Integration of Voice Assistant and SmartDeviceLink to Control Vehicle Ambient Environment

Ayush Shah[1] and Anastacia Gusikhin[2]
[1]*Ford Research and Advanced Engineering, Dearborn, MI, U.S.A.*
[2]*University of Michigan, Ann Arbor, MI, U.S.A.*

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Abstract: Over the past few years, the popularity of personal voice assistants has grown, particularly for use in the vehicle environment where voice is a preferred mode of interface to minimize driving distractions. Amazon Alexa, one of the most popular voice assistants, has been integrated in many vehicle brands. While existing Alexa car applications provide vehicle occupants with access to a multitude of voice skills in infotainment and smart home control, these applications lack the capability to manage the vehicle's ambient environment. This paper discusses an efficient and effective integration of Amazon Alexa with vehicle climate control, potentially augmented with brought-in devices, using SmartDeviceLink API. The paper overviews the architecture, Alexa skill development, and examples of dialogue. We also present the results of a customer evaluation of the presented system and directions for future research and development toward Ambient Intelligence.

1 INTRODUCTION

In recent years, Personal Voice Assistants (PVA) and Ambient Intelligence (AmI) are technologies that have received substantial attention in academia and industry (Gams et al., 2019). A personal voice assistant is a digital assistant that uses voice interactions to aid users through dialogue, invoke infotainment audio applications or remotely control Internet of Things devices, such as thermostat, light, TV, etc. Voice Assistants help users perform a task with minimal effort and knowledge of the system. A study conducted (Ammari et al., 2019) concludes that more that 50 percent of use of voice assistants is for search, music and the control Internet of Things devices. Well-known examples of PVA technology are Amazon Alexa, Microsoft Cortana, Apple's Siri, and Yandex's Alice.

Ambient Intelligence (AmI) refers to digital environments that provide flexibility, adaptation, anticipation and a sensible interface to support people's needs (Augusto and McCullagh, 2007). PVA and AmI technologies are complimentary, heavily rely on AI and Machine Learning, and support the trend toward human-centered ubiquitous computing. Smart Homes technology is one of the prominent examples of PVA and AmI applications. One can use natural language to interact with voice assistants to perform tasks like changing the color of lights, changing thermostat settings, playing music, or doing a web search.

The automotive industry has been pursuing intelligent driver assistant technology, including voice applications, for over two decades (Gusikhin et al., 2008). The early implementations of vehicle intelligence were focused on the driver only and were constrained by in-vehicle hardware limitations. The progress in connected car technology has enabled vehicle controls to leverage cloud-based architecture (Gusikhin et al., 2011) (Siegel et al., 2018) and seamless integration of aftermarket sensors and devices into vehicle ambient environment control. It has allowed to separate fast-paced information and consumer electronics technology applications from the vehicle development cycle. Connected car technology allows the introduction of new capabilities at any point of a vehicle's life cycle.

Connectivity allows automakers to efficiently leverage existing popular PVAs, such as Apple's Siri as a part of CarPlay, or Google Voice as a part of Android Auto. In recent years, Amazon Alexa has become more and more popular for application to vehicles. It has been widely used as a voice control system for smart home devices since 2014. There are many devices that have been developed that are compatible with Amazon Alexa, and there are several ways in

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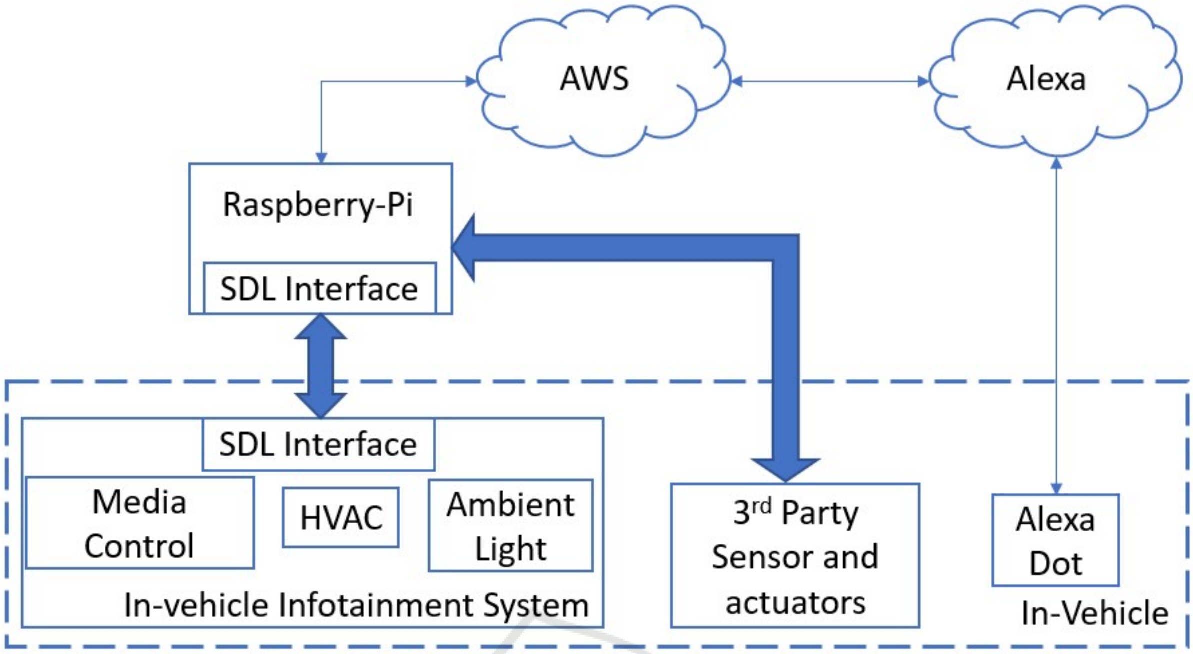

