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The research interests in our laboratory are biorobotics, medical robots, rehabilitation robots, and intelligent robots. The laboratory consists of a professor, a doctor student, seven master students, and three undergraduate students. A picture of the members is shown in Fig. 1.

One of the main research projects in our laboratory is power assist with exoskeleton. Due to a decrease in birthrate and progress of aging society, role of robotics technology becomes important in the field of medicine and welfare. We have been developing robotic exoskeletons to assist motion of physically weak persons such as elderly, disabled, and injured persons. These kinds of robotic systems can be used for power assist of physically weak persons in daily activity and rehabilitation. It is important for the robotic exoskeleton, especially that for medical or welfare use, to move according to the user's intention. The skin surface electromyogram (EMG) is one of the most important biological signals in which the human motion intention is directly reflected. Consequently, we have been using the EMG signals to control the robotic exoskeletons in accordance with the users' motion intention.



Figure 1 Members of the laboratory

Figure 2 shows the robotic exoskeleton for upper-limb motion (elbow flexion/extension motion, shoulder vertical and horizontal flexion/extension motion) assist. Figure 3 shows the robotic exoskeleton for forearm motion (elbow flexion/extension motion, forearm pronation/supination motion) assist. The exoskeleton is supposed to be directly attached to the lateral side of the user and assist the motion based on the EMG signals of the user's muscles which is related to the upper-limb motion. There are many difficulties in designing the hardware and software of these kinds of exoskeletons.

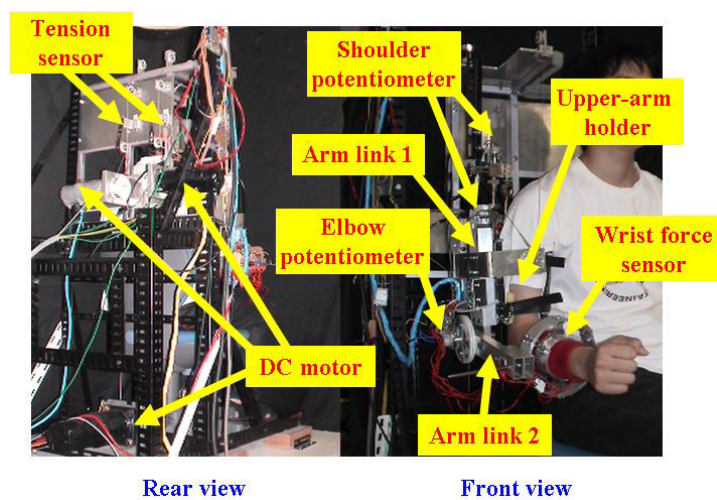


Figure 2 Exoskeleton for upper-limb motion assist

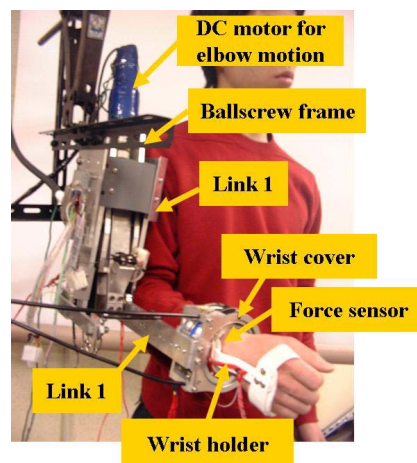


Figure 3 Exoskeleton for forearm motion assist

It is not easy to control the exoskeleton based on EMG signals of the user's muscles. We can not expect obtaining the same EMG signals for the same motion even with the same person.

Furthermore, each muscle activity for a certain motion is highly nonlinear, because the responsibility of each muscle for the motion varies in accordance with joint angles. One muscle is not only concerned with one motion but also another kinds of motion. Moreover, activity level of each muscle and the way of using each muscle for a certain motion is different between persons. Physiological condition of the user also affects the activity level of muscles. In addition to these problems, the activity level of some muscles such as bi-articular muscle is affected by the motion of the other joint, because the load acting on the other joint affects the activity level of them. The relationship between the load acting on the other joint and the change in bi-articular muscle activity level is different between persons. Furthermore, the activity level of muscles is affected by the external load acting on the arm. Therefore, flexible and adaptive nonlinear control must be applied to control the robot with the skin surface EMG signals. Moreover, real-time control ability is required to the controller for power assist systems since motion delay gives a lot of stress to the user. In order to cope with these problems, we have proposed the effective fuzzy-neuro control methods. Main publications on this project are listed in the end.

