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Arduino Uno Controlled Analgesimeter Device

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Abstract – In this article, the problem is posed on a device to evaluate the value of the pressure of pain on the limbs of an animal. So we studied and designed an analgesic device that consists of a pressure sensor and an Arduino card capable of displaying on a screen the value of the mechanical pressure felt by an animal during an experiment by applying a gradually increasing force.

The electronic system of this device is simulated with PROTEUS ISIS software.

The realization implements different electronic hardware such as strain gauge sensor, stepper motor, LCD screen and Arduino UNO board based on programmable Atmel microcontroller .

The applied force is given by the displacement of the 418g mass on a horizontal axis controlled by the stepper motor. Its variation is of the order of 0.02N/ mm.

This analgesimeter allows us to measure a pressure from 0 to 5,719,974 Pa at the tip of a 1.6mm diameter needle with precision. The measured grader is displayed on an LCD screen, or on a computer.

Keywords – Analgesimeter, Pain, Pressure, Arduino, Simulation, Microcontroller.

I- INTRODUCTION

In the field of research, in the laboratory, etc., researchers and technicians need electronic devices to facilitate the measurements of the physicochemical quantities characterizing a system.

In the pharmacological laboratory that conducts research on anesthetic products, devices that can evaluate the pressure and pain felt by a guinea pig are very necessary. Thus, in this article, we have determined the materials capable of measuring the intensity of pain or analgesia perceived by a guinea pig during an experiment. The device consists of a microcontroller that performs the calculation, a pressure sensor, a mechatronic system that gives a variable force and a display. It allows us to contribute to the research on the analgesia felt by animals.

In this paper, we study and realize an analgesic device capable of measuring pain and analgesia in small animals such as rats and mice.

II- METHODOLOGY

1. GENERALITIES

1.1. Strain gauge sensor

By definition, a sensor is an information collection device developed from a physical quantity into another physical quantity of a different nature.

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According to this definition, a sensor gives a physical quantity that is useful or usable under a digital, analog, or other signal.

systems such as CAN, DAC, amplifier, rectifier and chopper can be associated with a sensor to quantify or specify the measured grader.

In this study we have chosen a strain gauge sensor formed by a small aluminum bar containing four piezoresistors in series connected with four wires and a 24-bit converter. We use a CAN based on the HX711 integrated circuit. This sensor is powered at 5V.

Figures 1 and 2 show the aluminum bar gauge sensor and the HX711 converter

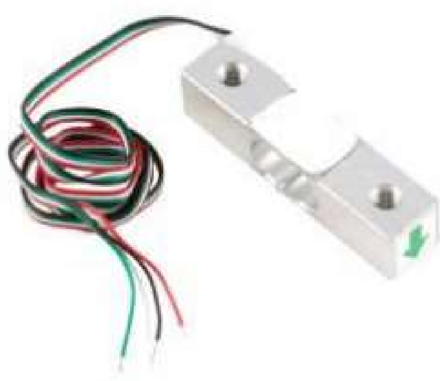

Figure 1: Strain gauge sensor.

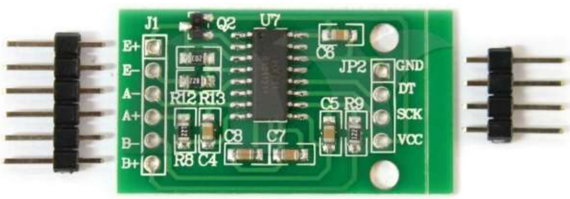

Figure 2: CAN H X711 weight gauge.

1.2. Stepper motor

It is a direct current that allows us to position an object precisely thanks to its small 1.8° step.

There are two types of stepper motors: unipolar and bipolar stepper motors.

The purpose of using these motors is to position its axis by rotating the motor with variable speed. To control the direction and speed of rotation of this motor by a microcontroller, it is necessary to use an integrated circuit capable of controlling its movement. The unipolar type is controlled by a ULN2003APG driver and the bipolar type is controlled by the L293D integrated circuit.

