

“Harnessing Motor Unit Activity: From Lab to Clinic”

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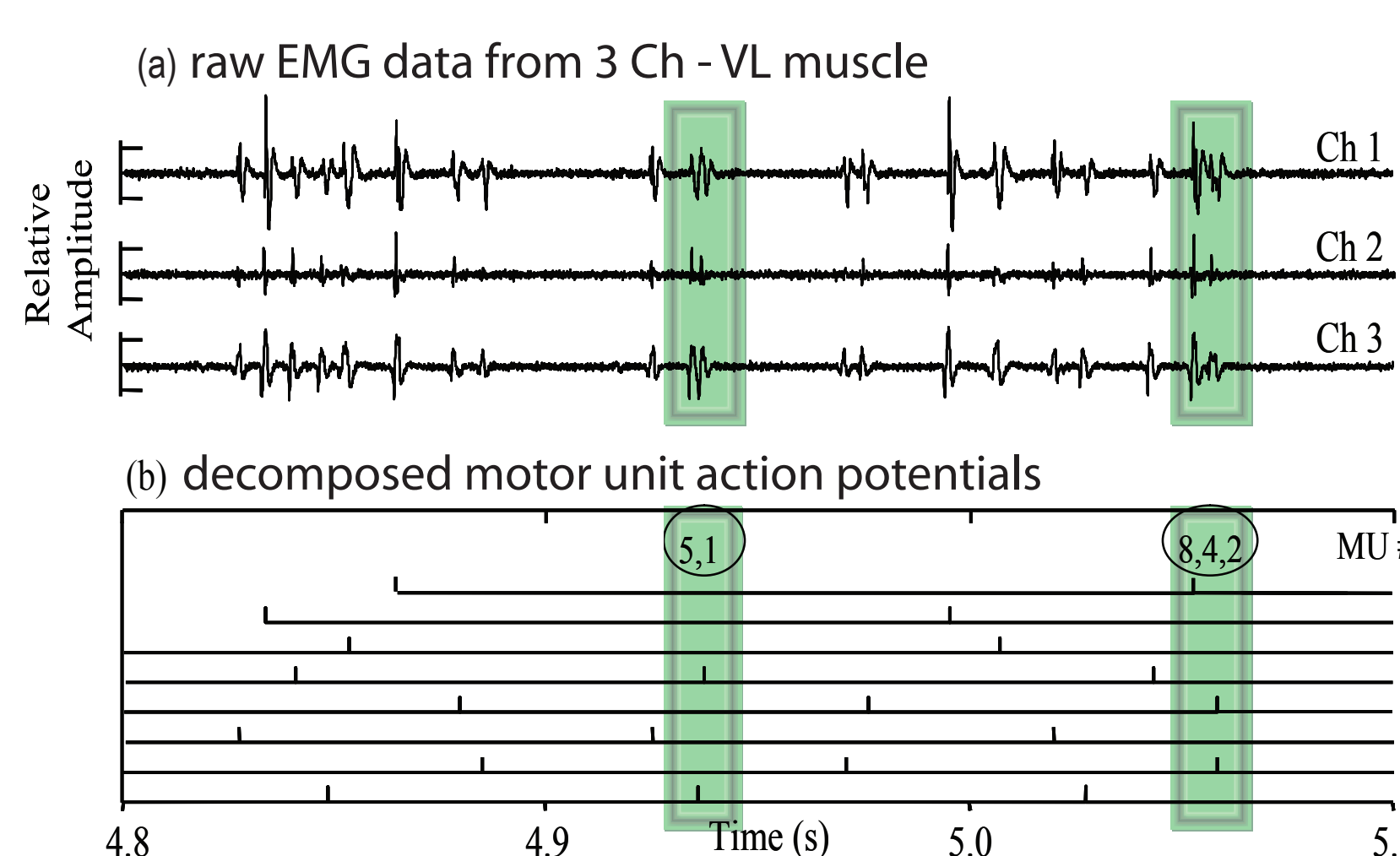


Goal: To develop an automatic system to accurately and quickly decompose electromyographic (EMG) signals into their constituent motor unit action potentials. This will enable a wider range of studies to investigate the workings of the healthy and diseased neuromuscular system. This project develops the technology and applies it to understanding the effects of aging and exercise on motor unit control.

