

Multi-functional Interface for CAT machine operators

Non Sync Techies

MADHUBHARATHI B 22N230

SHREENITHI C 22N250

SRISAIVARSHINI B 22N255

SWATHI M 22N261

Solutions offered

1. Simulated Training platform using RL based Learning
 - Statements 2,3,4
2. Dynamic Task Operator Match & Time Estimation System
 - Statements 1,5

Simulated Training platform using RL based Learning

3. Operator training hub:

Choose any creative learning format-e-learning videos, instructor booking or simulation module.

4. Machine behavior:

Identify unusual behavior in machine usage e.g. excessive idling or unsafe operation patterns.

2. Safety Features:

Implement features that improve real-time operator safety using available or assumed data.

1.Seatbelt compliance,

2 proximity hazards,

3. incident logging etc. (Working conditions to be considered)

Dynamic Task Operator Match & Time Estimation System

1. Daily task dashboard:

View scheduled tasks for the day.

5. Task Time Estimation:

Predict time to complete a task based on past data and environmental conditions

Timestamp	Machine ID	Operator ID	Engine Hours	Fuel Used (L)	Load Cycles	Idling Time (min)	Seatbelt Status	Safety Alert Triggered
2025-05-01 08:00:00	EXC001	OP1001	1523.5	5.2	12	30	Fastened	No
2025-05-01 10:00:00	EXC001	OP1001	1524.8	3.8	2	55	Unfastened	Yes
2025-05-01 14:00:00	EXC001	OP1001	1526.5	6.1	10	15	Fastened	No
2025-05-02 09:00:00	EXC001	OP1001	1530.2	2.0	1	60	Unfastened	Yes

Simulated Training platform using RL based Learning

To adaptively improve operator skills through interactive, feedback-driven simulated environments

Simulated Training platform using RL based Learning

Reinforcement Learning	Reinforcement Learning-based Learning
AI agent is the learner	Human is the Learner
The AI agent automatically adapts its behaviour to improve based on rewards/penalties	The human receives scores or penalties, but adapts voluntarily

