Hand Tremor Modelling in Parkinson's Disease - A Tutorial

[TThe material in this tutorial is based on standard curriculum of K. N. Toosi University of Technology, Faculty of Electrical Engineering. For more information, please write to Mahsa Bahrami: M.bahrami@email.kntu.ac.ir]

Tremor is the most commonly involuntary body movement and may be seen in the hands, arm, eyes, face, head, vocal cords, trunk and legs.

What is the reason for many tremors? Why do many old people get into trouble?

If you think they should exercise in young age, that not get this day, It's a big mistake. they suffer from the illness that Mohammed Ali Kelley (legendary boxer) has suffered.

So what's problem?

That named Parkinson. Do you like learn more of this illness? Come along with us.

Does Parkinson's disease have any signs?

Yes, first sign of parkinson rest tremor and other signs appear overtime. Fig(1) shown parkinson signs.

![Fig(1) Parkinson's signs](image)

All of these symptoms appear suddenly?

Not at all. Parkinson's is a completely creeping illness and may take years to evolve and has five steps that shown in fig(2).
And in general, Parkinson's can affect the human motor and non-motor system that Respectively shown in fig(3).

We only intend to model hand tremor in Parkinson's based on paper[2]

**Hand tremor modelling:**

**1st stage: determine the degrees of hand freedom**

Wait, I didn’t understand degree of freedom. Explain please!

Look at fig(4), Freedom of hand shown.
The number of independent ways by which a dynamic system can move, without violating any constraint imposed on it, called degree of freedom.

The hand has a total of 7 degrees of freedom, but it raises the problem for modeling these 7 degrees of computation and complexity so that we can achieve 3 degrees of freedom for the hand in order to have a perfect and simple modeling. Fig(5) shown 3 degrees of freedom in hand.

2nd stage: Detect base joint in hand tremor

Hand tremor model by considering motion at the wrist joint. The wrist joint must be considered since it’s the most joint related to the tremulous limbs of patients. That shown in fig(6).
3rd stage: Mechanical modeling of hand

Then introduce Mechanical model of hand. For mechanical model of hand detect joint (box with red rectangle). Each of joints swing around pivot. mechanical model of hand shown in fig(7).

The four muscles modeled to produce movement:

The single joint shoulder, elbow and wrist joint muscle and the double joint Biceps brachii muscle. Please see the figure (8) to understand this joint.
NOTE: muscles can be assumed to be regulated independently

Damping and stiffness coefficient of muscles are assumed to be linearly proportional.

Stiffness is the extent to which it (an object) resists deformation in response to an applied force.

Damping is a material characteristic which can generally not be influenced by the shape or form of a component. Damping describes the energy dissipated by a vibrating system (mainly appearing as heat) and causes the vibration amplitude to decay over the time.

In order to be able to understand the subject, it is necessary to enter into mechanical discussions. In fig (9) mechanical model consist of mass(M), stiffness (k), damping(R) shown.

4th stage: extract DVA equation for mathematical modelling

Equation of motion describing the dynamics of the hand at its proximal joints is derived and used for designing the tremor suppression device.
Dynamic Vibration Absorbers (DVA) are based on the concept of attaching a secondary mass to a primary vibrating system such that the secondary mass dissipates the energy and thus reduce the amplitude of vibration of the primary system[5].

\[
M\ddot{\theta} + C\dot{\theta} + k\theta = f
\]

input moments exerted from muscular activity

acceleration  velocity  displacement

There are many application of DVA, a few are noted below:

- vibration control of transmission cables
- control of torsional oscillation of crankshaft
- control of rolling motion of ships
- chatter control of cutting tools
- control of noise in aircraft cabin
- vibration control of hand held devices

DVAs are generally of three types

Vibration Neutralizer: Here, a secondary mass is connected to the primary using a spring element.

Auxiliary Mass Damper: Here the secondary mass is connected to the primary by a damper/dashpot.

Dynamic Vibration Absorber: A general case where both spring and damper are used to connect the secondary mass, with the primary system[5].

Example: extract DVA for under shape?

\[
m_1\ddot{x}_1 + k_1x_1 + k_2(x_1 - x_2) = Fe^{j\omega t}
\]

\[
m_1\ddot{x}_1 + k_1(x_1 - y) = f(t)
\]
\[ m_2 \ddot{x}_2 + k_2(x_2 - x_1) = 0 \]

This figure from [5]

**Now, for extract DVA in hand tremor what we can doing?**

detect unknown parameter in DVA equations:

\[
M = \begin{bmatrix}
M_{11} & M_{12} & M_{13} & M_{14} \\
M_{21} & M_{22} & M_{23} & M_{24} \\
M_{31} & M_{32} & M_{33} & M_{34} \\
M_{41} & M_{42} & M_{43} & M_{44}
\end{bmatrix}
\]

**Why matrix dimension 4x4? Have a specific reason?**

Yes of course. Four muscles used for modeling.

After matrix defined, element of matrix determined as:

\[
M_{11} = (L_1 + m_1 a_1^2) + (L_2 + m_2 a_2^2) + m_2 L_1^2 + m_3 (L_1^2 + L_3^2) + m_4 (L_1^2 + L_2^2 + a_4^2 + 2L_2 a_4) + m_a (L_1^2 + L_2^2 + a_3^2 + 2L_a a_3)
\]

\[
M_{12} = (L_2 + m_2 a_2^2) + m_3 L_3^2 + m_4 (L_2^2 + a_4^2 + 2L_2 a_4) + m_a (L_2^2 + a_3^2 + 2L_a a_3)
\]

\[
M_{13} = m_4 (a_4^2 + L_2 a_4)
\]

\[
M_{21} = M_{12}
\]

\[
M_{22} = M_{12}
\]

\[
M_{23} = M_{13}
\]

\[
M_{24} = M_{14}
\]

\[
M_{41} = M_{14}
\]

\[
M_{42} = M_{24}
\]

\[
M_{43} = M_{34}
\]

\[
M_{44} = m_a a_3^2
\]

**But exactly where are parameters like m1 and other parameters?**

Look at fig(10, 11)
Muscles damping coefficients are assumed to be directly proportional to muscle stiffness by a constant.
What's Parameters value? for example L1?

Look at table1:

Table1- parameter of hand[7]

<table>
<thead>
<tr>
<th>Right Hand</th>
<th>Length (cm)</th>
<th>Density (kg/m³)</th>
<th>Centroid (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper arm</td>
<td>l₁</td>
<td>D₁</td>
<td>a₁</td>
</tr>
<tr>
<td>Forearm</td>
<td>l₂</td>
<td>D₂</td>
<td>a₂</td>
</tr>
<tr>
<td>Palm</td>
<td>l₄</td>
<td>D₄</td>
<td>a₄</td>
</tr>
</tbody>
</table>

Reference:


