Nanopore Sensor Devices and Algorithms

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***Abstract*— Nanopore sensors allow for the detection of biochemical agents. The signals generated from ions passing through an ion channel have a low signal to noise ratio (SNR) and are thus difficult to process. Several different denoising techniques currently exist, in particular, power distribution-based features extracted using the Fourier and Wavelet domain work quite well. We aim to reduce the aperture size of the suspended lipid bilayer in the nanopore sensor and to implement machine learning algorithms to increase the quality of the ion channel current signals.**

Key words: ion channel, lipid bilayer

I. Introduction

Ion channels are naturally occurring pore-forming membrane proteins with a channel pore that can allow ions to pass through. Ion channels can be created in a lab environment by inserting proteins into a lipid bilayer [1]. When an ion passes through the channel pore, a characteristic change in the baseline current of the ion channel occurs. This change in current is observed by using the patch-clamp method [2][3].

The patch clamp method creates a giga-seal with a lipid bilayer that has an ion channel suspended in it which causes the resistance of the bilayer to be in the giga-ohm range [1]. The high resistance increases the signal to noise ratio (SNR) of the ion channel current which in turn allows for more accurate data capture.

An ion channel sensor works by analyzing the changes in the baseline current to detect if a specific analyte has passed through the channel pore or not. An ion channel sensor is particularly useful in detecting biochemical agents or small metals. Reducing the aperture size of the lipid bilayer to the sub-micron range would allow for both the stability of the membrane and the mechanisms responsible for the noise of the lipid bilayer to be studied [2].

Once the proposed ion channel sensor is built, the obtained data will be denoised with the applications of advanced signal processing techniques and machine learning algorithms. One of the supervised signal processing techniques used is dwell time analysis. Dwell time analysis works by analyzing the closing times of the poor, or dwell times, and then fitting the dwell times with lifetime histograms [1].

Other supervised approaches for processing ion channel signals has been explored by using synthetic ion channel data [4]. Extracting transform domain features based on the distribution of power in the Fourier, Wavelet, and Walsh-Hadamard domains has shown promising results [4]. The transform domain feature extraction in conjunction with support vector machines (SVM) results in high classification, specificity, and sensitivity when applied to synthetic ion channel data.

The transform domain feature based extraction methods applied to real ion channel current data would perform well given the results with the synthetic data. Other signal processing techniques used to process ion channel current data can be applied to the data recorded by the ion channel sensor. The Discrete Wavelet Transform (DWT) helps denoise the signal. Suitable wavelet transforms are applied to the noisy ion channel signal to produce noisy coefficients to a point such that the state transitions between when the nanopore is opened or closed can be properly distinguished [4].

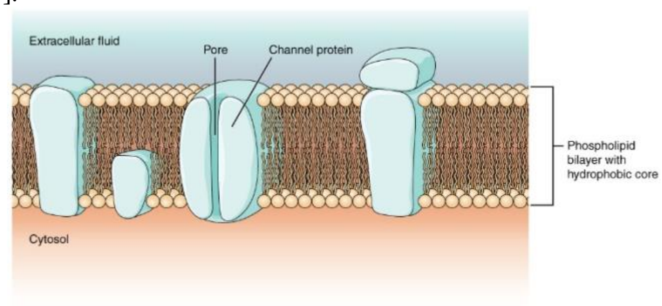

Figure 1: Ion channel suspended in a lipid bilayer.

The existing signal processing techniques used for processing ion channel signals can be further refined and used in combination with the smaller aperture size of the lipid bilayer to result in a high SNR of the ion channel current. The sub micron aperture size and the transform domain feature based extraction methods have been theorized to denoise the ion channel current signals quite well in their own right [2][4]. Combining the theorized methods for processing ion channel current data with the smaller aperture sized lipid bilayer needs to be explored further as this could lead to classification accuracy improvements.

The goal is to successfully develop a true nanoscale ion channel sensor that can properly denoise the ion channel current signals. The advanced signal processing techniques that have shown promising results would be applied to the data recorded by the nanoscale ion channel sensor. The aim is to develop an ion channel sensor that can capture and process ion channel current data with higher classification, specificity, and sensitivity than what has previously been achieved with larger ion channel sensors.

References

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