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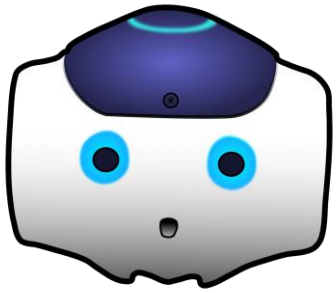

AriGato

NAO Documentation

Human-Robot Interaction

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ARIGATO, CENTRAL WASHINGTON UNIVERSITY
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"Our mission is to create and showcase meaningful and exciting human-to-robot interaction using the Aldebaran NAO robots recently required by CWU." – AriGato Robotics

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SECTION 1: INTRODUCTION

1.1 PROBLEM

The AriGato team has been tasked with showcasing the capabilities of the Aldebaran NAO robots that were recently acquired by Central Washington University, by means of creating various forms of human-to-robot interaction using NAO's numerous technological features. The client has specifically asked for the robot's ability to recognize and follow verbal commands, display both basic and advanced movement options, and finally use of its cameras to some extent to all be incorporated into this software project.

1.2 SCOPE

NAO comes pre-packaged with a vast library of Application Programming Interfaces (API's) consisting of libraries of functions that will help AriGato achieve their tasked goals mentioned in Section 1.1. The team will create many modules for the NAO robot over the course of the three-month project, using the NAOqi framework (NAO's operating system and proprietary library of functions), as well as the Python programing language; these various modules will be created to accomplish all of the tasks desired by the client. These tasks will operate by interacting with the user via verbal communication and physical responses. The goal of these responses is to showcase the potential capabilities of the NAO robot, so it is important to make sure NAO has a wide variety of responses and functions of different types.

Many of NAO's features make use of its built-in high definition cameras and sound processors, which allow it to take in input through a variety of methods and produce output. The NAO does not require a constant connection to the internet, however some features will be limited when "off-the-grid"; such as when the NAO needs to fetch data or perform certain calculations. AriGato has the ability to upload programs and features to the NAO's memory unit – meaning NAO will not need to be connected to a computer or the internet at all times to be interacted with.

1.3 DEFINITIONS, ACRONYMS, AND ABBREVIATIONS

ALDEBARAN

A French robotics company, acquired by SoftBank Robotics in 2015. Developer of NAO, NAOqi, and Choregraphe.

API

Application Program Interface.

AUTONOMOUS LIFE

The application housed on NAO that "gives it life". With Autonomous Life activated, NAO becomes visually alive – by moving, "breathing", and being aware of its surroundings.

CHOREGRAPHE

A multi-platform desktop application that allows users to create animations and behaviors for the NAO and test them in both simulated and real environments. It also allows users to monitor the NAO's visual and audio sensors.

CLIENT
Dr. Szilard Vajda, professor at Central Washington University's Computer Science department, the requester of this project

ETHERNET
A common form of network cable. It allows a connected device to join a local area network (LAN) in order to connect to and browse the internet.

LIBRARY
A collection of well-defined resources and implementations of behavior, written for/in a particular programming language for use by other developers to simplify and speed up development for a system.

MODULE
A program that is developed for use with/on the NAO robot. A module is classified as a feature for NAO that has a "trigger phrase", and then a timeline of events using Python code to have the NAO move around or speak certain phrases in responds to the corresponding trigger phrase.

NAO
An autonomous, fully programmable, humanoid robot designed by Aldebaran Robotics.

NAOQI
A Linux-based operating system stored in the robot's memory at all times; used for running and controlling features and programs.

SEE
The NAO robots cannot "see" in a physical sense but has cameras that it can use to record images to identify its surroundings.

SENSOR
Measures the robot's configurations, conditions, and its environment and sends such information to the robot for processing.

SOFTWARE
A set of computer instructions used to obtain input, and then manipulate that input in order to generate relevant output in terms of function and performance as specified by the user.

USER
A person who will interact with and make use of the NAO's various capabilities.

WI-FI
Short for "Wireless Fidelity". A means of allowing computers, smartphones, and other internet-enabled devices to communicate with one another wirelessly.

1.4 OVERVIEW

The purpose of this document is to describe the requirements of AriGato's Aldebaran NAO project. Section 2 provides an overall description of the project and its requirements, including the hardware, users and individual functionalities. This section is followed by a requirements overview (section 3) that describes more in-depth the required functionalities of the NAO robot, as well as a question and answer section. Section 4 then analyses the validity, feasibility, and consistency of these requirements. Finally, section 5 prioritizes these requirements.

SECTION 2: OVERALL DESCRIPTION

Note: This project will be independent and self-contained. It will not be a part of a larger system.

2.1 PROJECT PERSPECTIVE & FUNCTIONALITY

2.1.1 HARDWARE

This project will require the use of an Aldebaran NAO robot. AriGato will have access to a NAO robot provided by the CWU Robotics Lab, as well as an office space in the newly constructed Samuelson Building, complete with both Windows and Mac computers that can run the Choregraphe software. Choregraphe is fully functional on Windows and Mac, and available on Linux with limited support. Finally, a stable internet connection is required (and provided) for development of this project in order to access documentation pages, as well as make use of API and HTTP requests for various NAO modules.

