

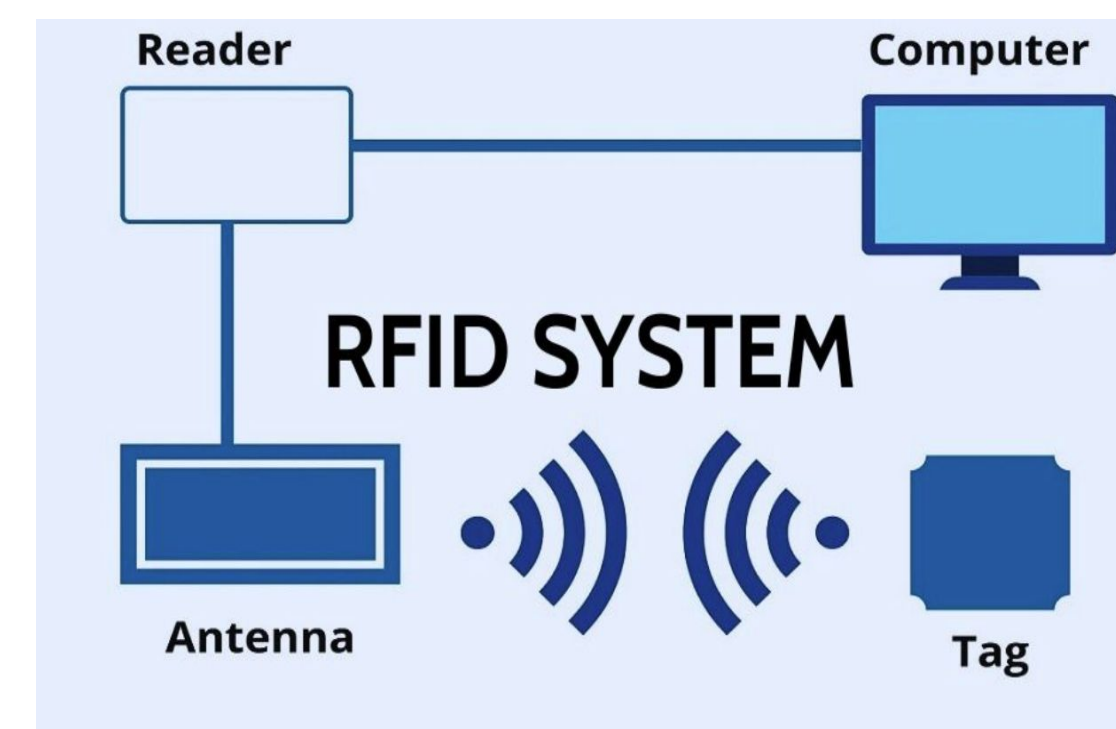
STUDENTS: Momoka Sakamoto, Cheryl Chen, Zora Gao, Christine Chang, Zhuoran Wu

