

## Electromyography (EMG) and Human Locomotion

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**Abstract.** The biomechanical analysis assists to provide evidences in the performance of the system used for stroke rehabilitation of lower and upper limb of human body. This could be done by providing a better understanding of human lower extremities movement through implementation of electromyography (EMG). As human body is a complex biomechanical machine, conducting analysis using only EMG is not sufficient in representing muscle coordination pattern for functional task (i.e. walking). For that, Genetic Algorithm (GA) is implemented in the selection process of best fit mathematical model and its parameters used in conversion of EMG signal into estimated torque. Several experiments are conducted to validate the proposed method

**Keywords:** Biomechanical analysis, functional task, Electromyography (EMG), Genetic Algorithm (GA).

### 1. Introduction

Cerebrovascular accident (CVA) also known as stroke is being the major cause of long term disabilities. The only way to aid stroke patient is restoring loss through rehabilitation training, which can be enhance using rehabilitation device [5]. As referred in [2, 6], the training can be enhanced using exoskeletal systems by guiding patients in relearning motions on correct trajectories, or by giving them force support to perform certain motions. However, mathematical representation of human lower extremities is required in order to build the device. From the past studies, it is clear that EMG system [3, 4] provide changes of neuromuscular system while the muscles experiencing fatigue. Nevertheless, relationship between EMG signal and human movement in most studies is just approximation, which is not practical for kinematic analysis. Therefore, a more practical method is required to select the best fit mathematical model.

Based on D.G Lloyd's model [8] the reliability of EMG system in estimating knee joint moments are proved and to be validated by experimental studies. In this study, comparison of moment are made between results obtain from EMG and inverse dynamic model.

On the other hand D. Shin et al [7] proposed a mathematical model, which is used to estimate joint torque of human arm based on EMG system. The authors suggest that alternative methods for estimating joint torque using neural network and GA may further enhance the EMG versus Joint torques relationship. The main objective of this project is to provide a plan in the development of biomechanical approach towards understanding of human lower limb movement patterns. This can be achieved by measuring and comparing muscle activities using EMG and best fit model identified by GA for torque conversion. In this study, special focus is given to walking motion.

Based on various literatures such as [1], the most basic technique to obtain muscle coordination pattern for specific given task is by assuming that muscles are in steady state condition during recording raw EMG signal while the most basic method for signal processing is Smooth Rectified EMG (SRE) processing.

### 2. Methodology

The experiment is conducted in two (2) stages, which include actual joint data and EMG signal acquisition. Oqus motion cameras and surface EMG (sEMG) are used in the experimental studies. Various

mathematical models are suggested as discussed in [9] and 7 of them are tested in the proposed system for torque estimation.

*Qualisys Track Manager (QTM)*: In this section, Surface marker, which is used to track the human motion are placed on lower limbs of the subjects and captured motion by QTM. Meanwhile, the acquisition of EMG signal from the right muscle group are recorded separately.

*Visual 3D (V3D)*: The coordinates of tracking markers obtained from QTM are processed through V3D to get the actual joint parameters of the subjects such as displacement, velocity and acceleration. The anatomical model is built based on data obtained from V3D and this enables for non-expert to visualize musculoskeletal motion of the subjects.

*MATLAB*: MATLAB is used for processing the EMG data where the signal is rectified and filtered before the conversion process.

### 3. Experimental Setup

*Subject Selection*: Four (4) healthy male subjects ranges from 21 to 22 years and one female with osteoarthritis (above 60 years) are selected for the experimental studies. The elderly female subject is used as a mean of EMG signal comparison. As shown in TABLE I, the subjects have mean height of 166.4cm and mean weight of 69.2kg.

TABLE I. SUBJECT PROFILE

	Age (years)	Gender	Height (cm)	Weight (kg)	BMI	Status
Subject 1	22	Male	175	60	19.6	Normal
Subject 2	21	Male	167	80	28.7	Overweight
Subject 3	22	Male	167	66	23.7	Normal
Subject 4	21	Male	170	76	26.3	Overweight
Subject 5	62	Female	153	64	27.3	Overweight
Mean	29.6	-	166.4	69.2	-	-
Standard Deviation	16.2062	-	7.3103	7.5472	-	-

*Data Acquisition*: Six (6) motion cameras interfaced to QTM, which enable time-distance parameters (i.e. position, velocity and acceleration) for lower limb of the subjects to be detected and record coordinate data of the markers. Readings are sampled at a frequency of 100 frames/s.

*System Calibration*: Before the experiment, the system need to be calibrated to ensure correctness of axis, workspace and frame of origin in a global coordinate [10]. During experiment, subjects are asked to remain idle for at least 2s until static data is recorded and later perform walking motion to record dynamic data.

*Marker placement*: Since the research is focus on lower extremities of human movements, the markers were attached only on lower body of the subjects. Based on V3D guideline, this includes pelvis, thigh, shank and foot segments. Placement of the markers is as shown in Fig. 1.