2.1.2 USER INTERFACES (CONTROL METHODS)

The software has two possible modes of operation: The first by using a computer as a control terminal. In this mode, the NAO will be connected via Ethernet cable to a computer running Choregraphe. The Choregraphe software allows users to send premade or custom-made sets of instructions to the NAO, which will then be acted upon. This mode is limited however, as the robot can only go as far as the attached Ethernet will allow (basically, the robot must be in very close proximity to the control terminal computer). This mode is mainly for testing purposes.

The second mode, and main focus of this software project, is directly uploading the created modules to the NAO robot's memory unit located in its head. This will allow the NAO to operate with full functionality while completely disconnected from a computer, i.e., an Ethernet cord will not need to be attached to the robot for it to receive and act upon instructions. The NAO is capable of this thanks to its microphones and cameras. Users can interact with the robot using touch, motion, and spoken commands, using the multitude of sensors located around NAO's body.

2.2 SUGGESTED FUNCTIONALITIES

- Facial detection & recognition.
- Demanding physical tasks (e.g., dancing)
- Make the robot solve written equations.
- Give the robot ability to read and point out simple objects.

- Give the robot an understanding of American Sign Language (ASL) or simple hand gestures.
- Human/Robot game.
    - Like “Bop It”
    - Human is given instructions to perform within a certain amount of time
- Make robot act more human-like.
    - Casual standing position.
    - Reacts to stimulus with body language.

2.3 USER CHARACTERISTICS

There will be two classes of users that will interact with the NAO unit: regular users, and administrators (who also act as demonstrators).

The NAO robot will be interacting with a wide range of people that classify as “regular users,” such as computer science students, department faculty and staff, the general university population, university visitors, and more. The Users will have differing levels of experience. AriGato envisions the NAO to be used as a demonstration tool for any person that might be interested in the realm of computer science or robotics, such as primary school students or prospective college students. Regular users will interact with the NAO by giving it verbal commands and specific gestures or movements to invoke a corresponding response.

Administrators are people who will manage the NAO unit after the AriGato software team has delivered the final product. These users will manage the storage and maintenance of the NAO, as well as plugging the robot into control terminals, and charging it. They will also be responsible for keeping the NAO updated to any new firmware changes from Aldebaran, and possibly adding new functionality to AriGato’s software in the future, if desired. Finally, administrators will typically be the ones to demonstrate the NAO’s full range of capabilities to anyone interested in the robot.

2.4 CONSTRAINTS AND LIMITATIONS

The NAO model in use contains 8GB of onboard memory, meaning all code and additional data, such as stored images, will have to be able to be stored within this limited memory. While it is unlikely that this constraint will become a problem, it is something that should be kept in mind.

Another unfortunate constraint of the NAO robot is the overall quality of its various sensors around its body; including, but not limited to: its microphones, cameras, and gyroscopes. Although the NAO comes packed in with HD cameras in its eyes, it occasionally has difficulties locating a target (e.g., a user, or an item in front of it). Additionally, the sensors are not always accurate because a robot’s environments are always changing, so it will be taking in a lot of information at once, potentially causing slowdown or accuracy difficulties.

Furthermore, through AriGato’s independent study of the NAO’s capabilities, they have noticed that the unit’s microphones require commands to be given loudly, relatively slowly, and with extremely clear pronunciation in order for the NAO to correctly parse the commands and give appropriate responses. It is also difficult for the microphones to pick up specific commands if it’s in a crowded room with many different voices talking or faces in NAO’s field-of-view. Despite these limitations, AriGato will work diligently to make their NAO software perform quickly and accurately.

Additionally, NAO should always be kept connected to the internet to make use of all the offered features. Though the NAO is functional without an internet connection, some commands will potentially require the NAO to make use of an internet connection to provide a response. This should not be an issue, as the NAO is primarily kept within university premises, which has a persistent Wi-Fi connection around the entire campus.

Given the steep cost of the robot, AriGato will also have to be mindful when programming physical activities, such as balancing or walking. If something were to go wrong, the robot may end up walking off a table, or falling onto a sharp object. The robot's arms have many mechanical joints which move along three axes. When programming an arm joint to specifically move, it could damage the hardware if the arm tries to move in a way it physically cannot. The same goes for NAO's leg and finger joints.

A small note should be made that the NAO robot has about a 90 minute active-use battery life, meaning that future users will only be able to use the NAO unplugged for around an hour and a half before it must be charged again. This constraint should not affect our development, as we will always be near charging ports and control terminal computers.

2.5 ASSUMPTIONS & DEPENDENCIES

The first assumption we've made about the NAO is that it will typically, if not always, be kept on university premises, where its status will be resting when not in use, and will always be in range of an internet connection. In the case that a future administrator of the NAO would like to take the unit out of the university network, it will need to be configured to the new location's internet settings.

The NAO robot can be programmed to do tasks such as using web APIs, but those functions would be a small portion of what it will be able to do. The assumption being made is that it will have access to the internet while being demonstrated. Not having any internet access would prevent it from being able to perform tasks using web API's.

