Self-powered sensor integrated platform for autism rehabilitation

Team 8

Members: Zhassulan Turar, Merey Sembay, Ainur Aman
Supervisor: Professor Gulnur Kalimuldina
Co-Supervisor: Dr. Azamat Yeshmukhametov

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Team Contribution

Ainur Aman

- Literature review of the project
- Design
- Animations
- Video editing

Zhasulan Turar

- Sensor fabrication, testing and arduino connection
- Noise canceling
- Sensor integration with the balancing platform
- Device testing and data analysis

Merey Sembay

- Sensor fabrication, testing and arduino connection
- Noise canceling
- Sensor integration with the balancing platform
- Device testing and data analysis

Table of Content

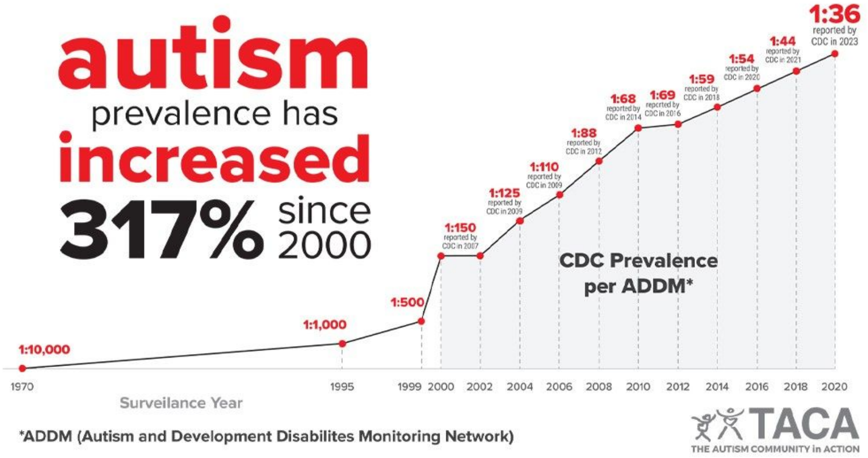
Autism and Existing Physical Therapy

Autism spectrum disorder (ASD) is a diverse group of conditions related to development of the brain.

- 1 in 100 children are diagnosed with ASD in the USA[1].
- 75 mln children around the world.

Existing rehabilitation systems fail to address

- Real time feedback
- Dynamic interaction
- Lack of individualization
- Data-driven insights are missing



Cerebellum and Autism Connection

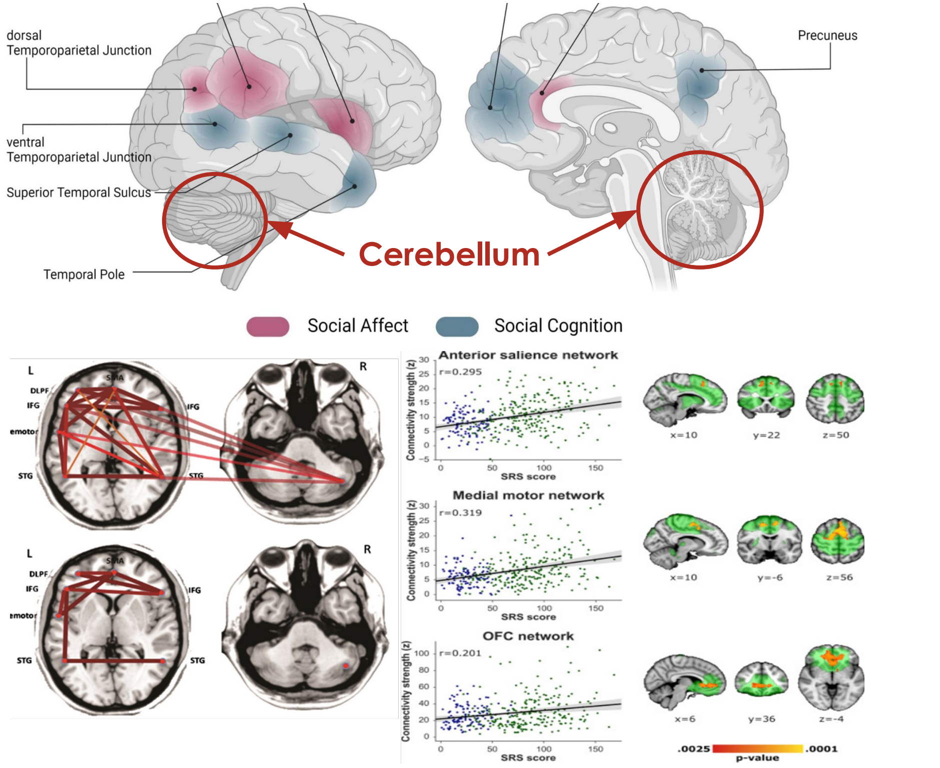
Cerebellum's known functions:

- Coordinates movements
- Controls **posture, balance** & fine motor movement
- Involved in motor learning

RECENTLY DISCOVERED functions (Hopkins 2023):

- Dynamic **social cognition**
- Sensory processing patterns
- Abnormalities contribute to **ASD** behaviors

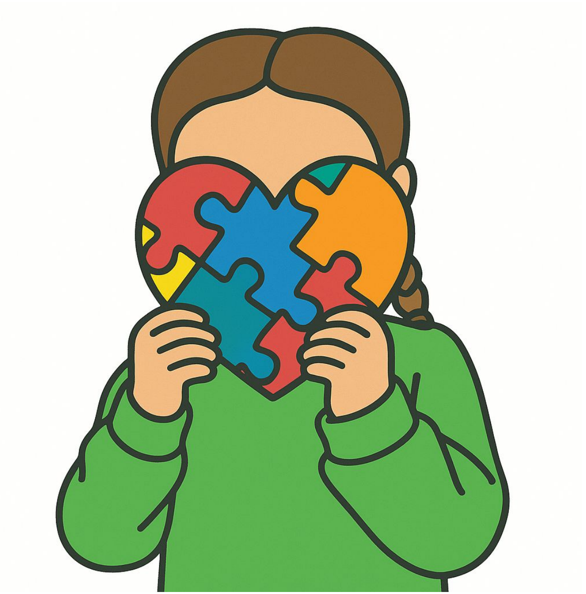
Improving balance → alleviate ASD symptoms



(a) Brain structure (b) Functional connectivity comparison of patients with TD and ASD-LI [3]. (c) Increased SRS-2 scores link autism to altered brain connectivity [4].

