

CHAPTER 2

THEORITICAL FOUNDATION

2.1 Theoretical Foundation

This section will provides detail explanations of terms and theories used throughout this thesis. All the terms and theories are explained in detail in order to support the idea behind the thesis itself where the problem has been assisted with proper solution.

In “ARDUINO HEART RATE AND SKIN TEMPERATURE BASED WIRELESS EMOTION DETECTOR”, there are 3 main components: the human input to the Arduino devices through Temperature Sensor, Pulse Sensor and Arduino UNO, the data sender devices which are the XBee, and lastly is the PC that is set to receive this signal.

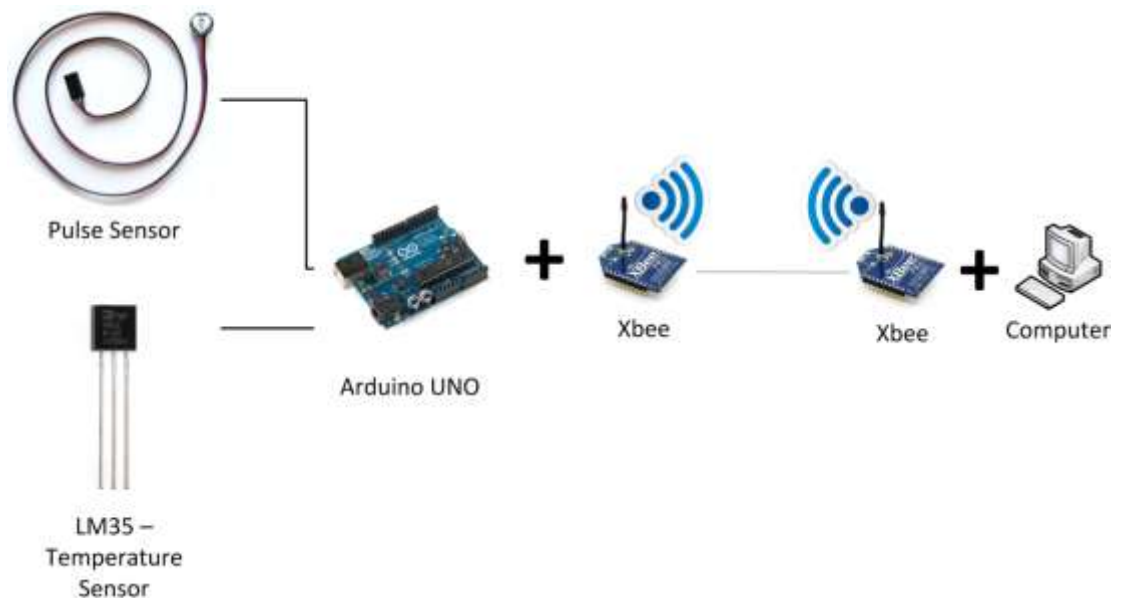


Figure 2.1: Arduino XBee Illustration

The illustration in Figure 2.2 show that the pulse sensor which will be used to detect heart rate and temperature sensor to detect skin temperature will be connected to Arduino UNO and the data will be analyze to get the emotion which will later on be sent through wireless signal by XBee to the XBee module on PC side.

2.1.1 Emotion

2.1.1.1 What is emotion?

The word emotion actually represents a wide range of concepts and perception where the main idea is about feelings that vary from one individual to another. There is no exact explanation or definition of what emotion really is. Researchers have always been trying to find the exact definition of emotion, but still there is no single fix explanation to it. Everyone knows what an emotion is actually like. They experience it every day, but they don't know how to fully define it in a proper sentence when ask to define emotion. Based on Oracle explanation, **emotion** could be explained as “**a state of psychological expression or display of distinctive somatic and autonomic responses**” [8]. Emotion is not only something that we feel, it is an essential part that play a major role in motivation, perception, cognition, coping, creativity, attention, planning, reasoning, learning, memory, and decision making.

