
CAPSTONE PROJECT

PREDICTIVE MAINTENANCE OF INDUSTRIAL MACHINERY

Presented By:

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Github - [Shubham-Chaturvedi-23/IBM-AICTE-Internship](https://github.com/Shubham-Chaturvedi-23/IBM-AICTE-Internship)

OUTLINE

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PROBLEM STATEMENT

- Modern industries rely heavily on a fleet of complex machines for production. Unexpected machine failures lead to increased downtime, higher maintenance costs, and reduced productivity.
- There is a critical need to predict machinery failures in advance so that proactive maintenance can be scheduled, minimizing disruptions. This project focuses on leveraging real-time sensor data from industrial machines to identify patterns that precede failures.
- The ultimate aim is to develop a robust classification model that can automatically predict the type of failure (such as tool wear, power outages, or overheating) and enable timely, cost-effective maintenance.

PROPOSED SOLUTION

Our proposed system offers a predictive maintenance solution for industrial machinery using machine learning and real-time sensor analytics. The system aims to:

- Collect and analyze vast amounts of sensor data from machinery (e.g., vibration, temperature, current, pressure).
- Identify and learn the critical patterns or signatures that typically precede common machine failures.
- Train a machine learning classification model to predict specific failure modes before they occur.
- Integrate the model into a real-time monitoring dashboard via IBM Cloud Lite, triggering proactive maintenance notifications to reduce unplanned downtime and operational expenses.

Components:

- **Data Collection:**
 - Aggregate machine sensor logs, operational records, and maintenance histories.
- **Data Preprocessing:**
 - Clean, normalize, and engineer relevant features (e.g., rolling averages, thresholds, anomaly flags).
- **Model Building:**
 - Implement robust machine learning algorithms for multi-class failure prediction using Auto AI.
- **Cloud-based Deployment:**
 - Deploy the solution using IBM Cloud Lite (Watsonx.ai Studio, Object Storage, Runtime).
- **Performance Monitoring:**
 - Evaluate live predictions and refine the model for accuracy and efficiency

SYSTEM APPROACH

System Requirements:

- Sensor-enabled industrial machines transmitting real-time operational data.
- Access to IBM Cloud Lite for data storage, model training, and deployment
- User interface for maintenance alerts and analytics.

Libraries Required:

- Python
- IBM Watsonx.ai Studio
- IBM Cloud Storage

Workflow:

- Sensor data ingestion and real-time storage (IBM Cloud Object Storage)
- Data preprocessing and feature extraction in Python notebooks (Watsonx.ai Studio)
- Model training and evaluation in AutoAI
- Deployment as an online service for live

ALGORITHM & DEPLOYMENT

Algorithm Selection:

- The core of the predictive maintenance system is a **Batched Tree Ensemble Classifier (ICNR specialization)**.
- This algorithm is specifically chosen for its ability to handle high-dimensional industrial sensor data, efficiently manage batch processing, and yield robust, interpretable classification results.
- Batched ensemble methods combine the predictive strength of multiple decision trees with specialized techniques for class imbalance and noise reduction

Data Input:

- The prediction model leverages the following real-time sensor features, namely, Air temperature, Process temperature, Rotational speed, Torque, Tool Wear, Fault Type.
- These features collectively capture the thermal, mechanical, and operational health of the machinery.