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The IC L293D with its electronic components is capable of controlling both types of stepper motors. Figure 3 shows the bipolar stepper motor reference 17HS3001-20B and the integrated circuit L293D which controls the motor with a 4-wire cable

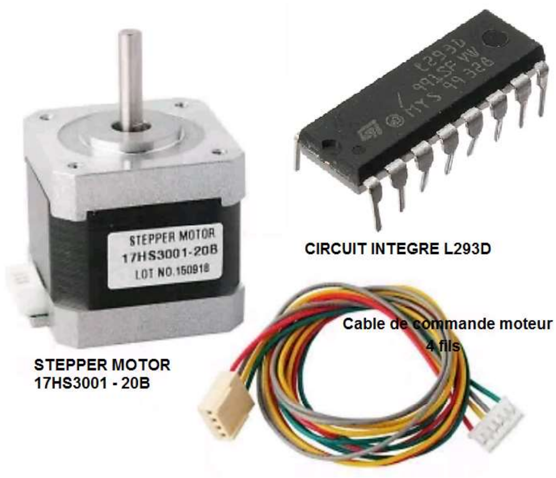

Figure 3: 17HS3001-20B bipolar stepper motor and the control circuit IC L293D.

1.3. LCD display

An LCD display (see Figure 4) is an electronic device that displays signal values using a decoder or converter that converts the input signal into a readable digital value. This display is compatible with the microcontroller arduino works under a 5V power supply but to be able to save the pins of the Arduino board, we use the I2C module which reduces the pins to 4 pins only connected with an Arduino board. Using this add-on makes the installation easy because it has a potentiometer to vary the brightness, [1].

Figure 5 shows the PCF8574A I2C module board

Figure 3: LCD display with 16 input pins.

Figure 5: PCF 8574A I2C module.

1.4. Arduino microcontroller

A microcontroller is a programmable electronic component with a processor, memories and peripherals.

Atmel microcontroller with the reference ATMega328 and the AVR family (see figure 6). This type of Arduino board is powered by a 5V voltage (USB port) and an external voltage of 7 to 12V (USB port type B). It has 6 analog input pins and 14 digital input/output pins. Its clock frequency is 16MHz and it has 32kB flash memory, 2kB SRAM and 1kB EEPROM memory.

In this study, we chose the Arduino microcontroller for processing information given by a sensor.

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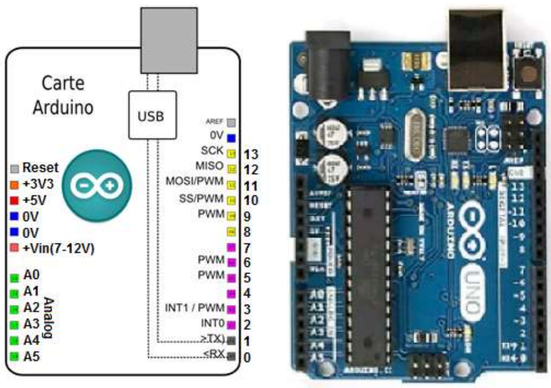

Figure 6: Representation of the ARDUINO UNO board

2. Mechatronic system: stepper motor, mass and needle.

To have a force applied to the gauge sensor, a moving mass is used on a fixed and horizontal axis in an oscillating system. A force corresponds to each movement of the mass controlled by the stepper motor. By using a small surface conical point needle, a mechanical pressure is obtained from the applied force.

The pressure Prs exerted on the surface S by a force P is given by the formula

$$Prs = \frac{F}{S} \qquad (1)$$

Prs : pressure applied to a wall of surface S,

F : force applied to the surface

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Table 1: Some pressure unit conversions.

Starting unit	Bar	Atmosphere (atm)	Newton/m2 or Pascal
1Bar	1	0 .987	10^5
1Atm	1,013	1	1,013.10 ^{5}
1N/m ^{2}	10 $^{-5}$	0,987.10 $^{-5}$	1
1Pa	10 $^{-5}$	0,987.10 $^{-5}$	1

Figure 7 shows the mechanical structure of the device.