Figure 1: System Architecture.

which Amazon Alexa can be used with vehicles, including integration with a number of aftermarket devices. Amazon also released an SDK that allows for tighter integration of Alexa with the vehicle infotainment unit. For the vehicles with an embedded modem, Alexa allows for integration of vehicle remote control functionality such as start/stop or lock/unlock. There is, however, one area of PVA vehicle application that has been lacking: the control of vehicle ambient environment, particularly climate control.

We believe that vehicle environment is the next frontier for large scale application of PVA and AmI technologies. AmI and PVA are clearly promising for providing superior user experience and personalization. In addition, due to the trend to shift from personal vehicle ownership to shared mobility, particularly using autonomous vehicles, AmI and PVA's ability to anticipate each new rider's preferences and modify vehicle ambiance using natural dialogue interaction will eliminate the daunting task for setting adjustment for each new ride. One of many benefits of voice control within shared autonomous vehicles is that during health concerns like the COVID-19 pandemic, for example, the rider does not need to touch dials or the vehicle's screen in order to change the settings. The goal of the presented research is to investigate the capability, potential merits and user acceptance of an in-vehicle AmI with PVA. This paper describes the experimental system that integrates the Amazon Alexa voice assistant device with vehicle climate control and other brought-in devices, such as a scent dispenser or ionizer. The management of vehicle climate control is implemented using SmartDeviceLink APIs. The paper presents some results of the user acceptance survey from representatives of different functional areas of the company. We also discuss the areas of future research and development.

2 VEHICLE SMART ENVIRONMENT PROTOTYPE

To study user experience with in-vehicle AmI, we developed a prototype that includes embedded vehicle climate control, a brought-in scent dispenser by Inhalio (INHALIÓ, 2020) and Alexa Voice Services. The connectivity is provided by a WiFi LTE modem. The overall architecture of the system is presented in figure 1. The individual components of the system are linked through Smart Environment Gateway. Smart Environment Gateway (SEG) is implemented on the Raspberry Pi. SEG can support multiple connection protocols - in our case WiFi and BLE that allows SEG to link heterogeneous IoT devices with different connectivity standards.

We use Amazon Echo Dot as a voice-input device for Alexa Voice Services. We use Alexa Custom Skills to implement dialogue to manage vehicle ambience. The output of the skill is connected to the Amazon Web Services (AWS) Lambda func-

(a) Cartridge. (b) 3D Printed Container.

Figure 2: Scent Dispenser.

tion. The AWS Lambda function communicates through MQTT protocol that is connected to the AWS MQTT broker. When AWS Lambda function publishes MQTT command, the SEG is triggered, and it maps the MQTT message to the specific commands to control a vehicle embedded subsystem, such as heating, ventilation, and air conditioning (HVAC) unit, and control other external IoT devices, such as Inhalio scent dispenser.

