Wearable Medical Gyro Sensors Based on Joint Tracking for Elderly

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Abstract. This article concentrates on Linear Quadratic Estimation Hybridised Computer Algorithm (LQE-HC) which has been proposed to detect the behavior method of muscles with the implementation of accelerometers to find the angular speed of joints. Remote monitoring can give valuable data on regular exercise level and functional potential of individuals. Furthermore, a low drift in the observed speed leads to a longer integration error. Supplementary data from gyroscopes are normally fused with the Linear Quadratic Estimation (LQE). A computer algorithm structurally measures instructions to a wearable device so that an optimal muscle stimulation sequence is inducted for goal muscle powers.

Keywords: wearable devices, joint tracking, LQE

1. Introduction
Healthy people will change the activation of muscles through exercise and atmosphere[1]. However, people with nervous system diseases will encounter motor control problems, mainly because they cannot properly regulate their muscle stimulation process[2-3]. Human motion assessment and interpretation have many applications in the treatment of cognitive motor problems, accident recovery and physical function enhancement[4]. A variety of devices and strategies can be used to evaluate motion. Muscle movement leads to joint tracking in healthy people[5]. It is clearly explained that joint motion can be divided into adduction, abduction, flexion, extension, wrapping and rotation[6]. Interaction between Cognitive Impairments It is important to study the way of joint flexion for potential nursing and treatment, because the mode of muscle activation after enlargement should be related to the form and degree of disability[7]. Compact and wearable devices, including accelerometers and gyroscopes, are typical inertial measurement units (IMU) [8]. Sensors measure and interpret velocity and gravitational acceleration. Inertial sensors are designed to test geometric velocity [9].

A function check at single muscle level that examines the operation of a muscle of interest in different motor tasks that contributes to the degree of strength at the muscle level. No study has been carried out to implement exoskeleton wearable devices routinely to cause specific muscle activation. A machine program technology manages a wearable robot, so that a specific muscle stimulation pattern can be produced for the desired body powers. Recently, portable inertial devices were used to monitor movement of people in and outside the laboratories. Periodic observation of human movement can
give useful information applicable to physical and functional rates of individuals. Orientation has been determined by application of the gyroscope angular velocity. Nevertheless, a slight shift in the calculated speed contributes to a longer integration flaw. Complementary results from accelerometers are usually combined with the Kalman or expanded Kalman filter for correction of drift. Such understanding was achieved for both normal and high speed motion of the arm between our inertial sensor and the optical reference device. In author introduced a modular 8 channel data processing device with active muscle contraction identification that can cancel static, cellular, portable sEMG[10-14]. The design includes two stages, the sEMG and the multi-channel data processing units. In recent years, wearable technology has expanded its interest in education, sport science and biomedical applications. The wearable technology is especially useful for the processing of physiological signals, because of its comfortable existence. Different gain is made from this technology in both clinical and industry applications in the (surface electromyography) sEMG systems which measures muscle activations potential. The sEMG signal is processed in the data processing unit using built-in advanced methods to identify muscular contractions and reject the noisy energy-line noise. A wearable technology is desperately required to track muscle fatigue anywhere. Furthermore the four-electrode structure further enhances the sensitivity of EIM detection, an analogous inhomogeneous 3D finite-element model has been developed for a human arm. Present muscle layer density and differential electrodes capacity were chosen to provide efficiency evaluation indices. The results indicate that the tissue tension (r), which correlates to a Middle Speed (MS) of calculated superficial electromyographical (sEMG) signals, decrease almost 8 between totally relaxed and tired muscles. To overcome all these drawbacks, Linear Quadratic Estimation Hybridised Computer Algorithm (LQE-HC) has been proposed to detect the behavior method of muscles with the implementation of accelerometers to find the angular speed of joints. A supplementary data from gyroscopes are normally fused with the Linear Quadratic Estimation (LQE) and a computer algorithm structurally measures instructions to a wearable device so that an optimal muscle stimulation sequence is inducted for goal muscle powers.

