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Stress Detection Based on Multimodal Data Using Machine Learning Techniques

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Abstract

Stress affects everyone differently but it leads to a variety of health issues. Early detection of stress can prevent many stress-related health problems. Physiological stress can be identified by basic parameters like heart rate, pulse rate, face recognition, respiratory signals, which provide detailed information about the person state of mind. These parameters vary from person to person on the basis of certain things such as their body condition, age, and gender.

Physiological sensor analytics is becoming an important tool to monitor health. Physiological multi-sensor studies have been conducted previously to detect stress. This paper focuses on features like respiration rate, pulse rate and facial expressions that can now be performed with Microsoft Kinect Xbox 360 sensor, Pulse sensor and Camera, to develop an efficient and robust mechanism for accurate stress identification. Using machine learning algorithms on the above features high accuracy in detecting the stress can be achieved.

Index Terms; *Physiological stress, Physiological multi-sensor, Microsoft Kinect Xbox 360 sensor, Pulse sensor*

I. INTRODUCTION

Stress can be simply defined as a “State Of Mind” because a person can take the situation or work in an easy way or in a hard way which can lead to the person to be stressed. It completely depends on how the person has seen the situation. Generally it applied to various mentally and bodily pressures experienced or felt by people throughout their lives. In this paper, we propose a stress detection model by analyzing multi-physiological features.

Physiological Stress

“The process of physiological stress response starts from the moment the body realizes the existence of the stressor, lead by the sending of signals to the brain, and to the specific sympathetic and hormonal responses to eliminate, lessen or manage with the stress.” [1] Features use to detect physiological stress:

1. **Facial Expressions:** Facial expressions of emotion signal biological responses to stress. Fear, anger, disgust expressions signal inflated cortisol and cardiovascular reactivity.
2. **Pulse rate:** A stressful situation start out a chain of events. Human body releases adrenaline, where a hormone that temporarily causes people breathing and heart rate to speed up and also blood pressure rises.
3. **Respiratory rate:** Stress-related emotions such as anxiety generate rapid and shallower breathing. During the stress response, people breathe accelerate in an effort to quickly distribute oxygen-rich blood to body.
4. **Others:**

a. Increases blood flow in the forehead and around the eyes.

b. Electrical conductivity of the skin surface.

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Previous Studies

The definition of many mental states is still debated [12]. For instance, Andrews et al. recommended renaming the generalized anxiety disorder as generalized worry disorder [2, 12]. Regarding Social Signal Processing (SSP), the concepts like synchrony and engagement are still being polished [3, 4, 12]. This lack of definition is an important issue since it impacts how a mental state can be elicited and assessed.

Bolhari, Alireza et al. (2012) [5, 11] have examined the office place stress. Kim, Jong-Ho et al. (1992) [6, 11] explored the social life of college students and emphasized the effect of physical exercises in reducing stress levels. Salai, Mario et al. (2016) [7, 11] have researched on automatic stress detection by measuring the heart rate variability (HRV) using a low cost heart rate sensor and chest belt, used the galvanic skin response (GSR), electromyography (EMG), skin temperature, electrocardiography (ECG) and skin conductance as the indicators of stress.

In current work, used a machine learning approach to detect stress using physiological features by taking measurements from Kinect sensor to get respiration data, pulse sensor to get pulse rate and camera to get facial expressions.

II. PHYSIOLOGICAL MULTI-SENSOR

Microsoft Kinect Xbox 360Sensor

As Luo and Yang state, Microsoft Kinect for Xbox 360 and Xbox One video game consoles and Windows PCs uses line of motion sensing input devices [8]. It uses a device similar to web camera, designed in a way that users can control through various gestures and even speech. In late 2011, Microsoft released a Software Development Kit (SDK) for its Kinect sensors. The SDK allows users to establish refined computer-based human motion tracking applications in C# and C++ programming languages.

Kinect sensor for xbox 360 components as shown in Figure 1 explained below:

a. **3-D Depth Sensors** tracks your body within the play space

b. **RGB** (red, green, blue) **Camera** helps to identify human body and takes in-game pictures and videos.

c. **Multiple microphones** uses for voice recognition and chat.

d. **Motorized Tilt** automatically tilts the sensor head up and down when needed. Do not manually tilt the sensor.