SEG is integrated with vehicle controls using SmartDeviceLink API. SmartDeviceLink is a platform that enables integration to access and trigger vehicle sensors and actuators. Such a platform can help develop vehicle features and applications without going through a vehicle development cycle. SmartDeviceLink can also enable a mobile application to control vehicle modules as cited in the paper (Yeung et al., 2017). Recently, SDL consortium released Java SE SmartDevicelink SDK for embedded platforms that we used in our prototype (SmartDeviceLink Java Suite, 2020). The example of the Java code to implement switching AC on is presented below:

```
public void enableAC(boolean value) {

    ClimateControlData cd =
                new ClimateControlData();
    cd.setACEnabled(value);
    cd.setInteriorDataType
                (ModuleType.CLIMATE);

    ModuleData mdata = new ModuleData();
    mdata.setModuleType(ModuleType.CLIMATE);
    mdata.setControlData(cd);

    SetInteriorVehicleData sd =
                new SetInteriorVehicleData();
    sd.setModuleData(mdata);

    try {
        proxy.sendRPCRequest(sd);
    } catch (SdlException e) {
        e.printStackTrace();
    }
}
```

SEG is also connected to Inhalio scent dispenser over WiFi. The scents are incorporated in the cartridges installed within the device. The device allows to hold up to four cartridges at the same time (figure 2). In our experiment, we used Cool Mint, Pure Odyssey, Vanilla Dream, and Black Woods scents. The device is controlled using WiFi commands. Following is the java code that was used to trigger the Scent dispenser.

```
int timeOut=60;
Client client = ClientBuilder.newClient();

WebTarget resource = client.target(
"http://192.168.1.1:5551/diffuse?name=
CoolMint&intensity="+String.valueOf(timeOut));

Builder request = resource.request();
request.accept(MediaType.APPLICATION_JSON);
Response response = request.get();

if (response.getStatusInfo().getFamily()
    == Family.SUCCESSFUL) {
    increaseFanSpeed(timeOut);
}
```

SEG is connected to both the Inhalo and the vehicle, which work hand in hand. The advantage of such an implementation is that it would be possible to connect, read sensor data and trigger actuators of various devices simultaneously. For example, we can increase the HVAC fan blower speed when the scent dispenser is triggered.

3 VEHICLE AMBIENCE VOICE SKILLS

In this section we will discuss the skill interaction design model. The code below shows the sample implementation of the Alexa Skills interaction model. We used Custom Skills with an invocation word called “car”. We created Slots for various nouns and verbs which can be used in sentences. Each slot had all the different alternative words for that word or phrase. For example, AC can also be called heater, HVAC, Air Conditioner, Fan, cooling system and so on. These slots were then used in the intents. As shown in the code, custom Slot “ACsyn” is used in the intent “HVACTurnOnAC.” This helped us create a rich and robust set of utterances due to all of the available combinations. The user can say a phrase using natural language, (a sentence, which contains at least a noun and a verb) and the program will understand numerous different variations of the same phrase due to the different sentence structures provided in the list of utterances and the slots for each noun, verb, and even preposition depending on the sentence’s structure. We

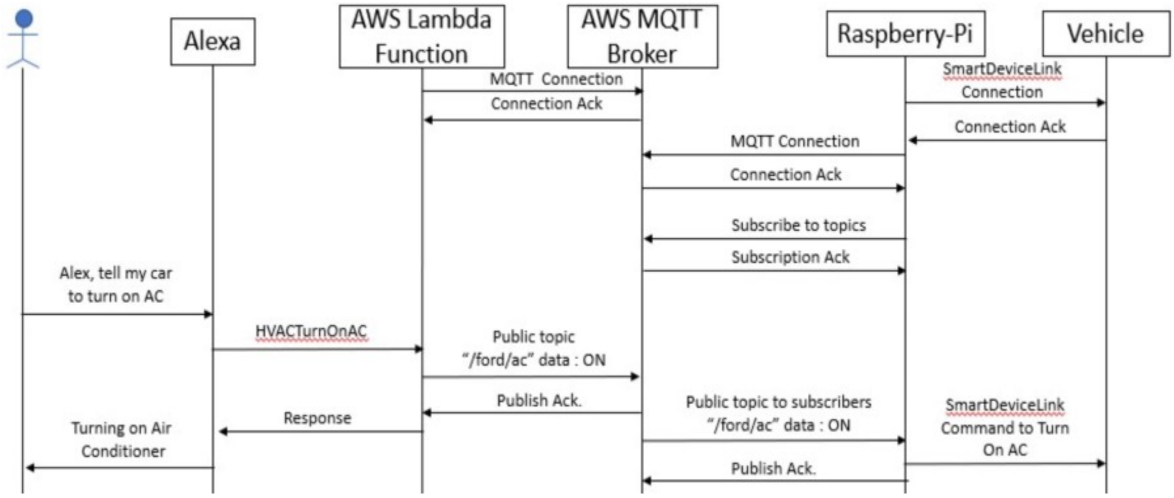

Figure 3: Sequence Diagram.

