Cursor Controlled Prosthetic Grasping from 2D Subspaces

Aggeliki Tsoli Odest Chadwicke Jenkins

Neurally controlled prosthetic devices capable of object manipulation have much potential towards restoring the physical functionality of disabled individuals. However, the number of user input variables provided by current neural decoding systems is much less than the number of control degrees-of-freedom (DOFs) of a prosthetic hand and/or arm. More specifically, efforts to decode user neural activity coming from feasible sensing technologies, such as electroencephalogram (EEG) [3] and cortical neural implants [4], [8], into control signals have demonstrated success limited to 2-3 DOFs with bandwidth approximately 15 bits/sec.

Fig. 1. **Snapshot of our control system driving a DLR/HIT robot hand to assist a human eat a meal. The user selects points on the 2D control space displayed on the screen using the mouse.**

With such decoding bandwidth limitations, previous attempts to control robot systems from low-dimensional user input have focused on low-DOF systems. Example control applications are 2D cursor control [7], planar mobile robots [3], and discrete control of 4 DOF robot arms [5], [2]. Also, Bitzer and van der Smagt [1] have performed high-DOF robot hand control by reducing the DOFs to a discrete set of poses that can be indexed through kernel-based classification.

In our work, based on the control approach in [6], we propose the use of low-dimensional subspaces embedded within the pose space of a robotic limb. As shown in Fugure 2, first, a 2D control subspace is derived from human hand motion capture data (x) and displayed on a 2D screen. Our assumption about a 2D control subspace is enhanced by the fact that efforts in neural decoding [5], [8], [7] have shown that disabled individuals physically incapable of moving 2D mouse can drive a 2D cursor from neural activity. Then, in order to control a robot hand, the user clicks on points on a 2D screen (z) and their corresponding hand pose is sent as a motor command to the robot hand. After the user observes the result of his action, he selects another point on the screen and so on until he achieves a predefined grasping task.

To evaluate our approach, we explore a set of current state-of-the-art dimension reduction techniques and show results for effective control of a DLR/HIT robot hand with 13 DOF. The grasping tasks performed contain finger tapping motions, powergrasps and precision grasps. Example tasks include grasping of a bottle of water, an eraser, an oscillating box and simulation of the grasping actions taking place while having a meal. This work is illustrated in more detail in http://robotics.cs.brown.edu/projects/bpdenoising.

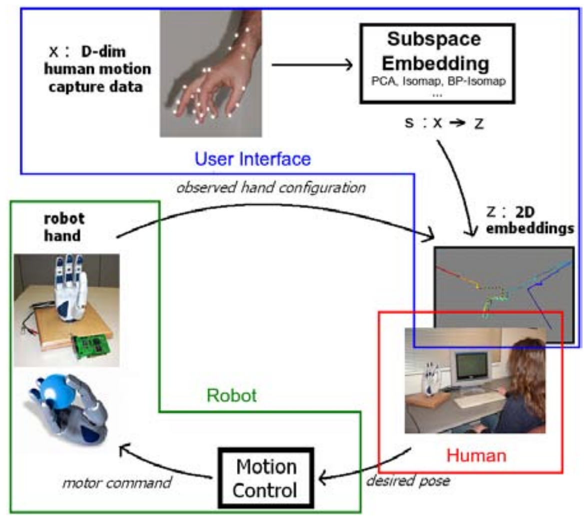

Fig. 2. **Diagram for hand control by the user using human hand motion capture data for training**

References

[1] S. Bitzer and P. van der Smagt. Learning EMG control of a robotic hand: towards active prostheses. In *IEEE International Conference on Robotics and Automation*, pages 2819–2823, Orlando, May 2006.

[2] B. Crawford, K. Miller, P. Shenoy, and R. Rao. Real-time classification of electromyographic signals for robotic control. In *Association for the Advancement of Artificial Intelligence (AAAI)*, pages 523–528, Pittsburg, PA, July 2005.

[3] J. del R. Millan, F. Renkens, J. Mourino, and W. Gerstner. Brain-actuated interaction. *Artif. Intell.*, 159(1-2):241–259, 2004.

[4] J. Donoghue, A. Nurmikko, G. Friehs, and M. Black. Development of neural motor prostheses for humans. *Advances in Clinical Neurophysiology (Supplements to Clinical Neurophysiology)*, 57, 2004.

[5] L. Hochberg, M. Serruya, G. Friehs, J. Mukand, M. Saleh, A. Caplan, A. Branner, D. Chen, R. Penn, and J. Donoghue. Neuronal ensemble control of prosthetic devices by a human with tetraplegia. *Nature*, 442:164–171, June 2006.

[6] O. C. Jenkins. 2D subspaces for sparse control of high-dof robots. In *Intl. Conference of the IEEE Engineering in Medicine and Biology Society (EMBC 2006)*, New York, NY, USA, Aug-Sep 2006.

[7] M. Serruya, A. Caplan, M. Saleh, D. Morris, and J. Donoghue. The BrainGate pilot trial: Building and testing a novel direct neural output for patients with severe motor impairment. In *Society for Neuroscience Annual meeting*, October 2004.

[8] D. Taylor, S. H. Tillery, and A. Schwartz. Information conveyed through brain control: Cursor versus robot. *IEEE Transactions on Neural Systems and Rehabilition Engineering*, 11(2):195–199, June 2003.