Problem Statement

Existing rehabilitation devices for children with autism lack real-time data collection and feedback, often fail to provide dynamic interaction, limiting their use and effectiveness in therapy.



Objective

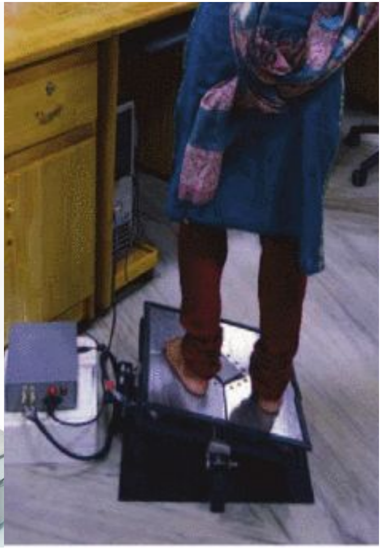
To integrate sensors into a platform for data collection to personalize treatment, enhancing motor skills, speech development and overall engagement in therapeutic activities for children with autism.

Sensor

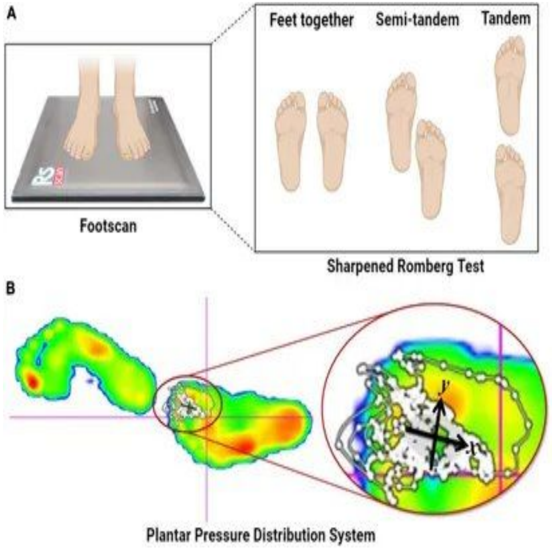
Data Collected

Literature Review

Hunova Robot (Date et al, 2023)



Amritha et al, 2016



Romberg Test (Deng et al, 2023)

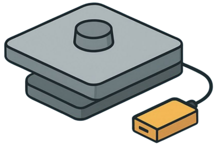
✗ Main focus in rehabilitation after injury
✗ Costly, non-portable
✗ Metallic Force Sensors are used

✗ Platform design without sensors

✗ No integration with platform
✗ Metallic Force Sensor
✗ Statistical Work

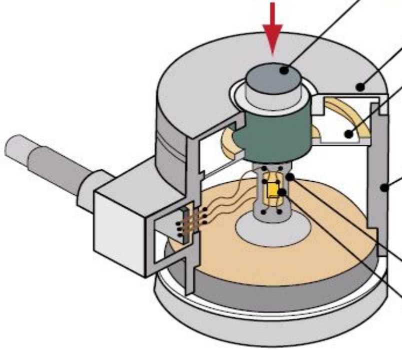
No current solution combines **flexible sensing** with **interactive therapy** for autism-specific balance training!

Literature Review: A Novel Application of Piezoelectric Sensors



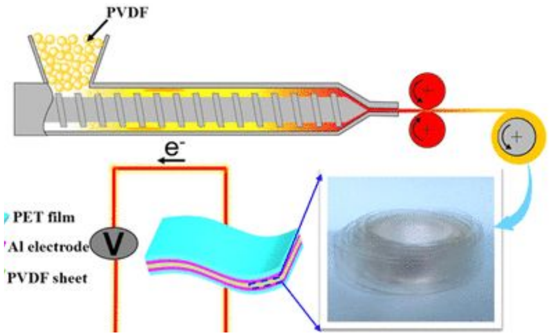
Traditional Metallic Force Sensors

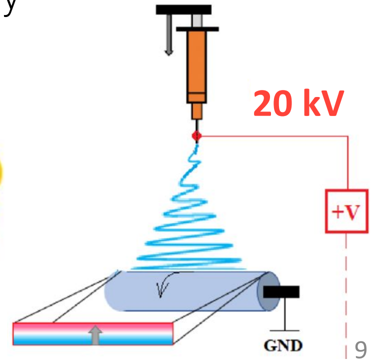
❌Requires external power
❌Rigid and bulky
❌Prone to damage under strain
❌Limited sampling, often delayed
❌Complex electronics and amplification
❌Non-adaptive, sensory-intrusive



Piezoelectric Sensors

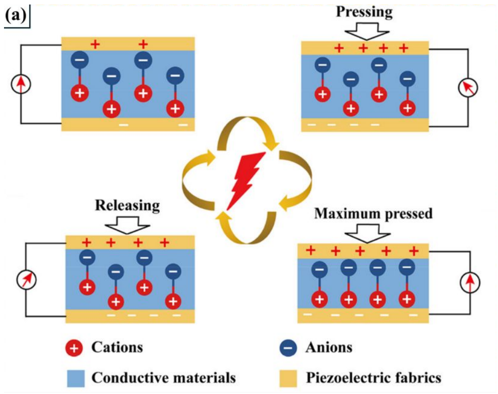
✅Self-powered
✅Flexible and thin
✅Real-time feedback
✅Simplified signal processing with Arduino
❌Literature traditional manufacturing is complicated and costly



