# Intelligent Maintenance Recommender System

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# Recommender System

- **1. Introduction**
- **Recommender System**
- Plant Application
- Use Case
- Customer Benefits
- 2. Technology
- 3. Evaluation
- 4. Conclusion
- 5. Q&A

A **recommender system**, or a **recommendation system** (sometimes replacing 'system' with a synonym such as platform or engine), is a subclass of information filtering system that provide suggestions for items that are most pertinent to a particular user.

Wikipedia: https://en.wikipedia.org/wiki/Recommender_system

# Plant Application


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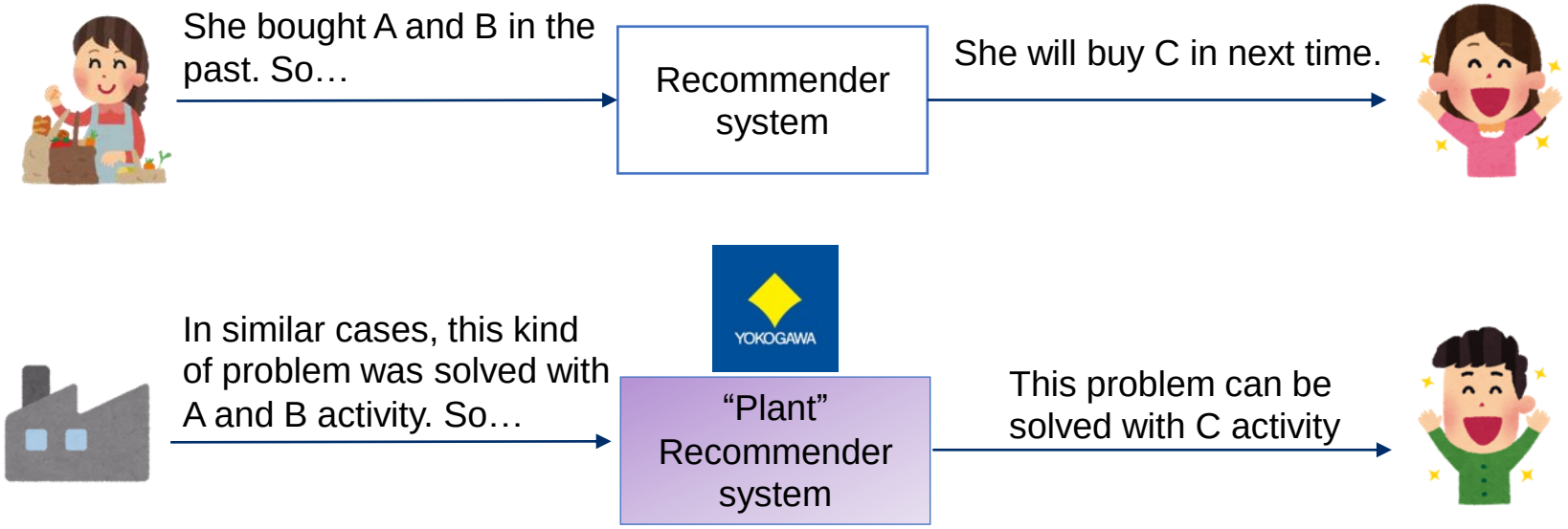
- Recommender system is usually used in e-commerce site, to suggest possible expected items for users.
- In plant, recommender system can be used for suggesting maintenance actions.