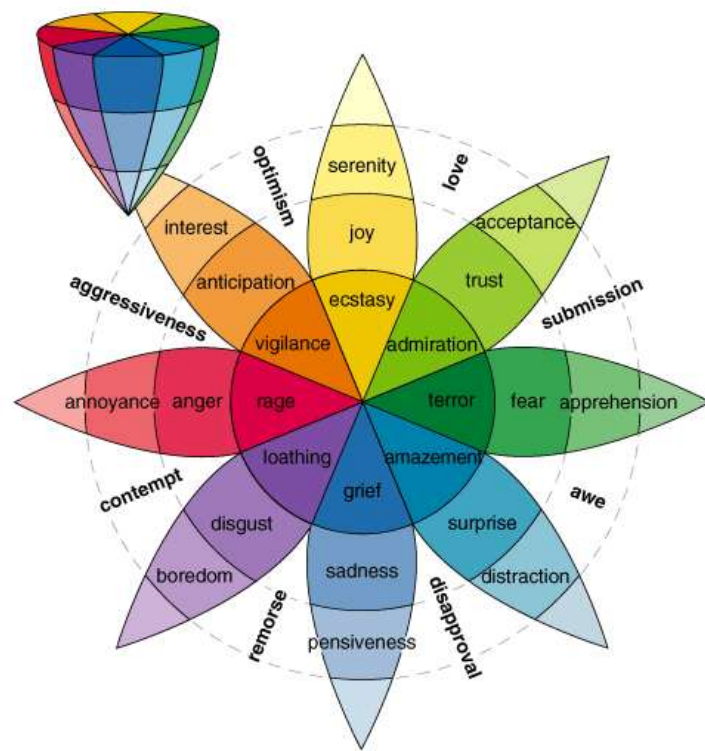


Figure 2.2: Plutchik's Wheel of Emotions

Some psychologists have tried to define different types of emotion and group emotions into certain categories. One of the most well-known emotions grouping is a study by Robert Plutchick. He created a wheel of emotions where he believed there were eight primary emotions arranged as four pairs of opposites: joy versus sadness; anger versus fear; trust versus disgust; and surprise versus anticipation (Figure 2.1) [9].

2.1.1.2 Emotion Recognition

Emotion recognition is one of the greatest challenges in human-human and human-computer interaction. There are various factors in human that can be used for emotion recognition, such as speech recognition, face expression, and physiological changes. The most well-known factor is by using physiological signals in human. This physiological signals include electromyogram signal (EMG), respiratory volume (RV), skin temperature (SKT), skin conductance (SKC), blood volume pulse (BVP) and heart rate (HR) [7]. Any one of those signals could actually determine people's emotion, but to get a more accurate result, at least two of the method should be used to obtain data for analysis. In this thesis, heart rate (HR) and skin temperature (SKT) will be used as the data for emotion analysis.

Heart Rate is the number of heartbeats (pulse) per unit of time, known as beats per minute (BPM) that vary with the number of oxygen needed by the body, such as during exercise or resting [10]. The best place to find a person's heart rate are wrists, inside of your elbow, side of your neck and top of the foot [11].

Skin is the largest organ in human body. Skin help protects us from injuries and help to control body temperature through pores. **Skin temperature** depends on

the activity of sweat glands and blood vessels [12]. There is no fixed normal skin temperature but by using a range over which temperature changes.

2.1.2 Single-board microcontrollers

Microcontrollers are computer in a small hardware form used inside electronic devices. Any product or device that interacts with the user has a microcontroller buried inside [13].

The most well-known microcontrollers used are usually the single-board microcontroller. Single-board microcontrollers appeared in the late 1970s when the first generations of microprocessors, such as the 6502 and the Z80, made it practical to build an entire controller on a single board, and affordable to dedicate a processor chip to such a relatively minor task [14]. Single-board microcontroller is a microcontroller built onto a single printed circuit board. This board provides all of the circuitry necessary for a useful control task: microprocessor, I/O circuits, clock generator, RAM, stored program memory and any support ICs necessary. The intention is that the board is immediately useful to an application developer, without needing to spend time and effort in developing the controller hardware [14]. Also they are usually low-cost hardware. Thus single-board microcontrollers have long been popular for educational purposes. Example of popular single-board microcontrollers are: Arduino, Dwengo and Wiring (development platform).

