

**ÇANKAYA UNIVERSITY**

**FACULTY OF ENGINEERING**

**COMPUTER ENGINEERING DEPARTMENT**

**Test Plan, Test Design Specifications and Test Cases**

**Version 1**

**CENG 408**

Innovative System Design and Development II

**SUMMER TRAINING**

**INFORMATION SYSTEM**

**Team ID: 202311**

**AI-based Firefighting Vehicle**

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# INTRODUCTION

## Version Control

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| --- | --- | --- |
| **Version No** | **Description of Changes** | **Date** |
| 1.0 | First Version | March 28, 2024 |

## Overview

This project will test the effectiveness of an AI-driven fire engine autonomous control system developed using the Unity game engine and ROS 2. The focus will be on reinforcement learning (RL) techniques applied to navigate fire trucks through urban environments efficiently and safely.

## Scope

The scope of this document includes the development and implementation of an autonomous fire engine control system. This encompasses AI algorithms, simulation environments, sensor integration, and performance metrics. The document will detail the system's design, functional and non-functional requirements, testing strategies, and evaluation methods.

## Terminology

# metin, ekran görüntüsü, yazı tipi, makbuz içeren bir resim Açıklama otomatik olarak oluşturuldu

# FEATURES TO BE TESTED

## Autonomous Navigation (AN)

The ability of the AI-driven fire truck to navigate autonomously through urban environments, adhering to traffic rules and avoiding obstacles.

## Lidar Data Acquisition (LDA)

The ability of the AI agent to acquire and process Lidar data to create accurate point cloud representations of the environment.

## Emergency Response (ER)

The system's capability to respond to emergency scenarios efficiently, prioritizing the fastest and safest routes to the fire scene.

## 2.4 Reinforcement Learning Adaptation (RLA)

The effectiveness of the reinforcement learning algorithms in adapting the fire truck's navigation strategies based on dynamic urban layouts and traffic conditions.

## 2.5 Performance Metrics Dashboard (PMD)

The functionality of the dashboard to display key performance metrics such as response time, route efficiency, and compliance with traffic rules, allowing users to assess the AI's performance.

## 2.6 Real-Time Data Visualization (RTDV)

The ability to visualize the fire truck's movement and Lidar-generated point cloud data in real-time within the simulation environment.

# FEATURES NOT TO BE TESTED

Payment processing, hardware compatibility, data backup and recovery, network security, performance under extreme load, and cross-browser compatibility are not within the scope of this project. These areas require specific resources, configurations, or are typically managed by dedicated teams, and therefore will not be tested in this AI-driven fire engine navigation system project.

# ITEM PASS/FAIL CRITERIA

A test case is deemed to pass if the actual result matches the expected result as specified in the test case description. Conversely, a test case fails if the actual result deviates from the expected result.

## Exit Criteria

For the AI-driven fire engine navigation system project to be considered successful and ready for release, the following criteria must be met:

* 100% of the test cases are executed.
* 95% of the test cases must pass.
* All High and Medium Priority test cases must pass.

# REFERENCES

1. <https://github.com/CankayaUniversity/ceng-407-408-2023-2024-AI-based-Firefighting-Vehicle/wiki/Project-report>

# TEST DESIGN SPECIFICATIONS

### 6.1 UI Interactions

##### Features to be Tested

#### Autonomous Navigation (UI.AN)

Ensures that the AI-driven fire engine autonomously navigates along a designated route.

#### Lidar Data Collection (UI.LDA)

Ensures the AI agent collects and processes Lidar data to create an accurate point cloud representation of the environment.

**Lidar Data Collection (UI.LDA) Test Cases**

|  |  |  |  |
| --- | --- | --- | --- |
| **TC ID** | **Requirements** | **Priority** | **Scenario Description** |
| UI.AN.01 | 3.1 | **High** | The fire engine autonomously reaches the destination from a specified starting point. |
| UI.AN.02 | 3.1 | **High** | The fire engine adapts to obstacles and road conditions. |
| UI.AN.03 | 3.1 | **Medium** | The fire engine determines an alternative route. |
| UI.AN.04 | 3.1 | **High** | The fire engine moves in accordance with traffic lights and signs along the designated route. |
| UI.AN.05 | 3.1 | **Medium** | The fire engine recalculates the fastest and safest route upon receiving an emergency signal. |

#### Reinforcement Learning Adaptation (UI.RLA)

Evaluates how reinforcement learning algorithms adapt the navigation strategies of the fire engine based on dynamic environmental conditions.