Introduction



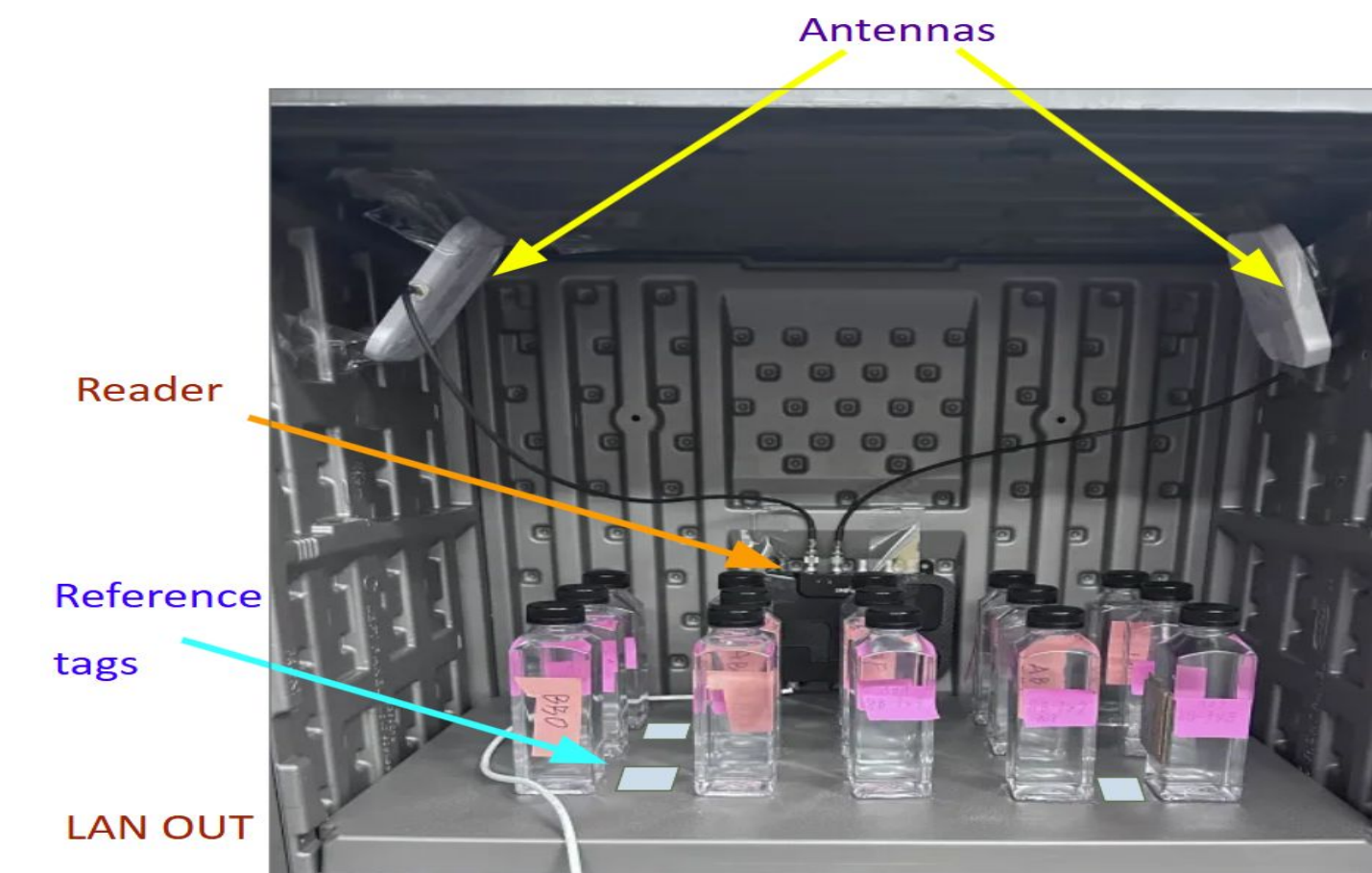
- RAIN RFID is widely used in inventory and logistics because of its **low cost, scalability, and non-line-of-sight operation**. Current RFID systems mainly focus on object identification and tracking.
- This project explores a smart storage system that extends commercial RAIN RFID technology for bottle detection and relative liquid fullness estimation inside a cabinet environment.
- Our goal is to develop a **low cost and scalable sensing approach** by analyzing RFID signal measurements under different bottle configurations, liquid levels, and environmental conditions.

RFID Sensing Principle



- RFID (Radio-Frequency Identification)** is a wireless technology that uses radio waves for object identification and tracking. A typical RFID system includes a reader, antenna, computer, and RFID tags.
- Passive RFID tags communicate through backscatter by reflecting electromagnetic waves transmitted from the RFID reader.
- In this project, bottle liquid levels and surrounding objects affect RF propagation and reflections, causing RSSI variations that can be used for bottle detection and relative fullness estimation.

