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Lie Detector Product Report

Executive Summary

Our aim was to produce a device that can identify signs of deception to determine whether a user is lying or telling the truth. It is to be used in a casual setting, such as an office game of two truths and a lie. The device required non-invasive biometric input from users in order to determine a confidence level that is displayed through light. For our purposes, we chose to measure heart rate, as well as skin conductance and temperature. These values were chosen based on a study conducted at the University of Wisconsin[1] which sought to determine physiological indicators of deception. The product was also intended to be battery-powered and compact, with the central detection unit durably enclosed.

This product is powered by two 18650 batteries. An Arduino Uno is used in conjunction with a heart-rate sensor, the MAX30102, and a temperature and humidity sensor, the SHT20. These sensors connect to the user's index and middle finger via velcro. The Arduino was coded to compare user input to pre-calculated parameters which were determined through testing. Based on the calculated confidence level, a result is displayed via LCD screen. All components are enclosed within an acrylic enclosure.

The product fails to meet the set metrics for precision and accuracy as testing displayed no real correlation between these biometrics and a person's honesty. Upon further talk with the client, we determined that accuracy was not substantially important to the goal of the product. The product's purpose is to be used in a game, so one of the non-measurable goals is for the product to be fun and used as an ice-breaker.

Key Functions and Metrics

The goal of this product was to develop an easy-to-use lie detector to be triggered by trained users to match calibrated values of reliability in order to win a game of two truths and a lie. It was to be completed by 12/5/23 with a budget of $200.

The key functions of this product include its ability to read temperature, humidity, and heart rate non-invasively. The MAX30102[2] and SHT20[3] sensors were determined to effectively measure these quantities without causing harm to the user based on their description as being used in wearable technology. These signals needed to be processed in order to determine a result. This function is achieved through the use of the Arduino Uno R3. Finally, these results were required to be displayed via light, specifically the I2C/TWI LCD1602 Module (DFR0063).

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[1] Relevant information presented in the study can be found in the reference section.
[2] MAX30102 Calibration Plot
[3] SHT20 Calibration Plot

Our primary objective for production was ensuring the safety of the user. Therefore, the voltage used to operate the device is under 25 V, and it is not connected to a wall current. Moreover, all biometric input is taken noninvasively.

Secondary objectives include durability and portability. Specifically, the product was expected to withstand a drop of up to five feet and have dimensions of less than 5 x 8 inches.

To ensure proper functionality, the device needed to be easy to use and require minimal training on the user's behalf. It was intended to provide quick results in order to be useful in a casual setting, such as while playing a game. For this reason, results needed to be displayed in ten seconds or less.

Due to the casual nature of the product while accuracy is not a prioritized objective, it's still a concern of the client. To mitigate as much error and uncertainty as possible despite the unreliability of standard polygraph machines, two sensors were used to log biometric values cited by the University of Wisconsin. Those values were what that university's study concluded to be the best biometric values to have a better guess at whether or not the test subject was lying.

Design Alternatives Considered

We considered using H124SG electrodes to measure the heart rate of the user. These are disposable electrodes used to measure EEG, ECG, and EMG. These electrodes would have been used like antennae to amplify the signals received from the MAX30102. We deemed the electrode unnecessary because we could obtain raw data from the MAX30102. Additionally, the electrodes would not be reusable, as they attach to the user via gel adhesive and are disposed of after each use. Using disposable sensors for this product would also not be environmentally efficient. Furthermore, electrodes would not be the most efficient means for data collection, due to the intended use case of the product being for a relatively quick game.

The production of this device required displaying results via light. Based on this objective, we could display results via an LCD screen or LEDs. For LEDs, results would have needed to be displayed through a signal, such as varying blinking or intensity. The LCD on the other hand provided a more accessible reading. This eliminated any training that the user may need to understand the results. It also allowed a confidence level to be displayed more clearly.

Evaluation of Results

From the SHT20 and the MAX30102 calibration results found in appendix (Document 12 and 13), we see that there is no correlation between the measured biometric values and the user's honesty. Both sensors' values for truth or lie were less than five units away from each other, and their bounds of standard deviation were essentially overlapping. There is no clear bin range of data values that distinguish between truth or lie from our testing. This leads to being unable to meet the metrics initially sought in the design process of the product with regards to its accuracy.

The calculation of the confidence value displayed on the device's screen is by the logic that if values fall within the bin's range, it displays truth or lie depending on which mean has the greatest error percentage from the measured value. One hundred minus this error percentage is the confidence value displayed to the participants. This is the case for if both sensors detect the same result, as in both truth or lie, since the bounds of standard deviation overlap for both truth or lie. When a dataset falls in one sensor's bound but outside another sensor's bound, depending on whether or not the error percentage is smaller for lie or truth one of those two gets displayed with the confidence level of 100 minus error percentage.

We initially intended to drop test our product from a height of five feet, but ultimately decided against this. Acrylic is brittle and we used individual panels with acrylic adhesive for our housing. Adhesive was selected to decrease the device's weight and increase portability. Because we chose not to use any mechanical fasteners, the bondability of our acrylic adhesive was a limiting factor which made the device unsuitable for a drop test. The drop test was also deemed unnecessary based on the product's intended use. In an office setting, the device would be placed on a surface that would likely be lower than five feet, and transporting the device is easy given its compact and portable size. It is unlikely that the device would undergo a drop of five feet.

The desired dimensions for our product were less than 5 x 8 x 3 inches. This was to ensure that it is portable and compact. The final product housing has dimensions of 4.7 x 4.7 x 2.7 inches.

For user ease, the product was intended to produce results in ten seconds or less. To meet this goal, the device was coded to produce a result in five seconds. This can be seen within the product video.

To guarantee safety, the device must operate at a voltage of less than 25V and not be connected to a wall current. The two 18650 batteries in series provide a combined voltage of 7.4V, which is only used to power the Arduino. All other components are connected to the 5V or digital pins of the Arduino, and thus have a maximum voltage of 5V. These values are significantly lower than our maximum of 25V. The device is battery powered and thus not connected to the wall current.

Lessons Learned

For the wiring used in our device, we learned that the I^2C protocols allowed our devices to be grouped into a single SCL/SDA wire rather than having an individual SCL/SDA wire and pin for each component. These components would still work properly in parallel with this setup. In terms of our product's housing, the design made the difference in how we wanted the user to interface with the product. OnShape allowed us to better decide how much space our components would require and what the optimal placement of said components would be. When it comes to manufacturing and assembling, it is important to be patient and allow yourself a certain room for error. The software side of the device made all of us understand the nuance of statistics about data analysis and how to draw conclusions based on the data collected with regards to the mean and standard deviation of a dataset. Also, we learned a lot about how to filter noise and outliers from a sensor's reading and also how to properly calibrate a sensor's value.

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Appendix

1.) A1 Group 5- Glass Box

2.) Power Budget

3.) Cost List

4.) Circuit Diagram

5.) MAX30102 Modeling

6.) Morph Chart

7.) Product Objectives and Metrics

8.) Pairwise Comparison Chart

9.) CAD Drawings & Assembly

10.) Code FlowChart

11.) Group 5 Lie Detector User Manual

12.) Truth and Lie Chart for Humidity

13.) Truth and Lie Chart for MAX30102