Toward a "Well-balanced" Design: A Robotic Case Study
— How should Control and Body Dynamics be Coupled? —

Akio Ishiguro[1], Kazuhisa Ishimaru[1], Koji Hayakawa[1] and Toshihiro Kawakatsu[2]

[1]Dept. of Computational Science and Engineering, Nagoya University
Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan
ishiguro@cse.nagoya-u.ac.jp, {ishimaru/koji}@cmplx.cse.nagoya-u.ac.jp
[2]Dept. of Physics, Tohoku University
Aoba, Aramaki, Aoba-ku, Sendai 980-8578, Japan
kawakatu@cmpt.phys.tohoku.ac.jp

In robotics, traditionally, a so-called "hardware first, software last" based design approach has been employed, which seems to be still dominant. Recently, however, it has been widely accepted that the emergence of intelligence is strongly influenced by not only control systems but also their embodiments, that is the physical properties of a robots' body[1]. In other words, the intelligence emerges through the interaction dynamics among the control systems(i.e. brain-nervous systems), the embodiments(i.e. musculo-skeletal systems), and their environment(i.e. ecological niche). In sum, control dynamics and its body(i.e. mechanical) dynamics cannot be designed separately due to their tight interdependency. This leads to the following conclusions: (1) there should be a "best combination" or a "well-balanced coupling" between control and body dynamics, and (2) one can expect that quite an interesting phenomenon will emerge under such well-balanced coupling.

On the other hand, since the seminal works of Sims[2], so far various methods have been intensively investigated in the field of Evolutionary Robotics by exploiting concepts such as co-evolution, in the hope that they allow us to simultaneously design control and body systems[1]. Most of them, however, have mainly focused on automatically creating both control and body systems, and thus have paid less attention to gain an understanding of well-balanced coupling between the two dynamics[3]. To our knowledge, still very few studies have explicitly investigated this point(i.e. appropriate coupling)[1].

In light of these facts, this study is indended to deal with the interaction dynamics between control and body systems, and to analytically and synthetically discuss a well-balanced relationship between the dynamics of these two systems. More specifically, the aim of this study is to clearly answer the following questions: (1) how should these two dynamics be coupled?, and (2) what sort of phenomena will emerge under the well-balanced coupling?

Since there are virtually no studies in existence which discuss what the well-balanced coupling is, it is of great worth to accumulate various case studies at present. Based on this consideration, a decentralized control of a multi-legged robot consisting of several body segments is employed as a practical example. The derived result indicates that the convergence of decentralized gait control can be significantly ameliorated by modifying both control dynamics(e.g. information pathways among the body segments) and body dynamics(e.g. stiffness of the spine) to be implemented.

References

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[1]Pfeifer introduced several useful design principles for constructing autonomous agents[1]. Among them "the principle of ecological balance" does closely relate to this point, which states that control systems, body systems and their material to be implemented should be balanced. However, there still remains much to be understood about how these systems should be coupled.