Project 1: Develop Technology for Decomposition of EMG Signals

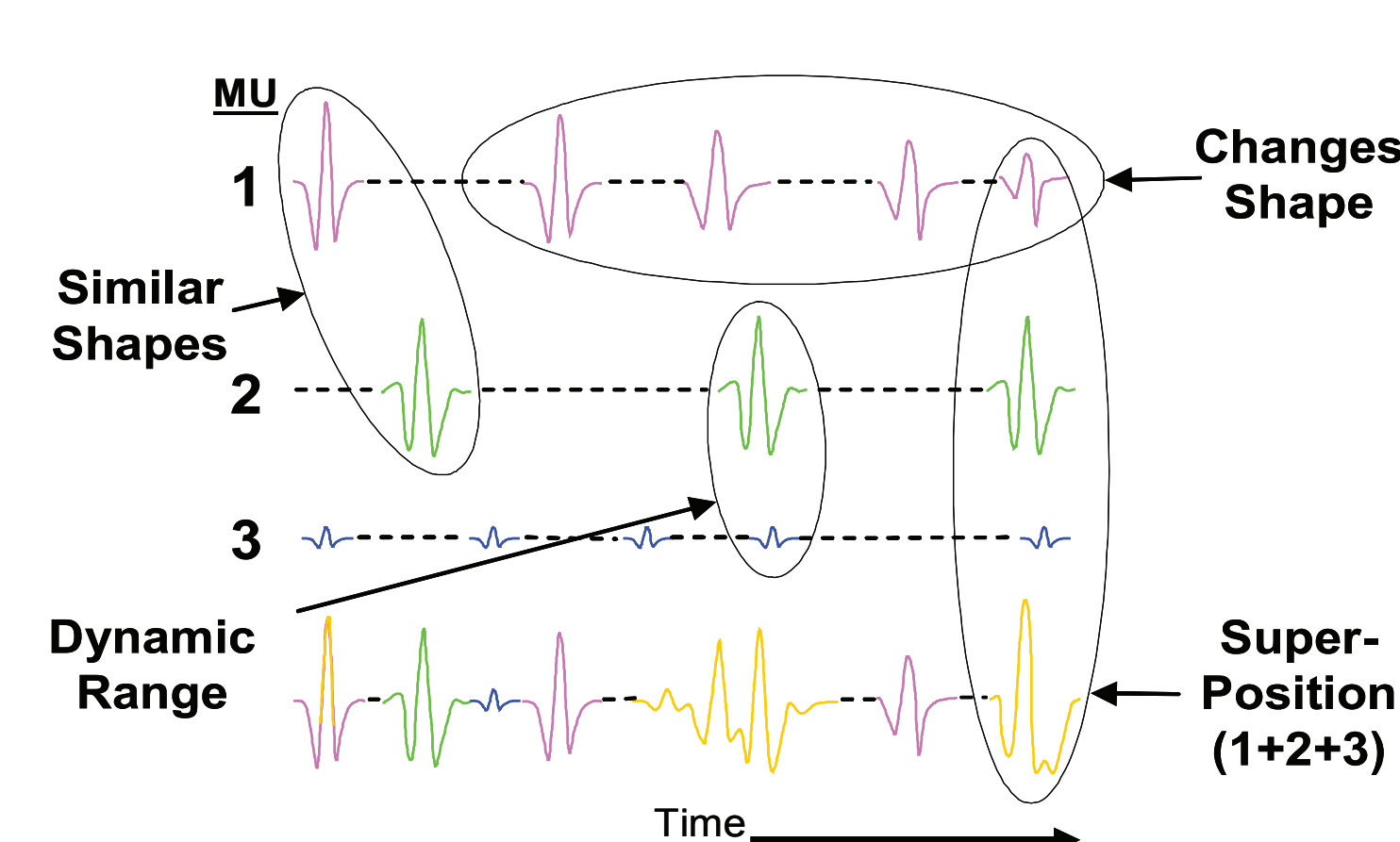
Aim 1: to improve the yield and accuracy of decomposing the raw EMG signal into concurrently active motor unit action potential trains.

