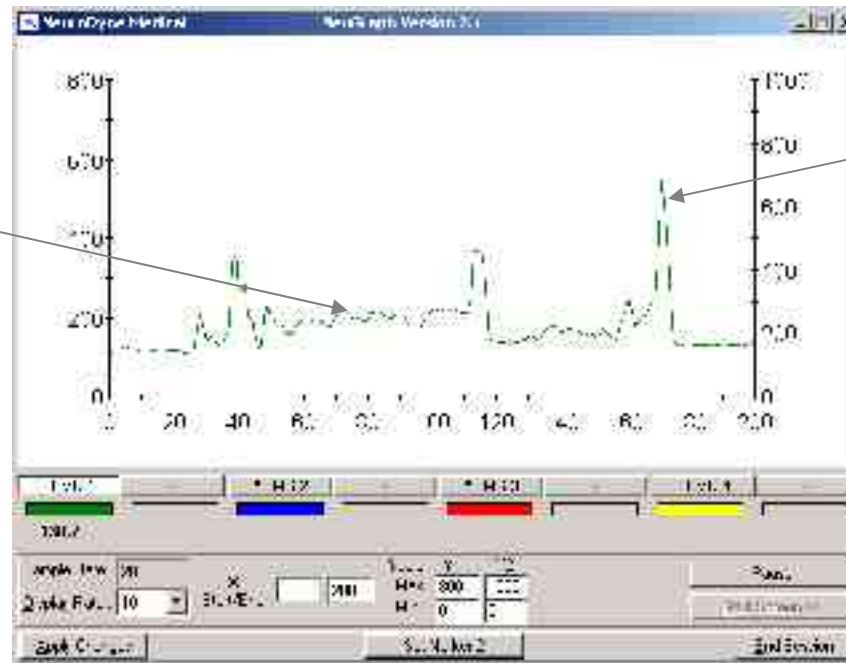


Surface Electromyographic [EMG] Control of a Humanoid Robot Arm

by Edward E. Brown, Jr.

Goal is to extract *position* and *velocity* information from sEMG signals obtained from the biceps and triceps antagonistic muscle pairs when subject performs elbow flexion motions in the sagittal plane.

