Results report

１．Title of Research and Development ： Impedance regulation during energy transfer motor tasks: from human experiments to computational modeling and robotics

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４．Results of Research and Development:

We planned and achieved the aims of the project over a series of steps-

1) We developed a behavioral experiment using the NICT TVINS manipulandum to examine the behavior of humans during impact tasks.

2) We developed a new analytical method to measure human arm impedance (both stiffness and damping) during impacts.

3) We examined the human behaviors in these tasks and found that humans can utilize haptic feedback during impacts to change their impedance and optimize the energy transfer during impacts. **This result was presented in the NCM conference.**

4) We analyzed the human behaviors computationally, and determined how the haptic feedback during impacts is used to optimize subsequent impacts. **This result will be submitted as a full journal paper.**

5) Using these results we developed a robot algorithm that enables robots to perform impacts like humans. This robot algorithm was implemented in Germany this year. **The paper will be submitted in the next months.**

6) In addition to the initial project goals, we also examined an additional issue of tool embodiment during fast movements. Embodiment issues are closely linked to control, and in this experiment, again with the NICT TVINS manipulandum we isolated a new embodiment process. **The results were published in Nature Communications in 2014.**

7) Finally we also examined learning in virtual impact (penalty kick) task to isolate for the first time, interactions between choice learning and motor learning by humans. **This result was presented in the NCM conference and has been submitted as a full journal paper.**

8) On the German side, the collaborators worked on algorithms to estimate human arm impedance from recordings of electromyography (EMG). **These were presented in the NCM conference**

9) The German side developed a new fast manipulandum specialized for human impedance measurements.