ALEXA FOR HEALTH PRACTITIONERS

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Vidisha Nareshkumar Bhatt

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Program:
Software Engineering

April 2020

Fargo, North Dakota

North Dakota State University
Graduate School

Title

Alexa for Health Practitioners

By

Vidisha Nareshkumar Bhatt

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

SUPERVISORY COMMITTEE:

Dr. Juan Li
Chair

Dr. Zubair Malik

Dr. Jacob Glower

Approved:

April 24, 2020
Date

Kendall Nygard
Department Chair

ABSTRACT

Many industries, including healthcare, are trying to take advantage of voice assistant systems by incorporating their technology into the industries' environment. However, not many companies or researchers have successfully integrated this technology into the daily practice of healthcare practitioners. Doctors, nurses and other healthcare practitioners spend much of their interaction time with patients clicking on the Electronic Medical Record (EMR) screen trying to access and update data. An important contribution of this research is to analyze this healthcare need for this technology in the healthcare practitioner's workflow. This research developed an Alexa chatbot skill, "Doctor's Assistant," as a generic application to help healthcare practitioners access and update EMR data via speech, while reducing data entry time and providing better patient care. The evaluation of this application illustrates that the "Doctor's Assistant" skill is both effective and accurate.

ACKNOWLEDGEMENTS

I would like to extend a sincere gratitude to Dr. Jen Li who helped, encouraged and guide me all throughout this project. Her support and quick responses have been truly valuable. I could not have finished my thesis without her help.

I would like to give special thanks to Dr. Zubair Malik, Professor in Computer Science at North Dakota State University, for his time and to be a member of my supervisory committee with great enthusiasm.

I am also grateful and appreciative of Dr. Jacob Glower, Professor in Electrical and Computer Engineering at North Dakota State University, for his consideration and taking time out of his busy schedule to be part of my supervisory committee.

A special thanks to all the staff and faculty of Computer Science department for all their help and support at all the time throughout my program.

Lastly, I express my deepest gratitude and love to my parents, close friends and family for their unconditional support and encouragement. Their kindness, motivation and constant assistance has truly pushed me towards the end goal.

DEDICATION

I would like to dedicate this thesis to whoever would read and benefit from the ideas presented in this thesis to betterment the life of doctors and nurses across the globe. Thank you, for all the hard work you do to save people's lives.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure | Page

LIST OF ABBREVIATIONS

NDSU	North Dakota State University.
EMR	Electronic Medical Record.
EHR	Electronic Health Record.
AWS	Amazon Web Services.
AVS	Alexa Voice Service.
HIPAA	Health Insurance Portability and Accountability Act.
UX	User Experience.
PHI	Protected Health Information.
BAA	Business Associate Addendum/Agreement.
IOT	Internet of Things.
NLP	Natural Language Processing.
R&D	Research and Development.
VIVOCA	Voice Input Voice Output Communication Aid.
AES	Advanced Encryption Standard.
ASK	Alexa Skills Kit.
ASR	Automatic Speech Recognition.
NLG	Natural Language Generation.
SDLC	Software Development Life Cycle.
IDE	Integrated Development Environment.
MIT	Massachusetts Institute of Technology.
UI	User Interface.
RDS	Relational Database Service.
IRB	Institutional Review Board.

CUX .... Conversational User Experience.

VUI... Voice User Interface.

DB .... Database.

SQL .... Structured Query Language.

DNN .... Deep Neural Network.

RNN .... Recurrent Neural Network.

CHAPTER 1. INTRODUCTION

A voice bot or a chatbot is a powerful software tool which is smart, fast and efficient way to interact and determine appropriate and authentic conversational experience to its users. In other words, these devices are robots without a face and just with a voice. Voice assistants are becoming essential part of the consumer market with ever increasing number of gadgets in the world. According to the voicebot.ai survey of 2019[21], starting from January 2018 to the end of the year of 2018 the population accessing the smart speakers went up from 47.3 million people to 66.4 million people in United States. Out of that, Amazon Alexa had a market share of about 61.1% by brand as compared to other smart speakers in the market [21]. Another interesting fact that came out of that survey was the different industry usages by the consumers towards the smart speaker. For instance, the top use cases utilized in the smart speaker world were related to personal music, news movies and how-to instructions, followed by history, products restaurants, shops etc. [21]. All these use cases suggest that these industries are also partnering with smart speakers to allow the consumers to get the results from a smart speaker rather than other traditional ways of finding that query.

Looking at the health care in Unites States which is a $3.5 trillion industry [3], it is pertinent to include the smart speaker's abilities in this market. However, the smart speaker adoption in healthcare industry is still fall behind the other industries. Two important factors that cause this lag are defined in this survey report of 2019 by voicebot.ai [22]. First, was the concern towards Health Insurance Portability and Accountability Act (HIPAA) compliance given that all the use cases would be consuming health records in some way. Other concern would be if providers and health institutions are equipped to handle that kind of queries. Although, not significant, the third concern would be to share health related queries to a device. For example, talking to a device to play the user's favorite music is one thing and talking to the same device to for diabetes is another.

In addition to the issues surrounding using these devices in medical settings is the rapidity in which medical information must be taken by healthcare practitioners. Currently, the workflow in a clinic between a doctor/nurse practitioner and a patient entails going over the basics as well as the health practitioners entering the data manually, whenever required, which is usually at the beginning of the appointment and at the end of the appointment. For example, when a patient was going to their clinical appointment and was waiting on the health care provider to input all the information, they transcribed to them. If that health care provider was new to the industry and/or to the job and was not familiar with the EMR site, it would take them longer to find appropriate tabs, links etc. to fill in the appropriate data. Instead of spending more time in understanding the patient needs and providing them with the care plan, it can be bothersome for them to enter this data in. Thus, in order to increase the patient-provider interaction time, this research focused on a possible solution using voice assistant technology.

Indeed, the importance of having quality patient-provider time has long been recognized by the healthcare industry. The evolution of EMR data is an example of this. However, numerous healthcare practitioners are still plagued by the data entry time required for them to continue to adhere to industry standards. However, healthcare practitioners face barriers when implementing this kind technology: accuracy, patient health information confidentiality, language competency, and user familiarity. One step in alleviating the barriers facing widespread use of this technology in healthcare setting would be to address the issue of user familiarity by utilizing voice input for data entry.

With the latest development in AI assistants and machine learning programming, this research developed an Amazon Alexa chatbot that can help health practitioners spend less time in data entry and more time in patient care. This chatbot skill interacts with health practitioners, taking their commands and then acting on them. For simplicity's sake, we implemented two use case scenarios and evaluated them. Advantages of the developed system are efficient data entry, more patient-provider time, smaller learning curve for EMR site, and potential reduction of contamination risk. Furthermore, Chapter Four outlines other use cases that can be implemented because they are command-based actions.

Since becoming HIPAA compliant, the benefits of using Amazon Alexa chatbot over other chatbots are significant. According to Amazon's whitepaper documentation, "Amazon Web Services (AWS) enables covered entities and their business associates which are subject to HIPAA to securely process, store and transmit PHI" [28]. In other words, when a customer uses AWS for HIPAA compliant accounts, they can access and update the Patient Health Information (PHI) using the stringent rules and regulations as defined in the AWS Business Associate Addendum/Agreement (BAA).

The following three points from the Amazon whitepaper are of specific interest here. First, when interactions occur through Alexa, the interaction history and activity cards associated with this skill are not viewable through the Alexa app or through their general site like other skills, which protects the PHI. Second, the AWS servers that carry the interactions to the healthcare organizations are stored in HIPAA compliant servers that require the customers to encrypt the PHI using HIPAA-eligible services as indicated by the Secretary of Health and Human Services [28]. Third, because of HIPAA rules and regulations, many other voice-enabled systems require patients retrieve their own information rather than the health professionals retrieve patient information. These three points are compelling reasons to choose Amazon Alexa for this healthcare skill application. This paper does acknowledge that there are several other voice-enabled devices available in the market, such as Google Assistant, Apple HomePod etc. However, these services do not provide BAA contracts, their server backends are not HIPAA protected, and they do not have guidance on how to utilize their speakers in compliance with HIPAA regulations.

Objective

This research has three main objectives:

1. To gather market research and identify key requirements for having a chatbot in a clinic setting.
2. To design and develop an Amazon Alexa skill for health practitioners with use cases generated through the survey analysis.
3. To assess the accuracy of the skill and present a viable generic solution for the health practitioner.

Thesis Overview

1. The first chapter provides a basic introduction to this research including background, motivations and objectives.
2. The second chapter gives a brief overview of voice assistance technology, its current market demands, and applications that are associated with patients.
3. The third chapter goes into software requirements, hardware requirements, technologies utilized, and methodology chosen for this project. Then, this chapter will cover the overall system design, along with the sequence diagram, data flow diagram and data dictionary used in the entire system. The chapter also explains some background on how

Alexa chatbot operates and how it utilizes machine learning and natural language processing to conduct a requested query through voice.

4. The fourth chapter focuses on evaluating the developed chatbot “Doctor’s Assistant” system. The chapter begins with two use cases implemented in “Doctor’s Assistant” system and follows with how health practitioners’ evaluated the use cases through their survey response. In addition, Chapter Four will report on the testing techniques used in this application to evaluate the model, including the Amazon developer console evaluation model and testing interface.
5. The fifth chapter concludes this thesis by discussing limitations and future work related to this project.

CHAPTER 2. LITERATURE REVIEW

Voice assistant is the seminal advancement in the Internet of Things (IOT) commerce. Companies like Amazon, Google, Microsoft and Apple are funding large amounts of Research and Development (R&D) in voice assistant technology knowing that it will be tremendous success for the consumers. All these companies are joining the initiative for creating their respective applications by having the feature of voice enabled assistants available. Likewise, there are many academic and industry researches focusing on this technology's usability and adaptability. In other words, companies are developing voice-enabled applications for consumers to use in their routine. According to the publication [5], 50% of all queries made by consumers will be done through voice by 2020. The same publication of [5] concluded that the numbers will only likely to grow as voice-enabled devices are becoming more common and interactions with those devices become more feasible. Voice interfaces such as Amazon Alexa, Google Home etc. offers patients an access to variety of data by using voice commands while, making it easier for people with constrained technical experience [20]. With the advances in voice recognition software, natural language processing (NLP) and machine learning programs, Voice Assistants have become more reliable source of consumer interaction compared to the previous years. In hospital settings, voice recognition becomes another pillar of support to the patients where the healthcare practitioners are limited [14]. Below is a brief market research and literature review congregated through the references reviewed during this research:

General Alexa Skills and its Usage

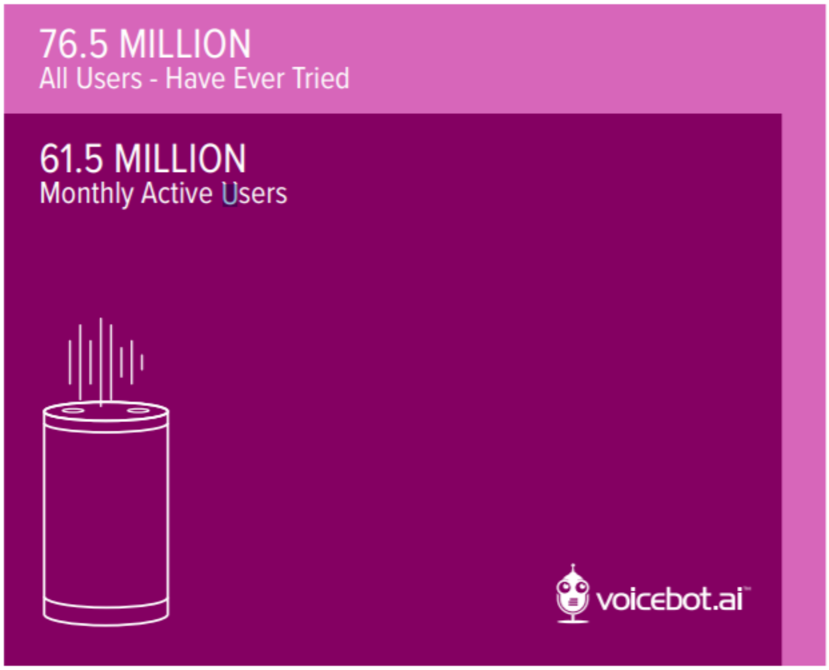

Figure 1. US Smart Speaker Adoption. Sourced from [22].

