Power/Accuracy Tradeoffs for Home Stroke Rehabilitation

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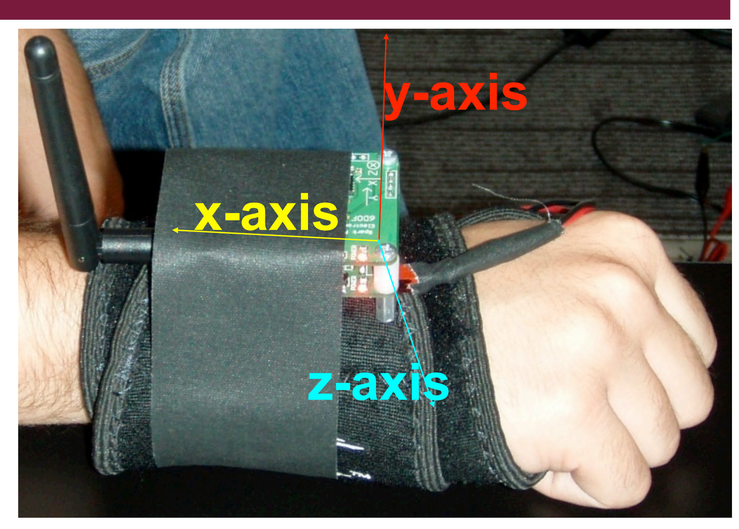
Background and Motivation

There are over 6 million stroke survivors in the United States and stroke is the No. 3 cause of death and the No. 1 cause of disability in adults. Stroke survivors continue to show improvement with therapy 6+ months post-stroke, but report progress and use of impaired arm to therapists with subjective, after-the-fact surveys. Therapists desire a way to objectively monitor use of an impaired arm in the home. Our goal is to build a wearable, low-power device that can recognize a set of activities. Accelerometers have been shown to be an effective, low-power sensor for activity recognition, but the activity classification (AC) algorithms are computationally complex and may quickly drain the battery of a wearable device if they were to run continually. One idea is to use transition detection to call the AC algorithms only when necessary, but there are power and accuracy tradeoffs in the system parameter choices.

Experimental Setup



- Wrist-mounted 3-axis accelerometer
- 5 Activities: walking, standing, sitting, eating, and reaching
- Tunable system parameters: sampling frequency (F_s), window size (S_w), frame size (S_f), feature calculation on signal
- 4480 Combinations!

Intuitively, to identify a possible transition, we measure how different one half of a window is from the other. A likelihood

$$L(x_1, x_2, \ldots x_N) = \sum_{j=1}^{N} \ln\left(p(x_j \mid \mu, \Lambda)\right)$$

is calculated for the left and right window "panes" and for the entire window, then combined in a simple ratio:

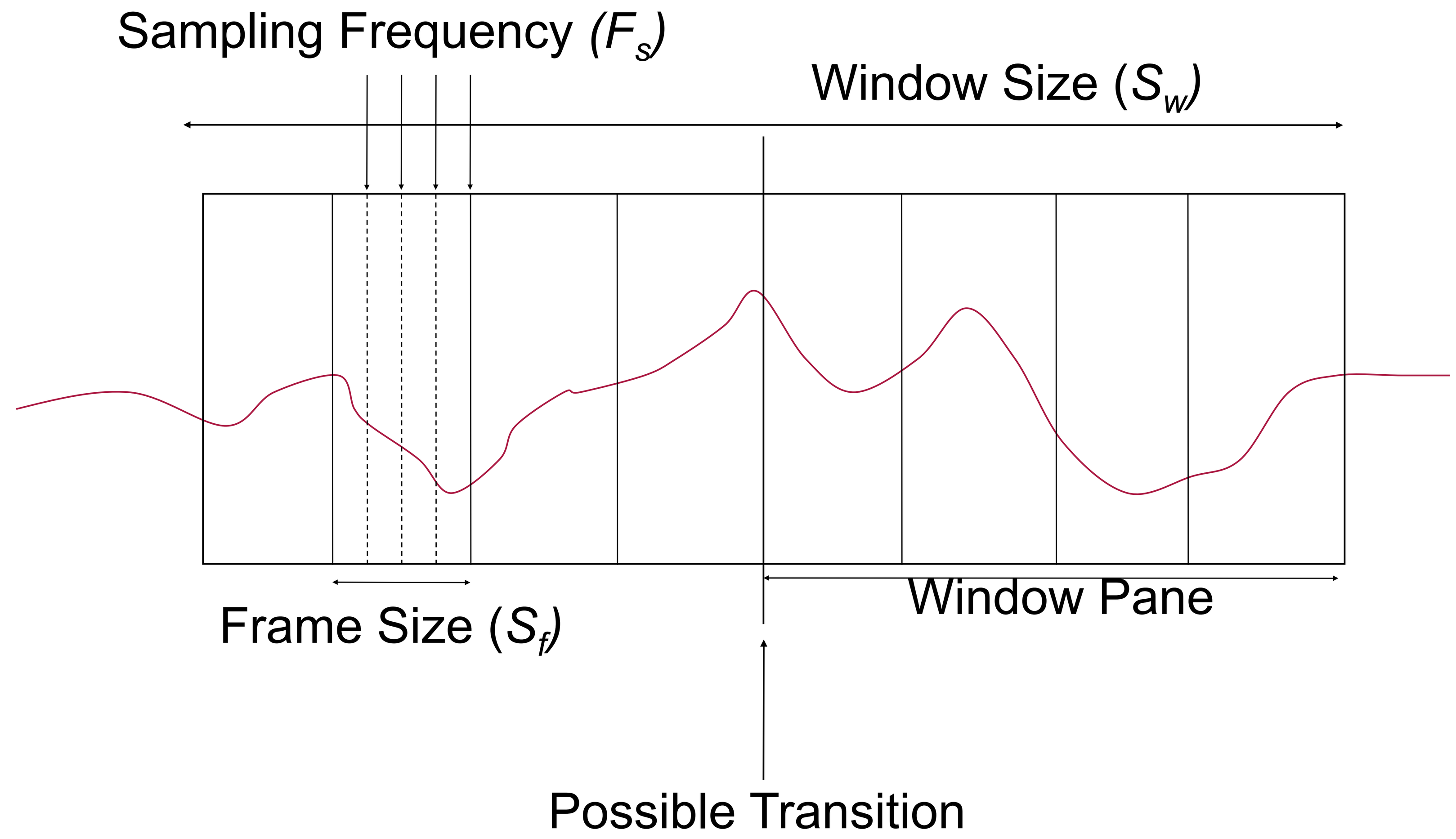
$$\frac{L_{\text{whole}}}{L_{\text{left}} + L_{\text{right}}}$$

which will peak when the probability of a transition is highest.

