

Master Thesis Presentation

An Audio-based Approach for Industrial Equipment Predictive Maintenance

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Agenda

- Motivation
- AudioForesight Solution
- Results
- Future Work
- Conclusion

There is a challenge in today's industry

an overview

Industrial equipment's **failure** events cause

 increased offline time of the equipment

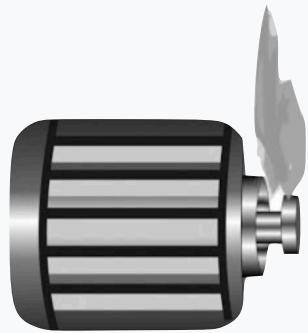
 substantial after-failure repairing costs

 losses for industrial operators

 supply outages for consumers, if not managed

Maintenance Philosophies

evolution of maintenance categories



Run-to-failure Maintenance

Fix the equipment when it fails

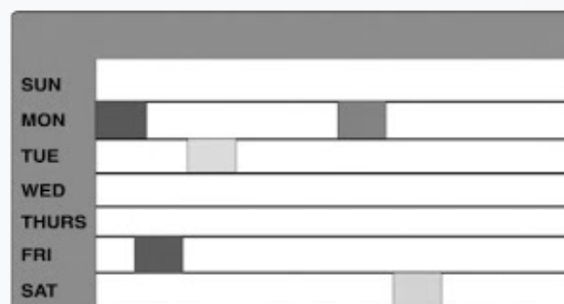


Proactive Maintenance

Identify root causes of failure

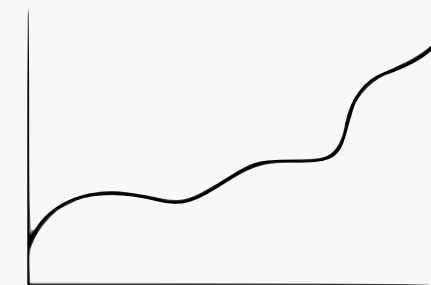
Maintenance
Categories

maintenance aims at ensuring a
virtual availability of 100 %



Preventive Maintenance

Fixed time maintenance



Predictive Maintenance

Condition-based maintenance

Predictive Maintenance

application domain overview

predictive maintenance
technique

“Preventing machinery failures by predicting when will they occur.”

in real-world scenarios :

Measuring
Sensors



Monitor Equipment
Physical Conditions



Perform Maintenance
Service

exploitable in the **industrial environment** to reduce equipment offline time and financial costs.

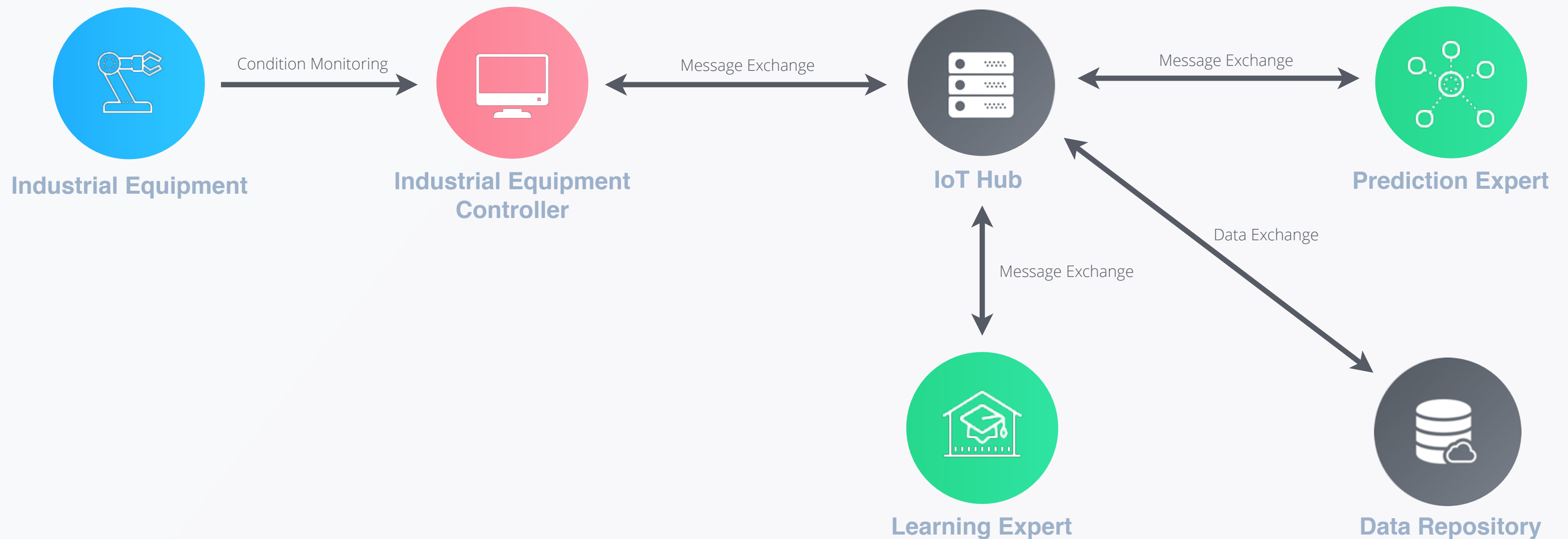
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What is AudioForesight?