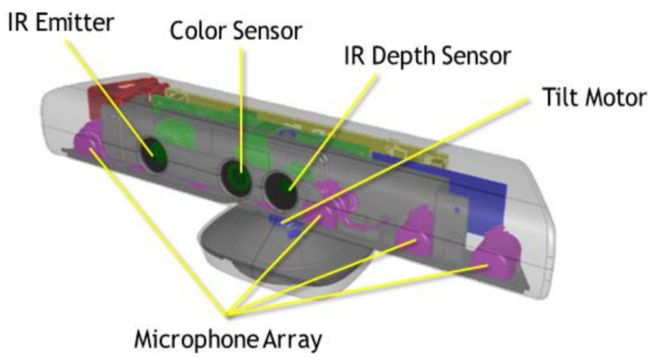

Figure 1 Kinect Xbox 360 with components

Pulse Sensor

Pulse Sensor as shown in Figure 2 Amped is a plug-and-play heart-rate sensor for Arduino and Arduino compatibles. It amplifies and noise cancellation circuitry to the hardware. It's noticeably faster and easier to get reliable pulse readings. It amped works with either a 3V or 5V Arduino.

When a heartbeat occurs blood is pumped through the human body and gets squeezed into the capillary tissues. The volume of these capillary tissues grows as a result of the heartbeat. The pulse sensor module has a light which helps in measuring the pulse rate. This affects the reflection of light and the light reflected at the time of a heartbeat will be less compared to that of the time during which there is no heartbeat. This variation in light transmission and reflection can be obtained as a pulse from the output of pulse sensor.

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March - April 2020
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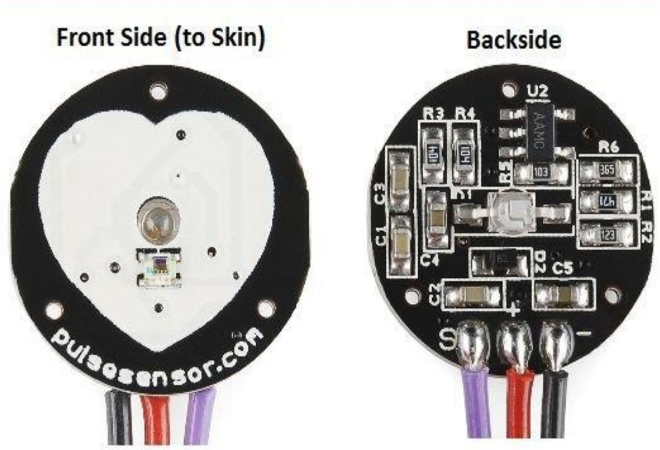

Figure 2 Pulse Sensor

Facial Expression

Human changes their facial expressions as per the stress. Some of the expressions are shown in Figure 3 like anger, disgust, fear and sadness

Figure 3 Facial Expressions

III. PROPOSED SYSTEM

In this model, the data collected from the physiological sensors like Microsoft Kinect xbox 360 sensor, pulse sensor and facial expression model.

Collected data is manually combined in a .csv file format. This data can be taken for dataset to build a model or taken to predict.

By using label encoder methods pre-processing the data to make sure that it fits the model. In this model, Facial expression model output is considered as a class probability for the naïve bayes algorithm. In this model the naïve bayes algorithm is taken into consider because it gives an efficient classification. After preprocessing the data, extract the features which are required.

To build a model using Gaussian naïve bayes as it is a one of the best model for continuous input format. Bell shape normal distribution output occurs which helps to get the output accurately. As now built a model, predict the new person is stressed or normal, take the measurements of the person by using physiological sensors and give them to the model.

The model evaluates the new data and checks the conditional probability and predicts weather the person is stressed or normal.

