Smart Diagnostic Toy

For early, at-home detection of development delays in young children!

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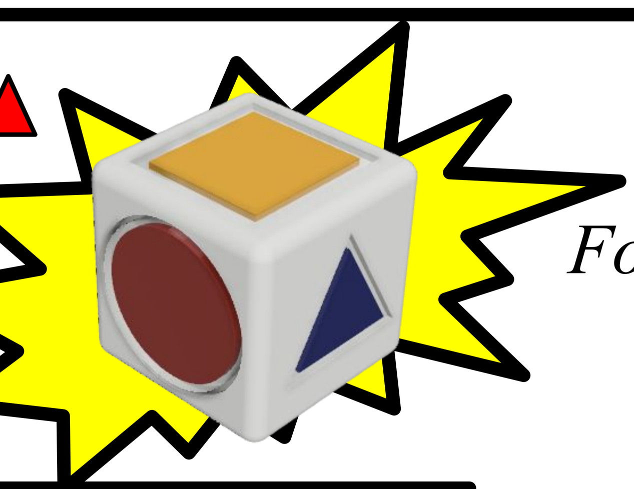
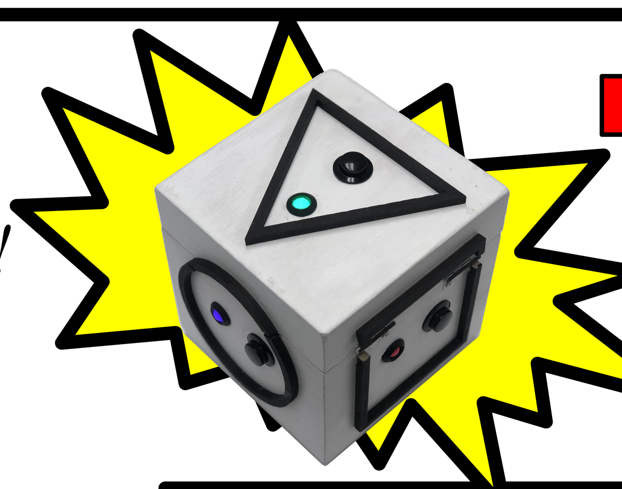