Sample Problem



Sample of raw EMG data (a) that has been processed by the decomposition algorithms to successfully identify the firing times of 8 motor units (b) from the Vastus Lateralis muscle. Two examples are highlighted in (b) of the ability of the algorithms to resolve superpositions at approximately 4.93 s. (where motor units #5 and #1 are superimposed), and at 5.06 s. (where motor units #8, #4, and #2 are superimposed). The 0.3 s of data were collected during an incremented force contraction from 18.75% to 21.55% MVC.

Challenges



The algorithms must be able to deal with four major complexities in the EMG signal that challenge the task of decomposition: 1) Superposition of action potentials from different motor units; 2) Large dynamic range of action potential amplitudes of different motor units; 3) Shape changes across the different action potentials of each motor unit; and 4) Similarity of shape at various times among the action potentials of different motor units.

Solution: Decomposition Algorithm

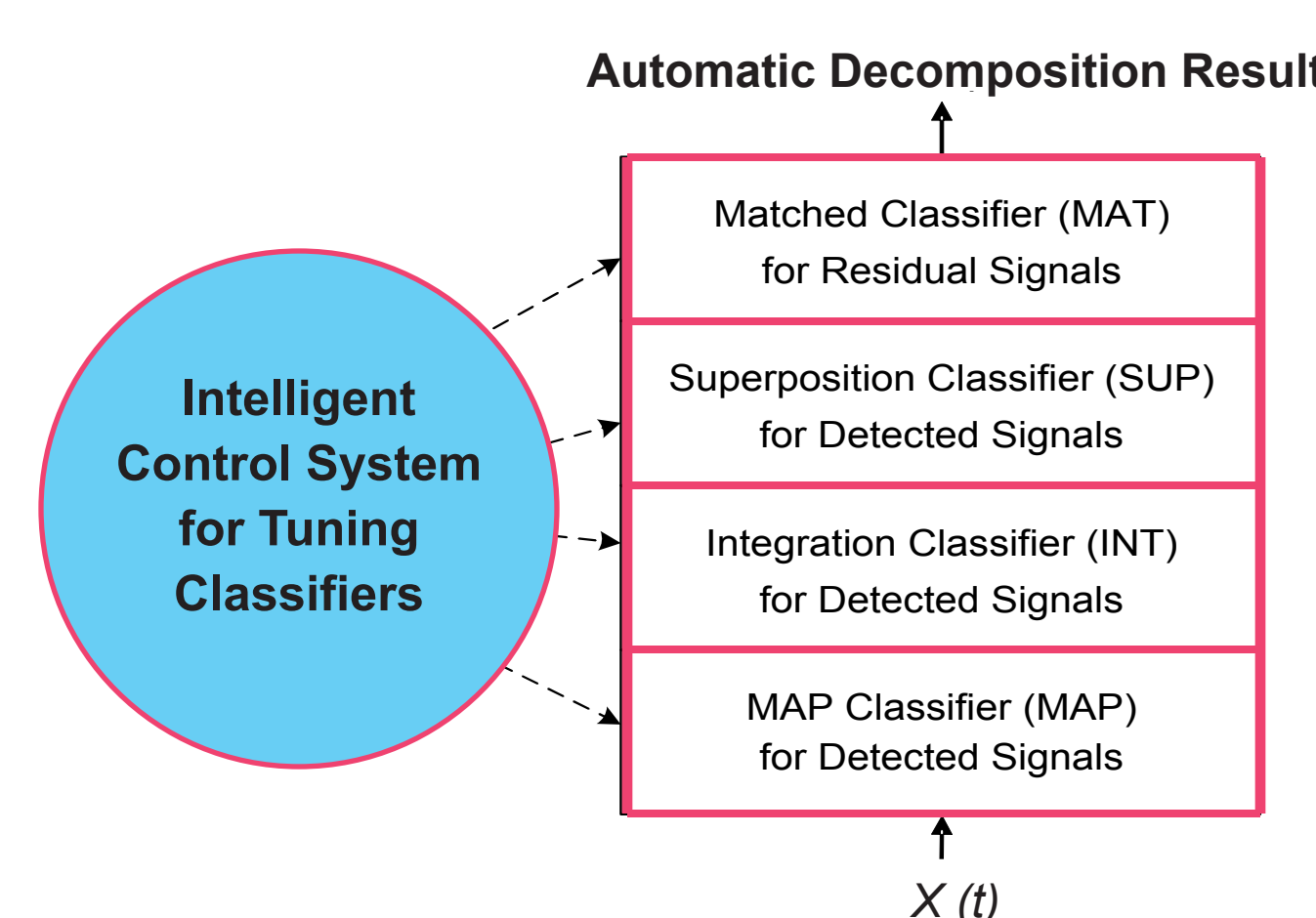
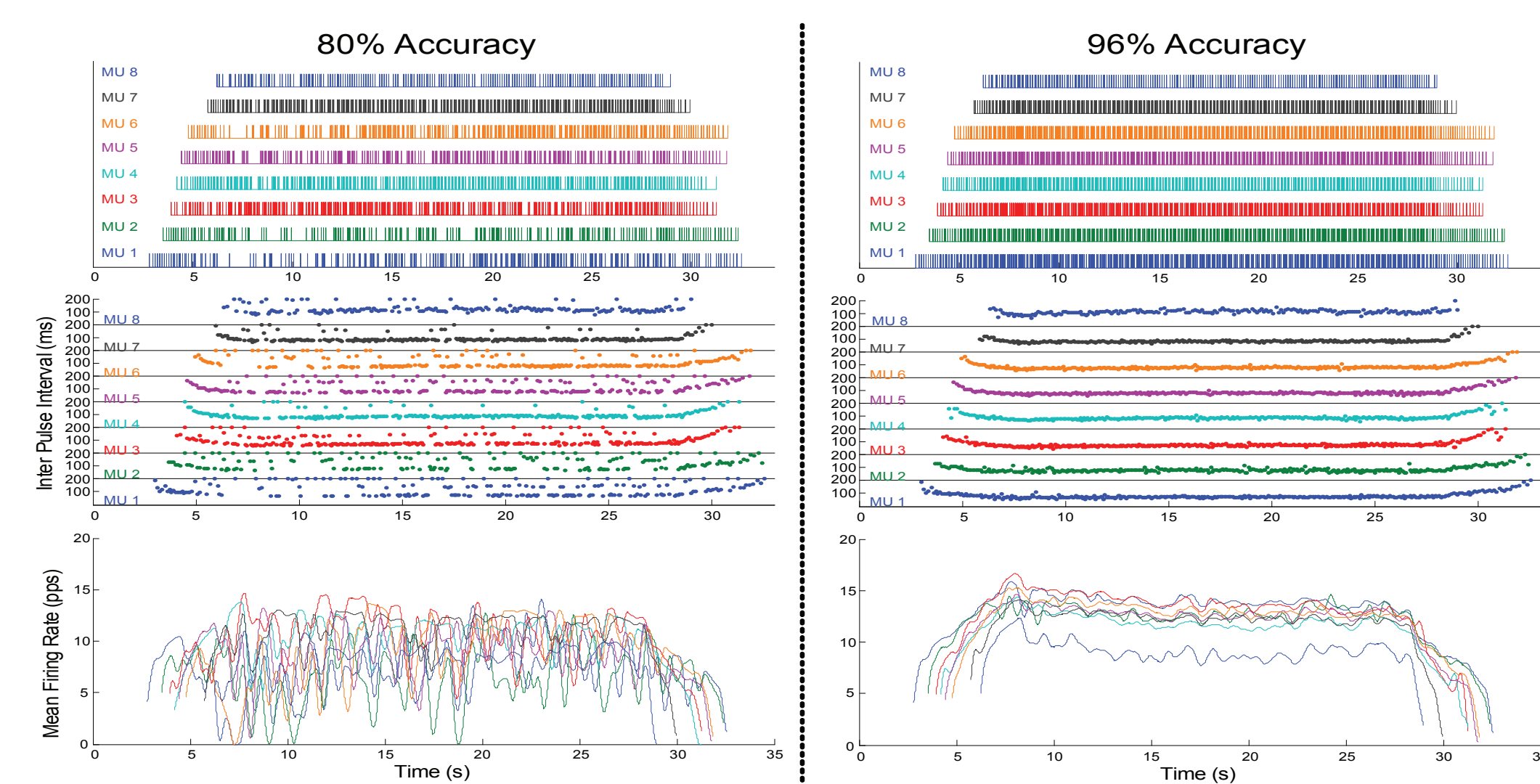


