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October 14, 2014

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 305/440 Functional Specification for *Svasth Healthcare's Comfort Mat System (CMS)*

Dear Dr. Rawicz,

In regards to the course requirements of ENSC 305W/440W, enclosed to this letter is *Svasth Healthcare's* functional specification for the product - *Comfort Mat System (CMS)*. We are designing and implementing a seat mattress, which can detect unfavorable conditions leading up to, advent of pressure sores and prevent them from developing.

The following documentation provides details of the product's functionality for its various stages of development. This document also covers an overview of the product design, general requirements of the proof of concept model, as well as a detailed test plan on the model functionality.

Svasth Healthcare consists of four talented engineers: Wei Lu, Di Luo, Henson Truong, and JabarJung Sandhu. If you have any questions, or concerns regarding the functional specification or product, then please feel free to contact JabarJung Sandhu at jss19@sfu.ca or 604.351.4927.

Sincerely,

JabarJung Sandhu
Svasth Healthcare CEO

Enclosure: Functional Specification for *Comfort Mat System*

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Functional Specification for Comfort Mat System (CMS)

Project team	**JabarJung Sandhu (CEO)** **Wei Lu (CFO)** **Di Luo (COO)** **Henson Truong (CTO)**
Contact	JabarJung Sandhu
Submitted to	Dr. Andrew Rawicz - ENSC 440W Dr. Steve Whitmore - ENSC 305W School of Engineering Science Simon Fraser University
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Executive Summary

Pressure sores, also called bedsores, or pressure ulcers are defined as the breakdown of the skin under long lasting pressures. According to *Agency for Healthcare Research and Quality* report, the numbers of patients who suffer from bedsores have increased by more than 80% over the last two decades (Griffin, 2008). This can lead to lack of blood flow and prevent blood from bringing oxygen and nutrients to the skin and underlying tissues. Another factor to consider besides pressure is the temperature and humidity. Increasing temperature and humidity under pressurized skin increases the rate at which the pressure sore is developed. Some common body parts where bed sores develop are hips, shoulder blades, knees, buttocks, backbone, and back of the heels.

With this in mind, we came up with the Comfort Mat System. The Comfort Mat System includes a number of innovations and features, which can help, prevent the causes of pressure sores. Anyone who sits on a chair for long periods of time can use this product, not just people in hospitals.

Development of the Comfort Mat System will occur in two phases namely 'Proof-of-concept model' & 'Development phase' described as follows:

<u>Proof-of-concept model:</u>

- Comfortable seat mattress
- Pressure detection for the seat mattress
- Unfavorable temperature and humidity alert
- Vibration motors embedded inside of the seat mattress
- LCD screen showing pressure and other sensors' data

<u>Development phase:</u>

Comfort Mat System will be integrated into a smartphone app for Android and iOS platform. App will ensure the following features:

- Alert the user of unfavorable temperature, humidity, and pressure
- Control the vibration motors to enhance blood circulation to the desired area

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Glossary

ANSI - American National Standards Institute
BMI - Body Mass Index
CMS - Comfort Mat System
CSA - Canadian Standard Association
DPI - Dynamic Pressure Image
FPGA - Field-programmable Gate Array
FSR - Force Sensitive Resistor
GUI - Graphical User Interface
ISO - International Organization for Standardization
LCD - Liquid-crystal Display

1. Introduction

Svasth Healthcare is designing *Comfort Mat System* (*CMS*), which will be able to monitor the conditions responsible for causing bedsores by collecting data from different sensors (pressure, temperature, and humidity sensors) and processing it with a smartphone application and displaying the results in a graphical user interface in real time. Another feature that *CMS* exhibits is once the collected data meets a preset threshold value, the system can automatically turn on different vibration motors to increase blood circulation in the affected area. It will send a reminder to the user to reposition their body or to the person who is the caretaker for that person. *Comfort Mat System* will be integrated with Android and iOS apps, which will allow people to monitor and control the system by using their own smartphone device.

1.1 Scope

This document illustrates the functional requirements that will be met by *Comfort Mat system (CMS).* The requirements listed will describe the major functionalities of both individual components and the fully integrated system. The *Svasth Healthcare* will use it as a vital reference during the design and development phase of *Comfort Mat System*. It also dictates some future modifications including system test plans, which may be applied during the product's design, development, and testing phase.

