

University of Exeter

Multi-task Learning for Transportation Mode Classification and Driver Identification

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Introduction to Driving Behaviour and Insurance

- **Car Insurance and Premiums**
 - Car insurance market increasingly uses driving behavior.
 - Usage-Based Insurance (UBI) or Pay-As-You-Drive schemes match premiums to driving habits.
- **Challenges in Data Collection**
 - Traditional telematic systems installed in cars.
 - Effective but costly to setup and maintain.
 - Privacy concerns due to lack of driver control over monitoring devices.



Introduction to Driving Behaviour and Insurance

- **Advantages of Smartphones**
 - Equipped with sensors (accelerometers, GPS, etc.).
 - No additional cost for users.
 - Drivers control data usage.
- **Research Challenges**
 - Transport Mode Classification
 - Driver Identification



Research Problem

01: Transport Mode Classification

Identifying user's mode of travel (walking, driving, cycling, etc.) based on mobility data.

02: Driver Identification

Distinguishing the driver from passengers using mobility data.

Aim & Objectives

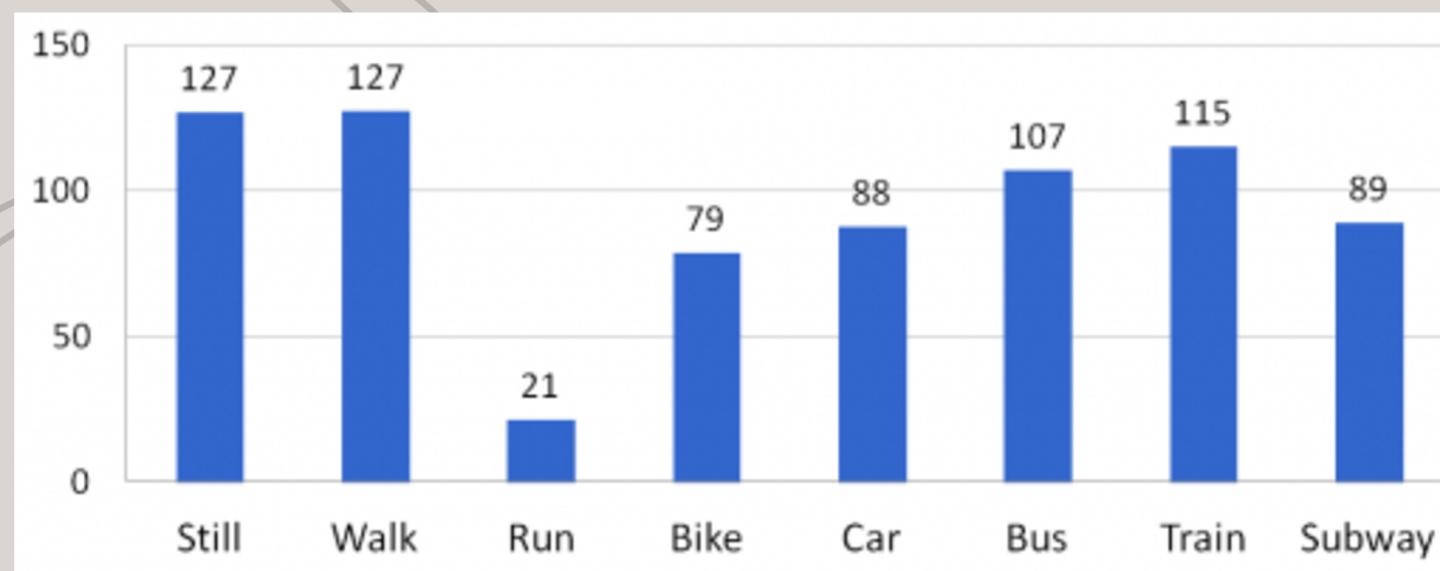
Aim

Build a multi-task deep learning model that can simultaneously perform both tasks using only sensor data from smartphones with 85% accuracy.

Objectives

- Enhance sub-trip classification accuracy;
- Increase robustness to phone orientation;
- Optimize efficiency and prediction time

Sussex-Huawei Locomotion (SHL) dataset



- A versatile annotated dataset of modes of locomotion and transportation of mobile users.
- Contains 750 hours of labelled locomotion data for 8 modes for each 4 phones for 3 users.
- Sensors of interest;
 - accelerometer sensor,
 - gyroscope sensor,
 - rotation vector sensor

Data Preprocessing

Phase 1

Down sampling data from 100Hz to 5Hz by selecting every 20th row

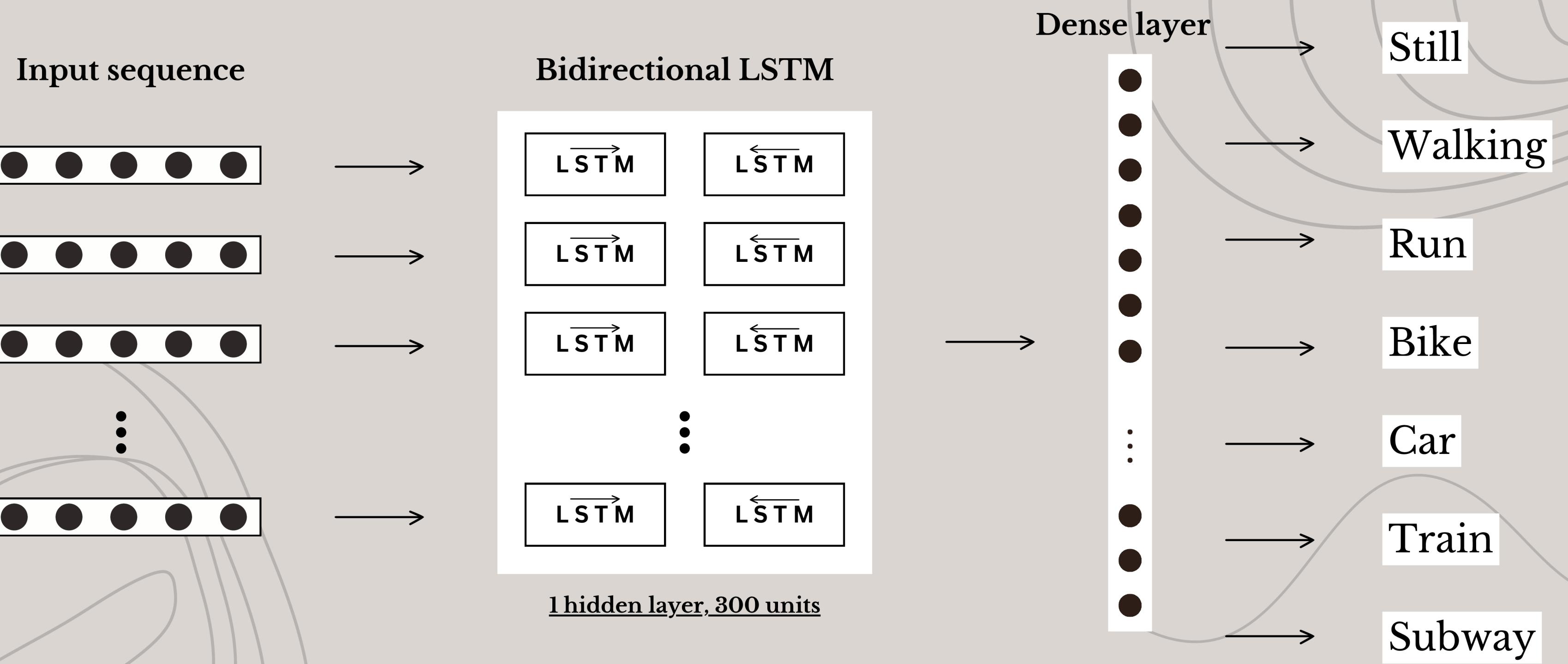
Phase 2

Daily trips broken into journey segments representing the different modes taken.