Another assumption is that users will expect only the listed set of commands to be the set of functionalities the robot has (i.e., there is a finite list of functionality). Of course, there are a few small built-in commands that each NAO unit has (such as "What is your IP address?"), aside from these small built-in functions, the only things the NAO will be capable of doing is what we program it to do.

Finally, we are assuming that the hardware of the NAO unit will work properly at all times. However, the video and audio processing capabilities of the NAO do occasionally limit the robot from understanding every command correctly. We will be working around these potential technical limitations, and assume that the sensors will all work properly, 100% of the time. To clarify, no work will be done to improve the sensors of the NAO, as that is out of the scope of our software-focused project.

2.6 HIGH LEVEL DESIGN

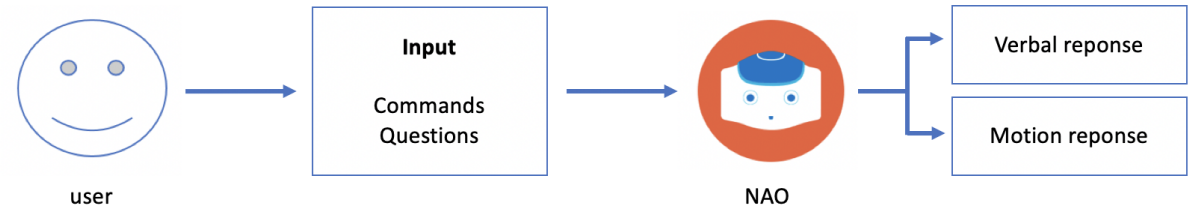

FIGURE 1 - USER-ROBOT INTERACTION

The user will input to the robot using verbal commands from a finite list. NAO will process and respond to these inputs with emotional responses, verbal responses and movement, depending on the input.

SECTION 3: REQUIREMENTS OVERVIEW

3.1: REQUIREMENTS CHECKLIST

NAO should be able to:

- Quickly recognize and act upon basic commands from a specific finite list.
- Quickly answer all questions and inquiries from a specific finite list.
- Demonstrate the movement of each appendage (arms, fingers, legs, etc.) when reacting to certain commands or gestures.
- Display advanced, possibly strenuous movement options (e.g., dancing).
- Recognize when a user has said “foul” language, and react by telling the user to watch their language, or some similar phrase.
- Access the internet for certain commands by means of API/HTTP requests.
- Use its cameras for facial detection & recognition features.
- Come provided with extensive documentation on the how’s, what’s, and why’s of the software system that has been programmed for it.

3.2: FUNCTIONAL REQUIREMENTS

- Be able to quickly recognize and act upon basic commands and gestures from a specific finite list. **[Requirement ID: FR-1]**
- Be able to quickly answer all questions and inquiries from a specific finite list. **[Requirement ID: FR-2]**
- Be able to demonstrate the movement of each appendage (arms, fingers, legs, etc.) when reacting to certain commands or gestures. **[Requirement ID: FR-3]**

3.3: NON-FUNCTIONAL REQUIREMENTS

- Be able to display advanced, possibly strenuous movement options (e.g., dancing). **[Requirement ID: NFR-1]**

- Be able to Access the internet for certain commands by means of API/HTTP requests. **[Requirement ID: NFR-2]**
- Be able to use its cameras for facial detection & recognition features. **[Requirement ID: NFR-3]**
- Be able to recognize when a user has said “foul” language, and react by telling the user to watch their language, or some similar phrase. **[Requirement ID: NFR-4]**
- Come provided with extensive documentation on the how’s, what’s, and why’s of the software system that has been programmed for it. **[Requirement ID: NFR-5]**

3.4: REQUIREMENTS Q & A

What will the system do?

- The goal of this project is to give the robot multiple functionalities of differing types to be showcased.

Should there be different modes of operation?

- Different modes of accessing NAO’s functionalities should be available.

What format should be considered for the input/output?

- Input for the robot will be verbal commands.
- Output will be verbal responses and physical movements, possibly using the internet.

Should we code responses to verbal commands?

- The robot should be able to respond to verbal commands as required by the operation it is performing.

Should the robot be able to recognize specific people?

- Yes, facial recognition is required for this project.

How should the NAO react? Verbally? With body language? Use of the NAO eyes? A mixture of these?

- NAO should be able to react verbally and with body language/movements.

Who might be changing our code in the future?

- Administrators, future CS481 students, as well as robotics students may be viewing and editing this project’s code in the future.

How easy should we make it to add our functionality to a different kind of robot? Will that even be possible with the NAO API?

- Moving NAO functionality to other Aldebaran robots, such as Pepper, could be a challenge as other robot models from this company have different functionalities than NAO, such as not having legs or having a screen on its chest.

How many NAO units will we have access to?

- The team will have access to a single NAO robot, however there are 6 NAO’s in total on the CWU premises.

When will AriGato have access to NAO?

- The team will be able to access their provided office during all of the Samuelson building's open hours (Mon-Fri, 8am-8pm). Due to the team having exclusive access to this office-space, there should be no scheduling conflicts with other teams/individuals.