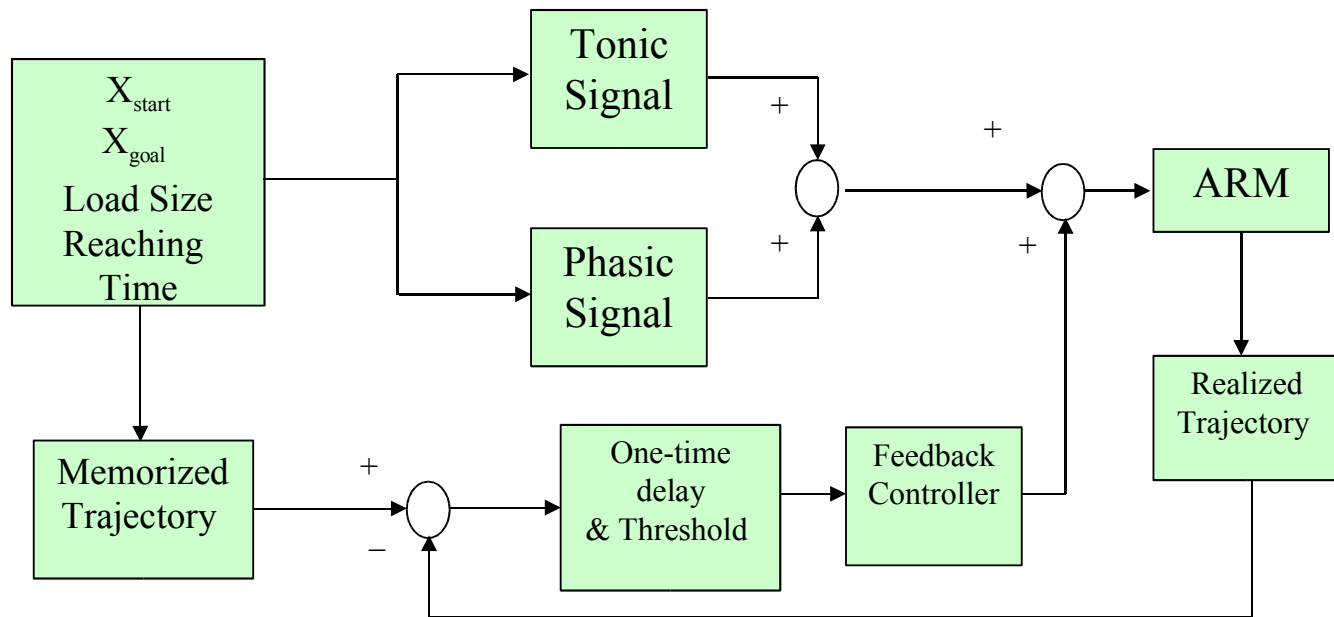
Position



Velocity

Biological Inspiration

Northrup demonstrated how the tonic (force) and phasic (speed) components of an EMG activation signal could be used to move ISAC in a human-like fashion.



**Northrup's biologically inspired control paradigm.
(Source: From S. Northrup, 2001)**

Hypothesis

Flanders suggests that a relationship exists between maximum muscle activity and applied force in a “preferred direction” that can be represented by the equation:

$$EMG = C + A|F|\cos(\theta_0 - \theta)$$

Where: C = Constant offset

A = Scaling Factor

F = Magnitude of force at wrist

θ_0 = Preferred direction of movement

θ = Current force direction

Some considerations:

- Spatial tuning of static EMG signals represents the convergence of multiple, descending motor commands from the motor cortex.
- A ‘cortical to motoneuronal’ transformation may be derivable if one can assume that all neuronal activity within the motor system (related to movement and direction) could be described using multiple cosine tuning functions.
- Transformation between preferred direction of cortical neurons and motoneurons could be achieved through a weighted, nonlinear mapping.

Experimental Methodology

- Record and analyze sEMG activation pattern from biceps and triceps during a constrained, isometric, muscle contraction along 1 degree of freedom in the sagittal plane.
(Flanders observes 9 shoulder and arm muscles in multiple reaching postures and planes of motion.)
- We focus on simple vs. complex motions to avoid biomechanical redundancy and synergistic muscle relationships (Gottlieb, 1989). This helps to characterize specific muscle activation patterns in a particular plane.
(Flanders focuses on 6 distinct postures representing the motion of opening a door or picking up a cup.)
- Focus on using simple, constrained movements: Arm curling in sagittal plane.

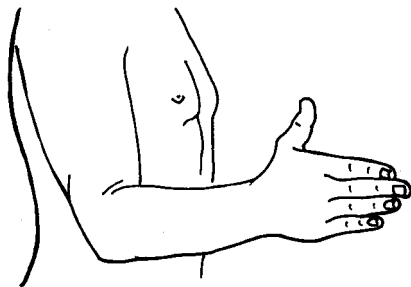


Diagram illustrating the participant's initial posture. The forearm is in a horizontal position parallel to the midsagittal plane of the participant's body. The wrist is kept in a neutral orientation with respect to the pronation/supination of the hand.

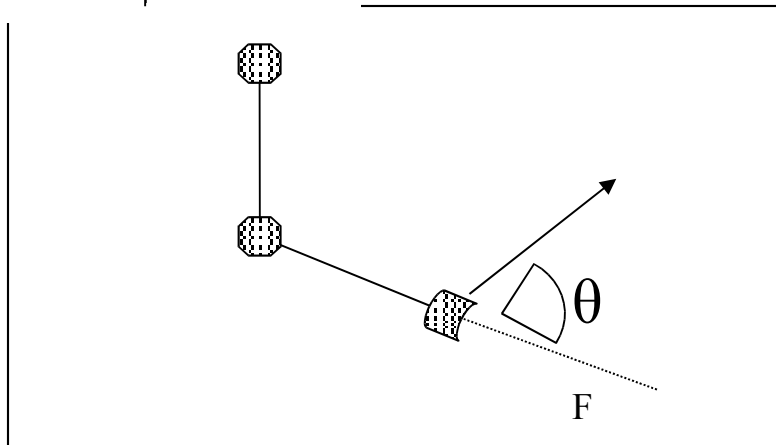


Diagram representing Flanders' application of an external pulling force to the wrist of a subject's arm. The direction of the pulling force F is applied relative to the subject's wrist.

