Efficacy of a Pressure-Sensitive Mat within the PANDA Gym in Assessing Developmental Delays in Infants

Susan Zhao[1,3], Mayumi Mohan[3-4], Wilson Torres[1,3], Laura Prosser, PT, PhD[5], Michelle J. Johnson, PhD[1-4]

[1] Department of Mechanical Engineering & Applied Mechanics, University of Pennsylvania
[2] Department of Biomedical Engineering, University of Pennsylvania
[3] Department of Physical Medicine and Rehabilitation, University of Pennsylvania
[4] Grasp Lab, University of Pennsylvania
[5] Children's Hospital of Philadelphia

ABSTRACT

Early diagnosis of developmental delay in infants is vital for providing early intervention. We have developed an infant gym with sensors which assesses infants in their natural play environment. Using this system, we hope to develop quantifiable metrics that can be used in place of current subjective analysis for early diagnosis of motor delays. This work details the pressure sensitive mat of the Play And Neuro-Development Assessment (PANDA) Gym that gathers center of pressure (CoP) information of infant movement while they play in the gym in a supine position. We present data collected from 9 healthy infants and 3 preterm infants.

INTRODUCTION

- Cerebral palsy (CP): a term used for non-degenerative neurological impairment that occurs early in an infant's life [1]. Current diagnosis such as the Bayley Infant Neurodevelopmental Screener (BINS) misdiagnoses 3-4 out of every 10 infants [2,3].
- The PANDA Gym is an affordable, sensorized environment that aims to provide early diagnosis of neuromotor disorder in infants and improve current screening processes by providing quantitative measures rather than subjective ones.
  - The system uses an array of toys with sensors, a camera-based computer vision system, and a mat structure which measures the center of pressure (CoP) of the infant.
- It was found that infants born prematurely exhibit different patterns of CoP movement than infants born full-term when assessing development impairments relating to postural control [4].
- This study examines the sensitivity of the mat to detect differences in CoP movement patterns for infants of different age groups and risk levels. Our ultimate goal would be to show results similar to previous studies and use data collected from the PANDA Gym subsystems to comprehend atypical infant motor behavior.

DESIGN

- The system comprises a load cell on each corner of the mat(Fig. 1)
- The mat comprises a dragon plate with additional foam padding
- Signals from the force sensors are scaled by the signal conditioners
- Signal conditioners, powered by a 24V battery, are adjustable and can change span and zero of the signal
- A pair of op-amp buffers the signal into the Arduino, and ensures no power surges are directed into the computer(Fig. 2)

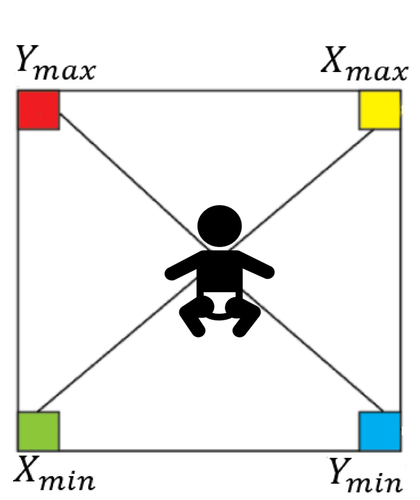


Figure 1: Diagram of infant placement on mat, with all load cells on designated corners.

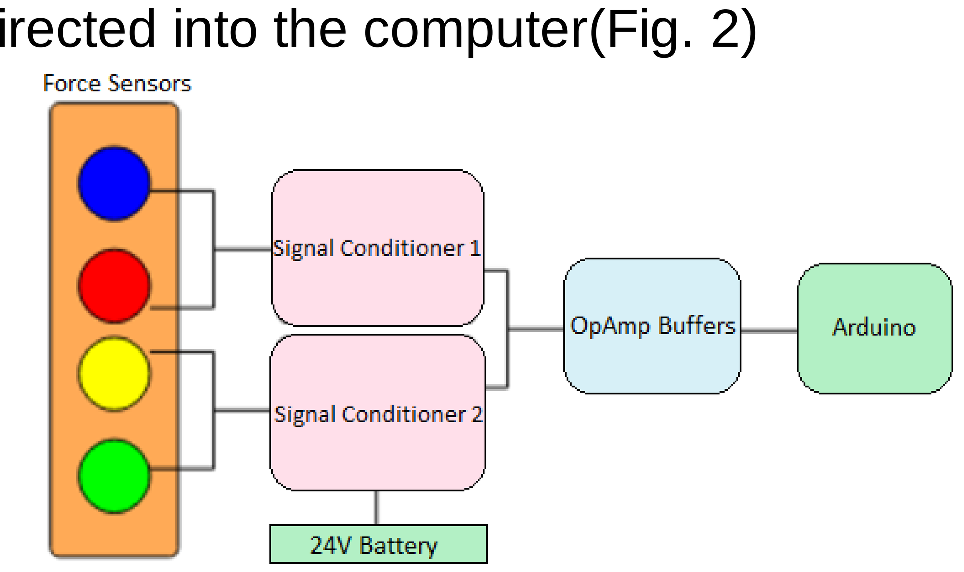


Fig. 2: System block diagram. 2 pairs of force sensors that each correspond to an axis.