As this model gives the prediction based on conditional probability which can be checked by finding the values like precision, recall and f1-score.Architecture design is shown in Figure 4

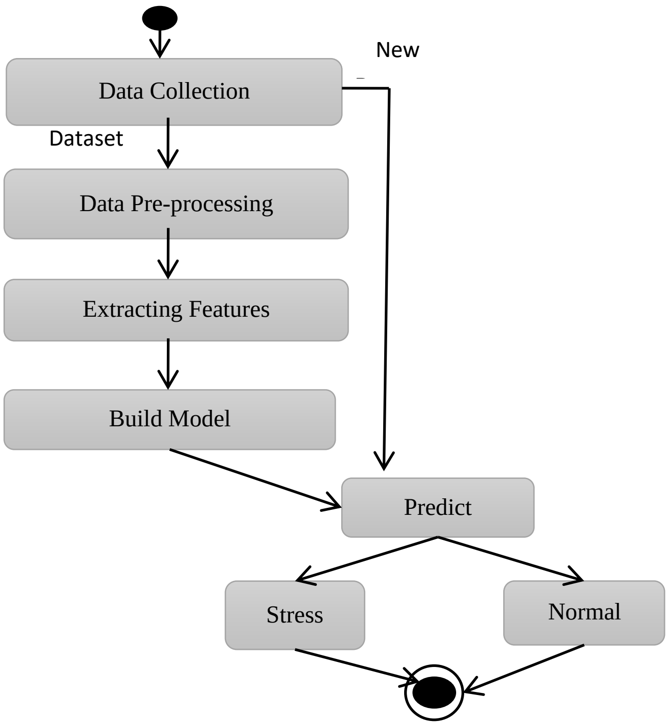

Figure 4 Implementation

As the dataset is not available to the project, so preparing a dataset itself is a major challenge. In this project, a dataset is prepared by using a Microsoft Kinect Xbox 360 sensor for respiration rate, pulse sensor for pulse rate and camera for facial expression.

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March - April 2020
ISSN: 0193-4120 Page No. 7403 - 7410

Respiration Rate

To collect the skeleton data from Microsoft Kinect Xbox 360 sensor:

1. Connect the sensor to the laptop/PC.
2. Open Kinect Stream Saver Application _SDK1 [9], enter required info and select required files formats.
3. Click on "Start" to record the selected skeleton and depth images data of the human. [ref Figure 5]

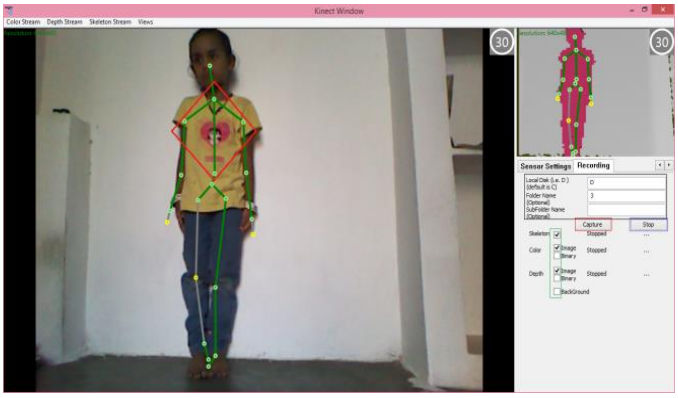

Figure 5 Kinect Recording Options

4. Click on "Stop" to terminate the recording.
5. After click on "Stop" button, can see the generated files in the destination folder. See figure 6

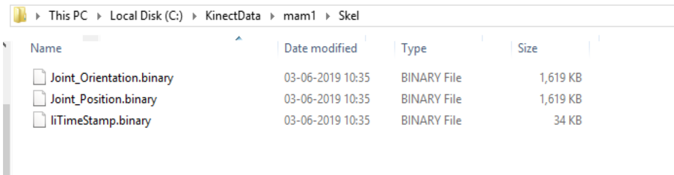

Figure 6 Generated Files

By using kinect collected skeleton data files needs to extract the information from Joint_Position.binary file and save in the .csv file. Since the Kinect sensor operates with a frame rate of 30 fps, can find the frame interval using:

frame interval = 1/ f ps = 1/30 = 0.0333

Respiratory rate readings are not instantaneous because they rely on calculating difference between two consecutive breaths in the frame sequences (N) [10]. Let Bi be a vector of length N for a number of consecutive breaths:

Bi = [Bi(1), Bi(2), Bi(3), ... Bi(N)]

To examine the differences between the conjoining elements of Bi, let assume B = di f f ([0 Bi]) which returns a vector of length N - 1. To define the positions of a nonzero value in B, applying C = f ind(B) which returns a vector with M length that containing nonzero values [10]. By calculating the differences among C values, and multiply them by the frame interval, can measure the vector of respiratory cycles (Rc) over time (t). This vector is stored in the workspace. For the next N sequence, repeat the previous steps to obtain other respiratory cycles and so on. Now can detect apnoea and respiratory rate (breaths/min) using the following relations:

Generally, the respiratory rate varies with age, but the normal range is between 30–60 breaths/min for infants, 22–28 breaths/min for children, 16–20 breaths/min for teenagers and 14–18 breaths/min for adults [10].

Pulse Rate

$$Rc_{current} = Rc_2 - Rc_1 = \begin{cases} Rc_{current} \approx Rc_1, Rc_2, \ldots Rc_{M-1} \Rightarrow normal \\ Rc_{current} \geq 10sec \Longrightarrow Apnea \end{cases}$$

$$respiratory\ rate = \frac{60\ \text{s}}{Rc}$$

To collect the pulse rate from pulse sensor:

Connection between Pulse Sensor to Aurdino as shown in Figure 7

1. '+' is connected to +5V or +3.3 or Vin (Vin Pin of the Arduino is used when the external power is supplied to the Arduino board)

2. '-' is connected to any one of the GND pins of Arduino

3. The 'S' pin i.e., the signal pin is connected to any of the analog pins (A0,A1,A2,A3,A4,A5) of the Arduino to use the sensor in analog mode.

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March - April 2020
ISSN: 0193-4120 Page No. 7403 - 7410

Figure 7 Pulse Sensor connection with Arduino

Following are the procedure to get the pulse rate:

1. Make sure that the sensor is properly connected

2. Make sure that the Arduino is connected to the desired port according to its configuration

3. Run the file

4. Place the finger gently on the pulse sensor over its light emitter (With hands non-wet)

5. Each data collected from the pulse is plotted simultaneously on the graph using drawnowfunction

6. If the collected data is a valid one store it else discard the data if there exists huge deviation from mean of the data

7. Output the values to a text file

8. Print the target heart rate range, average Resting heart rate.

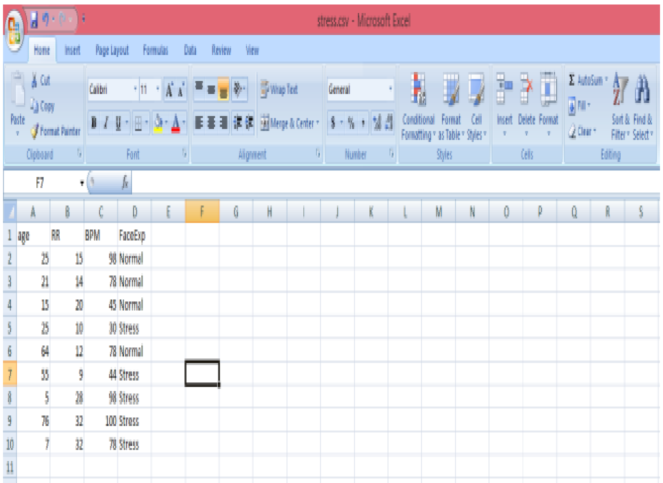
9. By using pulse sensor data files generated need to calculate the pulse rate. Average the person recorded data to get the pulse rate.

Facial Expression Status

1. Load face detector [13]: Load OpenCV's HAAR face detector (haarcascade_frontalface_alt2.xml). Take input as a cropped facial image.
2. Load landmark detector [13]: Next, landmark detector (shape predictor.dat) is loaded.
3. Capture frames from webcam: Next step, grab and process a video frame.
4. Detect faces [13]: Run the face detector on every frame of the video which gives the output as a vector of rectangles that contain one or more faces in the image.
5. Run facial landmark detector [13]: Pass the original image and the detected face rectangles to the facial landmark detector.
6. Draw landmarks [13]: Once it has obtained the landmarks, can draw them on the frame for display
7. Now note down the stress status as a reading in the FaceExp.

