1 Introduction

This project will create an Active Park Assist (APA) system to be installed in vehicles to improve the drivers parking experience. This document will cover the overall description of the APA system and specific requirements necessary to build it. It will also provide models and diagrams to clarify system specifications and provide an overview of the structure of the prototype.

1.1 Purpose

This document will describe the system, lay out its requirements, build models for system behavior, and describe a prototype interface for the system. This document is for development team members to reference during development and the Ms. Eileen Davidson from Ford Motor Company to confirm requirements are met.

1.2 Scope

The name of this project is the Active Park Assist System (APA). The APA is a feature that enables the car to select and park in a parking space at the request of the driver. The driver will not need to maneuver or control the vehicles steering while the system is active. This will greatly reduce the number of accidents that occur during parking maneuvers. This system will be embedded into the vehicles current computer systems and will interface with several of the vehicles subsystems. The APA will be able to see available parking spots when the driver turns the system on and will display the available spots to the driver. Upon selection, the system will then begin to park in the available space. The vehicle will avoid all obstacles and park with the bounds of the selected space. The system will be used only while parking the vehicle and will not provide autonomous driving in high speed conditions.

1.3 Definitions, acronyms, and abbreviations

1. Abbreviations and Definitions:
   a. Human-machine interface (HMI): The HMI is a control panel that the driver can use to adjust settings in the car and initiate the auto-pilot features
   b. Active Park Assist (APA): The Active Park Assist system we will build.
   c. Available parking spots: A parking spot width is >1.2x where x is the width of the vehicle.
d. Limited parking speed: < 5 mph.
e. A reasonable parking time: <15 seconds

2. **Terms:**
   a. Park Control Subsystem: The system that controls the APA system.
   b. Powertrain Management Subsystem: The system that controls the transmission and acceleration of the vehicle.
   c. HMI Subsystem: The system that receives and input from the driver and displays camera and warning information.
   d. Brake Control Subsystem: The system that controls the brakes on the vehicle.
   e. Steering Control Subsystem: The system that controls the steering of the vehicle.
   f. Vehicle Position Subsystem: The system that receives input from the cameras and sensors to determine parking spots and the position of the vehicle.

1.4 **Organization**

The rest of this document will describe, model, and prototype the APA project. Section 2 will describe the systems characteristics, functions, and constraints. This will include the motivation behind the system and the characteristics of the users that will be using this system. Section 3 will define requirements for building the system. These requirements will be used by the developers to build the system and by the customer to verify that all requirements are met. Section 4 will model various use cases and system diagrams to be referenced by developers. Section 5 will provide a prototype description and some sample scenarios.

2 **Overall Description**

This section will provide a general introduction to the system, which will include detail of the system such as the perspective and functions, and the user characteristics. Constraints, Assumptions and Dependencies will also be listed below.

2.1 **Product Perspective**

The Active Park Assist (APA) system is designed to provide drivers the option to park the vehicle automatically with minimum interaction. According to National Highway Traffic Safety Administration (NHTSA)'s data of 2015, 12000 nonoccupants were injured by backing vehicles, 284 were killed. Parking a vehicle can be a challenging task for any driver in any given circumstance. This system is intended to provide better experience for drivers to allow them park their vehicle easier. This system will also bring increased safety for both the passenger and the surroundings include pedestrians and other objects nearby.

The APA system is formed by 6 subsystems, which include Park Control Subsystem, Powertrain Management Subsystem, HMI Subsystem, Brake Control Subsystem, Steering Control Subsystem, and Vehicle Position Subsystem.

Figure 2.1 is a block diagram of the entire system with all major components. The arrow indicates the direction of communication.

Template based on IEEE Std 830-1998 for SRS. Modifications (content and ordering of information) have been made by Betty H.C. Cheng, Michigan State University (chengb at chengb.cse.msu.edu)
The user interface of this system is provided through the onboard Human Machine Interface (HMI) system. The HMI is a control panel that the driver can use to adjust settings in the car and initiate the auto-pilot features. The HMI will provide two options: the type of parking (parallel or perpendicular) and available parking spots. User may also interact with the system by control the vehicle directly.

This system requires additional hardware that has to be installed on the vehicle to function. Cameras installed at the front and back of the vehicle will be used to identify the parking spots available nearby. This system also requires ultrasonic sensors to measure the distance between the vehicle and surroundings. This system also requires radar to monitor the position of vehicle.

There will be some software required to process the data that is critical for this system. The system requires software to handle the input from the user. Then it needs to process the data gained from onboard sensors to identify the environment nearby. It also requires software to calculate the trajectory and handling the vehicle.