DESIGN CONSIDERATIONS

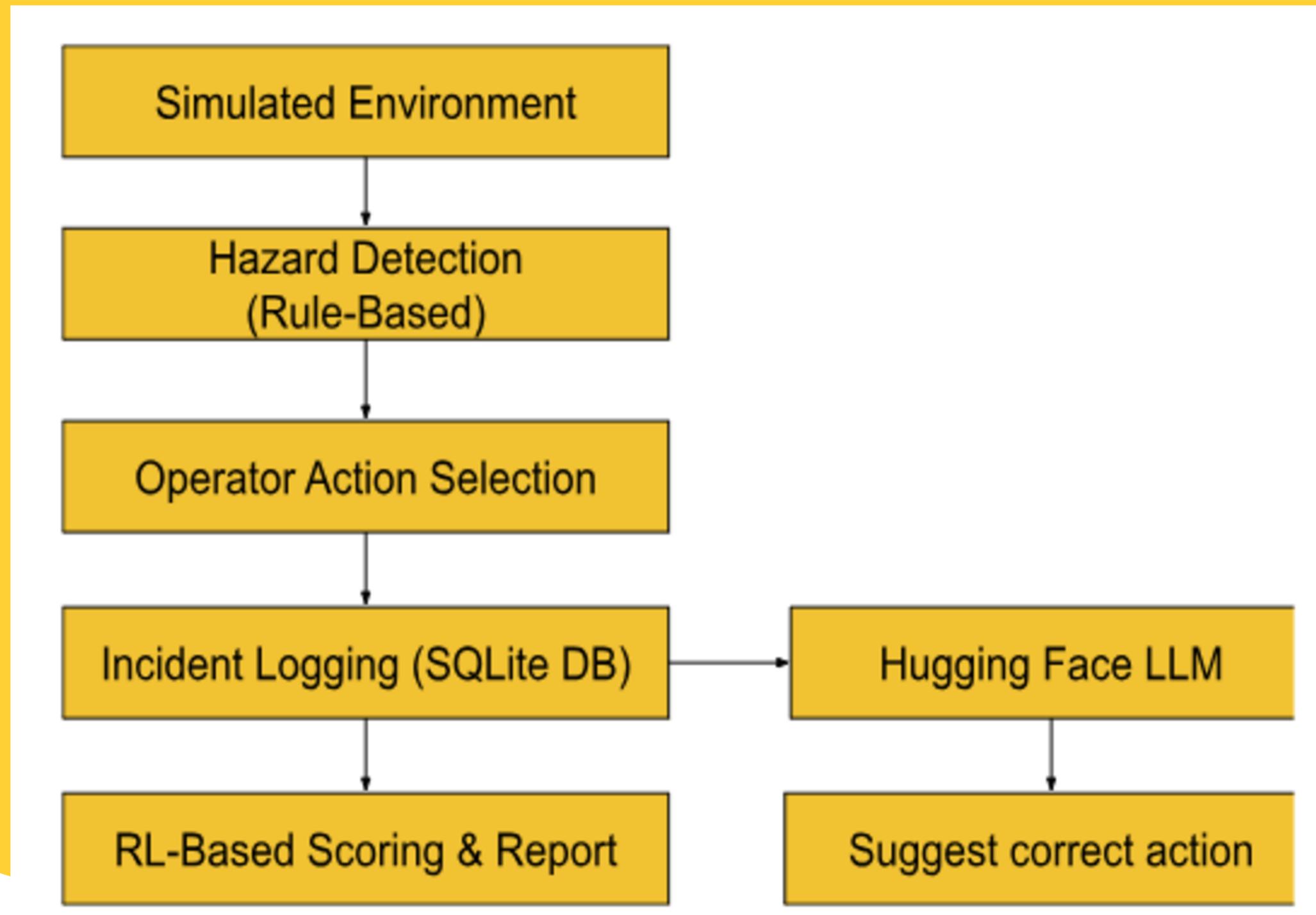
Single Hazard Focus

Training-Only Purpose

Hazard Response Learning

Realistic Learning

FLOWCHART



Simulated Training Hub

- Problem Statement 3

States are used to track user/agent performance in a reinforcement learning (RL) environment

Simulated states for different task

- Dig Trench (Rocky)
- Load Trunk (Flat)
- Navigate Slope (Incline)

Simulated States

```
{  
  "timestamp": "2025-07-17T11:28:26.947502",  
  "machine_id": "EXC001",  
  "operator_id": "OP1001",  
  "terrain": "flat",  
  "machine_type": "loader",  
  "task_name": "load_truck_flat",  
  "engine_hours": 1851.32,  
  "vibration_level": 0.6,  
  "weather": "dusty",  
  "pressure": 914.95,  
  "fuel_used": 0.97,  
  "speed": 3.13,  
  "torque": 437.55,  
  "engine_temp": 69.76,  
  "brake_status": true,  
  "proximity": 0.81,  
  "fuel_level": 12.57,  
  "idle_time": 11,  
  "load_weight": 930.64,  
  "seatbelt": "fastened",  
  "geofence_zone": "inside"  
}
```

- Dig Trench (Rocky)
- Load Trunk (Flat)
- Navigate Slope (Incline)

State ranges will vary for each task as they cover different terrains and machines

Hazard Detector

- Problem Statement 4

Uses different rule-based functions to detect a hazard from the simulated state values

Hazard Name	Rule
Seatbelt Violation	speed > 1.0 and seatbelt_status == False
Torque Spike	torque > 700 Nm
Obstacle Too Close	proximity < 2.0 meters
Fuel Efficiency Drop	fuel_level < 20% and load_weight > 300 kg
Overheating	engine_temp > 85°C
Idle Timeout	idle_time > 60 seconds
Terrain Mismatch	torque > 700 + terrain_type in <i>muddy, slope</i>

