance the underlying morphology is more integrated, making it difficult to identify functional sub-units of control. Musculoskeletal systems more than ever have to be analyzed in view of dynamic properties of mechanisms. The transfer of those molecular physiological and biomechanical concepts into applications on machine design will be an important topic of the conference.

1 Motivation

It is our dream to understand principles of animals' surprising abilities in adaptive motion and to transfer such abilities on a robot. Up to now, mechanisms for generation and control of stereotyped motions and adaptive motions in well-known simple environment were formulated to some extent and successfully applied to robots. However, principles of adaptation to various environments have not yet been clarified, and autonomous adaptation is left unsolved as seriously difficult problem in robotics.

Apparently, the adaptation ability shown by animals and needed by robots in a real world can not be explained or realized by one single function in control system and mechanism. That is, adaptation in motion is induced at every level in a wide spectrum from central neural system to musculoskeletal system. Thus, we organized this symposium for scientists and engineers concerned with adaptation on various levels to be brought in contact, to discuss on principles on each level and to investigate principles governing total systems. We believe that this symposium will stimulate interests of both scientists and engineers.

2 Outlines

Starting with "high level sensory adaptation" (vision), we arranged the following sessions in an order "decreasing level of neural control, increasing intelligence of construction/morphology/mechanisms".

- Visual Adaptation Mechanisms of Systems in Locomotion
- Neuro-Mechanics
- Design of Neural Controller
- Adaptive Locomotion
- Modeling and Analysis of Motion
- Adaptive Mechanics
- Behavior and Motion of Humans & Humanoids
- Technical Development of Mechanism and Control
- Super-Mechano Systems

The backgroud of papers in those sessions widely broaden on biology, physiology, biomechanics, nonlinear system dynamics and robotics. It is usually difficult for people from different disciplines to discuss on particular issues. In order to ease this problem, we invited five keynote speakers impressively studying on each field. We expect from each keynote speaker to give a comprehensive knowledge found in his field to the audience before the start of the more specialized technical sessions. We also asked the first speaker of each session to explain current states of related research field with additional 10 minutes of talk.

Although all presented studies are referring to principles of animals' motion in some sense, each study differs from others in the actual extent of reference. Roughly speaking, two thirds of all contributions are deeply inspired by principles discovered in animals' motion. In the remaining studies, new ideas are engineeringly proposed and not always constrained by principles of animals' motion. The comparison and competition between biologically inspired methods and engineeringly derived methods in view of ability and complexity in adaptation is important for the future development of novel machines.

3 Key Issues in AMAM

In this section, several key issues in AMAM clarified through discussion between IPC members are enumerated. Terms contrasted in each subsection are not always contrary to each other. But it is very interesting that there are different standing positions in considering generation and adaptation of motion.

3.1 Animals vs. Machines

Animals and machines are quite different in their sensors, actuators, and controlling devices. We would like to know what kind of principles in adaptive motion can be the same, similar or should be different in animals and machines.

3.2 Behavior vs. Motion

There were several interdisciplinary conferences concerned with "Adaptive Behavior": SAB2000[1], for example. In SAB and behavior based robotics, importance of "embodiness" and "dynamics" were emphasized. But these terms usually are used in the sense that a system has sensors and actuators, or that a time factor is considered, since they were proposed in artificial intelligence. The control system in most cases is represented by a diagram consisting of boxes and arrows or a state transition graph.

On the other hand, most of studies presented in AMAM are concerned with "natural dynamics" expressed by dynamic equations. The control system or mechanism for "Adaptive Motion" is described by using differential equations or transfer functions. Therefore, dynamic properties of both control system and musculoskeletal system are important, and adaptation at all levels is required.

Of course, differences between behavior and motion described above are not induced by their linguistic definition, but just the temporary status at this moment.

3.3 Model Based vs. Biologically Inspired

In conventional robotics, since exact models of a robot and environment are necessary and the whole motion of a robot in environment is described as an algorithm based on models, autonomous adaptation requires complicated programs.

