TEKNOFEST

AEROSPACE AND TECHNOLOGY FESTIVAL

ROBOTAXI-FULL SCALE AUTONOMOUS VEHICLE COMPETITION

(UNIQUE VEHICLE CATEGORY)

PRELIMINARY DESIGN AND SIMULATION REPORT

APPLICATION ID: 468176

TEAM NAME: TUNSA Space Robotics

VEHICLE NAME: TUNSA's Martian Settler Robotaxi (TUNMSR)

TEAM CAPTAIN: ELYES KHECHINE

CONTENTS

IV. Originality

V. Sensors

A. Localization Sensors

1. Localization Requirements for TUNMSR
2. Inertial Measurement Unit (IMU)
3. GNSS Module

B. Visual Perception Sensors

1. Perception Requirements for TUNMSR
2. Computer Vision (CV) Sensor: Options Assessment
   - *i. LiDAR*
   - *ii. 3D Flash LiDAR*
   - *iii. 4D/3D Imaging Radars*
   - *iv. Pseudo-LiDARs: Stereo Cameras*
   - *v. Breakdown Comparison*
3. Preliminary CV Sensor Choice: Stereo Camera
4. Time-of-flight Sensors

C. Powertrain Sensors

1. Powertrain Requirements for TUNMSR
2. Electronic Battery Sensor
3. Temperature Sensor
4. Transmission Sensor
5. Wheel-speed Sensor

D. Breakdown of Sensors

E. Sensor Wiring

F. Sensor Mounting

G. Sensor Autonomy Coverage

H. Sensor Fusion

1. Sensor Synchronization
2. Sensor Raw Data Processing
3. Sensor Fusion Algorithm

VI. Vehicle Control Unit

A. High-level Control Unit

1. VCU Selection Criteria for TUNMSR
2. Options Assessment

3. **Preliminary VCU Choice: NVIDIA DRIVE AGX Pegasus Developer Kit**

B. Low-level Control Unit

1. **Longitudinal Actuation**
2. **Lateral Actuation**

C. Wireless Control Unit

1. **Wireless Controller**
   - *i. Requirements*
   - *ii. Selection*
2. **Wireless Communication System**
   - *i. Wireless Communication Protocols*
   - *ii. Wireless Control Software*

VII. Autonomous Driving Algorithms

A. Vehicle Kinematics & Dynamics Modeling

B. Vehicle 2D Control

1. **Longitudinal PID Control**
2. **Lateral Model-Predictive Control (MPC)**

C. Visual Perception

1. **Computer Vision Toolbox**
   - *i. CNNs*
   - *ii. TensorFlow*
   - *iii. Object Detection with YOLOR*
2. **Stereo Camera Data Processing**
3. **Semantic Lane Estimation & Tracking**
4. **Visual Servoing & Trajectory Drawing**
   - *i. Visual Servoing Approach*
   - *ii. Coordinate Transformations*
   - *iii. Drawing Planned Trajectory*
5. **Object Detection**
   - *i. Traffic Sign Detection*
   - *ii. Traffic Light Detection*
   - *iii. Obstacle Avoidance*

D. Motion Planning

1. **Global Path Planner**
   - *i. Options Assessment*
     - Hybrid A*
     - Rapidly-exploring Random Tree (RRT)
     - RRT-A*
     - ABIT*

i. Implementation

2. **Behavioral Planner**
   i. Options Assessment
      - Finite State Machines (FSMs)
      - Extended Finite State Machines (EFSMs)
      - Hierarchical Finite State Machines (HFSMs): Harel Approach
      - Behavior Trees (BTs)

   ii. Implementation
3. **Local Re-Planner**
   i. Options Assessment
      - CBB-RRT*
      - Lattice-based Path Planner
      - Optimal Control Improvement

   ii. Implementation
4. **Velocity Planner**
   i. Options Assessment
      - Trapezoidal Profile Generation
      - Position Quintic Polynomial for Trajectory Generation
      - Speed Quartic Polynomial Trajectory Generation
      - Symmetric Polynomial Trajectory Generation

   ii. Implementation

E. State Estimation and Real-time Localization

1. **Options Assessment**
   i. Extended Kalman Filter (EKF)
   ii. Error-State Extended Kalman Filter (ES-EKF)
   iii. Unscented Kalman Filter (UKF)
2. **Implementation of the UKF**

VIII. Security Precautions

A. Security Hardware

1. **Signal Lights**
2. **Stop Lamps**

B. Battery Management System (BMS)

1. **Voltage Monitoring**
2. **Current Monitoring**
3. **Temperature Monitoring**
4. **State of Charge (SOC)**
5. **State of Health (SOH)**
6. **Balancing System**

C. Electrical Safety

1. **Ingress Protection (IP)**
2. **Low Current Emergency Disconnect Switch**
3. **High Current Emergency Disconnect Switch**
4. **Emergency Stop Button (Circuit Breaker)**
5. **Overcurrent Breakers**
6. **Remote Emergency Response System (RERS)**

D. Software Security

IX. Simulation

A. Simulation Environment

B. Map Creation

C. Implemented Algorithms

D. Vehicle Mission

E. Simulation Results

X. References