**Reinforcement Learning Adaptation (UI.RLA)Test Cases**

|  |  |  |  |
| --- | --- | --- | --- |
| **TC ID** | **Requirements** | **Priority** | **Scenario Description** |
| UI.RLA.01 | 3.3 | **Medium** | The reinforcement learning algorithm adapts navigation strategies according to environmental conditions. |
| UI.RLA.02 | 3.3 | **Medium** | The reinforcement learning algorithm is tested with new learning scenarios. |
| UI.RLA.03 | 3.3 | **High** | Evaluate the retraining and adaptation process of the algorithm under changing traffic conditions. |
| UI.RLA.04 | 3.3 | **High** | Test the algorithm's performance on different road types (urban, highway, rural). |
| UI.RLA.05 | 3.3 | **Medium** | Assess the algorithm's performance and coordination capabilities against multiple agents. |
| UI.RLA.06 | 3.3 | **Low** | Evaluate the algorithm's impact on energy efficiency and fuel consumption. |

#### Real-Time Data Visualization (UI.RTDV)

The ability to visualize the movement of the fire engine and the point cloud data generated by Lidar in real-time within the simulation environment.

**Real-Time Data Visualization (UI.RTDV) Test Cases**

|  |  |  |  |
| --- | --- | --- | --- |
| **TC ID** | **Requirements** | **Priority** | **Scenario Description** |
| UI.RTDV.01 | 3.4 | **Medium** | Real-time visualization of the fire engine's movement and point cloud data. |
| UI.RTDV.02 | 3.4 | **Medium** | Real-time data is visualized on different devices (tablet, computer). |
| UI.RTDV.03 | 3.4 | **High** | Test for seamless and low-latency real-time data streaming. |
| UI.RTDV.04 | 3.4 | **Medium** | Evaluate the performance of real-time data transmission under different network conditions (Wi-Fi, LTE, Ethernet). |
| UI.RTDV.05 | 3.4 | **High** | Monitor CPU and memory usage during real-time data visualization. |
| UI.RTDV.06 | 3.4 | **Low** | Assess the impact of real-time data visualization on user experience through surveys and feedback. |

## Client-Sever Communication

### Features to be Tested

#### ROS 2 and Ubuntu Integration (CS.RU)

Evaluates the autonomous navigation and data processing capabilities of the fire engine in the ROS 2 and Ubuntu environments

#### ROS 2 and Ubuntu Integration (CS.RU) Test Cases

|  |  |  |  |
| --- | --- | --- | --- |
| **TC ID** | **Requirements** | **Priority** | **Scenario Description** |
| SEC.DS.01 | 4.5 | **High** | Ensure data is transmitted and stored in an encrypted format. |
| SEC.DS.02 | 4.5 | **Medium** | Test the effectiveness of encryption algorithms used for data security. |
| SEC.DS.03 | 4.5 | **High** | Evaluate the effectiveness of measures and response processes against data security breaches. |
| SEC.DS.04 | 4.5 | **Medium** | Test the correctness of data access controls (user roles and permissions). |
| SEC.DS.05 | 4.5 | **High** | Ensure data integrity and accuracy are maintained throughout data processing and transmission processes. |
| SEC.DS.06 | 4.5 | **Low** | Regularly update and test the software and tools used for data security against vulnerabilities. |

## Backup and Restore

### 6.3.1 Features to be Tested

#### Data Backup (BR.BK)

Evaluates the system's ability to back up data at specified intervals.

#### Data Restore (BR.RS)

Ensures that backed-up data is restored correctly and completely.