2. LQE-HC hybridised mathematical model for joint tracking

2.1. Static equation for Isometric contraction of muscles

This paper takes into account that the isometric contraction-force regulation for static tasks and it does not alter its location during a process, that all muscle contractions are isometric. The organ and prosthesis system mechanics is ignored and human exoskeleton model has S joints and T muscles. The state equation of isometric muscle contraction is clearly explained in Equation (1) and (2)

\[ \tau_f = K(\varphi) + L(\varphi)^Tf - \tau_b = \begin{bmatrix} b_{11} & \cdots & b_{1T} \\ \vdots & \ddots & \vdots \\ b_{S1} & \cdots & b_{ST} \end{bmatrix} \begin{bmatrix} a_1 \\ \vdots \\ a_T \end{bmatrix} \]  \hspace{1cm} (1) \]

\[ \tau_f = \beta(\varphi)\alpha \]  \hspace{1cm} (2)

\( \tau_f \in X^S \) is the torque vector of individual human joint. \( \varphi = [\varphi_1, \ldots, \varphi_S]^T \) is the angle vector of each joint. \( f = [f_1, f_2, f_3] \) is Expression power at the top, \( l(\varphi) \) is the Jacobean between top-force and torques of joint. \( K(\varphi) \) is the gravitational force. \( \tau_b \in X^S \) is the torque of joint generated by exoskeleton. \( \beta \in X^{S \times G} \) is the arm matrix of muscles. \( \alpha = [a_1, \ldots, a_T]^T \in X^S \) is the muscle force vector of human.
Figure 1. The skeleton model to calculate torque, force.

The element $b_{ij}$ of B denotes the movement of arm muscle j for joint k, $b_{ij}=0$ is given if $f_j$ does not effect on joint k. $R(\phi), l(\phi), \beta(\phi)$, $\phi$ can be calculated by skeleton model as shown in figure 1.

2.2. Mathematical Model for Joint Tracking by Linear Quadratic Estimation (LQE)

The proven biomechanical modelling approach is focused on a sequence of joints. Every part of the human body may be this type of model.

Figure 2. Linear Quadratic Estimation (LQE) of arm model and shoulder bone.

The new pattern for five dimensionality (FD) movement for both shoulder and elbow is clearly explained. One of the most common joints of the human body is its shoulder and neck. Linear Quadratic Estimation (LQE) of arm model and shoulder bone is clearly shown in figure 2.

Usually this dynamic joint is generalized as a ball and socket relation with three FD. In figure 2 the pattern at center of shoulder joint with the static reference frame 0 is shown clearly. Frames 1 to 3 reflect flexion / extension of the shoulder, abduction / adduction, and internal / external rotation. The forearm joint is a mutual bend that makes movements in one surface, bending / extension, as shown in frame 4. A hinge joint for a pronation / plantar flexion of the forearm is defined by framework 5. The state-space model for each joint tracking is clearly shown in Equation (3) and (4).

$$s(m+1) = f_m[y(m), u(m)]$$

$$T(m) = H_m[y(m), u(m)]$$
\(y(m)\) is the condition unnoticed state, \(T(m)\) is the data evaluated. The un-linear system is denoted as \(l_m\) and analysis formulas is denoted as \(H_m; v(m)\) and \(u(m)\), the condition and observation white noise with negative mean.

The state model mathematical representation is clearly shown in Equation (5), (6), (7)

\[
\varphi_j(m+1) = \varphi_j(m) + S_t \varphi_j(m) + \frac{1}{2} S_t^2 \varphi_j(m) \\
\dot{\varphi}_j(m+1) = \dot{\varphi}_j(m) + S_t \dot{\varphi}_j(m) \\
\ddot{\varphi}_j(m+1) = \beta \ddot{\varphi}_j(m) + \mu_{\varphi}(m)
\]

Here \(j\) is the angle of five movements, \(\varphi_j(m)\) is the \(j\) th angle at time \(m\), \(\dot{\varphi}_j\) is the angular velocity, \(\ddot{\varphi}_j\) is the acceleration of angular movement. \(\mu_{\varphi}\) is the zero mean of white noise process. \(\beta\) is the parameter of the processing model. \(S_t = \frac{1}{T}\) is the sampling period. These are typical calculations for a continuously moving physical object.