Combining the data in the .csv format

After getting all data from the sensors, manually now integrating information and saving in the .csv[common separated values] files as shown in Figure 8



age	RR	BPM	FaceExp
25	15	98	Normal
21	14	78	Normal
15	20	45	Normal
25	10	30	Stress
64	12	78	Normal
55	9	44	Stress
5	28	98	Stress
76	32	100	Stress
7	32	78	Stress

Figure 8 Prepared Dataset

IV. RESULTS AND DISCUSSION

The experimental results obtained from the different age group of peoples. Collected data like respiration rate from Microsoft kinect Xbox 360 by using Kinect stream saver application _SDK 1 software, beats per minute by using pulse sensor and facial expressions from laptop camera, shown in figure 9.

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March - April 2020
ISSN: 0193-4120 Page No. 7403 - 7410

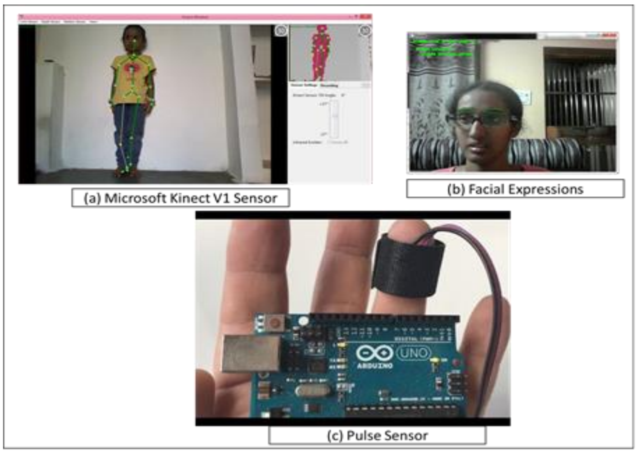

Figure 9 Data Collection

Save this data in .csv file. To preprocess the data [14], Label Encoding refers to converting the labels into numeric form so as to convert it into the machine-readable form. Machine learning algorithms can then decide in a better way on how those labels must be operated. It is an important pre-processing step for the structured dataset in supervised learning.

Here the "Stress" word is converted to 1 and "Normal" is converted to 0, shown in Figure 10. Now build the model by using Naïve Bayes algorithm.

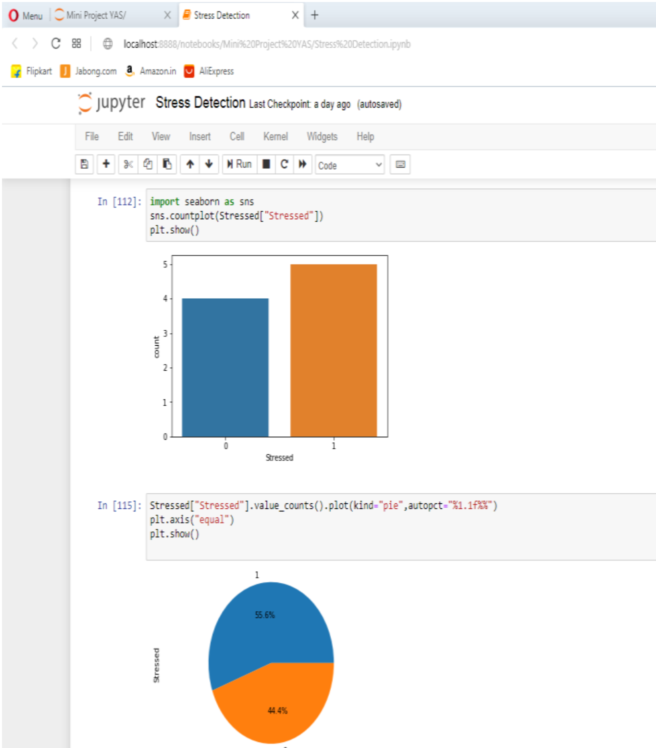

Figure 4 Pre-processed data

Plotted precision, recall and f1 score of classification report to check the model quality, in different types of graph shown in Figure 11