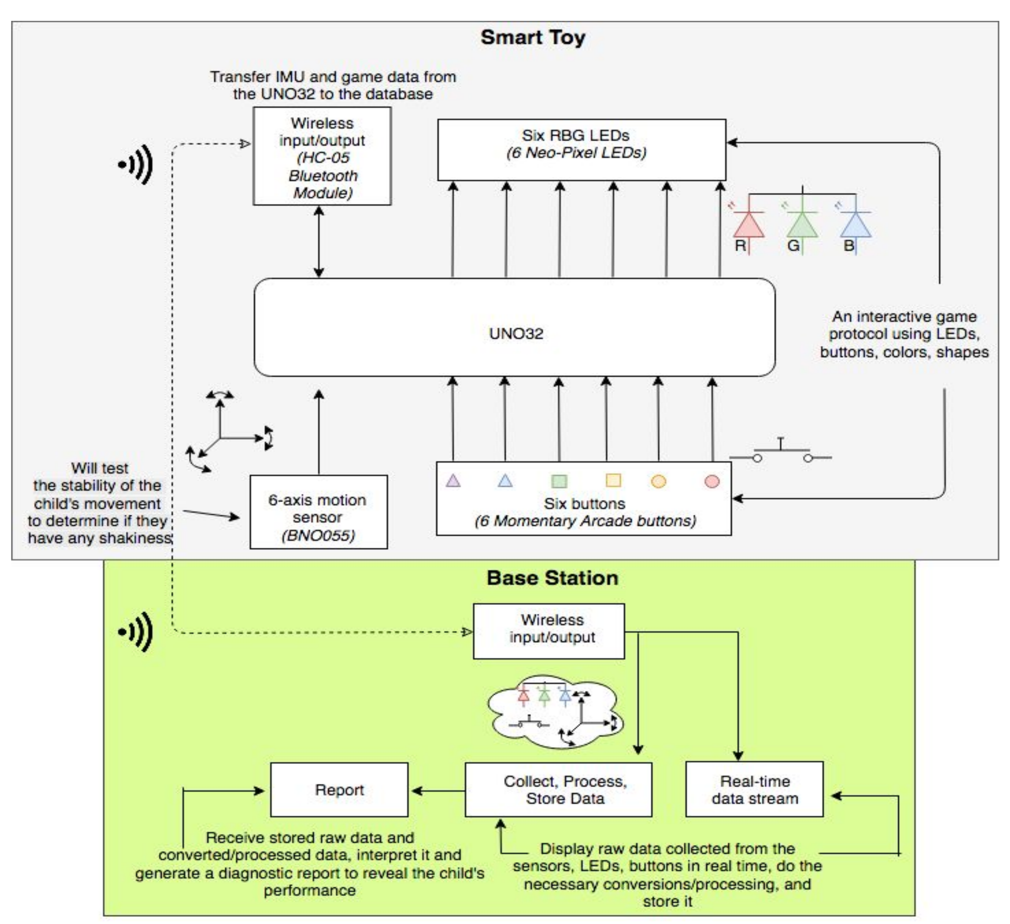
Background/Motivation

- Accurate and early detection of development delays in young children is crucial for maintaining good health
- Conditions such as attention-deficit/hyperactivity disorder (ADHD) and autism spectrum disorder (ASD) begin to show signs at an early age.
- It can be difficult to gather pertinent and impartial information just through ordinary doctor visits
- Thus it would be beneficial to have a device through which such diagnosis could be conducted over a period of time within the comfort of a child's own home

Design

- Our team proposed the creation of a "smart toy" in the form of an interactive cube entailing the following deliverables:
  - an interactive game with pressable buttons and reactive RGB LEDs
  - a 6-axis motion tracking sensor in order to provide diagnostic data regarding fine motor skills
  - a real-time data link that would be maintained through wireless communication from the device to a base station in order to monitor the data being generated in real time, collect it for analysis, and generate a diagnostic report

Overall Architecture



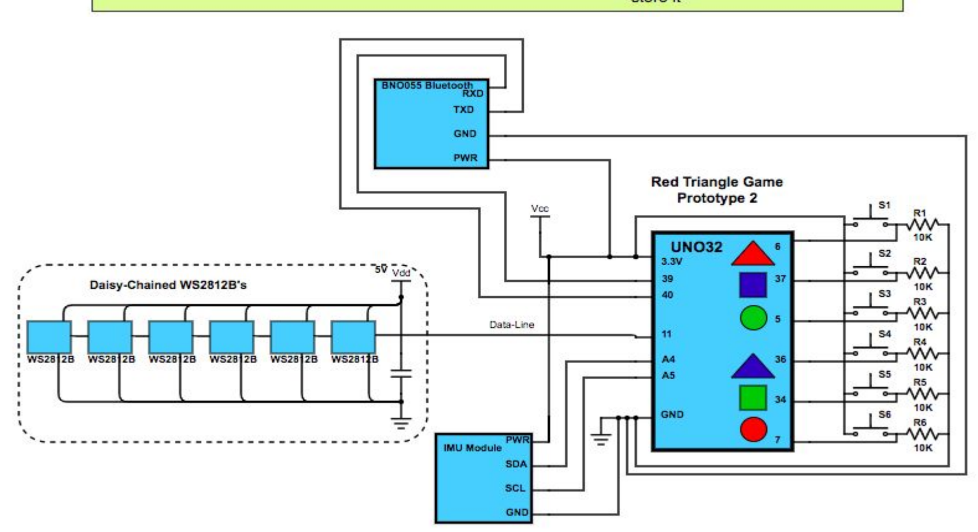


Figure 1: The main hardware components of the smart toy design are the UNO32 microcontroller board, 6 neo-pixel LEDs, 6 momentary arcade buttons, the BNO055 IMU module, and the HC-05 bluetooth. The UNO32, LEDs, and buttons are responsible for the interactive color-shape game. The IMU module records the cube's motion and the bluetooth maintains a real-time data link that transmits the results from the game and the IMU, displays the information in a window, and generates a diagnostic report based off of it.

