On Exploring the Use of Mobility Parameters in the Analysis of Early Childhood Developmental Disorders

Authors:
Rama Krishna Thelagathoti &
Hesham H.Ali
College of Information Science and Technology
University of Nebraska Omaha
Omaha, NE 68182, USA

Presenter:
Rama Krishna Thelagathoti
College of Information Science and Technology
University of Nebraska Omaha
Omaha, NE 68182, USA
rthelagathoti@unomaha.edu
Bio

• Name: Rama Krishna Thelagathoti
• Pursuing PhD In Information Technology at University of Nebraska Omaha.
• Research Interests
  • Mobility analysis for Healthcare
  • Correlation Networks
  • Artificial Intelligence for Health
• 10 + years of industry experience
• Ex-Qualcomm & Ex-NXP semiconductor
Projects

• A Population Analysis Approach using Mobility Data and Correlation networks for Depression Episodes Detection

• A novel population analysis approach for identifying decease levels using correlation networks and mobility analysis
Research question

How mobility and its associated mobility parameters have been used in the early childhood developmental disorders
Method

- Literature study and analysis from the articles that includes

  1. Data collection using wearable sensors
  2. Early childhood developmental disorders
  3. Mobility assessment as a method of diagnosis
Introduction
What is a developmental disorder?

5 stages in childhood

- New born [0-4 weeks]
- Infant [1-12 months]
- Toddler [1-2 years]
- Pre-school [2-5 years]
- School [6-12 years]

5 types of skills developed during childhood

- Cognitive (learning, thinking)
- Social and emotional
- Gross motor skills
- Fine motor skills
- Speech and language
What is a developmental disorder?

What most babies do by this age?

Motor skills milestones—4 to 18 months

- Sits without help
  - 4–9 months
- Stands with help
  - 5–11 months
- Crawls on hands and knees
  - 5–13 months
- Walks with help
  - 6–14 months
- Stands alone
  - 7–14 months
- Walks alone
  - 8–18 months

What is a developmental disorder?

- **Lag (delay)** in core functions
  - movements, speech, etc
- **Abnormal development of the nervous system**\(^1,3\).
- Manifestation during **birth** or **school age**
- **Delay** may lead to **lagging** in one or more **skills** of the child\(^2\).

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Major childhood disorders

• Major childhood disorders
  • Autism spectrum disorder (ASD)
    • Social, cognitive, language and communication
  • Cerebral Palsy (CP)
    • Impaired motor development
• Anxiety disorders
  • Mental disorder
• ADHD
  • Attention deficit hyperactivity disorder
Why childhood disorders?

- Main reasons for developmental delays\textsuperscript{3}
  1. Heredity
  2. complications during pregnancy
  3. premature birth
  4. Low birth weight
  5. unknown

Existing clinical diagnosis

- Self/Parent reporting feedback
- Trained physician consultation
- Milestone checks at each stage
  - Does the baby reached a milestone by the age

- Disadvantages
  - Observer dependent
  - Subjective
  - Time intensive
Mobility as a diagnostic feature
Mobility as a feature for diagnosis

• Early motor delays - initial signs of later developmental impairment

• Mobility of autistics child vs healthy child
  • Lower mobility profile
  • Stereo type movements
  • Lack of variable movements
Mobility as a feature for diagnosis

**TD**
- Typically developing
- Variable and complex movements

**AR**
- At-risk
- At risk of developing a disorder
- Lower mobility

**NDD**
- Neurodevelopmental disorder
- Diagnosed with disorder
- Lower complex and monotonous movements
Window of opportunity for AR kids

Mobility-based diagnostic methods

Mobility – based diagnostic methods

Qualitative
- Subjective
- Scales are used to assess the severity
- Observer-dependent

Quantitative
- Objective
- Quantifies the mobility to assess the severity
- Observer-independent
Qualitative diagnostic methods

• AIMS scale (Alberta Infant Motor Scale)\(^4\)
  • An observational assessment scale
  • Gross motor skills assessment of weight-bearing, posture and antigravity movements
• Prechtl's assessment for Cerebral Palsy (CP)\(^5\)
  • General movements assessment (GMA)
  • Record a video of infant in supine position for 60 minutes
  • Trained consultant can assess on the general movements (GM) and decide whether child has CP

Qualitative diagnostic methods

- Observer dependent
- Accuracy?
- Frequent clinical visits
- Increased human effort
### Quantitative methods using wearable sensors

<table>
<thead>
<tr>
<th>Sensor position</th>
<th>Impaired movements</th>
<th>Major disorders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forehead</td>
<td>Repetitive</td>
<td>Autism</td>
</tr>
<tr>
<td>Upper limbs</td>
<td>Crammed</td>
<td>Cerebral Palsy</td>
</tr>
<tr>
<td>Wrist</td>
<td>Asymmetric</td>
<td>ADHD</td>
</tr>
<tr>
<td></td>
<td>Trunk</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower variability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower movement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stereotyped</td>
<td>Down syndrome</td>
</tr>
</tbody>
</table>
Data and devices

• Sensors
  • Accelerometer – commonly used sensor
  • Combination of sensors (IMU)

• Sensor instruments
  • Skin adhesive
  • Sensors embedded in clothes
  • Cloth wrapper leg warmer sensors

• Others
  • Gaze tracking
  • Motion tracking devices
Biomarkers
(what mobility parameters are assessed)

• Limb movements
• General Movements (GM) vs abnormal movements
• Variability and repeatability
• Frequency
• Stereo typical movements vs variable movements
Data Collection challenges

• Subjects are infants or kids
• Pacifying crying child
• Cumbersome of wires, sensors
• Duration of sensor attachment
Data processing

