Work-in-Progress: Augmented Reality System for Vehicle Health Diagnostics and Maintenance

Prof. Yuzhong Shen, Old Dominion University

Yuzhong Shen received his B.S. degree in Electrical Engineering from Fudan University, Shanghai, China, M.S. degree in Computer Engineering from Mississippi State University, Starkville, Mississippi, and Ph.D. degree in Electrical Engineering from the University of Delaware, Newark, Delaware. His research interests include computer graphics, visualization, serious games, signal and image processing, and modeling and simulation. Dr. Shen is currently a Professor of the Department of Computational Modeling and Simulation Engineering and the Department of Electrical and Computer Engineering of Old Dominion University. He is also affiliated with Virginia Modeling, Analysis, and Simulation Center (VMASC). Dr. Shen is a Senior Member of IEEE.

Dr. Anthony W Dean, Old Dominion University

Dr. Anthony W. Dean has had several roles in academia. He is currently Assistant Dean for Research, Batten College of Engineering and Technology (BCET) at ODU. His previous appointments include Associate Professor of Engineering Technology and as Associate Director of the Institute for Ship Repair, Maintenance, and Operations at Old Dominion University (ODU).His research has focused mostly on control systems (integration and testing) and the reliability and maintainability of complex systems. He has been selected as both a NASA and an ONR Faculty Fellow. He regularly teaches courses in Marine Engineering and in Maintained Systems. Most recently Dr. Dean was on the Headquarters Staff the American Society of Naval Engineers. He received his Ph.D. from the Department of Engineering Management and Systems Engineering, and a B.S. in Nuclear Engineering Technology, from the Batten College of Engineering and Technology at Old Dominion University. Additionally, Dr. Dean received an MBA from the College of William and Mary. Prior to is academic career Dr. Dean was Director of Operations and Business Development for Clark-Smith Associates, P.C., and served as an Electrician in the US Navy aboard the USS South Carolina and the USS Enterprise.

Dr. Rafael Landaeta, Old Dominion University

Dr. Landaeta is an Associate Professor with tenure in the department of Engineering Management and Systems Engineering at Old Dominion University in Norfolk, Virginia. He holds a Ph.D. in Industrial Engineering and a M.S. in Engineering Management from the University of Central Florida, as well as, a B.S. in Mechanical Engineering from UNITEC Venezuela. He serves as an Associate Editor for the Engineering Management Journal and is the Old Dominion University Faculty Advisor of the Student Chapter of the Society of Hispanic Professional Engineers and the Student Chapter of the Engineering Management Honor Society.His scholarship focuses on generating, transferring, and applying multi-disciplinary knowledge that addresses current and future challenges in knowledge-intensive organizations. He has provided management coaching, training, and consulting to Fortune 100 companies and large government organizations. The American Society for Engineering Management recognized him with two Meritorious Service Awards in 2006 and 2012 and was elected Fellow of the society in 2014. Old Dominion University recognized him with the Shining Star Award in 2010, the Batten College of Engineering and Technology Excellence in Teaching Award in 2008 and the Industry Engagement Award in 2014. He was selected an entrepreneurship ”Entsminger fellow” by Old Dominion University in 2015.

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Abstract

This paper discusses undergraduate research to develop an augmented reality (AR) system for diagnostics and maintenance of the Joint Light Tactical Vehicle (JLTV) employed by U.S. Army and U.S. Marine Corps. The JLTV's diagnostic information will be accessed by attaching a Bluetooth adaptor (Ford Reference Vehicle Interface) to JLTV's On-board diagnostics (OBD) system. The proposed AR system will be developed for mobile devices (Android and iOS tablets and phones) and it communicates with the JLTV's OBD via Bluetooth. The AR application will contain a simplistic user interface that reads diagnostic data from the JLTV, shows vehicle sensors, and allows users to create virtual dashboards to display various information. It will also contain interactive presentation and visualization of JLTV external and internal parts and 3D animations for diagnostic and maintenance. The AR application will consist of two modes: Standalone Mode and AR Mode. Standalone Mode does not require a real vehicle and it contains interactive 3D visualizations and animations for diagnostic and maintenance. The AR Mode requires the presence of a vehicle and projects instructions and animations to the vehicle components and parts under diagnosis and maintenance.