1.2 Intended Audience

This document is intended to ensure that the design meets the required specifications throughout the design and development phase of *CMS* by the team members of the *Svasth Healthcare*. All of the team members will use this document as a guide to progress on the *CMS* project and it's relevant tasks. It will also be used as user documentation and for test planning purposes.

1.3 Classification

In the following section the convention described will be used throughout this documentation to represent a functional requirement:

[Rx.y - P#]

Rx.y = Denotes the section number and the feature number

P# = Priority Level, a number ranked from 1 to 3 designating the priority of the function

- **Priority 1** - Signifies a feature, which must be implemented into the testing and prototype. The function of the design may be dependent on the outcome of this feature.
- **Priority 2** - Signifies a feature, which is unnecessary but may be implemented if time permits. The feature is deemed useful, but the project may move on without it.
- **Priority 3** - Signifies the feature is not important and is a luxury item as deemed by the team engineers. If time permits, this feature will be implemented into the final product.

2. System Overview

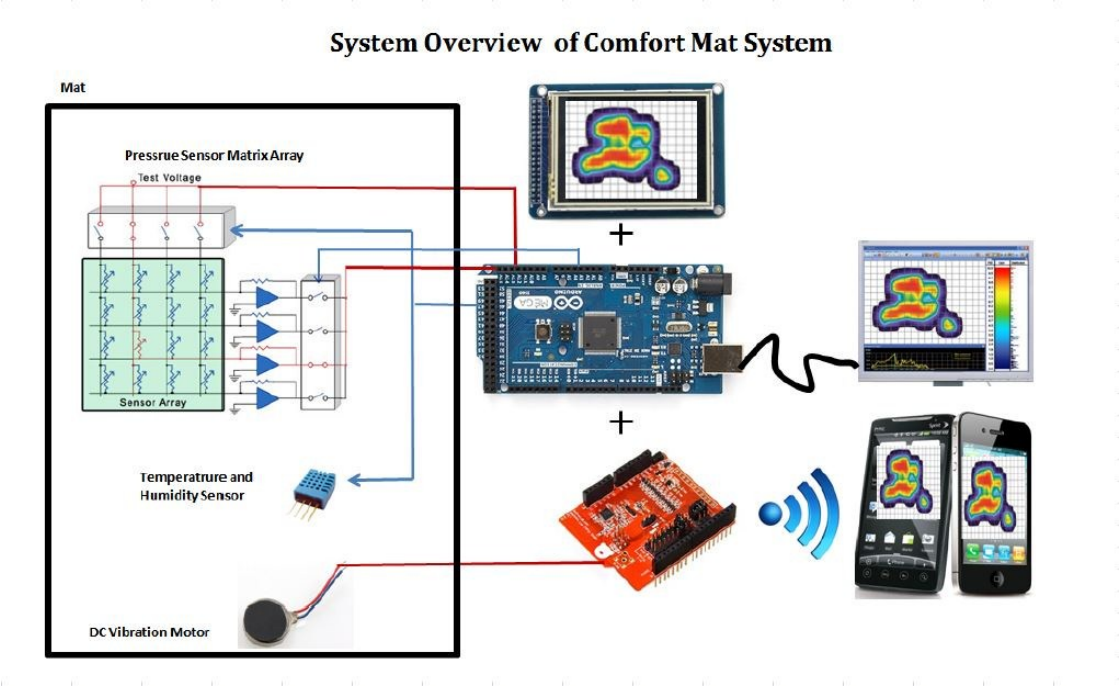

Figure 1: System overview of Comfort Mat System

Figure 1 illustrates the overview of *CMS*. It consists of a pressure sensitive mat, a smartphone, and a microcontroller. When the user is sitting on the mat, the mat outputs the pressure, temperature, and humidity sensors' data to the microcontroller. Microcontroller processes the data and sends the data to the attached device to display. There are three devices we can use to display the data – either a computer or a small LCD screen, or a smartphone. We will start with the computer first; move on to the small LCD display, then finally to the smartphone once we know everything is functionally working. The vibration motors can be set to vibrate whenever the reminder goes off or whenever the user sets it off.

2.1 General Requirements

[R2.1 - P1] Development costs of CMS must be under $800
[R2.1 - P1] Functions of CMS must not interfere with other electronic devices
[R2.1 - P2] Retail price must not exceed $300
[R2.1 - P2] CMS should be user friendly, easy to learn and operate
[R2.1 - P2] CMS should be portable and easy to handle and maintain
[R2.1 - P2] Maintenance costs must be low or if possible negligible

2.2 Physical Requirements

[R2.2 - P2] CMS is suitable for all users who have weight in the normal range i.e. BMI is under 24 (See Table 1 below), but CMS can be customized for overweight people by replacing the FSR part.