*Sensor Position*: EMG sensors are also placed only on major muscles of lower limb, which include Quadriceps, Hamstrings, Tibialis Anterior and Calves. These are the muscles responsible for flexion and extension of knee and ankle, essential motions during walking. According to [11], the sensor should be placed along longitudinal midline centre of muscle between motor point and tendon insertion. Sensor placement on one (1) of the subjects during experiment is shown in Fig. 1(b).

*Signal Processing*: Under this step, both actual joint torque and EMG are rectified and filtered for simplification. Rectification is done using MATLAB by taking only absolute values of the raw data into consideration while filtration is done by reading only signal at cut off frequency defined.

In the proposed system GA is employed to find a mathematical model that best map EMG signal into joint torque. GA will find the best mathematical model that translates the recorded EMG into the related joint torque. Processed EMG signal were then converted into estimated torque using mathematical models (1) to (7)

$$\tau_{est} = x_1 E_i + x_2 E_i^{1/2} \quad (1)$$

$$\tau_{est} = x_1 + x_2 E_i^2 + x_3 e^{E_i} \quad (2)$$

$$\tau_{est} = x_1 + x_2 \cos E_i + x_3 \sin E_i \quad (3)$$

$$\tau_{est} = x_1 E_i^{x_2} \quad (4)$$

$$\tau_{est} = x_1 + x_2 e^{E_i} + x_3 e^{-E_i} \quad (2)$$

$$\tau_{est} = x_1 E_i^{x_2} + x_3 E_i^{x_4} \quad (3)$$

$$\tau_{est} = x_1 E_i^4 + x_2 E_i^3 + x_3 E_i^2 + x_4 E_i^1 + x_5 E_i^0 \quad (4)$$

where  $x_i$  is the model parameter,  $E_i$  is EMG voltage.

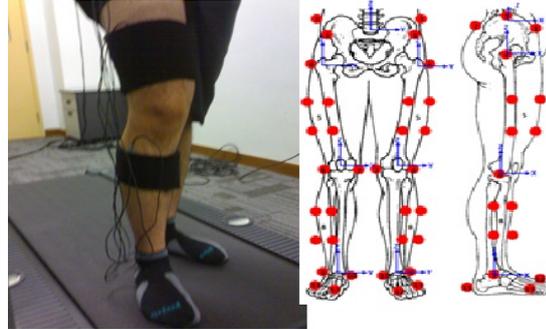


Fig.1: (a)Sensor (EMG) placement on lower limb of subject (b) Surface marker placement on lower body

GA codes represented in flowchart shown in Figure 2 are to randomly generate the model parameters ( $x_1$  to  $x_5$ ) to compute estimated torque along with EMG voltage value at each period. Roulette Wheel Selection will then randomly select pairs of best-fit chromosomes for crossover and mutation process.

$$FS = \sum_{k=1}^N (\tau_{actual} - MM_i(E_i, x_i))^2 \quad (5)$$

where  $MM_i$  is estimated torque from chosen model

During each iteration, fitness function (FS) based on above equation will be calculated, where smaller FS is preferable in order to reduce difference between both actual and estimated torque. Figure 3 and Figure 4 show step by step transformation of EMG on knee and ankle from raw into processed data.

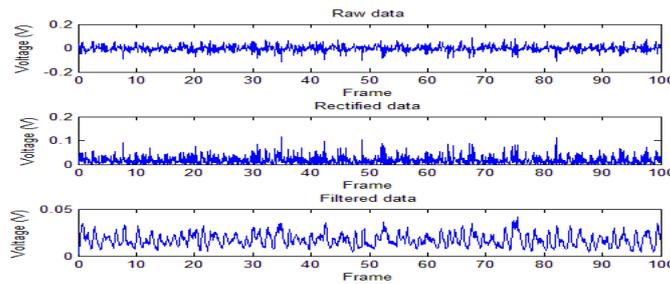


Fig. 2: Raw and processed (rectified and filtered) data on knee of subject 3 (young male, BMI: normal)

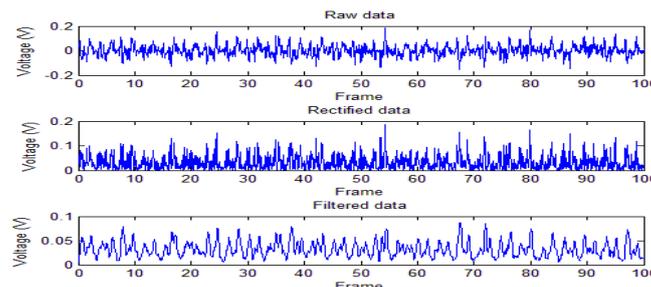


Fig.3: Raw and processed (rectified and filtered) data on ankle of subject 3 (young male, BMI: normal)