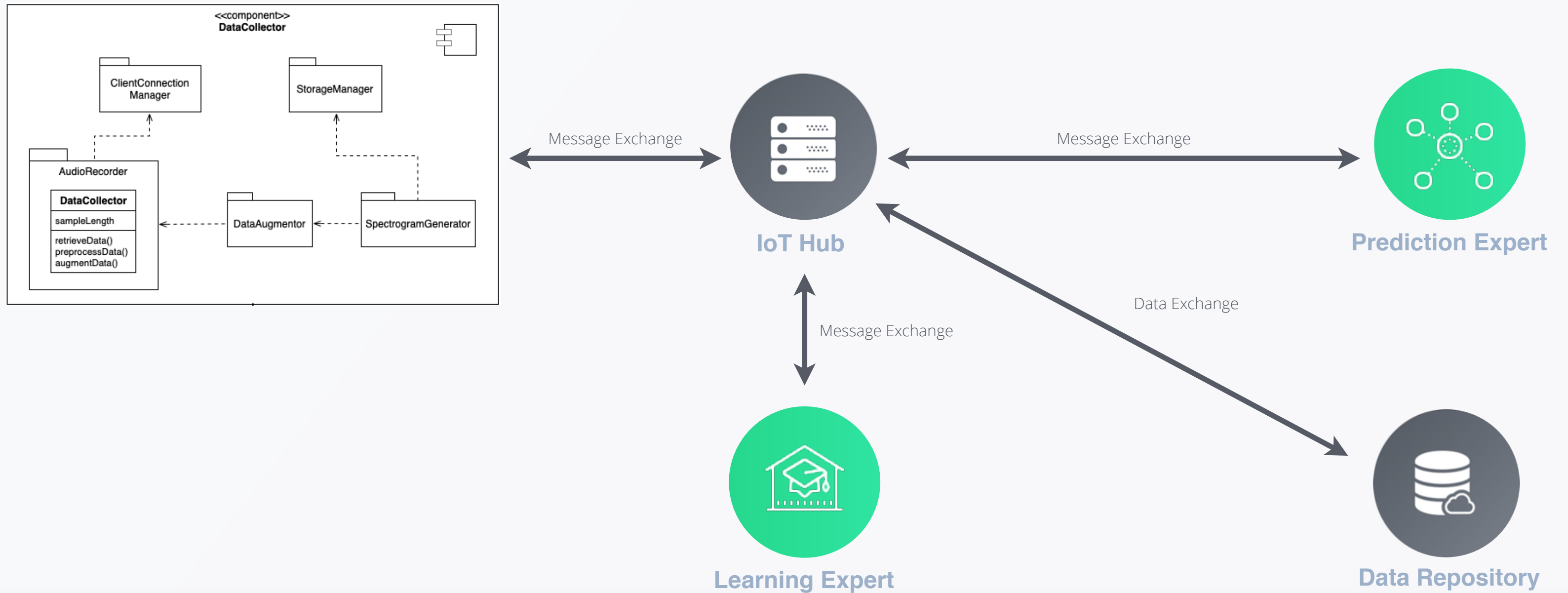
system design

facilitate maintenance prediction by exploiting neural networks to predict equipment failures.



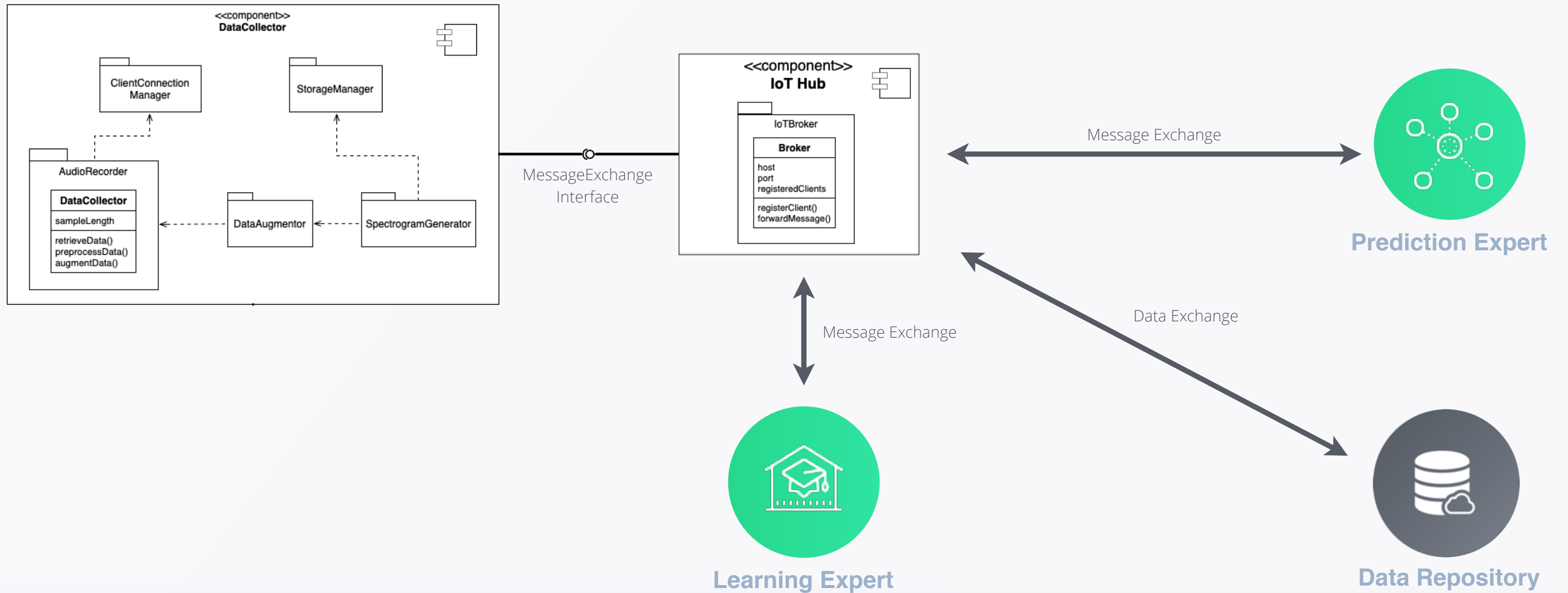
What is AudioForesight?