WEIGHT lbs	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215
kgs	45.5	47.7	50.0	52.3	54.5	56.8	59.1	61.4	63.6	65.9	68.2	70.5	72.7	75.0	77.3	79.5	81.8	84.1	86.4	88.6	90.9	93.2	95.5	97.7
HEIGHT in/cm	Underweight					Healthy					Overweight					Obese				Extremely obese				
5'0" - 152.4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
5'1" - 154.9	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	36	37	38	39	40
5'2" - 157.4	18	19	20	21	22	22	23	24	25	26	27	28	29	30	31	32	33	33	34	35	36	37	38	39
5'3" - 160.0	17	18	19	20	21	22	23	24	24	25	26	27	28	29	30	31	32	32	33	34	35	36	37	38
5'4" - 162.5	17	18	18	19	20	21	22	23	24	24	25	26	27	28	29	30	31	31	32	33	34	35	36	37
5'5" - 165.1	16	17	18	19	20	20	21	22	23	24	25	25	26	27	28	29	30	30	31	32	33	34	35	35
5'6" - 167.6	16	17	17	18	19	20	21	21	22	23	24	25	25	26	27	28	29	29	30	31	32	33	34	34
5'7" - 170.1	15	16	17	18	18	19	20	21	22	22	23	24	25	25	26	27	28	29	29	30	31	32	33	33
5'8" - 172.7	15	16	16	17	18	19	19	20	21	22	22	23	24	25	25	26	27	28	28	29	30	31	32	32
5'9" - 175.2	14	15	16	17	17	18	19	20	20	21	22	22	23	24	25	25	26	27	28	28	29	30	31	31
5'10" - 177.8	14	15	15	16	17	18	18	19	20	20	21	22	23	23	24	25	25	26	27	28	28	29	30	30
5'11" - 180.3	14	14	15	16	16	17	18	18	19	20	21	21	22	23	23	24	25	25	26	27	28	28	29	30
6'0" - 182.8	13	14	14	15	16	17	17	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27	28	29
6'1" - 185.4	13	13	14	15	15	16	17	17	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27	28
6'2" - 187.9	12	13	14	14	15	16	16	17	18	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27
6'3" - 190.5	12	13	13	14	15	15	16	16	17	18	18	19	20	20	21	21	22	23	23	24	25	25	26	26
6'4" - 193.0	12	12	13	14	14	15	15	16	17	17	18	18	19	20	20	21	22	22	23	23	24	25	25	26

Table 1: BMI Chart for different weight and height [4]

[R2.2 - P2] CMS can be installed with mostly any type of wheelchair

[R2.2 - P2] All components must be easy to be install and assemble

[R2.2 - P2] Cushion part of the system must be comfortable and shouldn't vary in texture over prolonged uses

[R2.2 - P3] CMS should be light in weight and must be under 1 Kg (See Table 2 below)

[R2.2 - P3] The circuits and sensors should not distort the appearance of the system

Name of the component	Weight[1] per unit (g)	Quantity of units	Total weight (g)
FSR 400	1	64	64
Humidity & temp. sensor	1	1	1
Vibration motors	20	4	80
BLE Shield	30	1	30
Mega 2560 board	35	1	35
Pressure relief cushion	500	1	500
			710

Table 2: Approximate weight of the major components of CMS

2.3 Electrical Requirements

[R2.3 - P3] Use rechargeable batteries to supply power to the system
[R2.3 - P3] Battery power should be sufficient for all components
[R2.3 - P3] Power consumption of the system should be under 6 Watts, based on the Mega 2560 operation manual

2.4 Environmental Requirements

[R2.4 - P2] *CMS* operating range should be between -10 °C to 50 °C
[R2.4 - P2] *CMS* must function perfectly under conditions at room temperature i.e. 20 °C - 25 °C
[R2.4 - P3] There should be no noise produced during the operation of the system
[R2.4 - P3] *CMS* consists of non-hazardous and easy to recycle materials

2.5 Standards

[R2.5 - P3] *CMS* should meet ANSI electrical and electronic standards
[R2.5 - P3] *CMS* should conform CSA standards for all electrical components (CSA Group, 2014)
[R2.5 - P3] The system should meet ISO/TR 11688-1:1995 low-noise machinery and equipment (ISO, 2009) and ISO 9001:2008/2009 quality management standards (ISO, 2011)

[1] All weights that are provided in Table 2 are estimates only. Some parts are not listed because of their negligible weight.