Arduino has certain advantages when compared with other microcontrollers. It simplifies the amount of hardware and software development for both programmers and non-programmers. The Arduino hardware platform already has the power and reset circuitry setup as well as circuitry to program and communicate with the microcontroller over USB. In addition, the I/O pins of the microcontroller are typically already fed out to sockets/headers for easy access. Besides, Arduino provides number of libraries to make programming easier.

2.1.2.1 What is Arduino?

Arduino is “an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software” [2]. It can sense the environment by obtaining input data from variety sensors and can also be used to control the surrounding, such as lights, air condition and other actuators.

Arduino microcontroller board is programmed using Arduino programming language (based on Wiring & C language) and the Arduino development environment (based on Processing) is an open-source IDE. Arduino projects can be stand-alone or they can communicate with software running on a computer (e.g. Flash, Processing, MaxMSP) [2]. The Arduino boards can be purchased or assembled by hand. It comes in many forms under different names, size and height, such as Arduino UNO and Arduino

LilyPad. One of the most available worldwide and popular Arduino formats to date is the Arduino Uno [15].

Arduino UNO is a microcontroller board based on ATmega328 that is currently made in Italy by SmartProjects. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button as shown below [16]:



Figure 2.3: Arduino UNO Microcontroller Board



The detail specifications of Arduino UNO are listed in the table below [16]:





Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Table 2.1: Arduino UNO Specification

2.1.2.2 Arduino Kit

Arduino UNO is just a board of microcontroller. To connect it and make it work, there are several components needed to be use. The basic components that are usually used are listed in the table below:

Component Name	Image	Details
Arduino Holder		<p>Arduino holder kit comes with different forms; it is usually design and produced by Arduino official distributor. This holder helps to keep things need and simple. It is design for breadboard and Arduino UNO to be placed side by side.</p>
Transparent Breadboard 400		<p>Transparent Breadboard with 400 points. Use for Arduino prototyping when using more than one sensors or Arduino compatible devices. Size: 82</p>

		x 53 x 8.5 mm
Jumper Wires		Jumper wires come in different size. It is usually used to connect the Arduino and breadboard to support multiple device usage.
LED (Red, Green, Yellow)		LED is used as an indicator light for different purposes depending on the Arduino functionality. Usually used by the one to try the Arduino for the first time.
Resistor (330 ohm, 1k ohm, 10k ohm)		Use to resist the flow of electricity (current) which means to control the current on where and how fast it flows. The bigger the resistance value (in ohms) the more current it could handle.
USB Cable		USB Cable. Standard A-B cable is required. Any length is OK.


Battery Clip 9V with 5.5mm/2.1m m plug		Battery clip is used to connect the battery with the Arduino board to support power through battery.
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Table 2.2: Common Arduino Kit

2.1.2.3 Arduino Terms

In Arduino Development Environment, there are some terms that should be understood before starting with the development. The important terms will be explained below.

- A *sketch* is the name that Arduino uses for a program. It's the unit of code that is uploaded to and run on an Arduino board. There are two special functions that are a part of every Arduino sketch: `setup()` and `loop()`. The `setup()` is called once, when the sketch starts. It's a good place to do setup tasks like setting pin modes or initializing libraries. The `loop()` function is called over and over and is heart of most sketches. You need to include both functions in your sketch, even if you don't need them for anything.
- Variables in the C programming language, which Arduino uses, have a property called *scope*. In the Arduino environment, any variable declared outside of a function (e.g. `setup()`, `loop()`, etc.), is a **global**

variable. While variable declared inside the function is called **local variable.**

2.1.3 Radio modules and communication

Wireless communication begins in 1886 by Heinrich Hertz through the discovery of electromagnetic waves. In 1895, Guglielmo Marconi develops wireless telegraphed which opened the way for modern wireless communication [17].

Wireless communication is a one-way communication system (machine-to-machine) where information is transferred over a distance without use of cables or wires [18]. Wireless communication can be via: radio frequency, microwave, GSM, HSDPA/3G, GPS or ZigBee.

ZigBee is a low-power and low-cost wireless technology that is a mesh network design to connect wireless sensor used in everything, from factory automation systems to home security systems to consumer electronics [19]. ZigBee is executed on top of the IEEE 802.15.4 radio standard [20]. ZigBee will be sending data in low rates, around 20 kbps to 250 kbps, which means it won't be able to send email or large documents, only sensor readings that is a few tens of bytes.