Currently, there are many general Alexa skills on the Amazon Skills marketplace. Some examples are finding the weather forecast, creating reminders for personal and professional use, checking one's credit card balances and playing desired music. The list of skills available is significantly large from the simplest single action command to more complex conversational interaction. When developed appropriately, Alexa is efficient in acting on those interactions. When smartphones came into the consumer market, there was an incremental increase in "apps" development. Similarly, the voice-enabled devices are seeing an escalation in "skill" (for Amazon Alexa) and "action" (for Google Assistant) development in the past few years. Not only these developments are occurring in the well-known parent company of these devices, but small third-party developers are also attracted towards these devices to create a voice-controlled technology system. A lot of research is done by the students in universities and big corporations to examine its usability, adaptability among the customers and then assess its success rate. Finance, productivity, travel, entertainment, smart homes and smart cars, food and beverages are few of the industries leveraging this new technology to better serve their customers. Some of the popular and well-known skills on Amazon website are:

1. Starbucks Reorder skill, which enables a user to order their coffee through Alexa, when they are running late. For example, the user could say: “Alexa, order a small Café Mocha from Starbucks skill”.
2. Another one would be the Fitbit skill which tracks a user’s sleep schedule, workout routines and other health facets to retrieve the general idea of your daily healthy habits. For example, a user could say: “How much sleep did I get last night?”.
3. Kayak skill is also remarkable as it can search flights for a user given their budget or location preferences. For example, one could say: “Where can I fly this month for $200?”.
4. TDAmeritrade also have a skill for its users where a user can get share prices and stock updates through Alexa. For example, one could say: “Alexa, ask TDAmeritrade for the price of Apple.Inc.”

All these skills allow a user to search, retrieve and order their consumable items without typing, manually searching or going to the store. Of course, there is an always a risk of sharing this information to a chatbot, but those concerns will be addressed later in this Chapter. Overall, while the concerns are important, the potential convenience these skills provide outweigh their prospective drawbacks. Often, consumers do not mind sharing their Starbucks, Fitbit etc. information to a chatbot considering these are not critical information. However, that might not be a case for Healthcare industry specifically. This chapter will be delving into that topic shortly.

Voice Enabled Devices Adoption

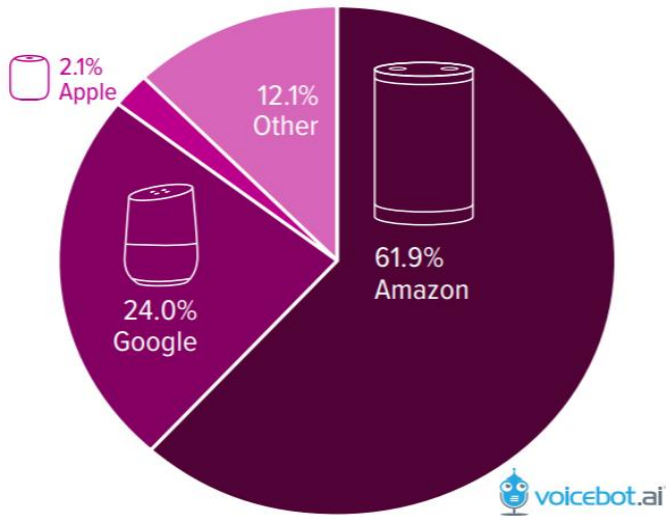

Figure 2. US Smart Speaker Market Share. Sourced from [22].

Voice-enabled devices have been attracting consumers for quite some time, however, recently their adoption in the consumer market have reached its highest. Especially with Google Home and Amazon's Alexa being so affordable compared to their early costing. According to the article [21], one in four consumers today have access to a smart speaker. According to same article [21], the number of smart speaker users rose at about 10% from 1.8 in 2018 to 2.0 in 2019 which suggests that there are 133 million smart speakers in use in the United States. The figure 2 illustrates that 61.9% of the smart speaker consumer market is controlled by Amazon, followed by 24.0% by Google, 2.1% by Apple and 12.1% by other voice-enabled device companies. A survey done by voicebot.ai found out that 50% of US adults say that they would like to use smart speakers for healthcare purposes [22]. The survey has shown that consumers using voice enabled devices for healthcare related services are on the rise, however, very small number of healthcare providers use the voice assistant to offer various services [22]. This is largely due to HIPAA rules and regulations that they need to follow for the patient-provider information. There are several laws and regulations within and besides HIPAA that requires that patient identifying information must remain protected. When HIPAA was passed into a law, the healthcare industry and their associates had made their software programs and applications in compliance with those rules to be protective of EMR data. For this reason, the most important aspect of utilizing voice-enabled devices would be to make them HIPAA complaint so that they can be used for healthcare practitioners. In 2019, Amazon's Alexa became the first and perhaps the only voice assistant which allows their skills to be HIPAA compliant. This created an open opportunity for creating Alexa skills for healthcare practitioners to help in their hospital/clinic settings. Hospitals such as Mayo Clinic, Boston's Children Hospital etc. have already partnered with several companies to be early adopters of voice assistant [6]. The impacts of having a smart speaker in a hospital setting are still unknown but there are ample of opportunities for technology companies to offer solutions that can benefit both the industries.

Healthcare Industry Needs

Healthcare in the United States is a $3.5 trillion industry [3], which is enormous. To have an early start in creating and distributing voice assistant skills that are HIPAA compliant gives Amazon a tremendous advantage to have early research and development done in the healthcare market. Other companies are going to follow Amazon's lead in getting themselves HIPAA compliant and benefitting from the $3.5 trillion dollar industry. According to the article [6] two thirds of doctor's workday involve clicking through EMR system filling in or selecting the data. If there are skills which can be developed for the voice assistant that can remove that manual work, it will give them that amount of time back to focus on patient-provider relationship and to provide them with better care. A hospital's chief officer from Cedars Sinai in Southern California have mentioned in an article [6] that they are in search of a "killer" app. Referring to their hospital's interest in Alexa apps. He does mention though that he doesn't know what that would look like; however, he is open to all ideas. Cedars Sinai has implemented a pilot program where patients use Alexa to control their environment and have a constant open communication line with their care team [4]. Through their pilot program they realized that having a smart speaker in the patient room has improved patient satisfaction and reduce the overhead on staff to constantly monitor them by physically being in the room. Along with implementing voice assistant technology in a healthcare setting, there is a need of making things standardized as well. There was another research [11] which found that standardization of a patient fall has not been implemented throughout the healthcare organization. Not having standard procedures and processes makes it harder to reduce and prevent these accidents from happening for Inpatients. But implementing an Alexa skill [10], which can be standardized have the potential to be helpful in the healthcare institution. Considering the skill [10] was to prevent and crash report when a bicycle fall occurs, the similar concept can be adopted in an Inpatient clinic to report and prevent patient fall. Another department of healthcare where voice assistants might be needed would be the departments treating people with special needs. As we know, speech recognition programs can be utilized for voice assistants and this can be phenomenally helpful for those in need. As developed in the article [13], their module of Voice Input Voice Output Communication Aid (VIVOCA) can aid in people with dysarthria's to have better communications with their providers or vice versa. Their module's experiment was able to recognize the speech with 95% accuracy which is remarkable. This was done only on an experiment but that allows healthcare practitioners to view its potential. For example, having that module on Amazon Alexa or Google Assistant and gaining patient's trust and helping providers with better tool to understand the patients. As we can see, the potential of using these voice-enabled devices for healthcare providers is vast and some are still undiscovered. Recently, Amazon created developer challenges to allow developers to create and showcase their ideas and projects to the company pertaining to healthcare practitioners' area, with the hopes for having those undiscovered opportunity to emerge.

Privacy Concerns

Accessibility of data and safety of that data goes hand in hand when it comes to any IOT devices. While voice-enabled devices can create ample of opportunities for better patient care, there are few drawbacks of using this technology. One of the areas of concern would be that there are still many people apprehensive regarding their privacy when it comes to using voice-enabled devices. Some people choose to shut off their "speech activated" features and some choose to have it on a turn on/turn off mode manually. Either ways, there are many confidentiality concerns related to voice-enabled devices which consumers use. As mentioned in this think tank research [7], because healthcare data is specifically regulated by HIPAA Privacy and Security Rules, it is even more important for the companies to meet those high standards. Many rules and regulations that were created for HIPAA, were before the smart devices became popular and affordable. The rules and regulations are getting altered to mold those with the ever-changing technology advancements, however, they do not nearly cover the breadth of privacy implications that these devices can create. According to this evaluated study [9], it is recommended that there is a paradigm shift in how those technologies are developed as well as having some legislative changes to support the future of IOT devices which includes the voice-enabled gadgets. To put it in another words, there needs to be changes in how these technologies are developed as well as government intervention in how these technologies can be implemented. However, in this paper [12] they have described how using homomorphic encryption and Mel

Frequency Cepstral Coefficient algorithm for encrypting the data and then using Advanced Encryption Standard (AES) to encrypt the voice data, they were able to store such highly secured and minimal data on the end server with the accuracy of 86.66%.This research demonstrates us that there are ways to have protection and control over the voice data navigating between servers and voice assistant devices. Although implementing that security is totally up to the device manufacturers, but there is a solution for those concerns related to using voice-enabled devices. If the government and the companies making these products work together, there are options and solutions available in the market to be adopted for the privacy concern of healthcare data to mitigate its drawback.

