**Robotics and Intelligent Systems Lab**

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Knight Bot

**April 20, 2018**

# Overview

Knightbot is a fully automatic assistant robot that can roam the halls of a Middle Georgia State University campus. It serves a similar purpose to the Google Assistant/Alexa that are common on several phones and home assistants. Knightbot can handle MGSU-specific questions, such as “When does Professor Kwak have office hours?” as well as virtually any question you could ask a regular assistant, such as “What time is it?” A team of six students during Fall 2017, plus four more in Spring 2018, worked to design, program, and build Knightbot as an undergraduate research course. They met twice a week during each semester, working in the robotics lab in Macon as well as on the Cochran campus.

# Goals

1. **Meet the needs of the campus:** The largest priority is to ensure Knightbot can serve its audience. We wanted to have Knightbot answer questions pertinent to an average MGSU student, like what time/where their professor’s office hours are, dates of upcoming MGSU events, and other MGSU-related topics.
2. **Be autonomous:** Theoretically, Knightbot could roam the halls of a building on campus as to be most accessible. To this end, we equipped it with wheels and visual processing to avoid obstacles.

# Specifications

## Software

We constantly run our own custom Python script to control each part of our system. We utilize Snowboy Hotword Detection to be able to detect the word “Knightbot!” Upon detection, the script records the user’s request, and submits it to the Dialogflow Client API. Dialogflow is a natural-language processing API provided by Google. Dialogflow processes the user’s input, and converts the bytes of audio into the text of what the user said. It then determines the intent of what the user asked (for example, if they wanted to know about a professor’s office hours). It sends this information to our webhook. The webhook is constructed, in part, using Flask-Assistant. We run a light-weight server using Ngrok that connects our webhook to Dialogflow. The webhook has instructions for what to do for each intent that the user has. After it receives the intent from Dialogflow, it returns how Knightbot should respond (for example, “This professor has office hours at 10:00”). Dialogflow sends this response back to our python script. Sometimes Knightbot might not know how to answer the question that the user asks (for example, “What’s the weather like?”). If so, we send the user’s question through the Google Assistant API, which utilizes the same technology that the assistant on your phone/Google Home uses. The Google Assistant API returns it’s response to our Python script. We output this response using Google’s text-to-speech tool.

At nearly every stage of this process the Pi sends instructions to an Arduino Mega. The Arduino controls Knightbot’s motors, eyes, and visual-processing. C++ is the main language utilized to control all components of the Arduino. The main file for the Arduino runs a loop which queries for input from the Pi every iteration. The idle state of the robot consists linear movement with the other peripherals turned off. If an input is detected from the Pi, the arduino parses the input into three distinct variables. These variables correlate to the eyes, head, and track movement. The integers passed to the Arduino are passed through a switch statement with cases for different movement patterns and eye presentations. While all of this is going on, the sensor constantly takes input and uses the information to determine whether to rotate right or rotate left. Getting the different components to work was the first struggle, but the second major obstacle for our group was developing a communication protocol for the arduino to receive commands from the raspberry pi. Our solution was a customly built event driven interface for receiving input and parsing to the three major parts of the robot. In addition to the interface, we developed Arduino libraries specific to this project to promote modularity and easy code reuse. All the libraries created for this library are hosted on Github.

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## Hardware

Knightbot’s main processing unit is a Raspberry Pi 3. For audio input/output, we use a generic microphone and speaker. The Pi runs all of the question/response protocols, and connects to the Arduino.

The Arduino team was tasked with developing components to enable the robot to traverse hallways and to communicate with a user via head movements and varied eye displays. The Arduino microcontroller harnesses the C++ programming language to manage components such as servos, motors, and leds. Our project in particular required the use of two 8x8 led matrices for the eyes, two servos for the head movement, and a pair of motors for the track system. Knightbot’s eyes are displayed using two MAX7219 Dot Matrix Display Modules and two Digital MG996 Servos control the vertical and horizontal head movement.