For the sampling time, the model assumes the speed is constant. This is enough for our details, which have been obtained with a sample rate of \(f_s = 128\) Hz. The Equation for movement of upper arm is shown in Equation (8), (9).

\[
X_x = \varphi_3 + \varphi_1 S \varphi_2
\]

\[
X_x = \varphi_1 C \varphi_2 S \varphi_3 - \varphi_2 C \varphi_3
\]

\(X_x, X_x\) is the gyro sensor, and magnetometer details at period \(m\). \(\varphi_1, \varphi_2, \varphi_3\) are the angle of movement of each joint. \(S, C\) are the parameter models.

Based on the mathematical computation, the Experimental results indicate that Linear Quadratic Estimation Hybridised Computer Algorithm is used to detect the behavior method of muscles with the implementation of accelerometers to find the angular speed of joints.

3. Results and Discussions
LQE-HC has no rigid attachment systems, whereas pneumatically compatible actuator is used for finding the movements of muscles and joints for safety reasons, unlike other exoskeleton structures. The compressor output pressure is decreased to a maximum force of not more than 60 N produced by a single actuator. This force would reduce contracts as an actuator and become 0 N with approximately 12 percent contraction. Therefore, if the subject shifts the joints along the paths of the applied powers, the torques used by the exoskeleton will decrease.

Therefore, no rigid part attaches the joint to another one; only actuators link the joints so that the motion of a subject is not limited kinematically. The actuator length and the pressure for each actuator are clearly shown in table 1.

| Pressure (MPa) | Length of actuator |
|---------------|--------------------|
| 110           | 0.1                |
| 105           | 0.15               |
| 104           | 0.2                |
| 100           | 0.25               |
| 98            | 0.3                |
| 95            | 0.35               |

Table 1. Actuator length and the pressure measurement
Even if all the actuators exert their maximum strength, the combined joint acceleration of the robot is not solid, enabling the subject to resist the exoskeleton robot to push his / her connections. The actuators are made of rubber that needs no protective cover. Moreover, no rigid part is connected to another joint; only actuators link the joints, so a topic does not constrain the movement kinematical.

Changes in pressure and the actuator length, the force exerted by the actuator are clearly explained in figure 3. For a shift in air pressure, the spring constant, i.e. the gradient of the relationship between each displacement factor, does not alter to any great extent, indicating that a constant may be used for modelling.

The following is a simple method for measuring air pressure. The joint angles of a subject are collected through a motion capture device. These merging angles are generated by the kinematic robot layout, which creates the existing duration of each pneumatic actuator.

For measuring a pressure to achieve a desired force on the basis of duration the total length of every actuator is added. This is used to monitor the feedback system. The feedback mechanism balances the actuators unshaped nonlinear and fluid properties. The force sensor settles at steady reference intensity within 15 s.

Next, the precision of the estimation of muscle strength is tested experimentally using the established musculoskeletal model with eight households. Simulated by the evolved musculoskeletal model, the corresponding tasks are expected for muscle powers. A non-linear association between the joint angle and the sensor calculations is observed in the Union-Space Arm design introduced earlier.

| Length (mm) | Flexion | Extension | Abduction |
|------------|---------|-----------|-----------|
| 0          | 10      | 15        | 19        |
| 50         | 20      | 27        | 35        |
| 100        | 30      | 36        | 40        |
| 150        | 40      | 52        | 55        |
| 250        | 50      | 58        | 60        |
| 300        | 60      | 65        | 70        |

This study provides information regarding Linear Quadratic Estimation Hybridised Computer Algorithm (LQE-HC) modelling. LQE-HC is used to detect the behavior method of muscles with the implementation of accelerometers to find the angular speed of joints. Remote monitoring can give valuable data on regular exercise level and functional potential of individuals. The precision of the
estimation of muscle strength could be enhanced by taking account of the various variations such as
time axes, anatomical cross sections, etc., and high accuracy is obtained for LQE-HC modelling.

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