Electronic Health Record (EHR) and Voice Assistant

As mentioned earlier, having doctors manually enter patient information and click on the EMR system to gather any data creates inefficiency and frustration to their day-to-day life. The usability of EHRs is very poor and leads to dissatisfaction among the users. Using voice commands for dictation in Healthcare started in early 2000s as described in [2] and gained a lot of popularity. As stated in that paper, speech is the natural mode of communications for humans which is faster and accessible for people even for whom there might be any special need. Thus, making voice interaction is ideal for healthcare industry. The paper [2] discusses how early adoption made cost reduction and timesaving apparent from this usage, however there were problems when the software could not recognize the correct work or insert incorrect syllable. But later, having the accuracy of as high as 99% on speech recognition has given the confidence among the peers to use voice interaction. Another benefit mentioned in the paper was having the ability to execute complex commands via short voice trigger. Example used was for the radiology department’s workers in the healthcare facility, who have substantial amount of repetitive dictation, which then can tremendously benefit when using a voice detector. They even showed how 91% of the users using the voice-initiated macros to dictate text, continued to use the voice-recognition feature. Thus, further adding to the pros for using this technology in the healthcare setting. With the advances in machine learning, deep neural networks (DNN) and recurrent neural networks (RNN), there is high possibility of accuracy in voice recognition. This gives consumers and healthcare practitioners more confidence when using this technology. With these research outcomes in mind and the continuous development of voice-enabled device's features, it is guaranteed that using those devices to retrieve, alter and insert EHR data would increase the productivity of those healthcare practitioners while decreasing some of their pain points. There are open questions and discussions to be considered when implementing this technology as various healthcare department users would need special kind of "skill" or "action" to work with their workflow to reach its full potential, however since the possibilities are increasing these discussions can be given a priority.

Related Work

The acceptability of voice-enabled devices in medical field is understandable given the technological advances and its feasibility. One example is the IOT based fall detection system for older generation using voice activated devices to monitor and generate help calls and texts to care givers to the elderly [15]. Second example was using voice-enabled devices to retrieve temperature of patients while being away from them [16]. Third example being, using voice commands to facilitate physical training of users [17]. Lastly, a conversational chatbot for couples suffering from PTSD [19]. Being a device in a home setting for a couple, gives them a private and intimate environment to practice and focus on their therapy [19]. There are many other pilot projects and research occurring in this area. Few of them are explained in detail in the section below this:

Post Hernia Surgery Action

The research generated by Ross James Lordon [8], is an example of using voice assistant in a healthcare setting. In this research, the investigators created an "Action" for Google Assistant for patients who had Hernia Operation and were seeking medical help after discharge from their home. They evaluated the Hernia Coach based on personas and scenarios created by the author. Author was trying to help with the low healthcare literacy levels and low interest in general for public to read and comprehend to medical instructions. The solution was to have a voice-enabled device to help with general patient query after the surgery. One thing to note here is that in this scenario the device that they used was a smartphone and not a smart-speaker, however the idea was similar to use voice-enabled device to communicate the information from information seeker to information provider and vice-versa.

Swedish Health Connect

This current skill available on Amazon Skill market is a voice-enabled skill which allows a patient to query and book an appointment at their nearest hospital. While booking patients can select different time slots if they choose. The hospitals need to opt into providing this feature and enabled on the patient's voice-enabled device. This skill is available for Swedish Medical Center location in Washington State in United States.

Atrium Health

This current skill available on Amazon Skill market is a voice enabled skill which can help patients find urgent care near their location and book an appointment (given that the urgent care provider is associated with this application's backend). Along with that, patients can retrieve wait times, urgent care hours and phone numbers as required. According to [23], 69% of patients are comfortable using voice assistants to search and locate urgent care facilities nearby. By having this skill enabled on a patient's Alexa device, this saves the time and effort to open and search for urgent care hours nearby through laptop, computer or mobile phone.

kBot

This researched developed bot was designed as an android application on the smartphone [14]. This chatbot was developed and researched by students at Wright State University. It was touted as one of a kind chatbot application for patients, specifically children, suffering from Asthma. It would allow them to ask specifications about the weather, report their conditions and based on the knowledge base give them suggestions. Since the knowledge base they used was part of another research, they had a starting point for their research. They were able to use all that data to prove and analyze their application. According to them, their holistic approach to chronic, multi-factorial asthma seemed to address the self-management issue in the patients. The app was designed for children to self-manage asthma symptoms on their day-to-day basis in association with Dayton Children's Hospital.

Summary and Conclusion

To conclude the discussions above, voice assistants are soon to become ubiquitous due to its vast integration with smartphones, smart cars, and other specialized devices developed to utilize its capabilities. Health in general is very important aspect of human life and thus needs more effective technological advancements to provide better care [18]. In the recent decade, healthcare has become one of the most important industry for survival of human species. Hence, having a voice enabled assistant for doctors' benefits both the doctors as well as the patients by providing more one-on-one time with the doctor to talk through their symptoms and limiting the time health practitioners otherwise would need to spend on the EMR site . Recognizing the complexity of healthcare data and its privacy rules and regulations, this research needed to choose a platform which can provide the safety and security to handle EHR data. Hence, this project has chosen Amazon Alexa to develop “Doctor’s Assistant”. Researchers and other private hospitals and developers have created many skills tailored towards patient and their use with similar high-level architecture [18] as shown in Figure 3, where patients were the point of start of a workflow for the voice enabled devices. However, the research on the doctor’s perspective and their usage was very limited and dedicated mostly towards few pilot projects. Considering that, this thesis developed a chatbot skill integrated with Amazon Alexa to provide an application from a health practitioner’s viewpoint.

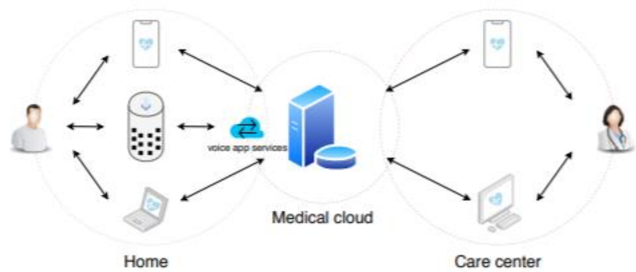

Figure 3. Architecture of Voice-enabled Device. Sourced from [18].

CHAPTER 3. METHODOLOGY

Given that this project had a definitive scope as well as a tentative end date defined for many reasons including the brainstorming session, survey responses deadline and semester ending, it was decided to follow the simplest Software Development Life Cycle (SDLC) to achieve the goal of fulfilling the objectives. As learnt in many Software Engineering courses, Waterfall is a sequential task based SDLC which is often defined as restricted and rigid lifecycle compared to others. It was the first SDLC model used in Software Engineering teams. It has six phases with each of them cascading their outputs into next phase to consume it as an input. With the current project, Waterfall would provide a rigid schedule with deliverables at the end of each phase, helping in achieving the desired goals. It would also help in documenting the processes and documentation as the project progresses, hence making milestones clear and concise for people involved. Another reason for using waterfall is that the project scope is given the simplicity and the amount of people involved in the development of this skill. To sum up, this SDLC would be the most efficient way of dealing with the development in a single person team along with the Advisor's help to effectively complete the project.

Requirements Analysis

As part of the requirements analysis, we had created a set of questions to be surveyed by health practitioners. The survey consisted of 10 questions where the first 9 questions were multiple choice with the last one being an open-ended suggestion request. We leveraged SurveyMonkey to create and send out the survey to the potential survey takers. Our survey, considering it was for human subjects, was approved by North Dakota State University's (NDSU) Institutional Review Board (IRB) board with protocol #SM20211 and was given permission to be send out via email to the potential human subjects. Below are the questions presented in the survey:

1. Do you use any smart speakers at home? Yes, all the time; Yes, sometimes; No.
2. How would you feel about using a smart speaker at work aka Healthcare Environment? Yes, I would like to use its capabilities, if done correctly; No, I am not interested; Maybe. I would like to explore the idea.
3. Considering a smart speaker (e.g. Alexa) which is HIPAA complaint and can retrieve information from EMR, and allows users to add/revise EMR information through voice, would you consider having it in the patient room to eliminate typing patient information? Yes; No; Maybe.
4. Roughly, on a regular day, what percentage of your time goes typing on a keyboard? A scale from 1-100%.
5. Do you think using voice would save your time on typing? Yes; No; Maybe.
6. Do you agree that manual input is one of the pain points of using EHR data? Yes; No; Don’t know.
7. Consider the following Alexa App. Using it, the Health Practitioner can speak to Alexa: "Hi Alexa, add a note on patient 456 that a follow-up is needed on their blood report in a year". Then the Alexa will automatically add a note to the patient's EMR and would reply to the practitioner: "Ok, I have added that note on the patient 456." Do you think this app would be useful, save your time and you would use that functionality? Yes, absolutely; Yes, but I am not sure if this use case covers entirely the actual scenario; Maybe; No, I don’t like using smart speakers; No, this is not a valid use case.

8. Consider the following Alexa App. Using it, the Health Practitioner can speak to Alexa: “Hi Alexa, create a follow-up appointment for patient 456 for July 4th, 2020”. Then the Alexa will automatically add a future appointment to the patient's EMR and would reply to the practitioner: “Ok, I have added an appointment for patient 456.” Do you think this app would be useful, save your time and you would use that functionality? Yes, absolutely; Yes, but I am not sure if this use case covers entirely the actual scenario; Maybe; No, I don’t like using smart speakers; No, this is not a valid use case.
9. Consider the following Alexa app. In a surgery, someone is responsible for saying a patient’s heart rate every 30 seconds. If a heart monitor is attached to Alexa, Alexa can now transcribe that information and allow nurses to focus on more important surgical operations. Using it, the Health practitioner can speak to Alexa: “Hi Alexa, tell me patient’s heart rate every 30 seconds”. And then the smart speaker would respond “OK”. Having the ability to get the Heart monitor data after 30 seconds the smart speaker would respond: “Heart rate-180” Do you think this app would be useful, save your time and you would use that functionality? Yes, absolutely; Yes, but I am not sure if this use case covers entirely the actual scenario; Maybe; No, I don’t like using smart speakers; No, this is not a valid use case.
10. Any other suggestions, guidance or advice for the research into using Smart Speakers to ease some manual input for Health Practitioner, or regarding any of the questions above.

The survey was taken by 8 health practitioners ranging from doctors, nurses and physicians. The survey takers included current staff from Family HealthCare, Essentia Health, Sanford in Fargo, ND, and few other members in United States who are currently practicing as a health practitioner. Our survey was a simple questionnaire designed to gauge the interest of potential users into this skill as well as understand their idea of voice-enabled devices in healthcare settings. Based on the responses we gathered through the survey, there are two main discoveries that need to be kept in mind for the success of this skill. We will be looking at the survey analysis and its results in the evaluation section of this thesis. To evaluate, we gave one point for each yes responses and half a point for each maybe responses, then combined the score to retrieve the overall percentage. The two main discoveries are:

1. 81.25% respondents said that they believe using voice than typing would help them save time.
2. 81.25% respondents said that manual input is one of the pain points in using EHR data.