What documentation is required?

- Create a fully-fledged documentation featuring software requirements specification, user manual, testing scenarios/data, bug/problem report, final progress report, and references.

In what environments will the NAO be used?

- NAO will be used exclusively within the Samuelson building during the project's three-month period, as well as possibly being showcased at CWU's SOURCE presentations in mid 2019.

What programming languages will be used?

- Python 2.7.

Where can information on the NAO API be found?

- Information on the NAO, NAOqi, and Choregraphe can easily be found by looking up "Aldebaran NAO" online and finding the corresponding documentation. For easy navigation to these pages, visit the references section at the end of this document.

Can NAO identify the face, and does NAO have any facial mapping algorithms already equipped?

- NAO has an API that locates the user's face and maps out its important features. There is no need to "reinvent the wheel" for this portion of the project.

SECTION 4: REQUIREMENTS ANALYSIS

4.1 VALIDITY CHECK

The purpose of all the suggested requirements is to showcase the abilities of the robot, as specified by the client. Following basic commands showcases the robot's ability to understand language as well as its ability to follow through commands. Using NAO's joints and "muscles" to perform various physical movements will showcase the ability NAO has to be humanoid and autonomous. Identifying the programmers and learning names will show off NAO's facial mapping and facial recognition abilities.

This project's requirements are **valid.**

4.2 FEASIBILITY CHECK

AriGato's team of software engineers have extensive experience in all tools and technologies mentioned in this document. Each of them have already developed and ran small test programs on the NAO unit, and performed extensive research on the different libraries and capabilities of the NAO. AriGato can confirm that there will be no conflicts in the different tools that they will make use of (Python, Choregraphe, etc.) and put together. Aldebaran's provided API's will allow a very timely development period, as functions such as "move right hand upwards"

for example are already written and tested. It will be up to our team to make use of and combine these provided functionalities to make an overall quality software package.

Some of the suggested functionalities are not feasible in the amount of time that we have. Learning American Sign Language (ASL) was a suggestion, however, NAO does not natively recognize finger positions, and writing a function to do this would take an incredible amount of time and study, and therefore is out of the scope based upon the team's current skills and allotted time.

It is currently unclear how the NAO API's facial recognition function works; however it does have facial mapping. It may be difficult, but facial recognition is a distinct possibility

This project's requirements are **feasible.**

4.3 CONSISTENCY CHECK

Thorough analysis of the requirements checklist has not shown any conflicts of consistency. The Choregraphe software is capable of taking in as input all of the different languages and libraries discussed in this document, and allows the AriGato team to easily test new code in a safe environment. The NAO robot is capable of taking on different "states", such as a "waiting state", where it will sit idly and wait for some command to be given, or an "active state" where the NAO is currently performing an action. This will allow all of our functions and methods to concurrently exist in the robot's memory and be acted upon when necessary (i.e., when a command is given). There will be no consistency conflicts in this software project.

This project's requirements are **consistent.**

4.4 PROJECT TIMELINE

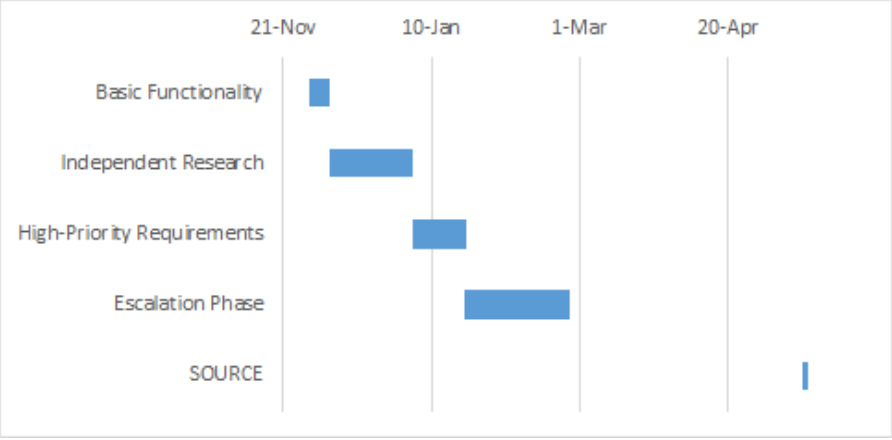

FIGURE 2 - PROJECT TIMETABLE

The team will begin this project by learning how to program basic functionality for NAO, until the winter break, in which they will begin independent research. January 3rd, when the break ends, the team will begin working on the high priority requirements. The team will divide into smaller groups of one to two, each working on a set of modules,

accompanied by meeting weekly to test and discuss current module projects. When all the high priority modules have been completed, the escalation phase will begin.

During the escalation phase, team members will be in larger groups of 2 to 3, as the lower priority modules are more complex, and will require more work. Again, the teams will meet at least once a week to test modules and discuss if the groups should take on more modules. At the end of February, the final testing will begin, and the project will be presented to the client for final approval, followed by the final presentation in early March.