## Design

Within this research course, the design team has worked diligently to master new techniques, such as 3D printing, and old techniques with new applications, such as problem solving and team building. Our main task within this research project was to design and construct a body for a robot using mainly 3D printing. We had our first experiences with 3D printing within this course, and throughout the year have been developing the skills necessary to construct basic and intermediate 3D models. Utilizing programs such as Blender, TinkerCAD, and Meshmixer, we were able to design and construct multiple parts of the body on our own that were later incorporated into the final design.

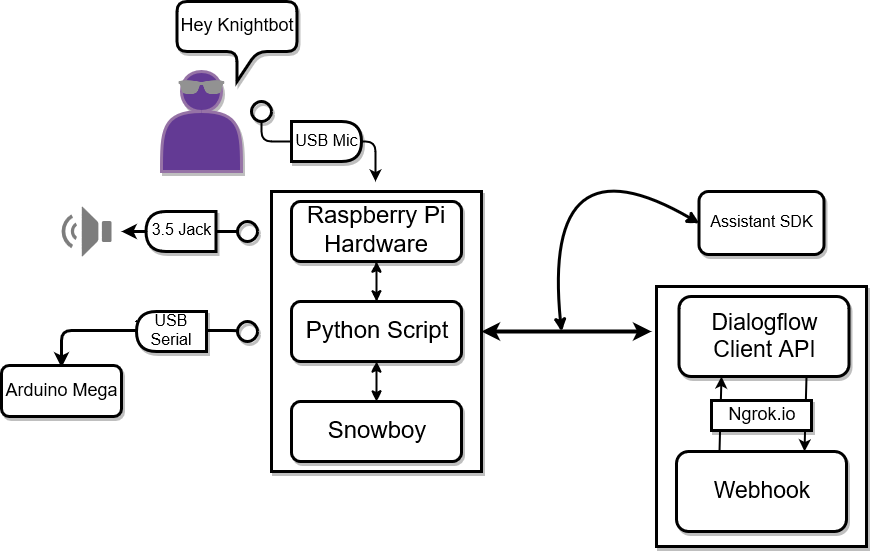
All members of the design team were new to creating 3D models and practiced to become fluent in Computer-Aided Design and Drafting Software. However, we quickly discovered that designing our own 3D models by hand was often time inefficient, and instead opted to use pre-made free-use models found using online print model search software. Using these search engines, we were able to find models that we utilized to become the physical manifestation of our vision for the robot. Our process involved finding models that could potentially be of use, reshaping them to our liking using CAD softwares, scaling them in 3D editing programs such as Cura, arranging them in a way that would be conducive to 3D printing, slicing them using programs such as Slic3r and Kisslicer, porting them out to the printers, and closely monitoring them for any print inconsistencies or malfunctions.

Throughout the project we encountered many difficulties while attempting to create the robot solely out of 3D printed materials. When we faced an obstacle with the design of the arms, we collectively decided to take a more creative approach and attempted to construct the arms out of carved Styrofoam rather than 3D printing the arms in multiple pieces over an extended period of time. In theory, this idea was okay, but the members of design team eventually realized that the Styrofoam was extremely messy, difficult to carve, and not easy to manipulate into the correct shape. After this realization, we decided to go back to our original plan of 3D printing, only to discover that each arm had to be split into six individual pieces that took at least a day to print each. Our biggest struggle within this research project was constructing the arms within the time that we were given due to the various setbacks we encountered. Despite this, the design team was able to assemble the 3D printed components of the torso, the head, and the apparatus that attaches the robot to its tracks with minimal complications.

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# Models

Hardware & Software



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# Reflections

During the short months of the spring semester I was able to pick up basics programming and wet my feet in the vast world of computer science. Although my time working with Knightbot was extremely short, I was both able to learn a lot from my time and contribute substantial amounts of work in the the development phase of Knightbot. But I can say that I would not have been able to complete and accomplish such tasks had it not been for the help, courage, and leadership of my fellow classmate Odell Blackmon III. Odell is the one that help my latch on to the basics of programing. Without his help I would not have been able to write nor understand the code involved with Knightbot. And as for collaboration with the other team members involved that contributed to Knighbot i will say that there are those that didn’t contribute much to the overall development of Knightbot and this became quite annoying and troublesome towards the last development days of Knightbot. Despite this, I can say that my overall experience with Knightbot was both quite intriguing and fun to experience.