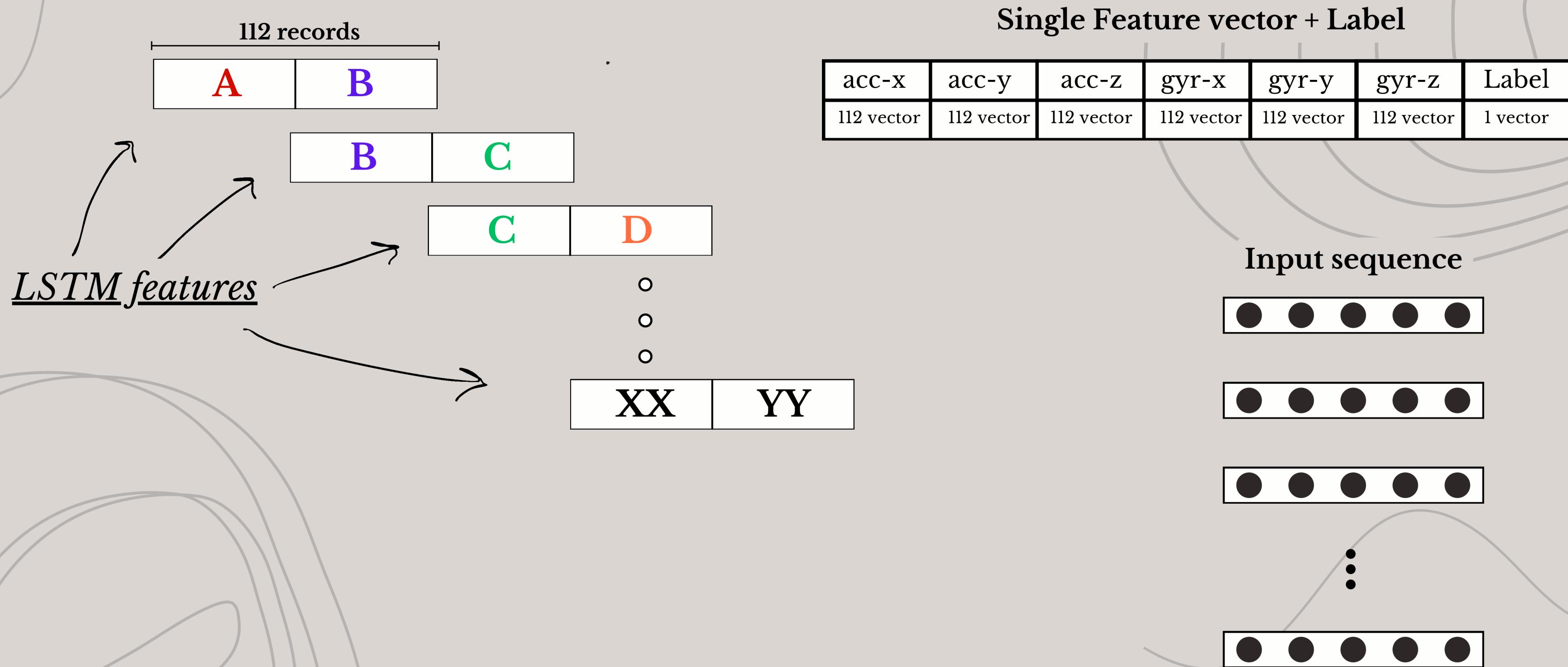
Phase 3

Journey segments further subdivided into pseudo-subsegments using a sliding window¹.

