Connor Johanson

Portfolio 2025

I enjoy building intelligent, sensor-driven systems that bridge hardware and software. My interests center on wearable technology, sensor fusion, control systems, and embedded development — especially for real-time motion tracking, human interaction, and assistive health applications.

I'm passionate about designing and integrating multidisciplinary systems that extract actionable insights from sensor data to create meaningful, data-driven devices.

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Rally and Rehab

Lightweight sleeve for biomechanical racket-sport analysis

Goal

- Design and prototype a wearable compression sleeve with **embedded IMUs** for swing tracking, feedback, and injury prevention.
- Emphasize comfort, low cost, and long battery life for continuous athletic use.

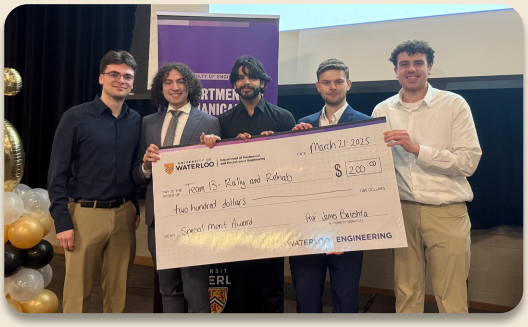
Method

- **Managed** and **led** a 5-person team.
- Designed flexible sleeve housing with 3D-printed ABS shells and 3 **BMI270 IMUs** at shoulder, elbow, and wrist.
- Implemented real-time tracking on **ESP32 microcontroller** with **I2C** and **Bluetooth Low Energy** communication.
- Deployed 6 live **Kalman Filters** in **Python** for motion estimation and noise reduction.
- Developed **feature extraction algorithms** to detect swings and injury risk.
- Built an **InfluxDB + Plotly Dash** dashboard for live visualization and long-term data storage using **SQL.**

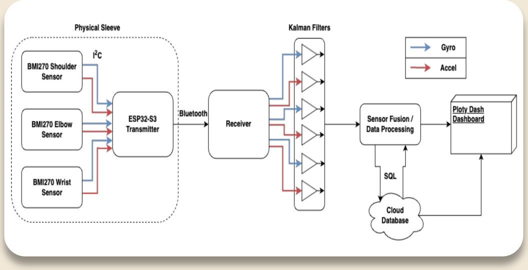
Results

- Awarded **James Baleshta Special Merit Award**; nominated for **Best Prototype.**
- Achieved **3-hour** battery life**,** high **swing-detection accuracy**, and cost of **$252.**
- Provides real-time and historical metrics.

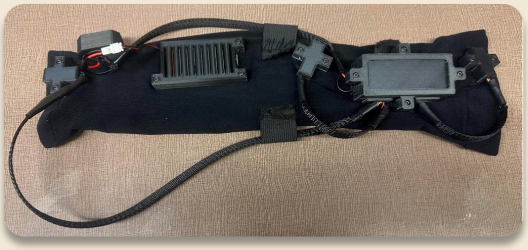
James Baleshta Special Merit Award



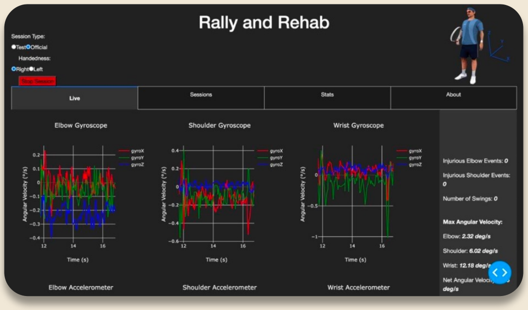
System Diagram



Prototype



Live Dashboard



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Doppler-Based Vehicle Speed Estimation

Audio-driven velocity estimation using CNN and Kalman filters

Goal

- Develop a low-cost, scalable system to estimate vehicle speed using only microphones and a 2 kHz tone.
- Compare data-driven **(CNN)** and model-based **(UKF)** approaches for accuracy and efficiency.