# Use case in plant

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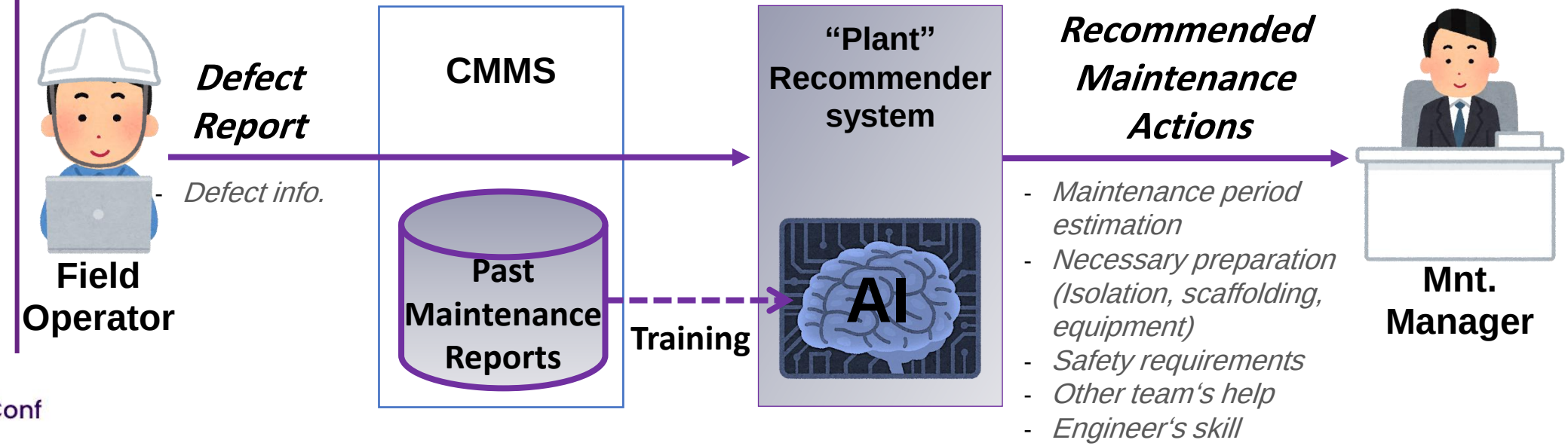
- Plant Recommender system infers the defect situation, and suggests possible countermeasures, by referring to past maintenance reports
- The countermeasures are used for maintenance planning used by th maintenance manager and planner.



# Customer Benefits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## 1. Re-work avoidance

This tool will suggest maintenance plan based on past maintenance actions and avoid the re-work

## 2. Shorten planning time

The system can provide diverse solutions that will optimize maintenance work.

## 3. Effective knowledge transfer

This engine can help to transfer the knowledge and experience from the expert maintenance engineer to the younger

# Data Structure

- 1. Introduction
- **2. Technology**
- **Data Structure**
- Mechanism
- 3. Evaluation
- 4. Conclusion
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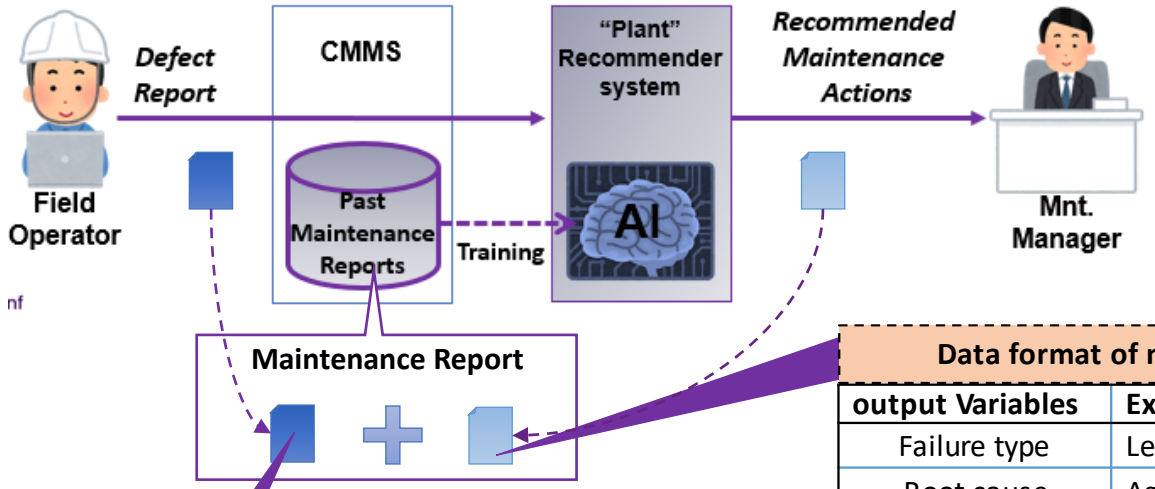
## Maintenance Report = Defect Report + Maintenance Action




**Data format of defect report (Input)**

| Input Variables | Type | Example |
|---|---|---|
| Position | Categorical | Area_1 |
| Team | | Team_1 |
| Priority | | Low |
| Problem | Text | Gas leak |
| Details | | Gas leak in the area 1 |