system design



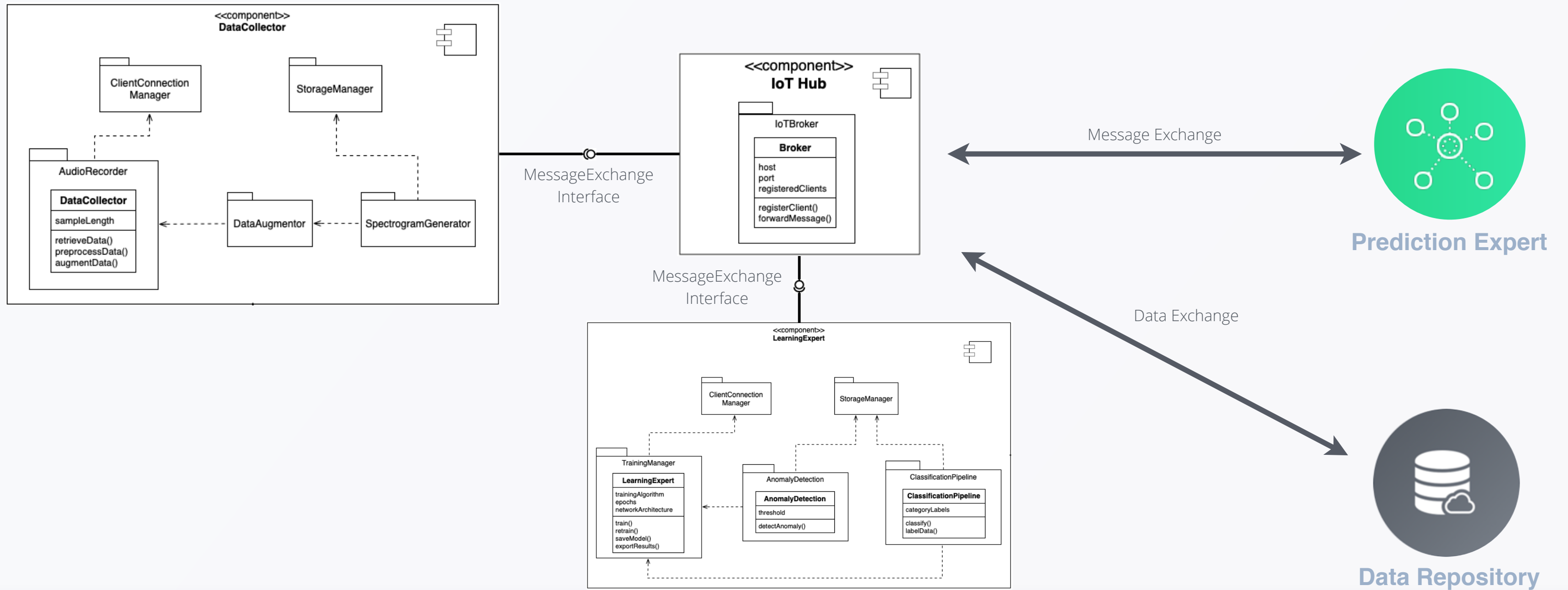
What is AudioForesight?

system design



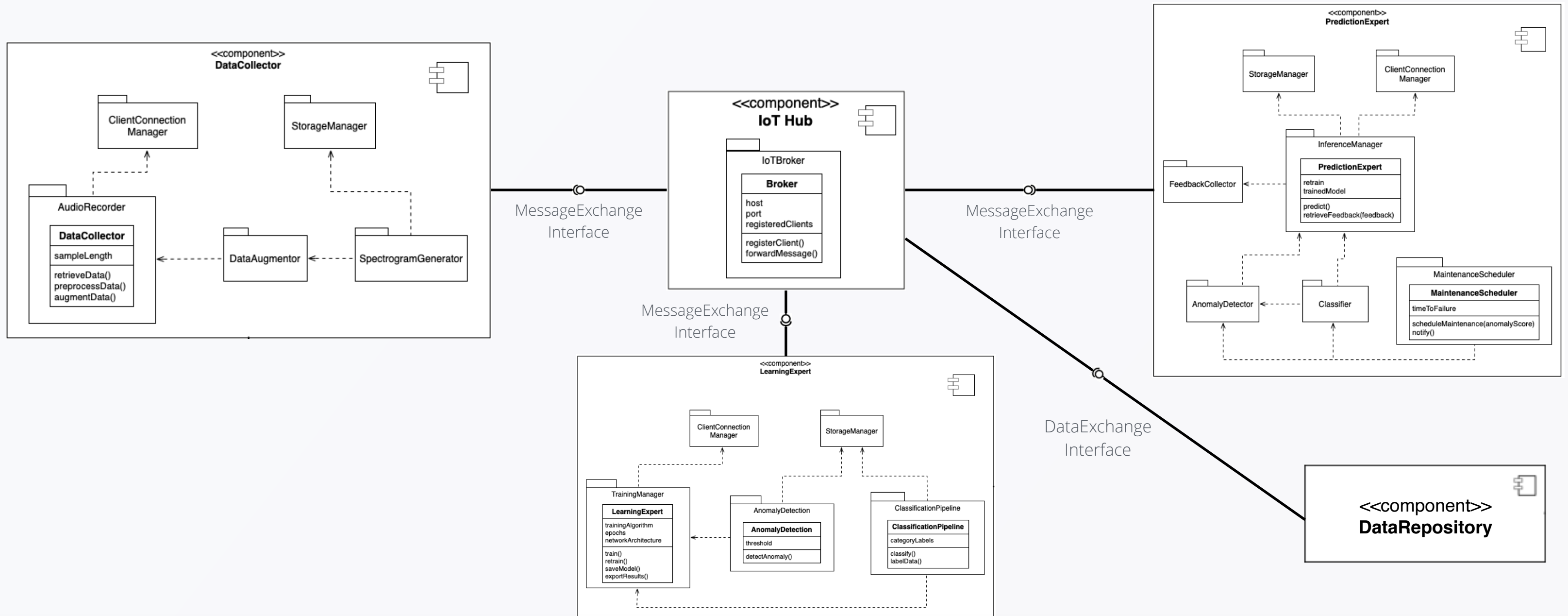
What is AudioForesight?

system design



What is AudioForesight?