This system will interface between the subsystems included. The Park Control Subsystem is responsible for the entire APA system. When the user activates this system, it will first accept user’s input through the HMI subsystem. Then it will call the Vehicle Position Subsystem to process the data gained from sensors to identify vehicle positions and nearby parking spots, and provide the information to the HMI. During the parking procedure, Park Control Subsystem will calculates the vehicle trajectory based on information from the Vehicle Position Subsystem, and then control the vehicle’s acceleration, brakes, and steering through the Powertrain Management, Brake Control and Steering Control subsystems. It will also provide information to the HMI subsystem that should be displayed to the user, including the camera information and other message related.

This system will be designed to integrated into other onboard systems, and thus, sharing the primary and secondary memory with other systems.

This system needs user's input to initialize the parking procedure, however once it is activated it does not requires regular interaction with the user until it is aborted. It also does not require specific action to be taken during unattended operation. Information will be given to the user if the system is aborted.
2.2 Product Functions

The major function of this software system is to provide the vehicle the ability to automatically park itself into an available parking spot. First the user will be able to activate the system through the HMI system. Then the user will be given the option to choose from parking parallel or perpendicularly. After the type of parking is chosen, the system will try to detect the available parking spots nearby. The system will use vehicle-mounted cameras to identify the parking spots, and the ultrasonic sensors will be used to measure the distance between the vehicle and parking spots. Then the user will be able to choose the desired spot through available spots identified.

Now the parking procedure will be initialized, and the system will take over the control of the vehicle. The system will use the sensors to determine the position of vehicle, and will accelerate, brake, and steer to direct the vehicle into the parking spot. The system will also continue to detect the obstacles through the sensors and take action if necessary. Once the vehicle is in the parking spot, the system will switch the automatic transmission in Park position and exit automatically. The entire parking procedure will take no more than 15 seconds to finish.

During the parking procedure, the user is able to abort this system and retake the control of vehicle at any time. The HMI will give information when the system aborts and normal control resumes.

Figure 2.2 shows the function included in the system.

![Figure 2.2 Product Functions](image)

2.3 User Characteristics

The user is expected to be a licensed driver. The user should be in good condition when operating the vehicle, and can finish the parking procedure manually without the use of assistance system.

This system does not require general expertise, however the user should read the manual and be able to interact with the onboard HMI.

2.4 Constraints

The APA is a complex system and there are some shortcomings in the subsystems, which may affect the overall performance.

- Auto-pilot function currently is not common on automobile vehicles, and the reliability is not proven yet. There may be legal issues with widespread installation of this system.
- The video cameras are vulnerable to the weather and brightness. And the ultrasonic sensors have blind spots. These factors may reduce the real-time performance of the Vehicle Position System.
Due to the limitations of the performance of the onboard computer system, if the information gained from the sensors is complex (there are irregular objects nearby) or conflict (if the camera or ultrasonic sensor is interfered and providing incorrect data), the system needs additional time to finish the procedure.

This system may be attacked by third-party, and this is severe security risk since this system can directly control the vehicle.

If some of the sensors become unreliable, or completely unable to function, this system may run in a downgraded mode, since it requires more time to try to recover the missing information from the data from other sensors.

If it is not possible to recover the missing part of information from other sensors’ data, or there is an issue in critical subsystems, such as the HMI, this system will not be able to function at all.

2.5 Assumptions and Dependencies

In order to make this system function normally, the following assertions and dependencies will be made:

- The vehicle is automatic transmission.
- The handling (steer/break/etc.) of the vehicle is in good condition.
- The sensors that this system relies on are in good condition.
- The vehicle is expected to be parallel, perpendicular, or diagonal to the parking spot and is fully stopped before the system is activated.
- The request to activate this system is initialized by the user via the HMI. Any other type of requests will be ignored.
- The parking spaces are clearly marked in line.
- If there are any obstacles in the path of the vehicle, the sensors will be able to detect them and necessary actions will be made.
- During the parking procedure, any attempts from the user to control the vehicle will be considered to be the user want to abort this system.

2.6 Apportioning of Requirements

The supporting of handle the manual transmission will not be implemented. This system does not support manual transmission vehicles. The supporting of double-parking will also not be implemented.

3 Specific Requirements

1. Hardware Requirements:
   a. Human-machine interface (HMI): The HMI is a control panel that the driver can use to adjust parking settings in the car and initiate the auto-pilot features
      i. The HMI will accept user input and allow user to choose or verify selections.
      ii. The HMI will display selection through the screen
      iii. The HMI will able to display vehicle position while APA is active.
   b. Cameras: The camera will allow the system to identify parking spots. The image will be shown on the HMI to provide the user rear visibility.
i. The cameras will be able to provide high resolution for the system to identify parking spots.

ii. The cameras will provide surrounding vision to support parallel, perpendicular and diagonal parking.

C. Ultrasonic Sensors: distance measurement hardware.

i. The ultrasonic sensors will have an accuracy at least 0.01m in distance measurement.

ii. The ultrasonic sensors will provide surrounding measurement to support parallel, perpendicular and diagonal parking.