Finally, May 15th to May 16th, the team will present the NAO robot at CWU's Symposium Of University Research and Creative Expression (SOURCE).

SECTION 5: PRIORITIZATION OF REQUIREMENTS

Based on AriGato's conversations with their client, the main requirement they should focus on is getting the robot to be controlled independent of the Choregraphe software, that is, all features should be **autonomous** and not require connection to the control-software. Specifically, the priority is to get the NAO robot to be able to understand human language and interpret it by reacting with a corresponding action.

Goals that will absolutely be met:

- Be able to quickly recognize and act upon basic commands and gestures from a specific finite list.
- Be able to quickly answer all questions and inquiries from a specific finite list.
- Be able to demonstrate the movement of each appendage (arms, fingers, legs, etc.) when reacting to certain commands or gestures.
- Be able to use NAO's cameras for facial detection & recognition features.
- Provide extensive documentation on the how's, what's, and why's of the software system that has been programmed for it.

Goals that we will strive to meet:

- Dance to music.
- Be able to display advanced, possibly strenuous movement options (e.g., dancing to music).
- Be able to Access the internet for certain commands by means of API/HTTP requests.

Goals that are possible, or "Stretch-Goals":

- Be able to recognize when a user has said "foul" language and react.
- Extra features, e.g., "Bop It" game.
- Read/solve written equations.

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NAO Documentation Part 2:

Tools Used

CONTENTS

AriGato has made use of a wide-range of tools to complete and enhance their Human-Robot Interaction project. This part of the documentation will discuss each of the tools that the team utilized, and an argument as to why these tools were necessary for successful completion of the project.

SECTION 1: HARDWARE

1.1 NAO ROBOT

The first, and perhaps most obvious tool that AriGato made use of was the NAO unit itself. As previously mentioned in this document, the CWU Computer Science department provided AriGato with one NAO robot to have full and exclusive access to throughout the course of the project. The project would have been impossible to complete without access to the NAO unit, as even though the Choregraphe software from Aldebaran provides a virtual (simulated) robot to test behaviors on, this simulation is quite limited; for example, it is not capable of playing sounds, meaning text-to-speech programs would've been impossible to fully test or interact with.

1.2 WINDOWS DESKTOP

Also provided by the CWU Computer Science department was a desktop computer running the Windows 10 operating system. Though it would also have been possible to complete the project's development on a Mac machine, the AriGato team members collectively had the most experience with the Windows operating system, and felt that development would be most efficient in this environment.

AriGato had discussions early on in the project's lifespan about using various Linux distributions to complete development, as this operating system provides heavy customization and control over the environment. The main reason that AriGato ended up not using Linux machines was due to the limited support that the Choregraphe software offers for this operating system. To take full advantage of the NAOqi API libraries, which is a necessity for the completion of this project, using Windows or Mac is a must.

SECTION 2: SOFTWARE

2.1 CHOREGRAPHE

Choregraphe is a proprietary program created specifically for the various robots created by Aldebaran Robotics. It provides an easy to use environment for developing behaviors the various robots. Choregraphe provides many useful features to make creating behaviors easy for both people new to programming, and for people with a greater knowledge of programming. There are many pre-built modules available which allows the user to quickly access any of the sensors in the robot, while also allowing the user to create their own modules. This combination creates a system that makes simple behaviors easy to develop, while allowing complex behaviors to also be worked on.

Of the various panels that are available to the user to display, the one of the most important ones is the Flow Diagram Panel. This is an area in Choregraphe where the user can take modules, small programs or functions, and connect them with lines to create the higher logic that ties the code together. Another important panel is the Script Editor. This is where the code inside the modules can be modified.

2.2 DOCUMENTATION

Aldebaran provides online documentation for both the NAO robot as well as the NAOqi framework. This documentation for the robot provides information on the different components of the machine. When it comes to basic information such as the names of the various motors and the functions which control them, there is plenty of information available.

However, when it comes to information which is not just explaining the different components and functions, there is little to be found. For example, to disable the fall manager for the pushup behavior, a specific variable needs to changed in order to allow it to be switched off. The current documentation provides two methods of doing so, but both methods are out of date. A solution was eventually found but it utilized a method that was not provided in the documentation.

SECTION 3: PROGRAMMING TOOLS

3.1 PYTHON 2.7

Python 2.7 is being used for this project because that is the language with the most support in both the robot itself, as well as in Choregraphe. AriGato chose to use Python 2 over Python 3 because both the robot and Choregraphe do not support Python 3, only Python 2. Additionally, Python was chosen over other supported languages, such as C and Java, because Choregraphe natively supports Python. To use the other languages, an external IDE would have to be used, and the process of uploading the programs to the robot is not as intuitive as Choregraphe. The APIs were much easier to implement, as most APIs as very easy to use with Python.

3.2 WEB-BASED API'S

For a few of our behaviors, we implemented web-based APIs to retrieve relevant data. The first API used is OMDB, which retrieves information about requested movies from Rotten Tomatoes. Specifically, we used it to get the ratings and a brief description of the movie. The second API is Open Weather Map, which is useful for getting weather information. We used it to get the current temperature and wind speed of Ellensburg, Washington. Using this information, we created a couple behaviors that gave the user relevant weather information. The last API is World Time API. Due to issues with using the robot's system clock, we decided to use an API that uses the device's IP address to get the current time and time zone.