**Data format of maintenance actions (Output)**

| output Variables | Example |
|---|---|
| Failure type | Leakage |
| Root cause | Aging |
| Solution | Modification and improvement |
| List of necessary preparation | Scaffolding required<br>Containers required |
| Safety requirement | gas detector required |
| Staff required | 5 |
| Time required | 6 hours |

# Mechanism (1/4):

- 1. Introduction
- **2. Technology**
- Data Structure
- **Mechanism**
- 3. Evaluation
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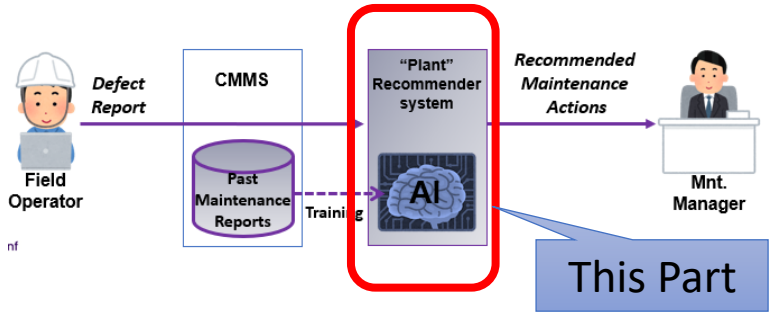
## Multi-stage Recommendation Overview




**Stage1**: Similar defect search

Finding similar defects to predict a proper failure from all of past defect reports.

**Stage2**: Finding proper maintenance record

Updating rating of maintenance records with the failure which picked up in the previous stage.

**Stage3**: Extraction of maintenance actions

Construct the full maintenance report for the given defect.

# Mechanism (2/4)

- 1. Introduction
- **2. Technology**
- Data Structure
- **Mechanism**
- 3. Evaluation
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## Similar defect search

| Input Variables | Type | Example |
|---|---|---|
| Position | Categorical | Area_1 |
| Team | | Team_1 |
| Priority | | Low |
| Problem | Text | Gas leak |
| Details | | Gas leak in the area 1 |

1 **Stage1**: Similar defect search

2 **Stage2**: Finding proper maintenance record

3 **Stage3**: Extraction of maintenance actions

**Textual Features**

| Input Variables | Type | Example |
|---|---|---|
| Problem | Text | Gas leak |
| Details | | Gas leak in the area 1 |

**Categorical Features**

| Input Variables | Type | Example |
|---|---|---|
| Position | Categorical | Area_1 |
| Team | | Team_1 |
| Priority | | Low |

TF-IDF weighting → Term-Document Matrix → Cosine method → Similarity Matrix 1

If Same Category = 5, otherwise = 1 → Rating Table → Cosine method → Similarity Matrix 2