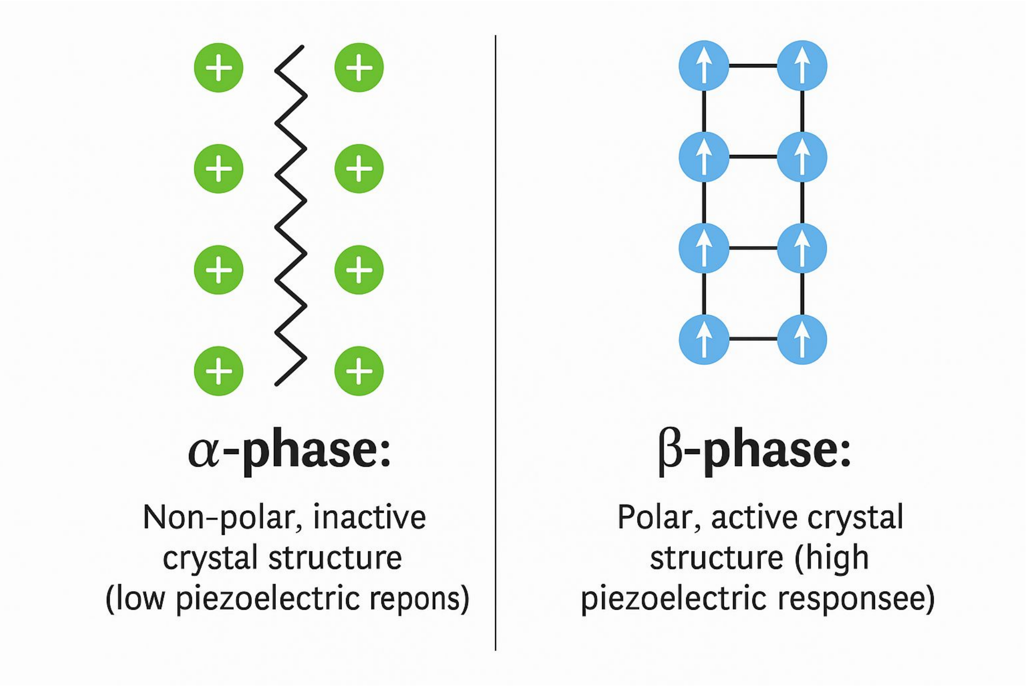


Piezoelectric Sensors: PVDF

- Simpler fabrication
- High sensitivity
- Flexibility and conformability (helps t cope with sensory processing differences)
- Safe for long-term skin contact



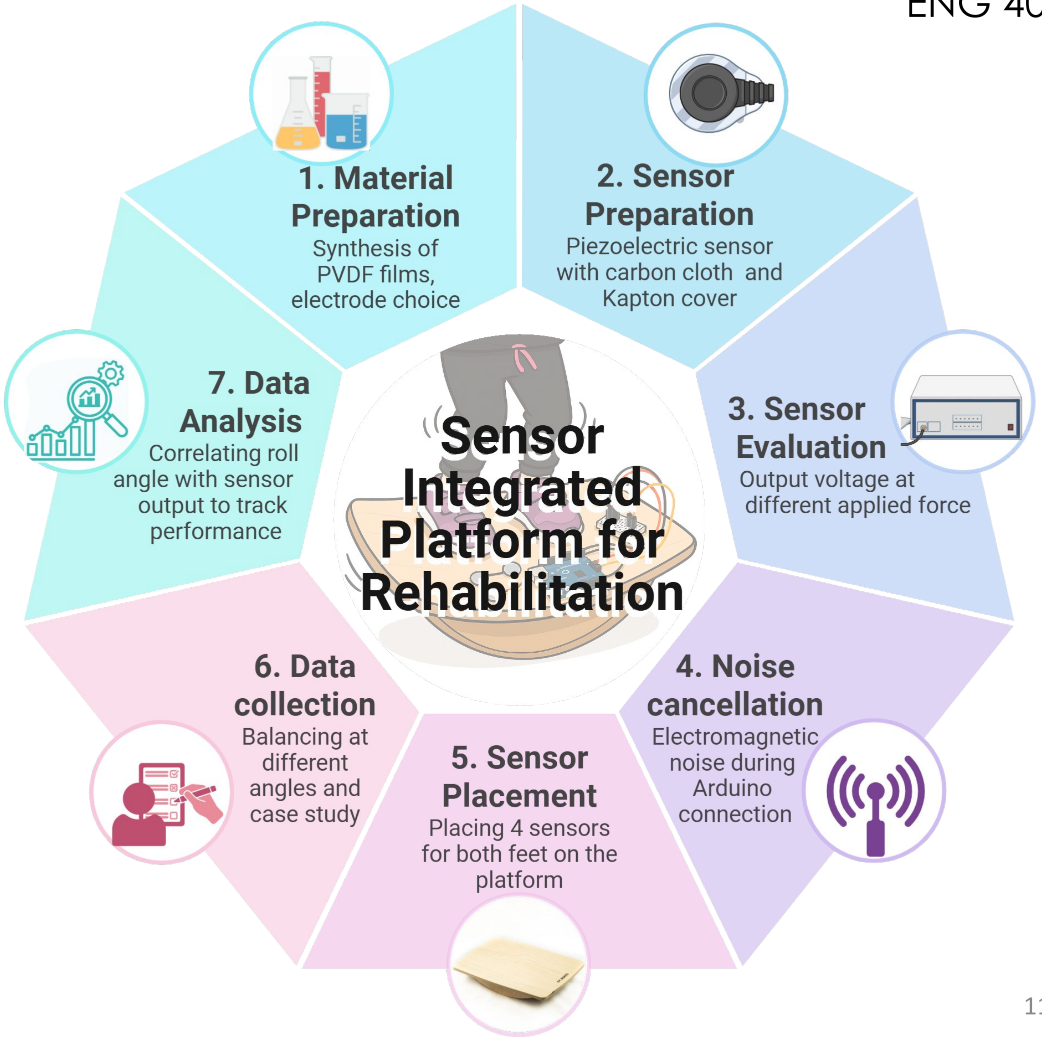
Working principle of PENG[11]