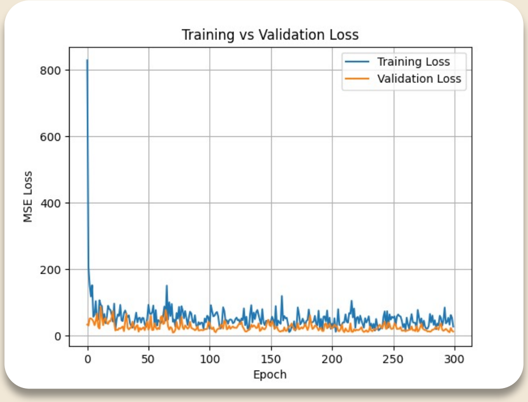
Method

- Collected audio on 5 devices across 10-50 km/h vehicle passes and converted to **mel spectrograms** with **Librosa.**
- Built a **CNN:** (8-16-32-64 filters, ReLU) → dense(64) → dropout(30%) → dense(1) using **Python** and **TensorFlow.** Trained with Adam (lr=0.001, batch 4) for 300 epochs using MSE loss and 5-fold cross-validation (80/20 split)
- Applied **thresholding** (-70 dB), **zero-padding**, and **normalization** [0-1] for preprocessing.
- Designed a **UKF estimator** using **MATLAB** to track peak frequency and rate of change for nonlinear modeling.

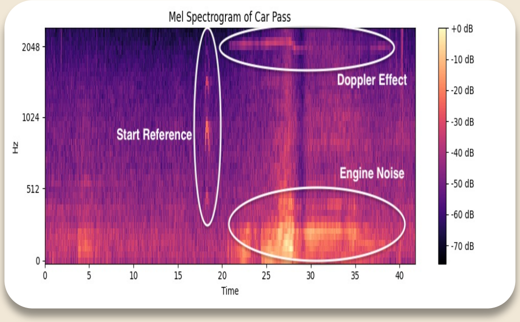
Results

- Achieved **<2.7 km/h** average error with CNN, outperforming UKF in accuracy and efficiency.
- Showed feasibility of UKF estimator.

Sample Training Curve



Raw Spectrogram



UKF Results at 40 km/h

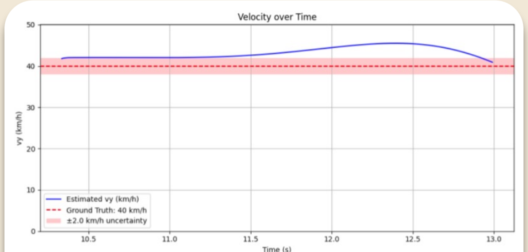


Figure 11: 40 kph constant straight-line motion

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IR Sensor & Thermocouple Based Localization

Multi-sensor probabilistic fusion and EKF-based tracking

Goal

- Develop a multi-sensor **localization** system combining **IR sensors** and **thermocouples** to estimate the position of a heated block.
- Implement an **Extended Kalman Filter** to track a moving object using **IR sensors.**

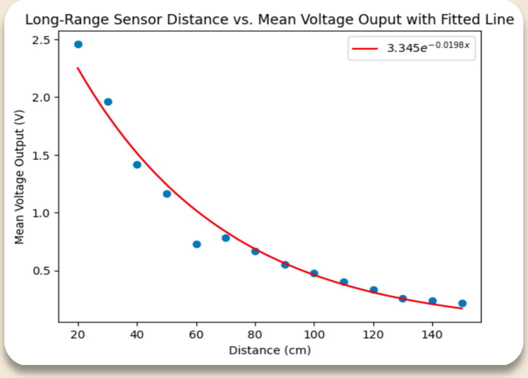
Method

- Modeled exponential voltage-distance relationships for sensors and analyzed Gaussian noise using **Python.**
- Applied inverse-variance weighted averaging for sensor fusion.
- Built **probabilistic localization maps** in **MATLAB** using **Gaussian distributions** for each sensor type; fused IR and thermocouple data to generate **posterior likelihood surfaces.**
- Designed and tuned an **EKF** for real-time tracking using nonlinear sensor and motion models. Validated in **Simulink** and on experimental data.