Figure 2.4: XBee Shield



Figure 2.5: XBee module with antenna

XBee shield (Fig 2.4) allows an Arduino board to communicate wirelessly using ZigBee network. XBee module (Fig 2.5) can communicate up to 100 feet indoors or 300 feet outdoors. The XBee shield has two jumpers to determine how the XBee's serial communication connects to the serial communication between the microcontroller (ATmega8 or ATmega168) and FTDI USB-to-serial chip on the Arduino board. There are multiple parameters that need to

be configured correctly for two modules to talk to each other, as set by the command listed in the table below [21]:

Command	Description
ID	The network ID of the XBee module.
CH	The channel of the XBee module.
SH and SL	The serial number of the XBee module (SH gives the high 32 bits, SL the low 32 bits). Read-only.
MY	The 16-bit address of the module.
DH and DL	The destination address for wireless communication (DH is the high 32 bits, DL the low 32).
BD	The baud rate used for serial communication with the Arduino board or computer.

Table 2.3: XBee Command

For XBee programming, an XBee Development Environment called Processing is used. Also we need XBee shield and XBee module with the specification as follows:

Name	XBee 802.15.4 (series 1)
Frequency	2.4GHz
Network type	point-to-multipoint
Max Range (Pro)	300' (1 mile)
Notes	most popular, cheap

Table 2.4: XBee Specification

2.1.4 Summary of the Cost of Components Used

Part Name	Quantity	Unit Price	Total
Pulse Sensor Kit	1	\$41	\$41
LM35	1	\$2.45	\$2.45
Arduino UNO	1	\$29.95	\$29.95
XBee	2	\$29.90	\$59.80
XBee USB Adapter	1	\$19.90	\$19.90
Arduino holder	1	\$3.95	\$3.95
Transparent Breadboard 400	1	\$3.75	\$3.75
Jumper Wires Set	1	\$4.90	\$4.90
USB Cable	1	\$5.99	\$5.99
USB Cable (USB to mini USB – male to male)	1	\$1.25	\$1.25
Battery Clip 9V with 5.5mm/2.1mm plug	1	\$2.95	\$2.95
Total			\$175.89

Table 2.5: Components Cost

2.2 Theoretical Frameworks

This section will explain how the solution for the problem will be implemented based on the theory above and how each component will be related to each other.

2.2.1 Emotion detector

As explained above, there are several ways of determining an individual emotion condition. In this research, only heart rate (HR) and Skin Temperature data gathering method will be used.

2.2.1.1 Pulse Sensor

Pulse is the easiest way to determine a heart rate. Checking a pulse is an easy way to determine heart rate. Resting heart rate should be counted for 60 seconds. Counting a resting pulse rate in less time increases the chance of error. During exercise, 6 or 10 second pulse checks can be used. If the pulse is counted for 6 seconds, multiply by 10 to get the heart rate in beats per minute. If the 10-second count is used, multiply by 6 to get beats per minute [22].

Two easy methods can be used when checking pulse rate. One method checks the pulse at the wrist, called the radial pulse, and the other is at the neck, called the carotid pulse.

For a radial pulse check, use the tips of your index and middle finger. The radial artery can be found on the thumb side of either wrist. It lies just a little below the

base of the thumb. The pulsing of the artery will be felt when the fingers are in the right place. Hold gently. Digital watches or those with second hands can be used. After locating the radial pulse, begin your count with "zero" on the starting time mark; then count the pulses for the desired time length.

The carotid pulse check is taken in a place just below the jaw along the windpipe and along the throat. Use the fingertips of the index and middle fingers to press gently. Do not move your fingers around in a massaging motion while trying to find your carotid pulse. This can lower your blood pressure and cause dizziness. The same counting systems used for the radial pulse check can be used for the carotid pulse check.