Action Selection by Operator (Through UI)

- Hazard will be popped up in the UI
- Set of actions are given to user to choose from based on the type of hazard
- Each action is mapped to a score

```
"engine_overheat": {  
    "description": "Engine temperature exceeded safe threshold.",  
    "severity": "medium",  
    "actions": {  
        "Cool Down": 3,  
        "Reduce Load": 2,  
        "STOP": 0,  
        "Continue": -3  
    }  
}
```

Incident Logging

- Problem Statement 2
- Each selected action is logged in the database (SQLite)
- A score is assigned to every action
- The final score is calculated by summing the individual action scores

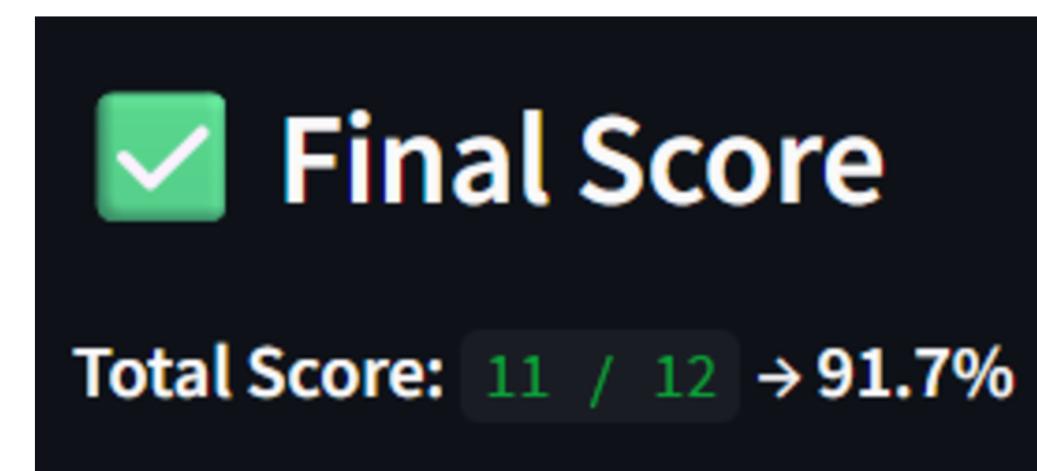
Action Log

- **Hazard:** proximity_alert
- **Action Taken:** Reverse
- **Reward:** 2 / 3
- **Result:**  Safe
-  **Correct:** Yes

- **Hazard:** vibration_spike
- **Action Taken:** Adjust Position
- **Reward:** 3 / 3
- **Result:**  Safe
-  **Correct:** Yes