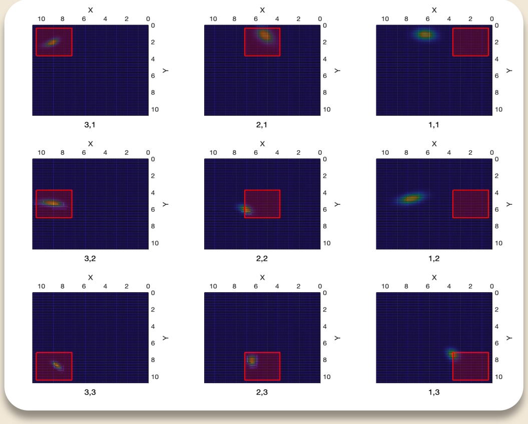
Results

- Achieved **4.4%** average distance error with inverse-variance fusion.
- Showed probabilistic fusion feasibility for multi-sensor localization.
- EKF achieved **< 5 cm** final position error.

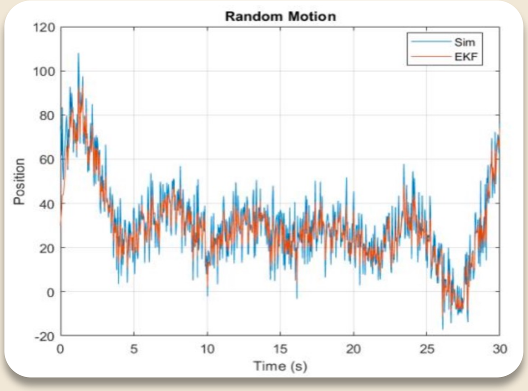
Exponential Model Fit



Fused Posterior Plots for Each Position



EKF Performance on Random Motion



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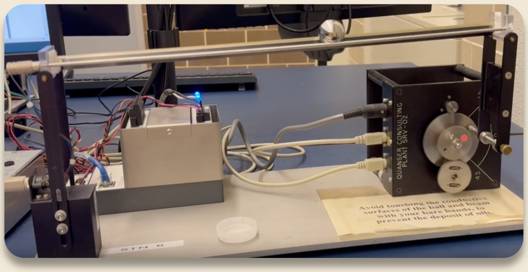
Digital Control System for Ball-on-Beam Stabilization

Discrete-time feedback control design and implementation

Goal

- Design and implement a **discrete-time control system** to stabilize and position a metal ball on a beam using a resistive strip and potentiometer feedback.
- Achieve control through system modeling, linearization, and feedback design.

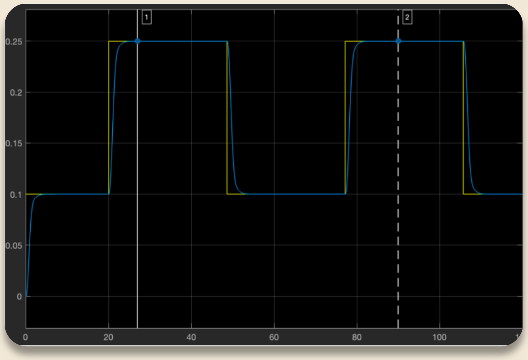
Real System



Method

- Derived and **linearized nonlinear system dynamics** using first principles and step-response experiments.
- Designed **inner and outer control loops** to regulate beam angle and ball position, addressing system nonlinearities.
- Applied Input-Output Parameterization (IOP) in **MATLAB/Simulink** to obtain controllers meeting specifications.
- Validated via **Simulink** simulations before deploying on hardware.
- Tuned real system controller to address **stiction, calibration errors, sampling effects**, and **non-idealities.**

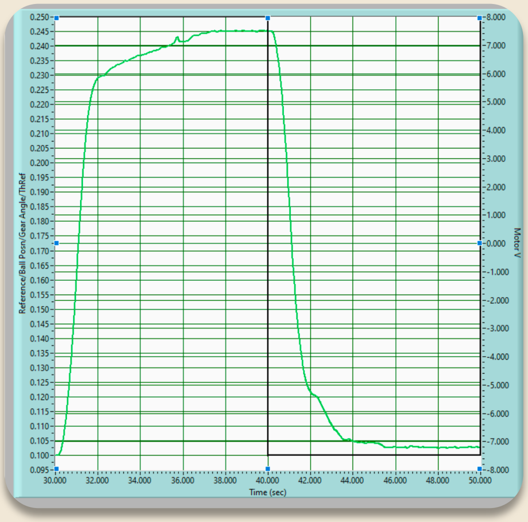
Simulated Step Response



Results

- Met **7 s settling-time, <5 mm position error**, and **control effort** requirements.
- Verified system behaviour in simulation and real-time operation.

Real Step Response



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