Scalable Cruise Control

Project Requirements Definition

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Project Overview, Benefits & Goals

Automobile manufacturers are constantly under pressure to innovate new safety and convenience features for motorists in order to gain a competitive edge. With recent developments such as the backup camera and lane assist entering widespread and multi-brand prevalence, the Ford Motor Company needs a signature feature to distinguish itself from other vehicle manufacturers. To accomplish this feat, Ford has proposed the Scalable Cruise Control system, which aims to enhance the versatility of existing cruise control technology by introducing a greater degree of automation into the cruising experience.

The Scalable Cruise Control system will consist of a multi-faceted solution incorporating new and existing technology. The foundation of the project is the *simple cruise system*, the current cruising solution present in most vehicles. This is the basic speed control interface which most drivers use and are familiar with. For added functionality, a *following distance management* module will grant drivers the ability to set their cruise to a trailing distance, rather than a constant speed. The third and final facet of the Scalable Cruise solution is the *automatic emergency brake.* This component, to be a standard feature beginning in 2022, will take control of the vehicle's brakes when the driver lacks sufficient time or strength to manually brake against an imminent collision.

Scalable Cruise Control will enhance the driving experience in several ways. The most prevalent benefits pertain to driver safety. In vehicles supporting only simple cruise, there are many use cases in which activating cruise control is unsafe. For example, cruise control is dangerous when the motorist is driving on any roadway with moderate to heavy congestion. In this scenario brake-checking, traffic snakes, and lane changes often occur unannounced. For an inattentive driver using only simple cruise, a collision will occur without manual intervention. However, with the following distance management module and automatic emergency brake module in place, the vehicle will know when to stop, and execute the stop long before a collision occurs.

These safety benefits also affect user convenience. With the ability to automatically scale cruising speed, drivers do not need to hassle about manually entering minor changes in speed in relation to other vehicles. Instead, they are free to focus on the other aspects of driving. Furthermore, because the scalable cruise is based on *following distance* and not only speed, each respective driver can cruise to the trailing distance in which they are comfortable and confident driving in.

Related Systems

The Scalable Cruise Control system requires integration with several existing vehicle components in order to safely and reliably operate. First and foremost, the cruising module needs access to the vehicle's throttle and brake controls. With access to the accelerator, the cruise control can match the desired speed and distance if the vehicle is moving too slow or too fast. Similarly, the cruise control needs access to the brake in situations where the vehicle is travelling too fast or too close. The automatic emergency brake system will also need access to the brake in order to effectively avoid collisions. Finally, input data from the brake and accelerator is needed to suspend or calibrate the cruise system.

Because the Scalable Cruise system is interactive with the driver, it will need access to a series of user-accessible buttons. These buttons will serve as input between the operator and the cruising system. The buttons must allow the operator to: enable and disable the cruise control system, suspend and resume the cruise control system, set the initial cruising speed, set the initial cruising distance, increase or decrease the cruising speed, and increase or decrease the cruising distance. The number of buttons may not match the number of required features, so these buttons may vary in functionality depending on which module(s) are currently active.

The cruise system would be inoperable without access to many of the automobile's distributed sensor inputs. Like all cruise systems, the Scalable Cruise Control will need access to the speedometer to determine if it is under or overperforming related to the desired speed. The following distance management and automatic emergency brake modules need access to additional sensors to perform their duties; both of these modules need to know the distance to the leading object in front of the vehicle, so output from a front-facing radar and camera is required.

Scalable Cruise Control will also need a certain amount of allocated memory to function properly. In addition to the memory needed to handle calculations, certain variables such as the desired speed and desired distance must be stored in case the cruise control is suspended but left enabled.

Finally, from a security standpoint, the system must be protected by a firewall and other intrusion prevention countermeasures. The evolution of the Internet of Things (IOT) has brought forth a multitude to security vulnerabilities and exploits, many of which pose a danger to life and property in situations pertaining to vehicle operation. If a hacker gains access to a vehicle's accelerator or brakes, there is an unacceptable level of risk. Therefore, all unrecognized traffic must be blocked through relevant (WiFi, LTE, 802.11, etc.) channels via firewall.