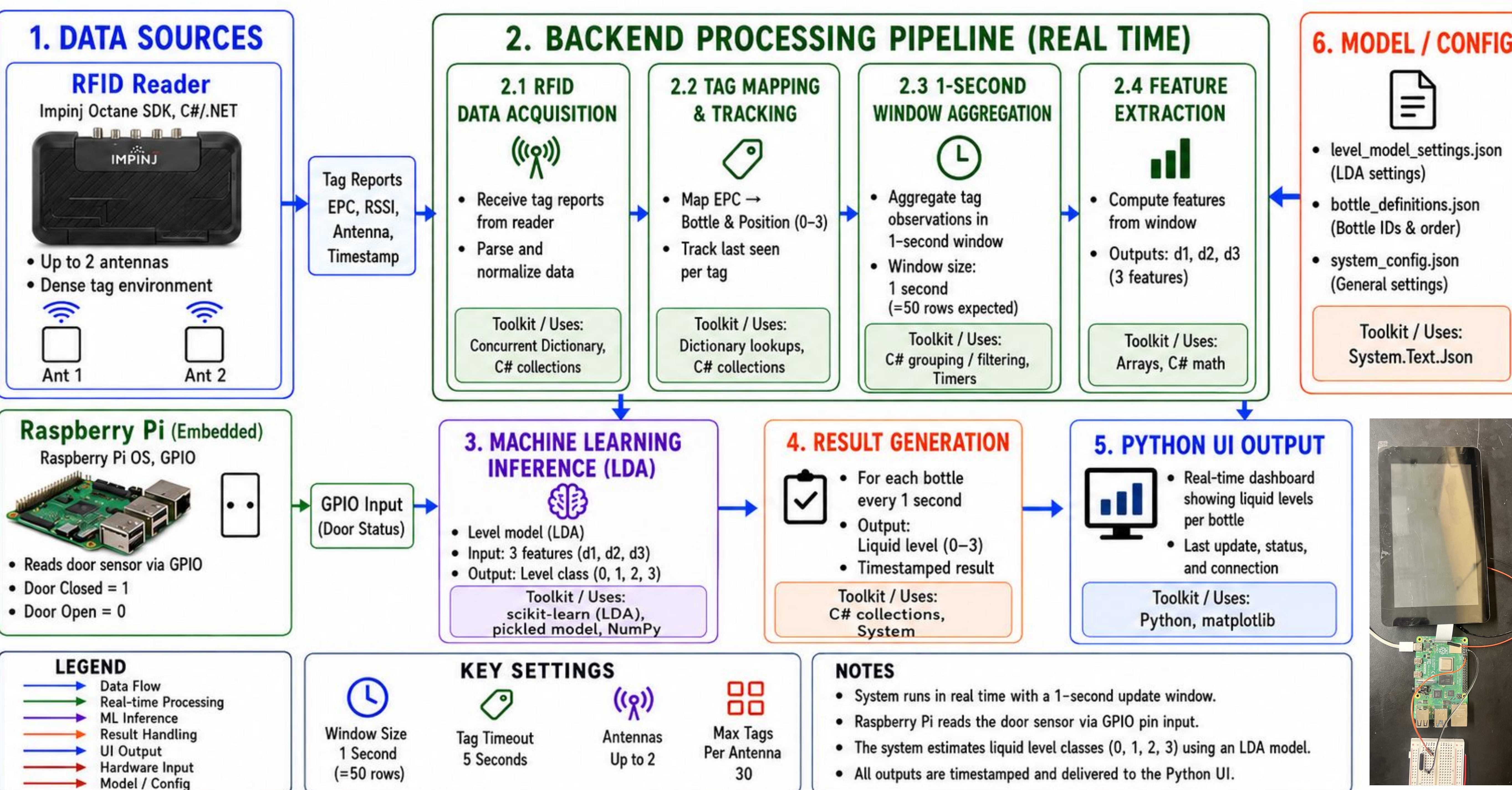
Cabinet Setting



- Plastic cabinets were chosen over metal because they don't reflect EM wave of the inside. Eliminate nulls inside the cabinet, will not affect the detection area.
- We choose to have two antennas placed at top two corners of the cabinet to prevent any signal blocking.
- These two antennas are connected to the RFID reader, which is placed on the back side of the cabinet as the figures show and uses a LAN cable to connect to the PC.
- Bottles are being placed in the center layer of the cabinet. The two independent antennas ensure the detection of those bottles.