This project contains several major tasks: 1) 3D modeling of the vehicle, including all internal and external parts to be displayed in the AR application, 2) 3D printing of the vehicles that only requires the external parts that requires conversion from the file format used in Task 1 and further optimization of the model for 3D printing, 3) software development in Unity that utilizes mobile devices and Vuforia to generate the AR application for vehicle maintenance and operation, and 4) preliminary research on software and information architecture to support efficient development of AR applications. This project is most relevant to the following ABET outcomes: 1) an ability to function on multidisciplinary teams and 2) an ability to communicate effectively, and 3) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. This paper discusses the challenges and effective approaches in designing and executing undergraduate research projects that utilizing the latest computing and information technology for military applications, such as proper project scope, open source hardware and software, emulators for large scale equipment, 3D printing to reduce development complexity and facilitate rapid application development.

1. Introduction

A. Augmented Reality

The last few years witnessed the steady growth of augmented reality hardware and software thanks to a variety of technological innovations. AR technologies are available on a variety of platforms, such as mobile devices, head mounted displays (HMD), and heads-up displays (HUD). Backup cameras are now required on all types of new vehicles and the visual guidelines augmented to the backup camera view greatly facilitates backup and parking. Heads-up displays are now available on consumer vehicles that project information to the windshield, such as speed limit, compass, navigation information. Realizing the potential of AR markets, technology giants including Apple and Google released software development kits (ARKit and ARCore) to facilitate development of AR applications on their mobile platforms. A variety of mobile AR applications have been successfully developed, ranging from productivity to entertainment to education, to name just a few. One major advantage of mobile/handheld applications is the ubiquity of mobiles devices and their low cost and high portability, which make mobile devices especially suitable for soldiers in the battlefield as they require no or little new weight load.

B. Joint Light Tactical Vehicle

The Joint Light Tactical Vehicle (JLTV) is a United States military program to replace the aging Humvee multi-purpose motor vehicle with a family of more survivable vehicles with greater payload. Multiple companies participated in various phases of the JLTV program and Oshkosh's JLTV was selected as the winner of the JLTV program in August 2015 and the first JLTV was delivered to the Army in January 2019. Oshkosh's JLTV hosts a complete C4ISR network solution while maintaining its payload, performance, protection and off-road mobility. It is powered by the TAK-4i intelligent independent suspension system, capable of performing armament carrier, utility, command and control, ambulance, reconnaissance and a variety of other tactical and logistic support roles. Figure 1 shows digital 3D models (exterior) of Oshkosh JLTV.

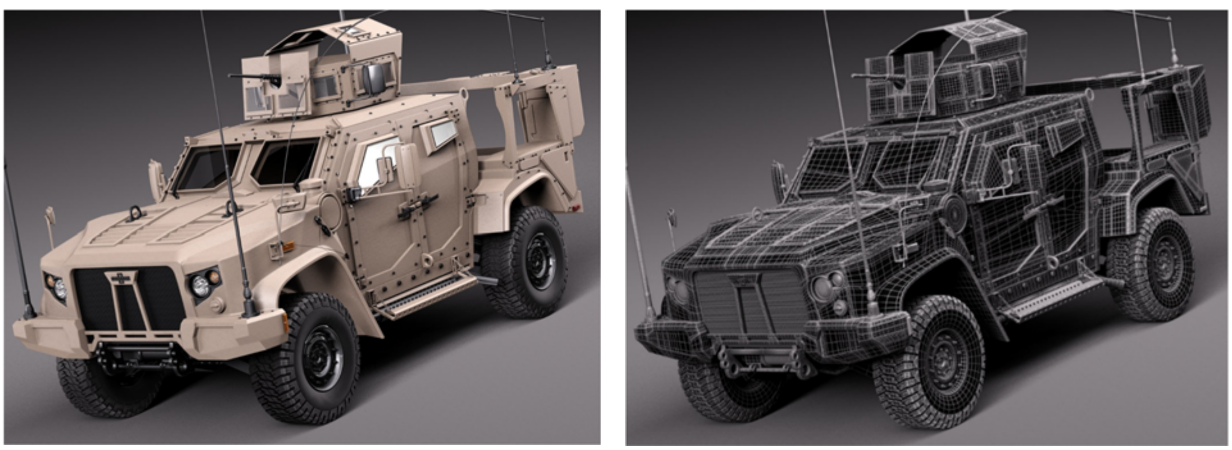
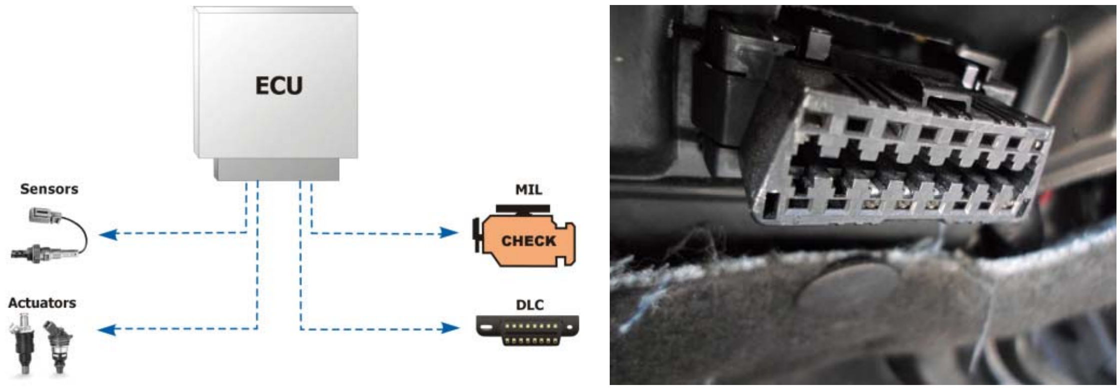


