Pathological Tremor Modeling & Active Compensation via Functional Electrical Stimulations

Principal Investigator: Professor Ang Wei Tech
Email: WTAng@ntu.edu.sg
Office: N3-02a-25
Tel: (65) 6790 5521 (Office)

PROJECT DESCRIPTION:

We are proposing an active compensation approach to attenuate pathological tremor of the upper limbs. From the sensed physical motion and the Electromyograph (EMG) signals of the upper limbs, a filtering algorithm would distinguish between the intended motion and involuntary component, and to counteract the tremor in real-time by controlling the flexor and extensor muscles via functional electrical stimulations (FES) to contract out of phase with their tremorogenic activation pattern.

Background
Tremor is defined as the involuntary rhythmic or semi rhythmic oscillation of a body part resulting from alternating of simultaneous contractions of antagonistic muscle groups. Pathological tremor affects more than 5% of the population age 40 and above. Common causes of pathological tremor include essential tremor, Parkinson's disease, multiple sclerosis, stroke, spinal cord injuries, orthostatic tremor, primary writing tremor, etc. Daily lives of these patients are greatly impaired by the involuntary hand motion, and in some severe cases, it becomes impossible for them to perform simple chores like drinking from a cup or inserting a key into a keyhole.

Objective
We are proposing an active compensation approach to attenuate pathological tremor of the upper limbs. From the sensed physical motion and the Electromyograph (EMG) signals of the upper limbs, a filtering algorithm would distinguish between the intended motion and involuntary component, and to counteract the tremor in real-time by controlling the flexor and extensor muscles via functional electrical stimulations (FES) to contract out of phase with their tremorogenic activation pattern.
Methodology

1. **Modeling**
   From an engineering perspective, each type of pathological tremor has its own distinctive structure. For example, Parkinsonian tremor is a resting tremor that lies in the band of 3 - 6 Hz and has high amplitude, essential tremor is characterized by a 4 - 12 Hz postural and kinetic tremor, and multiple sclerosis and stroke tremors are intention tremor – typified by an increase in tremor amplitude near the termination of a visually guided goal-directed movement. We will seek to understand in depth the engineering characteristics of different types of pathological tremor, and to propose mathematical models of these quasi-periodic movements in ways that are suitable for engineering manipulations.

2. **Sensing**
   There is a 20 ms time delay between the moment an EMG signal is sensed and the actual movement of the muscle. This provides our approach a critical time window to process the signal and actuate the appropriate muscle groups. The corresponding EMG signals and the resultant hand movements will be measured and analyzed. We will evaluate the current available models to correlate EMG signals and the resultant physical motion especially in describing the tremulous component. New EMG models will be investigated to integrate seamlessly with our proposed pathological tremor models. Decoding the noisy EMG signal is a challenging task, with an appropriate model we could fuse the sensed physical motion to improve the EMG signal-to-noise ratio.

3. **Filtering**
   The key technical challenge in tremor filtering is the real-time criterion of the application. Tremor has a distinctly higher frequency band than most voluntary motion. However, most classical frequency selective filters cause phase shift in the filtered signal, which means the filtered erroneous motion that we attempt to cancel is a time delayed version of the actual physical motion. To overcome this causality barrier, we propose to research and design an adaptive zero-phase filter with predictive capability. Learning algorithms will also be explored to extract the tremulous component from the sensed motion.

4. **Actuation**
   FES has been shown by neuroscientists to be a feasible mean to attenuate pathological tremor. If we could successfully decipher the tremulous erroneous motion component from the sensed EMG and the physical motion, we would be able to actuate the appropriate muscle groups with the correct intensity, sequence and timing to nullify the pathological hand tremor.

**GRANT:**
- Euro 30,000, Merlion Programme, French Embassy July 2008 to June 2010.
PERSONNEL:

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Ang Wei Tech</td>
<td>Associate Professor, School of Mechanical &amp; Aerospace Engineering, NTU</td>
<td><a href="mailto:wtang@ntu.edu.sg">wtang@ntu.edu.sg</a></td>
</tr>
<tr>
<td>Dr. Phillippe Poignet</td>
<td>Assistant Professor Labaroire d’Informatique de Robotique et de Micro-électronique de Montpellier (LIRMM), University of Montpellier II, France.</td>
<td><a href="mailto:poignet@lirmm.fr">poignet@lirmm.fr</a></td>
</tr>
<tr>
<td>Dr. Adela Tow</td>
<td>Consultant Department of Rehabilitation Medicine, Tan Tock Seng Hospital</td>
<td><a href="mailto:Adela_Tow@ttsh.com.sg">Adela_Tow@ttsh.com.sg</a></td>
</tr>
<tr>
<td>Jeanette Lee</td>
<td>Senior Occupational Therapist Department of Rehabilitation Medicine, Tan Tock Seng Hospital</td>
<td><a href="mailto:jeannette_lee@ttsh.com.sg">jeannette_lee@ttsh.com.sg</a></td>
</tr>
<tr>
<td>Dr. Louis Tan</td>
<td>Consultant Department of Neurology, National Neuroscience Institute</td>
<td><a href="mailto:louis_tan@nni.com.sg">louis_tan@nni.com.sg</a></td>
</tr>
<tr>
<td>Dr. Au Wing Lok</td>
<td>Associate Consultant Department of Neurology, National Neuroscience Institute</td>
<td><a href="mailto:wing_lok_au@nni.com.sg">wing_lok_au@nni.com.sg</a></td>
</tr>
<tr>
<td>Shee Cheng Yap</td>
<td>Research Associate</td>
<td><a href="mailto:cyshee@ntu.edu.sg">cyshee@ntu.edu.sg</a></td>
</tr>
<tr>
<td>Ferdinand Widjaja</td>
<td>PhD student (graduated)</td>
<td>-</td>
</tr>
</tbody>
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Refereed Journal (Published/In Press):

Refereed Conference (Published/In Press):


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