Based on the responses above, the one main requirement that this project need to keep in mind while developing this skill would be:

1. The Amazon skill need to help with the manual input during patient-provider appointment to allow them to have more care time.

Considering the requirement is very broad in nature, for this thesis purposes we will be implementing two use cases as listed in survey question 9 and 7 above. This will give us a proof of concept and a starting point in creating skill catered towards health practitioners and later add many more use cases catered towards various department’s workflow.

Technology Chosen

In this section the technology chosen for this project will be discussed followed by the background on Amazon Alexa system. This project will be using Amazon Alexa as the voice-enabled device for “Doctor’s Assistant”. Besides that, the skill will be deployed as part of the Amazon Lambda function to AWS. Amazon does not have a requirement that the skills need to be deployed through Amazon Lambda, however, since the access to developer account and the

Amazon Lambda services was easily available, it was chosen to ease the process. Another alternative would be to use Azure functions to deploy an Amazon Skill. Nevertheless, this project has used AWS Lambda Project in .Net Core 2.1 to create the function and deploy it to an AWS account. For ease and having experience in Visual Studio 2019, we utilized that Integrated Development Environment (IDE) for the development of the function. We have also utilized several NuGet packages available on GitHub. We have used Alexa.NET NuGet package which was available under Massachusetts Institute of Technology (MIT) license and Amazon.Lambda.Core and Amazon.KeyManagement.Service which was available under Apache 2.0 license. Along with that, utilization of the Continuous Integration feature was consumed for building the skill and publishing for the testing purposes through developer.console.com and through their Alexa User Interface (UI). If a build fails on the console server, the developer will get a UI prompt telling us exactly what the error was, and then we can debug it to fix the issue. Since our skill was going to be updating dataset through voice commands, the Amazon's Relational Database Service (RDS) service was selected to store the patient database information. It is an assumption that when this skill is implemented in a hospital an EMR database is linked to the skill to properly update and alter the PHI. Again, for ease and from experience, the chosen RDS was to work with Microsoft Structured Query Language (SQL) Server available through AWS cloud service.

The only hardware requirements for this project is to have a functioning device which has Alexa voice service as a voice assistant in the backend. For that choice the device options were, Amazon Echo, Echo Dot etc. Given that we had Amazon Echo at hand, we implemented the skill on that device. Apart from that, there was no other hardware need as all the other services and features used in the project were cloud based.

Background on Alexa

Let's first look into what Alexa as a technology is and how various backend systems from Amazon work together to deliver voice assistant technology in Amazon Echo. Alexa is the concept's name which responds and asks queries to the user. It is backed by a cloud service for Alexa. According to Amazon's developer site, it is Amazon's cloud-based voice service available on many devices distributed through Amazon themselves as well as some third-party ones. Alexa Voice Service (AVS) helps users build natural language interactions to help them in their everyday life. The AVS is based on Automatic Speech Recognition (ASR) technology which Amazon uses to convert the speech into text for AVS to process onto. According to the Amazon article [26], ASR can detect spoken sounds as words which can then be translated into a language that can be understood by computers. Although, to utilize AVS through AWS console, Amazon has done great advancements in hiding the background on that so the implementers do not need a strong background in how ASR works. As simply explained in [25], first the Alexa (Device) is started and enabled to push whatever commands it receive from its users to AVS in the cloud. It is then parsed into commands that the service understands. After the service processes the request, it returns some voice response for Alexa to utter to you. Whenever a command is asked for through a voice enabled Amazon Echo or Echo Dot, each time a user says it differently, it gets trained and becomes smarter the next time around the same command is given to Alexa. A simple visual illustration given by the Amazon developer blog [27] is shown in Figure below:

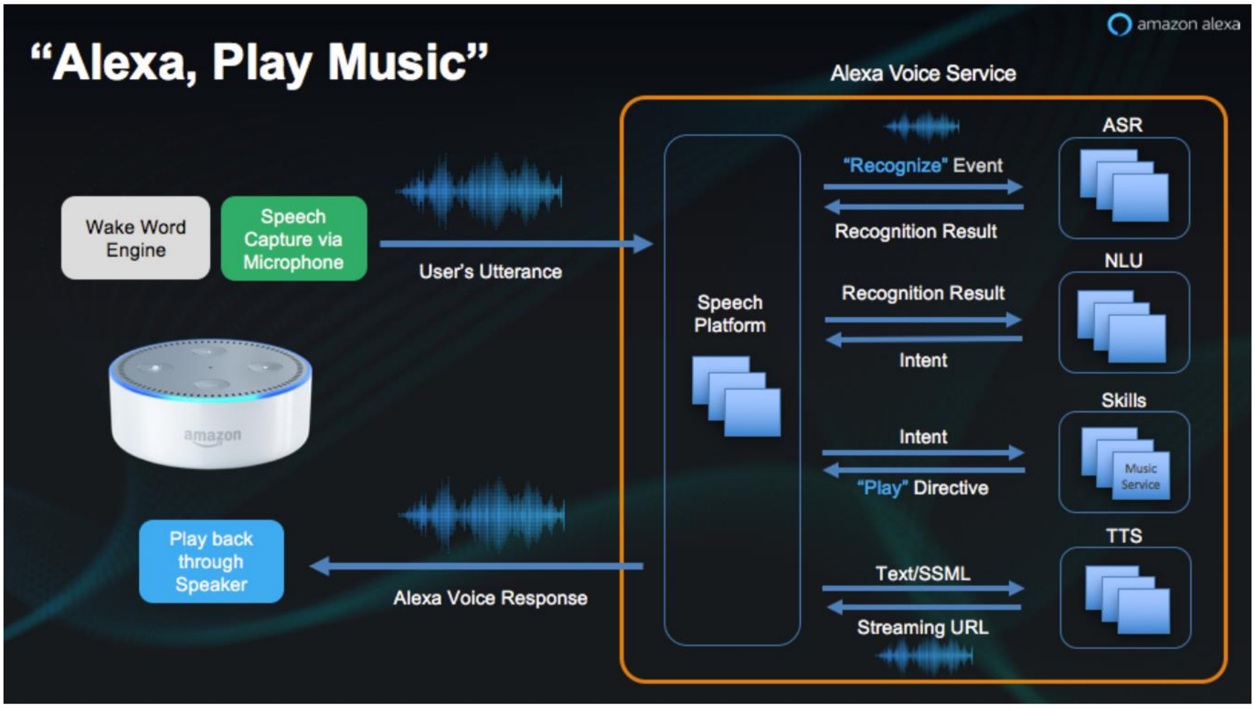

Figure 4. Visual Display of How ASR Works. Sourced from [27].

All of this is possible due to Natural Language Generation (NLG) and NLP, which are subfield in artificial intelligence with the focus on the interactions between computers and human beings. As mentioned in an article, "think of NLG as a writer that turns data into language that can be communicated and NLP as a reader that takes the language created by NLG and consumes it", NLP is part of the machine learning field in which there is a large data set need for a "machine" to learn or train on what the users might ask them do, specifically for task oriented conversations. Another explanation of natural language understanding in voice-enabled devices was explained in article [24] as follows:

"Natural language understanding in voice-controlled systems involves a process of semantic parsing for mapping transcriptions of spoken utterances to a formal representation of the utterances' meaning which the system can use to trigger an action."

Similarly, Alexa Voice Service has a data set of utterances, which the developer provides during their initial development process, which in turn is used through AVS's machine learning capabilities to further understand different kind of conversation and prompt a lambda function to respond. Most of the Alexa's capabilities rely on how well it can conversate with a human given a specific scenario. This capability is often measured from a skill to skill basis when it gets deployed. It is termed in one of the Amazon's paper as Conversational User Experience (CUX). How well the skill responds and how natural sounding the responses seem for a human is the basis of CUX. All these functionalities/features are currently being done in the AWS cloud platform.

For our application/skill to be capable of transferring PHI via a cloud service, they will need to be HIPAA complaint as per the Health Insurance Portability and Accountability Act. Amazon announced that the Alexa Skills Kit would be HIPAA compliant in April of 2019. Another achievement that Amazon made for Alexa's capabilities be used in healthcare space was to get into a BAA with a hospital who would be using Alexa for their use cases. Currently, there are six Alexa skills and their respective partners (hospitals/clinics) which make use of this resources. Due to this excellent addition to the Alexa Skills Kit (ASK) development world, this project have chosen to take this opportunity to dig deeper into this matter and present a potential Alexa skill that can be implement at a hospital to help the health practitioners in their day-to-day activities. The Alexa skill developed in this thesis, if implemented in a hospital setting could help doctor's save time and effort while doing their day-to-day activities.

System Design

A system design shows us a high-level abstraction of the system. To be able to understand the whole system design more in depth, this section is divided into two main parts.

One is outside the AWS environment and another one inside the AWS environment. Within the AWS environment, the large components being used in this system are shown. One can see in the Figure 5 that the user sends and receives voice utterances to and from the Alexa device. The Alexa device then sends the commands to ASK via AVS which have a function with a listening lambda to process the command. Based on the command the lambda function (depending on if its required) passes along the appropriate information to the RDS database for submission before returning success or failure. Here the Alexa device and of course the user, is outside the AWS environment and the rest is all set up in AWS. Below you can view the System Design for "Doctor's Assistant":

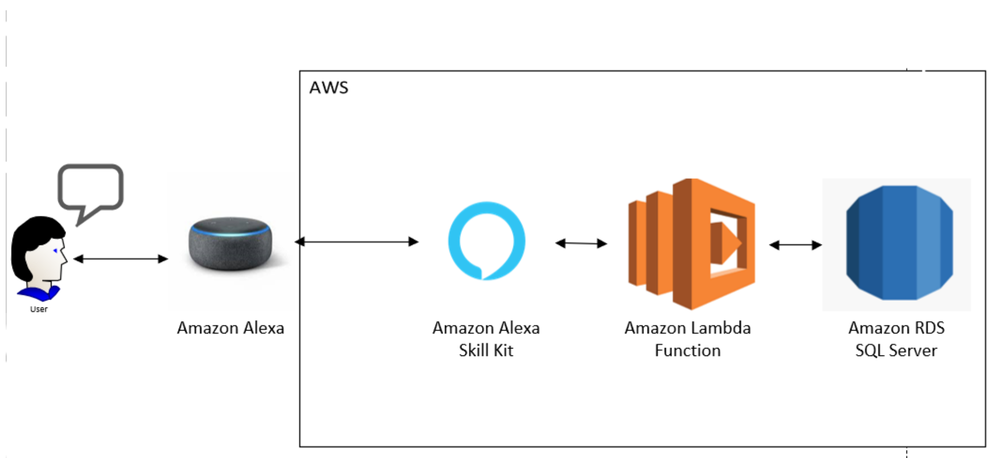

Figure 5. System Design.