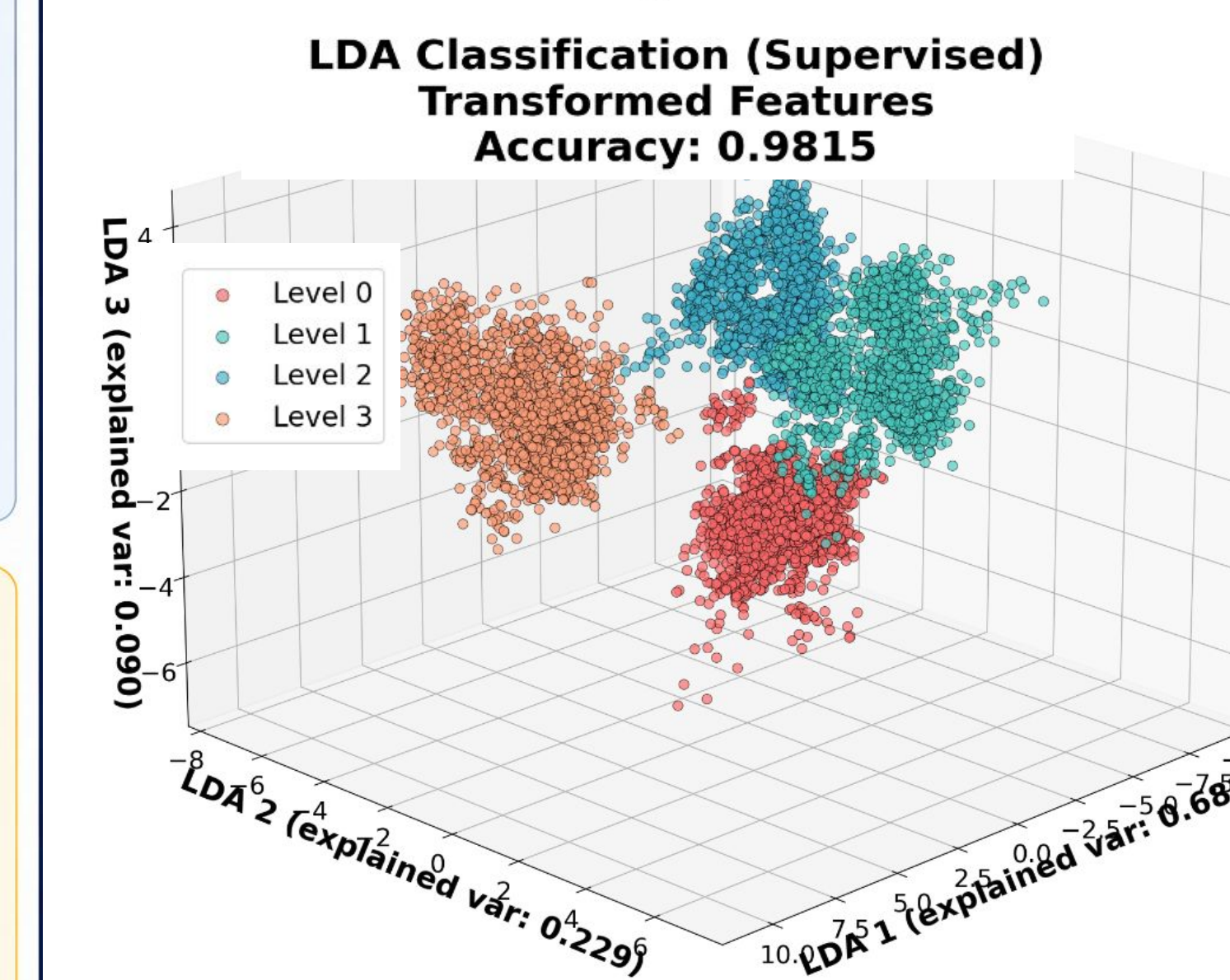
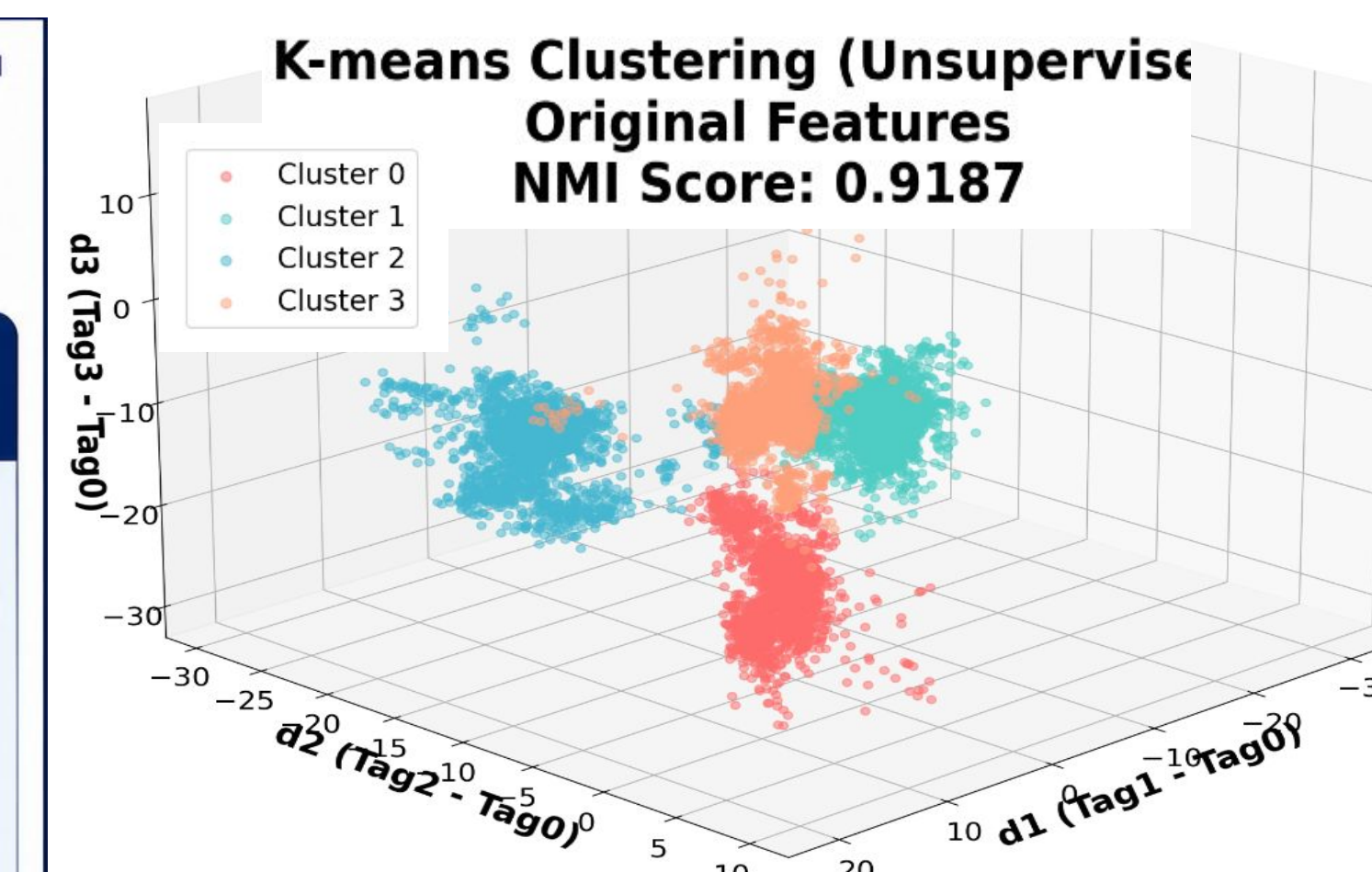
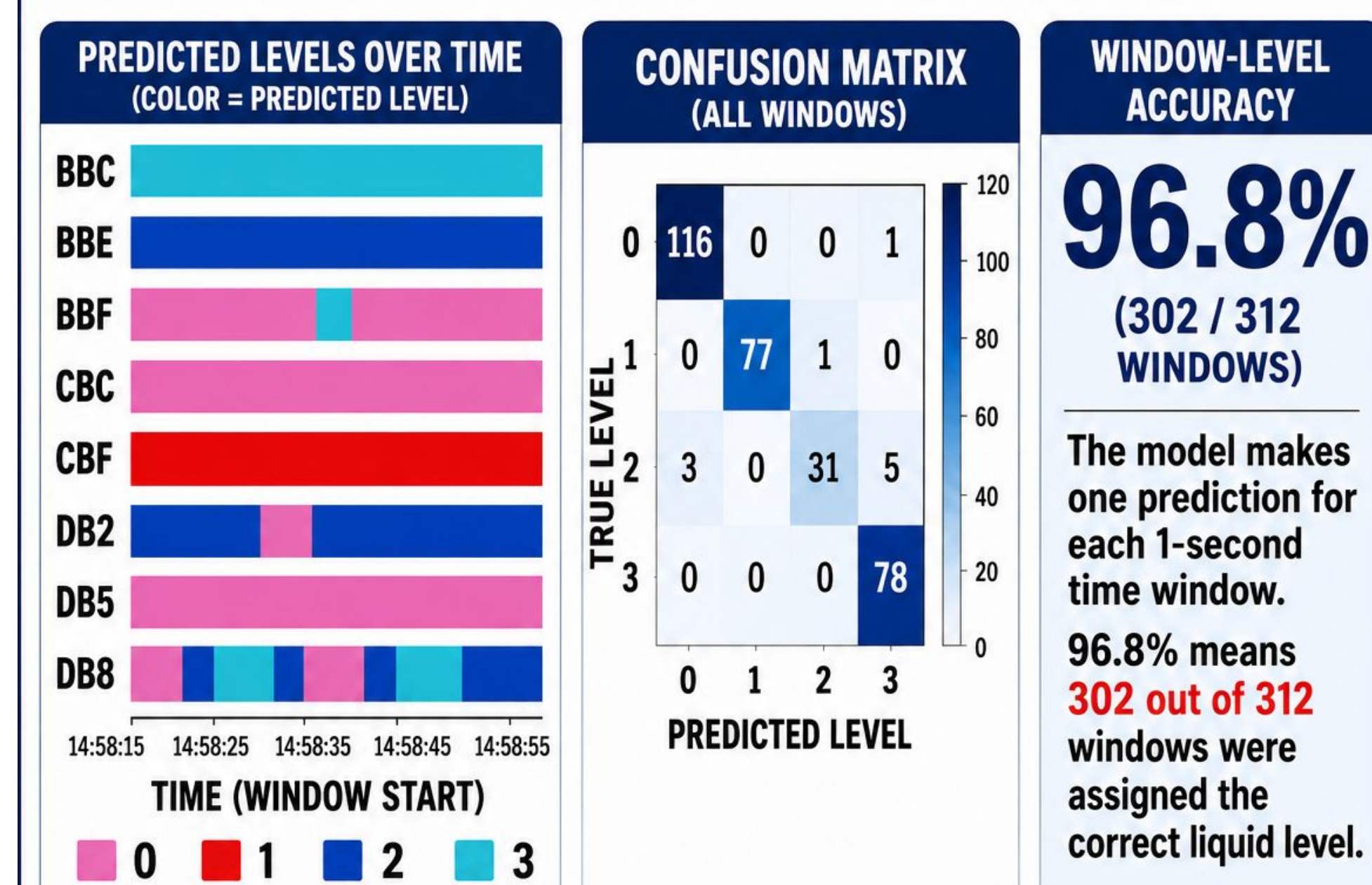
System Overview and Methodology

RFID LIQUID LEVEL ESTIMATION BACKEND SYSTEM DIAGRAM



Results

8 BOTTLES MOVEMENT IN CABINET COMPACT EVALUATION RESULTS



TEST CONDITION

Continuous bottle movement inside the cabinet, occasional hand blocking, and bottle tipping may affect RFID signal quality and cause short-term prediction fluctuations.

Future Plans, Acknowledgements and Conclusion

- We currently use four reference tags in the cabinet, but each bottle is assigned only one reference tag. A next step is to assign all four reference tags to each bottle, generating additional relative signal distributions and enabling majority voting to improve prediction robustness.
- We also plan to add more antennas. Since the reader supports up to four antennas, this can provide higher-dimensional data for model training and may further improve accuracy.

References

- R. Bhattacharyya et al., "RFID Tag Antenna Based Sensing: Does Your Beverage Glass Need a Refill?," IEEE RFID, 2010.
- R. Bhattacharyya et al., "Representation Learning Using RAIN RFID Tag Backscatter Features for Material Classification," IEEE RFID, 2025.