A WIRELESS MULTICHANNEL NEURAL RECORDING PLATFORM FOR REAL-TIME BRAIN MACHINE INTERFACES

by

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Richard Mooney

Dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy
in the Department of Biomedical Engineering
in the Graduate School of
Duke University

2004

ABSTRACT

(Biomedical Engineering)

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Abstract

Recent technological advances attempting to interface prosthetic limbs to the brain have been hampered by a lack of wireless multichannel data acquisition hardware. This work has attempted to fill that void by developing a portable recording platform for up to 16 chronically implanted cortical electrodes. The system consists of (1) an analog "Headstage" integrated circuit for buffering and amplifying the electrode signals (2) a low power analog front end (AFE) for conditioning and digitizing the neural signals, and (3) a digital back end for transmitting either the raw neural signals, or only the action potential waveforms. The 16-channel Headstage used a non-inverting feedback architecture to achieve tightly matched gains ($\mu = 1.99$) and an input referred noise of $10\mu V_{rms}$. The 16-channel AFE featured variable gain, 4^{th} order Bessel bandpass filtering, and a reference matrix for selectable bipolar recordings. The digital back end consisted of a programmable logic device for detecting spikes, a FIFO memory for queuing the data, and a wearable PC fitted with an 802.11b Ethernet card for transmitting the data over a UDP network protocol. The system measures $5.1 \times 8.1 \times 12.4cm$, weighs $235g$ (including batteries), and is capable of transmitting 12 channels of 8-bit raw data simultaneously over nine meters. *In vivo* recordings demonstrated that signals acquired with this system were of similar fidelity to those recorded by a commercial recording system. The spike detector was able to correctly detect over 90% of spikes at signal to noise ratios greater than 2.1. Detection reduced the volume of telemetered data by 97% when the mean spike firing rate was 9.3 spikes/channel/second.

A study was conducted to determine which spike detection algorithm is best suited for detecting neural spikes in a wearable system with limited computational resources. Detections were scored with a novel cost function that weighed the probabilities of correct detections, the rates of false positive detections, and the computational demands of the detection algorithm relative to the computational capabilities of the system. The results indicated that a simple algorithm, such as taking the absolute value and applying a threshold, is as effective for computationally limited systems as more complex energy or matched filter based detectors .

Acknowledgments

I would like to recognize a number of people who have helped me in various ways during my time at Duke. I am truly fortunate to have been surrounded by such an energetic and intellectual cast of characters.

First and foremost, I want to extend my sincerest gratitude to my advisor, Dr. Patrick Wolf, who made it possible for me to study at this world class institution. Dr. Wolf has been been both my teacher and my friend, tirelessly sharing with me his expertise and wisdom, which seem to know no bounds. Whether debating design approaches or the politics of the day, Dr. Wolf has always challenged me to think, to analyze, and to improve myself. I am a better person and a better engineer for having knowing him.

I also wish to extend a gracious thank you to my committee members: Drs. Craig Henriquez, James Morizio, Loren Nolte, and Richard Mooney. They have all been generous with their time and expertise, and I am grateful for having their input.

I was fortunate enough to have worthy role models in Mudit Jain, Scott Meyer, Chad Johnson, and Chrissie Merdes, who were Dr. Wolf's grad students when I first joined the lab. Collectively, they set the bar high for me, showing by example what it takes to be an exemplary graduate student. I am also thankful to my labmates Kit Au-Yeung, Amy Goodman, Debbie Won, Chad Bossetti, Ninita Brown, Mike Rizk, and Tom Jochum for making the lab a stimulating place to live and work.

Invaluable to my mental sanity were Kevin Sampson, Mark Freiberger, Rob Oliver, Silent Ken Eaton, and Irish John Finan, who were always on call to provide comic or liquid relief when the stress of grad school became unbearable. Whether discussing obscure 80's hip hop music (Rob Oliver does *not* get the gas face), or grilling bratwursts, they've always kept things upbeat for me. I am also grateful to

Mark for his tireless work with the Backpack printed circuit boards.

Thank you to Salim Idriss, John Castellucci, Steve Callender, Ellen Dixon - Tulloch, Himanshu Arora, and Greg Bredthauer for always being available to answer various technical questions for me; it is truly amazing how much knowledge one can accumulate from impromptu hallway conversations. Thank you especially to Ned Danieley for patiently dispensing exceptional computer and network support.

I am particularly indebted to a number of people in the Neuroscience department who selflessly shared their time and knowledge to teach me the nuts and bolts of recording neural data: Miguel Nicolelis, Don Katz, David Krupa, Jose Carmena, Aaron Sandler, Mike Wiest, Erin Phelps, and Kristen Dewey. Thank you also to Asif Ghanzafar, Mark Laubach, and Don Katz for generously sharing their animal data, thus allowing me to complete my spike detection simulations. And of course thank you to Harvey Wiggins at Plexon for his technical expertise in the recording arena.

I have been blessed with two incredible parents, George and Simone Obeid, who have been constant pillars of support and encouragement for me. Together, they instilled me with a love for knowledge, a respect for the institution of education, and a solid work ethic. I am also grateful for my brother, Samer, who has been my go-to guy for good advice, good humor, and best of all, free legal counsel.

And finally, for Jodi, my wonderful, wonderful wife, I save my my warmest thanks of all. There aren't words enough to describe how grateful I am that you were here to share this experience with me. You make everything better. Thank you.

For Jodi

"We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win."

John F. Kennedy, 1962

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