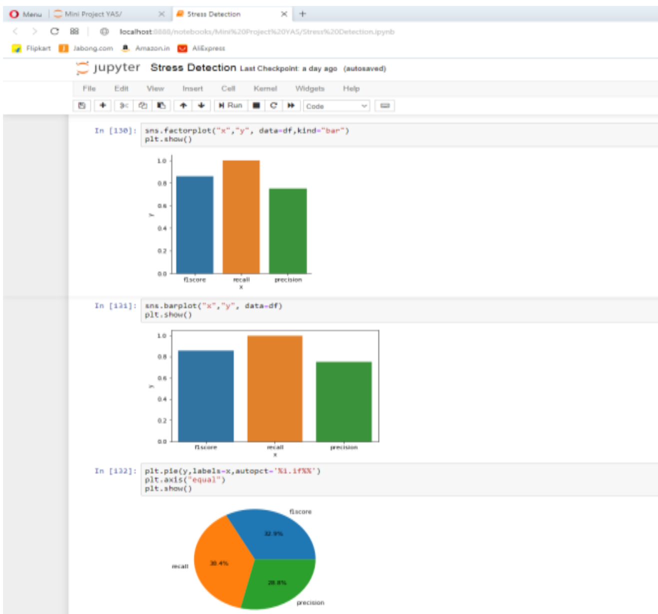

Figure 5 Classification Report

To test the model are giving test data from the new person like his/her age, respiration rate, bpm to predict the person is stress or normal based on the previous model data. Shown in Figure 13. Table 2

March - April 2020
ISSN: 0193-4120 Page No. 7403 - 7410

shows the normal respiration rate and pulse rate for different persons. If any person has abnormal rate, then that person is classified as "Stressed", otherwise "Normal"

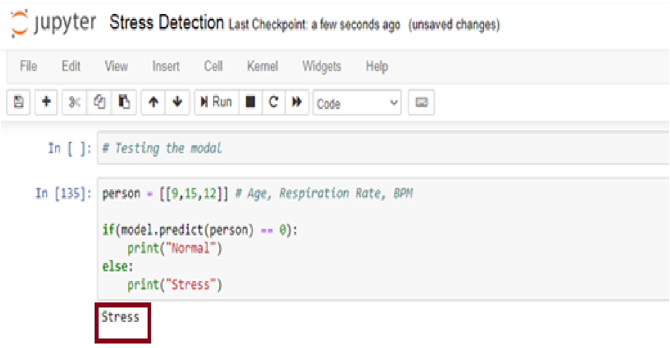

Figure 13Testing

Table 2: Comparison between different age, respiration rate, bpm for normal person		
Age	**Respiration Rate (bpm)**	**Pulse Rate (bpm)**
New born	30-60 breaths / minute	60-100 beats / minute
Infant (1 to 12 months)	30-60 breaths / minute	60-100 beats / minute
Toddler (1-2 years)	24-40 breaths / minute	60-100 beats / minute
Pre-schooler (3-5 years)	22-34 breaths / minute	60-100 beats / minute
School-age child (6-12 years)	18-30 breaths / minute	60-100 beats / minute
Adolescent (13-above years)	12-16 breaths / minute	60-100 beats / minute
Athlete	12-16 breaths / minute	40-60 eats / minute

V. CONCLUSION AND FUTURE ENHANCEMENTS

In this project, physiological features like respiration rate, pulse rate and facial expressions are used for detecting stress. In traditional systems, the data collected by the people perceptive like themselves, physiologist experts and external observer and then classified the person is stress or normal, which is biased classification. In this project to avoid the data bias, data collected from the sensors like Microsoft Kinect Xbox 360 for respiration rate, pulse sensor for pulse rate and camera for facial expressions. To classify the person is stress or normal, naïve bayes algorithm is used which is strong to classify based on the conditions. In dataset age, respiration rate and pulse rate (bpm) are considered as conditional probability and facial expression model result is considered as a class probability. By using this model 75% accuracy is achieved.

Data collection from the sensors is taken from three individual interfaces and combined manually. Future work needs to develop a single interface to collect and combine all data from the sensors to reduce the manual work.

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