Definition of Terms & Abbreviations

- **SCC (Scalable Cruise Control):** Ford's proposed solution. SCC is built upon existing cruise control systems. Consists of three facets: simple cruise, following distance management, and automatic emergency brake.
- **SCC Module:** One of the independently acting facets of the SCC system (e.g. Simple cruise, FDM, AEB).
- **Simple Cruise:** The cruise control technology that exists in vehicles prior to SCC integration.
- **FDM (Following Distance Management):** An SCC module that allows motorists to customize their cruising experience based on distance to the preceding car, rather than a constant speed.
- **AEB (Automatic Emergency Brake):** An SCC module that takes control of a vehicle's brakes if the driver is unable to manually prevent an impending collision. This module is active regardless of cruise control's status.
- **Internet of Things (IOT):** The ever-increasing integration of internet access into everyday objects such as appliances and vehicles.
- **Intrusion Prevention System (IPS):** A technology that examines traffic flows to and from critical systems to detect and prevent cybersecurity breaches.
- **Original Equipment Manufacturer (OEM):** The brand and model of part that was included with the vehicle in its initial assembly.
- **Cruising Speed:** A user-defined speed which the vehicle will try and maintain.
- **Cruising Distance:** A user-defined distance which the vehicle will try and remain behind the object in front of the vehicle.
- **Cruise Enable:** To activate the cruise control system's features (i.e. turn on).
- **Cruise Disable:** To deactivate the cruise control system's features (i.e. turn off).
- **Cruise Suspend:** To temporarily pause the cruise control system's features, but save its current settings.
- **Cruise Resume:** To return the cruise control to its full activation state.
- **Maximum Possible Safe Speed:** The highest speed the vehicle can maintain while still avoiding the possibility of a rear-end collision with the leading vehicle.
- **UI (User Interface):** The abstracted portion of the SCC that is presented directly to the vehicle operator.
- **I/O (Input/Output):** The potion of the SCC that allows for communication between the operator and the SCC system itself.

Analysis of Existing Solutions

The Scalable Cruise Control system seeks to address several issues with current cruising solutions. Basic cruise control functionality has remained largely unchanged for more than fifty years, and its obsolescence is now a hindrance to the driving experience. The stress of freeway driving has been greatly mitigated in recent years – innovations such as lane departure warnings, rear and side view cameras, and onboard GPS have made long haul driving a seamless experience. However, the lack of innovation with regards to cruise control has made it a niche and often unusable tool.

Existing basic cruise control's main issue is that it is restricted to low-traffic scenarios. With little traffic, a static-speed cruise control system works well. However, for the vast number of drivers who both live *and* work in urban environments, this rarely occurs. This nullifies the usefulness of static-speed systems due to the frequently changing speeds of heavy traffic. Ford's proposed solution of a static-distance (and thus variable speed) cruising system means traffic is no longer an issue when relinquishing driving control to the vehicle. As long as the automobile maintains a certain distance from the next car up, the driver does not need to focus on avoiding rear-end collisions.

There is also no existing parallel to the proposed automatic emergency brake module. Most rear-end collisions are avoidable, yet it is still one of the leading causes of motor vehicle accidents. Despite harsh fines, distracted driving remains a significant factor regarding the prevalence of rear-end collisions. In the case that distracted driving is impossible to mitigate, the implementation of the AEB system would decrease the amount of collisions and prevent damage to both life and property.

The field of automotive cybersecurity is also in its infancy. There have not been any high-profile attacks on vehicles thus far, but it's potential for widespread damage remains a very real threat. The Scalable Cruise Control system aims to implement tight security measures, which would allow Ford to become a pioneer in the field of vehicle cybersecurity. By engaging in rigorous penetration testing and input sanitation testing early on, other Ford technology can borrow from the Scalable Cruise Control's IPS foundation.