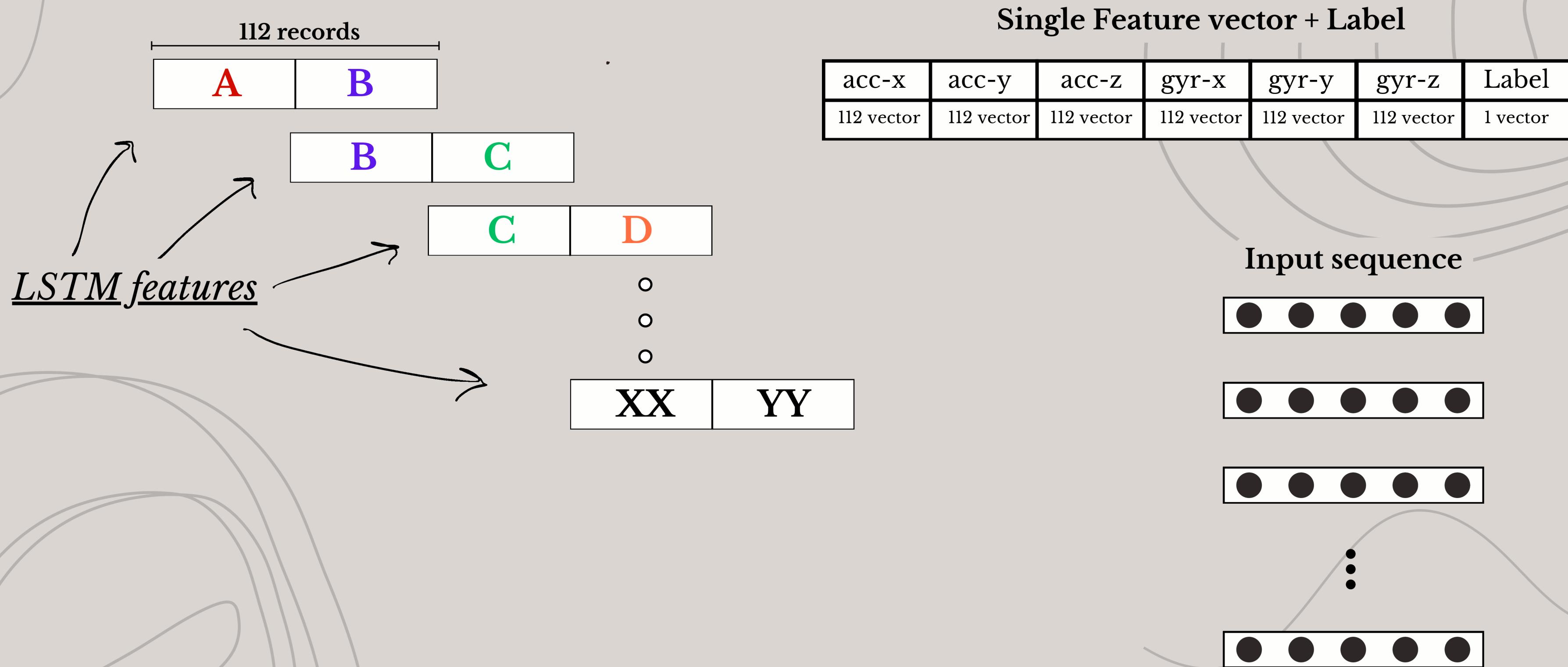
Model 1: Transport Mode Classification



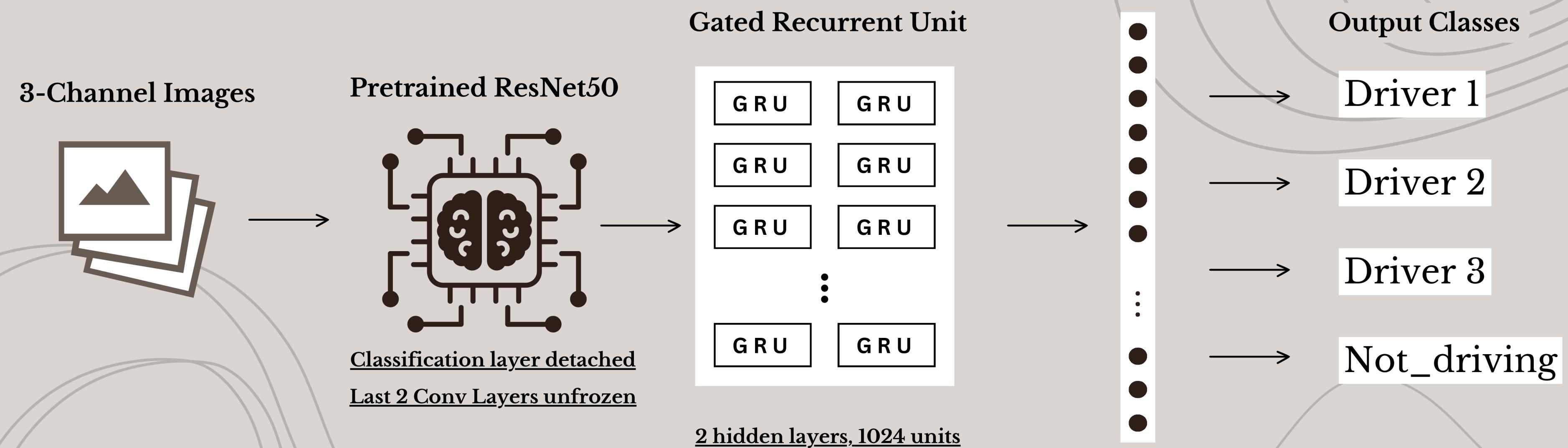
Feature Extraction



Feature Extraction



Model 2: Driver Identification



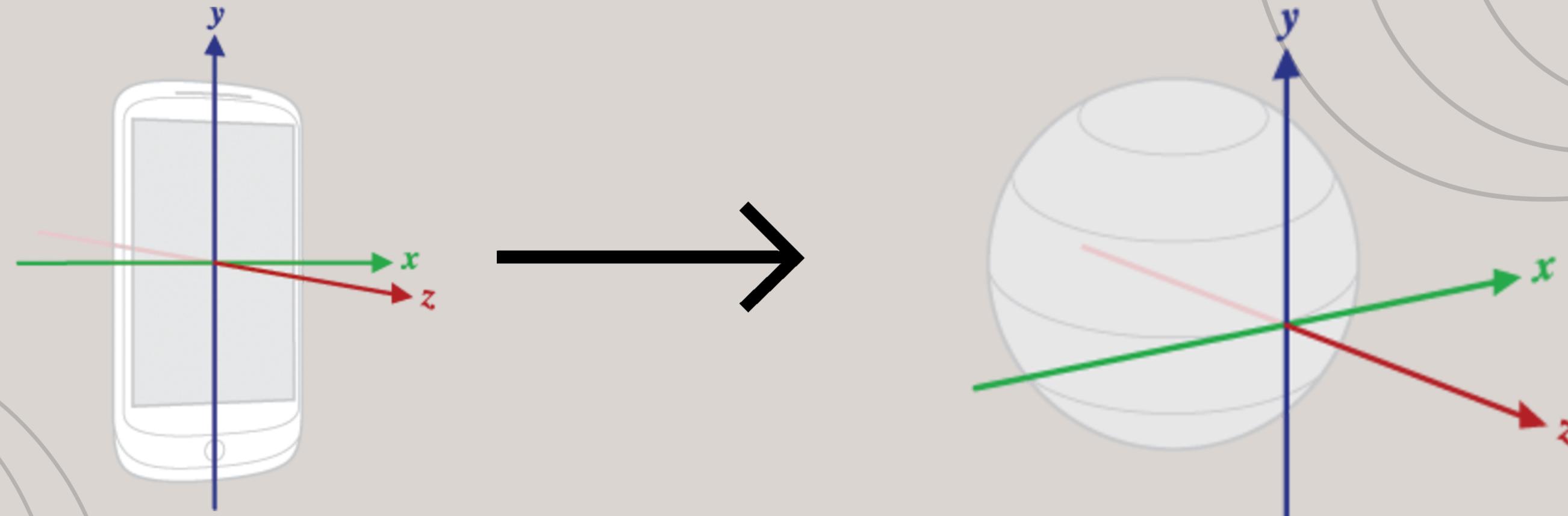
Feature Extraction

01: Transform accelerometer data's orientation

02: Map 1D signals to 2D images using a simple CNN

Feature Extraction

01: Transform accelerometer data's orientation



Device Coordinate System

- Used by accelerometer, gyroscope
- Defined relative to the device itself

World Coordinate System

- Used by rotation vector sensor
- Defined relative to the Earth's geomagnetic properties

Feature Extraction

01: Transform accelerometer data's orientation

Longitudinal acc.

Transversal acc.

Vertical acc.

$$\begin{pmatrix} a'_x \\ a'_y \\ a'_z \end{pmatrix} = R(q_0, q_1, q_2, q_3) \cdot \begin{pmatrix} a_x \\ a_y \\ a_z \end{pmatrix}$$

Rotation matrix a function
of quaternion components

Triaxial accelerometer data

Feature Extraction

01: Transform accelerometer data's orientation

Longitudinal acc.

Transversal acc.

Vertical acc.

Angular velocity

$$\begin{pmatrix} a'_x \\ a'_y \\ a'_z \end{pmatrix} = R(q_0, q_1, q_2, q_3) \cdot \begin{pmatrix} a_x \\ a_y \\ a_z \end{pmatrix}$$