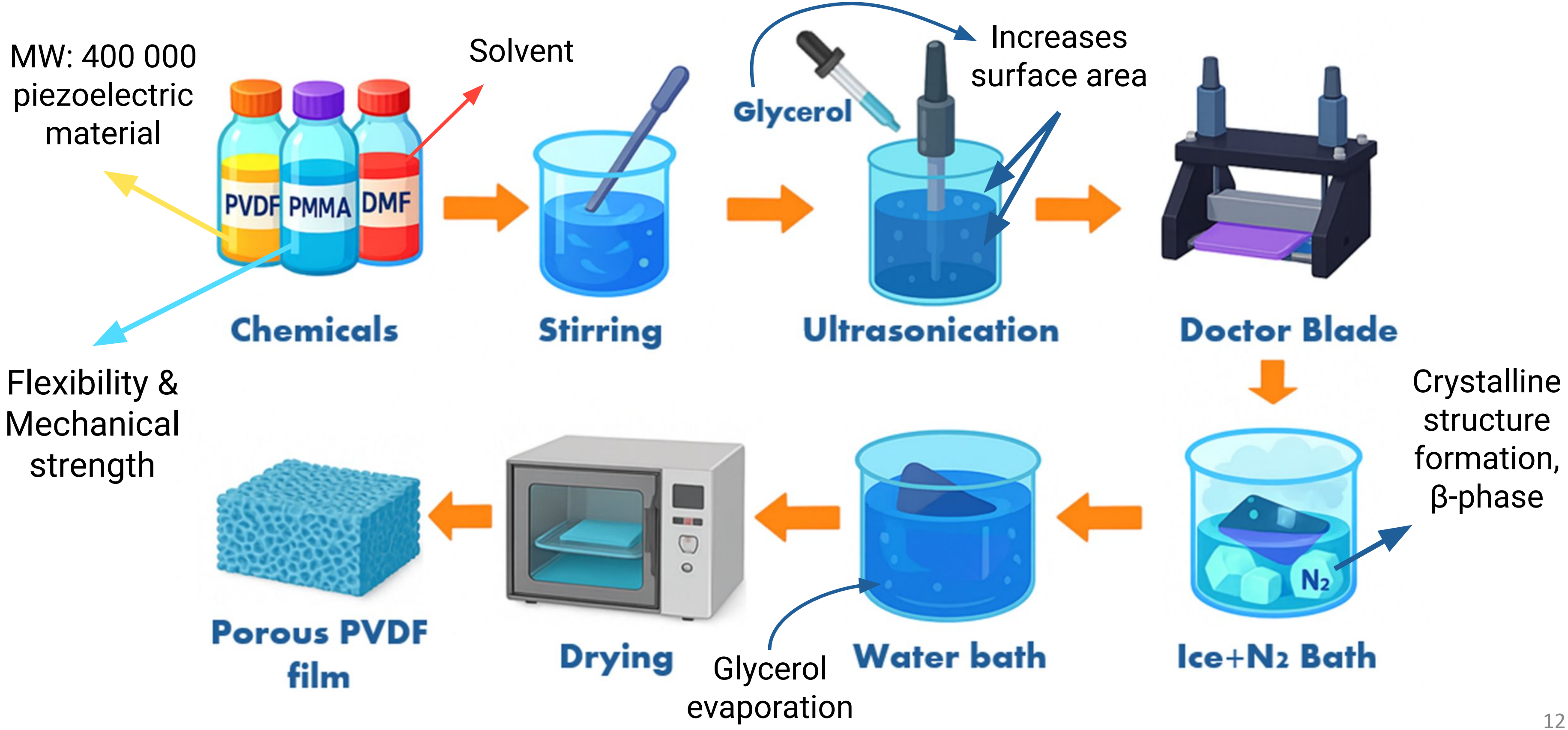
Crystal Phases in PVDF

Methodology

1. Material preparation
2. Sensor preparation
3. Sensor Evaluation
4. Noise Cancellation
5. Sensor placement
6. Data collection
7. Data analysis



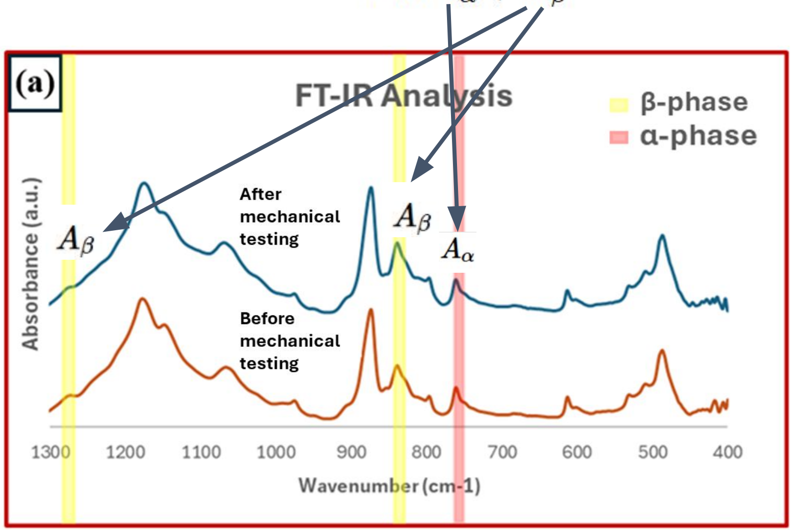
Material Preparation



Material Characterization

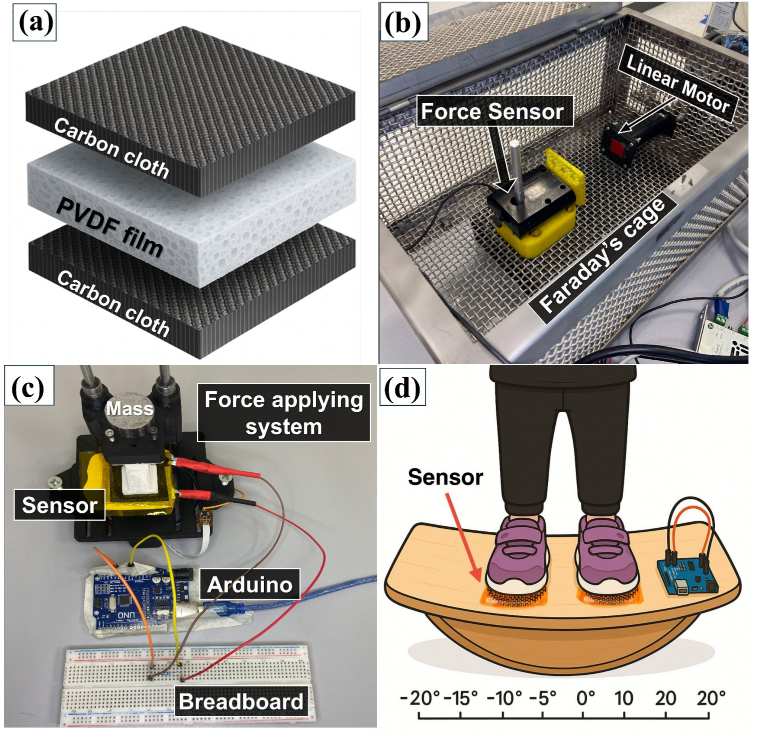
- FT-IR (Fourier Transform Infrared Spectroscopy): Identifying molecular phases by measuring infrared light absorption
- α-phase peaks: 765 cm^{-1}
- β-phase peaks: 840 cm^{-1}, 1275 cm^{-1}
- **~81% β-phase achieved.**