**Data Restore (BR.RS)Test Cases**

|  |  |  |  |
| --- | --- | --- | --- |
| **TC ID** | **Requirements** | **Priority** | **Scenario Description** |
| BR.BK.01 | 4.2 | **High** | Automatically back up system data at specified intervals. |
| BR.BK.02 | 4.2 | **Medium** | Manually initiate and monitor backups by the user. |
| BR.BK.03 | 4.2 | **High** | Evaluate system performance during backup operations. |
| BR.BK.04 | 4.2 | **Medium** | Test the integrity and accessibility of backup files. |
| BR.BK.05 | 4.2 | **High** | Simulate and analyze data loss and corruption during backup operations. |
| BR.BK.06 | 4.2 | **Low** | Compare the performance of different backup scenarios (full backup, incremental backup). |

# Detailed Test Cases

## UI.AN.01

|  |  |
| --- | --- |
| **TC\_ID** | UI.AN.01 |
| **Purpose** | Ensure the AI-powered fire truck autonomously reaches its destination from the starting point. |
| **Requirements** | 3.1 |
| **Priority** | High |
| **Estimated Time Needed** | 10 Minutes |
| **Dependency** | Previous user validation tests |
| **Setup** | Position at the starting point |
| **Procedure** | [A01] Autonomously reach the destination from the starting point.  [A02] The vehicle adapts to obstacles and road conditions.  [A03] Determines and follows an alternative route. |
| **Cleanup** | Stop the vehicle |

## ****UI.LDA.01****

|  |  |
| --- | --- |
| **TC\_ID** | **UI.LDA.01** |
| **Purpose** | Collect and visualize Lidar data as a point cloud. |
| **Requirements** | 3.2 |
| **Priority** | Medium |
| **Estimated Time Needed** | 12 Minutes |
| **Dependency** | Initial scenario created |
| **Setup** | Lidar sensor active |
| **Procedure** | [A01] Collect Lidar data and visualize it as a point cloud.  [A02] Analyze latency and data loss during data collection.  [A03] Collect and process Lidar data at different speeds. |
| **Cleanup** | Save the data |

## ****UI.LDA.02****

|  |  |
| --- | --- |
| **TC\_ID** | **UI.LDA.02** |
| **Purpose** | Update the 3D city model using Lidar data. |
| **Requirements** | 3.2 |
| **Priority** | High |
| **Estimated Time Needed** | 15 Minutes |
| **Dependency** | Lidar data must be collected accurately |
| **Setup** | Ensure Lidar sensors are working |
| **Procedure** | [A01] Collect Lidar data.  [A02] Process the collected data and add it to the 3D city model.  [ A03] Verify the city model is updated. |
| **Cleanup** | Backup the database |

## ****UI.RL.01****

|  |  |
| --- | --- |
| **TC\_ID** | **UI.RL.01** |
| **Purpose** | Ensure the AI agent develops traffic-compliant behavior using reinforcement learning. |
| **Requirements** | 3.3 |
| **Priority** | High |
| **Estimated Time Needed** | 20 Minutes |
| **Dependency** | Initial settings and learning algorithms |
| **Setup** | Start the AI agent |
| **Procedure** | [A01] Begin training the AI agent under initial conditions.  [A02] Reward behaviors that comply with traffic rules.  [A03] Penalize behaviors that violate traffic rules.  [A04] Observe and record the learning process. |
| **Cleanup** | Save learning data |

## ****UI.NG.01****

|  |  |
| --- | --- |
| **TC\_ID** | **UI.NG.01** |
| **Purpose** | Ensure the fire truck finds the shortest route in the fire suppression scenario. |
| **Requirements** | 3.4 |
| **Priority** | High |
| **Estimated Time Needed** | 10 Minutes |
| **Dependency** | Starting and target points must be determined |
| **Setup** | Position the fire truck at the starting point |
| **Procedure** | [A01] Run the shortest path algorithm.  [A02] Observe the fire truck reaching the determined target.  [A03] Record obstacles encountered on the route.  [A04] Evaluate the results. |
| **Cleanup** | Reset the vehicle position |

## ****UI.RO.01****

|  |  |
| --- | --- |
| **TC\_ID** | **UI.RO.01** |
| **Purpose** | Ensure healthy data exchange with ROS 2. |
| **Requirements** | 3.5 |
| **Priority** | High |
| **Estimated Time Needed** | 12 Minutes |
| **Dependency** | ROS 2 must be configured |
| **Setup** | Start ROS 2 |
| **Procedure** | [A01] Start data transmission through ROS 2.  [A02] Verify that the transmitted data is received.  [A03] Process the received data and verify accuracy.  [A04] Record the results. |
| **Cleanup** | Stop ROS 2 and back up the data |