Rotation matrix a function
of quaternion components

$$w = \sqrt{g_x^2 + g_y^2 + g_z^2}$$

Triaxial gyroscope data

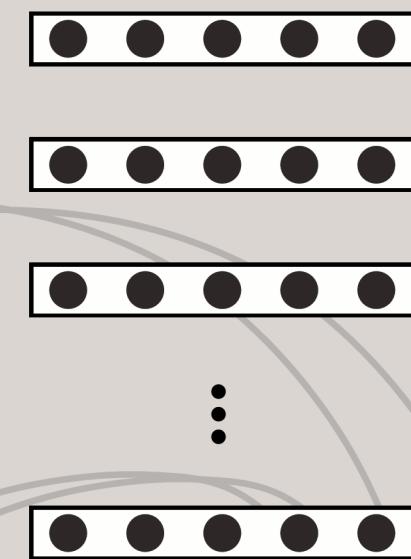
Triaxial accelerometer data

Feature Extraction

02: Map 1D signals to 2D images using a simple CNN

Input sequence

Long. acc / Transv. acc / Ang. velocity



Vectors of size 224

Simple CNN

Conv. Layer 1

1D Conv., 224 channels

Conv. Layer 2

2D Conv., 224 channels

Dense layer



Output Classes

Driver 1

Driver 2

Driver 3

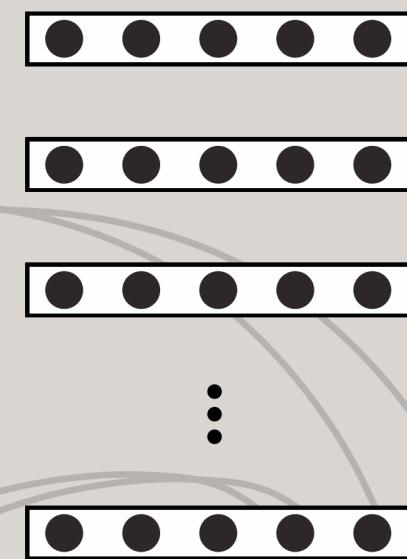
Not_driving

Feature Extraction

02: Map 1D signals to 2D images using a simple CNN

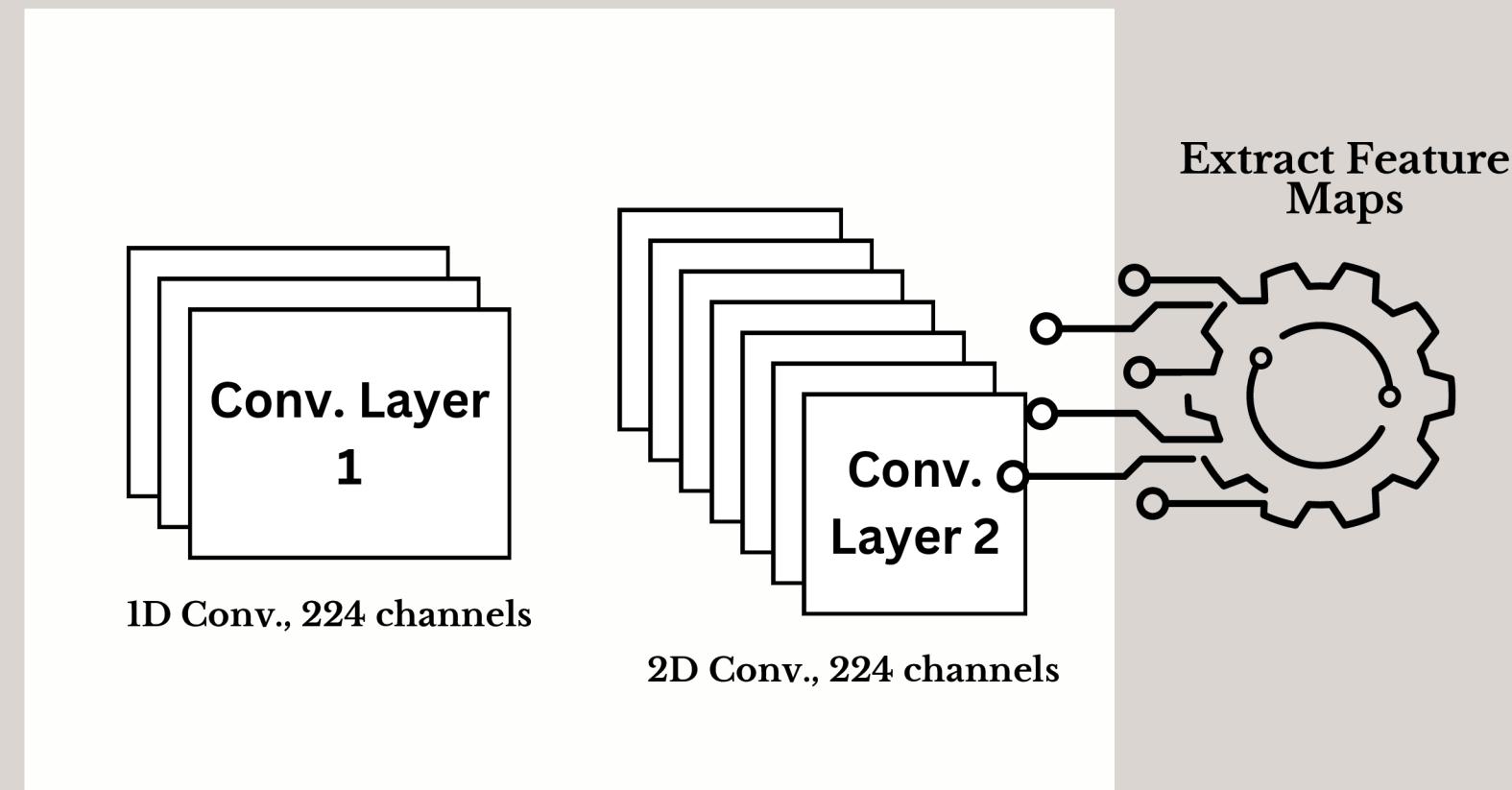
Input sequence

