# Design of an FLC technique to Study the Influence of Muscle Model on FES-cycling Performance

**Rasha Kazem Massoud***

## Abstract

*Abstract* **In this paper, three different muscle models have been investigated. The first model (Ferrarin's muscle model) is a transfer function between electrical stimulation and the resultant knee torque. The other two muscle models are physiological based (Riener's muscle model and Virtual Muscle). Riener's muscle is modelled in this paper by using Matlab/Simulink, while Virtual Muscle model has been built using Virtual Muscle software (Virtual Muscle 4.0.1). A quadriceps is modelled using each of the three models. The three models are tested in terms of their responses to activation and then they are implemented in a fuzzy logic control (FLC) strategy which aims to control the cycling cadence. The performance of the three models during control has been discussed and evaluated. It appears that the type of the muscle model has an influence on the control performance.**

**Keywords: Muscle model, fuzzy logic, Virtual Muscle, FES.**

For the Paper in Arabic see pages (13-25)

* Department of Biomedical Eng., Faculty of Mechanical and Electrical Eng. Damascus University

## References:


1. F. Huxley, "Muscle structure and theories of contraction", Progress in Biophysics and chemistry, vol. 7, pp 257-318, 1957.
2. V. Hill, "The heat of shortening and the dynamic constants of muscle". Proceedings of the Royal Society of London, B 126 (843), pp. 136-195, 1938.
3. Y. C. Fung, "Biomechanics, mechanical properties of living tissues", Springer-verlag, New York, 1981.
4. J. van Soest, and M. F. Bobbert, "The contribution of muscle properties in the control of explosive movements", Biological Cybernetics, vol. 69, pp. 195–204, 1993,.
5. S.L. Delp, F.C. Anderson, A.S. Arnold, P. Loan, A. Habib, C.T. John, E. Guendelman, D.G Thelen, "OpenSim: Open-source software to create and analyze dynamic simulations of movement", IEEE Transactions on Biomedical Engineering, vol. 54, Nov. 2007, pp.1940 – 1950.
6. J. Pons, C. L. Vaughan and G. G. Jaros, "Cycling device powered by the electrically stimulated muscles of paraplegics". *Medical & Biological Engineering & Computing*, vol. 27, pp. 1-7, 1989.
7. K. J. Hunt, B. Stone, et al. "Control strategies for integration of electric motor assist and functional electrical stimulation in paraplegic cycling: utility for exercise testing and mobile cycling". *IEEE Transactions on Neural systems and rehabilitation engineering*, vol. 12, pp.89-101, 2004.
8. C.Fornusek, G. M. Davis, P. J Sinclair., and B.Milthorpe, "Development of an isokinetic functional electrical stimulation cycle ergometre". *Neuromodulation*, vol. 7, no.1, pp. 56-64, 2004.
9. T. A. Perkins, N. Donaldson, N. A. C. Hatcher, I. D. Swain, and D. E. Wood, "Control of leg-powered paraplegic cycling using stimulation of the lumbo-sacral anterior spinal nerve roots". *IEEE Transactions on Neural systems and rehabilitation engineering*, vol. 10, no. 3, pp. 158-164, 2002.
10. K. F. Eichhorn, W. Schubert, and E. David, "Maintenance, training and functional use of denervated muscles". *Journal of Biomedical Engineering*, vol. 6, pp. 205-211, 1984.
11. J. Chen, N. Y Yu., D. G Huang., B. T. Ann, and G. C. Chang, "Applying fuzzy logic to control cycling movement induced by functional electrical stimulation". *IEEE Transactions on Rehabilitation Engineering*, vol. 5, no. 2, PP. 158-169, 1997.
12. S. Petrofsky, J. Smith, "Three-wheel cycle ergometer for use by men and women with paralysis". *Medical & Biological Engineering & Computing*, vol. 30, pp. 364-369, 1992.
13. D. A. Winter, "*Biomechanics and motor control of human movement*". Wiley_Interscience New York, 1990.
14. Ferrarin, and A. Pedotti, "The relationship between electrical stimulus and joint torque: a dynamic model", IEEE Transactions on Rehabilitation Engineering, vol. 8 (3), 2000, pp. 342-352.
15. T. Edrich, R. Riener, and J. Quintern, "Analysis of passive elastic joint moments in paraplegics", IEEE Transactions on Biomedical Engineering, vol. (8), 2000, pp. 1058-1064.
16. R. Riener, and T. Fuhr, "Patient-driven control of FES-supported standing up: A simulation study", IEEE Transactions on Rehabilitation Engineering, vol. 6, 1998 , pp. 113-124.
17. E. J. Cheng, I. E. Brown, and G. E. Loeb, "Virtual muscle: a computational approach to understanding the effects of muscle properties on motor control", Journal of Neuroscience Methods, vol. 101, 2000, pp.117-130.
18. J. J. Chen, N. Y Yu,. D. G. Huang, B. T. Ann, and G. C. Chang, "Applying fuzzy logic to control cycling movement induced by functional electrical stimulation", *IEEE Trans Rehabil Eng*, **5** (2)**,** 1997, pp.158-69.
19. Massoud, "Comparative Study of Three Human Muscle Models", UKSim 2010, Cambridge, 2010, UK, 24-26 March.
20. Massoud, "Intelligent control techniques for spring assisted FES-cycling", PhD Thesis. The University of Sheffield, Sheffield, UK, 2007.