

An investigation on the experimental measurement of conduction velocity of the nerve signals in the arm

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Abstract - It's well clear that our nervous system is composed by excitable cells called neurons. These cells produce bioelectrical potentials as a result of electrochemical activity between the inside and outside of the cell membrane, thus transmitting the electrical signals and allowing the nervous impulses to go through our body. An investigation on the experimental measurement of conduction velocity of the nerve signals in the arm is presented in the paper. The obtained results are very important not only for the process of medical diagnostic, but for process of design of robot system.

Keyword – nervous signals, conduction velocity, experimental measurement

I. INTRODUCTION

When a single nerve cell is stimulated, the amplitude of the signal does not affect the response. However, when the current applied to the nerve is increased, a higher number of neurons are stimulated, and so a larger number of muscle fibers are activated [1]. The way in which the number of pulses affects the response can be explained by two factors: the threshold and the refractory period [2].

Because in order to have an action potential the excitation value must exceed a threshold value of about 15 mV higher than the resting potential, for any value above the threshold level, the action potential will have the same value [1], [3].

Also the cells have a refractory period, that limits the frequency of consecutive action potentials, so no matter how strong the applied stimulus is, there will only be one response.

So for example if a stimulus of 150 mA in just one pulse is provided, the cells where only activated once with that signal. But when the same current is applied in five pulses, because the time interval between the pulses was higher than the refractory period of the cells, they were activated five times, thus making the nervous response stronger [4].

II. EXPERIMENTAL MEASUREMENT OF CONDUCTION VELOCITY OF THE NERVE SIGNALS IN THE ARM

The idea is to detect the onset of the stimulation on the stimulation point, and measure the time for the response at the target muscle. This is done for two different stimulation points, as will be described below. The stimulated nerve is the ulnar nerve. Two stimulation points would be designated, and the electrodes (AgCl) would be placed. The first stimulation point would be just below the elbow, the nerve passes beside the bone, and can easily be felt by the uncomfortable feeling

when it's pressed. The second point is near the wrist, again by the bone. The measurement electrodes would be attached to the palm, below the little finger, so that the activity on the 4th and 5th fingers can be detected. When the stimulation pulse is given to the skin, it would be conducted between electrodes as shown in Fig. 1.

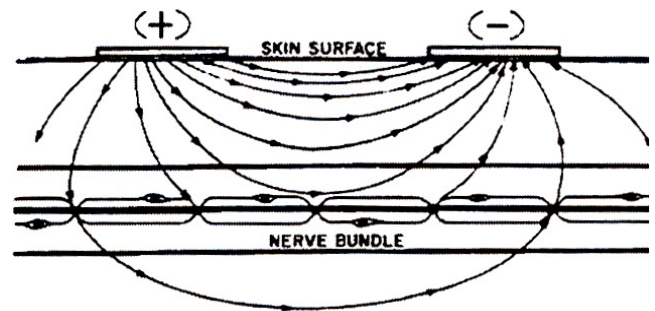


Fig. 1

So, the higher the stimulation is, the better response we would get (too high stimulation may be painful, care is needed). The Daq(data acquisition) channel to be triggered can be connected to electrodes nearby the stimulating electrodes, to recognize the stimulation pulse. The Daq program would be activated, and while it would be waiting for a trigger to occur at the stimulating side. The pulse(s) would be given by manually triggering the Transcranial Stimulator. The Daqboard (data acquisition board) would automatically record 300 values at a frequency of 10kHz for each channel and graph them.

The stimulation and response can be seen on the same graph, amplitude on the Y axis, and time on the x axis. By using these graph curves, the times between the first rise of the stimulation, and the beginning of the first distinguishable muscle activity can be recorded. If two different stimulation regions are used, it would be possible to obtain two graphs, thus giving us two different time measurements. These recorded times, say At_1 and At_2 can be subtracted from each other. The resulting time would give the time the pulse takes to travel between the two designated stimulation areas. The distance between these areas can be measured as the distance between the midpoints of the electrodes, namely, x . As the formula says: $v = x/t$, it's possible to get the nerve conduction velocity. There are two possibilities to measure the conduction velocity. Either measuring the action potential of the nerve, or to detecting the excitation of the target muscle. It is not easy to measure the potential of the nerve who is isolated from the skin surface, so it would be better to use the second method. The second method is much easier since the contracting muscles cause a detectable current flow in the surface of the

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skin. If only one measurement is used, it would measure the time difference between the activation and the contraction of the muscle. This time difference would not just include the propagation of the nerve pulse, but also other phenomena, related to the contraction of the muscle. If the measurement is from two different points it would be possible to eliminate the time delay due to those phenomena. A sketch of the measurement points can be found on Fig 2.