$$F(\beta) = \frac{A_\beta}{1.26\, A_\alpha + A_\beta}$$



Sensor Preparation and Evaluation

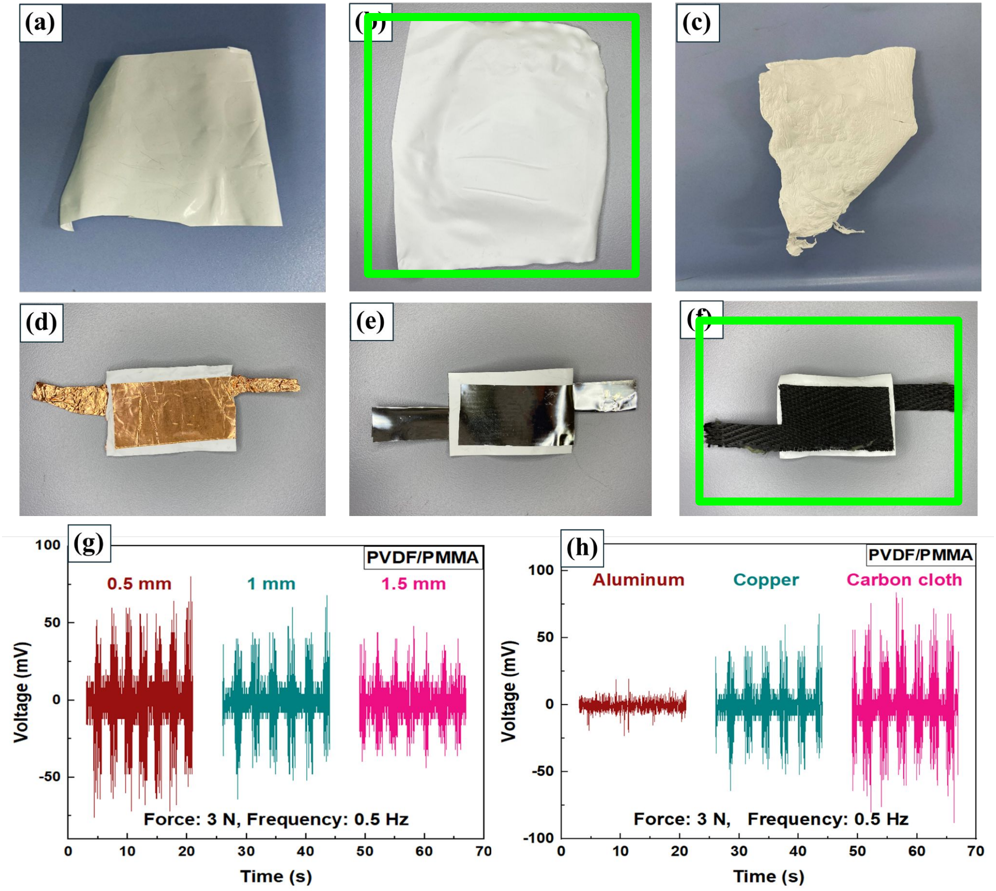
- Sandwich structure
- Output voltage tests under different force and frequency
- Force testing
- Balancing at different tilt angles from -20° to 20° degrees



Results & Discussion

For best performance and durability, final selection was:

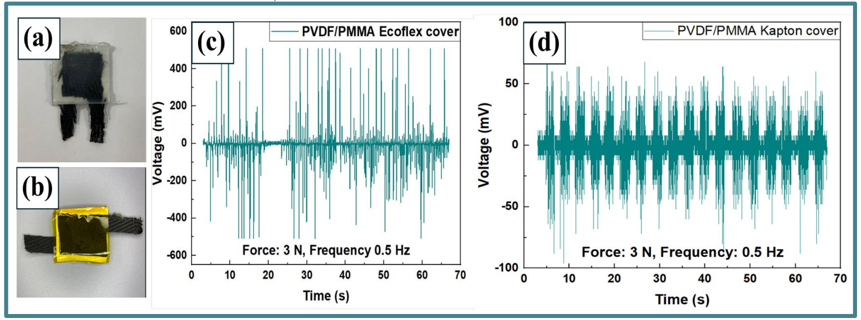
- 1 mm PVDF film
- Carbon cloth electrodes

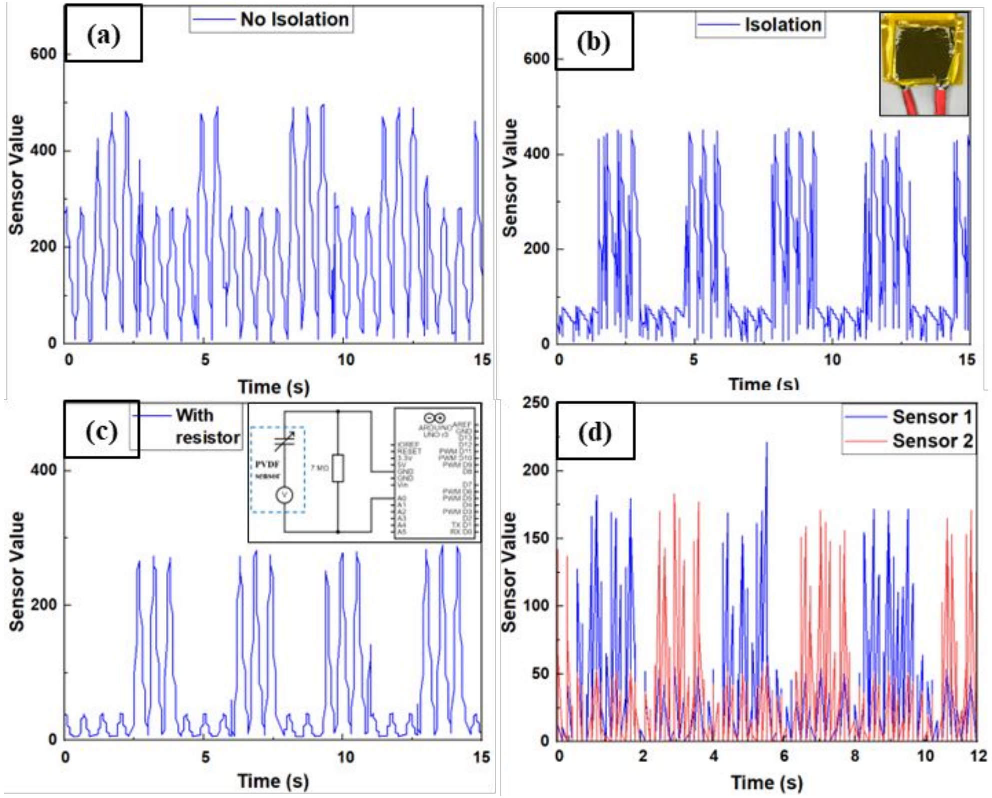


Noise Cancellation

Initially high noise (a), tried canceling through:

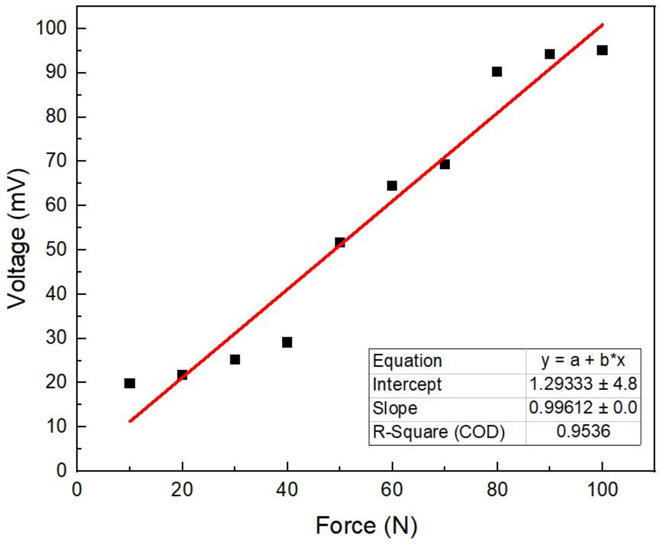
- Metal and resin isolation (b)
- Resistor of 7 MΩ (c)
- Protection cover

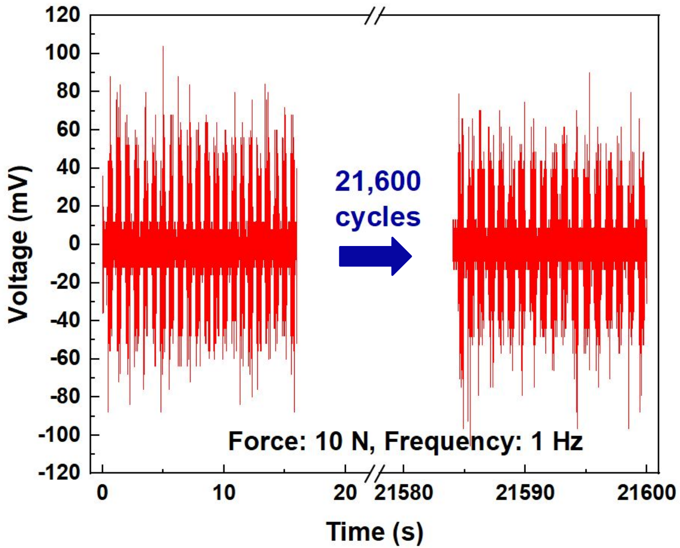




Force and Durability Testing

- Forces tested: 10-100 N.
- Linearity: 0.95 R-squared
- Sensitivity: 0.99 mV/N

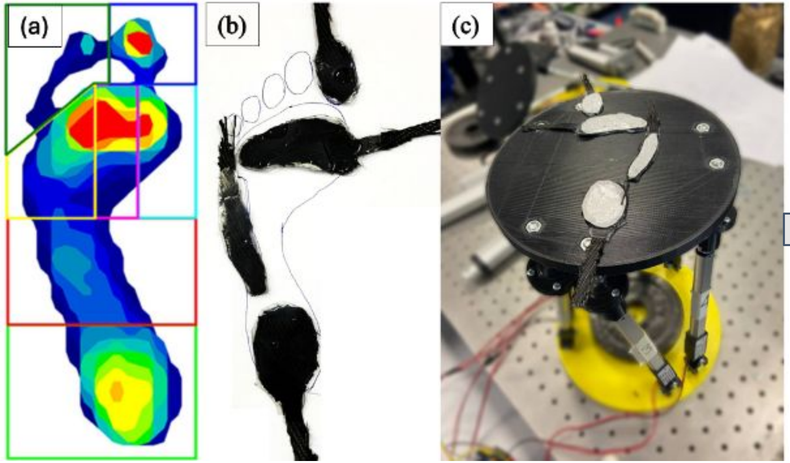




- No significant decrease in output after 6 h of testing.
- High durability.

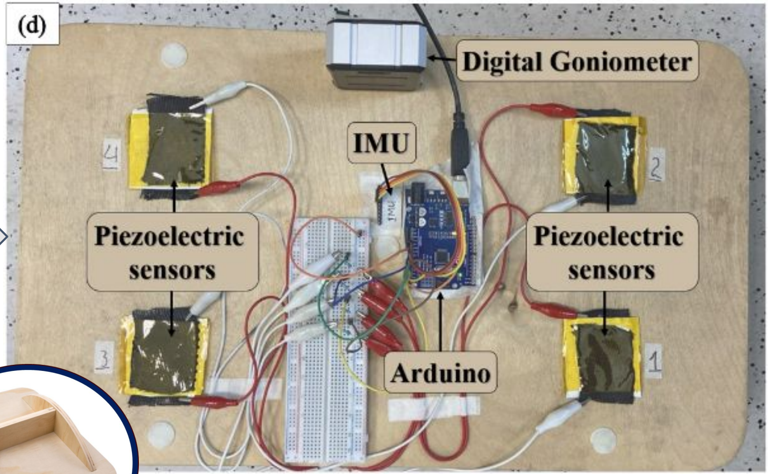
Design of balancing platform

Initial design



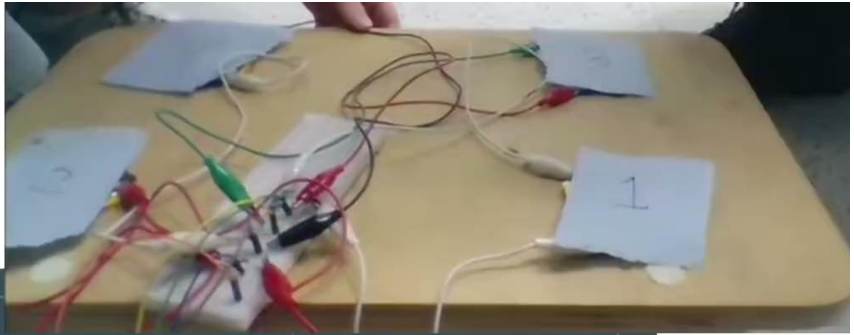
- 4 sensors per foot
- Based on pressure hotspots
- Stewart Platform