METHODS

Calibration

1. Identify the range of data $[X_{min}, Y_{min}] - [X_{max}, Y_{max}]$
2. Translate data: center frame to real world center(Fig. 3)
3. Rotate data by a factor of 45° depending on X_{min} corner
4. Scale the data using ratio of baby weight to calibration weight
5. Translate back to sensor frame, then map to world frame range

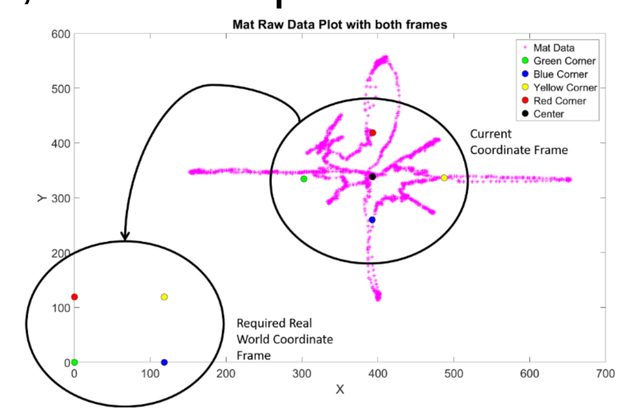


Figure 3: Real World and Sensor Frame –the calibration will transform the data from the upper frame to the one on the lower left corner

Data Analysis

- Place baby with head situated along red-yellow edge(Fig. 4)
- Record baby movement in four 2 minute trials: 3 with toys, and one without

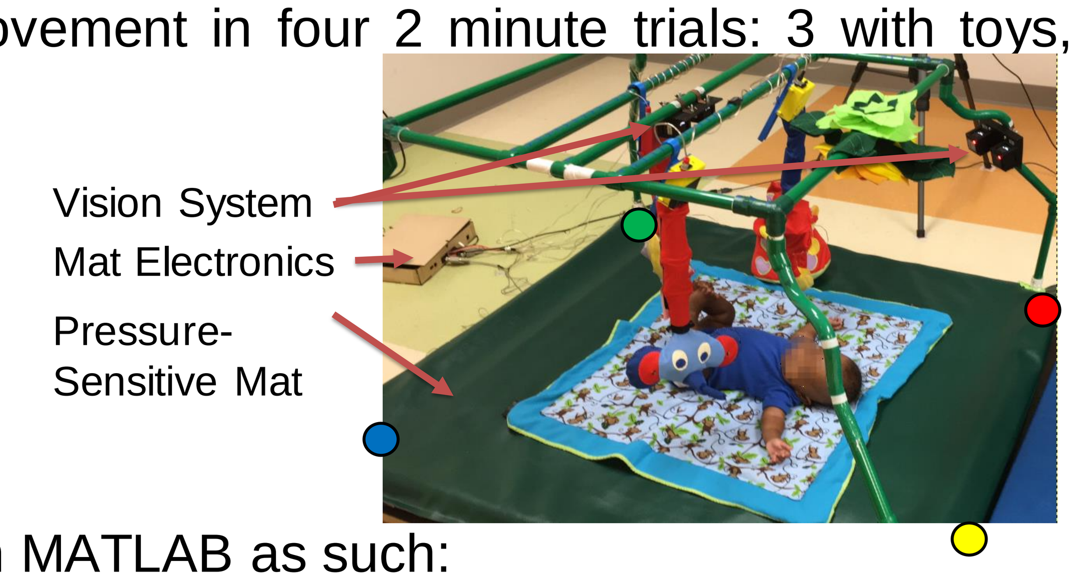


Figure 4: PANDA Gym assembly with subcomponents. Load cells at the corresponding corners under the mat.