Diagram of the Decomposition Algorithms being developed in this project. EMG data time series $x(t)$ is processed by a series of classifiers which are designed to resolve the major signal complexities described above and automatically produce a Decomposition Result of the firing times of concurrently active MUs. These Classifiers are controlled and tuned utilizing an AI architecture constructed around a knowledge-based blackboard specifically designed to manage signal processing algorithms that evolve in complexity and develop a knowledge base that becomes more comprehensive as the descriptors of the signal to be analyzed increase. An example of a Decomposition Result is shown in the figure below.

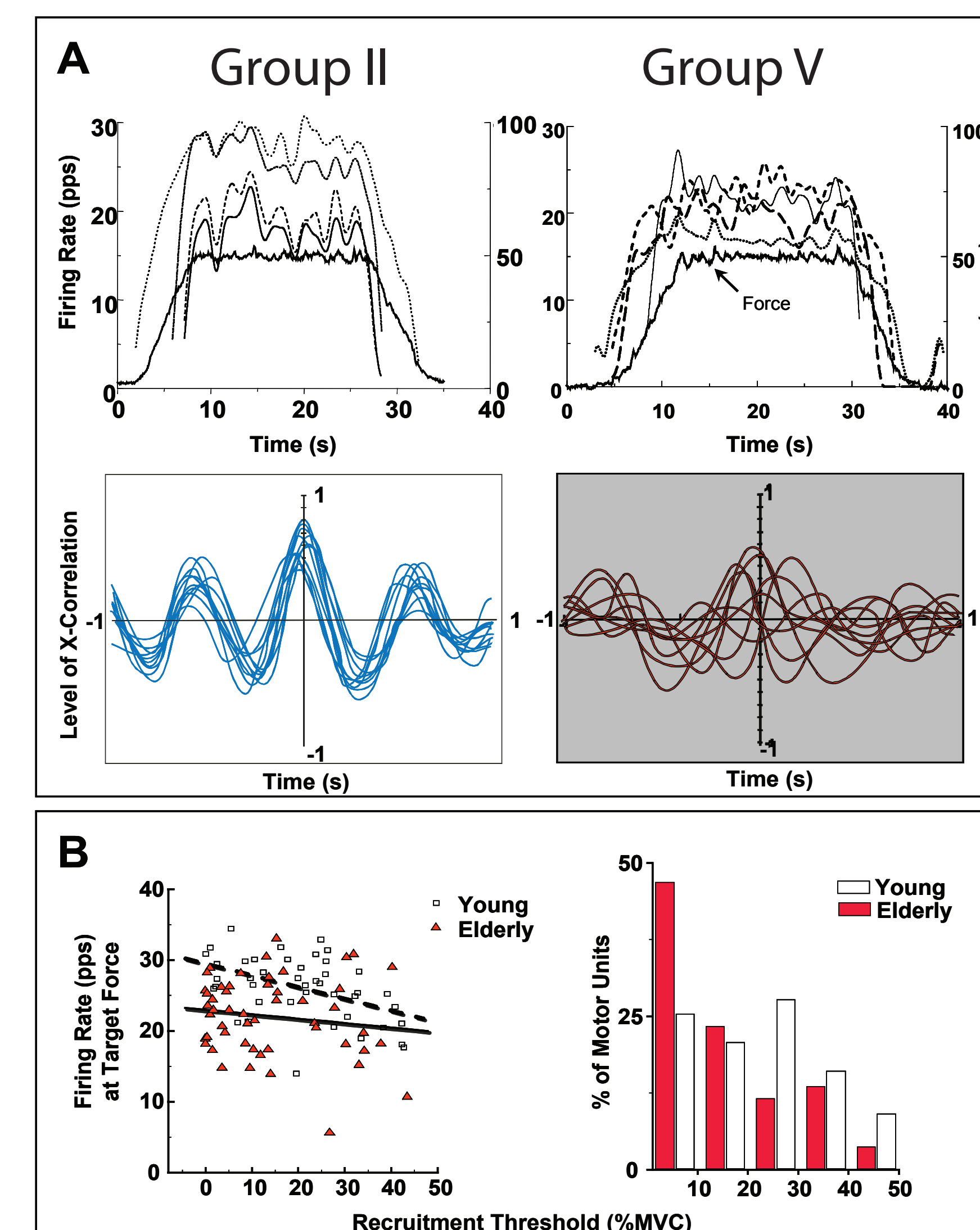
Decomposition Result: Importance of Improved Accuracy