Figure 1. Digital 3D models of Oshkosh JLTV

C. Vehicle On-Board Diagnostics

Vehicle On-board diagnostics (OBD) is a vehicle's self-diagnostic and reporting capability [1]. OBD systems give the vehicle owner or repair technician access to the status of the various vehicle subsystems. It is computer-based system originally designed in the early 1980's to reduce emissions by monitoring the performance of major engine component. The major component of the OBD is the Electronic Control Unit (ECU, Figure 3(a)), which receives inputs from various sensors and control the actuators. OBDs provide digital trouble codes (DTCs) that can be accessed via the Digital Link Connector (DLC, Figure 3(b)).



(a) Components of OBD (b) OBD-II Port

Figure 2. On-board Diagnostics (OBD)

The latest version of OBD is OBD-II, which is available on all cars and light trucks built since 1996. The OBD-II standard specifies the type of diagnostic connector and its pinout, the electrical signaling protocols available, and the messaging format. It also provides a list of vehicle parameters to monitor along with how to encode the data for each. The OBD-II standard provides a list of standardized DTCs that allow one to rapidly identify and remedy malfunctions within the vehicle. The OBD-II standard simplifies the diagnosis of increasingly sophisticated vehicle electrical and mechanical systems. The Digital Link Connector hardware for OBD-II is specified by SAE (Society of Automotive Engineers) J1962, which is shown in Figure 3(b)).

The multidisciplinary undergraduate research project team includes faculty and undergraduate students from three academic departments: Department of Computational Modeling and Simulation Engineering (CMSE), Department of Mechanical and Aerospace Engineering (MAE), and Department of Electrical and Computer Engineering in the College of Engineering Technology. This project is most relevant to the following ABET outcomes [3]: 1) an ability to function on multidisciplinary teams and 2) an ability to communicate effectively, and 3) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. This paper discusses the challenges and effective approaches in designing and executing undergraduate research projects that utilizing the latest computing and information technology for military applications.

2. Methodology

A. Overall Architectures

To obtain the vehicle status and the DTCs, an OBD-II scanner is usually connected to the OBD-II port shown in Figure 2(b) via a cable. The main problem with existing OBD-II scanners is that while it provides textual information regarding vehicle status and trouble status, it does not offer any visual aid to facilitate further diagnostics and maintenance. The purpose of this project is to develop an AR application for vehicle health diagnostics and maintenance using the latest mobile computing and communication technologies. Bluetooth, instead of direct wired connection, is used for communications between the mobile device and OBD-II, with utilization of a Bluetooth adaptor that is connected to the OBD-II port. While there are many commercial OBD-II Bluetooth adaptors, very few of them supports customized software development. Selection of a suitable OBD-II Bluetooth adaptor was important design decision in this undergraduate research project. The selected OBD-II Bluetooth adaptor should fit well the scope of the undergraduate research project and support rapid application development in a relatively short period of time (less than two semesters). In this project, OpenXC Platform [2] was selected to develop the AR application for JTLV diagnostics and maintenance.