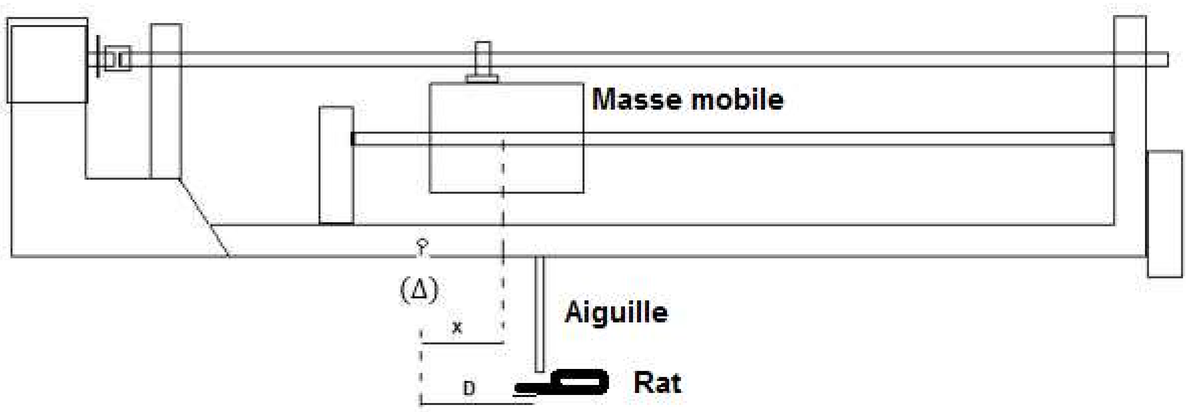

Figure 7: Representation of the mechanical part of the device.

Figure 7 shows the system around the fixed axis (Δ). The system is assumed to be formed by rods, a fixed mass, a vertical needle and a moving mass.

the moment of a force **F** $_i$ and **D** $_i$ be $\boldsymbol{M_{i/\Delta}}$ the closest distance between the line of action of the force F and the axis of rotation.

$$M_{i/\Delta} = \pm Fi * Di \qquad (2)$$

If the system is balanced, we have:

$$\sum_{i=1}^{n} M_{i/\Delta} = 0 \qquad (3)$$

Let R be the resultant of the forces in the system (Structure, motor, needle) except the moving mass

Applying the fundamental relation of dynamics (4), we have:

$x.P - D.R = 0$(4)

From where:

$$R = \frac{M.g.x}{D} \qquad (5)$$

According to formula (6) the resultant R varies depending on the distance $x$from the axis of rotation of the system.

The measured pressure Prs that we want to have comes from the resultant R

Then the pressure variation (1) is given by the formula:

$$Pr = \frac{M.g.x}{SD} \qquad (6)$$

If x=0, the system is perfectly horizontal and Prs = 0 Pa

3. Simulation tools: Proteus software and Arduino IDE

Proteus is a software package developed by the company *Labcenter Electronics* . It is a software that allows you to simulate electronic circuits with specific components in a practical and accessible way. It is also intended for the production of printed circuits.

Two software programs are included in the Proteus: *Intelligent Schematic Input System* (ISIS) and *Advanced Routing & Editing Software* (ARES). The ISIS software is mainly used to edit electronic circuits. Through simulations, errors, right from the beginning of the design stage, can be detected on ISIS. Thanks to *Virtual System Modeling* (VSM), it allows to control the graphic module of electronic circuits.

ARES software is a circuit editing and routing tool that complements ISIS. ARES allows automatic component placement and routing

Arduino IDE is a software that allows you to program the virtual Arduino card on Proteus by retrieving the Hexadecimal code of the program and also the real Arduino card by uploading the program via a USB serial port between the computer and the card.