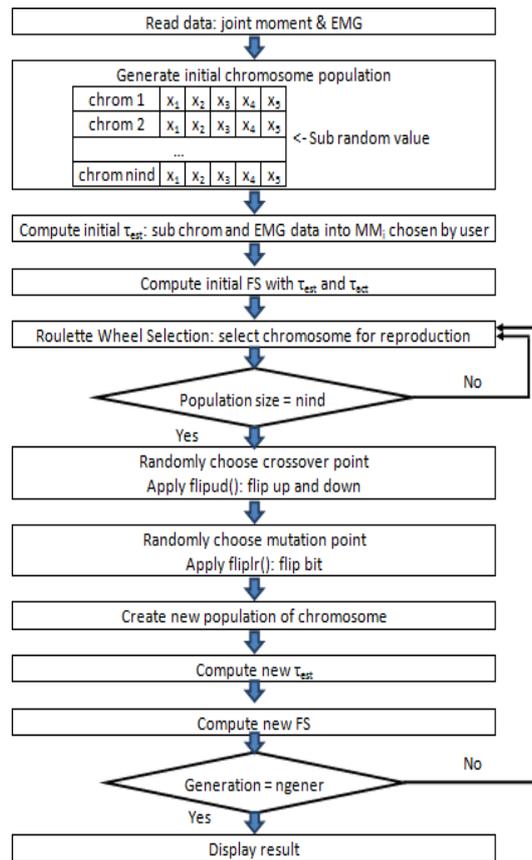


Fig.4: Flow chart showing GA for EMG to torque conversion.

#### 4. Results and Discussions

When comparing both actual estimated torque of knee, slight offset and phase shift could be observed. This might be caused by experiment conducted in separated stages instead of both (i.e. actual joint data and EMG signal) at the same instance.

On the other hand, unstable fluctuations in addition to slight offset were also can be observed on estimated torque of ankle although both actual and estimated torque still have similar pattern. This might be due to complexity on ankle (3DOF) as oppose to knee (1DOF), where more muscles are involve in its movement.

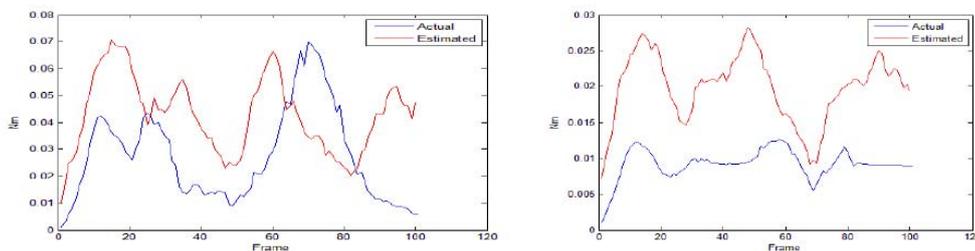


Fig.5: (a) Actual vs. estimated torque on knee of subject 3 (young male, BMI: normal) based on best fit model for knee (7) (b) Actual vs. estimated torque on ankle of subject 3 (young male, BMI: normal) based on best fit model for ankle (6).

At the same time, comparison of the results between the subjects in 1 to 5 shows that best fit model selection process is affected by factors such as BMI and health condition of each subject. As observed, subject 3 (young male, BMI: normal,) has most fit result as compared with subject 5 (elderly female, BMI: overweight, osteoarthritis) where estimated torque for both knee and ankle have larger offset and phase shift

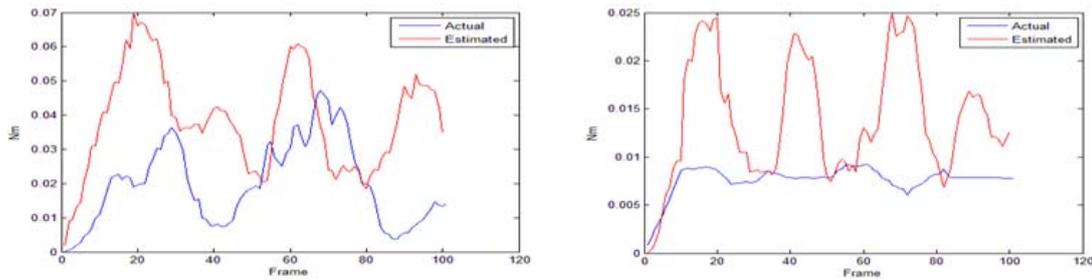


Fig.6: (a) Actual vs. estimated torque on knee of subject 2 (young male, BMI: overweight) based on best fit model for knee (7) (b) Actual vs. estimated torque on ankle of subject 2 (young male, BMI: overweight) based on best fit model for ankle (6)

## 5. Conclusion

From a number of literature review and research papers, it was understood that EMG is can be used to detect muscle fatigue and in treatment of motor disorder problem. Nonetheless, due to insufficient of mathematical model that can fit for general case, more research need to be done for improvement on available model. From the results, it was found that combination of EMG and GA is sufficient for determining best fit model for human lower limb although improvement is still required. The project has provided an enhanced understanding of human movement in walking motion, which is essential for building of stroke rehabilitation device.

## 6. References

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