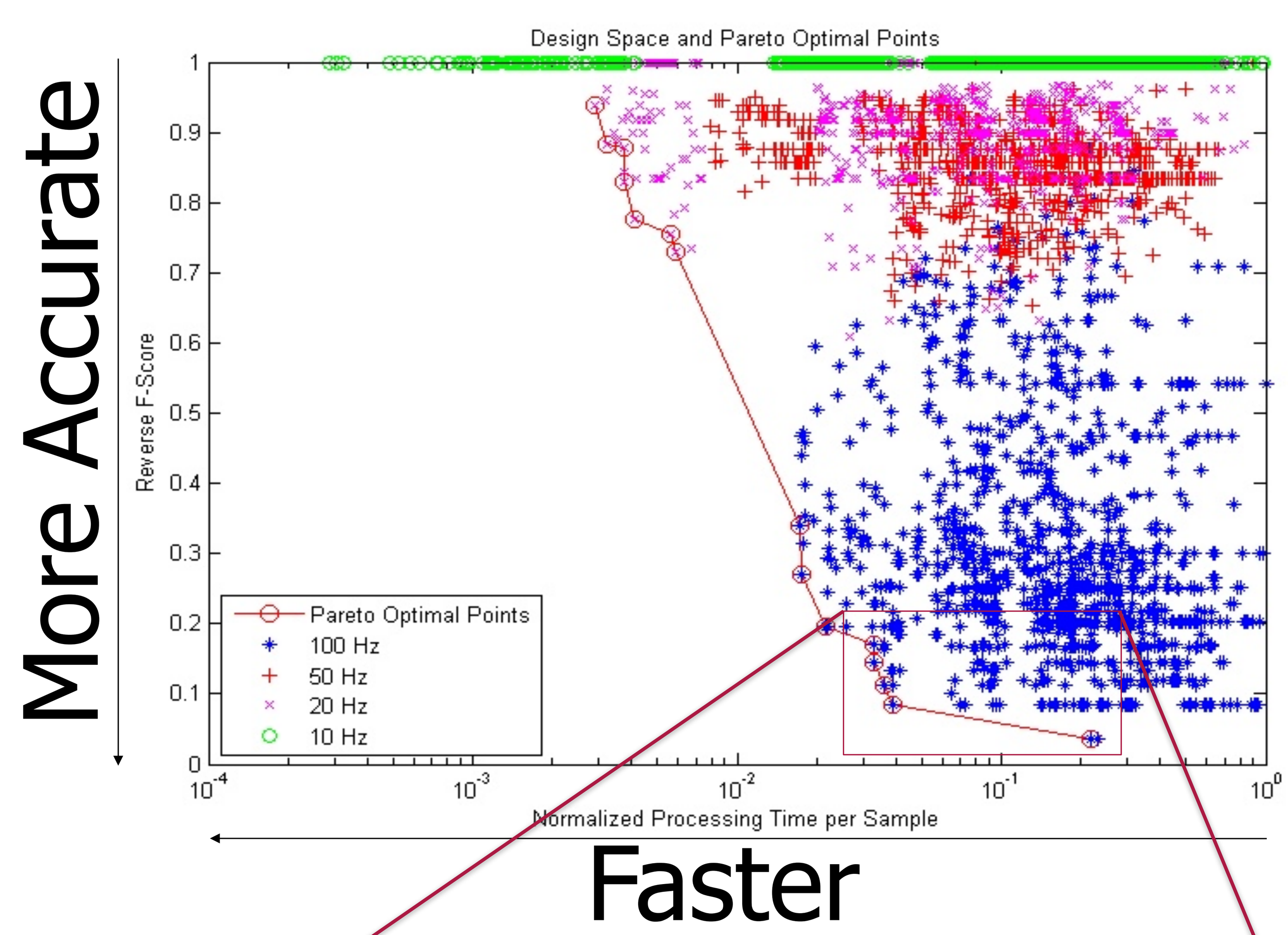
Discussion

- The figure labeled "Design Space" plots each permutation in relation to its accuracy in finding transitions and processing time, which is proportional to its energy consumption.
- The red-highlighted Pareto-front represent the most power-efficient combinations for a given accuracy
- Most of the Pareto-front combinations used simple scalar features, such as min, max, or variance, instead of larger, vector-based features such as FFT, DCT, or wavelet coefficients.
- The figure labeled "The Great Compromise" shows the most interesting result: some combinations were 5.5x faster than others but only 5% less accurate in detecting transitions, meaning great gains in energy efficiency can be attained with small compromises in accuracy