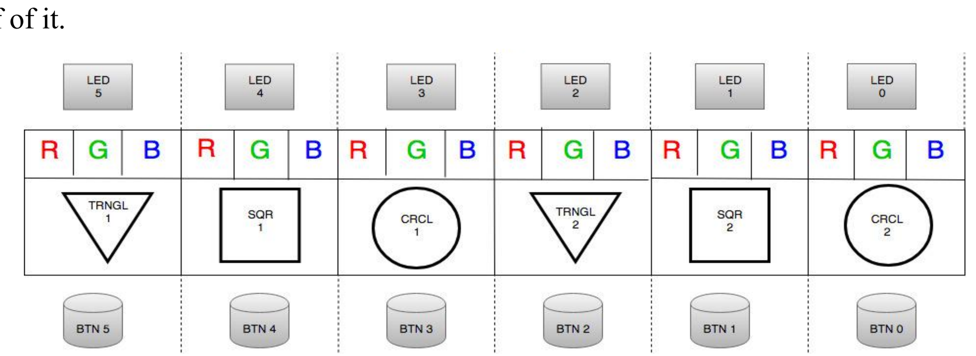
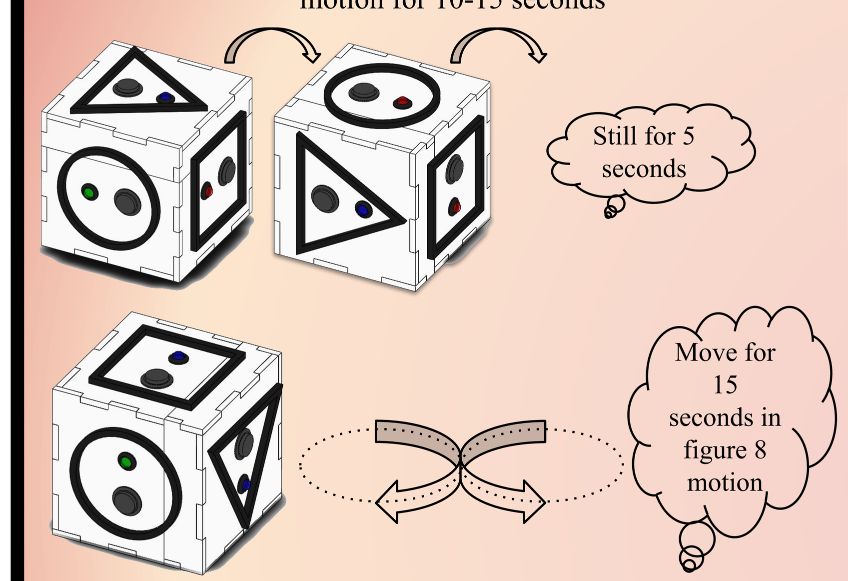


Figure 2: The software component of our design is a game dealing with different colors and shapes. Each face of the cube has a button, an LED, and a shape (triangle, square or circle). The LEDs randomly light up to different colors (red, green, or blue). The user is prompted to press the button pertaining to a particular color and shape combination. The prompts and responses as well as the accuracy and timing of the responses are stored as the results of the game.

Method/Approach

1 Calibrate/Set-up the Cube
- Turn it on
- Let it sit at each face for about 5 seconds
- Move it in a slow figure 8 motion for 10-15 seconds