A VUI is a voice user interface (VUI) and mostly done as a visual way to represent a general flow in a voice-enabled device skill. This project has utilized this for our Alexa skill to highlight the decision making that our skill will be responsible of doing. There are two main decision that Alexa needs to make (as its designed currently). First, when the user utterance is captured to see if there is a matching intent available and when the Alexa is waiting from the user to input another utterance. Based on the decision, the function responds with appropriate output to the AVS and eventually to the user. Below is the VUI for "Doctor's Assistant":

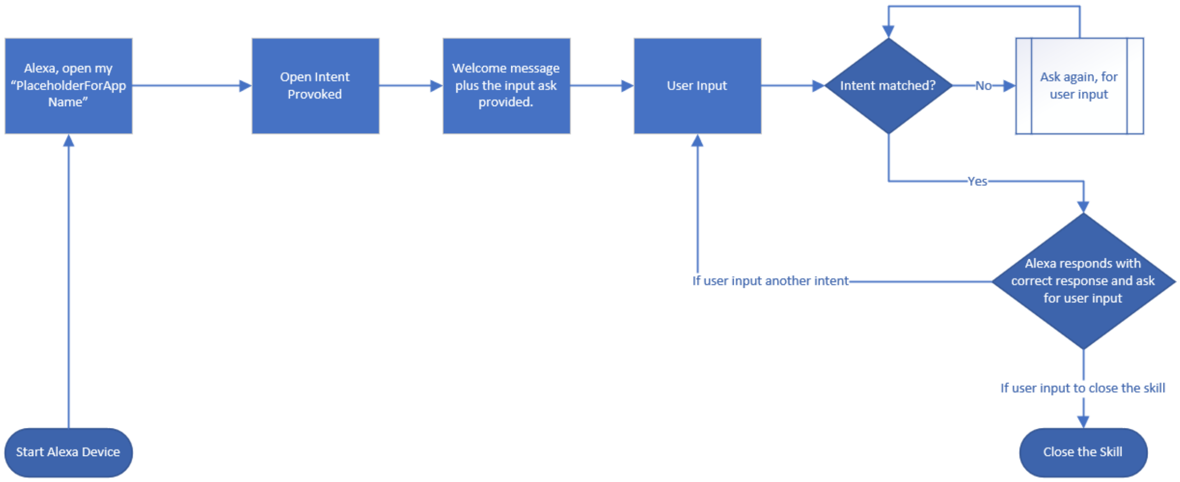

Figure 6. VUI of Doctor's Assistant.

A sequence diagram is a diagram which illustrates an actor/object's interaction with other actor/object in a sequential manner. There are two sequence diagrams to depict the sequence interaction between the user and Alexa.

1. First sequence diagram (Figure 7) depicts the flow of the user when he/she tries to open the "Doctor's Assistant". The health practitioner will say "Open 'Doctor's Assistant'" which will send the utterance to the AVS and then to the lambda function listening on the AVS for a command. Based on the input utterance, lambda will respond with "How can I help you, today?" to AVS which will be translated to speech and uttered through Alexa device to health practitioner.
2. The second scenario (Figure 8) will have the same opening sequence as listed above but then, will be taking the other utterance from the health practitioner to add a note on a patient with certain ID. Alexa will then convert the text into speech, send it to AVS to examine the utterance for an intent and in that intent if any variables are passed in. In our case the note and the patient ID are the variables. These variables are passed along with the complete utterance for the lambda function to process. Once the lambda function gets

the input, it will then extract the variable information and submit a query to the RDS service for a note to be updated on a patient ID. Once the RDS query is completed the lambda function will return success with some text to respond to the user. The AVS now will process the text and send it to the Alexa device, which will convert the text into speech to respond to the user.

Furthermore, in the future, it would be great to have cascading intents which can be triggered through only one command from the user. Through this research, we were not able to identify any functionality that would allow Alexa voice services to have cascading functions. This paper will go into this topic in more details in Chapter Five.

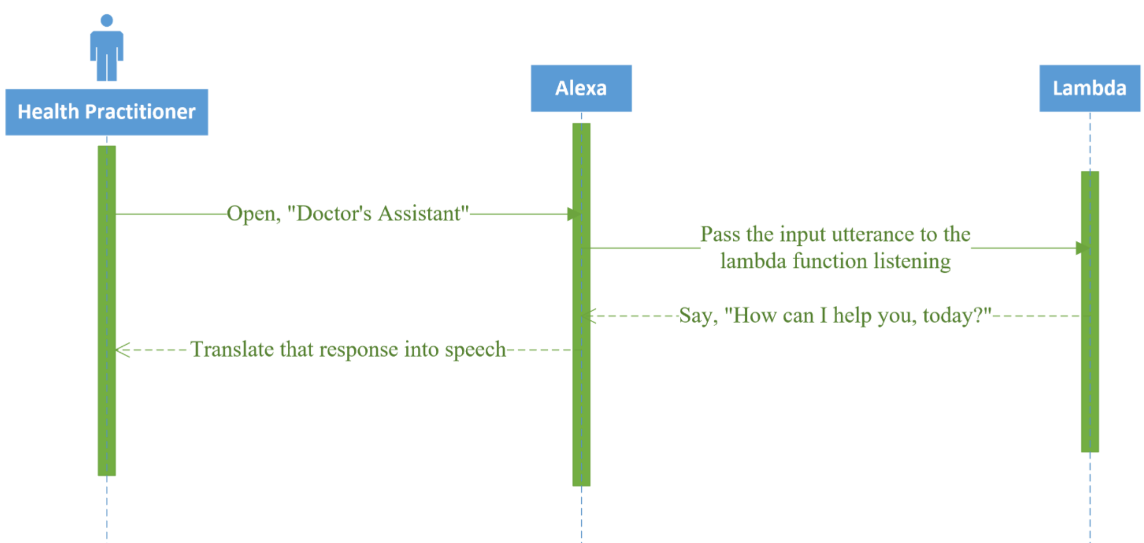

Figure 7. Wake Up Sequence Diagram.

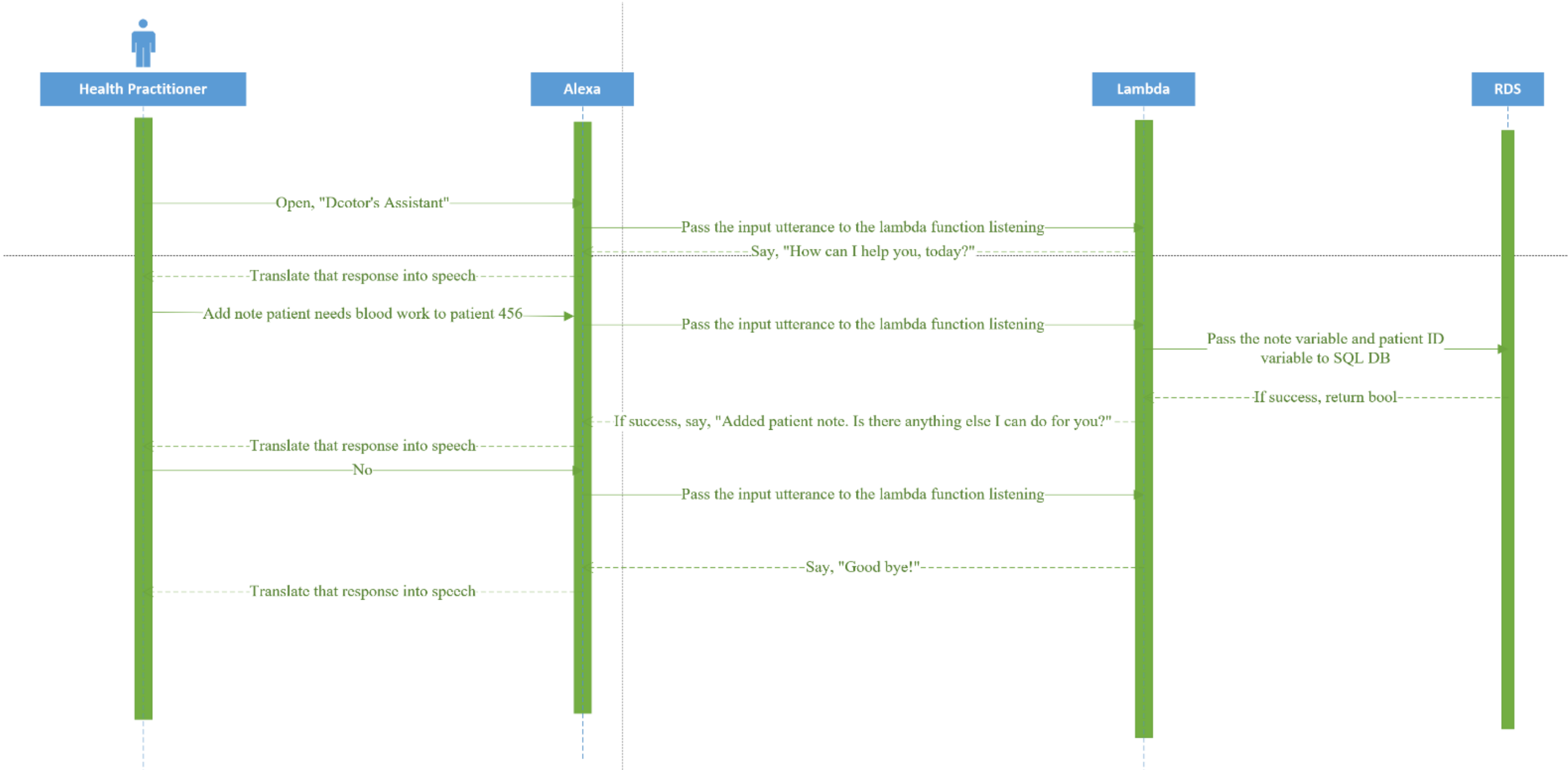

Figure 8. Use Case Sequence Diagram.

CHAPTER 4. EVALUATION

Although most of the command-based responses are straightforward to process and then to realize for its success and failure, reliability is the most important factor in the success of this skill to be effective in its usage. Considering that this skill needs to be used by doctors and other health practitioners, reliability towards this application is highly necessary. Our skill needs to respond to every request within reasonable amount of time and with the reasonable amount of accuracy.

In order to test the reliability of this skill, we are using basic testing skills to validate the response of Alexa based on various ways a health practitioner might interact with the device. We will analyze how our skill performed in two use cases tested for this experiment. Below is the general workflow that might occur during or after a patient/provider appointment:

Use case Scenario:

1) *User*: Hi Alexa, open Doctor's Assistant.
2) Alexa: How can I help you today?
3) *User*: Add a note that patient needs blood work to patient 456.
4) Alexa: Added a note to a patient. Is there anything else I can do for you?
5) *User*: Yes, add a follow-up appointment of patient 456 with me next month 29th April, 2020 at 9am.
6) Alexa: Added a follow-up appointment. Is there anything else I can do for you?
7) *User*: No.
8) Alexa: Goodbye.

For testing purposes, we have evaluated both the use cases separately for ease of comparison. We then note their variance, responses, success or failure and the time taken.