2.6 Reliability/Durability

[R2.6 - P1] Lifespan of *CMS* including all of its major components should be optimally around 5 years

Component name	Lifespan[2] (years)
AC motor	15
FPGA board	5

Table 3: Lifespan of major electronic components [1]

[R2.6 - P2] *CMS* will be resistant to damage caused by shock and vibrations and other environmental factors like temperature and humidity etc.

2.7 Safety Requirements

[R2.7 - P1] All components must not emit any radiations known for being harmful to the humans

[R2.7 - P2] *CMS* should have USB overcurrent protection

2.8 Usability Requirements

[R2.8 - P2] *CMS* utilizes graphical user interface for smartphone application

[R2.8 - P2] Vibrating motors can be controlled via smartphone app

[R2.8 - P2] The system will reset the pressure parameters once the pressure is released by readjusting the user's position

[R2.8 - P3] Users can monitor environmental parameters via smartphone application

[2] Lifespan is estimate based on the product operation manual.

3. Seat Mat

Seat mat is a vital component of the *Comfort Mat System (CMS)*. The mat contains vibration motors and three different types of sensors i.e. pressure, temperature, and humidity. The vibration motors are for microcirculation of the blood in the blood vessels. The pressure, temperature and humidity sensors detect unfavorable conditions under which pressure sores can develop and alerts the user. All of this is embedded inside a seat cushion to allow for comfortable sitting. Details on the specific requirements are listed below:

3.1 General Requirements

[R3.1-P1] No components should be blocking the sensor inputs
[R3.1-P1] The seat mat should be able to turned ON/OFF
[R3.1-P1] Device should be able to send sensors' data to Arduino microcontroller

3.2 Physical Requirements

[R3.2-P1] Sensors should fit inside the seat mattress
[R3.2-P2] Sensors and vibration motors should be firmly mounted
[R3.2-P2] All components inside the seat mattress must be able to withstand the pressure of a person sitting on top of the seat mattress
[R3.2-P2] Seat mattress should not have any sharp edges sticking out
[R3.2-P3] Seat mattress should fit most chairs
[R3.2-P3] Seat mattress should be waterproof

3.3 Electrical Requirements

[R3.3-P1] The sensors and vibration motors should use dedicated cables that provide reliable connection for the exchange of data and transmission of power
[R3.3-P2] The vibration motor should function on external batteries

3.4 Reliability Requirements

[R3.4-P2] The sensors should be able to be used repeatedly many times over the course of several years and must behave reliably under pressure

3.5 Safety Requirements

[R3.5-P1] All electrical components inside the seat mattress must be insulated

4. Smartphone App

The smartphone application will be used to access, monitor, and control the system via GUI of a smartphone app, which particularly will be based on Android and iOS. Development for the other platforms mainly BlackBerry and Windows can also be an option in the foreseeable future. A smartphone app needs to fulfill the following requirements:

4.1 General Requirements

[R4.1-P1] Displays the real time sensor data from the pressure sensors in the form of dynamic pressure images (DPIs)

[R4.1-P1] Along with the DPI, a bar displaying the pressure units will also be displayed on the screen which will relate the color codes on DPI to the specific pressure 'Pa' value

[R4.1-P1] Temperature is displayed in the form of °C or °F. Users have the option to switch between the two

[R4.1-P1] Humidity is displayed in relative, specific or absolute values

[R4.1-P1] App actuates the vibration motors based on a preset environment variables collected via the sensors or manually by the user

[R4.1-P1] App reminds the user of the high pressure areas based on the preset parameters via a reminder

[R4.1-P3] DPIs are to be refreshed at a rate of 100 Hz (optimal) so system can deliver fast sensor scanning

[R4.1-P2] Recording of the high pressure areas points in a form of universally compatible file format for the prior 24 hours

[R4.1-P2] App data can be transferred to other devices via a USB cable or Bluetooth.

[R4.1-P2] App can connect simultaneously to multiple CMS.

4.2 Usability Requirements

[R4.2-P1] App must be compatible with Android version 4.4 (Kitkat) or later and iOS 7 version or later with Bluetooth 4.0 hardware support.

[R4.2-P3] App must be running smoothly while utilizing as minimum as possible resources of device for e.g. CPU, GPU, and memory.

