Departmental Seminar: Electrical and Computer Engineering

Speaker: Paul Otto

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When: Monday, July 23, 2018 at 2:00 pm in ENGR 3507

Title: Robust Estimation of Muscle Contraction Velocities from B-mode Ultrasound Image Sequences

Abstract:

Musculoskeletal disease affects one out of two American adults. People suffer from pain and limited movement as a result of arthritis, back injury, or limb trauma. Understanding how musculoskeletal disease impacts the muscle and tendon (musculotendon) velocity can improve therapy results. Measuring musculotendon velocity during a person's daily activities can provide an accurate measure of muscle use. Unfortunately, most imaging systems either do not measure muscles directly, such as camera based motion capture systems, or cannot be practically used in daily activity, such as MRI. However, ultrasound can both image muscle directly and be used portably, with potential for use similar to that of wearable cardiac monitors. Low cost wireless ultrasound transducers can connect to smart phone apps to display musculotendons images. These images, known as brightness mode (b-mode) images, are a complex mixture of the transducer's elements, sound intensity returns from tissues boundaries, and tissue microstructure. This interaction makes measuring velocity difficult in a b-mode image. Techniques compensate in muscle by tracking bundles of muscle fibers (fascicles), which show up as bright lines in b-mode images. Current techniques require visualizing well-defined fascicle groups, but this limits their use to a few muscle groups. This research expands the ability to measure velocity of muscle groups with poorly visualized fascicles, while respecting the computation and power constraints of portable devices. The research uses OpenCV, a highly optimized open source computer vision library. Velocity is measured in b-mode images with OpenCV's feature detection, optical flow, and template tracking algorithms. OpenCV was optimized for vision applications which makes unclear the best combination of algorithms and algorithm parameters to measure muscle velocity in b-mode images. We resolve this by measuring velocity of human rectus femoris leg muscle using a combination of techniques. We find that the feature detection method, "Good Features to Track", combined with Lucas-Kanade Optical Flow, has the lowest mean average error when compared with MRI. We achieve energy efficiency by selecting the system's optimal processor frequency, core count, and compiler optimization level. This balance between power and performance is quantified with the Energy Delay Product density metric and is a guiding force to compare three embedded architectures: ARM, Atom, and NVIDIA's Tegra. We find that by operating at a lower frequency and reducing the core count improve the system's energy efficiency. We conclude with lessons learned when designing the velocity measurement algorithm, specifically difficulty of fusing b-mode results with motion capture data to create more robust measurements, which holds promise for future applications.