2 Enter patient information into a text
- Name
- Age
- Gender
- Date of birth
- Doctor name

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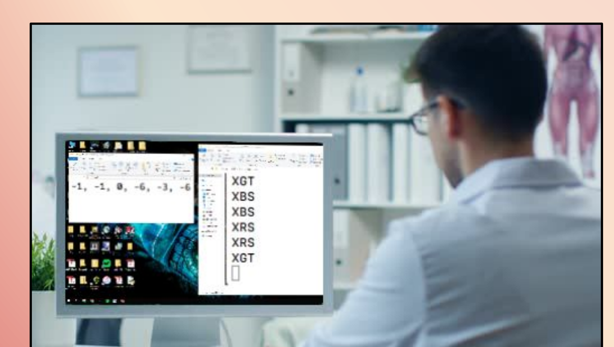
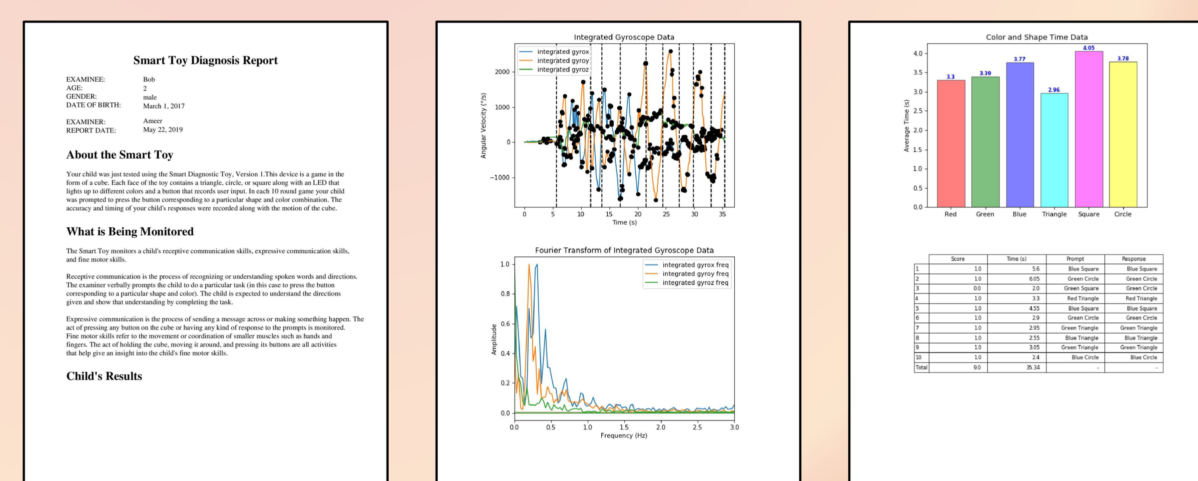
Enter patients name: Bob
Enter patients age: 2
Enter patients gender: male
Enter patients date of birth: March 1, 2017
Enter the examiners name: Ameer
```

3 Introduce the cube to the patient
- Start running the python script handling bluetooth communication

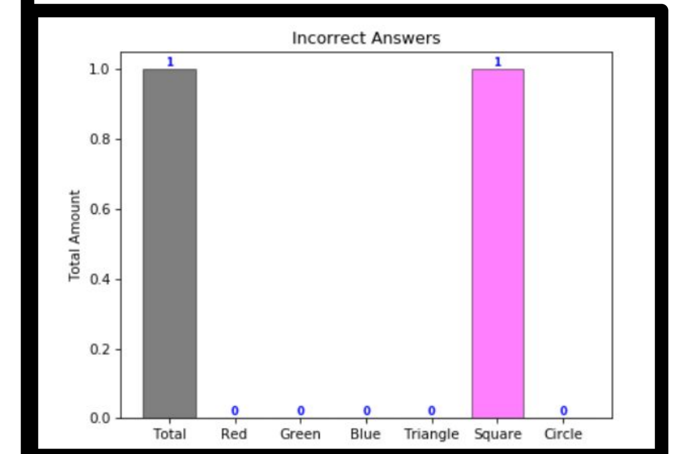
4 Have patient start the game
- Prompt information gets printed to serial port
- IMU Data gets streamed in a window
- IMU Data and game results get stored in a csv file

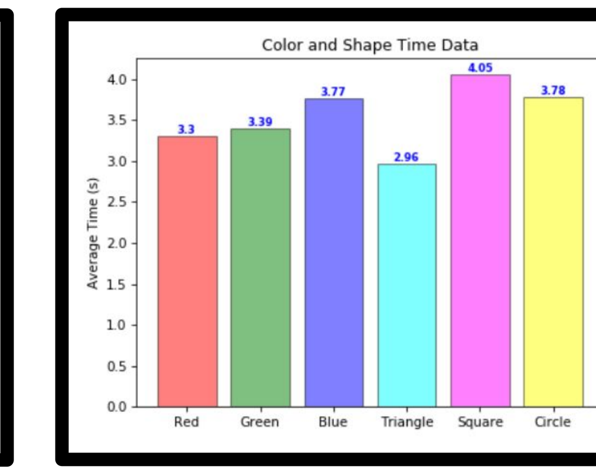


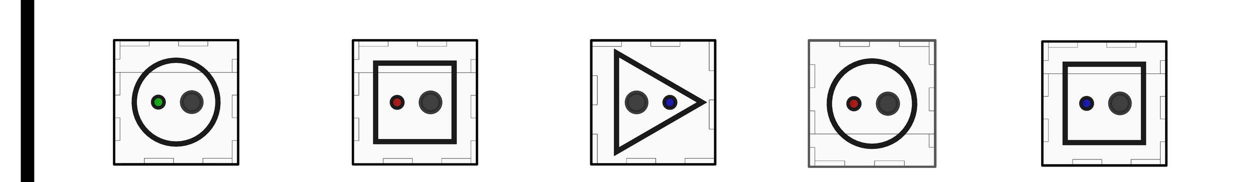
5 When the game is over run the python script that processes/analyzes the data and generates the report



Game Results