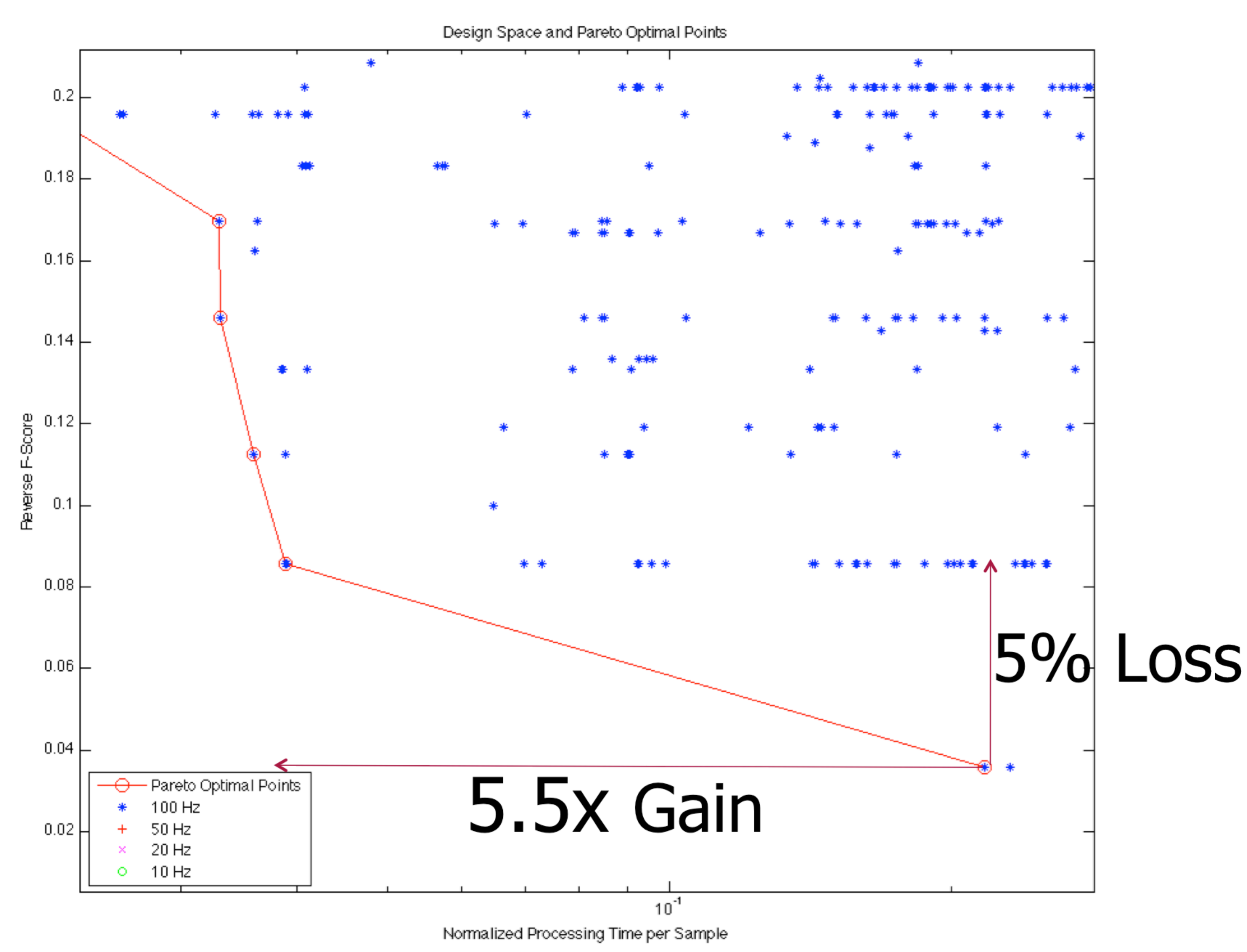
Transition Detection



Design Space



The Great Compromise



Conclusions

- If marginal loss in accuracy can be tolerated, great gains in battery life can be attained (The Great Compromise)
- A single axis and simple features are all that are needed to get great results. Simple features represented by scalars scale much better to longer time intervals than vector-based features
- Objective activity recognition systems could replace subjective patient surveys and enable a physical therapist to create better plans for at-home stroke rehabilitation
- Such systems need to be small, unobtrusive, durable, and able to run for days on a single battery charge
- Such a wearable system could be integrated into a larger home rehabilitation system that helps improve the lives of the 6+ million of stroke survivors

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