* Sir Laurence Cruz-Walton

Having joined the research team a semester into their work I did not have the pleasure of working with the robot the whole time. Despite that, I feel like I contributed as much as I could to the project and software team. My main role was to work side by side with Trevor Pope to help program the Raspberry Pi. The semester started out by him explaining what he had already finished and what needed to be done. However, it quickly turned into the both of us working together to complete all of the software needed in time. My prior knowledge in Python and my ability to troubleshoot helped immensely with this project. We encountered many speed bumps along the way. Some of which were crossed by going to the line of code which had the problem and adding one character, while others were not as simple. At one point we spent over a day fixing audio issues we were having. While I did come in with some prior knowledge in Python, I came out knowing even more Python plus some more in depth concepts that surround Python. I have also not only learned more about the concepts of Artificial Intelligence and Machine Learning but have learnt the basics of the code behind modern day public Artificial Intelligence machines.

* Elijah Trepper

Throughout this semester, I have been a part of creating Knightbot, a self -controlled robot that can answer questions related to Middle Georgia State University information. I was specifically on the hardware team, and throughout this research opportunity I have learned a lot of useful information.

Through this research project, I have learned a lot of things based on robotics, as well as team cooperation. I have learned about the different components that are used within a robot, for example, voltage regulators, bread boards, DC and AC motors, Arduino, and many other components. I have also learned that when working on a project where separate teams are responsible for different parts of that project, you have to make sure every team is communicating and on track with all other teams.

I feel like I mostly contributed to this project with my knowledge of electronics and robotics from my personal projects, as well as working on VEX robotics. I contributed my knowledge of DC motors and my limited knowledge of how to read programs and alter them to do different tasks. I also utilized my personality to make sure no one was overly stressed, as well as voicing my opinion on what I believe needs to be worked on and what needs to change.

I personally prefer project-based learning compared to classroom-based learning. I am a more kinesthetic person, so I am more interested in working with different materials and using the knowledge I have, as well as the knowledge I acquire in the process of the project to build or create something that I can physically see and witness in action. I believe project-based learning is more effective since it teaches students information, while also teaching them how to apply that information in real life applications.

The biggest thing I will take away from this project is perseverance. Something may not work the first, second, or third time, but retrying different things and finding your mistakes is what makes you a better person in any field you are working in. Eventually you will solve that problem which will make you feel amazing.

* Christian Mack

As a member of the design team, I had the opportunity to work on this robot for fall and spring semester. In the fall semester, the focus was to complete the upper body for the robot. In the spring, I was able to complete the mecanum drive and coordinate with arduino team to finalize the moving components. During the two semesters, I was able to learn many things through research.

One thing I learned was how to use the Computer-Aided Design software Blender and 3d printer. During the fall semester, I used blender to create many parts used in the body, neck, and the head. My skills in software are still at introductory levels, but I was able to teach myself how to create basic parts using online resources. Also, with the help of Dr.Kwak, I was able to earn the basic process of how to 3d print an object. In our case, we sliced the stl file in the software to convert it into gcode. After file was converted, we put it into printer so the 3d printer can print it. Another thing I learned was how to create things using available, cheap resources. As an example, I used newspapers and glue to compose the head of the robot. The method was used by cosplayers to make helmets. Also, upon building the mecanum drive, I purchased parts from different companies. This is because if mecanum drive was purchased as a set, it would be expensive. As a result of purchasing and integrating parts of different standards together, I was able to keep the cost under $150. The hardest part was looking at the specification and putting the components together. The mecanum drive system was not used this semester, but in the future, other students can test it as a possibility of another drive system.

* Ryota Tsutsumi

Despite joining the design team a semester later than the other members, my experiences with time management, innovation to solve the obstacles we faced, and 3D printing gave me an invaluable amount of knowledge that will help me in my future collegiate endeavors with engineering. My main job within the design team was delegating work and setting deadlines for myself as well as the other members. At the beginning of the spring 2018 semester, I projected that our final date for a completely finished robot body would be in March. However, throughout the semester, we had many complications that caused us to push back the completion date to the end of the semester. Even though these complications made the final product of the robot different from the vision we initially had, I found that these obstacles made me think harder about why I chose to do this research.