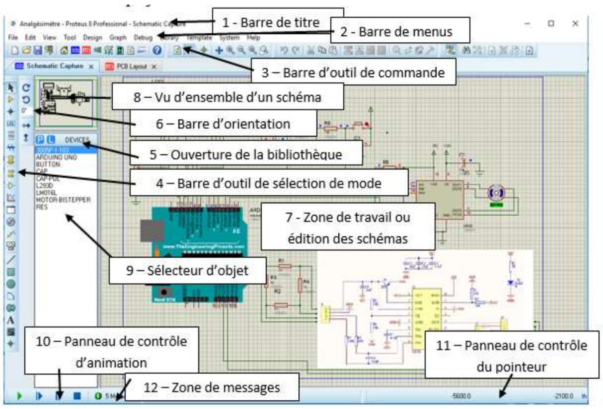

Figure 8: Presentation of the ISIS module of PROTEUS software with legend.

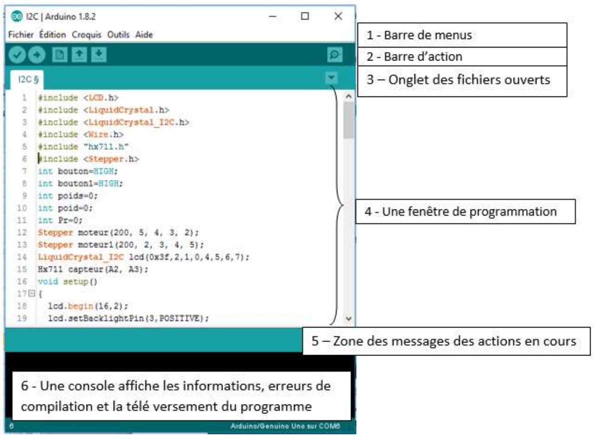

Figure 9: Presentation of the ARDUINO software with its legend

III- RESULTS

1. Simulation of the electronic circuit of the system on Proteus

We simulated the entire circuit on Proteus software.

This circuit contains the stepper motor control circuit group with IC L293D. The two push buttons ensure the rotation directions of the motor.

The resultant of the applied force and the pressure are displayed on the screen during the simulation.

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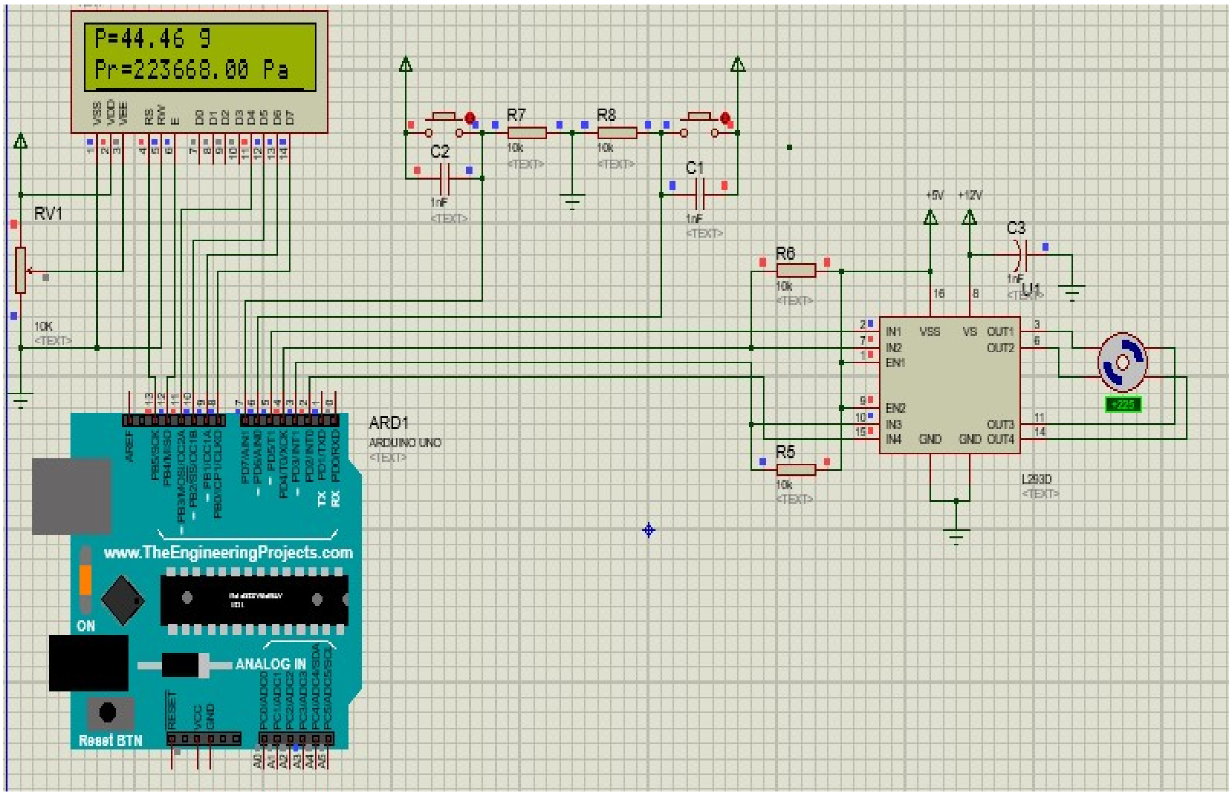