OpenXC is a combination of open source hardware and software that enables developers to create custom applications by providing a wealth of vehicle status and diagnostic data to the developers [2]. The OpenXC hardware includes the OpenXC Vehicle Interface (VI) that is connected to the OBD-II port and provides Bluetooth communication capabilities. The OpenXC software is an open source application programming Interface (API) for easily accessing vehicle data from different platforms, including Android, iOS, and personal computers. The OpenXC platform provides high level functionalities that enable user to rapidly develop applications without dealing with low level technological details, such as Bluetooth communications, the Controller Area Network (CAN bus) data format, and diagnostic message format. The open source nature of OpenXC hardware and software afford developers full control for low-level hardware and software customization and expansion when necessary. These characteristics of OpenXC make it especially suitable for short-term undergraduate research while providing great potential long-term in-depth research and development. The overall hardware architecture of the AR application in this project is shown in Figure 3.

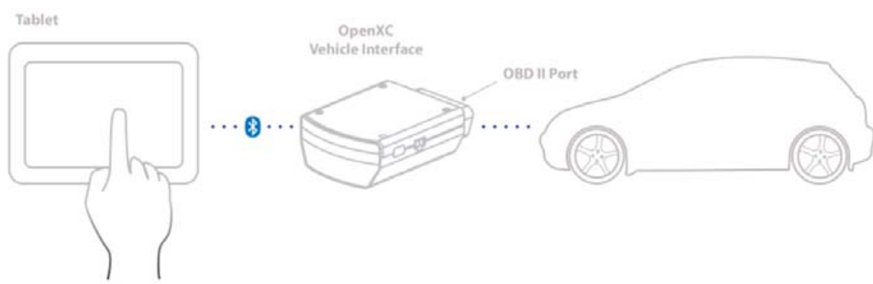


Figure 3. Overall hardware architecture [2]. The OpenXC Vehicle Interface (VI) is connected to the vehicle's OBD-II port. The AR application on the tablet communicates with the OpenXC VI via Bluetooth.

The overall system (hardware and software) architecture is shown in Figure 4. The CAN bus is a vehicle bus standard designed to allow microcontrollers and sensors to communicate with each other without a host computer. All vehicles sold in the U.S. since 2008 provide standard diagnostics data from a car with OBD-II on CAN. The Vehicle Interface (VI) can be programmed to access manufacturer (or vehicle) specific data in addition to the standard diagnostics data. The VI communicates with the host device (Android, iOS, or PC) via Bluetooth (this project) or USB interface. The OpenXC library provides high level software classes and methods to facilitate application software development that utilize vehicle data without dealing with low level details.

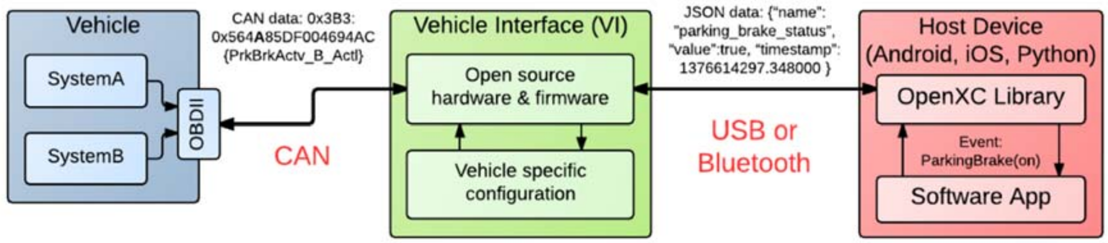


Figure 4. Overall system (hardware and software) architecture [2]

In this project, we will connect the Ford Reference Vehicle Interface (VI), a Bluetooth dongle shown in Figure 5, to the OBD-II port. The mobile devices will communicate with the OBD-II interface using Bluetooth signals.

Figure 5. Ford Reference Vehicle Interface (VI) that enables Bluetooth communications with ODB-II.

B. Project Development

Through communication with the Program Manager, a JTLV is extremely unlikely available for the AR system development in this project. It is also extremely unlikely that a vehicle (even a used one) can be purchased for this project. Therefore, the developers' personal vehicles will be utilized, e.g., an SUV or a pick-up truck. As JLTVs also utilize the OBD-II standard, the AR application developed in this project will work on JTLVs without any problems. To further mitigate the dependency on a real vehicle and its OBD-II for the AR application development, the beginning phase of the project utilizes an OBD-II emulator (Figure 6), which is controlled by a PC and functions like a real OBD-II on the vehicle. This will greatly facilitate the software development, substantially reducing development time needed. In addition, we use 3D printers to print a scaled-down version of the vehicle so that it can be used as a reference model for the beginning phase of the project development. Real vehicles will be utilized in the later phase of the project.