Final design



- 2 sensor per foot for testing and signal processing
- Balancing Platform

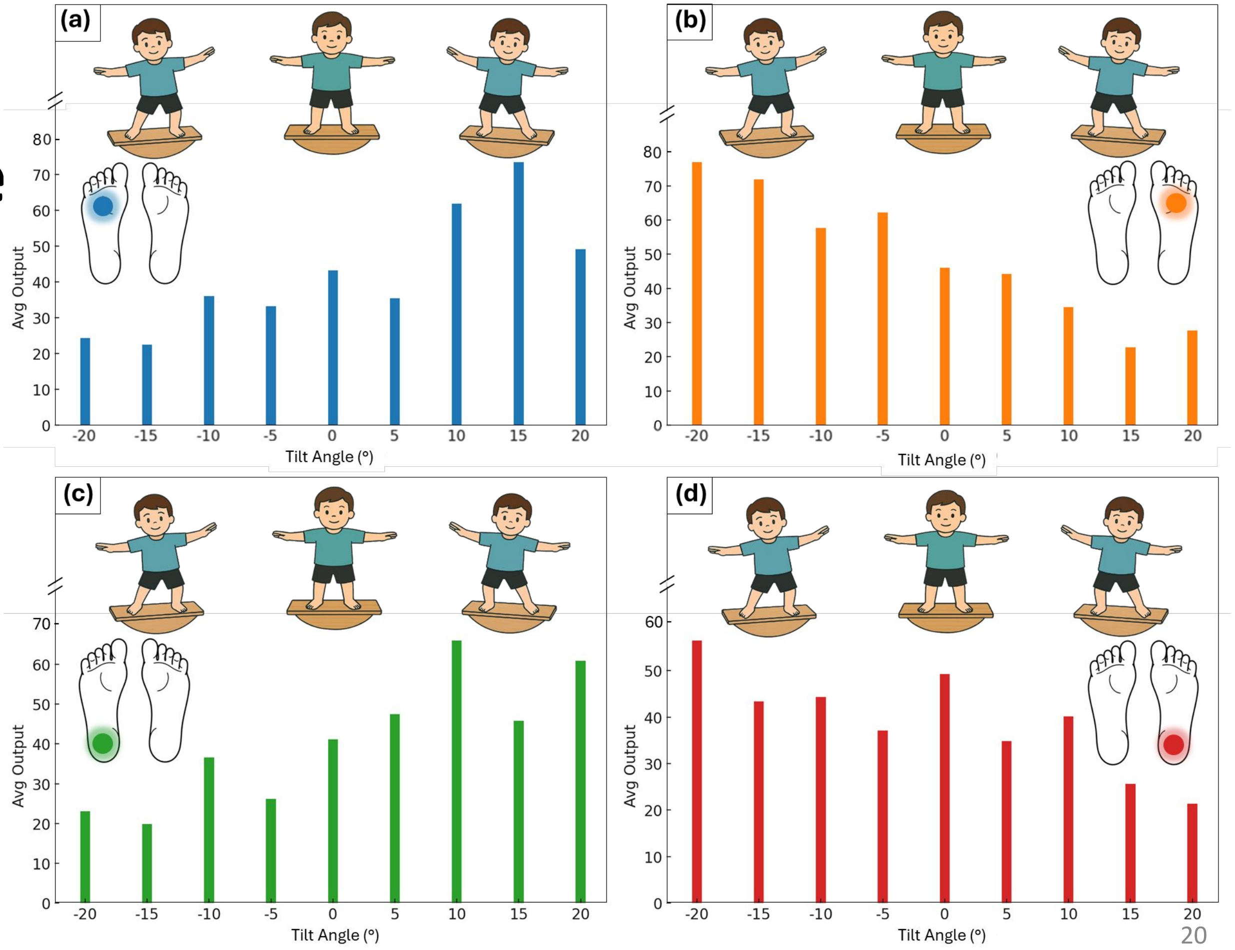
Sensor’s output



Sensor Output at Different Tilt Angle

- Python scripts used for data extraction
- Captured sensor outputs at tilt angles: 0°, 5°, 10°, 15°, 20°

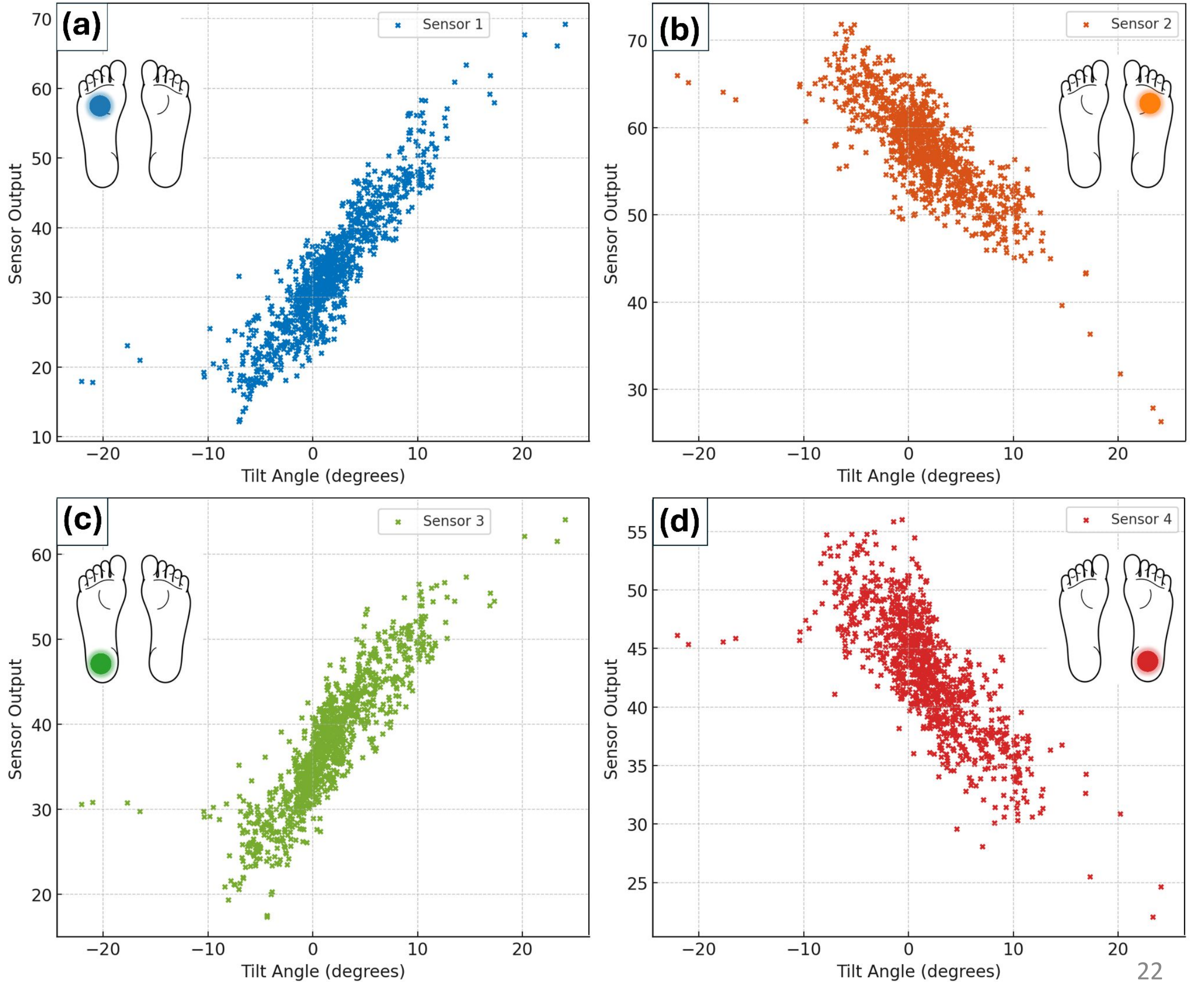
Opposite-leg pressure increases proportionally with rising tilt angle