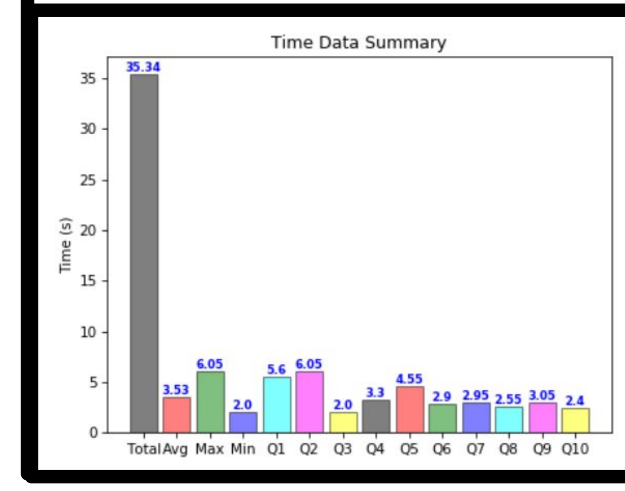
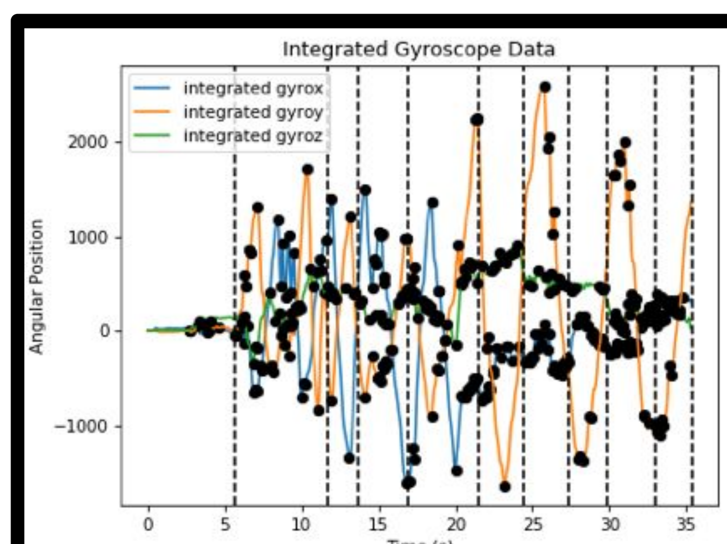


Figure 4: The following set of bar graphs summarize the results of the test. The first bar graph keeps track of incorrect answers which are categorized by shape and color. The second bar graph shows the total time, average time, maximum time, minimum time and time taken to answer each question. The last bar graph shows the average time taken to recognize each color and shape.

Sensor Data



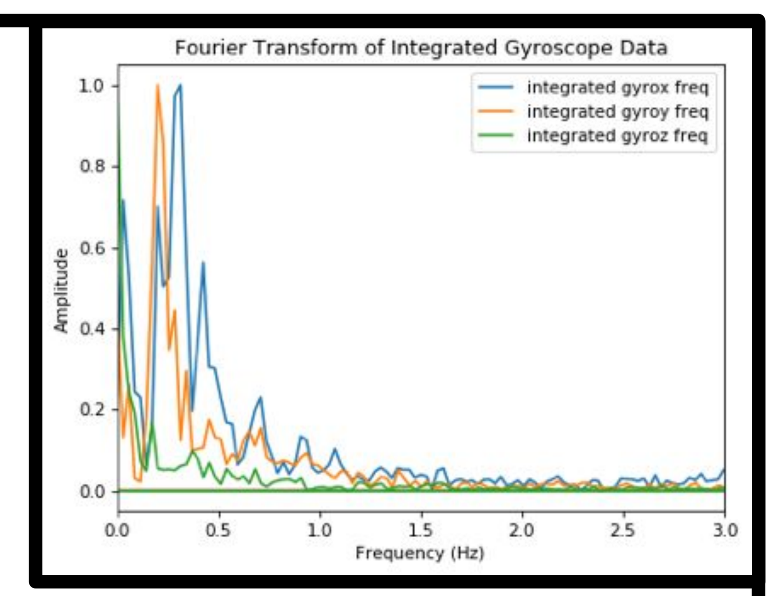
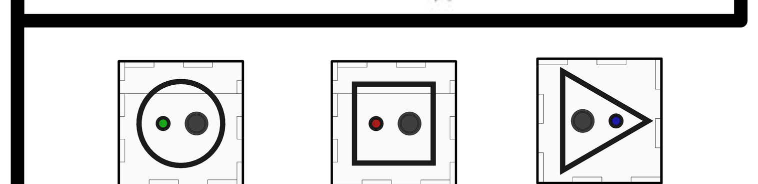
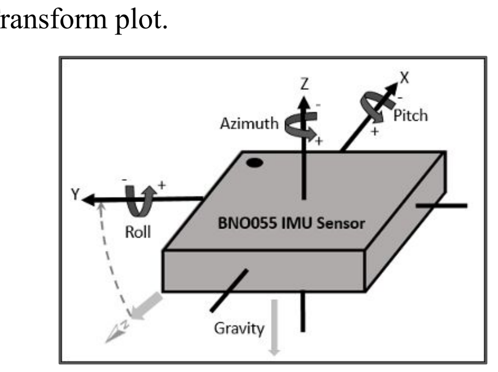
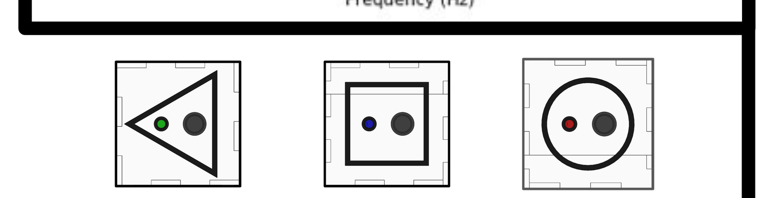
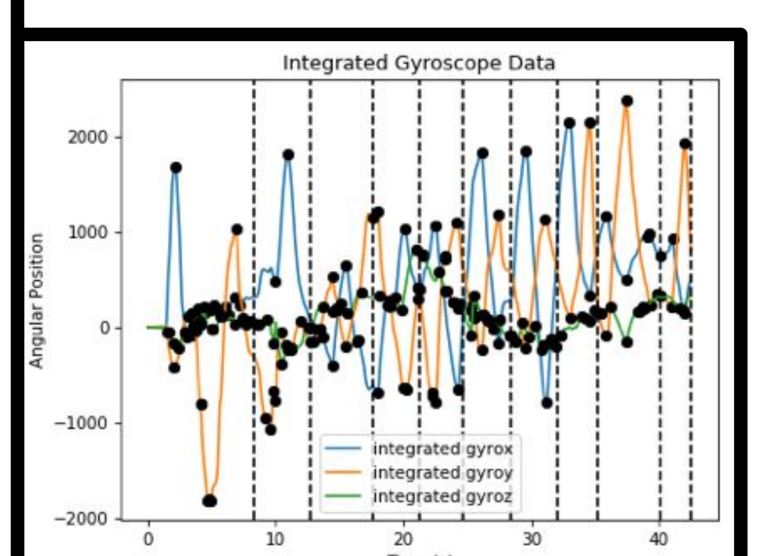


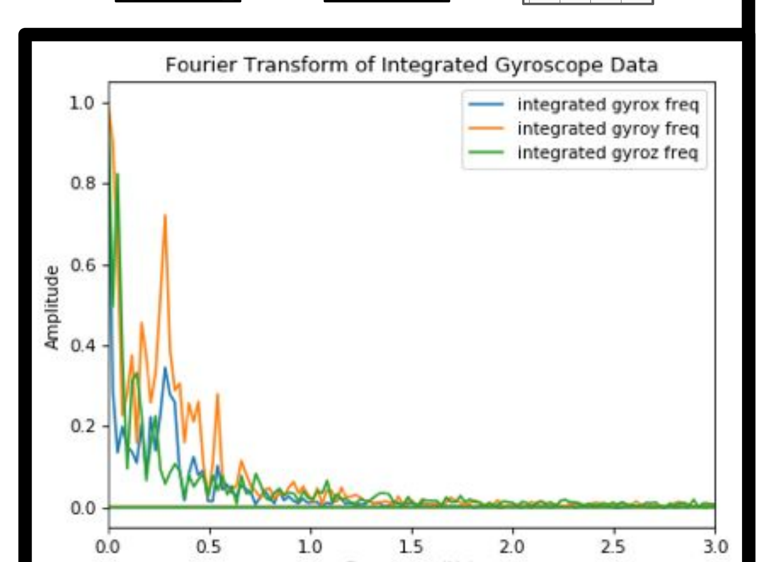
Figure 3: The plots on the left display the integrated lateral, longitudinal and vertical angular positions collected from a gyroscope. The black dots on the graph mark