Figure 10: Presentation of the electronic circuit of the device under the ISSIS module

The strain gauge sensor is characterized by four variable resistors depending on the deformation of the aluminum bar. These four variable resistors are connected according to Figure 11 which represents the Wheatstone bridge circuit. The Wheatstone bridge circuit is suitable for measuring small variations in electrical resistance during the use of strain gauges.

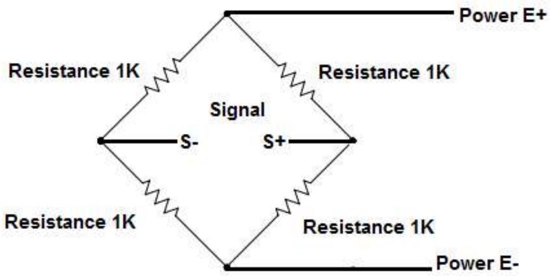

Figure 11: Internal structure of the weight strain gauge sensor.

The weight strain gauge sensor module is based on HX711 IC which has 24 bits accuracy analog to digital converter. HX711 IC works in high integration with fast response to evaluate the sensor signal at the same time.

The electronic circuit diagram of the strain gauge is shown in Figure 12.

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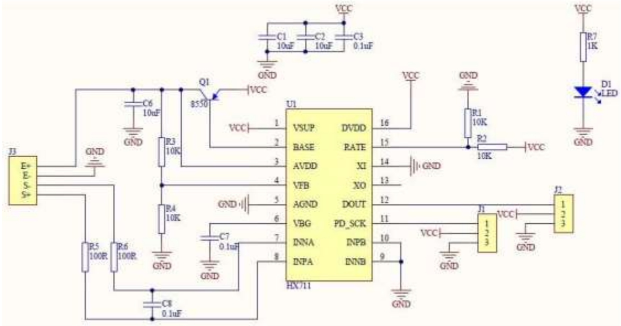

Figure 12: Circuit of the SC HX711 weight sensor module.

1. **Motor Control IC L293D**

Figure 12 shows the motor control circuit printed on a breadboard. This board contains electrical connectors to control the motor.

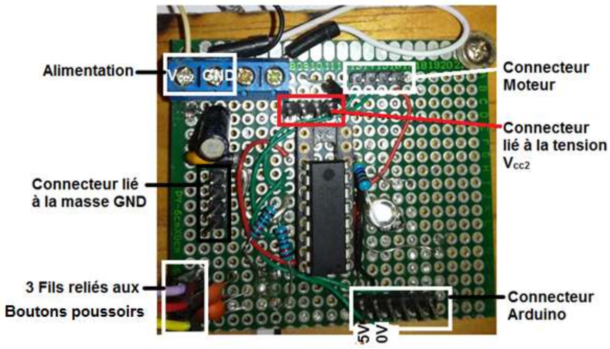

Figure 4: Engine control plate.