On the other hand, such biologically inspired methods like connectionism or behavior based robotics employ a quite different approach. In those methods, motion is not described by using algorithms governing the whole system but by using relations between elements, and adaptive motion is generated through emergent interaction with the environment. Since relations between elements in response to sensor input are sufficient as a description, autonomous adaptation can be derived by simple programs and complicated dynamics of systems in biologically inspired methods. But we have some difficulties in predicting what kind of motion is generated in particular environment.

The comparison between the methods is illustrated in Table 1.

	Model Based	Biologically Inspired
model	robot and environment	not necessary explicitly
description for motion	algorithm governing whole system	relation between elements
prediction/ reappearance	easy	difficult
adaptation	complicated program	emergence in dynamics

Table 1 Comparison between a model based method and a biologically inspired method for adaptive motion

3.4 Control vs. Mechanics

In high speed motion like running, it is difficult to realize effective control in very short stance phase. Therefore, the importance of the passive dynamic properties of the musculo-skeleton is pointed out in biology, and machine design in such view point is emphasized in robotics in these days. The passive dynamic properties yet identified to be relevant in this context are the configuration of joints and links (geometry, morphology, topology) and spring and damping factors in muscles, tendons, soft tissues, joints or exoskeletons (structural or material properties).

On the other hand, one of the reasons why motion generation and adaptation can be derived by using relatively simple neural systems is that part of the dynamics of the musculoskeleton is encoded in neural systems as parameters of CPG(Central Pattern Generator) and reflexes. Therefore, the coupling between the dynamics of neural system and the passive dynamic properties of the musculoskeleton will become increasingly important in biologically inspired robotics.

Studies of "Super-Mechano Systems" also are aiming at the new machine design method by combining control theory and mechanical design.

3.5 Locomotion vs. Manipulation

Are locomotion and manipulation based on the same principles, as far as mechanisms of motion generation and adaptation are concerned? IPC members have no consensus about how to answer this question. At least in robotics, locomotion and manipulation have been developed independently to some extent. For example, fine motion in assembly tasks, and motion planning and control in vision coordination are typical sensor based adaptations in manipulation. Manipulation theories for such motion types are established completely independently of locomotion. But we have established sufficient locomotion theories in neither sensor based nor sensorless dynamic adaptation yet. It seems that this is the reason why a lot of people are interested in biologically inspired locomotion control.

We even would like to provoke any comments from participants from different fields to this topics.

3.6 Visuomotor Adaptation in Locomotion

Even if we accept that basic walking patterns to some extent are generated by CPGs, it is not clear enough how vision based adaptation is related to CPGs. There are several hypotheses:

(1) directive signals based on vision are sent to CPG and CPG itself adjusts motion of a leg,

(2) reflexes based on vision adjust motions of a leg independently of CPGs generating basic walking patterns,

(3) only reflexes generate walking patterns and adjust motion of a leg without CPGs.

We are expecting active discussion in related sessions.

In addition, it is also very important to make it clear how adaptation based on vision is acquired through learning.

3.7 Being Genetically Programmed vs. Learning vs. Development

It is well known that a horse can start walking several hours after its birth perhaps mostly by a genetically programmed mechanism with slight tuning mechanism at spinal cord. However, as sensor informations for adaptation become sophisticated, learning at the cerebellum for adaptation and learning at the basal ganglia for adjustment based on vision becomes more important. When we design control systems for a robot, it will become important to make it clear what kind of combinations of these mechanisms are totally effective in view of costs of programming, experiments and computation. In addition, during ontogenetic development not only parameter tuning but also drastic changes of structure are a very important matter of adaptation.

4 Future

It is important how to combine contrasted issues in Section.**3** according to task level.

No matter what we discuss on, "Science vs. Engineering" or "Biology vs. Robotics" is not one of the key issues in AMAM. When we solve unknown complicated problems, it is desirable to proceed analysis and synthesis concurrently. It is well-known that analysis by synthesis is a really good and important methodology to understand principles. That means the beginning of a new interdisciplinary research field where science and engineering are merged.

References

[1] SAB2000, Int. Conf. on Simulation of Adaptive Behavior, http://www-poleia.lip6.fr/ sab2000/