DESIGN OF WEIGHT DISTRIBUTION MONITORING SYSTEM

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Abstract

There exists a need for a device that can supplement patients as they undergo physical therapy for balance issues. The device should measure four-directional weight distribution and operate for 20-minute intervals. For the convenience of the patients, the device should be portable (less than 5 kg), thin (less than 5 cm), and loud enough to be heard in an ambient setting (at least 60 decibels). The four-directional weight distribution device was designed using load cells from a commercial bathroom scale by utilizing a speaker that provided real-time feedback of the patient's weight distribution. The device is reliable and has adjustable volume from 0 to 65 decibels.

Background

- Neurological disorders affect over 800,000 people per year in the U.S., and this rate is rapidly increasing.[1,2,3]
- Those who suffer various disorders often develop balance issues.[3]
- Physical therapy methods exist to treat balance disorders by treatment involving effort, gait, and muscle training.[4]
- Kim Skinner from Tactile Communication and Neurorehabilitation Laboratory (TCNL) has innovative physical therapy method that involves tongue electrical stimulation to stimulation retention of balance training.[5]
- TCNL instructs patients to practice balancing at home by standing in front of a mirror; very subjective and inaccurate.
- There is a need for a more objective balance biofeedback device that can be used in non-clinical settings.

Motivation

Current devices:

- Wii Fit Balance Board ($100)
  - Requires external monitor
  - Requires Nintendo Wii ($200)
- SMART Balance Master ($100,000)
  - Expensive
  - Bulky
  - Delay in response

Figure 1: Wii Balance Board (top) and SMART Balance Master (bottom)

Design Criteria

Client Requirements

- Measure four-directional weight distribution
- Withstand up to 900 N (200 lb)
- Operate for 20-minute intervals
- Cost less than $200

Board Specifications

- Portable (less than 5 kg)
- Thin (less than 5 cm)
- Loud (at least 60 decibels)

Previous Design

- Designed in Fall of 2013 for hemiplegic stroke victim
- Health O Meter Glass Digital Scale with four load cells
- Signal from rear load cells sent to differential amplifier
- Data input to an Arduino Leonardo and then tone sent to speaker
- Only Left/Right audio balance biofeedback
- Speaker was not loud enough for an ambient setting
- Improper packaging
- Limited battery life

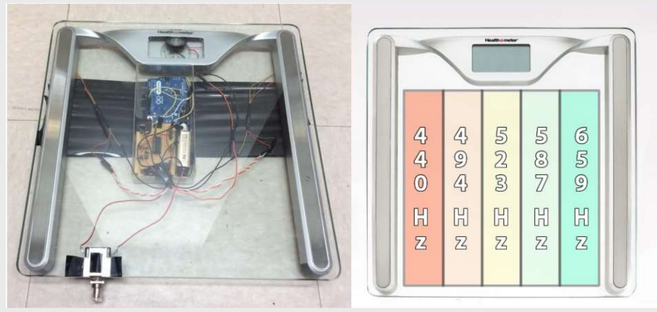

Figure 2: Actual device (left) and conceptual diagram (right) of the Fall 2013 design. Colored areas on the diagram indicate "zones" at which the subject's center of gravity of may be when their balance is shifted. Tone of indicated frequency plays in each zone.

Experimental Testing

- Testing was conducted by placing various weights on the edges of the board to mimic weight distribution (i.e. net weight of 50 lbs means the right side had 50 lbs more than left side)
- 3 trials for weight combination
- Linear trendline with average coefficient of determination (R^2) value of 0.98
- Voltage showed to change linearly to a change in weight distribution

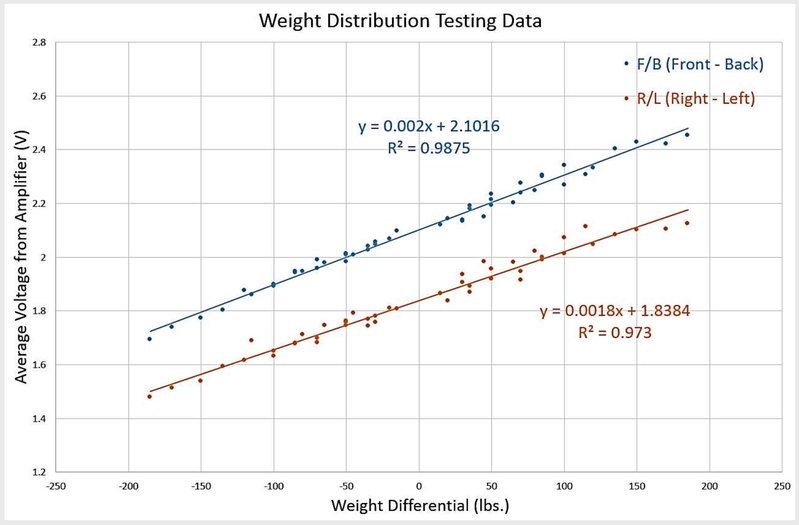

Figure 3: Weight distribution testing by measuring voltage with various amounts of weights put both for front-back and left-right feedback

Final Design

- Bathroom scale load cells in parallel form Wheatstone bridge that produces variable voltage depending on the weight distribution
- Constant tone when centered; pulsating tone when off balance.
- Frequency increases as weight distribution shifts right
- Distinct sound when the patient is leaning too forward or back
- Circuit made on printed circuit board for ease of packaging
- Vinyl covering to provide recommended foot positions to minimize user error
- Potentiometer to allow for adjustable volume
- Total cost: $125
- Final weight: 2.6 kg
- Final thickness: 4.16 cm
- Audio output: 65 dB
- All design criteria were met

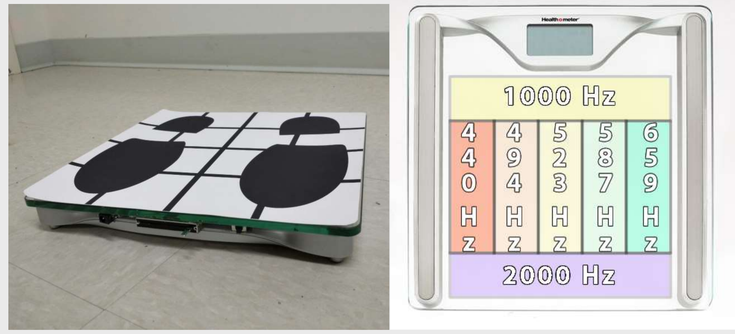

Figure 4: Actual device (left) and conceptual diagram (right) of the final design. Colored areas on the diagram indicate "zones" at which the subject's center of gravity of may be when their balance is shifted. Tone of indicated frequency plays in each zone.

Future Work

- Build memory into the device to track improvements over individual sessions and long-term
- Incorporate battery power for improved portability
- Create varying levels of difficulty
- Account for patient's weight to when setting balance threshold

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References

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