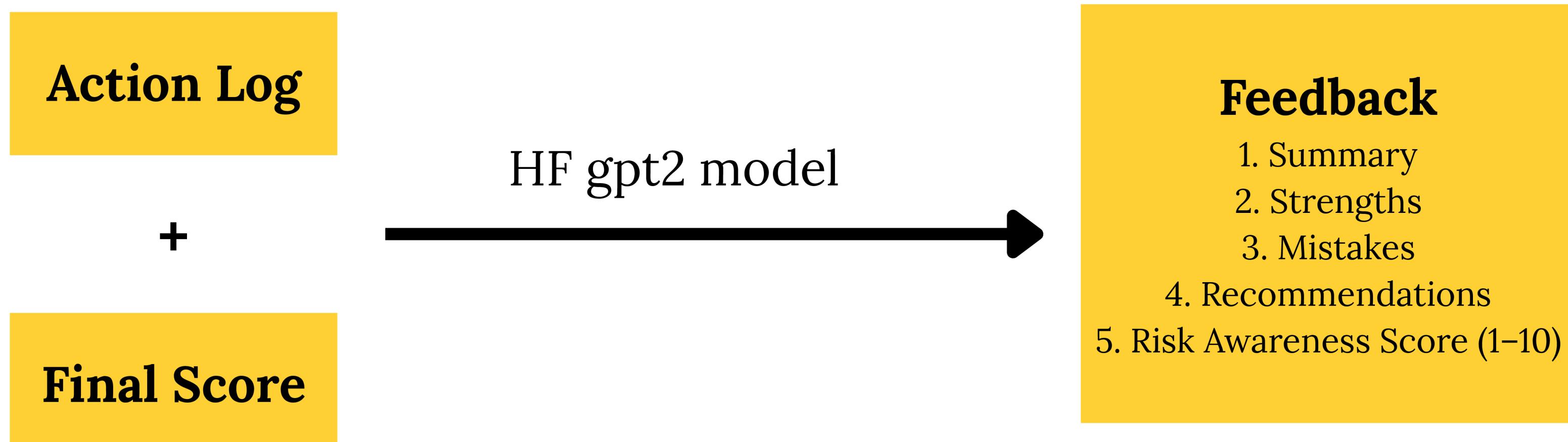
- **Hazard:** hydraulic_pressure_surge
- **Action Taken:** Reduce Load
- **Reward:** 3 / 3
- **Result:**  Safe
-  **Correct:** Yes

Score



Feedback

- Problem Statement 2



PS: LLM is in the process of tuning

PROBLEM STATEMENT 5

Dynamic Task- Operator Match & Time Estimation System

Enhancing Productivity, Safety & Operator Experience
using AI

Problem Statement:

How can we assign the right operator to the right task on the right machine, and predict the time needed?

Key Issues

- Wrong operator-task match = inefficiency, safety risk
- No real-time system to suggest best match
- Need intelligent, data-driven task allocation

OUR SOLUTION

Dynamic ML-based System to:

- Classify the best-fit operator for a given task
- Predict estimated time to complete that task

TECH STACK

ML - Classification + Regression

FastAPI (ML Serving)

Streamlit (Frontend UI)

SQLite (Logging)

ML MODELS

Classification model

- **Goal:** Predict Is_Good_Match (0/1)
- **Input:** Task + Operator features
- **Output:** True or False
- **Model:** RandomForestClassifier

Regression model

- **Goal:** Predict Time_Taken
- **Input:** Task + Operator features
- **Output:** Estimated Time
- **Model:** RandomForestRegressor

Dataset Overview

```
[63] df.columns
```

```
→ Index(['Operator_ID', 'Experience_Yrs', 'Familiarity_Score', 'Safety_Score',
       'Fatigue_Score', 'Previous_Accident_Count', 'Tasks_Completed_Count',
       'Task_Type', 'Terrain', 'Task_Complexity_Level', 'Max_Allowed_Time',
       'Weather_Condition', 'Machine_Type', 'Time_Taken', 'Is_Good_Match',
       'Shift_Hours_Worked', 'Operator_Preference_Level',
       'Seatbelt_Compliance_Rate'],
      dtype='object')
```