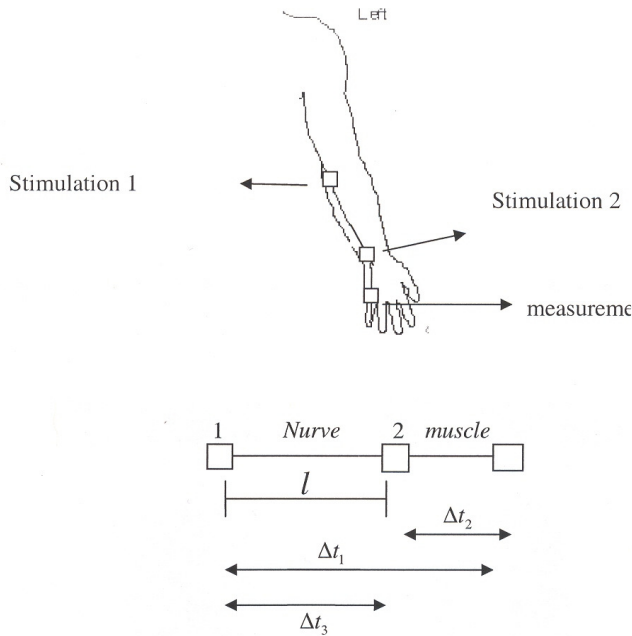


Fig. 2

If the first time interval Δt_1 is measured and afterwards time interval Δt_2 it's possible to find time interval Δt_3 by subtracting:

$$\Delta t_3 = \Delta t_1 - \Delta t_2 \quad (1)$$

It's possible to find the time Δt_3 that is needed for the nerve pulse to propagate from electrode one to electrode two. In this way only the nerve propagation is taken in account.

The nerve pulse velocity can be easily calculate using the distance between the electrodes one and two:

$$v = \frac{l}{\Delta t_3} \quad (2)$$

In practice a pulse train of 10 kHz is used, this means a 100μs per pulse. Results are given by:

$$\Delta t_1 = 13,2ms \quad (3)$$

$$\Delta t_2 = 10ms \quad (4)$$

This gives for the velocity:

$$v = \frac{0,21m}{3,2 \cdot 10^{-3}s} = 65,6ms^{-1} \quad (5)$$

According to the reference the average nerve velocity is about 55 to 70 meter per second [4]. So, the obtained experimental result is acceptable.

III. EXPERIMENTAL SYSTEM FOR MEASUREMENT OF CONDUCTION VELOCITY OF THE NERVE SIGNALS IN THE ARM

It's clear that a preliminary muscle stimulation should be provided before the above mentioned measurement of impulse velocity. Apart from thinking and reflexive movements, the muscles can also be stimulated by external magnetic and/or electric fields, as these simulate what happens when the brain sends a signal commanding the muscles to move. The measurement schematics (Fig.3) includes: Electrical Stimulator, Bioamplifier (LNA), DaqBoard and PC.

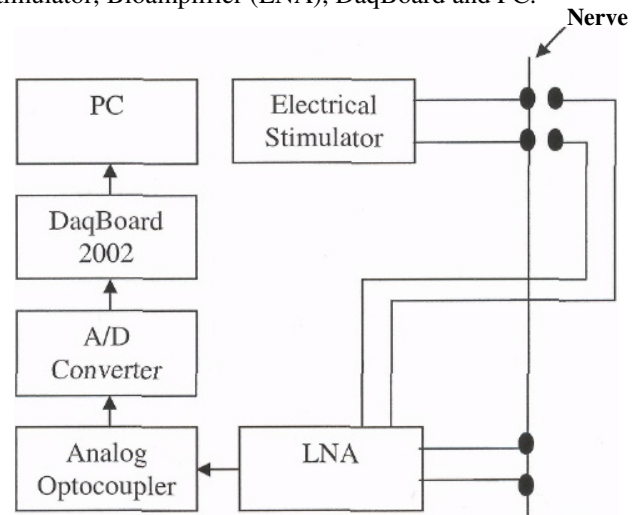


Fig. 3

A. Electrical Stimulator

The stimulator produces a 50 μs square pulse at variable amplitude. The stimulation can also be done as a pulse train, having up to 5 pulses in one sequence. The current amplitude can be changed from 30 to 990 mA, in incremental steps of 30, by using the rotational knob.