the inflection points. The black dashed vertical lines mark the time in which each button was pressed. The least amount of dots between the peaks and valleys would suggest a stable rotation. The plots on the right display the Fourier Transform for the integrated gyroscope data. The examiner can determine the steadiness of the cube by analyzing the frequency from the Fourier Transform plot.











The upper two plots are from an 'unsteady' test; there are more inflection points (particularly noticeable between the peak and valleys) on the plot of angular position and the Fourier Transform plot has its highest peaks at higher frequencies. The lower two plots are from a 'steady' test, with the angular position plot displaying fewer inflection points and the Fourier Transform's highest peaks at lower frequencies.

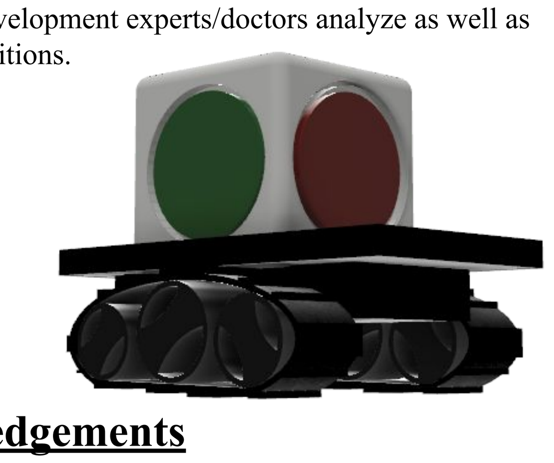
Conclusion

We have a proof of concept for a device that can help in the diagnosis of early development delays in young children via:
- An interactive game
- A motion sensing protocol
- A communication setup through which the data can be transmitted
- Automatic analysis of data to generate a report

Future Work

This device can be built upon to increase its use and testing capabilities. Some ideas include:
- Adding a mobile component to test for gross motor skills
- Building multiple cubes that could interact with one another
- Adding sounds
- Adding numbers

In addition to possible expansions that can be made to the physical device, the data generated by the sensors can be used in a variety of ways to help child development experts/doctors analyze as well as test for different conditions.



Acknowledgements

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References

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