also added a help intent which works if the skill is invoked but an appropriate intent is not triggered. It would explain to the user how they can phrase the utterances to actuate the model or get sensor data.

```
{"interactionModel": {
    "languageModel": {
      "invocationName": "my car",
      "intents": [
        {"name": "HVACTurnOnAC",
          "slots": [
            {"name": "Ac",
              "type": "ACsyn"}],
          "samples": [
            "power on the {Ac}",
            "switch on {Ac}",
            "activate the {Ac}",
            ...]},
        {"name": "SmellOnIntent",
          "slots": [],
          "samples": [
            "make it smell good ",
            "I want a good smell",
            "I want it to smell good",
            ...]}],
            ...
      "types": [
        {"name": "ACsyn",
          "values": [
            {"name": {
                "value": "AC",
                "synonyms": [
                  "a. c.",
                  "fan speed",
                  "fan",
                  "air ",
                 "air conditioning"]}
}]}]}}}
```

The responses and follow-up questions to the user are randomly selected, which allows for the exchange between the user and the device to be much like a conversation as opposed to a mechanical response. For instance, if a user asks to increase the fan speed, the skill can ask a question, which may be phrased differently each time. Some sample questions include “Would you like to turn on AC?”, “Shall I switch on the AC?”, ”How about turning on the AC?”. In addition, responses are also randomly chosen from the list, which include “sure!”, “ok”, “done”,” got it”, “there we go”, etc. The design of the model was focused to provide a natural language interaction. Whenever a user interacts with the skill, it generates the request to change ambient environment and responds with a confirmation or a follow-up question. For example, a user says, “tell my car to activate air conditioning”. In this case, SEG would turn on the air conditioning and then Alexa would ask the user “what temperature would you like HVAC to set to?” In this implementation, we would ask or respond to a user command randomly. Whenever a follow-up question is asked to a user, a session is created to keep track of all the inputs the user is providing corresponding to the question. Based on these user answers, SEG would actuate the corresponding modules. As seen in the sequence diagram (figure 3), initially the AWS Lambda Function would establish a connection with AWS MQTT Broker. Then SEG would establish connection and subscribe to all the topics at startup. Once a user interacts with Alexa, for example by saying “Alexa tell my car to turn on AC,” the Lambda function would be called and the corresponding intent would be triggered. In this case, it is the “HVACTurnOnAC” intent. The Lambda function would then publish a message on topic “/ford/ac” with data ”ON.” SEG would re-

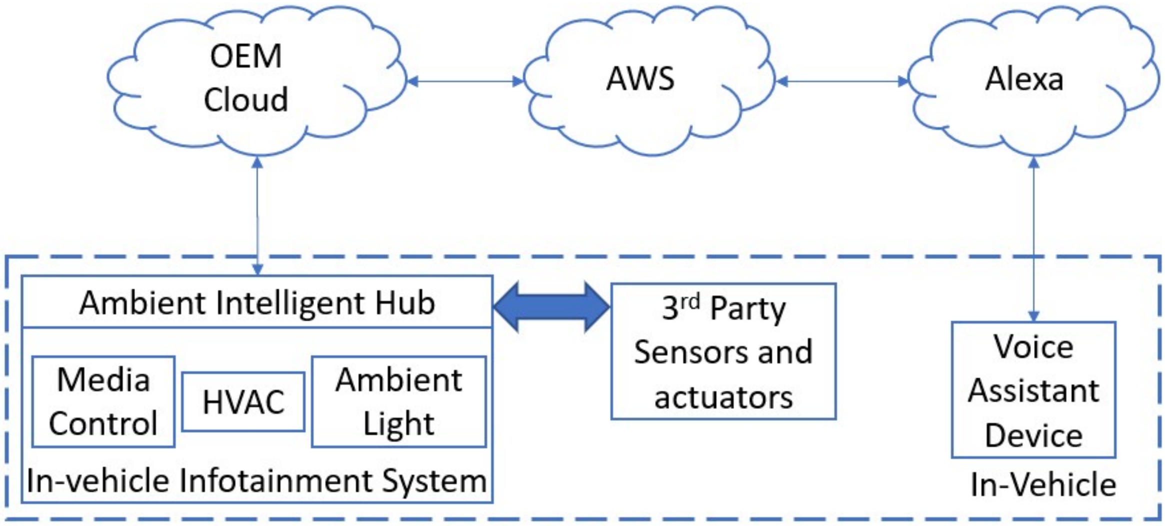

Figure 4: Proposed System Architecture.

ceive a message to turn on the Air Conditioner and it would perform respective operations. A response or follow-up question is asked, which is triggered from the Lambda function.

