One example of robotic teleoperation in medicine is the very well known Da Vinci robots (Figure 1.7).

Figure 1.7: Da Vinci Robotic Surgery System [29]

### 1.3.3 Nervous System

How humans feel is associated not with the skin or muscles, but instead with the nervous system. The nervous system is basically a collection of nerves (cylindrical bundles of fibers that start at the brain and central cord) and specialized cells (neurons) that transmit signals between different parts of the body[30].

In vertebrates, it consists of two main parts: the Central nervous System (CNS) that consists of the brain and spinal cord and the Peripheral Nervous System (PNS) that consists mainly of nerves that connect the CNS to every other part of the body.

The nerves that transmit data from the body to the brain are called sensory nerves. On the other hand, the motor nerves work the other way around. The Spinal nerves can operate both to receive and send data from the body to the brain, so they are called mixed nerves.

Neurons send signals to other cells through thin fibers called axons that cause chemicals known as neurotransmitters to be release at junctions called synapses [31]. Then the synapse gives a command to the cell. This entire communication process usually only takes a fraction of a millisecond.

Sensory nerves react to physical stimulus and send feedback to the CNS and the motor nerves transmit signals to active the muscles or glands [30].

One of the most important part of the nervous system is the spinal cord. It is a long structure with a cylindrical shape that begins at the end of the brain stem and continues down almost to the bottom of the spine (spinal column).

Emerging from the spinal cord between the vertebrae are 31 pairs of spinal nerves [32] [33]:

- 8 cervical (C)
- 12 thoracic (T)
- 5 lumbar (L)
- 5 sacral (S)

- 1 coccygeal (Co) - mainly vestigial

Each nerve emerges in two short branches (roots):

- One at the front (motor or anterior/ventral root) of the spinal cord

- One at the back (sensory or posterior/dorsal root) of the spinal cord

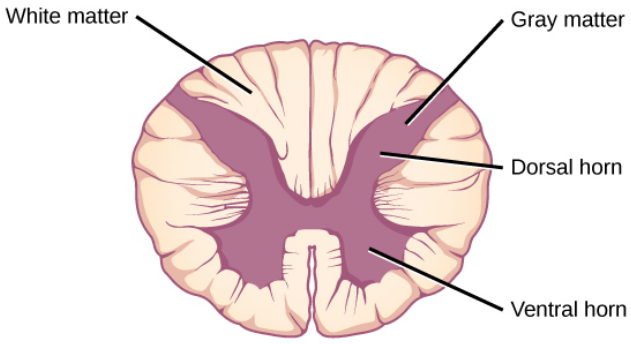


Figure 1.8: Spinal Cord [34]

The spinal nerves consist of the sensory nerve roots (dorsal), which enter the spinal cord at each level, and the motor roots (ventral), which emerge from the cord at each level. [32]

The surface of the skin is divided into specific areas called dermatomes in which sensory nerves derive from a single spinal nerve root. Dermatomes are useful to help localize neurological levels [35] because when information is detected in a dermatome the data is then sent to one of the peripheral nerves.