system design



AudioForesight Features

Learning Algorithm Control

Define the learning procedure and its parameters

Uncommon Behavior Detection

Detect and notify for uncommon behaviors

Anomaly Classification

Provide information about the type of the detected anomaly

Maintenance Service Performing

Provide information regarding the needs for maintenance service performing

Feedback Providing

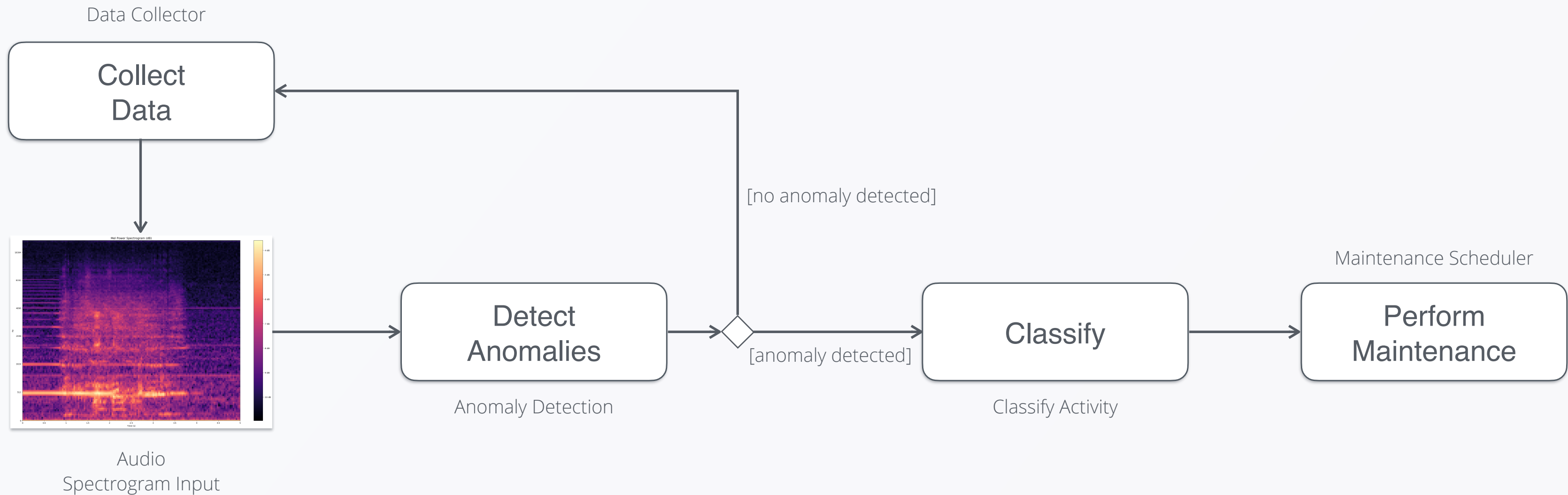
Classification labels and learning feedback