When I first came onto the project, I had many misconceptions of how well the design team could manage our first encounters with 3-D printing and modeling. As we try new things in life, they often do not turn out to be perfect on first attempt, but after many attempts and practice, you develop the skills needed to properly execute your plans. This is an important lesson I learned from robotics research. In a classroom setting, it can be hard to have life experiences and recognize how to apply valuable knowledge beyond class. My skills in time management, critical thinking, and leadership benefitted the project by encouraging more structure within our work and offering unique solutions to the various problems the design team encountered. Some of my contributions to the project include our initial work outline for spring semester, the suggestion to use Styrofoam to craft pieces while the 3-D printer in Cochran was inoperable, and creating a knight base to conceal some of the excess wiring underneath the robot. Throughout my time spent on the robotics research project, I have sharpened my pre-existing abilities, and collected a plethora of new technical and experiential based abilities.

* Haley Stokes

Over the course of the last two semesters, I have had the pleasure to work as a member of the design team of the Middle Georgia State University Information/Technology Robotics Research Project. My main role has been as the primary designer of the robot and the resident head of 3D printing. In the past few months, I have gone from knowing practically nothing about 3D design and printing to building, owning, and modifying my own personal 3D printer. I have learned to use 3D Computer-Aided Design and Drafting Software in conjunction with 3D Slicer Software and 3D printers to turn my designs into reality.

This has been an invaluable experience. Not only have I developed technical knowhow that I can carry over into the next stages of my college career, I have learned how to teach myself to operate new and complex machinery, read technical instruction manuals, and seek help on Internet technical support forums. Furthermore, I have gained experience in closely working with multiple people and teams to build a finished product. For example, I had to collaborate with the programmers of the robot in creating a design that would allow their programs to function properly. Overall, this research project has been an invaluable experience that I would not trade for the world.

* Maci Harrell

There were many things I learned from this research class over the last two semesters. Some of there were intellectual while others were more social than others. In this class, I learned how a 3D printer works as well as how to use one, how to use Blender and other 3D modeling software, and also a little bit of programing. On the more social side, I learned how to appropriately divide out work, how to come up with and share ideas, and also to locate premade models that we were allowed to use. I was originally brought on to this project to come up with ideas for the robot and to think of potential problems the project may run into and then come up with a unique and creative solution to any problem. One of the solutions was to use a random number generator to select how the robot would blink out of a set of designs me, Ryota, and Maci came up with so the robot would feel more human.

* Will Suggs

Going into the project, I had proficiency with object oriented programming in languages such as Java and Python and absolutely nothing else. The project pushed me beyond my boundaries to try technologies I had no prior experience with or knowledge of. The group I was assigned to was responsible for developing the moving parts of the robot such as the head and wheels in addition to creating and controlling the eyes. The technology we used to control all the components was Arduino, a specialized microcontroller, and it required an understanding of C++.

The first semester was not difficult because I had prior experience with languages similar to C++, but the second semester was when I had to change my programming style. All of my previous projects were solo and success depended on whether I could read my own code. Second semester The hardware group gained two new members at the beginning of the second semester. The addition of Sir Laurence and Christian prompted me to organize my code for readability and longevity. Github was the next technology I harnessed to track code changes among four developers as well as to benefit those who may use our code in the future.

The amount of experience I gained through this project learning approach significantly surpasses all I could have learned within a classroom. Having the ability to experiment and fail without the repercussions of a bad grade gave me the liberty to push boundaries and to develop a deeper understanding of the underlying technologies. The beginning of this project lacked general direction and instructions, but this opportunity allowed us to develop our own systems for success.

* Odell Blackmon, III

After two semesters of working on Knightbot, I’ve learned a lot about what it means to be a student researcher.