Use case 1: Adding a note to an existing patient.

Expected Response: Ok, I have added a note on patient 456.

Table 1. Use case 1 command performance evaluation

Sample	**Use case 1 variance**	**Alexa Response**	**Success**	**Time taken**
Sample 1	Add a note patient needs blood work on patient 456	Ok, I have added note to patient 456.	True	<2s
Sample 2	Alexa, add note to patient 456 that he needs bloodwork.	Ok, I have added note to patient 456.	True	<2s
Sample 3	Patient 852 needs bloodwork.	Ok, I have added note to patient 456.	True	<2s
Sample 4	Alexa, could you please add a note on patient 456 that she needs bloodwork?	Ok, I have added note to patient 456.	True	<2s
Sample 5	I need a note on patient 456 that he needs bloodwork.	Ok, I have added note to patient 456.	True	<2s
Sample 6	Will you add a note on patient 456 that she needs bloodwork?	Ok, I have added note to patient 456.	True	<2s
Sample 7	I would like to add a note to patient 456 that he needs bloodwork	Ok, I have added note to patient 456.	True	<2s
Sample 8	You can add a note of bloodwork about a patient 456.	I am sorry, I do not understand. Can you repeat the command again?	False	<1s
Sample 9	Can you remind me that the patient 456 has a note that they need bloodwork in a year?	I am sorry, I do not understand. Can you repeat the command again?	False	<1s
Sample 10	Note to be added to a patient that they might need bloodwork and the ID is 456	I am sorry, I do not understand. Can you repeat the command again?	False	<1s

Use Case 1: Analysis

As one can gauge from the above given table, our skill was able to pick up 7 out of 10 commands to add a note to an existing patient record, which is a 70% success rate. There was another round of the same samples being tested with the same skill and that time, sample 8 was able to recognize as a success case as well, which gives us an 80% success rate. As the intent's utterances are noted by the AVS and more trained each model registers in its system, the more our skill can pick up user utterances more effectively. Most of the responses did not take long time to respond with weather it was success or failure either. The most amount of time for a success response was due to the lambda function interacting with SQL server Database (DB) in the backend to enter the data in.

Use case 2: Adding a future appointment for a patient.

Expected Response: Ok, I have created an appointment for patient 456.

Table 2. Use case 2 command performance evaluation

Sample	**Use case 2 variance**	**Alexa Response**	**Success**	**Time Taken**
Sample 1	Alexa, create a follow-up appointment for patient 456 for July 4th, 2020 at 9am.	Ok, I have created an appointment for patient 456 with date time July 4^{th}, 2020 9'o clock.	True	<2s
Sample 2	Add an appointment next year on February 23^{rd} at 6am for patient 456.	Ok, I have created an appointment for patient 456 with date time February 23^{rd}, 2021 12'o clock.	True	<2s
Sample 3	Create an appointment in a month at 12pm for patient 456.	I am sorry, I do not understand. Can you repeat the command again?	False	<3s
Sample 4	Add a regular checkup appointment for patient 456 on 25^{th} of November 2020 around 3pm.	Ok, I have created an appointment for patient 456 with date time November 25^{th}, 2020at 15:00 hours.	True	<2s
Sample 5	Can you add a lab appointment for patient 456 for tomorrow at noon?	Ok, I have created an appointment for patient 456 with date time March 9^{th}, 2020 at 12' o clock.	True	<2s
Sample 6	Will you add an ultrasound appointment for patient 456 next week Tuesday at 3pm?	Ok, I have created an appointment for patient 456 with date time March 10^{th}, 2020 15:00 hours.	True	<2s
Sample 7	Can you add a lab appointment in a week from now on Wednesday for patient 456 at noon?	Ok, I have created an appointment for patient 456 with date time March 11^{th}, 2020 at 12' o clock.	True	<2s
Sample 8	Please add a follow-up appointment with Dr. Ruiz for patient 456 next year March 3^{rd} at 2pm.	Ok, I have created an appointment for patient 456 with date time March 3^{rd}, 2021 14 hundred hours.	True	<2s
Sample 9	Can you remind me of an appointment with a patient 456 in a year?	There was a problem with the requested skills response.	False	<3s
Sample 10	Appointment to be added to a patient whose id is 456 and the timing can be next week around noon.	I am sorry, I do not understand. Can you repeat the command again?	False	<1s

Use Case 2: Analysis

In the second use case scenario, our skill was also able to pick up 7 out of 10 commands to add an appointment to an existing patient record, which is a 70% success rate. Most of the responses did not take long time to respond with weather it was success or failure either. The most amount of time for a success response was due to the lambda function interacting with SQL Server DB in the backend to enter the data in. An important revelation that was discovered through this testing was utterances like “next week from now”, “in a year from today” etc. are still not able to be recognized by the Alexa skill when we are using the slot type of Amazon.Date. Another revelation that was discovered during this testing was utterances like “half past noon”, “quarter to three” etc. were also not recognized when we used the slot type of Amazon.Time. The date and time were needed to be said exactly for it to recognize in the variable slot to be entered in the RDS system.

Conclusion

The above two tables show us that our skill was able to correctly identify proper intent based on several ways a health practitioner could ask the Alexa to perform an action. However, there are some utterances that Alexa did not recognize correctly, as it did not have enough training material for deep learning mechanism to understand that the intent could be out of the ordinary besides the one defined in the skill. According to the AWS console app site, there is a section of intent history which gets enabled as soon as you have 10 active users for that skill. With the help of the intent history, one can measure and check out how the users are interacting with that skill. The intent history keeps the utterances spoken by your users in that tab in your development console for you to go over them and add some of the utterances to a matched intent whenever possible. Since our skill was tested by one person, we were not able to view that functionality/section of the Alexa's developer console. Although, one could conclude it being extremely helpful once one has a team of people testing on their skills to add more knowledge base to your skill.

Below are some screenshots of the developer console testing feature which Amazon allows you to send the commands through to test your skill via the console. As you could see, the results were pretty much the same as you saw earlier in the table above. Once difference being that simulator was not able to pick up the patient ID very well. One would have to provide the patient ID again. But since, we added the patient ID variable to be required, the developer can provide Alexa speech prompts to ask for those values again without adjusting any code for it. Once can also provide sample user utterances based on the confirmation question created above for the variable slot. Developer console test section gave us an opportunity to build and test the skill online while not deployed on the device. In the console window, few other information is shown to debug an intent, in case of a failure. For instance, the JSON input and output of the skill and lambda function service is printed in left- and right-hand side of the window. Another thing, one could view in that window is device logs (as if that conversation occurred in a real device). Lastly, there is an option to replay Alexa's response in the same screen. With all the features in that window, this was another great tool for testing our skill through the developer console.

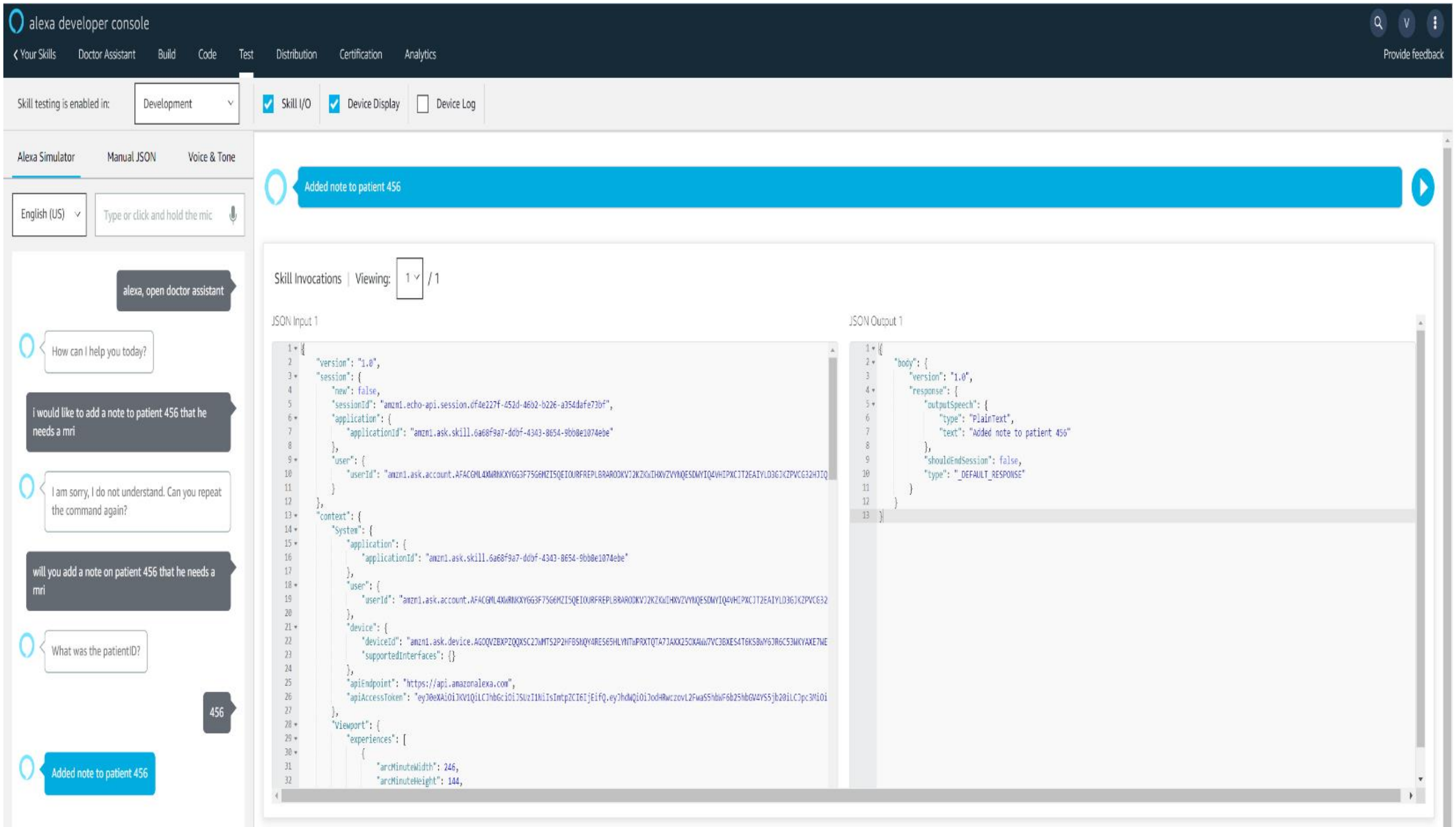

Figure 9. Taken from Developer Console. Simulator Response.