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NAO Documentation Part 3:

Testing

CONTENTS

SECTION 1: UNIT TESTING

1.1 BEHAVIOR DEVELOPMENT TESTING

While modules are in the development stage, different parts of the behavior will be methodically tested for functionality to ensure that the entire behavior will function smoothly. When the behavior is completed, the author of the module/behavior will test it multiple times using Ethernet connection to the robot to make sure that it is ready to be implemented.

For example, if speech recognition module is used within a behavior, it will be tested multiple times to make sure that it responds to the appropriate phrases with certain reliability before connecting it to the response module to be triggered. The result of this testing is a higher quality and more reliable module that will be sent to the integration lead.

1.2 INTEGRATION TESTING

Before a behavior is to be implemented, it will be sent to the integration lead for testing and eventual integration. The integration lead will make sure that the module is properly documented with names and description, check and expand upon the verbal triggers, and then do their own round of

testing on the behavior. Another responsibility of the integration lead is to make sure that none of the trigger phrases interfere with the trigger phrases used in other behaviors.

SECTION 2: SYSTEM TESTING

2.1 VERBAL COMMAND TESTING

To test how well NAO will do in various environments, AriGato tested the reliability of NAO's speech recognition with various background noises. This ensured that the team members would know what to expect when demoing with the interference of different background noises.

To test this, the tester would repeat the same trigger phrase several times with the same background noise, and take note of NAO's confidence in the speech recognition. This confidence is shown in grey next to the green "Human" text in Figure 3. The tester would then repeat the test with various kinds of background noises and noise levels.

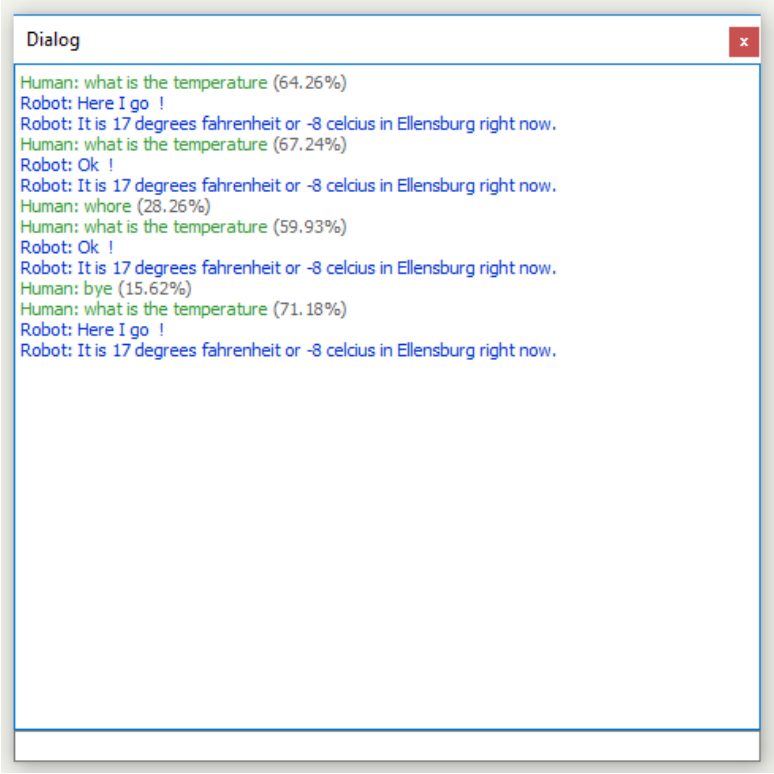

FIGURE 3 - NAO'S DIALOG BOX

What the team found during this testing was that quiet to moderate music had little effect on NAO's speech recognition confidence, while loud music inhibited its ability to hear anything at all. It was also found that multiple people speaking in quiet to normal volumes in the background had little effect on his speech recognition as well.

SECTION 3: USER TESTING

3.1 BLIND TEST

Users are told to interact with NAO only given a basic understanding of how NAO works. Users will be told that NAO must be looking at them with blue flashing eyes to receive commands, NAO can only take input from one user at a time, and that a nod from NAO with no other response means he heard what was said, but either did not have enough confidence in what was said to give a response, or did not understand at all.

The purpose of telling the users to interact with NAO without any other prompting is to see what commands/interactions the user expects of NAO. If a user gives a command for a behavior that is not implemented, but seems feasible enough to do, the team can then implement it on the robot. Some behaviors that have resulted from this testing are "What is your favorite song?" "What is your favorite color?" and "Can you tell me a joke?"

3.2 BEHAVIORS REVEALED

After the blind test, users are given the list of behavior names, giving them an idea of what NAO is capable of. They are then told to try to get NAO to do some things on the list by guessing the command phrases. The purpose of this is to see what commands a user might try without any prior knowledge of trigger phrases. This will give AriGato an idea of if the trigger phrases already on NAO are reasonable, and if other trigger phrases should be added

3.3 CONCLUSION OF TESTING SESSION

To conclude the testing session, the users are given a look at the behaviors section of the documentation. This way they can see the actual triggers for all the behaviors, and give any additional suggestions they have. They are asked for their overall impression of their experience with NAO, and then the session is over.