For the first semester, I was primarily focused with the servo motors, controlling the angular movement capabilities and neck component of the robot. It became apparent to me that the servo motors were quite simple in design and functionality. They come with three wires, typically red for power, yellow for analog, and black for ground which are to be connected to the Arduino mainframe. After inputting various codes on the Arduino, the servo motors have a wide range of capabilities. My first code was simply programming the motor to rotate 180 degrees and then back to its original point in a continuous loop. While previously I had very limited programming experience, I learned quickly that the technical skill wasn’t as difficult as I had imagined. I go on to program multiple servos at once, controlling the servo manually with a potentiometer and joystick, and attempt to wirelessly change the angle of rotation through Bluetooth, although I was not successful.

In the second semester, I had moved on from my near mastery of the servo motors and decided to further specialize in the lateral movement capacities of the robot. While several options were available, the team made a consensus decision to use the tracks already in our possession from a previous project. While the tracks were functionally operable, it was another challenge to program them to work in specific ways. After extensive collaboration with Christian Mack, my primary research partner, we could program two DC motors to move backwards, forwards, and alternate their power so that while one was off the other was on and vice versa. We then went on to attach an ultrasonic sensor so that the tracks would now avoid walls and other objects instead of blindly moving in a direction. Additionally, I programmed the tracks where they could move forward for ten seconds before switching direction and moving backward on a continuously loop and where one DC motor would temporarily shut off while the other was on, alternatingly allowing for circular movement.

Engaging in research requires a certain level of teamwork, organization, and commitment that I previously had not been exposed to. After completing my robotics course, I believe I am a better student than before enrolling. And considering that I plan to major in computer engineering at the Georgia Institute of Technology, I can declare that my work with the electrical-hardware aspects of the Arduino has better prepared me for success in the field.

* Adetunji Adeoba III

I spearheaded the AI aspect of Knightbot, and the learning curve was quite steep. I had to learn the in’s and out’s of Google’s APIs, how to communicate between these API’s, how to handle a front-end user experience with a python application, as well as how to run a server and construct a webhook. Not only this, but I accomplished all of it while having limited experience with Python and absolutely no experience working in linux. At nearly every stage of development there were countless issues, and my inexperience certainly showed. It wasn’t the major things that were causing problems, but the tiny details that I’d rush by. Thankfully, during second semester I got some assistance from Eli, and it was great having a second pair of eyes looking at everything. This brought it’s own set of challenges. I had to make sure to teach him everything that I had learned in the first semester so we could both independently work on the project. But I realized just how much I had learned when teaching him. During the first few days, I’d get him to do a small task and he’d ask me about something simple like how to rename a file in the linux terminal, or the command for powering off the Pi. Learning linux by actually working with it was much more effective than I’d imagine it would be inside a typical class, and I’m glad I got to learn so many things by moving beyond my boundaries and learning through experience.

However, the most important aspect of the project was the developer experience as a whole. I did FRC Robotics in highschool, which had a very similar team-oriented aesthetic. However, this experience felt completely different. I felt wholly responsible for my piece of Knightbot, and I felt really attached towards its success. The deadlines felt serious, I could feel every ounce of progress that we were making, and I was much more invested in the project than I was in previous projects similar to this one. This learning experience was extremely enriching, and I look forward to more research opportunities in the future.

-Trevor Pope

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# Summary

Knightbot was a success for everyone. In regards to learning, each person grew beyond what they could achieve inside a regular classroom environment. It was more than learning a new programming language, or harnessing a 3D printer, rather the hands-on experience that drove us to overcome obstacles as we became more and more familiar with our tools and our goals. Moreover, the experience was one that we shared together. As a team, we supported each other through those obstacles. The Arduino team often had solutions for the Pi’s python errors, and the Pi team often had advice for fixing a part of the design. We drafted the design entirely, with a few vague bullet points at the beginning, and eventually molded it into a functional robot. From nothing, we made something, which is absolutely incredible. Of course, it’s certainly not perfect. There’s still a noticeable delay between question and response; a nest of wires poke out of Knightbot’s armor and it’s LEDs are a little wonky; and the frame is fragile and stiff. However, there’s nothing but pride when we look at it.