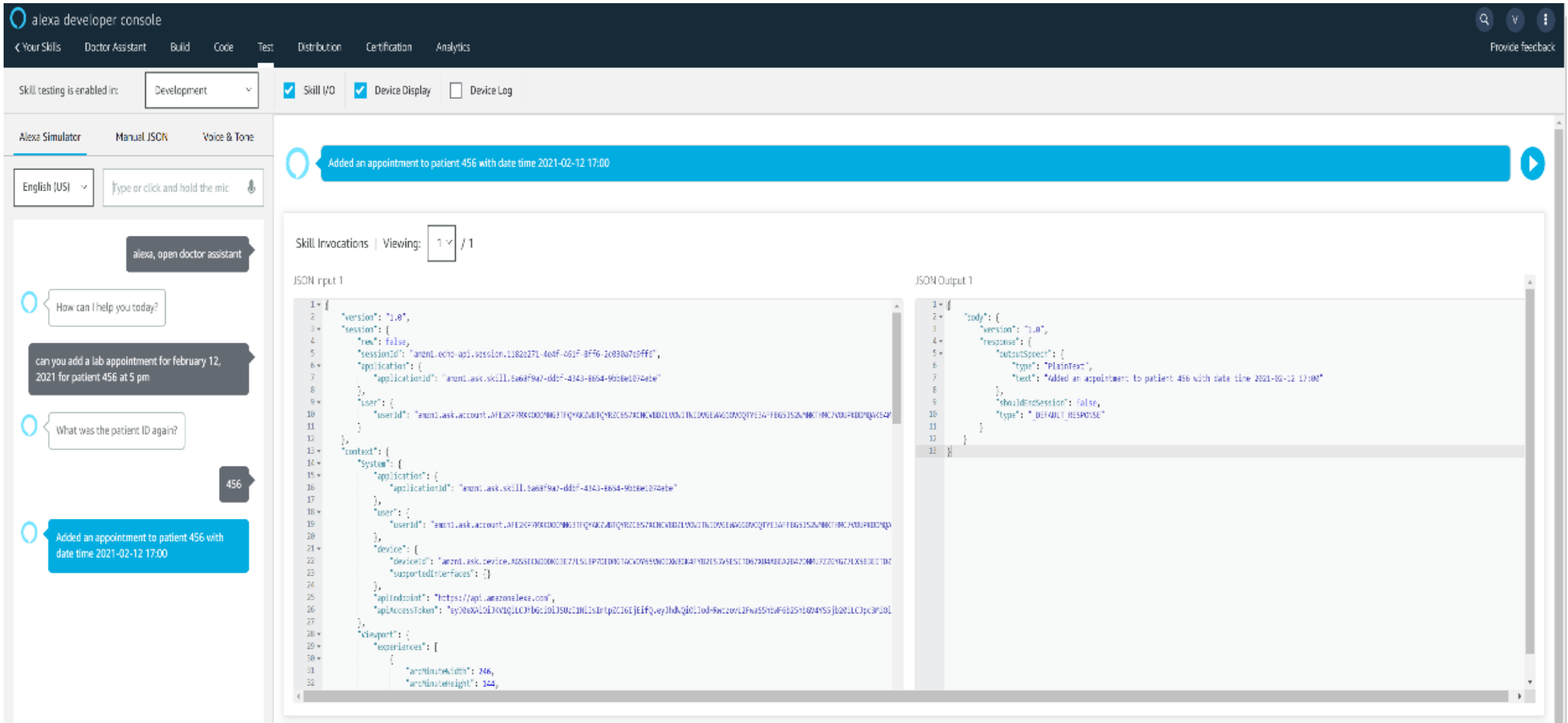

Figure 10. Taken from Developer Console. Simulator Response.

Survey Analysis

As mentioned earlier in the thesis, we conducted a survey of several doctors and nurses who gave us more in-depth analysis of how our system would evaluate in the clinical field. Note: this use cases are a general idea of how a skill can be designed, however, the exact use cases will need to be defined and designed as per health practitioner's day-to-day activities. For example, someone in the surgery probably not need either of the use cases, similarly, someone in the patient-provider meetings might not need use case 2. They survey resulted in major revelation as shown below:

Table 3. Usability Evaluation

Case	**Recommendation Score**
Add a note	68.75%
Create a follow-up appointment	62.5%
Heart rate command	62.5%

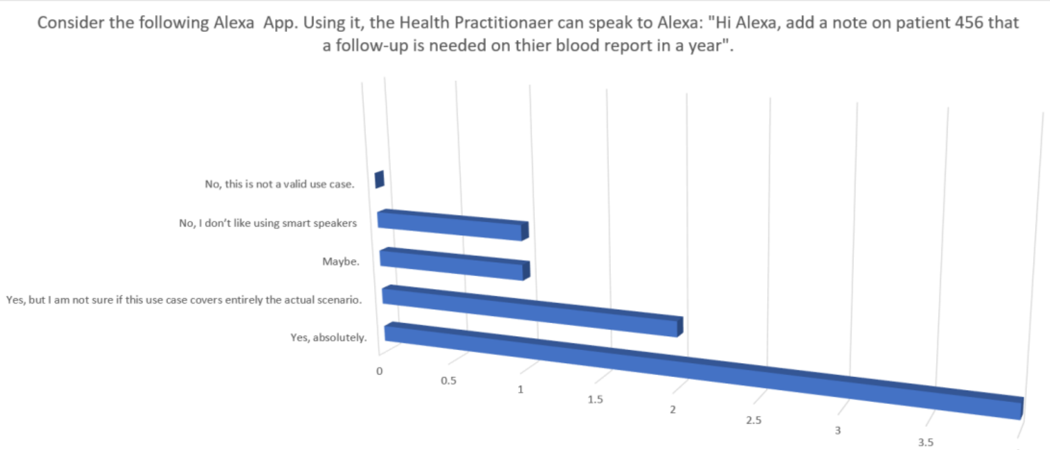

Figure 11. Survey Result for Question 7.

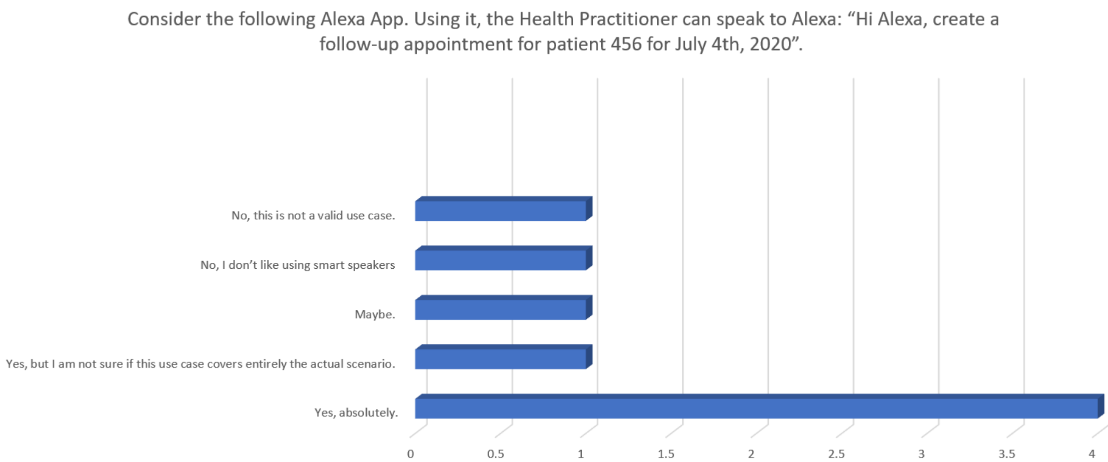

Figure 12. Survey Result for Question 8.

Although, the number of use cases we used in our evaluation were limited, we had a better understanding of how these can be utilized to implement various other use cases in a general command-based scenario for a health practitioner. Survey responders also replied in great enthusiasm towards developing and using smart speaker in a hospital and clinic settings as shown in Figure 11 and 12. Below are couple of those great feedback from them:

1. "I think a Smart Speaker would be extremely beneficial for medication verification. For instance, the nurse is in the room with a handful of meds which range from blood pressure meds to pain meds, antibiotics, insulin, PPI's, etc. if a nurse could somehow verify via the speaker if there were any medication contraindications, allergies, etc. it would be a great tool as another means of checking if meds are safe to administer. So, a Smart Speaker, with pharmacy checks and capabilities, in my opinion, would be fantastic."
2. "During wound care: "Hi Alexa, please document the left ischial pressure ulcer on Mr. X measures 6cm by 5cm by 4cm." This would decrease the risk of contamination presented by having to write or type with gloved hands during wound care."

Below are few other use cases which can be implemented in a similar way as an action-based response:

Use care 1: As a doctor/physician, I can ask Alexa to provide me the patient's past vital information, medications list and past notes history before going in the room with the patient so that I don't spend time doing those tasks while the patient watch me try to find the information in the EHR system.

For example:

- Doctor: "Alexa, what is patient 456's vital information?".
- Alexa: "Patient 456 has blood pressure of 140/90, with BMI of 40 and body temp of 98.5. Their weight is 180lbs which is 5lbs less than last time."

Use case 2: As a doctor/physician, I can ask to update my location as per the Alexa's current location when I am in the room with a patient for the nurse and clinicians to view my status.

For example:

- Doctor: "Alexa, update my location to be in room 102 with status of 'With Patient'".
- Alexa: "What is your doctor code ID?"
- Doctor: "123".
- Alexa: "Your location has been updated to be in room 102 with status of 'With Patient'".

Use case 3: For an ambulance nurse, nurses can leverage Alexa in providing information/notes regarding the patient to the nearest hospital's charge nurse mobile phone so the Emergency nurses can be ready for the patient beforehand.

For example:

- Nurse: “Alexa, inform the charge nurse in Hospital XYZ to get ready for a lower leg fracture to a 52-year-old male with heart rate of 90”.
- Alexa: “Ok, your message has been sent to the charge Nurse.”

Use case 4: For a nurse, when the patient is highly contagious and nurse needs to set a reminder in her pager to inform all other health practitioners on the floor without touching any surfaces, Alexa can provide that assistance in sending out that information.

For example:

- Nurse: “Alexa, inform the nurses on the floor of a contagious patient with disease “XYZ” is in room 205.”
- Alexa: “Ok, your message has been sent to all the team members active on this floor.”

CHAPTER 5. CONCLUSION

The goal of the Alexa skill "Doctor's Assistant" with use cases provided was to prove that it was an important skill to be included in healthcare institutions. We learned that we could design and produce the skills in a generic way for healthcare practitioners to evaluate their usefulness and customize those skills according to a healthcare department's need before deploying them in hospitals and clinics. Given the increasing popularity of smart speakers and Amazon Alexa having the HIPAA compliance capability, utilizing voice assistants in a healthcare industry is a smart and efficient ideology to adapt into. The AVS and ASK are two strong technological components, which are developed and incorporated in various industries including the healthcare system. The primary focus of "Doctor's Assistant" is to demonstrate the capabilities of AVS and ASK, as well as to help provide an alternative to typing for healthcare providers.

Our assumption was the EMR database system was in the backend of the skill, it is more likely that a provider will use the voice assistant to enter and update the data without spending time entering that data manually into the system. Our approach showcases some of the command-based interaction and proves how it can be helpful for healthcare practitioners in doing some of the day-to-day tasks, and how it is evaluated by them as seen in the survey results. Although, the survey responders were low compared to the number of people working in this industry, the percentage of people understanding its importance were high, giving us the determination for its necessity. In conclusion, our skill evaluated in the right direction regarding the use of smart speakers in the healthcare domain.