To avoid confusion: the amplitude of the stimulation does not affect the response. That is true when stimulating single nerve fibers. When stimulating an arm, as we are doing, a higher current enables the stimulation of a higher number of neurons, thus affecting a larger number of muscle fibers. The additive effect of stimulation also plays a role, so that: A one pulse with 90 mA stimulation has more effect than 1 pulse, 30 mA stimulation. A one pulse with 90 mA stimulation has less effect than 5 pulses, 90 mA stimulation. All these parameters can be adjusted using the control buttons, and manual triggering is used in the experiment.

B. Bioamplifier (LNA)

The bioelectrical signals to be measured range between 20 μV to 300 μV, which are relatively low. The difficulty in measuring these values lies in the system's susceptibility to noise, artifacts and the 50 Hz interference. The accuracy of the measurement depends on the susceptibility to noise, so it's necessary to take care on the signal to noise ratio. To obtain the optimum measurement, the amplifier used is a differential input, high Common Mode Rejection Ratio (CMRR), variable gain amplifier with a frequency response set for the ECG

measurements, which is adequate for the purpose. The differential input type is needed since the signals measured are the potential differences between two points of the body. The amplifier is battery operated, at ± 15 V and +5V. Two channels of the amplifier are used. They are connected to an isolation amplifier utilizing optical isolation. The gain can be adjusted using the parallel port of the PC, two channels at one. The parallel port has 8 output pins, which can be used to represent a 2 digit hexadecimal number.

C. DaqBoard (Data acquisition Board)

DaqBoard is located between the amplifier and PC (it is installed to a PCI bus). The measurements coming from the amplifier are fed into the DaqBoard – data acquisition board. This card is installed to a PCI bus in the PC. The card allows Windows to sample data at a high rate without loss, in real time.

D. PC

The package MATLAB is used to plot the stimulation and the answer (x axis - time in samples, y axes - amplitude).

E. Common Mode Rejection Ratio

The measured signals have very low amplitudes. So, it is necessary to amplify these signals, before to continue with the signal processing. This is done by a normal instrumentation amplifier. This has the advantage (to other amplifiers) that many influences from other sources (e.g. power supply, mobile phones ...) were filtered out (the instrumentation - should - amplify only the differential potential between the two wires from the bipolar electrodes). The second advantage is the very high input resistance and which provides a very good sensitivity.

In reality it isn't true, that the amplifier amplifies only the differential signal but this amplification (which is called common mode gain) should be as small as possible.

More important is the relation between the differential gain and the common mode gain. This relation is described by the CMRR - Common Mode Rejection Ratio which is defined as:

$$\text{CMRR} = A_{\text{diff}} / A_{\text{cm}} [\text{dB}]$$

Isolation of amplifier's output

The Low Noise Amplifier is fully isolated from the PC (no electrical connection to the DaqBoard or to the ground-potential). So it is impossible to get impressed any current from outside, which could be dangerous for the test person, especially when the power supply from the PC has a connection to the electrodes. The isolation is realized by 2 components:

First: The Low Noise Amplifier has his own power supply (± 15 V, +5V), which is provided by normal 9V batteries and a Voltage stabilization circuit.

Second: The Signals are transmitted with optocouplers, which separates it completely from the potential of the PC.

F. A/D Conversion

The A/D converter is a very important and very sensitive part of the whole measurement. It is located after the optocouplers. There are many different types of A/D-converters, every with its advantages and disadvantages. The conversion time and of course the price are important for the described investigation. One type makes the conversion in one step (2ⁿ comparators are required) or step by step (successive approximation, using only one comparator). It's necessary to have a reference voltage of very high quality. It's clear that the ideal converter isn't able to convert the signal without a failure, because the signal is quantified (in the case of resolution of 8 bits it's only possible to get 256 different solutions for the input signals, but the input signals can have infinite different values. Therefore the resolution should be flexible.

G. Patient's electrodes

The most important things required for patient's electrode using are: symmetric stimulation in order the electrode does not get polarized, decrease the motion artefact, and good Connection between the skin and the electrode. Usually the physicians stretch the skin or they clean it with alcohol, or they use some gel in order to decrease the impedance and the noise.

IV. CONCLUSION

1. A simple experimental method and system for measurement of conduction velocity of the nerve signals in the arm is described in the paper. The method and system can be used for measurement of conduction velocity of nerve signals in other parts of the human body.
2. The obtained experimental results on the base of described method and system can be used successfully in the process of medical diagnostic and in the process of engineering design of medical information systems, robot systems, etc.
3. The described experimental method and system can be used easily in the process of practical engineering education, also

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