4 CUSTOMER EVALUATION AND FUTURE WORK

The system prototype has been presented at the Internal Technology show as a part of autonomous vehicle user experience. The evaluators were from different organizations of the company. All evaluators provided feedback on the experience with the technology. Everybody responded to the question: “Do you agree this concept will improve the customer experience for private customers?” The feedback was overwhelmingly positive. Figure (figure 5) shows a quadrant graph that represents the average score among each group and to what extent the group participants agreed with each other. Quadrant I: low score, high agreement; II: low score, high spread in answers, III: high score, high spread in answers; IV: high score, high agreement. Quadrant IV is the most important. The size of the bubble is determined by the size of the group.

It is interesting that the representatives from non-engineering functions, such as marketing, finance, global programs, and general management expressed more excitement than the engineering community, such as PD, R&A and AV.

Based on the experience with the initial prototype and feedback from the customer evaluation, we identified the several directions that need to be addressed in the future.

One of the future enhancements of the dialogue system is to eliminate the need for the invocation word ”my car”. In the current implementation, we used custom skills that provide a simple and flexible way to relatively quickly try different scenarios, but they require a key word to invoke the skill. Alternately, we could use Smart Home Skills and treat Smart Environment Gateway, discussed earlier in the paper, as an IoT device with various features like HVAC, media, radio, Ambient Light, etc. Each individual SEG would have to be registered with the OEM Cloud. A high-level architectural diagram is shown in figure 4) where all the commands from Amazon Lambda function would go to the OEM cloud. OEM would then trigger the corresponding vehicle SEG using a unique key/identifier.

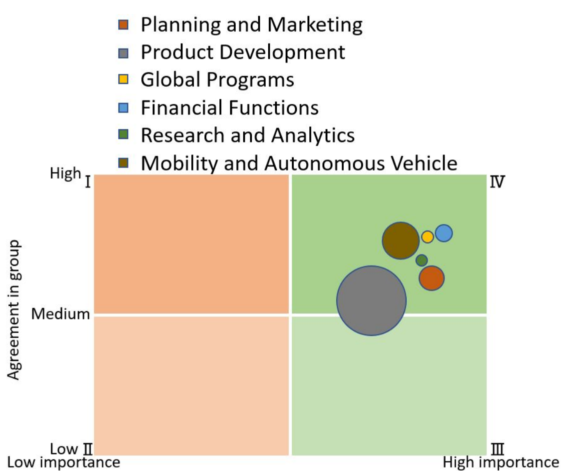

Figure 5: Evaluation.

To provide a more personal experience, the customers can connect their Voice Assistant account to the SEG. Then the user can play their favorite music, open their calendar, turn on/off Smart Home devices and leverage other user-specific services associated with a given account. In the case of ride-sharing applications, the user profile can be dynamically associated with a given vehicle. When a new passenger is picked up, a session on Alexa is created with the given user's profile. The session is cleared when the ride ends.

Another promising area of future enhancement is provisioning the integration with wearables (Gusikhin et al., 2016). Typically, wearables provide at least one type of biometric sensor, such as a heart rate monitor, skin temperature sensor, or blood oxygen sensor. Using this biometric data, the system can parameterize the intensity of the action. For example, if a user requests "Increase temperature," the current version of the system would always increase the temperature by 5 degrees. If skin temperature is available, the increase of the cabin temperature can vary based on the sensor data.

The critical aspect of intelligence is the ability to learn user preferences to anticipate and automatically adjust ambience based on the context. While our current prototype is focused on dialogue-based interaction, the next step in the system development would be to implement machine learning capability.

5 CONCLUSIONS

The paper discusses the opportunities and benefits of Ambient Intelligence within vehicle environment. The advancement of intra- and inter- vehicle connectivity technology, proliferation of connected devices and sensors, and the emergence of Personal Voice Assistants enable the efficient implementation of vehicle AmI even as an aftermarket feature. To illustrate this point, the paper presents a prototype that integrates Amazon Alexa personal voice assistant with vehicle in-cabin ambient control. The ambient control is exemplified by vehicle climate control and brought-in scent dispenser by Inhalio. The proposed system provides the capability for easy interaction to adjust in-cabin ambiance using commonly used natural language expressions and commands.

The prototype of the system has been evaluated at the Internal Technology show. The evaluation has been done by representatives from different groups representing different company functions, including engineering and non-engineering. The evaluation shows that this functionality has been positively perceived. The results of the study showed that non-engineering functions had more positive responses than engineering.

The paper also discusses potential future direction of the development to further enhance and simplify the interactions. Another area of enhancement includes the integration with machine learning to facilitate ambient intelligence to anticipate the user needs based on the prior experience and environmental conditions.

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