[R4.2-P2] App must be updated on a regular basis to improve functionality or to remove a glitch.

[R4.2-P1] App should be able to turned ON/OFF

[R4.2-P1] App must be available via Google Play Store and Apple App store.

[R4.2-P3] App can be made available via Amazon app store or other outlets if need arises in near future.

[R4.2-P1] The device on which app will be installed should be portable and fits in the hands of the user with ease.

4.3 Electrical Requirements

[R4.3-P1] App should use the minimum power as possible while operating therefore running for longer periods of time on battery power.

4.4 Reliability Requirements

[R4.4-P1] App must not crash that often.

[R4.4-P1] App must clean up the old files and redundant settings periodically so that it functions smoothly over the course of time and its cache size stays stable

[R4.4-P2] Sensors' data displayed should be as accurate and precise as possible. The amount of error should be minimal.

[R4.4-P1] App must not interfere with the parent operating system and other apps functionality.

4.5 Safety Requirements

[R4.5-P1] App must not cause the device to operate abnormally such as the device temperature exceeds the threshold limit.

[R4.5-P1] App must not cause the vibration motors to operate abnormally like actuating the motors without any warning, which might surprise the user or keep the motors running forever which will waste the battery power.

5. System Test Plan

Svasth Healthcare intends to implement some tests in order to ensure both individual modules and the final product meets the functional specification, while making sure the product is durable and reliable. To achieve this, the product testing includes testing done on each part, which includes: individual prototype hardware, complete hardware components, and a combination of hardware and software.

5.1 Pressure Sensor Matrix

The pressure sensor matrix is going to be tested by applying different forces to different areas of the matrix. Having different people with different body weights sit on the pressure sensor matrix and move around can help test it. The sampled weight data should have a large variance in order to make this test work out. Based on the specifications of the 0.5" FSR 400 pressure sensor, the operating force should be around 10g ~ 1.0kg which is equivalent to 0lbs ~ 2.2lbs (Interlink Electronics, 2012). Therefore, *CMS* is expected to function well under a healthy weight (assuming BMI is under 24).

5.2 Temperature and Humidity Sensor

Temperature and humidity sensor will be tested under different environments. The average body temperature of a healthy person is in the range of 32°C - 35°C. *Comfort Mat System* will sense body temperature that does not lie in this range especially with a high degree of accuracy. Test plans are

mainly based on temperature and humidity factors. Tests can be classified into outdoor and indoor tests.

For the indoor test plans, the *Comfort Mat System* measures the user's body temperature ranging between 20°C to 25°C. Humidity does not play a major role in this test because air temperature doesn't vary over large values and humidity is fairly constant. This is not the case for outdoor test plans though. The Figure 2 shown below shows the relationship between air temperature and relative humidity. Therefore, more number of test plans is necessary for outdoor tests because the outdoor temperature varies much more than indoor and especially over a larger range.

Humidex range (°C)	Degree of comfort
20-29	Comfortable
30-39	Some discomfort
40-45	Great discomfort; avoid exertion
Above 45	Dangerous; heat stroke possible

Table 4: Degree of comfort based on temperature [2]