We are going to extend the motion to be assisted in order to realize the whole body motion assist. Please access our homepage "[http://web.me.saga-u.ac.jp/~kiguchi/biorobot\\_E.html](http://web.me.saga-u.ac.jp/~kiguchi/biorobot_E.html)" for details.

#### Publications

- 1) Kazuo Kiguchi, Toshio Fukuda : "A 3DOF Exoskeleton for Upper-Limb Motion Assist – Consideration of the Effect of Bi-Articular Muscles", Proceedings of IEEE International Conference on Robotics and Automation (ICRA'04), New Orleans, LA, pp.2424-2429, 2004.
- 2) Kazuo Kiguchi, Koya Iwami, Makoto Yasuda, Keigo Watanabe, Toshio Fukuda : "An Exoskeletal Robot for Human Shoulder Joint Motion Assist", IEEE/ASME Trans. on Mechatronics, vol.8, no.1, pp.125-135, March, 2003.
- 3) Kazuo Kiguchi, Ryo Esaki, Takashi Tsuruta, Keigo Watanabe, Toshio Fukuda : "An Exoskeleton for Human Elbow and Forearm Motion Assist", Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS'03), Las Vegas, USA, pp.3600-3605, 2003.
- 4) Kazuo Kiguchi, Takakazu Tanaka, Keigo Watanabe, Toshio Fukuda : "Design and Control of an Exoskeleton System for Human Upper-Limb Motion Assist", Proceedings of 2003 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM 2003), pp.926-931, Kobe, 2003.

- 5) Kazuo Kiguchi, Ryo Esaki, Takashi Tsuruta, Keigo Watanabe, Toshio Fukuda : “An Exoskeleton System for Elbow Joint Motion Rehabilitation”, Proceedings of 2003 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM 2003), pp.1228-1233, Kobe, 2003.
- 6) Kazuo Kiguchi, Koya Iwami, Keigo Watanabe, Toshio Fukuda : “A Shoulder Joint Motion Support System for Rehabilitation”, Proceedings of the 11<sup>th</sup> International Conference on Advanced Robotics (ICAR’03), vol.1, pp.11-16, Portugal, June 30-July 4, 2003.
- 7) Kazuo Kiguchi, Koya Iwami, Keigo Watanabe, Toshio Fukuda : “An Assist Level Adjustment Method of an Active Shoulder Orthosis”, International Journal of Human-friendly Welfare Robotic Systems, Vol. 4, No. 2, pp.8-12, June, 2003.
- 8) Kazuo Kiguchi, Takakazu Tanaka, Keigo Watanabe, Toshio Fukuda : “Exoskeleton for Human Upper-Limb Motion Support”, Proceedings of IEEE International Conference on Robotics and Automation (ICRA’03), pp.2206-2211, Taipei, 2003.
- 9) Kazuo Kiguchi, Shingo Kariya, Takakazu Tanaka, Keigo Watanabe, Toshio Fukuda : “An Interface between an Exoskeletal Elbow Motion Assist Robot and a Human Upper-Arm”, Journal of Robotics and Mechatronics, vol.14, no.5, pp.439-452, Oct., 2002.
- 10) Kazuo Kiguchi, Shingo Kariya, Keigo Watanabe, Toshio Fukuda : “Application of Multiple Fuzzy-Neuro Controllers of an Exoskeletal Robot for Human Elbow Motion Support”, Transactions on Control, Automation and Systems Engineers (CASE), vol.4, no.1, March, pp.49-55, 2002.
- 11) Kazuo Kiguchi, Ryo Esaki, Takashi Tsuruta, Keigo Watanabe : “An Elbow Joint Motion Support System for Rehabilitation”, Proceedings of International Congress on Biological and Medical Engineering, Singapore, Dec. 4-7, No.360, 2002.
- 12) Kazuo Kiguchi, Makoto Yasuda, Koya Iwami, Keigo Watanabe, Toshio Fukuda : “Design of an Exoskeletal Robot for Human Shoulder Motion Support Considering a Center of Rotation of the Shoulder Joint”, Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS’02), pp.1493-1498, 2002.
- 13) Kazuo Kiguchi, Shingo Kariya, Takakazu Tanaka, Noritaka Hatao, Keigo Watanabe, Toshio Fukuda : “Intelligent Interface of an Exoskeletal Robot for Human Elbow Motion Support

Considering Subject's Arm Posture", Proceedings of IEEE International Conference on Fuzzy Systems (FUZZ-IEEE 2002) (WCCI 2002), pp.1532-1537, 2002.

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