- Wear time and Duration of data collection is often ranging from hours to days
- Processing challenges
- Noise elimination
  - Infant vs adult subjects
- Data storage
  - Minimal internal memory
  - Cloud storage
  - Latency due to cloud communication
Techniques

• Predominantly Machine learning techniques
  • Random Forest
  • Support vector Machine
  • Decision trees

• Statistical techniques

• Discriminant analysis
Quantitative approaches

• Using Wearable Sensor Technology to Measure Motion Complexity in Infants at High Familial Risk for Autism Spectrum Disorder

• Sensor - Accelerometer

• Wear time – 8 to 13 hours

• Computed Motion complexity (MC) – a measure of infant’s movements profile

• Result
  • TD infant’s MC is higher than AR
  • movements are complex and variable

• MC measures complexity level of the movements to classify group of infants into TD and AR
Quantitative approaches

- Sample Entropy Identifies Differences in Spontaneous Leg Movement Behavior between Infants with Typical Development and Infants at Risk of Developmental Delay.

- Sensor - Accelerometer and gyroscope
- Wear time – 8 to 13 hours
- Sample entropy is a measure of infant’s variability and repeatability of spontaneous leg movements
- Result
  - Sample entropy values are higher for TD, lower for AR
# Summary of Quantitative methods

<table>
<thead>
<tr>
<th>Reference</th>
<th>Purpose</th>
<th>Sensor</th>
<th>Sensor placement</th>
<th>Wear time (in hours)</th>
<th>Setting</th>
<th>Disorder</th>
<th>Movement type</th>
<th>Subjects</th>
<th>Age (in months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[7]</td>
<td>Classify TD and AR</td>
<td>IMU</td>
<td>Ankles and ankles</td>
<td>8-13</td>
<td>Natural</td>
<td>NA</td>
<td>Spontaneous leg and arm movements</td>
<td>12 TD 19 AR</td>
<td>1-15</td>
</tr>
<tr>
<td>[14]</td>
<td>Early diagnosis</td>
<td>IMU</td>
<td>Wrist and ankles</td>
<td>NA</td>
<td>Clinical</td>
<td>ASD</td>
<td>Spontaneous leg and arm movements</td>
<td>NA NA</td>
<td></td>
</tr>
<tr>
<td>[19]</td>
<td>Classify TD and AR</td>
<td>IMU</td>
<td>Ankles</td>
<td>8-13</td>
<td>Natural</td>
<td>NA</td>
<td>Spontaneous leg movements</td>
<td>12 TD 19 AR</td>
<td>1-16</td>
</tr>
<tr>
<td>[20]</td>
<td>Diagnose ASD</td>
<td>IMU</td>
<td>Ankles</td>
<td>8-12</td>
<td>Natural</td>
<td>ASD</td>
<td>Spontaneous leg movements</td>
<td>5</td>
<td>3-12</td>
</tr>
<tr>
<td>[21]</td>
<td>Diagnose CP</td>
<td>Accelerometer</td>
<td>Forehead, ankles, and wrist</td>
<td>20 min</td>
<td>Clinical</td>
<td>CP</td>
<td>Spontaneous leg and arm movements</td>
<td>19 TD 4 AR</td>
<td>&lt;10</td>
</tr>
<tr>
<td>[18]</td>
<td>Diagnosis CP</td>
<td>IMU</td>
<td>Forehead, ankles, and wrist</td>
<td>1 min</td>
<td>Clinical</td>
<td>CP</td>
<td>Spontaneous leg and arm movements</td>
<td>1 TD</td>
<td>3-5</td>
</tr>
<tr>
<td>[22]</td>
<td>Quantify leg movements</td>
<td>Inertial sensor</td>
<td>Ankles</td>
<td>8-13</td>
<td>Natural</td>
<td>NA</td>
<td>Spontaneous leg movements</td>
<td>12 TD</td>
<td>1-12</td>
</tr>
<tr>
<td>[4]</td>
<td>Predict impaired motor activity</td>
<td>Accelerometer</td>
<td>Head, ankles, and wrist</td>
<td>1</td>
<td>Clinical</td>
<td>CP</td>
<td>Spontaneous leg movements</td>
<td>10 AR</td>
<td>&lt;3</td>
</tr>
<tr>
<td>[23]</td>
<td>Number of days required for assessment</td>
<td>IMU</td>
<td>Ankles</td>
<td>5 days</td>
<td>Natural</td>
<td>NA</td>
<td>Spontaneous leg movements</td>
<td>16 AR</td>
<td>2-14</td>
</tr>
<tr>
<td>[24]</td>
<td>Assess leg movements</td>
<td>Accelerometer</td>
<td>Right ankle</td>
<td>48 hrs. x 4 times</td>
<td>Natural</td>
<td>DS</td>
<td>Spontaneous right leg movements</td>
<td>8 TD 8 AR</td>
<td>3-6</td>
</tr>
<tr>
<td>[16]</td>
<td>Predict motor disorder</td>
<td>Accelerometer and gyroscope</td>
<td>Trunk, upper and lower limbs</td>
<td>4</td>
<td>Clinical</td>
<td>CP, stroke</td>
<td>Predefined body movements</td>
<td>4 AR</td>
<td>9-12 years</td>
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<tr>
<td>[17]</td>
<td>Clinical vs motor assessment</td>
<td>Accelerometer</td>
<td>Wrist</td>
<td>75</td>
<td>Natural</td>
<td>CP</td>
<td>Spontaneous upper arm movements</td>
<td>26 TD 26 AR</td>
<td>1-17 years</td>
</tr>
</tbody>
</table>
Thank You

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