SECTION 4: TESTING SCENARIOS

For all testing purposes, you must get NAO's attention to initiate any interactions. Stand within a two-foot distance from the front of the robot and make eye contact to begin facial detection. Once NAO's eyes flash blue, the detection has finished and NAO will train its eyes on you. Users may greet the robot to ensure that it is listening and ready to execute an AriGato module. Commands and questions are recommended to be spoken loudly towards the robot with each word being clearly enunciated. Below are the main testing scenarios that AriGato has used to improve NAO's human-robot interaction.

Note: Actions are indicated by square brackets i.e. [NAO does jazz hands]. Variables are indicated by triangle brackets i.e. <Integers up to 12>.

AgeGuesser

User: Can you guess how old I am?
Robot: Okay. I'm going to give my best guess. Let's see, you look like you're <approximate age> years old.

CanYouDoMyWork

User: Can you do my work?
Robot: Nope! Doing your own work builds character!

DanceMoves

User: Can you dance?
Robot: [Dances to Beyoncé's Single Ladies]

Developers

User: Who is developing your programs?
Robot: The people who are developing my projects are Casey Chen, Hailey Dhanens, Matthew Harker, Angie Quach, and Derek Vaughan.

FavClass

User: What is your favorite class?
Robot: My favorite class is CS 481, because it is where I met my Capstone team before they were to graduate.

FavColor

User: Do you like any colors?
Robot: Red is my favorite color.

FavoriteProfessor

User: Who is your favorite professor?
Robot: Dr. Davendra is my favorite professor!

HowOldAreYou

User: How old are you?

- Robot: I am 42.
- Robot: You should never ask a robot its age.
- Robot: 1249 and a quarter years old.
- Robot: Old enough to know better.
- Robot: I was born yesterday.
-

JazzHands

User: Jazz hands
Robot: [Lifts both arms and rotates hands back and forth]

MoodGuesser

User: Can you guess how I'm feeling?

- Robot: You look sad. Cheer up! Try thinking about puppies.
- Robot: You quite happy today. That makes me happy too!
- Robot: Not looking so expressive today. Maybe you could try asking me to dance, it'll make you smile.

MoveFingers

User: Move your hands
Robot: [Opens and closes its hands]

NodYes

User: Nod your head
Robot: [Nods head twice]

OMDB Movies

User: Tell me about a movie.
Robot: Which movie would you like to know about?
User: <Movie name>
Robot: <Movie name> came out in <Year> and stars <Starring list>. Its Rotten Tomatoes rating is <Rating>%.

Pushups

User: Push ups
Robot: How many?
User: <Amount up to 10>
Robot: Okay, doing <amount> pushups. [Does pushups]

RaiseLeftFoot

User: Raise your left foot
Robot: [Raises left foot]

RaiseRightFoot

User: Raise your right foot
Robot: [Raises right foot]

SeeYouLaterAlligator

User: See you later alligator
Robot: In a while, crocodile!

SingAnthem

User: Sing the anthem

- Robot: [Sings the United States National Anthem]
- Robot: [Sings the United States National Anthem]
  User: Stop!
  Robot: [Stops singing and exits the module]

Temperature

User: What's the current temperature outside?
Robot: It is <current temperature in F> Fahrenheit, or <current temperature in C> Celsius in Ellensburg right now.

Time

User: What's the time?
Robot: [Returns time from worldtimeAPI]

TurnAround

User: Turn around
Robot: [Turns around]

TurnLeft

User: Turn left
Robot: [Turns in place to the left]

TurnRight

User: Turn right
Robot: [Turns in place to the right]

Turn Head Left

User: Turn your head left
Robot: [Turns head left]

Turn Head Right

User: Turn your head right
Robot: [Turns head right]

WalkBackwards

User: Walk backward
Robot: [Walks backward]

WalkForward

User: Walk forwards
Robot: [Walks forwards]

WalkLeft

User: Walk left
Robot: [Walks left]

WalkRight

User: Walk right
Robot: [Walks right]

WalkVariableDistance

User: Walk for me
Robot: What direction?
User: Forward/backward/left/right
Robot: Feet or inches?
User: <Unit of measurement>
Robot: How many units?
User: <Amount in integers up to 12 units>
Robot: [Walks <Amount> in <Direction>]

Weather Clothing Picker

User: What should I wear outside today?

- Robot: It's a little chilly but not too breezy, feel free to put on a warm coat.
- Robot: It's a bit warm and a little breezy, feel free to wear shorts and a t-shirt, maybe bring a long sleeved t-shirt just in case.

WhatTimeIsIt

User: What's the time?
Robot: The time is <current local time>.

FacialRecognition

User: Do you know me?

- Robot: Hi, <NAME>.
- Robot: Sorry I don't recognize you.