Finding nearest Maintenance Report with KNN

5 Most Possible **Failures**

# Mechanism (3/4)

- 1. Introduction
- **2. Technology**
- Data Structure
- **Mechanism**
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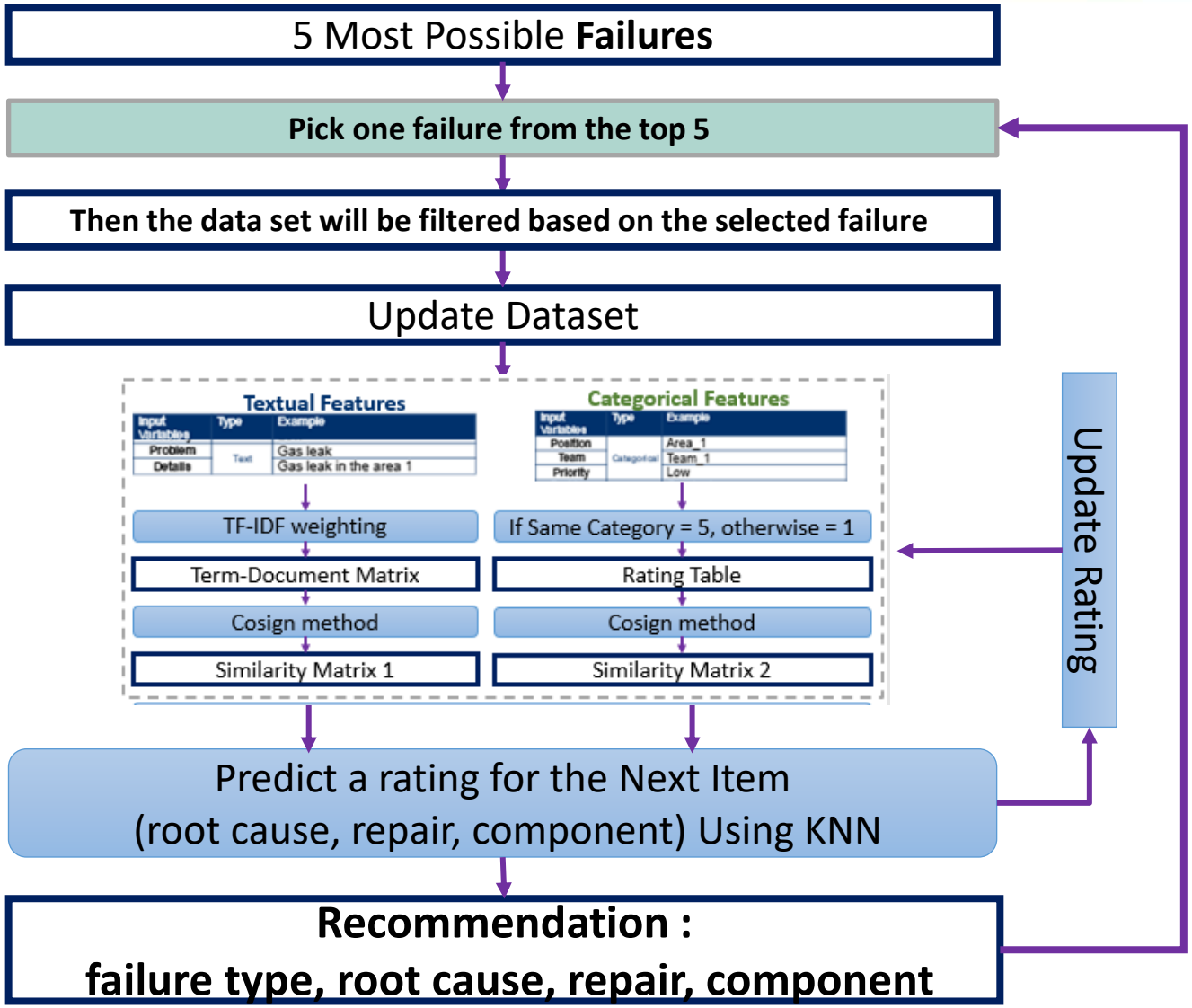
## Finding similar maintenan records

1. **Stage1**: Similar defect filtering
2. **Stage2**: Finding proper maintenance record
3. Extraction of maintenance actions