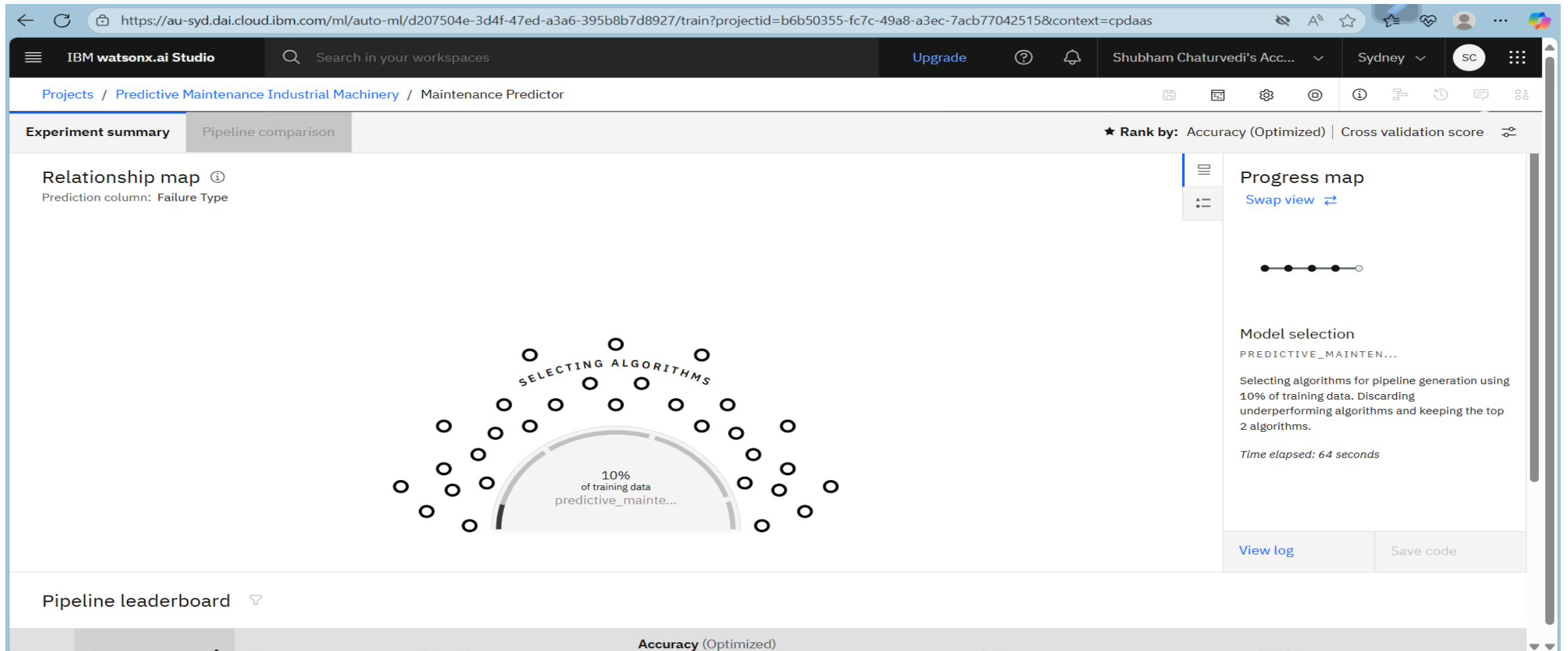
Training Process:

- Model Training: The Batched Tree Ensemble Classifier (ICNR) is trained using labeled historical data. The process includes stratified cross-validation and hyperparameter tuning to optimize performance for imbalanced classes and noisy signals.
- Evaluation: The model's performance is assessed via standard metrics—accuracy, precision, recall, and F1-score.