Data Collection: Case Study

Case Study: Balancing Child

- Balancing pattern of a 3-year-old child
- Weight 14 kg
- Stronger left-leg pressure at right tilt
- Stronger right-leg pressure at left tilt



Conclusion

Rehabilitation platform

Developed a piezoelectric sensor-integrated platform for ASD rehabilitation

Linear relationship

Demonstrated a clear linear relationship between applied force and sensor output

Noise cancellation

Effectively eliminated sensor noise for clean and reliable data

Case study

Successfully detected and analyzed child's balance and pressure adjustments

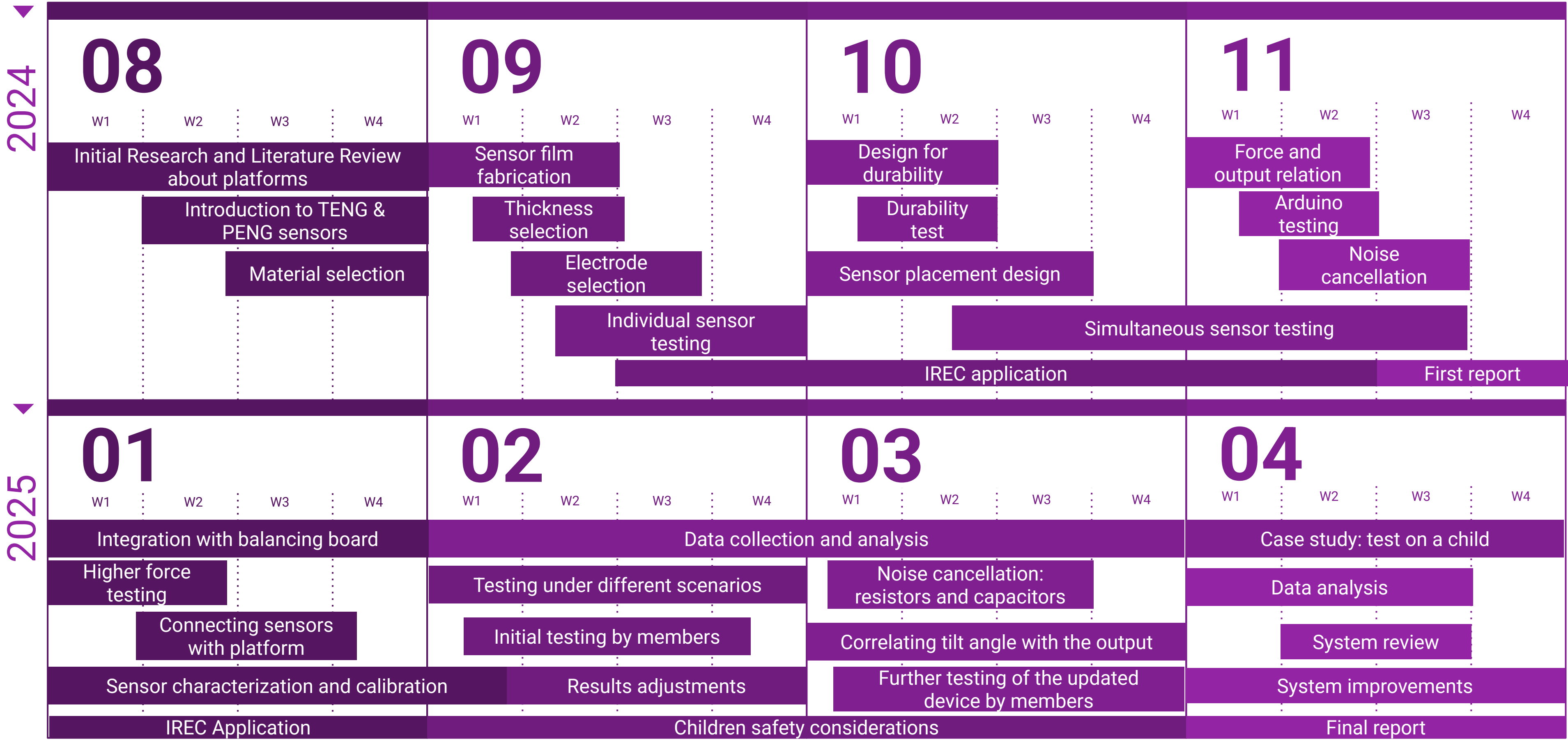
Future perspectives

Technical Improvements
- Placing more sensors per foot
- Robotic platform

Clinical Research
- IREC approval for data collection from ASD children
- Compare results with neurotypical children
- Develop personalized rehabilitation protocols

Data Analytics & Intelligence
- Machine learning for pattern recognition
- Adaptive difficulty level algorithm
- Visualize progress through mobile app feedback

Calendar of the project



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Thank you for your attention!