2. **Presentation of the analgesimeter**

This is a device that evaluates the threshold pain induced by increasing the pressure on a rat's paw. This equipment is characterized by its use and operation and it contains several elements, each of which has its role in measuring the pain induced and felt by the animal following the application of the mobile weight on a horizontal axis (see Figure 15). In general, the pressure due to the force is uniformly increasing on a rat's paw thanks to the operation of the stepper motor and the conical tip of a needle, [2]. At the ends, there are two bearings that ensure the free rotation made by the motor. On the tray of the device, there is a small sensor panel where the animal's paw is placed during the experiment. Very close to the vertical support of the oscillator, there is an LCD screen that displays the value received by the sensor and the weight is converted into pressure afterwards. The hardware box includes ARDUINO, the motor control board and the strain gauge sensor conversion module. The device has two push buttons.

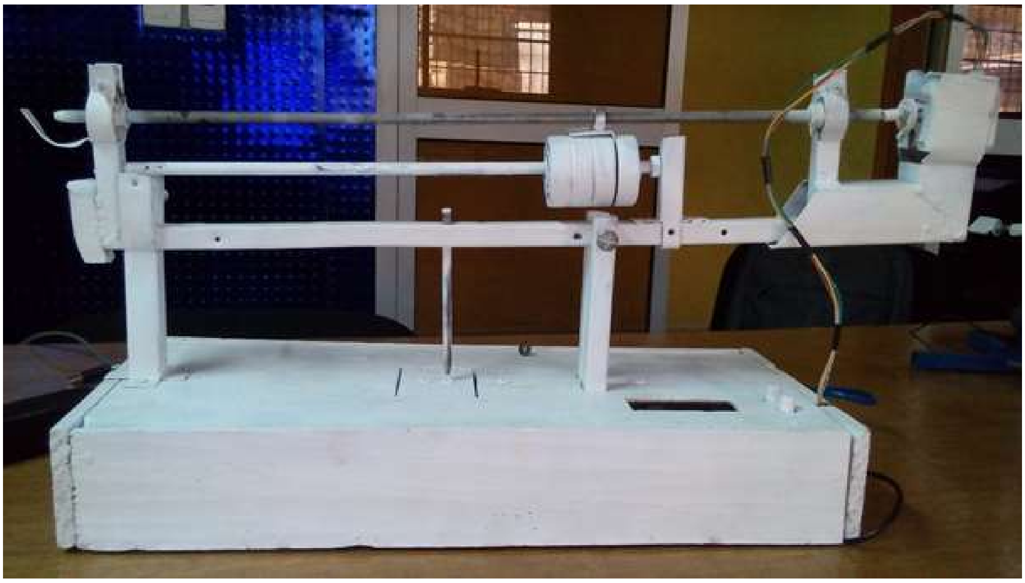

Figure 13: Representation of the analgesimeter device .

- **The different values of this analgesimeter device**

Regarding our device that we have made, it is capable of measuring the applied force or mechanical pressure in a part of a small animal's limb by applying a force that gives pressure using a needle with a conical tip. According to the manufacturer of the strain gauge sensor, the value of the maximum force measured is 5kg with the resolution 2g per measurement step. Its sensitivity speed is very fast and its accuracy is of the order of 0.5g.

In the case of this device, the strain gauge sensor normally operates to evaluate the mechanical force and pressure has a measuring range of 0 to 1,166g of weight or by converting the force into pressure is between 0 to 5,719,974 Pa. These values are obtained by moving a 418g mobile mass on a horizontal axis and a vertical needle applied to a surface with a conical tip of diameter 1.6 mm.

To determine the maximum variation in pressure to be evaluated, we rotated the motor half a turn at each movement and the variation in force thus obtained is close to 2g which corresponds to a force of ~0.02N .

For the results on the evaluation of the pressure on the rat's tail, the weight that causes pain is 241g, which translates into pressure of 2.364N. The needle used has a conical tip with a diameter of 1.6mm, so the pressure applied to the rat's limb is 1,182,105 Pa (11.82105 bars) and for the mouse, the weight applied to its tail is low enough compared to that of the rat to have its reaction. The latter is 88g on the tail. The same needle is used as for the rat and the pressure is determined to be of the order of 431,640 Pa or 4.3164 bars.

