A Robot to Mimic Horizontal Fast Eye Movement System

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Main Goals

- Replicate the Linearized Horizontal Fast Eye Movement System
- Quickly target a stimulus in a +/-15° range
- Camera capture an image simulating stimulus
- Image will be processed and appropriate movement executed
- Movement should mimic that of the human Saccade
- Target Saccade profiles for Human Eye
  - Speed
  - Acceleration
  - Viscoelasticity
  - Precision
The Human Eye

Anatomy
- Eye
- Optical Nerve
- Six Muscles

Types of Movement
- Smooth Pursuit
- Vestibular ocular
- Optokinetic
- Vergence
- Saccades
This linear muscle model exhibits accurate nonlinear force-velocity and length-tension relationships. No other linear muscle model to date is able to accurately reproduce these nonlinear relationships.

- Actuator motion doesn’t account for the natural elasticity or viscosity of muscle, thus we need to model these viscoelastic components to better model movement.
- Antagonist/Agonist – Lateral and Medial Rectus
- Superior/Inferior Rectus/Optic Nerve - Don’t have muscle input horizontally, but do affect the eye rotation, nudging the system towards a straight ahead orientation because of slight tensions.

$F_{ag}$ and $F_{ant}$ represent the agonist and antagonist active-state tensions, which drive the saccade. These are modeled by our motors, which, in conjunction with our viscoelastics, actuate to simulate the muscle contraction.
• \( F \) constants represent forces based on the ocularmotor elements.
• \( \tau \) and \( k \) and \( c \) constants intrinsic to humans and are set values based on experimental data.
• \( F_{ag} \) and \( F_{ant} \) functions will output to the motors.
**SPECIFICATIONS**

- 30 degree range (±15)
- Peak Velocity of ~400 degrees per second
- Duration
  - ~30 ms for < 5 degree saccades
  - 50+ ms for > 10 degree saccades
- Neural and Agonist/Antagonist inputs shown
- These inputs produce a 15 degree simulated saccade with a max velocity of 400 deg/s.
- Notice the unit step like input, and the near instantaneous force increase in the action state tension generators
MigeOne-10 Shape Memory Alloy (SMA)

- Force of 8.82 N
- Time - 0.034 seconds (32 Volts)
- Speed 243.6 mm/s
- Stroke length 9.17 mm
- Four Miga Motors (2 Actuation, 2 Position)
- Clutching Mechanism
Actuation—Left Turn

Stationary

Miga 3 & 2 Actuation

Miga 4 Relax

Miga 4 Actuation
SECOND ACTUATION

Left Turn – Miga 3 Relax
Then Repeat

Right Turn – Miga 1 Relax

Right Turn – Miga 2 Relax

Right Turn – Miga 1 & 4 Actuation
Miga MOSFET Drivers

- External GATE (CNTL) Signals
- Range (5 V–30V)

Alps Position Sensors

- 10k Linear Potentiometer
- Analog Output (0V–5V)

Arduino Mega 2560

- Receive Position Information (Analog-to-Digital Converter)
- Generate Control Signals
• Actuating motors require a 15 degree saccade to be completed in 75ms.

• 20 volts chosen as input to the drivers for both actuating motors to meet these requirements.

• 5 volts chosen as input to the drivers for both movement motors.

<table>
<thead>
<tr>
<th>Applied Voltage (V)</th>
<th>Current Drawn (A)</th>
<th>Actuation time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.84</td>
<td>1494</td>
</tr>
<tr>
<td>10</td>
<td>1.78</td>
<td>257</td>
</tr>
<tr>
<td>15</td>
<td>2.51</td>
<td>110</td>
</tr>
<tr>
<td>20</td>
<td>3.4</td>
<td>61</td>
</tr>
<tr>
<td>25</td>
<td>4.15</td>
<td>38</td>
</tr>
<tr>
<td>30</td>
<td>4.66</td>
<td>28</td>
</tr>
</tbody>
</table>
Supplying both 20 and 5 volt sources with varying current cannot be done with a standard voltage divider.

The LM2596 is a voltage regulator that can take any input above 5 volts and provide a stable 5 volt output.