Augmented Data Generation

Increase dataset size through data augmentation

Maintenance Performing

dynamic model

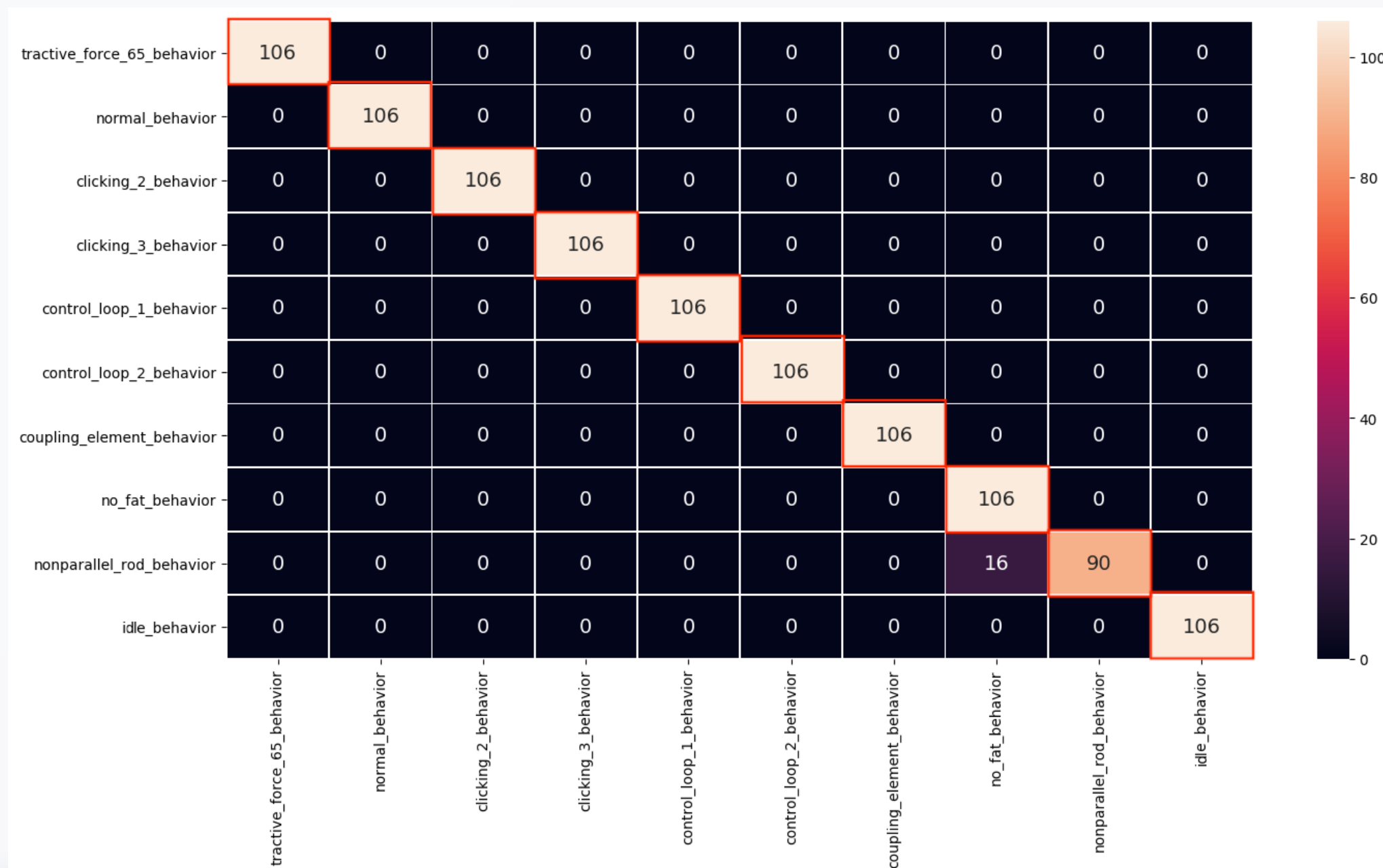


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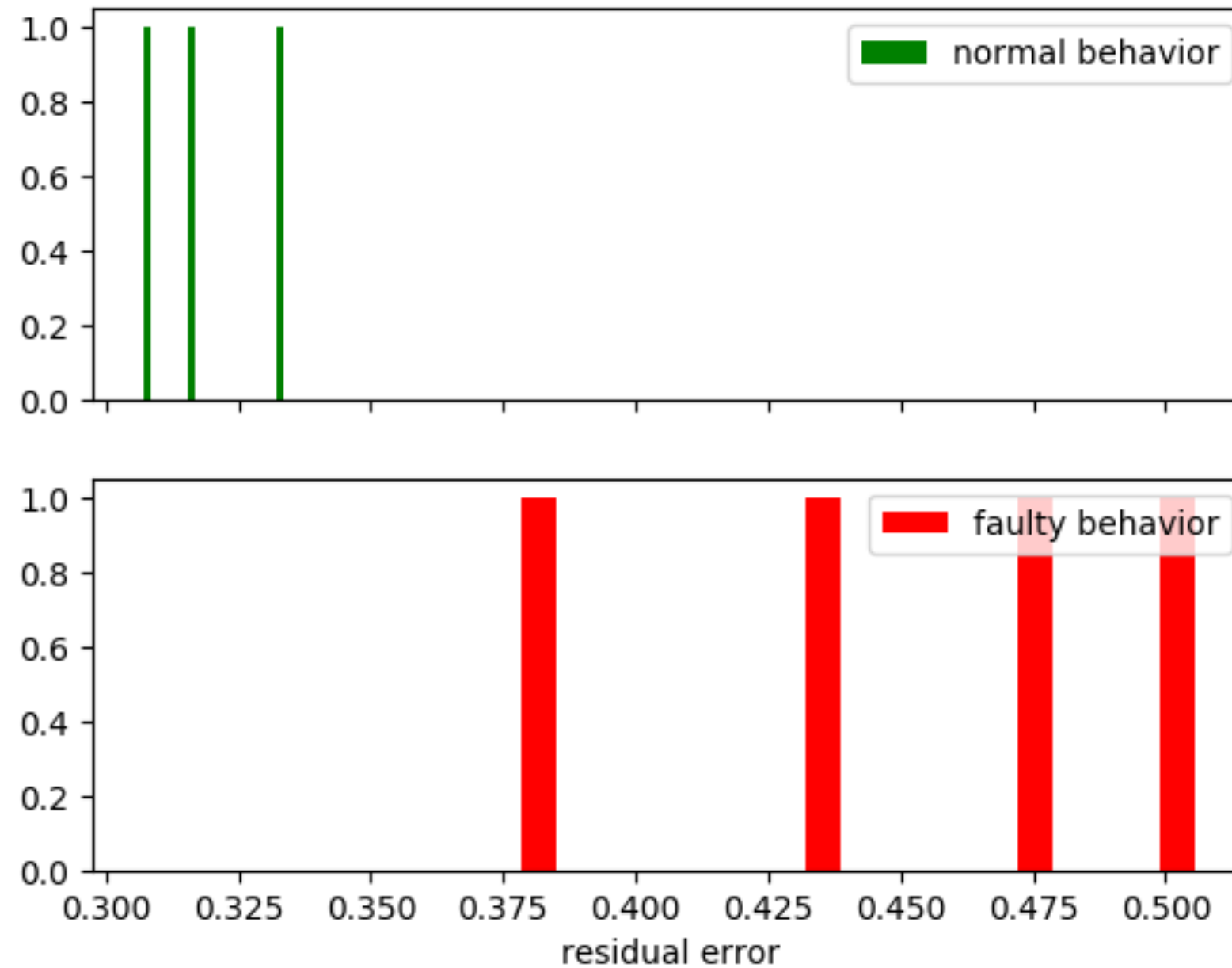
Classification Pipeline

experiment results



Anomaly Detection

experiment results



Prediction Accuracy

experiment results

Metric / ML Algorithm	Classification Pipeline	Anomaly Detection
Prediction Accuracy	0,98	0,98
Recall	0,98	0,99
Precision	0,98	0,98

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What comes next?

system extensibility



Fog Computing
Architecture



Adding New
Types of Sensors



Implementing Client
Applications

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Thesis Methodology



Agile Software
Development Process



Research &
Development



Collaboration
With Industry Partners

Conclusion

project summary

- Implemented an audio-based approach for predictive maintenance in industrial environments.
- Established an extensible architecture design for predictive maintenance.
- Exploit several ML techniques for providing reliable decisions.
- Flexible deployment setup.
- Grant human feedback a role in the decision-making process.

Credits

I am deeply grateful to all the people who supported me through this undertaking:

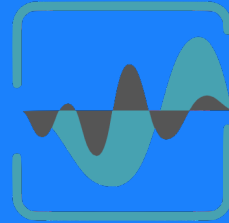
TUM Chair for Applied Software Engineering (LS1)

- *Professor Bernd Brügge, Ph.D.*
- *Dominic Henze, M.Sc.*

Zeiss Digital Innovation Partners

- *Jan-Philipp Simen, Ph.D.*
- *Kaveh Pouran Yousef, Ph.D.*

Thank you for your attention!