2. Functional Requirements:

   a. User input and pre-parking phase: Accept user input and identify parking spot.
      
      i. The vehicle must be in park for the system to be initiated.
      
      ii. The system will allow parallel, perpendicular and diagonal parking mode.
          - The parking mode can be chosen by the user through HMI before parking process.
      
      iii. The system will use the front and rear cameras to identify the available parking spots.

      iv. The system will use ultrasonic sensors to measure if the parking spot is large enough to fit in.
          - The width of the parking spot should be >1.2x where x is the width of the vehicle.

      v. After parking spot identified, System will display all available parking spots.

      vi. Wait for user selection and verification through HMI

   b. System maneuvering phase: System take over the control of the vehicle and start park the car into the spot.
      
      i. Once the spot is verified by the user, the system takes over the driving of the vehicle. During the system maneuvering, any user interference will abort the system.
          User interference includes:
          - User click abort on the HMI
          - User step on the accelerator or brake pedal
          - User Steer the wheel
          - User active the Handbrake

      ii. The system will shift the automatic transmission into the appropriate range (reverse or drive).

      iii. Steer the vehicle to the appropriate angle.

      iv. Accelerate or brake the vehicle to park into the spot.

      v. System will continue to monitor vehicle position to ensure that vehicle does not bump into any of the other parked vehicles.
          - The distance between other vehicles should be kept at least 0.2m.
          - The system should steer, accelerate or brake the vehicle to keep the distance between other vehicles and obstacles.
          - If the vehicle is about to bump (distance <0.2m) the brake should be activated, and system should abort.

      vi. When vehicle is parked into the spot:
Put the automatic transmission into the Park position.
Return control of the vehicle to the user
Indicate to the user that the parking process has completed through HMI.
Exit The system.

c. System Abort: Any system error or user manually abort will enter the system abort phase.
i. The system should stop the vehicle and return the transmission to park.
ii. Notify the user System abort information on the HMI.
   - Information includes: Abort message, Abort Type (e.g. manual or system error), Abort time.
iii. Return vehicle control to user.
iv. The system should be able to resume or restart the parking from abort state.
   - When resume clicked, the system will continue the parking from previous abort point.
   - When restart clicked, the system will restart from the selecting the parking mode.

3. Quality Requirements:
   a. Security:
      i. The system must verify that the driver has initiated the request
      ii. System must verify the request was not a result of a fault in the HMI system or a malicious 3rd party attack.
      iii. If any security issue is detected, APA feature will not be allowed to be started and indicate user through HMI.
   b. Safety:
      i. The system should be able to identify obstacles that have moved into the path of the vehicle after a parking maneuver has started.
         - If the system detects an obstacle moving into the path of the maneuver, the maneuver should be aborted.
         - The driver will be notified that the maneuver has been aborted through the HMI.
      ii. Once a parking event is initiated, it shall be completed in a reasonable time (15 seconds). If time expired, the system should abort the parking process.
      iii. A single point failure of any sensor input shall be detectable and notify the user on the HMI.
         - The system will verify that it has been initiated correctly.
         - The system will not be initiated if any of the vehicles sensors required for the maneuver are not working correctly. The required sensors are the front and rear cameras, ultrasonic sensors, and radar systems.
4 Modeling Requirements

Use Case

Figure 1 below is the use case diagram for the Active Park Assist system and describes different scenarios between the user/driver and system.

![Use Case Diagram](image)

Figure 1. Use case diagram describing the interactions of the APA system.

The operator uses the APA system in order to park their vehicle with minimal interaction. The operator activates the system through a Human Machine Interface. Once activated, the user will select the spot type and the system will identify the available spots by monitoring the vehicle's location. Then through the HMI, the user can select which spot they would like to park in and the system will park the vehicle in the spot and notify the driver through the HMI once parking is complete. Any driver interference will abort the APA system and notify the user. The descriptions of each use case is in Table 1 below.

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select Spot Type</td>
<td>The user uses the Human Machine Interface to select what type of parking space they would like to park in.</td>
</tr>
<tr>
<td>Select Spot</td>
<td>Using the HMI, the driver selects which spot to park the car in.</td>
</tr>
<tr>
<td>Park Vehicle</td>
<td>The APA system steers the vehicle into the parking spot and then notifies the user through the HMI.</td>
</tr>
<tr>
<td>Identify Spots</td>
<td>Using the sensors and cameras on the vehicle, the system locates available spots to park in.</td>
</tr>
<tr>
<td>Abort APA System</td>
<td>The user interferes with the system by manually using the steering wheel, brake pedal, or gas pedal. The APA system will abort and give control back to the driver.</td>
</tr>
<tr>
<td>Monitor Vehicle</td>
<td>The APA uses the sensors and cameras to park the car without hitting adjacent</td>
</tr>
</tbody>
</table>

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vehicles or any object the move into the path of the vehicle.

| Table 1. Description of Use Cases |

Class Diagram

Figure 3. APA system class diagram.