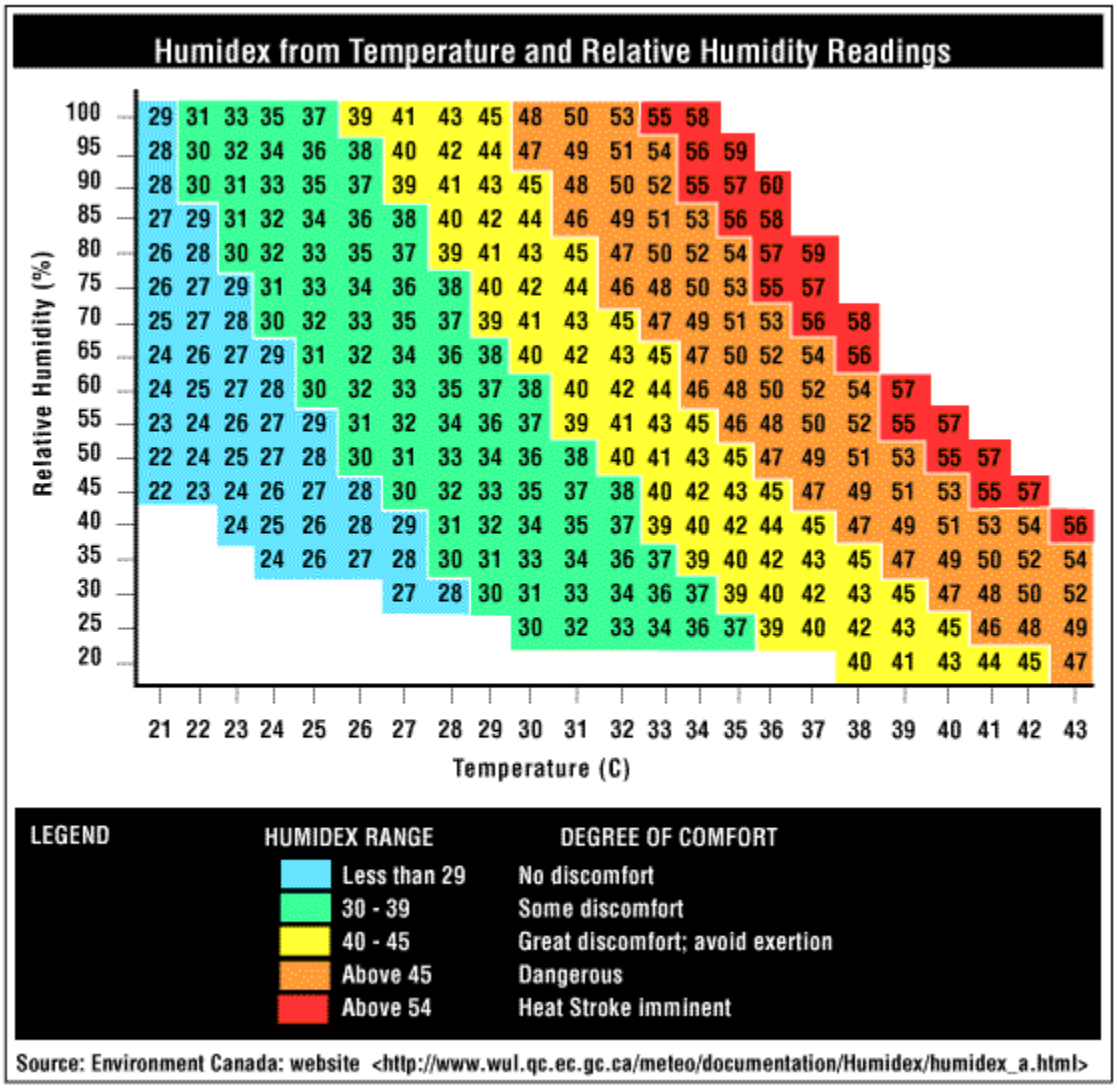

Figure 2: The relationship between temperature and relative humidity [2]

5.3 Motor

The motor will be tested similarly to the pressure sensor i.e. different people with different weight, but motor's test plan will mainly focus on the user's experience such as comfort level etc.

5.4 Smartphone App

It will be tested simultaneously while testing the seat mat component of the system.

- DPIs will reflect the change in the pressure on the mat in real time when the person adjusts or repositions himself. Higher the refresh rate of the receiving signal; faster the change will be reflected via the DPI.
- Humidity and temperature sensors will show the change in the parameter values based on variation in the surrounding conditions as expected for e.g. for cooler and dry surroundings the temperature and humidity values should drop & for hotter and humid surroundings the temperature and humidity values should rise comparatively.
- Vibration motor should turn ON/OFF and run for the specified amount of time as set via the app, which can be measured with the help of external instruments like a stopwatch to confirm the desired functionality.

All of these specified tests will be executed multiple times so that the reliability, durability, and robustness of app can be verified.

6. Conclusion

The goal of *Svasth Healthcare* is to help people prevent pressure sores from developing by creating a *Comfort Mat System*, which informs the user, how much pressure is exerted in a specific area in real time and issuing reminders if the high-pressure area persists for longer durations. It also monitors the other factors involved in causing pressure sores such as temperature and humidity. The proposed *Comfort Mat System* also incorporates vibration motors, which would relieve pressure without even moving. This is especially useful for people who are paralyzed and cannot move on their own. Currently there is nothing in the market for chairs involving pressure sensitive mattresses. People who are bound to wheelchairs are the main target for this product but it can also be used by anyone who uses chair or similar structure for prolonged periods of time. Our team strongly believes that this Comfort Mat System will greatly improve current wheelchair technologies. It will be an easy to adopt solution because it is just an add-on to their existing chair or wheelchair.

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