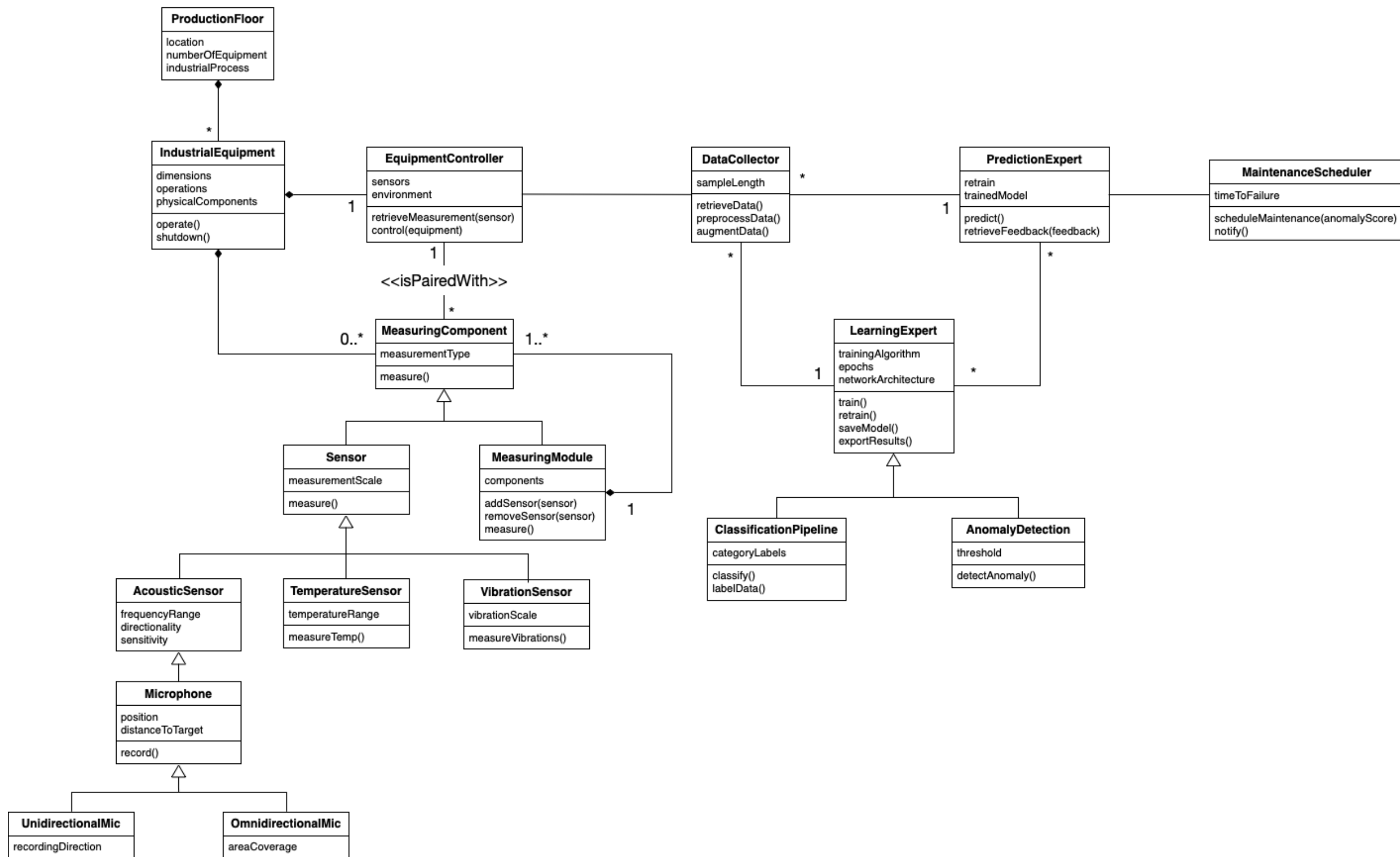


AudioForesight

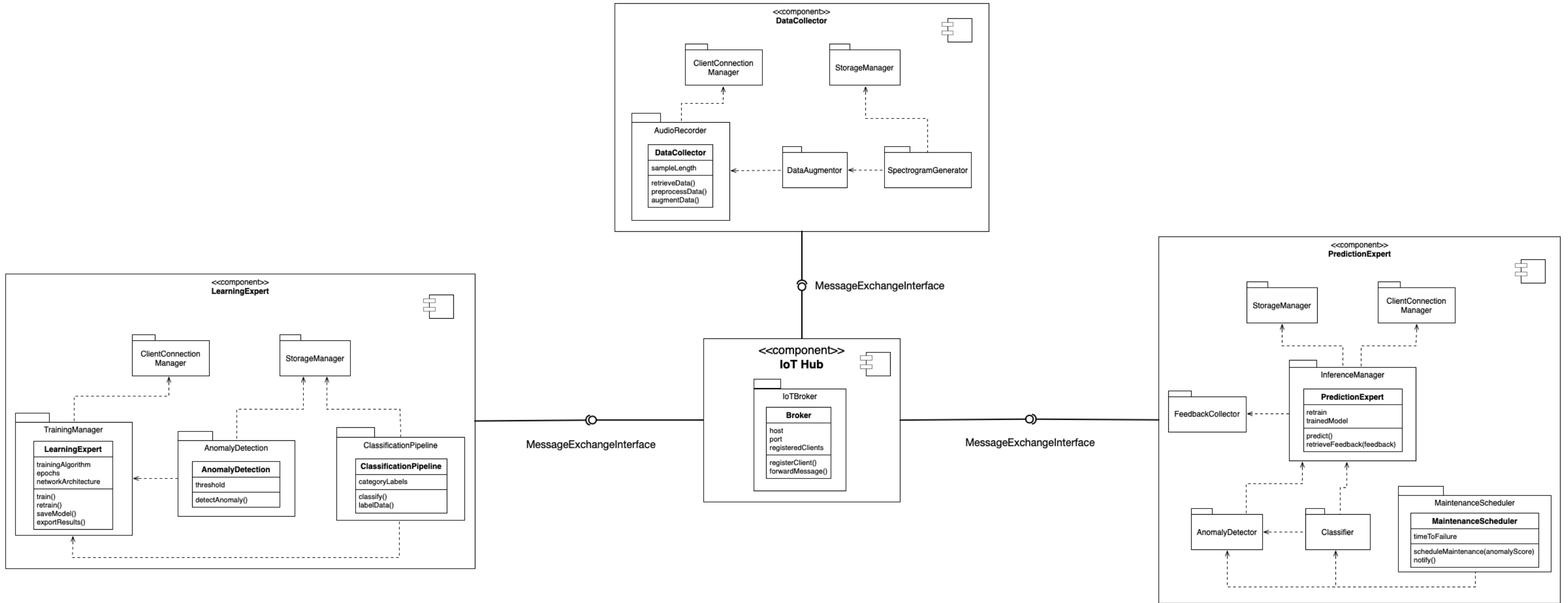
Questions & Comments?

