International Journal of Innovative Computing, Information and Control
Volume **7**, Number **4**, April **2011**
ICIC International ©2011 ISSN 1349-4198
pp. 1661–1674

EFFECTS OF MECHANICAL COUPLING ON THE DYNAMICS OF BALANCING TASKS

Katsutoshi Yoshida[1], Atsushi Higeta[2] and Shinichi Watanabe[3]

[1]Department of Mechanical and Intelligent Engineering
[2]Department of Innovation Systems Engineering
[3]Innovation Center for Research and Engineering Education
Utsunomiya University
7-1-2 Yoto, Utsunomiya-shi, Tochigi 321-8585, Japan
{ yoshidak; swtnb }@cc.utsunomiya-u.ac.jp; higeta@katzlab.jp

Received December 2009; revised April 2010

Abstract. *Coupled human balancing tasks are investigated based on both pseudo-neural controllers characterized by time-delayed feedback with random gain and natural human balancing tasks. It is shown numerically that, compared to single balancing tasks, balancing tasks coupled by mechanical structures exhibit enhanced stability against balancing errors in terms of both amplitude and velocity and also improve the tracking ability of the controllers. We then perform an experiment in which numerical pseudo-neural controllers are replaced with natural human balancing tasks carried out using computer mice. The results reveal that the coupling structure generates asymmetric tracking abilities in subjects whose tracking abilities are nearly symmetric in their single balancing tasks.*
Keywords: Neural controller, Mechanical coupling, Visuomotor tracking, Stability, Sensitivity

1. **Introduction.** Competitive and cooperative dynamics can arise when multiple agents (autonomous entities) share common resources and environments. Extensive research has been conducted on such mutual interactions. Research in this area can be broadly classified into two categories: the field of mathematical ecology [1], which finds group behavior models having low degrees of freedom, and the field of multi-robot systems [2], which develops individual agents generating group behavior. In these conventional approaches, couplings between agents are constructed using shared resources or information.

On the other hand, it is also reasonable to consider another type of coupling, constructed of mechanical structures, for instance, connection rods placed between agents. Such a mechanical type of coupling appears to play an important role in clarifying the dynamics of agents, including humans and robots, which are in physical contact with one another. This type of knowledge will be applicable to developing robots working together or robots supporting human activities, based on physical contact. However, it appears that little is known about the type of dynamics that is produced by mechanical coupling. Therefore, as a preliminary step toward solving this problem, we have developed the coupled inverted pendula (CIP) model with four DOF [3], in which nonlinear behavior similar to interspecific competition in an ecosystem [1] can be directly generated by individual mechanical structures of agents. The CIP model proposed by the authors consists of a pair of independently PD-controlled inverted pendula, the tips of which are connected through a rigid rod.

The primary approach used in the present study is to replace the PD controllers of the CIP model with human balancing tasks. It follows that the two subjects perform stick balancing tasks under the situation in which the tips of the sticks are mechanically