Analysis and classification of individual digit movements in ultrasound images

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Introduction: Approximately 1.7 million people in the United States are living with limb loss. Recently, there have been major advances in the electromechanical design of limb prostheses. However, control strategies have lagged far behind. Electromyogram (EMG) signal readings, used for controlling prosthetic limbs, remain particularly inaccurate for finger and hand movements, whose complexity gives way to large amounts of difficult-to-interpret crosstalk. In addition, only a limited number of signals can be recorded noninvasively from the skin surface. The objective of this project was to develop a novel way of analyzing and classifying forearm muscle movements, captured using ultrasound imaging, with the overarching goal that such a method could be used to control prostheses, specifically prosthetic hands or arms.

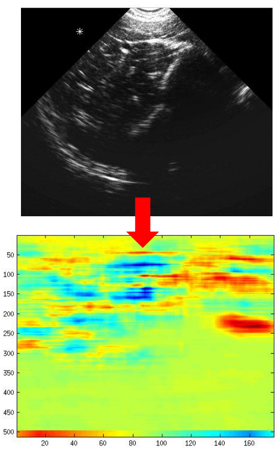

Fig. 1 The ultrasound image sequences (top panel) were processed by computing a pixel-wise difference with a baseline reference frame to yield spatially resolved patterns of movement (bottom panel).

Materials and Methods: A single-element ultrasound transducer (Interson Corporation, Pleasanton, CA) that connects to a computer via a USB interface was used for imaging. The transducer was attached to the arm of ten healthy subjects using a cuff to keep the transducer in place. Subjects were asked to contract each individual digit in a fast flexion (24 contractions/min), a slow flexion (20 contractions/min), and at large and small angles. In addition, complex finger movements, such as pinching, grasping, and clenching were also recorded. The data collection, on ten healthy subjects, yielded records of 33 different types of movements, with an average of 6-7 instances of each movement per patient. In total, 2,084 movements, distributed across 33 types and 10 patients, were recorded and processed (Fig. 1).

A data-mining approach using a k-nearest neighbor (k-NN) algorithm was developed to identify 'novel' movements based on a database of existing ones. The nearest neighbor algorithm classifies movements based on the *k* closest training examples in the database. Nearest-neighbor pair-wise similarity was computed between the images of movement patterns. We experimented with using a correlation coefficient and a warping-based correlation approach. The algorithm was implemented in MATLAB.

Results and Discussion: Table 1 shows a confusion matrix for classifying five digits using this k-NN method and a preliminary dataset for 10 patients with the 5 digit motions. The value of k for k-NN was set to 3. Based on this approach, an average accuracy of approximately 76% was obtained. Further refinement of the algorithm is currently underway to identify more accurately individual's digit movements *and* more sophisticated movement patterns, and to identify movements between people.

Table 1. Confusion matrix for digit classification

		Predicted class				
		1	**2**	**3**	**4**	**5**
Actual class	**1**	28	7	1	2	2
	2	14	17	4	1	4
	3	10	12	8	7	3
	4	12	6	6	14	2
	5	14	8	0	3	15

1: Thumb, 2: Index, 3: Middle, 4: Ring, 5: Pinky

Conclusion: Preliminary results suggest that it is possible to capture muscle movements corresponding to individual digit motion non-invasively, using a highly portable and inexpensive ultrasound imaging system. Using a machine learning approach, we can recognize and classify digit movements belonging to an individual person. Further improvements on such a program hold enormous potential for accurate movement recognition and applications in the control of upper extremity prostheses.