## ****UI.UB.01****

|  |  |
| --- | --- |
| **TC\_ID** | **UI.UB.01** |
| **Purpose** | Ensure the simulation works properly on the Ubuntu operating system. |
| **Requirements** | 3.6 |
| **Priority** | High |
| **Estimated Time Needed** | 10 Minutes |
| **Dependency** | Installation of Ubuntu and necessary dependencies |
| **Setup** | Start the Ubuntu operating system |
| **Procedure** | [A01] Run the simulation on Ubuntu.  [A02] Observe that the simulation works properly.  [A03] Record performance data.  [A04] Evaluate the results. |
| **Cleanup** | Stop the simulation and back up the data |

## ****UI.ML.01****

|  |  |
| --- | --- |
| **TC\_ID** | **UI.ML.01** |
| **Purpose** | Ensure the AI model is correctly trained and can make predictions. |
| **Requirements** | 3.7 |
| **Priority** | High |
| **Estimated Time Needed** | 15 Minutes |
| **Dependency** | Training data sets and model configuration |
| **Setup** | Load training data sets |
| **Procedure** | [A01] Start training the AI model.  [A02] Observe and record the training process.  [A03] Make predictions with the trained model.  [A04] Evaluate and verify prediction results. |
| **Cleanup** | Save the model and training data |

## ****UI.DA.01****

|  |  |
| --- | --- |
| **TC\_ID** | **UI.DA.01** |
| **Purpose** | Ensure data is correctly analyzed and reported. |
| **Requirements** | 3.8 |
| **Priority** | Medium |
| **Estimated Time Needed** | 10 Minutes |
| **Dependency** | Analysis tools must be configured |
| **Setup** | Start analysis tools |
| **Procedure** | [A01] Start analyzing the data.  [A02] Report analysis results.  [A03] Evaluate and verify reports.  [A04] Record the results. |
| **Cleanup** | Stop analysis tools and back up the data |

## ****UI.AU.01****

|  |  |
| --- | --- |
| **TC\_ID** | **UI.MA.01** |
| **Purpose** | Ensure the model adaptation and learning processes are accurate. |
| **Requirements** | 4.5 |
| **Priority** | High |
| **Estimated Time Needed** | 20 Minutes |
| **Dependency** | Training data and model configuration |
| **Setup** | Load training data |
| **Procedure** | [A01] Start the model adaptation process.  [A02] Observe and record the adaptation process.  [A03] Start the learning process.  [A04] Observe and verify the learning process. |
| **Cleanup** | Save training data and model parameters |

## ****UI.ML.02****

|  |  |
| --- | --- |
| **TC\_ID** | **UI.ML.02** |
| **Purpose** | Ensure the accuracy of machine learning models. |
| **Requirements** | 5.0 |
| **Priority** | High |
| **Estimated Time Needed** | 20 Minutes |
| **Dependency** | Training data and models |
| **Setup** | Load training data and models |
| **Procedure** | [A01] Train the machine learning model.  [A02] Observe and record the training process.  [A03] Test the model's prediction accuracy.  [A04] Verify the results. |
| **Cleanup** | Save training data and models |

## ****UI.AI.01****

|  |  |
| --- | --- |
| **TC\_ID** | **UI.AI.01** |
| **Purpose** | Analyze the performance and decision-making process of AI algorithms. |
| **Requirements** | 5.6 |
| **Priority** | High |
| **Estimated Time Needed** | 30 Minutes |
| **Dependency** | AI algorithms active |
| **Setup** | AI performance monitoring tools active |
| **Procedure** | [A01] Analyze the performance and decision-making process of AI algorithms  .[A02] Examine the data and methods used in the decision-making process.  [A03] Develop and implement recommendations for performance improvements. |
| **Cleanup** | Save the data |

## ****UI.CP.01****

|  |  |
| --- | --- |
| **TC\_ID** | **UI.CP.01** |
| **Purpose** | Ensure the fire suppression process is correctly simulated. |
| **Requirements** | 4.3 |
| **Priority** | High |
| **Estimated Time Needed** | 15 Minutes |
| **Dependency** | Fire suppression scenario |
| **Setup** | Start the fire suppression scenario |
| **Procedure** | [A01] Start the fire suppression process.  [A02] Observe the fire suppression process.  [A03] Record and evaluate the results.  [A04] Verify the simulation results. |
| **Cleanup** | Stop the fire suppression scenario and back up the data |