# Mechanism (4/4)

- 1. Introduction
- **2. Technology**
- Data Structure
- **Mechanism**
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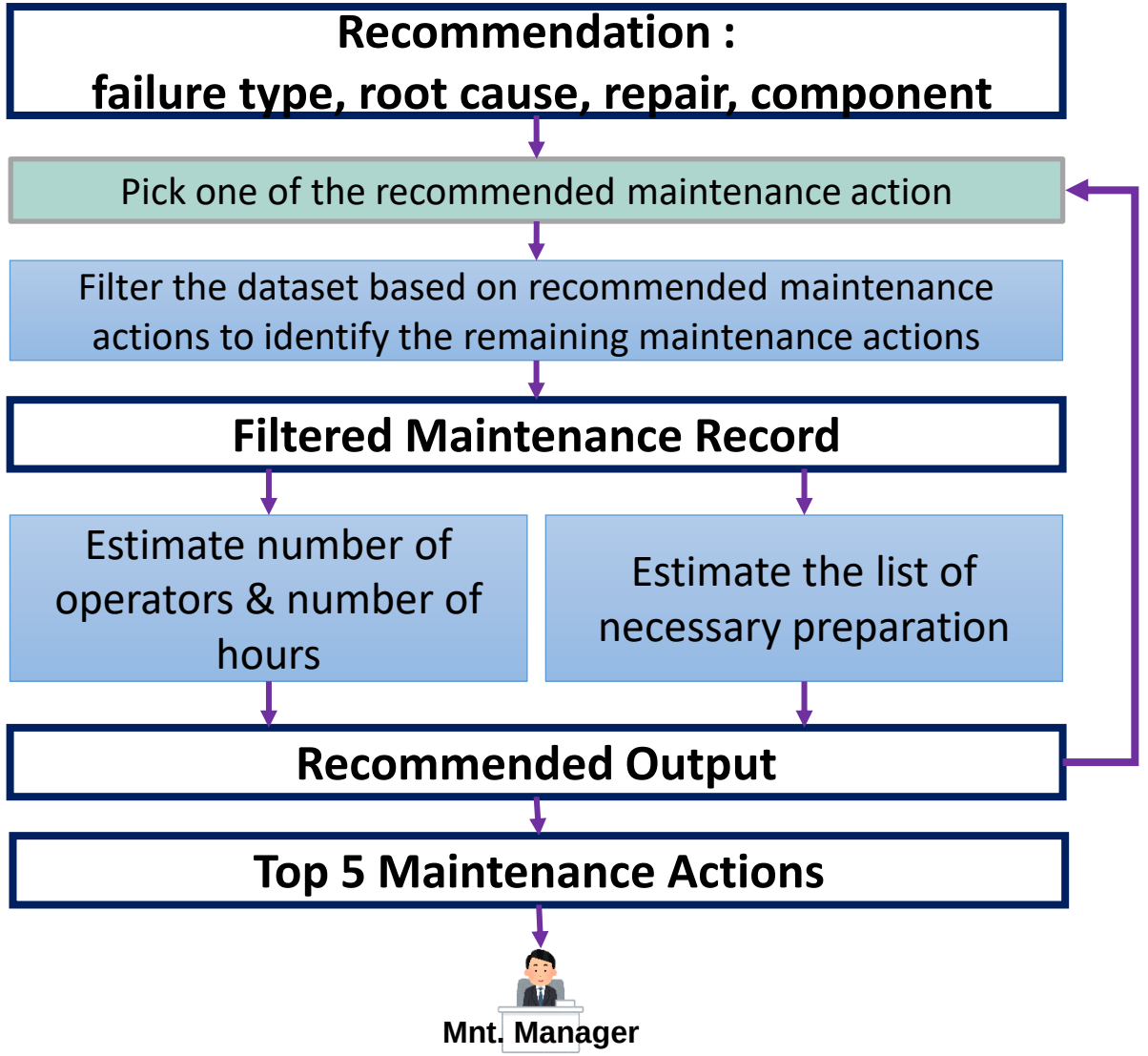
## Finding similar maintenance records

1. **Stage1**: Similar defect filtering
2. **Stage2**: Finding proper maintenance record
3. **Stage3**: Extraction of maintenance actions



# Evaluation (1/4) : Evaluation Overview

- 1.Introduction
- 2. Technology
- **3. Evaluation**
- **Evaluation Overview**
- Evaluation Method
- Result
- Evaluation with Customer
- 4. Conclusion
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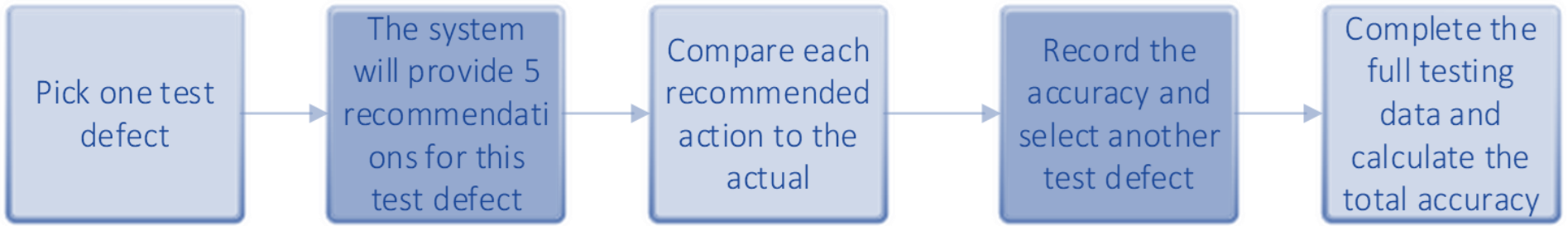
| Test param. | Description |
|---|---|
| Data | Past maintenance history (defect and repair action information).<br>Both of scheduled and unscheduled maintenance history. |
| Testing Criteria | Split the data into 90% (22500 points) for training and 10% (2500 points) for testing. |
| Evaluation Scenario | ▪ Finding the proper maintenance actions against one of the defects in the test set .<br>▪ To evaluate the model, we collected the top 5 recommended maintenance actions for each defect in the test set.<br>▪ We compare the recommended actions with actual actions for the defect with considering the output data type. |