Easy to use open source pulse sensor for Arduino is created by Yury Gitman and Joel Murphy [23]. It is intended to simplify those who wanted to use a pulse sensor for their Arduino projects, so it wouldn't need to be created repeatedly. The pulse sensor is easy to plug into Arduino and also easy to use. It cost around \$25 for each Pulse Sensor Kit that include Pulse sensor, Velcro Dots, Ear Clip, Standard Connector End and 24 inch Color-Coded Cable. Pulse sensor is available in two forms: Pulse sensor 3Volt (Red) and Pulse sensor 5Volt (Black). Since this research is using Arduino UNO which operates using 5Volt,

so the Pulse sensor 5Volt will be used. Below is the image of Pulse sensor 5Volt [24] :



Figure 2.6: 5Volt Pulse Sensor kit

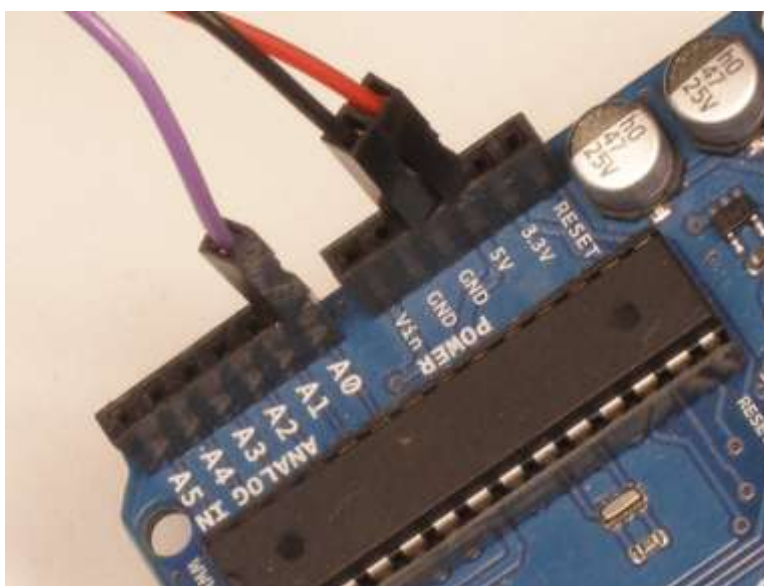


Figure 2.7: 5V Pulse Sensor connected to Arduino UNO

To connect the Pulse Sensor with Arduino UNO, simply plug the red wire to +5V, black wire to GND and purple wire to Signal (A0) as shown in Figure . The

programming environment used is called Processing which is platform independent, which means it could run in GNU/Linux, Mac OS X, and Windows

2.2.1.2 Skin Temperature

As the human skin forms the interface between the human internal body organs and the external environment, skin temperature is essential to control heat transfer. The temperature distribution over the body's surface provides useful information for many research and clinical applications [25]. To obtain a person's skin temperature, any part of the body could be measured. Only the temperature of the body usually varies according to the parts of the body measure.

For skin temperature measurements, the following sensor types are generally applied: thermocouples, thermistors, RTDs and IC sensors [26].

Most commonly electrical temperature sensors such as thermocouples or thermistors are difficult to apply. Most commonly-used electrical temperature sensors are difficult to apply. For example, thermocouples have low output levels and require cold junction compensation. While thermistors are nonlinear (the outputs of these sensors are not linearly proportional to any temperature scale).

Monolithic IC sensors overcame many of these difficulties in 1983 [27]. Two IC.'s, the LM34 Precision Fahrenheit Temperature Sensor and the LM35 Precision Celsius Temperature Sensor, were introduced. Throughout the world, Celsius Temperature Scale is used except in USA. Thus this research will be using LM35 which provide Celsius Temperature Scale.

LM35 sensors circuitry is sealed and therefore it is not subjected to oxidation and other processes. LM35 measure temperatures more accurately that with a thermistors. It uses a small electric power to operate and has low self-heating temperature. It operates at the range from - 55°C to 150°C. The output voltage varies by 10mV in response to every °C rise/fall in ambient temperature, *i.e.*, its scale factor is 0.01V/°C. The below is the pin diagram of LM35 [28]:

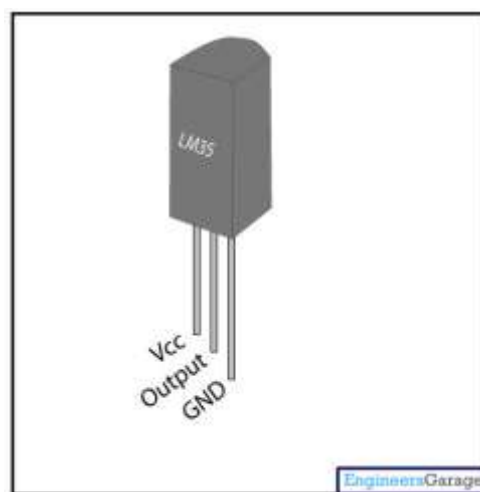


Figure 2.8: LM35 Temperature Sensor

Below is the illustration of how to connect Arduino UNO with LM35:

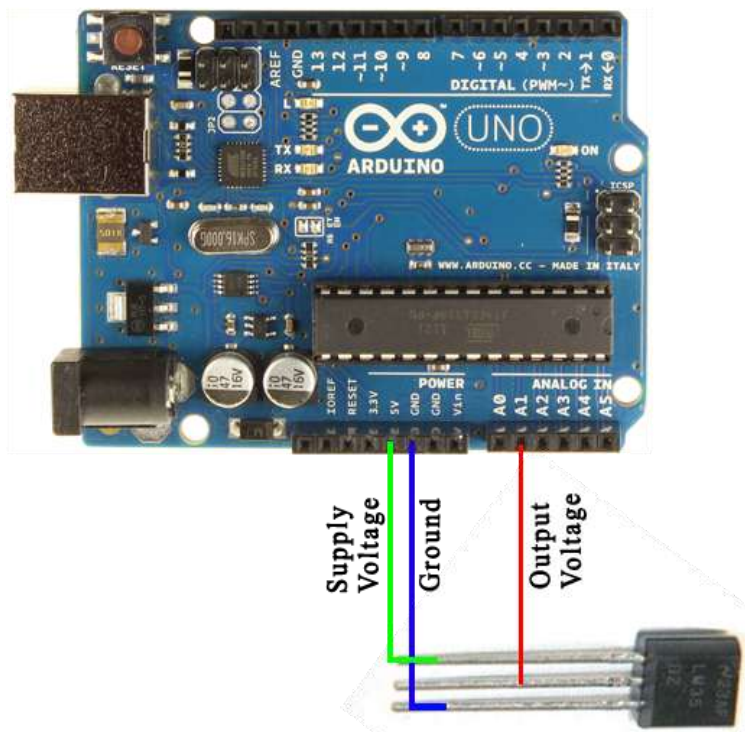


Figure 2.9: LM35 Temperature Sensor connected with Arduino UNO

As explained in section 2.2.1.1 and section 2.2.1.2, 5 Volt Pulse Sensor is used to obtain heart rate data and LM35 Temperature Sensor is used to obtain human skin temperature data. Both of this data gather from an individual will then be analyze to determine the mood of the person. To analyze the pulse sensor, an emotion correlation table will be used for comparison purposes [29]:

Emotion	Skin Temp	Heart Rate
Happy	> 36°C	< 80 BPM
Relaxed	30-36°C	< 90 BPM
Passionate	> 36°C	> 80 BPM
	> 33°C	> 90 BPM
Anxious	< 30°C	> 75 BPM
	< 33°C	> 90 BPM
Stressed	< 30°C	< 75 BPM

Table 2.6: Emotion Correlation Table

Though Table 2.6 is taken from another source, the table is taken based on some research to find the average human skin temperature and heart rate. Based on comparison of several trusted source [30], it has been found that the average skin temperature be about 33°C. Based on American Heart Association, the average resting heart rate when you're sitting or lying and you're calm, relaxed and aren't ill, your heart rate is normally between 60 (beats per minute) to 100 (beats per minute) [31]. From the research, it can be concluded that skin temperature rises when a person is in a more pleasurable mood [32], and a person's heart rate also increases with excitement. From there five different moods are chosen and put "Relaxed," our neutral mood, in

the middle. The others are placed in their correct positions relative to each other. Then based on the averages and some common sense, skin temperature and heart rate ranges are assigned to them. If there is more time, it will be better to consult the table with an expert for more accurate and better result.