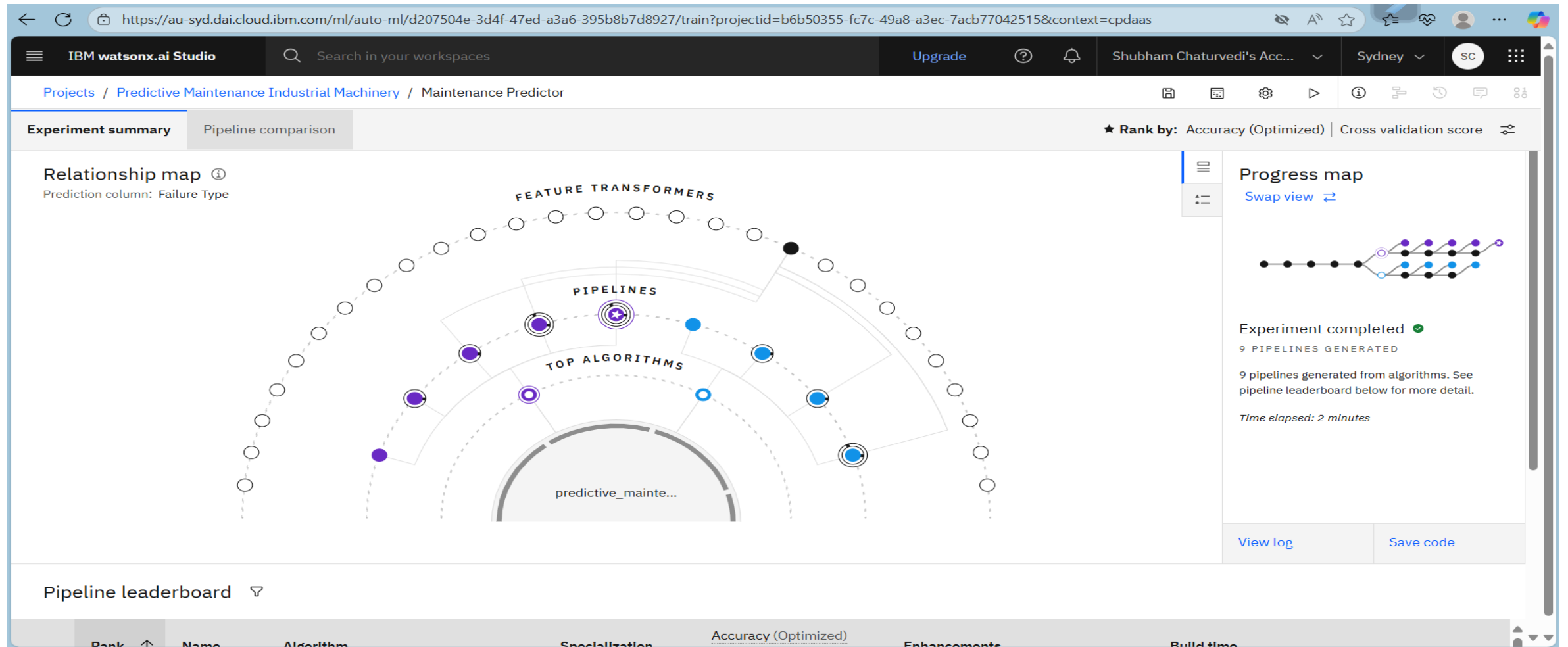
Prediction & Deployment:

- The final trained model is saved and promoted within IBM Watsonx.ai Studio.
- Deployment is performed in an online (real-time) mode, enabling instant predictions for incoming machine data streams.
- Sensor readings (air temperature, process temperature, rotational speed, torque, and tool wear) are input live into the deployed model.

RESULT



RESULT




RESULT

← ↻ <https://au-syd.dai.cloud.ibm.com/ml/auto-ml/d207504e-3d4f-47ed-a3a6-395b8b7d8927/train?projectid=b6b50355-fc7c-49a8-a3ec-7acb77042515&context=cpdaas> 🔍 🔔 ⚙️ 👤 ...

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Projects / Predictive Maintenance Industrial Machinery / Maintenance Predictor 📄 📅 ⚙️ ▶️ ⓘ 🔗 ⌚ 💬 👤

Experiment summary Pipeline comparison ★ Rank by: Accuracy (Optimized) | Cross validation score ⚙️

 Time elapsed: 2 minutes

[View log](#) [Save code](#)

Pipeline leaderboard 🔽

| | Rank ↑ | Name | Algorithm | Specialization | Accuracy (Optimized) Cross Validation | Enhancements | Build time | |
|---|--------|----------------------------|---|----------------|--|----------------------|------------|-------------------------|
| ★ | 1 | Pipeline 5 | 🌀 Batched Tree Ensemble Classifier (Snap Random Forest Classifier) | INCR | 0.995 | HPO-1 FE HPO-2 BATCH | 00:00:43 | |
| | 2 | Pipeline 4 | 🌀 Snap Random Forest Classifier | | 0.995 | HPO-1 FE HPO-2 | 00:00:40 | |
| | 3 | Pipeline 3 | 🌀 Snap Random Forest Classifier | | 0.995 | HPO-1 FE | 00:00:32 | Save as |
| | 4 | Pipeline 9 | 🌀 Snap Decision Tree Classifier | | 0.994 | HPO-1 FE HPO-2 | 00:00:03 | |

RESULT

←↻🔒https://au-syd.dai.cloud.ibm.com/ml-runtime/deployments/5c4c9122-cee2-4545-aba3-4c64119da420/test?space_id=b7400565-5771-4859-8000-0372271cef0b&context=cpdaas&fl...

