

# Man–Machine Synergy Effector: Anthropomorphic Robotic Tools based on Hybrid Approaches

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## Abstract

Man–Machine Synergy Effector (MMSE) is our concept of high-performance robotic tools for human use, which is realized by introducing robotic technologies into ordinary or extraordinary mechanical tools. MMSE makes it possible to perform conventionally impossible tasks by human alone or machine alone, because the better assets of the both parties are synergized in MMSE.

This hybridization of human and machine is the basic principle of MMSE. Then, what assets should be hybridized in MMSE? And how?

The Brain–Machine Interface (BMI) can be a solution to realize the cooperation between human and machine. However, the current BMI does not suit for our concept. Not only that invasive techniques are complex and controversial, but also we think the direct connection between human brain and machine body passing through human physical body may spoil the experienced physical skills of human.

The hybridization in MMSE is based on the Man–Machine interface via human body mechanics, where human controls his/her body, machine controls its body, and their bodies are physically connected to each other. This is almost the same as the interface of ordinary mechanical tools. Human operator feels the physical feedback through his/her body. The feedback is the interaction among the dynamics of the human body, machine body, and environment. We expect that the feedback information contributes to exercise the experienced physical skills of human. It can be a synergy effect of human and machine in real environment so we call this MMSE.

Some of the hybridization techniques used in MMSE are described in this talk.

Firstly, we focus on the hybridization of human operation and robot control. It is realized by human power amplification by robot. An important characteristic of this amplification is a force amplifying control under force control. The implementation of the force amplifying control is easy itself, but here the human and the robot are physically connected. This is a human-in-the-loop system. So the force amplifying control causes instability due to the positive feedback.

A technique to avoid the instability is proposed. We call this Virtual Power Limiter System (VPLS). VPLS monitors and limits the power flow between human and robot so that the human-in-the-loop system never go unstable. By using VPLS, the force amplifying control is realized on MMSE. This also means the superposition of the human power amplification and other controls at the level of driving force of actuators is easy.

Secondly, we focus on the bipedal walking of MMSE which has lower extremities. The human power amplification is also effective to the operation of lower extremities. But it is not enough. The dynamics of human operator with MMSE as a mechanical tool is quite different from the human body itself. Keeping balance while walking with MMSE is too difficult to do only by the human operation.

We need another hybridization of human operation and automatic balancing control for MMSE with lower extremities. This hybridization requires some techniques in terms of hardware and software. These techniques are also described.

Bipedal robots are autonomous in general. On the other hand, our bipedal MMSE is hybridized. The hybrid approaches proposed here will quickly lead bipedal robots into the robust bipedal walking even on unknown uneven terrains, which is not accomplished yet by autonomous robots.