The LM2596 is rated at 3A. Both movement motors require a maximum of 900mA each during their positioning.
**Spring Selection**

- Component only exerts force relative to POSITION
- Select for resting length and K

**Damper Selection**

- Component only exerts resistive force relative to VELOCITY, representing muscle viscosity

- Using Eddy Currents (a pure drag force) we can resist velocity by dragging a non-magnetic highly conductive metal through a magnetic field created by two opposing magnets.

\[ B = \sigma B_0^2 w \cdot \pi r^2 \]

- Select parameters for metal conductivity (\(\sigma\)), magnet size/field area (\(\pi r^2\)), magnet strength (\(B_0\)), aluminum thickness (\(w\))
## Eddy Current Parameter Determination

<table>
<thead>
<tr>
<th>Component</th>
<th>Required Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kse</td>
<td>125 N/m</td>
</tr>
<tr>
<td>Klt</td>
<td>60.7 N/m</td>
</tr>
<tr>
<td>K</td>
<td>16.24 N/m</td>
</tr>
<tr>
<td>B1</td>
<td>5.6 Ns/m</td>
</tr>
<tr>
<td>B2</td>
<td>0.50 Ns/m</td>
</tr>
<tr>
<td>B</td>
<td>0.327 Ns/m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Damper</th>
<th>Plate Thickness</th>
<th>Magnet Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>1.74mm</td>
<td>1/4&quot;</td>
</tr>
<tr>
<td>B2</td>
<td>2.55mm</td>
<td>1/8&quot;</td>
</tr>
<tr>
<td>B</td>
<td>1.845</td>
<td>1/8&quot;</td>
</tr>
</tbody>
</table>
Slider System

- A system of low friction sliders on a guided track will transfer energy step-by-step from actuation to Saccade
- Keeps the motion linear with no torque
- Provides attachment for Springs and dashpots

Material Selection - UHMWPE

- Low Friction Coefficient
- Low Density
- Easy to machine
- Lowest friction with steel, our track material
Eye properties to mimic

- Inertia
- Weight
- Size
- Muscle Attachment
- Suitable Material - HDPE

<table>
<thead>
<tr>
<th></th>
<th>Fabricated Globe with Peg</th>
<th>Fabricated Globe</th>
<th>Human Eye</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (g)</td>
<td>7.84</td>
<td>7.38</td>
<td>7.57</td>
</tr>
<tr>
<td>Volume (cm³)</td>
<td>7.73</td>
<td>7.62</td>
<td>7.24</td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>1.01</td>
<td>1.01</td>
<td>1.04</td>
</tr>
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</table>
3 Step Process

- Video feed from camera
- Hue Saturation & Value (HSV) transform & Threshold based on Color
- Calculate the center of mass for the resultant binary image
**Communication**

**Arduino**
- Written and uploaded to ATMega328 from Arduino IDE
- Serial read loop waits for input
- Input coordinates are translated into motor movement

**PySerial**
- Specify port and baud rate
- Establish serial connection
- Relay coordinates to Arduino for translation

```python
import serial

def writeSerial(pt):
    port = 'COM3'  # Specify port Arduino is listening on
    BAUD = 9600  # Baud rate

    a = serial.Serial(port, BAUD)  # Establish connection

    if a:
        a.write(pt)  # Write to serial
```

```cpp
void loop() {
    while(Serial.available() > 0) {
        pt = Serial.read();
    }
}
```
Flow of Automation

- Arduino
  - Actuation
  - Serial read/write

- Python
  - Image Processing
  - Serial read/write

Coordinates

Validation of Movement
LIMITATIONS AND IMPROVEMENTS

- Variable force motors
  - Would provide a more homeomorphic model
- Larger Stroke and more accurate stroke control
  - Increased stroke would allow for an increased “visual field”
  - Higher Coefficient Miga Springs would allow greater control
- Arrange for vertical saccades and other eye movements
  - Would model the human eye system in 3 dimensions
- Latency and Granular Control over Metrics
  - Less friction, weight of linear blocks
  - More control over motor relaxation time
  - Account for cooling latency of motors, and variable room temperatures
  - Force Transducers to more accurately relay force relationships
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