COMPUTER SCIENCE & ENGINEERING
UNIVERSITY OF MICHIGAN

DISSERTATION DEFENSE

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Novel Sensing Approach for Shoulder Kinematics – Exploring Kirigami-Inspired Sensing and Machine Learning Platforms for At-Home Joint Monitoring

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3725 Beyster
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ABSTRACT: Sensors are increasingly integrated into smartphones, smartwatches, and wearables to monitor health and daily activity. Common applications, such as pedometers, track steps, and exercise routines, while specialized devices like glucose monitors and blood pressure cuffs aid in managing chronic conditions. The rise of personalized medicine has fueled interest in at-home monitoring to support preventative care and rehabilitation, allowing individuals to maintain independence. There is an interest in developing devices for at-home monitoring of joint movements. However, there have only been limited attempts to develop at-home insights into shoulder joint mobility.

The shoulder, the most complex joint in the human body, presents significant challenges for motion tracking due to its six degrees of freedom and three articulating surfaces. The current gold standard for shoulder tracking is optical motion capture, which is costly and impractical for home use. Inertial measurement unit (IMU) systems offer an alternative but are often obtrusive due to the need for multiple units to accurately measure shoulder angles. Our research, however, focuses on developing a practical and cost-effective solution for shoulder tracking, overcoming many of the challenges with existing technology.

This dissertation addresses these challenges by developing a novel sensing platform for shoulder tracking, drawing on advances in materials science and computer science. We first extend prior work by integrating a kirigami-inspired substrate with strain gauges into a wireless system, conducting a user study to validate its ability to track shoulder movements. We then introduce the Shoulder Tracking and Angle Measuring Patch (STAMP), which was tested alongside motion capture systems and IMUs to evaluate its feasibility in replicating shoulder kinematics. Finally, we explore the use of strain-sensitive materials as a cost-effective alternative to strain gauges. By placing these materials on a flexible printed circuit board (PCB), we aim to reduce costs and improve the adaptability of the shoulder patch across different body types.

Our findings suggest that these innovations could lead to low-cost, accurate shoulder monitoring tools suitable for at-home use. Ultimately, this dissertation's findings and device development could help revolutionize how clinical providers and patients track and manage shoulder health.

CHAIR: Prof. Alanson Sample and Prof. David Lipps