(a) (b)

Figure 6. (a) Freematics OBD-II Emulator, which is used to emulate an OBD-II on a real vehicle. (b). The Freematics OBD-II Emulator is connected to and controlled by a PC to generate various vehicle status and diagnostic trouble codes.

This project demonstrates the importance of research topic and existing hardware and software tools for undergraduate research. Most universities don't have lab spaces that are large enough to accommodate a real vehicle; however, the availability of the OBD-II emulator makes it possible for students to develop the application without presence of a real vehicle. Without the OBD-II emulator, it is almost impossible to perform this undergraduate research project on an average university campus. The project development consists of the following tasks.

a. Build a mobile application that communicates with the OBD-II emulator using the OpenXC API.
b. Generate digital 3D models of the real vehicles to be used in this project, e.g., a Ford SUV. Although many 3D vehicle models are available for purchase, they usually only contain the exterior of the vehicle and don't have any internal parts of the vehicle. We plan to use 3D scanning to generate partial 3D models of some typical internal parts, e.g., engine and pump.
c. Develop the Standalone Mode of the AR application that contains interactive visualizations and animations that illustrate a variety of vehicle maintenance and repair procedures. Interactive visualization guides the user through the troubleshooting or maintenance process, showing one step of instruction at a time with 3D animations that greatly improve user's perception. The Standalone Mode provides the users the opportunity to familiarize themselves with the vehicle without the need and presence of a real vehicle.
d. Print a mockup of the vehicle using 3D printing. Develop the augmented reality (AR) Mode of the AR application. The interactive visualizations and animations created in Tasks (a) and (c) will be projected to the vehicle parts and components using the mockup vehicle as a reference. More typical vehicle failures and maintenance procedures will be

added with step by step guidance that are placed carefully close to the parts under diagnostics and maintenance.

e. Expand the AR application developed in Tasks (a), (c), (d) so that it will communicate with the OBD-II on a real vehicle.
f. Employ the AR application on a real JLTV if it becomes available. This involves reprogramming the Vehicle Interface (VI) hardware to access vehicle data that are specific to the JLTV in addition to the standard diagnostic data specified by the OBD-II standard.

Both Android and iOS mobile devices will be utilized as the host device for the AR application. The project will use Vuforia, an industry-leading AR development software library that supports target recognition and tracking using digital 3D models and markers [3]. Unity[4] is a leading game engine for developing games, simulations, virtual environments, virtual reality, and augmented reality applications, and is the default development platform for new VR and AR hardware releases. Unity will be used by this project to develop the AR application [4-11]. Various techniques can be used to recognize and track real-world objects, such as optical tracking, structured light, electromagnetic tracking, marker-based tracking, and model-based tracking [12-14]. Vuforia utilizes advanced computer vision to recognize and track real-world objects using a variety of methods, such as images, markers (VuMarks), 3D models, and multi targets.

3. Current Results

A mobile version of the AR application for JLTV operation and maintenance is being developed and has been deployed to Android platforms. The mobile app is able to communicate with the Freematics OBD-II Emulator and real vehicles via Bluetooth communications provided by the Ford VI. Figure 7(a) shows the Vehicle Configuration menu that allows the user to select a specific vehicle. Figure 7(b) shows the Diagnostics menu in which the user can select the diagnostics parameter name or the parameter ID (PID) directly. It will then show the value of the selected parameter. Figure 7(c) shows interactive visualization of Ford F-150, which supports pan, orbit, zoom, and various operation and maintenance procedures (part labelling, part highlighting, and maintenance). Figure 7(d) shows interactive visualization of Hyundai Veloster 2012. Figure 7(e) shows the vehicle status, which include a set of common parameters. The app supports both landscape mode and portrait mode and automatically adjusts and switches between landscape mode and portrait mode.

Ongoing work include generating 3D surface (mesh) models for some internal parts of the vehicle, e.g., engine and transmission, as the current vehicle models only include the vehicle exterior. The AR version of the app will be developed using Vuforia Model Target technology, which is a markerless tracking method that utilizes the outlines of 3D object from different perspectives. The final version of the application will include real vehicles, and the highlighted parts and instructions will be aligned with the real vehicles.