Long. acc / Transv. acc / Ang. velocity



Vectors of size 224

Simple CNN

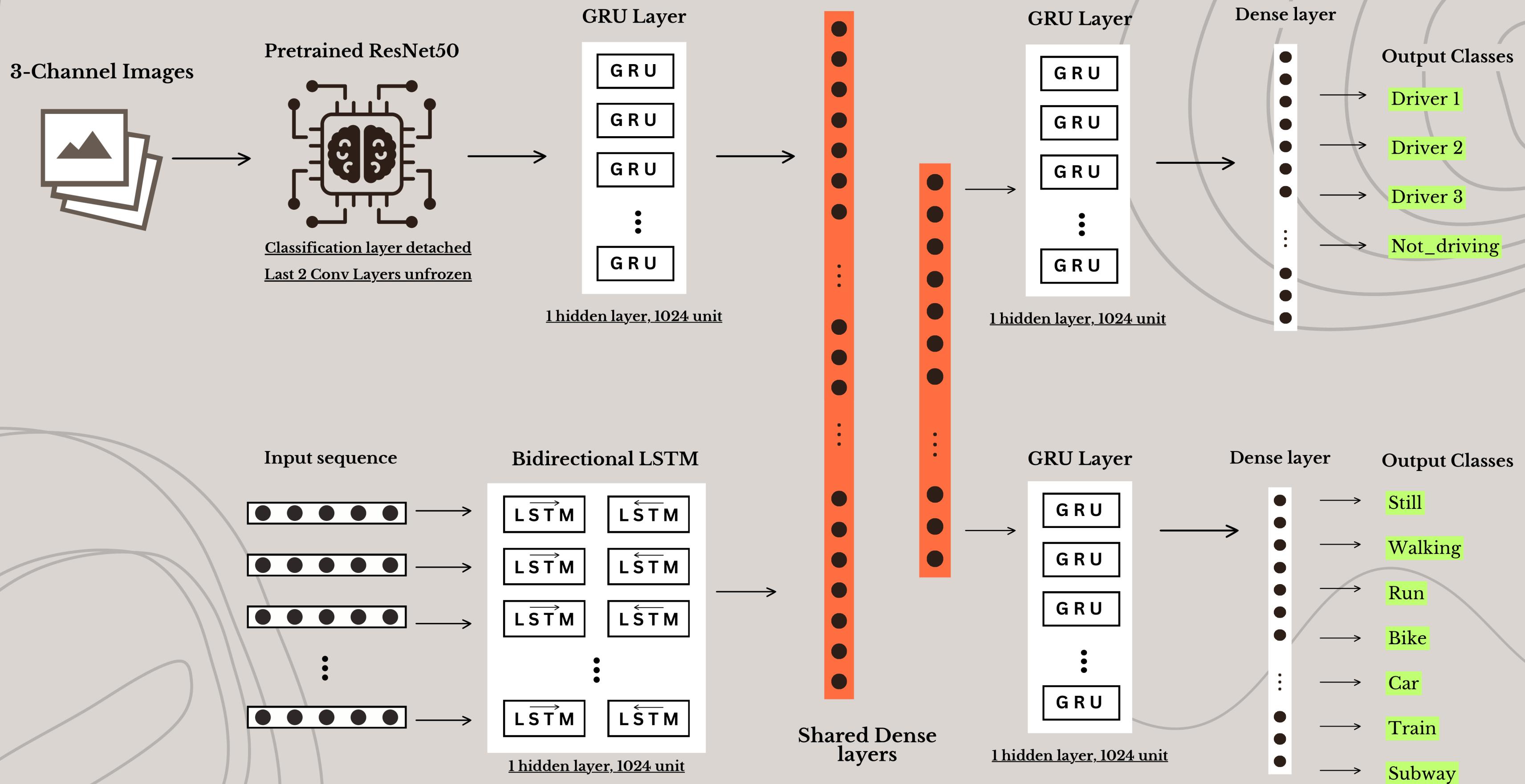


1-Channel Images

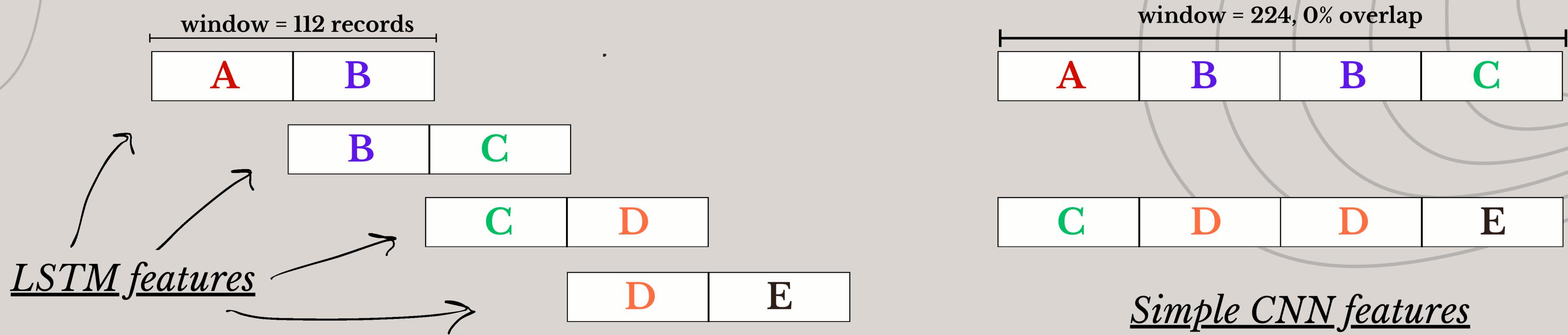
Long. acc / Transv. acc / Ang. velocity



Model 3: Multitask Model

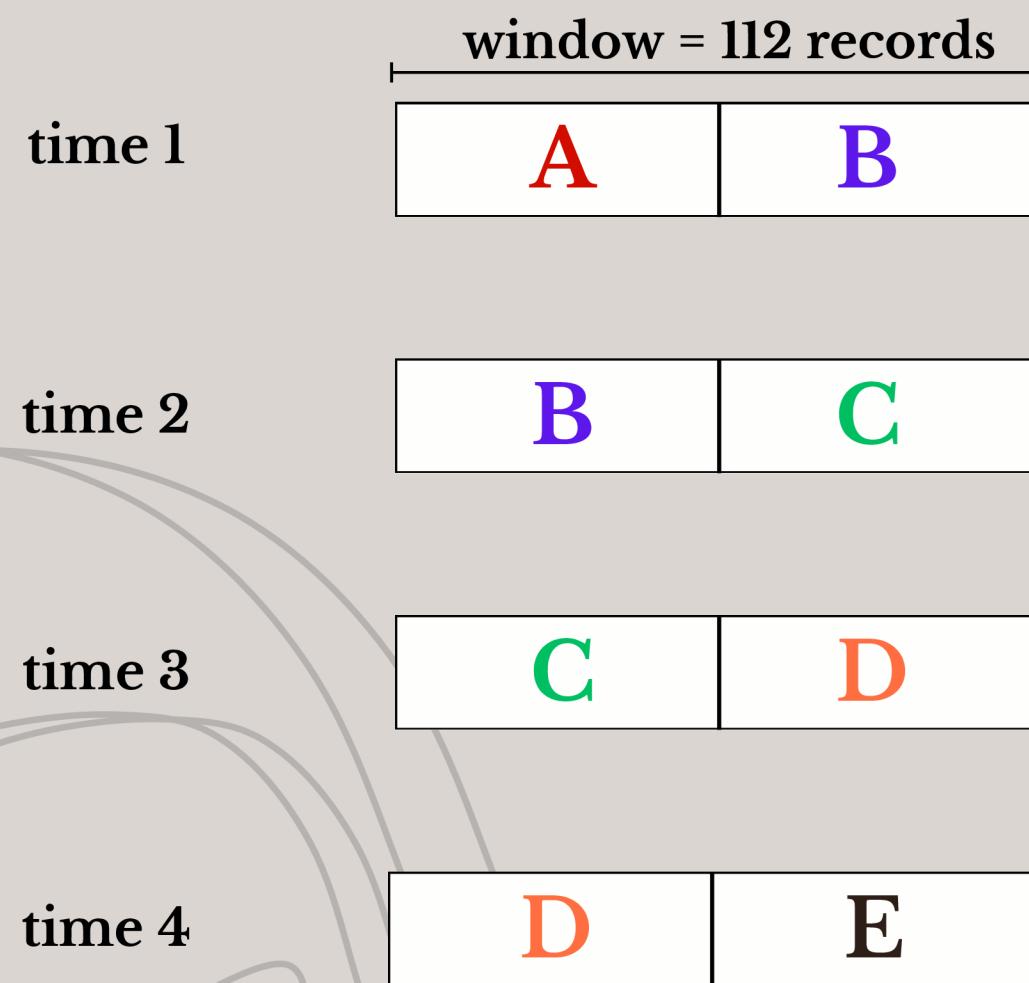


MTL Data Synchronization