Solution Essential Characteristics

The Scalable Cruise Control system requires a variety of attributes to function effectively. The most importable functional requirement is safety. If the system damages the vehicle or well-being of its occupants, it is a total failure. Safety is guaranteed by ensuring that the system reliably responds correctly and immediately to user inputs. If the user wishes to decrease speed or following distance, the system must react accordingly in real-time. If the automatic emergency brake module receives a signal to active, it must activate immediately.

The system must also be lightweight and portable. This is necessary for several reasons. Building upon existing cruise technology avoids functional overlap and additional overhead, allowing development resources to be allocated elsewhere. Additionally, a lightweight solution is more portable, decreasing the hassle of applying the SCC to all Ford vehicle models. A lightweight solution also maximizes security of the security. A smaller codebase leaves less opportunities for vulnerabilities. This is important as if the SCC modules are vulnerable to remote attacks, then safety is no longer guaranteed, regardless of system performance.

The system must also be convenient so that it is used by drivers. Confusing features are often not worth the hassle to operators, especially those who are not very familiar with driving or have been driving a very long time. Most drivers are familiar with the simple cruise interface. Due to this existing familiarity, additional cruising modules must match this UI as closely as possible. It is important for the SCC to be minimally intrusive to minimize the learning curve of adapting to vehicles with Scalable Cruise enabled.

The simple cruise system must function with the following constraints. The driver must be able to enable/disable cruising and set a maximum speed to be maintained. This speed will only be saved if greater than 25mph. The vehicle must internally maintain this speed through throttle control and speedometer readings. The driver must be allowed to exceed this through accelerometer inputs or suspend it through a button press or brake pedal. Another button will resume the cruise to the last saved speed. Finally, the saved speed can be changed through button press.

The following distance management system must function with several restrictions. The driver can set a following distance from a scale of 1 (close) to 4 (far) with button controls. This distance is internally maintained by the cruise controller based on the “time to intercept”, calculated by the position and relative speed of leading vehicle. The vehicle will maintain the maximum possible safe speed through throttle and brake control, considering real-time inputs from itself and the following vehicle. These data points must come from the on-board camera and radar, within the user-set speed, distance, and manual throttle/brake constraints.

Finally, the automatic emergency brake system must function with the following constraints. The AES will function regardless of cruising status. The AES, when prompted to take action, will apply maximum braking force to minimize stopping distance. The AES will take action if it determines the driver cannot stop in time to avoid a collision depending on the vehicle speed, and camera and radar output.

System Environment

The Scalable Cruise Control system will function solely within the provided hardware of a Ford automobile. Regarding software, the SCC will deliver its own codebase as well as building upon existing simple cruise functionality.

There are several key advantages to operating within Ford's automobile hardware. These benefits pertain to the fact that all sensors, calculations, and input/output are done in-suite. This simplifies the process significantly, as each relevant component can access each other directly *if needed.* Furthermore, working within one set of hardware limits the amount of differing syntaxes and interfaces the SCC could run into, as each component will be comprised of Ford-sponsored OEM parts. Finally, this means that inter-module communication is more secure, as there is no need to access modules outside of the vehicle being used. Given this scenario, any incoming traffic attempting to directly interfere with SCC functionality can be deemed malicious.

The Scalable Cruise Control system also suffers several risks from being restricted in the vehicle's hardware. Memory, processing power, and time limitations create the greatest obstacles. Vehicles do not contain supercomputers, and processors are substantially more limited than personal computers. The SCC requires accurate calculations to be completed in real-time to ensure driver safety, which can be challenging to achieve in restricted hardware. These issues also arise if the system is allocating resources to other processing-intensive components, such as GPS or audio playback. The SCC is also restricted in its limited I/O capacity. Only a limited number of buttons are available to the driver, so functionality may have to be combined in an intuitive fashion. Furthermore, output will likely be restricted to the dashboard and console. These two regions already compete for space with other car features, so the SCC will need to present a significant amount of important information (target speed, target distance, system status) in a limited amount of space.