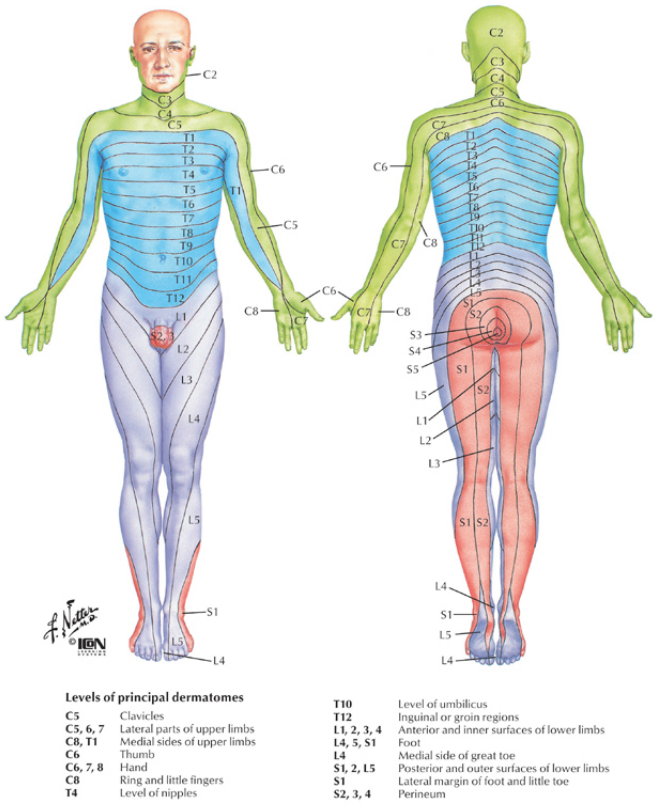


Figure 1.9: Schematic demarcation of dermatomes shown as distinc segments [36]

### 1.3.4 Rehabilitation

Physical rehabilitation is the process of restoring and regaining physical strength and function [37]. It is used to return (or give) the maximum of functionality to a person that has an acquired condition (for instance, to help treat a simple ankle sprain or to help a stroke survivor walk, talk and eat again). In rehabilitation, what the doctor tries to do is to restore, in an anatomic way, but more important, give the patient autonomy and functionality executing daily routines with the maximum normality.

It can be used in orthopedic cases, musculoskeletal, neurological, cardiorespiratory, palliative and so on. It is applied since birth till death.

Figure 1.10: Rehabilitation [38]

Sometimes, only one root of the spinal cord gets ruptured and depending on which part a person can feel different symptoms. For instance, if the dorsal root gets a rupture, a person can still be able to feel pain but not know how their foot is positioned or feel vibration.

*Tabes dorsalis*, also known as *syphilitic myelopathy*, is a genetic disease that does exactly that [39].

Nowadays, the tests that are done to check the vibratory sensibility of the patient are done using a tuning fork (also known as a diapason).

A tuning fork is a steel or magnesium-alloy device that produces harmonic vibration when its two prongs are struck [40].

Usually, in a diagnose test using the tuning fork, the doctor asks the patient to close their eyes and then proceeds to lean the diapason in the patient body (with the patient having to ignore the sense of touch and cold of the sudden contact). The patient is then requested to tell the doctor when the sensation is gone.

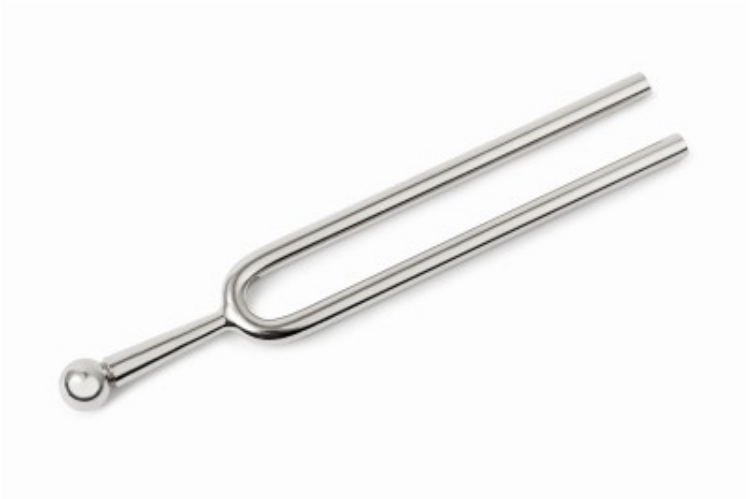

Figure 1.11: Tuning Fork [41]

# Chapter 3

# Development of an Application

## 3.1 Creation of the Prototype

### 3.1.1 Stimulus

A stimulus is an external or internal signal capable of causing a reaction in a cell or body. Every stimulus has four important features:

- Type (sensory way).
- Intensity.
- Location.
- Duration.

In this project the intensity, the location and the duration of the stimulus can be controlled.

### 3.1.2 Placement of the Motors

In this project, the prototype was made to be used in the arm/hand with vibration motors. The vibration is felt in the dorsal root (white matter). With the help of Figure 3.1, it can be easily seen that the dermatomes the motors need to focus on are C5, C6, C7, C8 and T1.

