Terrain Classification using Tactile and Proprioceptive Data – UE23CS352A Machine Learning Mini Project

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Problem Statement

Terrain recognition helps robots adapt gait for stability and efficiency. We adapt tactile deep-learning methods to IMU-based proprioceptive data for terrain classification.

Dataset

We primarily focused on the BorealTC proprioceptive dataset, specifically the IMU data. This dataset provides inertial measurements (angular velocity and linear acceleration) from a robot's IMU sensor. The data used for model training and evaluation consisted of 6 features: wx, wy, wz, ax, ay, and az. Data was segmented into fixed windows (~100 samples based on the notebook), normalized, and labeled for training.

Methodology

* **Data Preparation:** Loaded BorealTC IMU data, segmented into fixed windows (100 samples, step 50), normalized, and mapped to 4 terrain classes ('hard', 'unstructured', 'soft', 'indoor'). Data split into 70/15/15 train/val/test sets with random seed 42.

* **SVM Baseline:** Implemented an SVM classifier using a pipeline with StandardScaler and SVC.

* **1D CNN:** Implemented a 1D CNN with 4 Conv1D layers (filters 64, 128, 128, 256, kernel 5, stride 1, ReLU), followed by BatchNormalization, MaxPooling1D (pool 2), Dropout (0.5), Flatten, and two Dense layers (256, num_classes) with BatchNormalization and Dropout.

* **Training:** Trained models using Adam optimizer (learning rate 1e-4) with sparse categorical crossentropy loss for 50 epochs, batch size 32.

* **Evaluation:** Evaluated models on the test set using accuracy, confusion matrices, and classification reports.

Results

Model	Test Accuracy	Macro Avg F1-score
SVM Baseline	0.7037	0.6700
1D CNN	0.8950	0.8900

Observations

The 1D CNN model achieved a significantly higher test accuracy and macro average F1-score compared to the SVM baseline on the BorealTC IMU test data. This demonstrates the effectiveness of the convolutional architecture in capturing temporal features within the IMU data for terrain classification. The SVM, while providing a reasonable baseline, did not perform as well on this sequential data. Confusion matrices (not shown in this summary) provided detailed insights into per-class performance.

Conclusion

This project successfully implemented and evaluated a 1D CNN model for terrain classification using the BorealTC IMU dataset, which significantly outperformed an SVM baseline. This highlights the suitability of 1D CNNs for this task. Future work could involve exploring other deep learning architectures, incorporating other modalities from the BorealTC dataset, and hyperparameter tuning to further improve performance.