Continuous 2-DoF SMG Control via Optical Flow Feature Grouping

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***Abstract*—Sonomyography (SMG) enables continuous control of assistive devices by measuring muscle deformation, but achieving multi-degree-of-freedom (DoF) control with minimal sensors remains challenging. Our prior work demonstrated 2-DoF control from a single ultrasound probe using optical flow, but with substantial signal coupling. We propose a modified algorithm that assigns each control signal to subsets of features exhibiting the greatest motion during user-defined movements, aiming to improve independence between DoF. When tested by a single user performing a cursor control task, the method achieved 2-DoF control but exhibited coupling comparable to our prior approach, likely due to overlap between feature groups. This work establishes a platform for exploring improved grouping strategies and alternative feature tracking methods, toward efficient control of high-DoF assistive devices.**

I. Introduction

Sonomyography (SMG) is a promising technology for controlling assistive devices, providing continuous signals of muscle tissue deformation that can be mapped to device motion. We [1] and others [2] have shown that both continuous 1-DoF control and classification-based control are possible. While high-DoF control could be achieved with many sensors, in order to remain cost-effective and non-bulky, we aim to extract multiple continuous control signals from one ultrasound probe. Our team showed that preliminary 2-DoF control is possible with a single B-mode ultrasound probe [1]. In this algorithm, users perform self-selected movements while the motions of Shi–Tomasi corner features [3] in the ultrasound image are tracked via Lucas–Kanade optical flow [4], projected onto two perpendicular point-specific axes, and averaged across all points to generate corresponding horizontal and vertical cursor motions. However, tests of the 2-DoF system revealed high levels of signal coupling between the two DoF, making it difficult for users to complete desired tasks.

In this work, we aim to address this signal coupling by reformulating this 2-DoF algorithm to calculate each control signal using only the subset of tracked points that move the most during the corresponding user movement, facilitating independence of the two control signals.

II. Materials & Methods

Our modified point-grouping 2-DoF algorithm is illustrated in Figure 1. We tested the performance of this algorithm in generating two independent control signals on a single user with a B-mode ultrasound probe mounted on their bicep. Note that this algorithm (like its predecessor) is sensor-location-agnostic and will be tested across more locations and users in the future.

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The study protocol employed in this work was approved by the University of Utah Institutional Review Board under Protocol IRB_00183389, and written informed consent was obtained from each study participant.

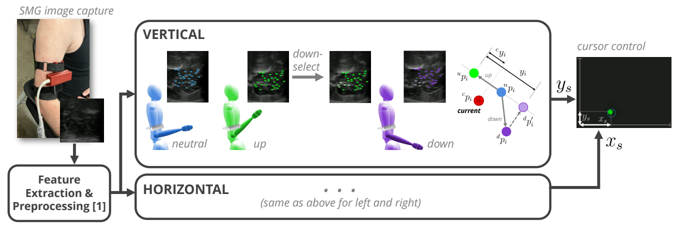

Fig. 1. Algorithm to extract two continuous SMG control signals from single B-mode ultrasound time series. Image features are selected for tracking and preprocessed [1] (*left*), then passed into two independent algorithmic blocks generating vertical (*top*) and horizontal (*bottom*) cursor locations (*right*). Each block begins with the same neutral (*blue*) configuration. Users then move to a selected "up" ("right") pose (*green*), and points that do not exhibit sufficient movement (*light green*) are eliminated. Users then define a "down" ("left") pose (*purple*) using only non-eliminated points. Aggregate motion of these points along each point i's axis y_i (x_i) is then mapped to cursor position y_s (x_s) using our existing 1-DoF control algorithm [1]. Note that these subsets of optical-flow-tracked points are allowed to overlap, and it is likely that some tracked points will belong to neither group.

III. Results & Discussion

While the user was able to perform 2-DoF cursor control using our modified algorithm, the system exhibited levels of coupling between signals comparable to our previous algorithm [1] (e.g., attempting purely vertical movement resulted in a diagonal motion). We hypothesize that a major contributor to this coupling is that the current algorithm allows for overlap between point groupings, motivating further exploration and testing of point grouping methods.

IV. Conclusion

The performance of our naive algorithm was limited, but our developed infrastructure enables us not only to explore refinements in our grouping methods, but to systematically characterize the properties of our SMG signals (e.g., using principal component analysis), toward development of robust, personalized interfaces. We are also exploring alternative feature tracking formulations that allow us to maintain the same point-grouping algorithmic structure, such as Oriented FAST and Rotated BRIEF (ORB), as well as image processing methods that require a more complete system reformulation, such as dense optical flow. Ultimately, we aim to use these signals to control high-DoF assistive devices like robots.

References

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