The values discussed above are average values because the sensitivity of animals depends on their sex and age. In addition, the animal being tested is placed in a box to prevent its movement during the evaluation. This movement can result in a false value when the animal touches the sensor plate or the needle.

IV- Discussions

Practically, we find that the accuracy of the values is about 2g. The sensor cannot measure a pressure lower than 2g and it counts the value by jumps of 2g at each measurement. The maximum value measured by the sensor is 5kg. But this device works for a maximum evaluation of 1,228g for the mass used of 526g. When we change this mass used to 418 g the maximum value obtained by the sensor is 1,166g. To have a pressure higher than the previous value, it is necessary to add an additional mass to have the forces applied to the sensor. Moreover, the measurement evaluation of an analgesimeter device Smalgo has a measuring range of 0 to 1,500 g for small mammals and Vetalgo has a wide measuring range of 0 to 5,000 g with precision as it is used for large mammals. For the other two devices, the stimulation is done by a 7mm $^{2 \text{ conical tip}}$ or a 314 mm $^{2 \text{ surface disk}}$.

The device works under two power supplies, one for ARDUINO and the other for the stepper motor control board with IC L293D and the strain gauge sensor. It is then used in the presence of a current and its capacity is intended for the quantification of calibration of the mechanical stimulation of the animal (rat or mouse) on a linear scale. The analgesimeter is a device thus allowing to evaluate the mechanical pressure on the limbs of the animal. The results are little variable when using the ARDUINO card.

The comparative study demonstrated the accuracy of the values given by our analgesimeter through easy measurements, fast enough to have precision and reproducibility of the threshold of mechanical pain on the rat's limbs.

The measurement of pain with this device is less rapid compared to the RODENT PINCHER analgesimeter because the increase in force is around 2g. Therefore, an alarm system is required to record the time interval after which the pressure value imposes pain on the rat's limb [3].

During the experimentation of the device, we notice the possible imperfection of the sensor in the measurements of the values because of its precision during its operation. In addition, the external environment including the temperature, the atmospheric pressure and the unstable power supply disturbs these measurements.

All the sensor values are displayed on an LCD screen or they can be presented on a computer screen. But the sensor records all the forces on their support, so there is the problem of pain assessment because the weight of the animal's paw or tail is taken into account by the sensor. So, it is necessary to visualize the value on the screen before controlling the motor by knowing the initial mass. After the evaluation, we make the difference between the initial mass and the final mass, then the difference is the value of the mass induced by the conical tip needle.

V- Conclusion

The lack of measuring devices is one of the factors that does not develop the field of scientific research in our country. Our goal is to realize a pain measuring device on the limb of a small animal such as a rat or a mouse using the evaluation of the mechanical pressure caused by a force. It involves using an ARDUINO microcontroller and its peripherals including the stepper motor, the weight sensor and the LCD screen to display the value of the pressure measured through this sensor. The pressure measured in Pascal is that exerted by an object of surface S in contact with the pressure sensor, hence the mechanical pain felt by the animal thanks to the pressure of a needle with a conical tip.

Apart from the theoretical studies on the different components of this device that we have carried out in this work, we have simulated our device with the ARDUINO 1.8.2 and PROTEUS 8.1 software when designing its electronic circuit and its program code. And so to plot the calibration curves of pressure and force captured by the sensor, we used the Matlab software. These three software lead to obtaining and verifying the results that we obtain with the device when using it.

During the experimentation in the Pharmacology laboratory of the Science and Technology Domain, we found that this device allows us to evaluate the pressure and pain applied to a rat induced by a needle. The device can measure a pressure resulting from a mass of up to 1,166g. Therefore, this device is widely used in the field of scientific research to determine the effectiveness of anesthetic products on the limbs of an animal in a laboratory in the "pharmacology" field.

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