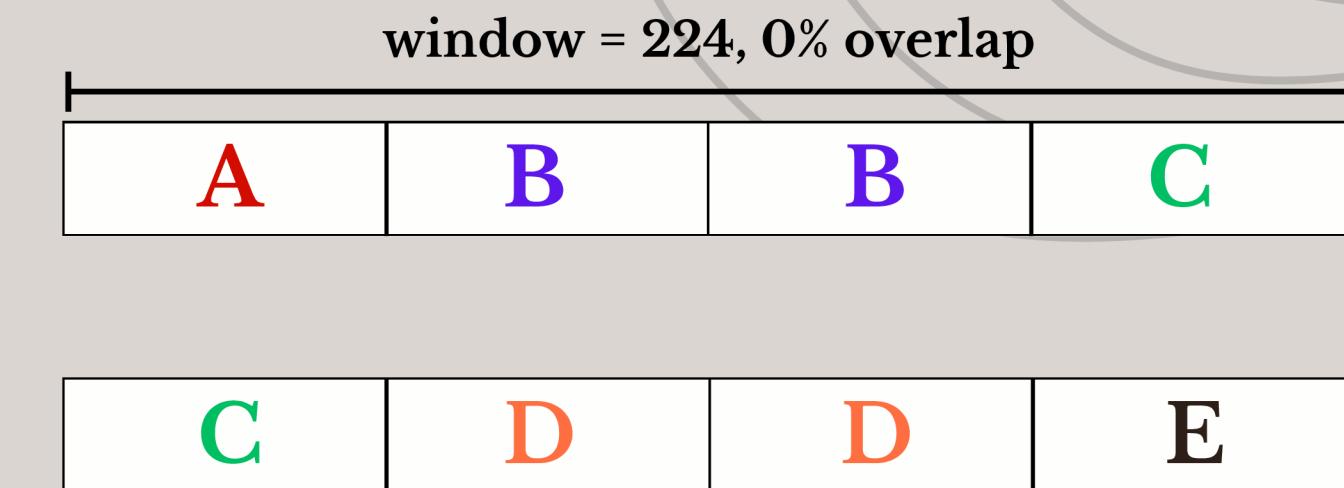


MTL Data Synchronization

LSTM features

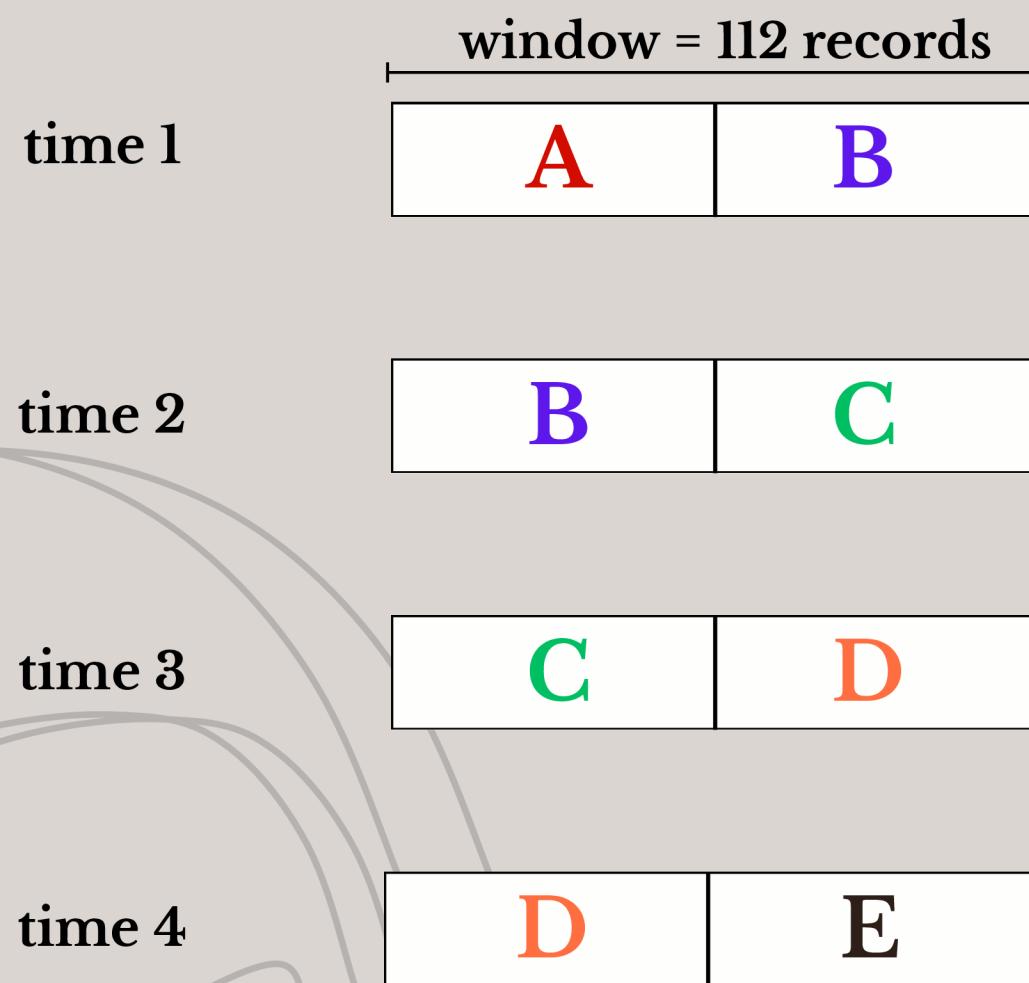


Simple CNN features

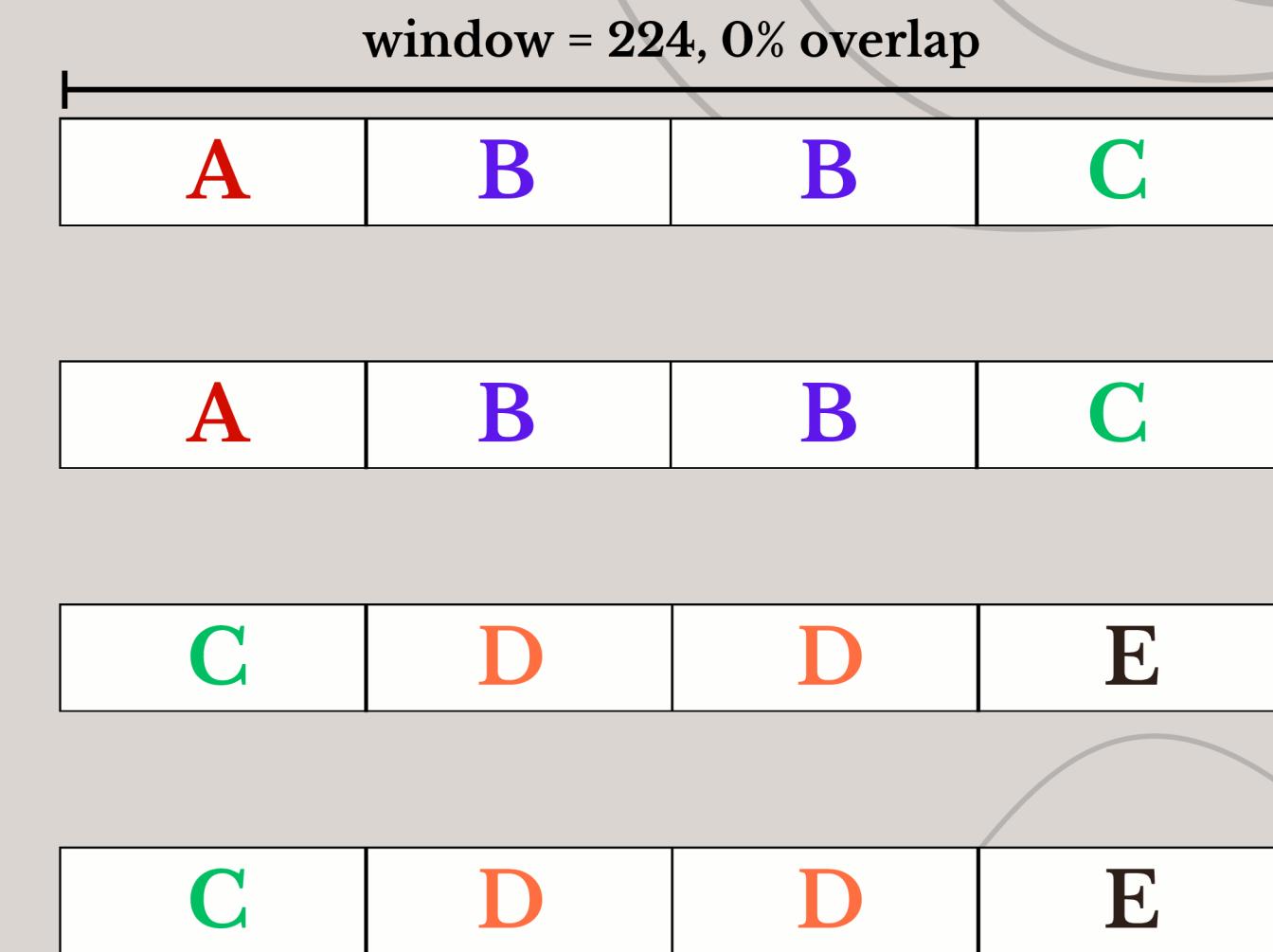


MTL Data Synchronization

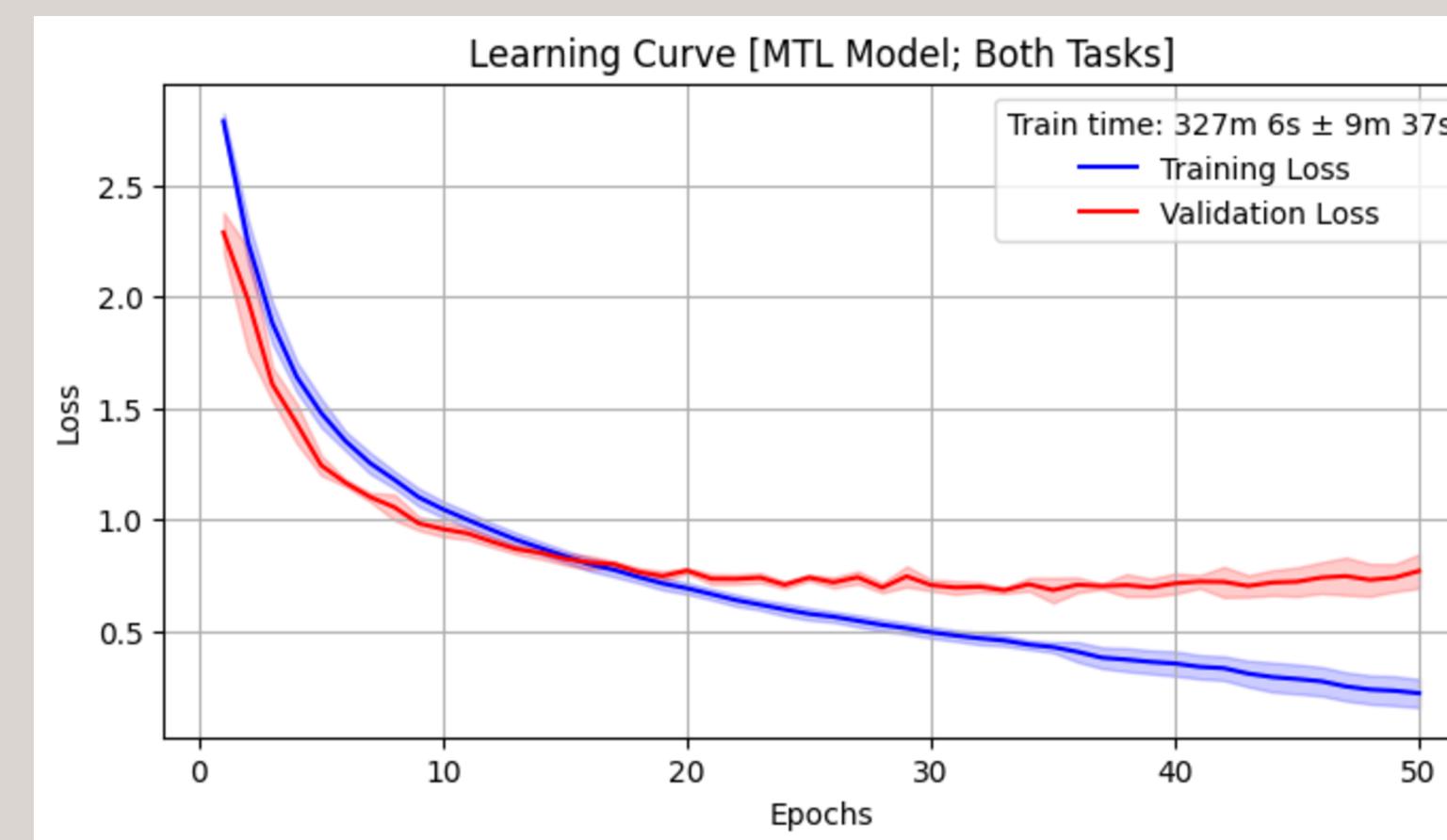
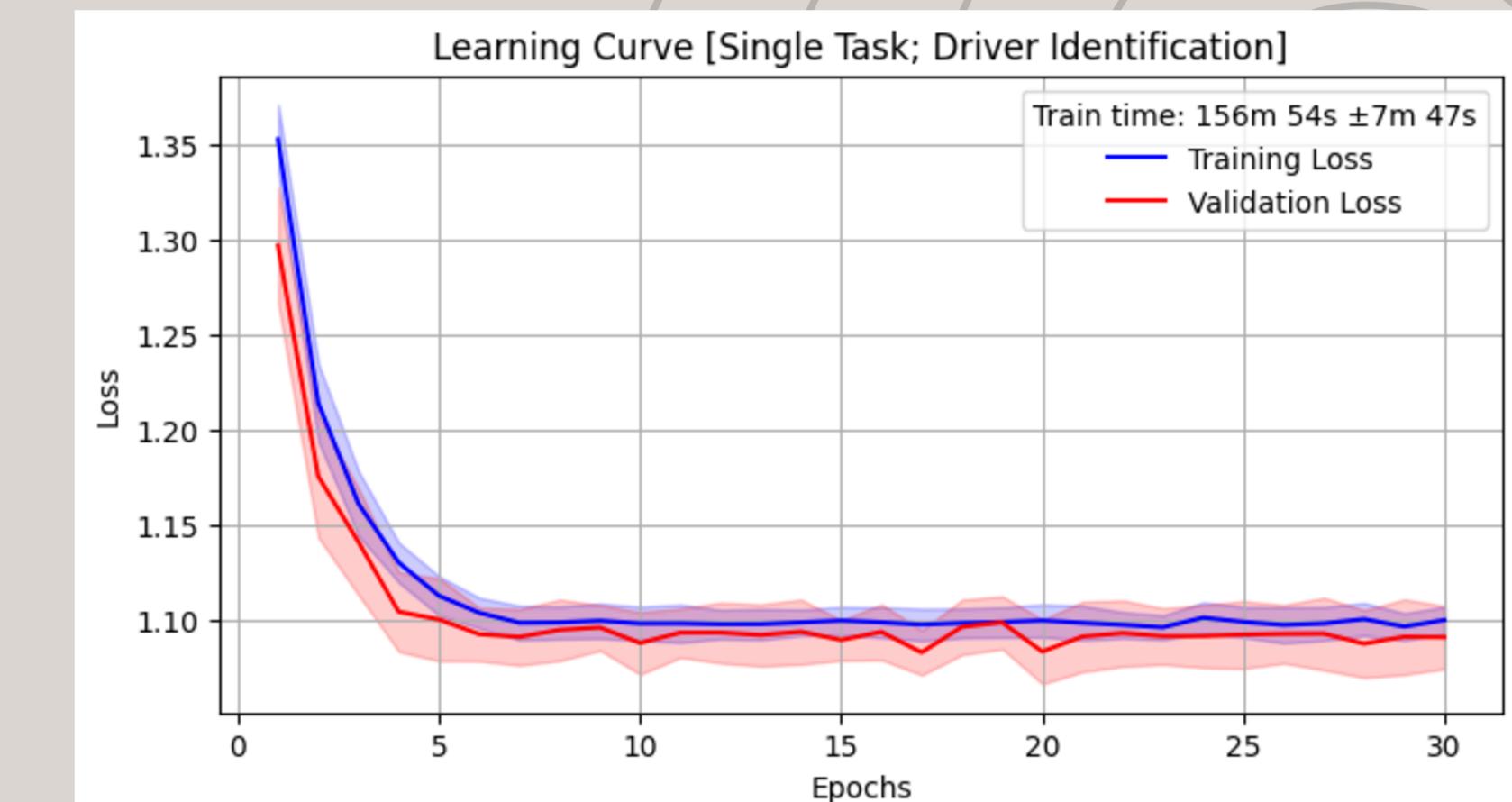
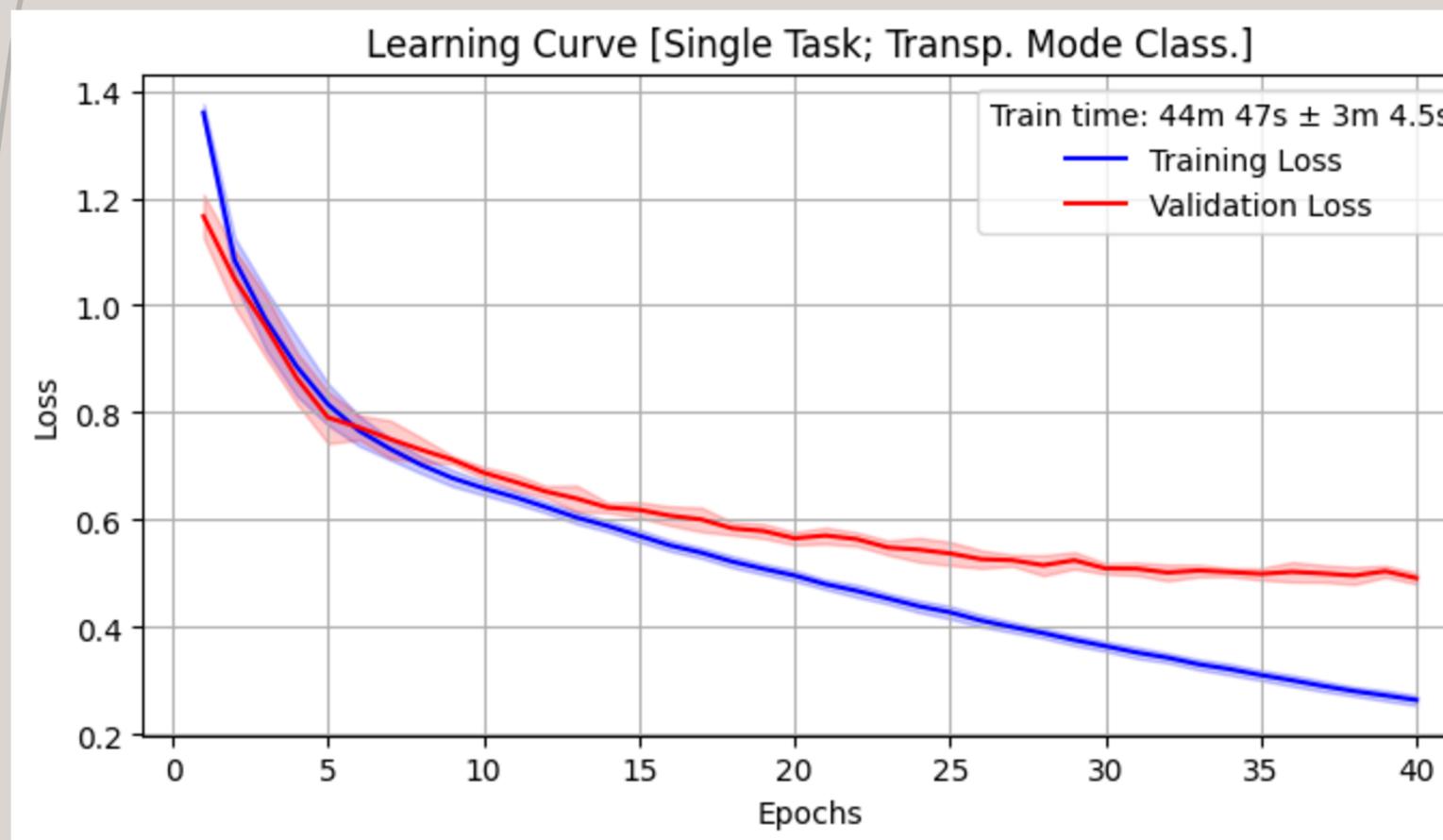
LSTM features