# Evaluation (2/4) : Evaluation Metrics

- 1.Introduction
- 2. Technology
- **3. Evaluation**
- Evaluation Overview
- **Evaluation Metrics**
- Result
- Evaluation with Customer
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Accuracy, Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Mean Absolute Error (MAE).

5 Recommended maintenance actions

**Numeric Output**

Number of operators & number of hours

**Categorical Output**

list of necessary preparation

| | |
|---|---|
| Mean squared error | $\text{MSE} = \frac{1}{n}\sum_{t=1}^{n} e_t^2$ |
| Root mean squared error | $\text{RMSE} = \sqrt{\frac{1}{n}\sum_{t=1}^{n} e_t^2}$ |
| Mean absolute error | $\text{MAE} = \frac{1}{n}\sum_{t=1}^{n} \lvert e_t \rvert$ |

$$accuracy = \frac{correct}{correct + incorrect}$$

# Evaluation (3/4) : Results

- 1.Introduction
- 2. Technology
- **3. Evaluation**
- Evaluation Overview
- Evaluation Metrics
- **Result**
- Evaluation with Customer
- 4. Conclusion
- 5. Q&A

The system is promising as it achieves an accuracy of **72.95%**

| Output Features | Accuracy | MSE | RMSE | MAE |
|---|---|---|---|---|
| Failure | 77.91 | - | - | - |
| Root Cause | 57.70 | - | - | - |
| Repair | 74.02 | - | - | - |
| Component | 59.19 | - | - | - |
| Total Accuracy (for the previous output) | 67.21 | - | - | - |
| Necessary preparation list | 95.94 | - | - | - |
| Total Accuracy | 72.95 | - | - | - |
| Number of hours | - | 5125.93 | 70.14 | 23.15 |
| Number of operators | - | 107.91 | 10.22 | 3.71 |

This result can be improved by considering the customer KPI or Feedback to enhance the quality of the recommendation.

# Evaluation (4/4) : Evaluation with Customer

- 1.Introduction
- 2. Technology
- **3. Evaluation**
- Evaluation Overview
- Evaluation Metrics
- Result
- **Evaluation with Customer**
- 4. Conclusion
- 5. Q&A

- We have developed a prototype application for the maintenance recommender system to be evaluated with customer real maintenance data.
- The proposed prototype is an online application that reads the defects reports from the CMMS system.
- In addition, the system can be tuned automatically by comparing the recommendations with the actual maintenance report taken later.

| Evaluation param. | Descriptions |
|---|---|
| Evaluation period | TBA |
| Use case | Daily patrol and its maintenance actions |
| Scenario | On daily basis, experts from maintenance team will use the system to find recommendations for the new defects being appended to the CMMS. Then, the experts will select the most appropriate recommendation and compare it with the appropriate maintenance action. |
| Status | System integration (w/ CMMS) was completed. |

# Conclusion

- 1. Introduction
- 2. Technology
- 3. Evaluation
- **4. Conclusion**
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- Plant Recommender system analysis the new defect and suggests possible maintenance action, with referring past maintenance report.
- In this work, we proposed Multi-Stage recommender system to recommend proper maintenance action for a given defect.
- The system is promising as it achieves accuracy of 72.95%.
- Systems achieve promising results which leads to:
  - Re-work avoidance
  - Shorten planning time
  - Effective knowledge transfer
- For Future work:
  - We will improve the recommendation quality by considering the customer KPI to enhance the following recommendation and design it as close loop system.
  - We will improve the recommendation accuracy by using the customer knowledge in the current evaluation.
  - We will include more advanced machine learning techniques to improve the recommender system

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