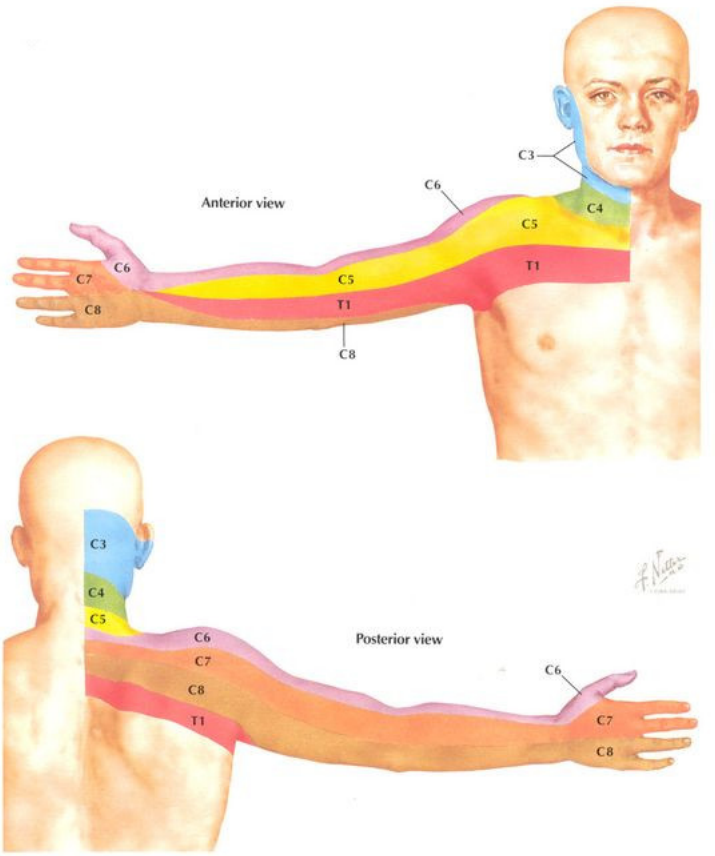


Figure 3.1: Schematic demarcation of dermatomes in upper body [36]

Having this information in mind, Figure 3.2 presents the proposal for the motors placement in this project.

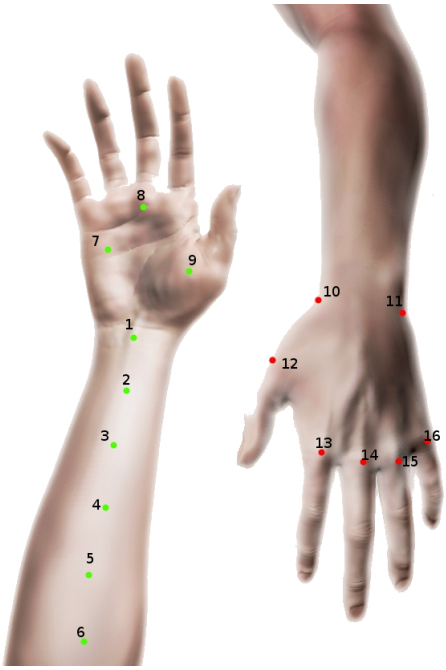


Figure 3.2: Placement of the motors

There are nine motors placed in strategical dermatomes places in the lower part of the arm/hand. On the upper part the other 7 motors were placed in the joints for diagnose purposes.

### 3.1.3 ROS nodes

As Figure 3.3 shows, for this project 3 nodes where created.

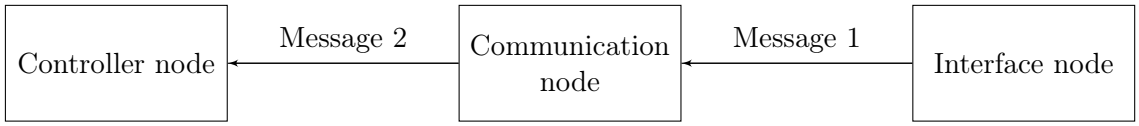


Figure 3.3: ROS nodes flowchart

The Interface node is a publisher node and it publishes to the Communication node a message that contains the number of motors to turn on, their duty-cycle and their location.

The Communication node makes the connection between the Interface and Controller node, being both a publisher and a subscriber. It receives the message from the Interface node and converts it in a way that the Controller node will understand, sending the duty-cycle and the location of the motors.

As for the Controller node, it is a subscriber and it acts according to the message that it receives: it turns on the correct motors with the correct duty-cycle.