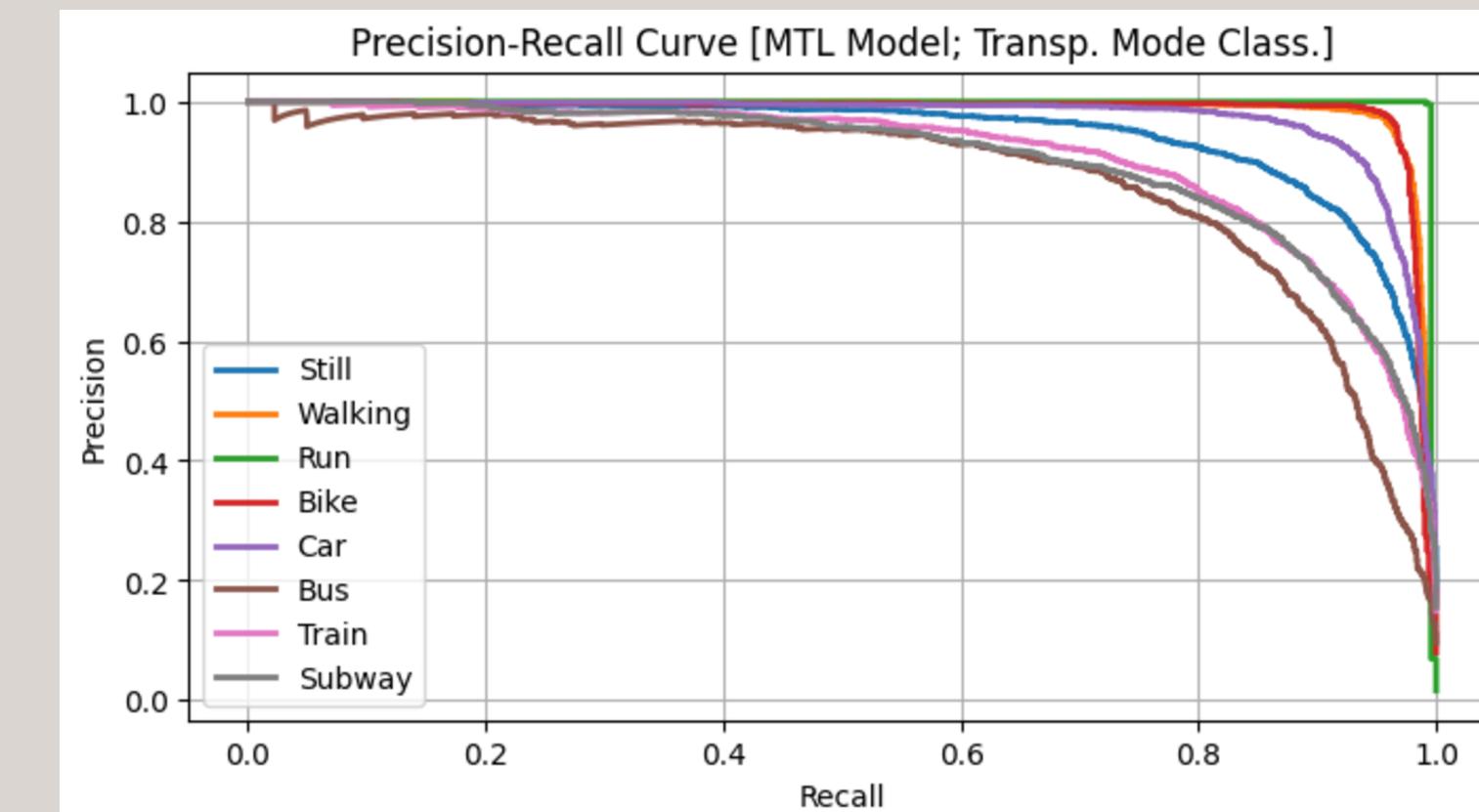
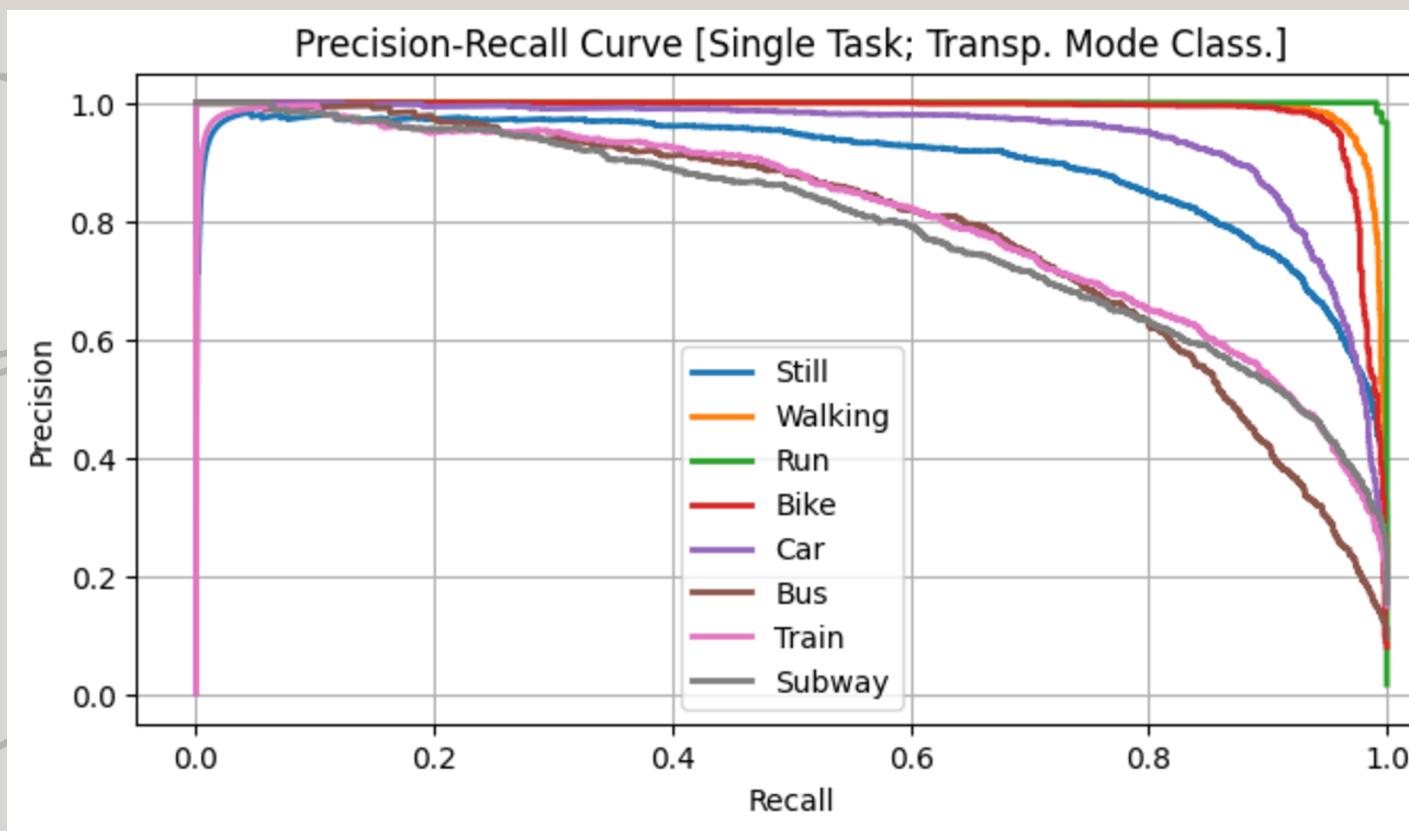
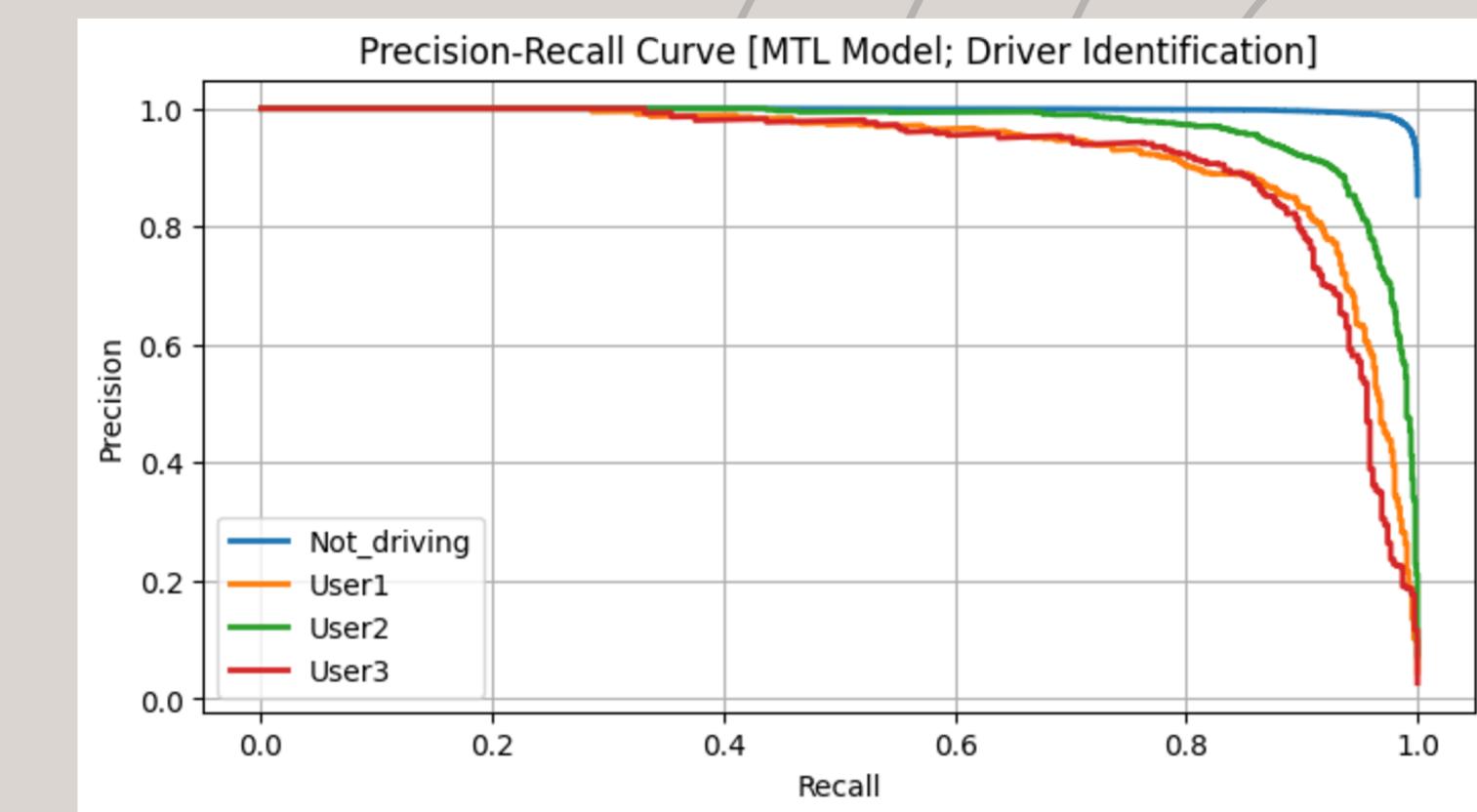
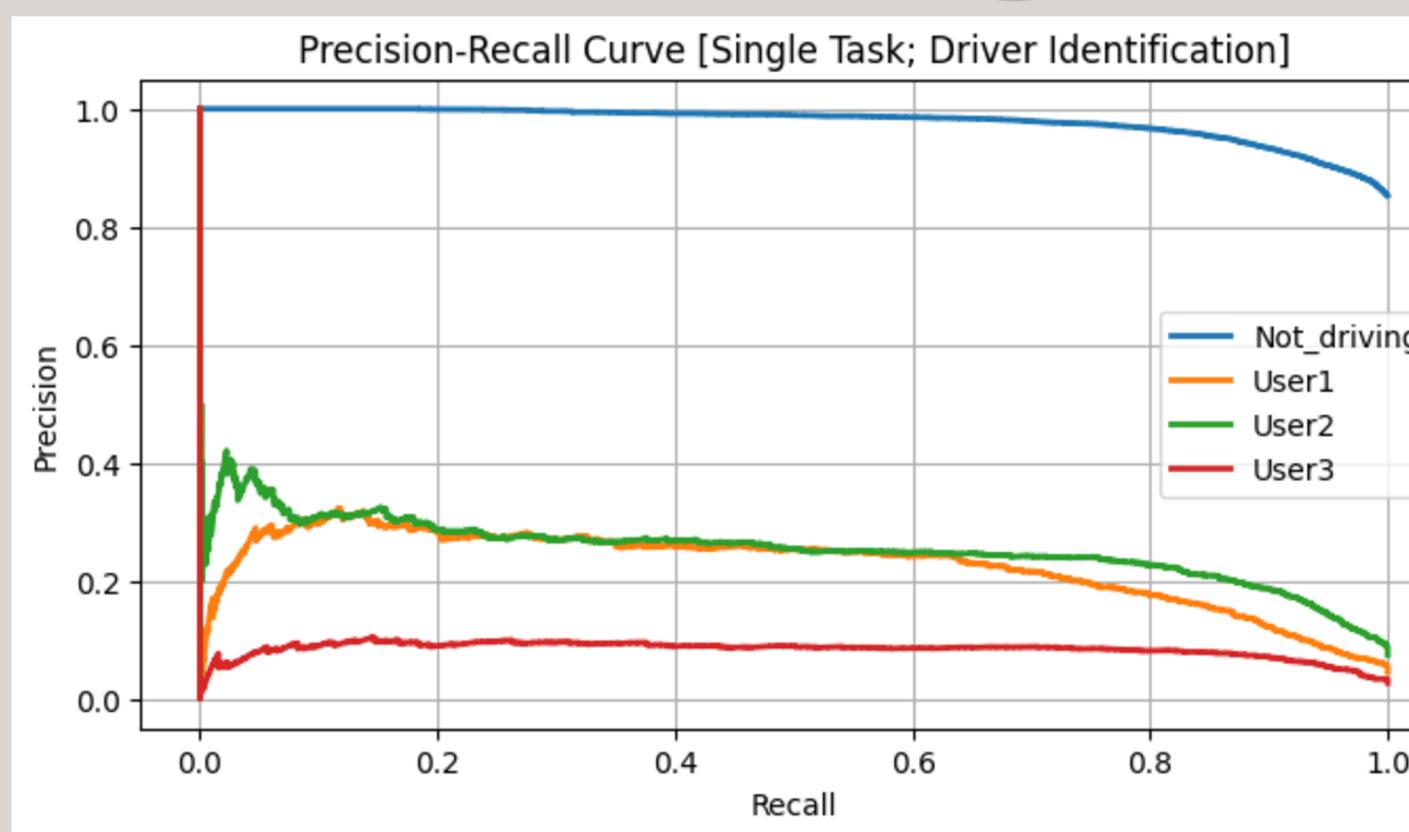
Simple CNN features



Results



Results



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Conclusion

**Thank
You**