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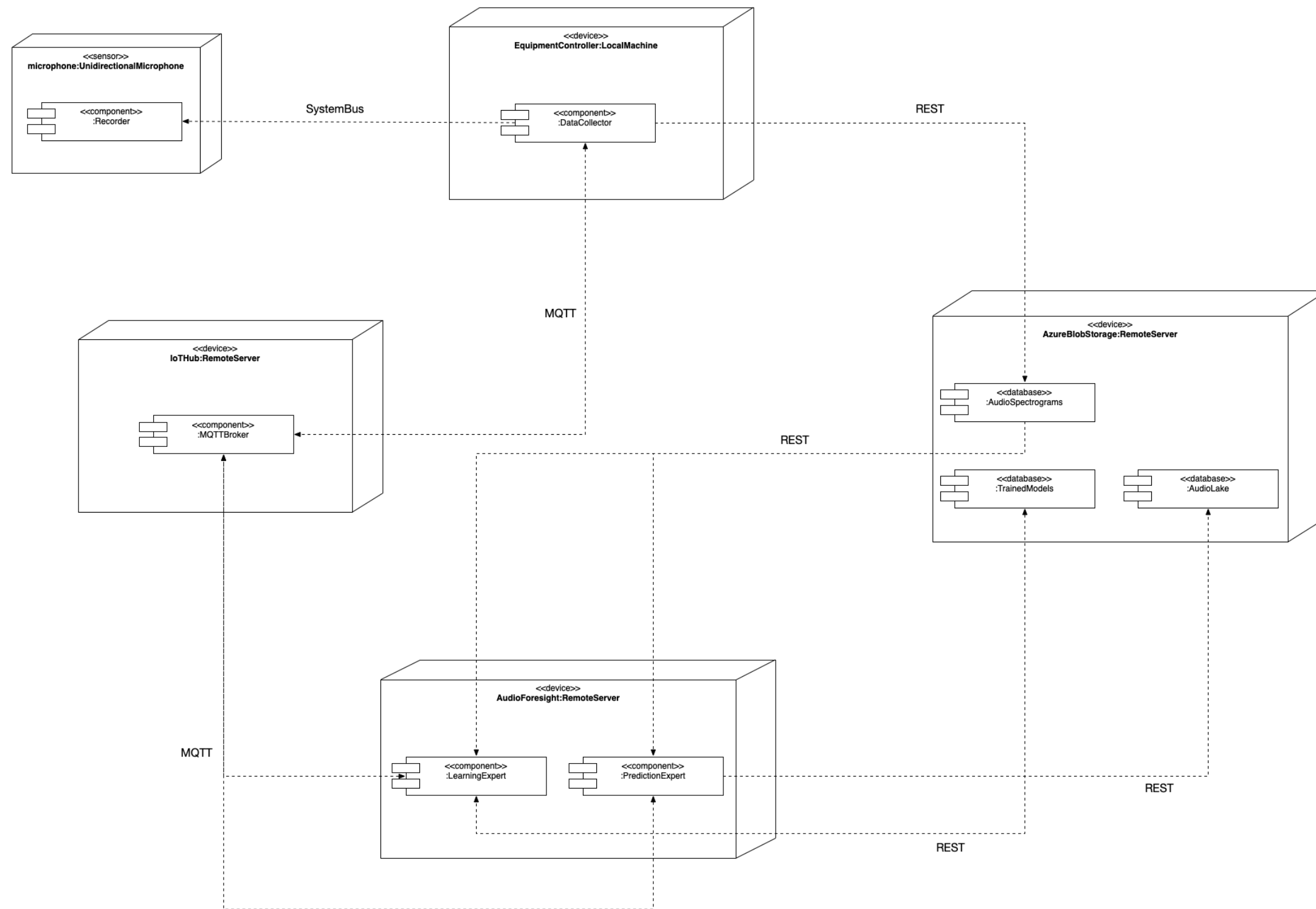
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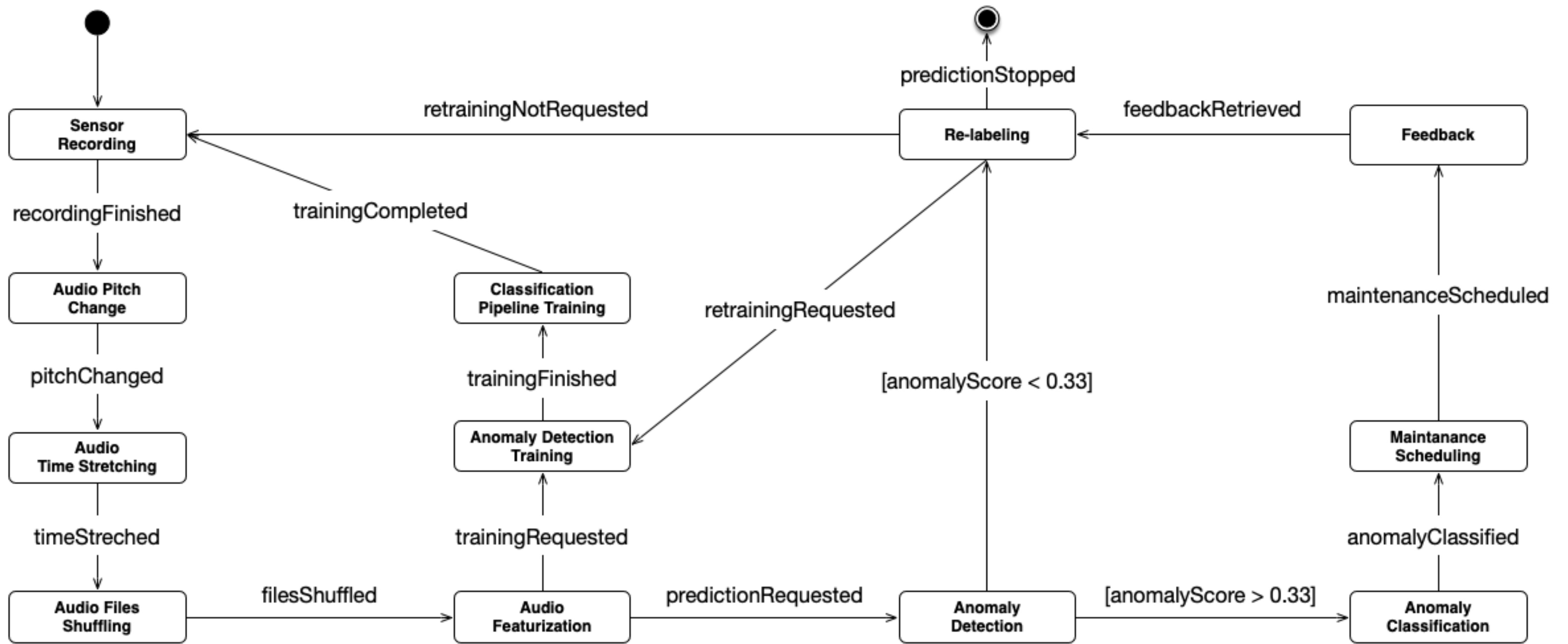
Analysis Object Model (UML Class Diagram)



