

**Comparison between Cascade Forward and Multi-Layer Perceptron Neural  
Networks for NARX Functional Electrical Stimulation (FES) based Muscle  
Model**

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## ABSTRACT

This paper exhibits the improvement and correlation of muscle models taking into account FES incitement parameters utilizing the Nonlinear Auto-Regressive model with Exogenous Inputs (NARX) using Multi-Layer Perceptron (MLP) and Cascade Forward Neural Network (CFNN). FES stimulations with varying frequency, pulse width and pulse duration were utilized to evaluate the muscle torque. 722 data points' focuses were utilized to make muscle model. One Step Ahead (OSA) prediction, correlation tests, and residual histogram analysis were performed to accept the model. The ideal MLP results were obtained from input lag space of 1, output lag space of 43, and hidden units 30. A total of three terms were selected to construct the final model, namely  $u_1(t-1)$ ,  $y(t-1)$ , and  $u_4(t-1)$ . The last MSE delivered was 1.1299. The optimal CFNN results were gained from input lag space of 1, output lag space of 5, and hidden units 20. The terms selected are similar to that of the MLP model. The final MSE produced was 1.0320. The proposed approach figured out how to rough the system well with unbiased residuals, with CFNN demonstrating 8.66% MSE change over MLP with 33.33% less hidden units.

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## CHAPTER 1

### INTRODUCTION

#### 1.1 BACKGROUND OF STUDY

Throughout the years, there is a great deal of leg orthosis model has been proposed. The prior idea of leg orthosis was introduced by Hill. Hill expressed that force produced can be clarified by mechanical limit which involve of series and parallel nonlinear contractile component. Since that, many researchers exploited the essential idea of hill and numerous models have been proposed [1].

Research and development by using FES in rehabilitation engineering has been increase from time to time [2, 3]. Figure 1 show the timeline where FES has been used for muscle activation [4] in order for paralysis person to regain their lost function in spinal cord injury (SCI). Exercising the part where paraplegic patient suffer from SCI can increase their recovery. Leg orthosis can help paraplegic patient to improve their mobility to walk.

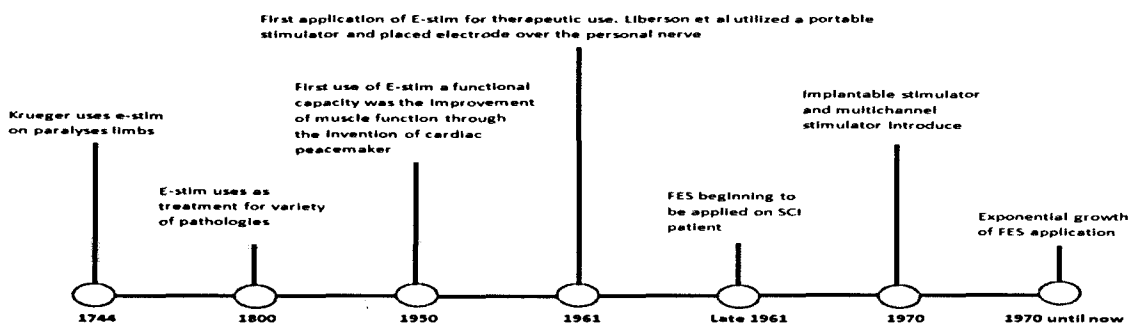


Figure 1. History of FES application [2]

The parameter of FES which is pulse stimulation intensity, pulse width and frequency need to be study [5, 6]. Muscle is a soft tissue of the body that can generate force and causes motion. Incorrect amount of electrical stimulation applied on the muscle can cause serious damage to the muscle. To study the parameter of FES, Mathematical model that can represent the