Data is processed in MATLAB as such:

- Timed trials of roughly 120 seconds are filtered out for analysis –trials where the baby becomes restless, cries, or crawls off the mat are excluded
- Data is then calibrated and converted into the real world frame(Fig. 5)

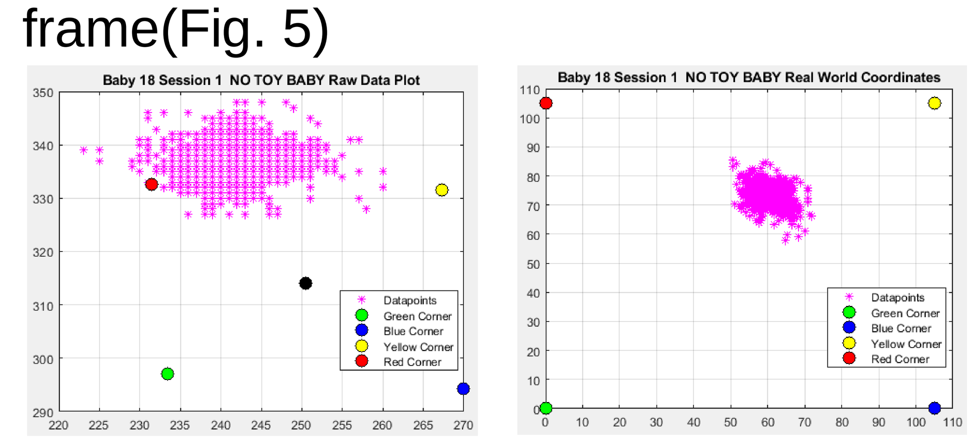


Figure 5:
Left: Raw data plot
Right: Data in Real World Coordinates, post-calibration

- An ellipse is fit to the data, indicating excursion and as a visual indication of the magnitude of infant movement

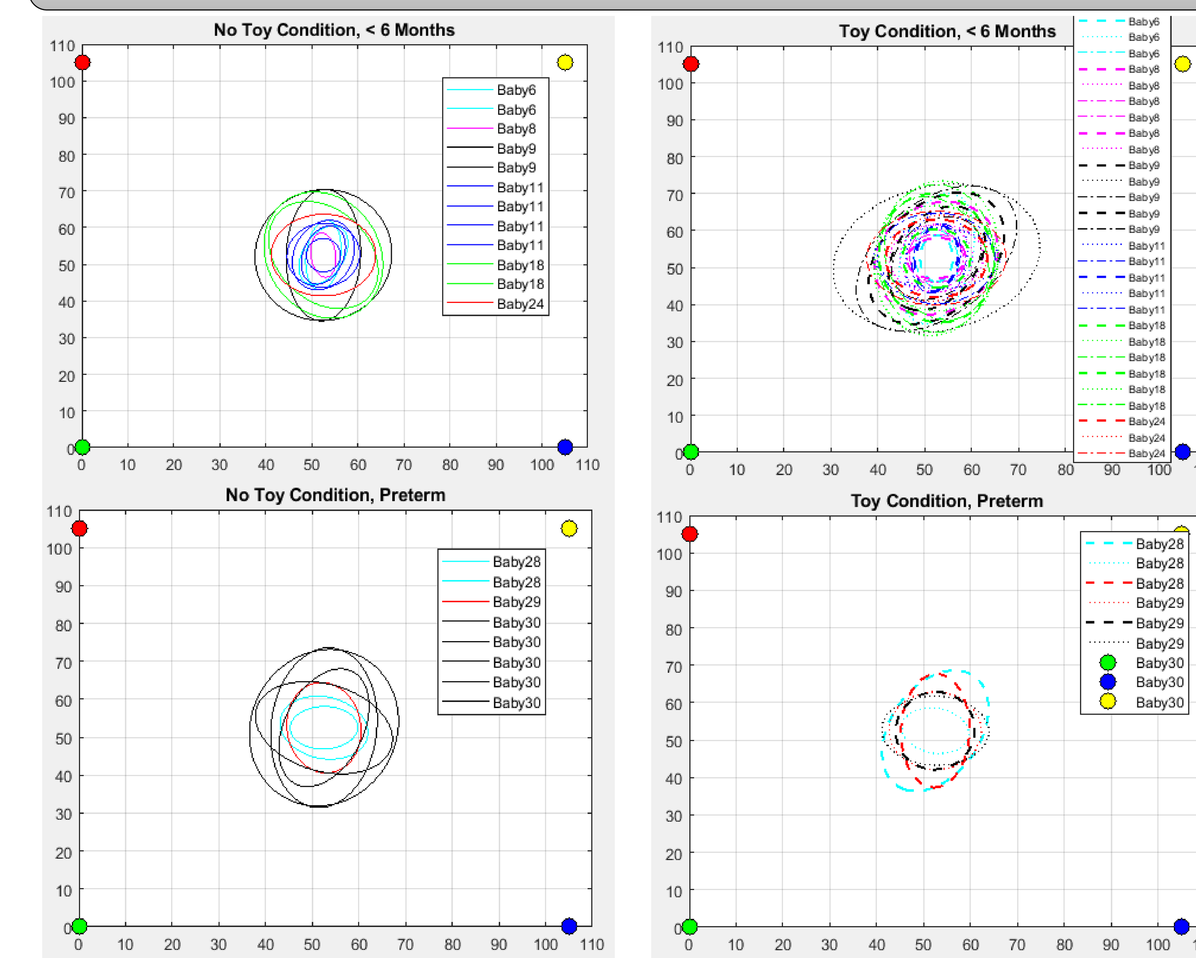
The following metrics are then calculated:

- CoP: a linear measure that quantifies infant movement
- Approximate Entropy (ApEn): a nonlinear measure that quantifies unpredictability of variations in a time series
  - It can help describe the nature of variability and evaluate risk factors [5]
  - Relatively small ApEn: many repetitive patterns
  - Higher ApEn: a less predictable, more complex process
- Infants are categorized as such: Fullterm < 6 mo and > 6mo and Preterm

We tested for the following hypotheses:

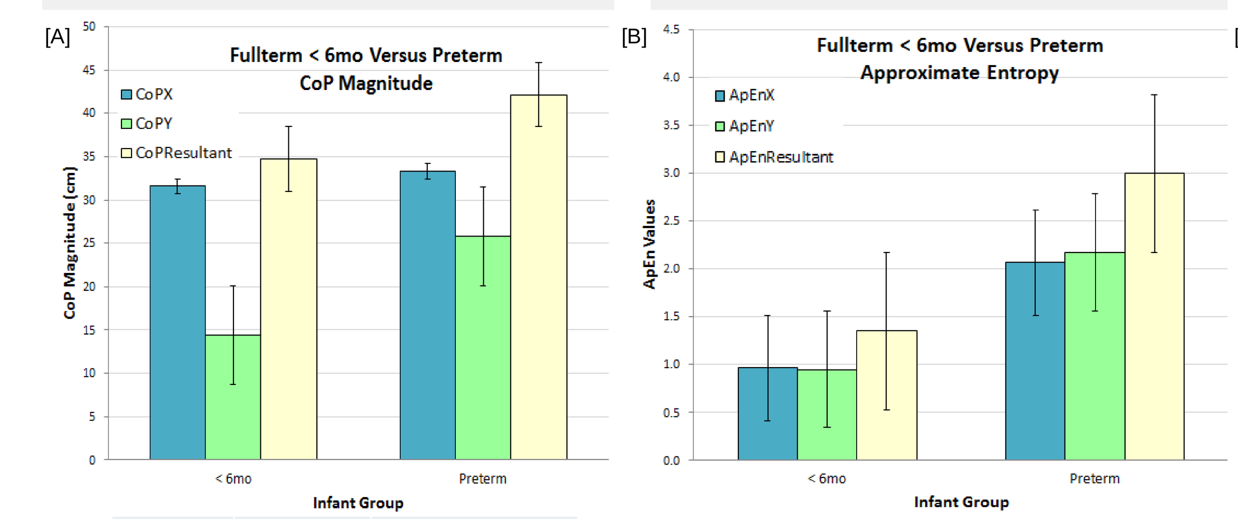
- Increase in CoP movement from No Toy to Toy condition
- Greater CoP movement in preterm babies, but lower ApEn values compared to fullterm babies [1]

DISCUSSION AND CONCLUSION



Additional Legend:
Elephant: ---- (dashed line)
Lion: …… (dotted line)
Orangutan: -.-.-.-. (dash-dotted line)

Figure 6: Infants with an ellipse fit to datapoints of their CoP in the time frame of a trial. These trials are further separated into the No Toy and Toy condition.



[C]

	CoPX	CoPY	CoPResultant
< 6mo	31.60	14.43	34.74
Preterm	33.31	25.82	42.14
	ApEnX	ApEnY	ApEnResultant
< 6mo	0.96	0.95	1.35
Preterm	2.07	2.17	3.00

X,Y corresponds to medial-lateral, caudal-cephalic direction respectively

[D]

CoPX	CoPY	CoPResultant
21.51	17.63	27.81
ApEnX	ApEnY	ApEnResultant
1.26	1.59	2.03

[A]No Toy condition, CoP comparison. [B]No Toy condition, ApEn comparison. [C]Table of corresponding values, preterm vs. fullterm < 6 mo. [D]Table of metrics for fullterm > 6 mo, has no correlated preterm age group for analysis.

We found that:

- Infants exhibited greater unpredictable movement with the Toy Condition (higher ApEn)
- Significant difference in movement in caudal-cephalic than medial-lateral direction [1]
- Greater CoP magnitude movement in preterm infants than fullterm in No Toy
- Mean ApEn values for preterm infants were greater than fullterm

We hope to collect more data in order to identify if this system can be used to identify motor delay in infants.

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