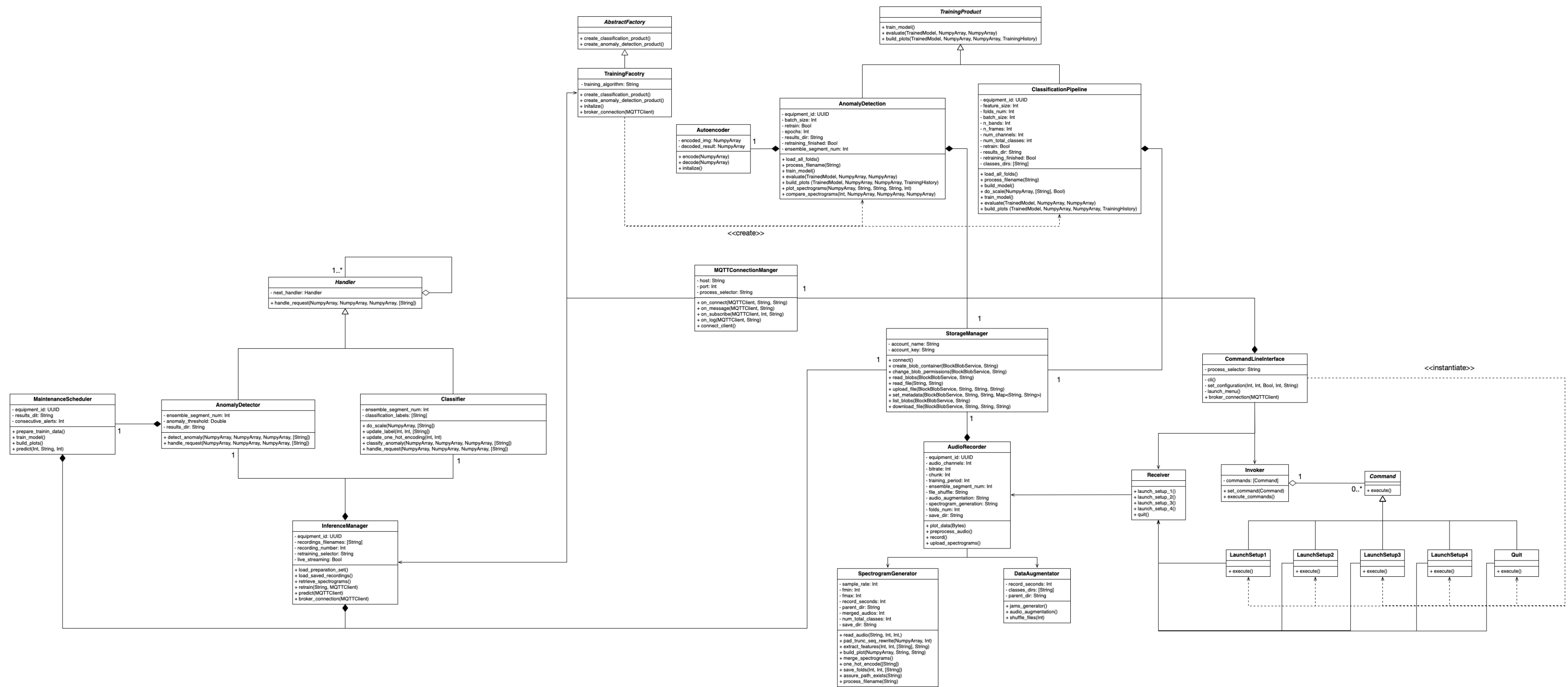
AudioForesight Subsystem Decomposition (UML Component Diagram)



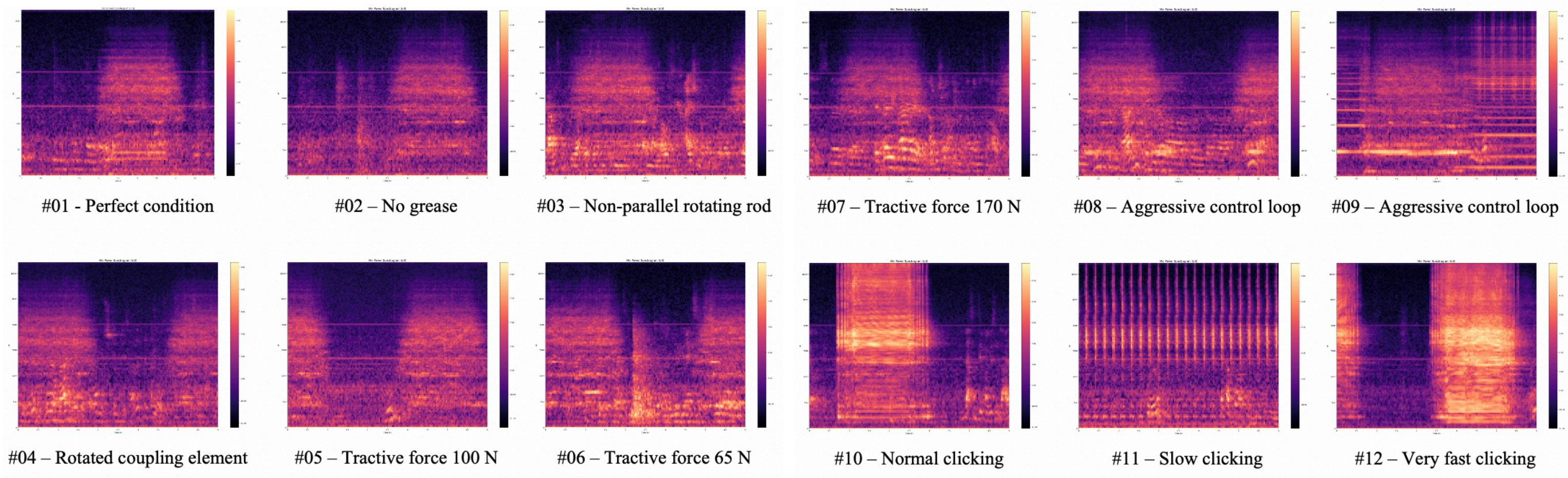
AudioForesight Hardware/Software Mapping (UML Deployment Diagram)



Dynamic System Model (UML State Chart Diagram)



AudioForesight Object Design Model (UML Class Diagram)



Audio Spectrograms Samples from the Experimental Procedure