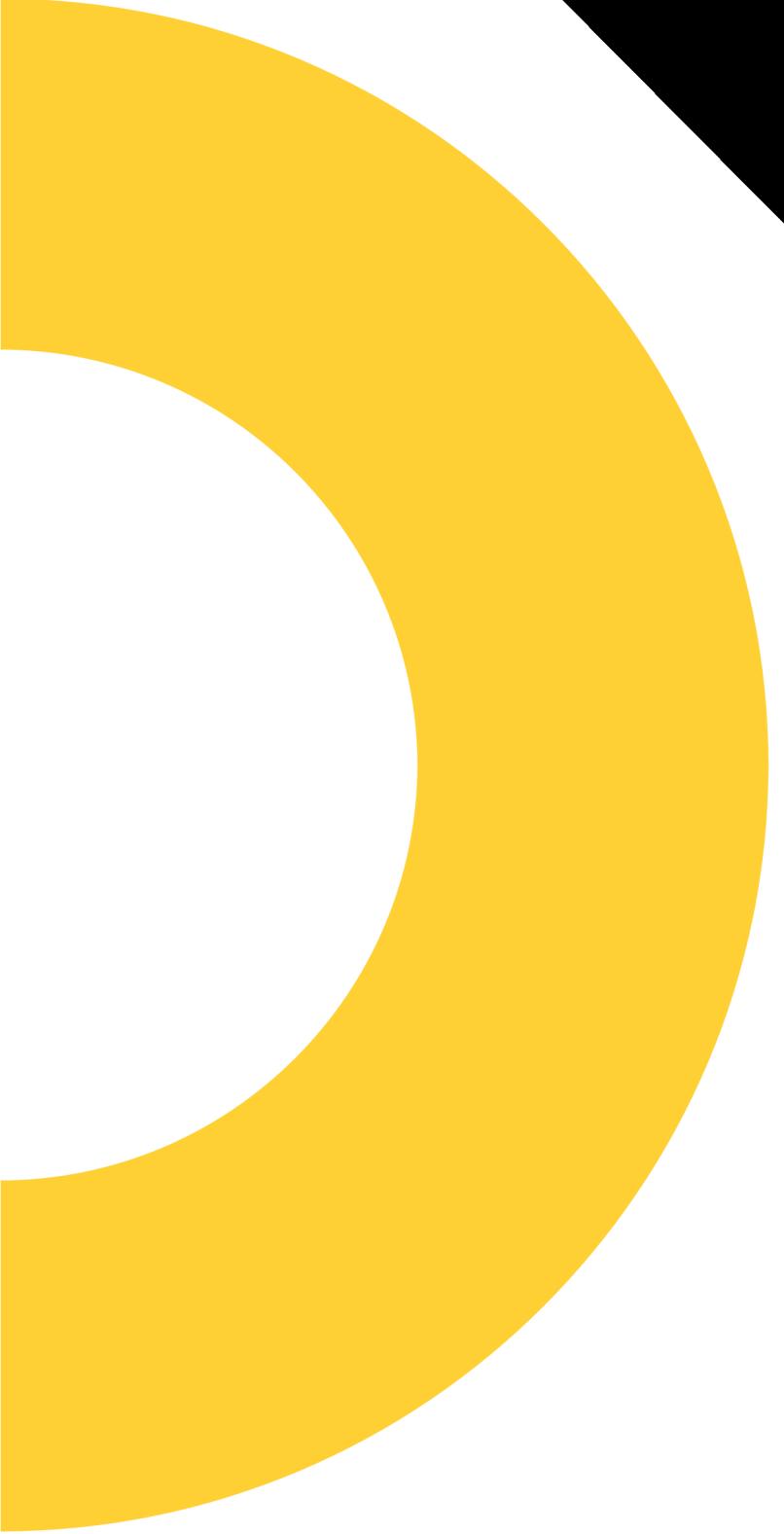
	Operator_ID	Experience_Yrs	Familiarity_Score	Safety_Score	Fatigue_Score	Previous_Accident_Count	Tasks_Completed_Count	Task_Type
0	OP1163	5.0	0.82	0.65	0.59	0	119	Load
1	OP1026	3.9	0.77	0.07	0.64	0	85	Lift
2	OP1059	4.4	0.75	0.72	0.46	2	106	Lift
3	OP1071	3.8	0.93	0.63	0.47	1	85	Load
4	OP1195	3.0	0.67	0.46	0.21	2	48	Carry

problems we faced

- Limited or Imbalanced
- Inadequate Feature Engineering Time
- Model Overfitting.

Possible Extensions

- Mobile interface for field use
- voice integration for onsite operator to interact with intelligent agent.
- Generating diverse dataset without any bias and predicting accurate estimations.
- VR integration for simulated training.



Thank you!