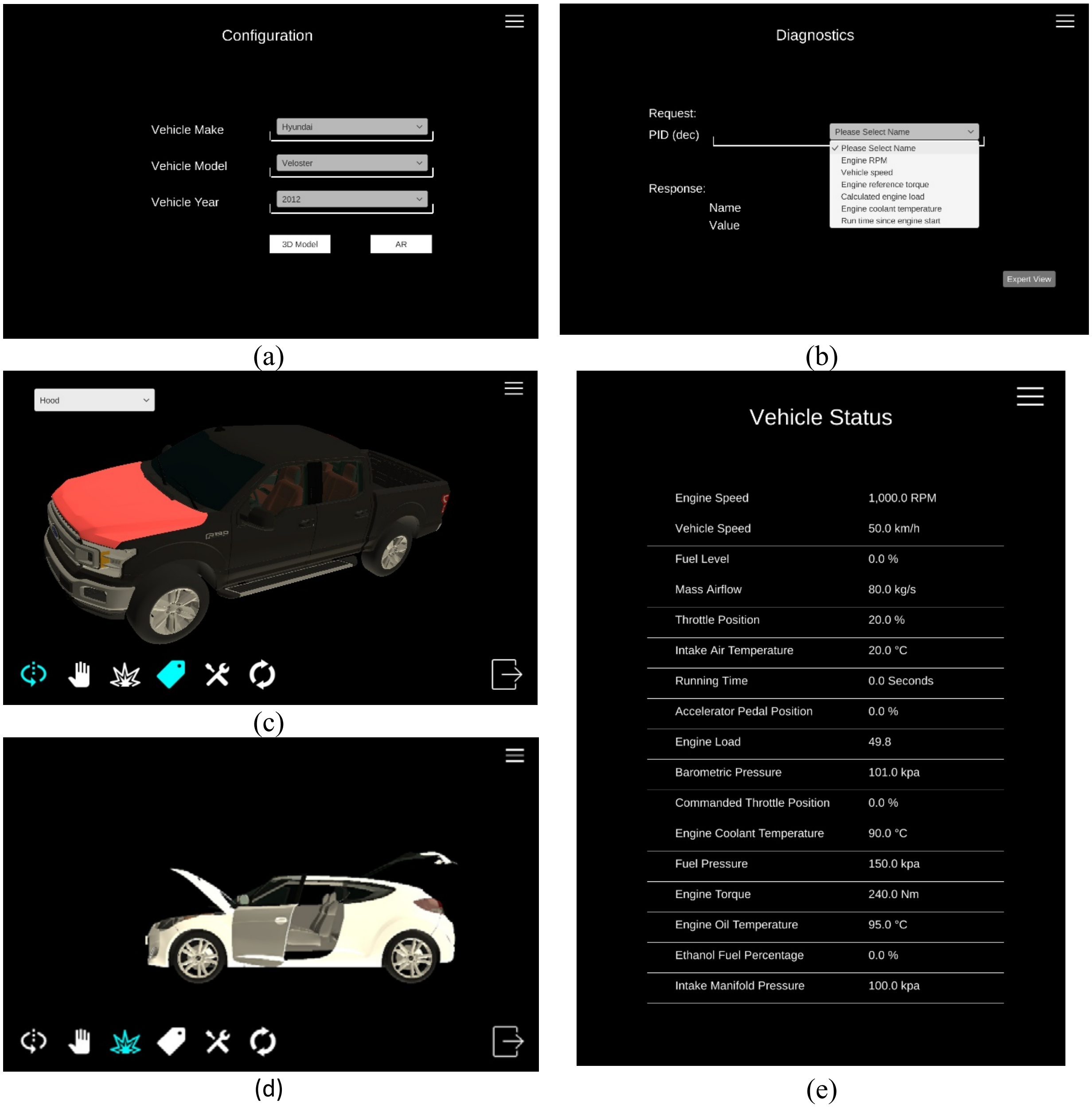


Figure 7. Screen captures of the current AR application. (a) Vehicle Configuration. (b) Vehicle Diagnostics. (c) Ford F-150. (d) Hyundai Veloster. (e) Vehicle Status.

4. Acknowledgments

This undergraduate research project is supported by Rapid Solutions Learning Projects (RSLP) grant N00014-18-1-2682 funded by the Office of Naval Research and its purpose is to educate undergraduate engineering students using hands-on learning projects that solve problems recommended by the local ONR Science Advisors, the Naval Warfare Centers and Fleet Forces Commands.

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