The figures are from the same EMG data acquired from the Vastus Lateralis (VL) muscle at 50 %MVC. The differences in decomposition accuracy demonstrate the improvements that need to be made to the algorithms during the project. An older version of the EMG decomposition algorithms achieved an accuracy of 80% (Left). The motor unit firing pattern contains many obvious missed firings as well as grouped firings. The firing rates of these trains are very disorganized and are overlapping erratically. The same record when manually edited (Right) achieved an accuracy of 96%. Top - firing intervals of motor units, Middle - Inter-pulse intervals. Bottom - Mean firing rates.

Project 2: Application of Technology to Motor Unit Control and Aging

Aim 1: to delineate the age-related progression in the deterioration of motor unit control properties in skeletal muscle and identify the effects of sedentary activity on these changes in elders.



Age Groups

Group I: 10-20 yr

Group II: 21-44 yr

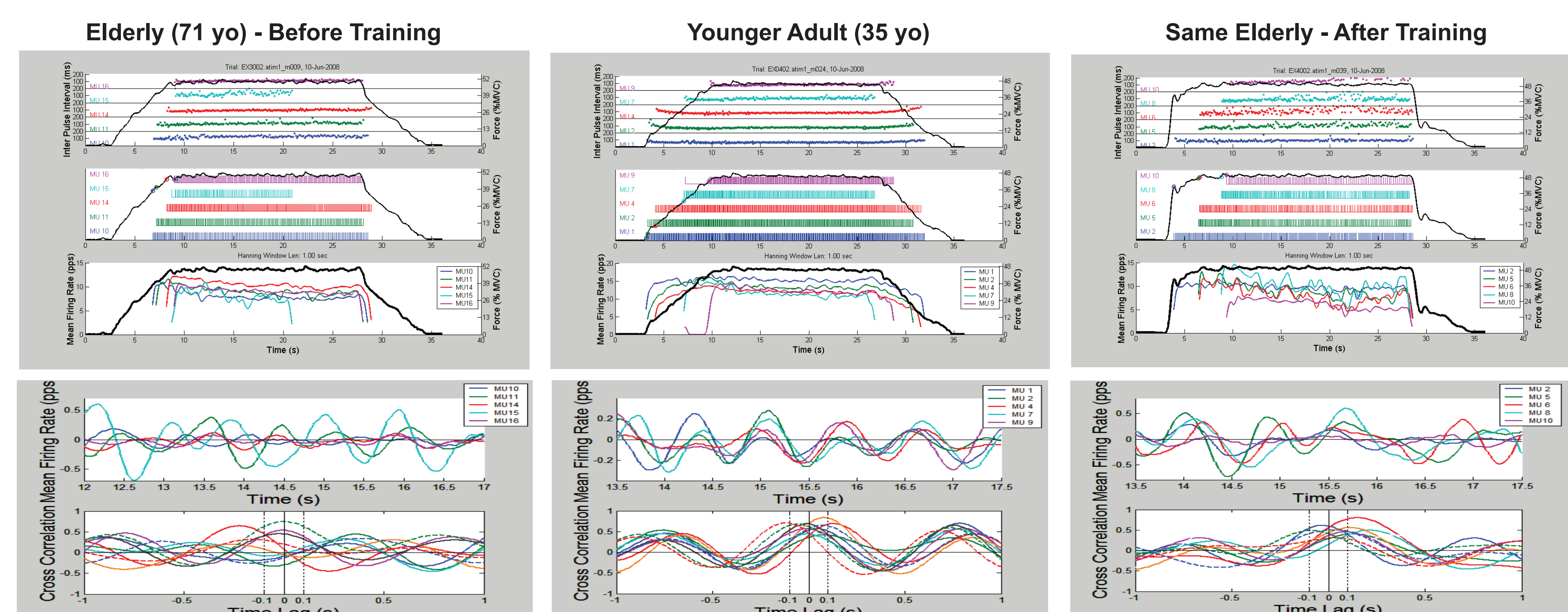
Group III: 45-64 yr

Group IV: 65-79 yr

Group V: 80+ yr

Example of altered motor unit firing behavior in the elderly from pilot data acquired from the first dorsal interosseus muscle of the hand. The plots in A compare mean firing rates and cross-correlation values between MU pairs for a 33 yo “control” subject (Left) and a 80 yo subject (Right). The plots in B demonstrate that MUs in the elderly have higher mean firing rates when first recruited than the younger adults. The goal of this part of the project is to acquire a data base to delineate the influence of age on MU control. The data base will include postural and non-postural muscle groups tested at different target force levels. The five different age categories of the subject population is listed on the right of the figures.