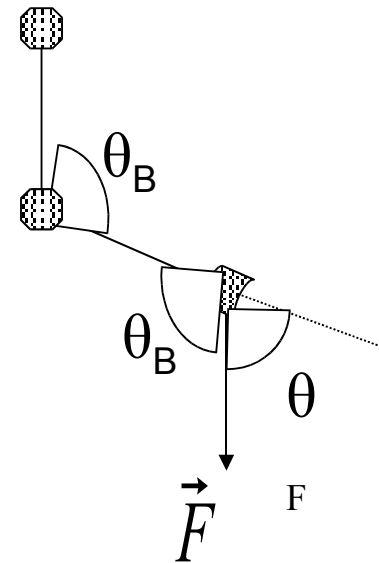


Diagram representing the application of an external pulling force due to gravity to the wrist of a subject's arm in the sagittal plane for this project. The preferred elbow angle θ_B is located between the subject's upper arm and forearm is shown.

Experimental Methodology *(con't)*

Average Biceps and Triceps Static EMG Measurements for Each Elbow Angle (μV)

Load (lbs.)	0°		30°		60°		90°		120°
0	X		X		X		X		X
0	X		X		X		X		X
0	X		X		X		X		X
3	X		X		X		X		X
3	X		X		X		X		X
3	X		X		X		X		X
5	X		X		X		X		X
5	X		X		X		X		X
5	X		X		X		X		X
7	X		X		X		X		X
7	X		X		X		X		X
7	X		X		X		X		X
10	X		X		X		X		X
10	X		X		X		X		X
10	X		X		X		X		X

Suite of experimental trials performed in this research project. There are 45 combinations of motions performed by each subject.

Experiment

Non-invasive sensors called Active Electrodes were placed on the belly of the subject's biceps and triceps muscles.



Experimental posture arrangement for each participating subject.



Active Electrode Sensor on Biceps



Active Electrode Sensor on long/lateral head area of the Triceps

Static sEMG Measurements

1. Upper arm is placed in the vertical position, forearm placed in the following positions: 0°, 30°, 60°, 90°, and 120°.
2. Subject's wrist is kept in a neutral orientation with respect to the pronation/supination of the hand.
3. sEMG measurements were taken 3 times each for all elbow angle positions.
4. Each posture is held for 10 seconds with a 20 second rest break in between sessions.
5. Each experiment was performed for the following loads applied to the wrist: 0, 3, 5, 7, and 10 lbs.

Discussion of Results

- Modest position predictions are achieved for each subject, but velocity study is inconclusive.
- Biceps and triceps exhibited broad tuning characteristics (active for forces over wide range of positions), so multiple cosine peaks were necessary.
- There is potential for using this method to discern motion primitives via sEMG.
- Solutions to eq. (3) represent global minima, but in some cases, the nearby local minima provided better results.

Contributions and Conclusions

- Extended Flanders' research by pursuing broader approach (Used larger test population, additional loads, and single joint motions to eliminate muscle synergies).
- Demonstrated method showing how cosine tuning functions can be used to model sEMG data and produce potential control inputs.
- Delved deeper into biologically-inspired control paradigm using actual sEMG data to develop a *volitional proportional vectorial* control paradigm.
- Showed that Cosine tuning functions could be used to model sEMG signals based on internal dimensions of the elbow joint instead of pulling force directions.
- Used a noninvasive sEMG approach to “intimately connect” the man with a machine.