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Deployment spaces / Failure type / P5 - Snap Random Forest Classifier: Maintenance Predictor / 🗑️ ⓘ 🔗 ⌛ 💬 ⚙️

Maintenance_Predictor ✔️ Deployed Online

API reference **Test**

Enter input data

TextJSON

Enter data manually or use a CSV file to populate the spreadsheet. Max file size is 50 MB.
[Download CSV template](#) ⬇️ [Browse local files](#) ↗️ [Search in space](#) ↗️ Clear all ×

| | UDI (double) | Product ID (other) | Type (other) | Air temperature [K] (double) | Process temperature [K] (double) | Rotational speed [rpm] (double) | Torque [Nm] (double) | Tool wear |
|---|--------------|--------------------|--------------|------------------------------|----------------------------------|---------------------------------|----------------------|-----------|
| 1 | 3815 | M18674 | M | 302.1 | 310.6 | 1326 | 59.1 | 88 |
| 2 | 161 | L47340 | L | 298.3 | 308.1 | 1412 | 52.3 | 218 |
| 3 | 70 | L47249 | L | 298.9 | 309 | 1410 | 65.7 | 191 |
| 4 | 78 | L47257 | H | 298.9 | 308.9 | 1455 | 41.3 | 208 |
| 5 | 3066 | M17925 | M | 300.1 | 309.2 | 1602 | 32.3 | 2 |

6 rows, 9 columns

Predict

RESULT

IBM watsonx.ai Studio

Deployment spaces / Failure type / P5 - Snap Random Forest Classifier: Maintenance Predictor

Prediction results

Display format for prediction results

☒ Table view ☐ JSON view

☐ Show input data

| | prediction | probability |
|----|--------------------------|---|
| 1 | Heat Dissipation Failure | [1,0,0,0,0,0] |
| 2 | Overstrain Failure | [0.0030303031206130983,0,0.9969696998596191,0,0,-2.9802322831784522e-9] |
| 3 | Power Failure | [0,0,0,1,0,0] |
| 4 | Tool Wear Failure | [0,0,0,0,0,1] |
| 5 | No Failure | [0,1,0,0,0,0] |
| 6 | No Failure | [0,1,0,0,0,0] |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| 11 | | |

Download JSON file

The deployed predictive maintenance model achieves high cross validation accuracy of **99.5%** in predicting machine failure types before they occur as per IBM Watson AutoAI pipeline leaderboard.

CONCLUSION

- The predictive maintenance solution successfully demonstrates the power of machine learning in anticipating machine failures using real sensor data.
- Deployment on IBM Cloud Lite ensures scalability, accessibility, and ease of integration within industrial environments.
- The system enables industries to move from reactive to proactive maintenance, delivering measurable improvements in uptime and operational efficiency.
- Continuous data collection and retraining further enhance accuracy over time.

FUTURE SCOPE

- Expand sensor integration (add more sensor types and data sources).
- Apply advanced algorithms (deep learning, anomaly detection, edge deployment).
- Generalize the solution for other types of industrial equipment and processes.
- Integration with enterprise maintenance management systems (CMMS).
- Explore predictive maintenance at scale (multi-site, multi-factory deployments).
- Use AI explainability tools to interpret failure causes and suggest specific maintenance actions.

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Journal: IJCRT (2025)

Link: <https://ijcrt.org/papers/IJCRT2502697.pdf>

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Author: Bajaj, A.

Source: IIP Series (2025)

Link: <https://www.iipseries.org/assets/docupload/rs120251889AB5EB0B56CC.pdf>

5. IBM Watsonx.ai Documentation

Source: IBM Cloud Docs

Link: <https://www.ibm.com/cloud/watsonx-ai>

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Learning hours: 20 mins



THANK YOU