Through the Active Park Assist System class, the parkVehicle command is called and the Vehicle Controls class issues commands to the vehicle controls including the velocity of the vehicle which controls the speed, direction, and braking of the vehicle, and steering of the vehicle which controls the direction that the vehicle will turn. The Active Park Assist System gathers data from the Vehicle Sensor class which uses the Radar to detect the available parking spots and objects that may come into range of the vehicle, and the Camera which detects the parking spot that the user would like to park. The system is controlled by the Human Machine Interface class. The user interacts with the system through the HMI by selecting the type of spot, and selecting a specific parking spot after the HMI displays the available spots to park in. Once the vehicle is finished parking, the HMI will display a message notifying the driver that the parking process is complete.

Data Dictionary

Active Park Assist | System controlling the parking process of the vehicle. This class gathers data about the vehicle position and its surroundings and issues commands to the vehicle controls to park the vehicle.

<table>
<thead>
<tr>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>vehicleWidth : double</td>
</tr>
<tr>
<td>VehicleLength : double</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>parkVehicle()</td>
</tr>
<tr>
<td>abortParkingProcess()</td>
</tr>
</tbody>
</table>
### Velocity Control

**Operations**
- **SetVelocity(velocity)**: Sets the velocity of the vehicle. Values above 0 denote forward movement and values below 0 denote a reverse movement. The value is set in miles per hour.
- **SetBrakes(brake)**: Initiates the brakes of the vehicle. The brake parameter is either 1 or 0. 1 if the brakes should be on, 0 otherwise.

### Steering

**Operations**
- **setSteering()**: Sets the value for the steering to maneuver the vehicle into the parking spot.

### Human Machine Interface

**Operations**
- **displayMessage()**: Displays a message to the user when the parking process is complete or when the process is aborted by the user, or by a detected object.
- **activateAPASystem()**: Activates the Active Park Assist System and detects the available spots.
- **selectSpotType()**: Allows the user to select what type of parking spot the vehicle should be parked into (perpendicular or parallel).
- **selectSpot()**: Allows the user to select which spot they would like to park in.

### Camera

**Operations**
- **detectTargetParkingSpot()**: Locates the spot that the user selected to park in.

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Radar Collects and sends data to the Active Park Assist System about the spots that are big enough to park in and detects objects that are in the way of the vehicle.

<table>
<thead>
<tr>
<th>Operations</th>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>detectObject()</td>
<td></td>
<td>Detects if an object is in the way of the vehicle. If so, the process is aborted.</td>
</tr>
<tr>
<td>findAvailableSpots()</td>
<td></td>
<td>Finds spots that are big enough to park in that the user will choose from through the HMI.</td>
</tr>
</tbody>
</table>

**Sequence Diagram**

Figure 4. Sequence diagram for successful APA operation

Figure 5. Sequence diagram for APA operation when an object interferes with the radar

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Figure 6. Sequence diagram for APA process when the user interferes with vehicle controls

State Diagram
5 Prototype

The Prototype will show the center display which will be a bird’s eye view of the car consisting of possible parking spaces and any popup notifications. The user will start with a popup asking which type of parking space to search for (fig. 1). Once selected, the screen will highlight all available spaces of that type in yellow. The user will then select one of these spots for the car to park in (fig. 2). At this point the screen will highlight that space in blue and ask the user to verify that they have selected the correct spot (fig. 3). Once the user verifies the spot, the car will park in the spot and the parking app will disable.

Figure 7. State diagram for APA system.
5.1. How to Run Prototype

The prototype will be run using C++ and can be accessed from GitHub via a link on our website. We will have an executable so it should be able to run properly on any windows operating systems without having to compile. (URL: https://git.cse.msu.edu/xubenten/cse435-apa1-prototype2)

5.2. Sample Scenario

Scenario 1: Start with a car in a parking lot and two possible parking spots (left and right). The user will pick one of the two parking spots on the screen (fig 1). The display will then highlight that parking spot and ask the user for verification via a popup (fig 2). Once the user verifies the spot, the car will then move into the spot and you will see it in the spot from the overhead view.

Scenario 2: With the same conditions as scenario 1, the car will be moving into a parking spot when the user decides to abort the parking operation, causing the abort message to pop up on the screen (fig. 4).

5.3. Images

(fig. 1: Select parking mode)
(fig. 2: Select parking space)
6 References


7 Point of Contact

For further information regarding this document and project, please contact Prof. J. Daly at Michigan State University (dalyjame at msu.edu). All materials in this document have been sanitized for proprietary data. The students and the instructor gratefully acknowledge the participation of our industrial collaborators.

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