With all new technology there are areas for improvement. Similarly, there are limitations with our proposed approach. First, from the technology perspective, the AVS does not get automatically trained to include multiple utterances as its similar system in the market, DialogFlow, does. DialogFlow is a similar technology service provided by Google for their Google Home Assistant. DialogFlow allows the user to give a few sample utterances to begin with and trains the model in the backend to receive various enumerations of utterances with the similar intent. There might be future features planned in Alexa services to include similar capabilities, but currently it does not have a feature for auto accepting related utterances. Due to that important feature, this project could have been designed for Google's smart speaker (Google Home), however, Google has not been able to deliver a proper way to makes their "actions" HIPAA compliant. This limits our desire to use this device given our target audience would be in the healthcare system. Another limitation would be how hospitals and clinics could deploy these skills in a patient room across their institutions, considering its complexity. Hospitals and clinics need to have an appropriate BAA contract with Amazon to deploy and use their skills in order to be in compliance with HIPAA rules and regulations. Lastly, the intent matching for our skill was not 100% accurate. In other words, our skill was not able to accurately match all the utterances a human being can make to do certain command-based operations. For example, when our experiment asked for a note to be added to patient 456 for blood work, if the user uttered 'four hundred and fifty six for blood work', the skill was able to pick up the patient ID correctly; however, if the user uttered 'four five six for blood work', the device picked up four thousand five hundred and sixty four as a patient ID, which was incorrect. The conclusion given by [24] based on a small-scale experiment, shows that these systems are vulnerable to being misled by adversarial or unrelated utterances which can trigger a function incorrectly. This can be a no-go for hospitals based on how important the command trigger is.

Future Work

The possibility of voice assistants or smart speaker technology in the future as part of the healthcare industry is immense. Some of the limitations described above are potential future work items that could be worked on to improve upon the developed skill. The upcoming projects should start with analyzing and designing correct ways to interact with EMR/EHR systems and databases through Amazon servers. As noted in the research project done by [1], the integration of Alexa's API's to each medical institution's EHR site do not come standardized and hence needs to be implemented per institution basis. This also includes partnership with each department (wound care, inpatient, outpatient, surgical etc.) to pilot these concepts. Once we have that documented and designed, the use case implementation in hospital settings will be easier for the implementors. Future work should consider the various role-based use cases, for instance how a nurse can utilize one feature in an operational setting vs. how a nurse can utilize one feature in an In-Patient setting. The work should also focus on getting the generic system implemented and analyzed by a larger number of healthcare practitioners to get their genuine input regarding the development of voice assistants. Based on the result from that, we could create a backlog for enormous amounts of researches and discussions into incorporating smart speakers in the healthcare industry. It is the hope of this research that the combination of the benefits described in the thesis and the evaluation of the developed skill will entice more researchers and corporations to choose to create and develop skills to benefit the healthcare practitioners who are in the frontline saving people's lives.

REFERENCES

[1] K. Blansit, R. Marmor, B. Zhao and D. Tien, "National Center for Biotechnology Information, U.S. National Library of Medicine," 16 April 2018. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5977698/. [Accessed 5 January 2020].

[2] Y. Kumah-Crystal, J. C. Pirtle, M. H. Whyte, S. Goode, H. S. Anders and U. C. Lehmann, "National Center for Biotechnology Information, U.S. National Library of Medicine," 18 July 2018. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6051768/. [Accessed 5 January 2020].

[3] "Knowledge@Wharton," University of Pennsylvania, Wharton School, 15 April 2019. [Online]. Available: https://knowledge.wharton.upenn.edu/article/alexa-hipaa-compliant/. [Accessed 5 January 2020].

[4] Cedars Sinai , "Cedars Sinai," 25 February 2019. [Online]. Available: https://www.cedars-sinai.org/newsroom/cedars-sinai-taps-alexa-for-smart-hospital-room-pilot/. [Accessed 5 January 2020].

[5] R. Basatneh, B. Najafi and D. G. Armstrong, "Health Sensors, Smart Home Devices, and the Internet of Medical Things: An Opportunity for Dramatic Improvement in Care for the Lower Extremity Complications of Diabetes," Journal of Diabetes Science and Technology 12, no. 3, 2018.

[6] C. Farr, "Health Tech Matters," CNBC LLC, 18 June 2017. [Online]. Available: https://www.cnbc.com/2017/06/18/hospitals-are-looking-for-the-killer-amazon-alexa-app.html. [Accessed 5 January 2020].

[7] S. Gray, "The Future of Privacy Forum," 9 August 2016. [Online]. Available: https://www.ftc.gov/system/files/documents/public_comments/2016/08/00003-128652.pdf. [Accessed 5 January 2020].

[8] J. R. Lordon, "Design, Development, and Evaluation of a Patient-Centered Health Dialog System to Support Inguinal Hernia Surgery Patient Information-Seeking," 2019. [Online]. [Accessed 5 Janurary 2020].

[9] J. Kohr, "The Rise of Smart Devices; Implications of the Internet of Things in Healthcare." Order No. 10845489, Utica College, Ann Arbor, 2018.

[10] B. Williams, "Bicycle Crash Detection: Using a Voice-Assistant for More Accurate Reporting." Order No. 10828551, University of Oregon, Ann Arbor, 2018.

[11] W. Charles, "Exploring the Strategies Needed to Standardize an Accidental Falls Program in a Healthcare Organization." Order No. 10813289, Colorado Technical University, Ann Arbor, 2018.

[12] M. Hadian, T. Altuwaiyan, X. Liang and W. Li, "Efficient and Privacy-Preserving Voice-Based Search over mHealth Data," 2017 IEEE/ACM International Conference on

Connected Health: Applications, Systems and Engineering Technologies (CHASE), Philadelphia, PA, 2017, pp. 96-101.

[13] M. Krishnaveni, P. Subashini, J. Gracy and M. Manjutha, "An Optimal Speech Recognition Module for Patient's Voice Monitoring System in Smart Healthcare Applications," 2018 Renewable Energies, Power Systems & Green Inclusive Economy (REPS-GIE), Casablanca, 2018, pp. 1-6.

[14] D. Kadariya, R. Venkataramanan, H. Y. Yip, M. Kalra, K. Thirunarayanan and A. Sheth, "kBot: Knowledge-Enabled Personalized Chatbot for Asthma Self-Management," 2019 IEEE International Conference on Smart Computing (SMARTCOMP), Washington, DC, USA, 2019, pp. 138-143.

[15] S. Greene, H. Thapliyal and D. Carpenter, "IoT-Based Fall Detection for Smart Home Environments," 2016 IEEE International Symposium on Nanoelectronic and Information Systems (iNIS), Gwalior, 2016, pp. 23-28.

[16] S. Sinha, S. Chattopadhyay and A. Mukhopadhyay, "Voice Controlled Digital Thermometer for Medical Application," 2018 2nd International Conference on Electronics, Materials Engineering & Nano-Technology (IEMENTech), Kolkata, 2018, pp. 1-5.

[17] S. F. Ali, S. Noor, S. A. Azmat, A. U. Noor and H. Siddiqui, "Virtual reality as a physical training assistant," 2017 International Conference on Information and Communication Technologies (ICICT), Karachi, 2017, pp. 191-196.

[18] Andrej Ilievski, Dimitri Dojchinovski, and Marjan Gusev. 2019. Interactive Voice Assisted Home Healthcare Systems. In Proceedings of the 9th Balkan Conference on Informatics (BCI'19). Association for Computing Machinery, New York, NY, USA, Article 19, 1–5. DOI:https://doi-org.ezproxy.lib.ndsu.nodak.edu/10.1145/3351556.3351572

[19] Nasim Motalebi and Saeed Abdullah. 2018. Conversational Agents to Provide Couple Therapy for Patients with PTSD. In Proceedings of the 12th EAI International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth '18). Association for Computing Machinery, New York, NY, USA, 347–351. DOI:https://doi-org.ezproxy.lib.ndsu.nodak.edu/10.1145/3240925.3240933

[20] Mengxuan Ma, Marjorie Skubic, Karen Ai, and Jordan Hubbard. 2017. Angel-echo: a personalized health care application. In Proceedings of the Second IEEE/ACM International Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE '17). IEEE Press, 258–259. DOI:https://doi-org.ezproxy.lib.ndsu.nodak.edu/10.1109/CHASE.2017.91

[21] B. Kinsella and M. Ava, "Voicebot.ai," March 2019. [Online]. Available: https://voicebot.ai/wp-content/uploads/2019/03/smart_speaker_consumer_adoption_report_2019.pdf. [Accessed 5 January 2020].

[22] B. Kinsella and A. Mutchler, "Voicebot.ai," October 2019. [Online]. Available: https://voicebot.ai/wp-content/uploads/2019/10/voice_assistant_consumer_adoption_in_healthcare_report_voicebot.pdf. [Accessed 5 January 2020].

[23] L. Hedges, "Are Patients Ready for Amazon Alexa, MD?," Software Advice, Inc., 9 August 2019. [Online]. Available: https://www.softwareadvice.com/resources/alexa-healthcare-skills/. [Accessed 5 Janurary 2020]

[24] K. M. Bispham, I. Agrafiotis and M. Goldsmith, "Nonsense Attacks on Google Assistant," University of Oxford, United Kingdom, [Online]. Available: https://ora.ox.ac.uk/objects/uuid:22a26ee8-9c36-4dda-878f-09f3ec32cc9c/download_file?file_format=pdf&safe_filename=nonmissense.pdf&type_of_work=Conference+item.

[25] B. Marr, "Machine Learning In Practice: How Does Amazon's Alexa Really Work?," Forbes Media LLC, 5 October 2018. [Online]. Available: https://www.forbes.com/sites/bernardmarr/2018/10/05/how-does-amazons-alexa-really-work/#2271f0bb1937. [Accessed 5 January 2020].

[26] Amazon.com Inc. , "What Is Automatic Speech Recognition (ASR)?," [Online]. Available: https://developer.amazon.com/en-US/alexa/alexa-skills-kit/asr. [Accessed 5 January 2020].

[27] W. Kaminski, "The Basics of Amazon Alexa Developer Tools and Services," Amazon.com Inc. , 18 September 2017. [Online]. Available: https://developer.amazon.com/blogs/alexa/post/b015c5bd-2b01-4f7f-923e-dd34c998f3d0/avs-tech-series-the-basics-of-amazon-alexa-developer-tools-and-services. [Accessed 5 January 2020].

[28] Amazon.com Inc., "Architecting for HIPAA Security and Compliance on Amazon Web Services," January 2020. [Online]. Available: https://d1.awsstatic.com/whitepapers/compliance/AWS_HIPAA_Compliance_Whitepaper.pdf. [Accessed March 2020].