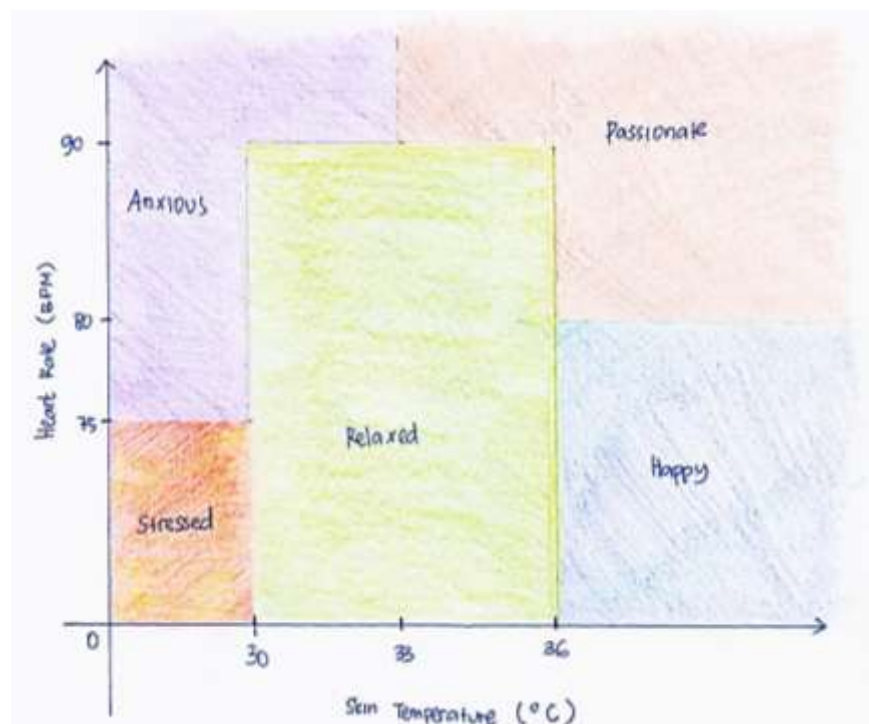


Figure 2.10: Simulation Chart Based of Emotion

Correlation Table

The simulation chart above show that all temperature and heart rate are covered in the emotion correlation table and there is no overlapped emotion. Also that all heart rate and skin temperature are measured in positive value, since it is impossible for heart rate and skin temperature to be negative.

2.2.2 Model used for communication between XBee in Arduino UNO and XBee in PC (Client-Server Architecture)

Client-server architecture can be considered as a network environment that exchanges information between a server machine and a client machine where server has some resources that can be shared by different clients. Below is the illustration of client-server architecture [33]:

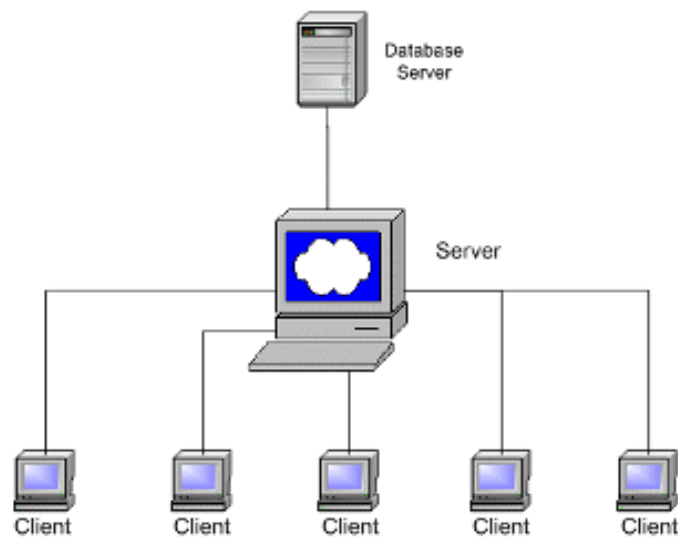


Figure 2.11: Client – Server Architecture

In figure 2.2, it is shown that XBee connected to Arduino UNO sent data in the form of signal to XBee module connected to the PC through USB port. This explains that XBee module on the PC side is a Server while XBee module on the Arduino UNO side is the client. The reason is simply because in reality, more than one XBee from different Arduino could all connect to the XBee module on the PC side and send data to it. This data received by the PC will then be processed, either for analyses or storage purposes.