Aim 2: to investigate the mitigating effects of exercise on age-related neural adaptations and use this information to develop a clinical marker for initiating exercise prior the elderly.



Samples of decomposed data from the Vastus Lateralis muscle at 50% MVC indicating that: a) the control scheme of motor units is more disorderly in the Elderly (Left) compared to the younger Adult (Middle) subject. However, the control scheme of motor units in this elderly subject becomes more like the younger subject following a 12-week strength-training program (Right).

Year 1 Progress

- We have designed and implemented a multi-model robust shape tracker algorithm for decomposing low-amplitude EMG signals, resulting in a 50% reduction of unresolved/ambiguous motor unit firings.
- We have completed a preliminary design of the multi-strategy analysis component of the decomposition software and are currently in the process of implementing it.
- The decomposition software has also been made more efficient than its previous version, reducing the execution time for decompositions by at least 50%.

Year 1 Progress

- We have acquired a database of EMG signals from elderly and younger subjects from hand and leg muscles. Decomposition will enhance our understanding of how neuromuscular strategies for regulating force in a muscle is affected by aging.
- We are decomposing and editing data files from the database using the enhanced software developed in Project 1.
- We have been analyzing pilot data from elderly subject participants in a strength training protocol. Results will guide us in planning new experiments to determine the effects of exercise on motor control.