Natural Arm Trajectory Generation for Brain-Controlled Prosthetics

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Introduction

These last years have seen important progress concerning brain-controlled arm prosthetics, both with invasive and non-invasive interfaces. However, independently of the method chosen for delivering the command, the prosthesis needs a model to re-create human-like trajectories. In this work, we compare three models for arm trajectory generation taken into account the characteristics of human natural movements.

Modeling Human Kinematics

- Need of a kinematic model in order to determine the reachable space and possible postures of the arm.
- 4 DoF arm Model
- Arm reachable space model

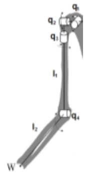

Fig1: Human Arm (adapted from Klopcar et al., *J Biomech.,* 2007)

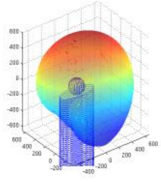

Fig2: Workspace Model

- Simulation of prosthetics
- Test of the model

Fig3: WAM Robot used to simulate a prosthetic

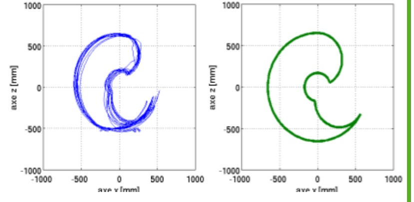

Fig4: Vertical workspace: raw data (blue) VS. model (green)

Material

- Tracking of the position of the hand, elbow, and shoulder using an ultrasound tracker (Zebris).
- Point-to-points movements monitored on a referenced frame.
- 20 occurrences for 6 back and forth point-to-point movements were recorded with 10 subjects.

Fig5: Experimental setup

Trajectory Features

- Total Time
- Curvature
- Maximum Speed
- Velocity Profile

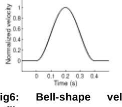

Fig6: Bell-shape velocity profile

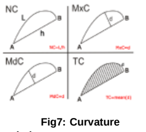

Fig7: Curvature indexes (Bernabucci et al., *J. of NeuroEng. and Rehab., 2007*)

Selected Models

- Minimum Jerk Model [1]
  - Maximizes the smoothness of the speed
  - Straight trajectory
- F2REACH [2]
  - Control of the curvature
  - Statistical trajectory
- Multi-referential VITE [3]
  - Control of the Cartesian and the joint angle space
  - Whole arm trajectory generation

Human Movements Vs. Generated Trajectories

- Models are compared to the actual human movements in order to chose the most human-like, with parameters chosen to comply with natural movements.
- Trajectories

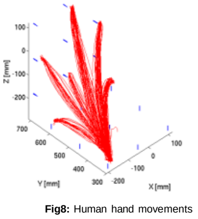

Fig8: Human hand movements

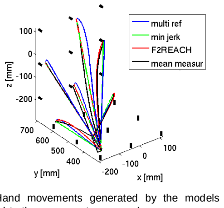

Fig9: Hand movements generated by the models and compared to the movements mesured

- Speed Profile

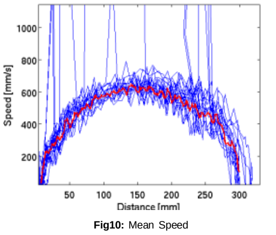

Fig10: Mean Speed

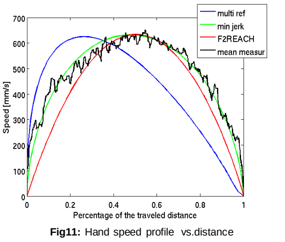

Fig11: Hand speed profile vs.distance

Conclusion and Future Work

- Among these models, the F2REACH model seems to be the best compromise for natural movements, between the curvature and the speed profile.
- Further work is being developed to analyze elbow position generation.
- The F2REACH model has several parameters that demands to be tuned, it thus needs further investigation from the user point-of-view in order to come up with a well-suited trajectory.

References

[1] Flash, T., and Hogan, N., The coordination of arm movements: an experimentally confirmed mathematical model, *The Journal of Neuroscience* 5, pp. 1688-1703, Society for Neuroscience, 1985.

[2] Petreska, B. and Billard, A., Movement curvature planning through force feld internal models, *Biological Cybernetics* 100, pp. 331-350, Springer, 2009.

[3] Hersch, M. and Billard, A. G., A Biologically-Inspired Controller for Reaching Movements, *Proceedings of the First IEEE/RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics*, Pisa, Italy, 2006.

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