FavoriteSong

User: Do you like any songs?
Robot: I love Beyoncé's Single Ladies. It's so fun to dance with!

Jokes

User: Tell me a joke.

- Robot: Why was the robot so mad? People kept pushing its buttons.
- Robot: Why did the robot go to the doctor? It had a virus.
- Robot: What do you call a pirate droid? Argh2-D2.
- Robot: What did the man say to his dead robot? Rust in peace.

AriGato

NAO Documentation Part 4:

Bug Report / Problems Encountered

CONTENTS

SECTION 1: PROBLEMS ENCOUNTERED

1.1: INTERNAL CLOCK

PROBLEM

NAO's internal clock is originally set to UTC time. Time should be able to be changed on NAO's website by accessing his IP on the web browser, however after changing it and leaving the page, the time will always revert back to UTC. NAO's computer runs a Linux operating system, so NAO's computer was accessed via SSH and an attempt was made to change the time using command line. This was successful for a short time, however the time was 5 minutes off, and then after NAO was reset, the time was again changed back.

RESOLUTION

Because the team could not reliably change NAO's internal clock, whenever a user wants to get the time from NAO, an HTTP request is made to an API that gives the time, relative to the IP address making the request. The API could give time relative to an area code given, but it was decided that using the time relative to the IP address was beneficial, as wherever NAO is, the time will be accurate, assuming that NAO is not using a VPN.

1.2: SEGMENTATION FAULTS

PROBLEM

After extensive use, or if NAO has been running for an extended period of time, occasionally NAO will move to the crouching position, and his chest light will blink red, usually warm to the touch. The blinking red light means that NAO is in an unusable state, and cannot be recovered. After some research in documentation and command line investigation, it was found that this was indicative of a segmentation fault.

RESOLUTION

Because NAO reaches this state when doing absolutely nothing, the team could not narrow the problem down to a single module, and no changes could be made to fix it. The only solution found was to make sure NAO is not unnecessarily running for a long time, and does not do strenuous activity in succession for a long period of time. **It is stressed that this problem is not solved as the actual cause of the problem has not been found, however preventative measures have been made.**

1.3: TRIGGER CONDITIONS

PROBLEM

NAO would frequently trigger behaviors with no user prompting them. As more modules were put on the robot, the problem became more and more apparent as there were more modules fighting to run. Trigger conditions were set to activate when there was a person in view for more than 6 seconds

RESOLUTION

The team originally understood trigger conditions to mean the conditions under which a behavior could be prompted by the user. In actuality, trigger conditions meant that the behavior could trigger autonomously, meaning without user input. Once trigger conditions were removed the team no longer had such problems.

1.4: SPEECH RECOGNITION

PROBLEM

NAO could not take verbal parameters in commands (akin to Google Assistant or Apple's Siri).

RESOLUTION

After testing and research, the team concluded that NAO's speech recognition does not recognize what a user says word for word but recognized specific phrases **from a finite list**. This meant to take parameters, first the behavior had to be triggered, the parameter would be asked for by NAO, and then a list of specific answers had to be put into the speech recognition module in a switch statement that will return the answer.

1.5: OVERHEATING

PROBLEM

Occasionally when performing strenuous behaviors, a motor overheating warning will be triggered.

RESOLUTION

During both demoing and development, be careful not to do too many strenuous modules in a row. This avoids annoying warning messages and potential motor damage. If an overheat does occur, keep the NAO unit shut off for 30 minutes to an hour to allow cool-down.

1.6: MYSTERY RESPONSE

PROBLEM

When NAO is not doing anything, one is speaking to NAO, or someone else is in the same room as NAO, NAO will occasioanlly say strange responses, like "Let's go is been to" or ", and lets go has been too" (with ',' said as "comma"). When looking in the dialog, whether or not anything was actually said by "human", NAO believes that "bye" has been said.

RESOLUTION

No resolution has been made for this problem, as the cause is a mystery. It triggers regardless of if any input was given, and there are no behaviors implemented by the team that have the trigger phrase "bye", and when the user intentionally says "bye" to NAO, the same response is not given. This problem is but a small annoyance/"quirk", and does not affect regular functionality.

SECTION 2: BUG REPORT

AriGato

NAO Documentation Part 5:

User Manual

CONTENTS

SECTION 1: INTRODUCTION TO THE NAO ROBOT

1.1 WHAT IS NAO?

NAO is an autonomous, humanoid, fully programmable robot. NAO robots are capable of 25 degrees of freedom, and thanks to their humanoid nature and design, are able to walk around, adapt, and interact with their surrounding environment. Furthermore, NAO has 4 directional microphones, loudspeakers, and 2 cameras capable of filming and analyzing the robot's environment, and human faces, for example. NAO is additionally capable of connecting to the internet by means of ethernet or Wi-Fi – this enables features such as http requests or big data analytics using the cloud.

All of these features add up to NAO's capabilities essentially being limitless, it is truly up to the developer's imagination to decide what the robot will eventually be capable of. Development for NAO can primarily be conducted in either Python or C++, though some other programming languages have small amounts of support as well (e.g. Java, MatLab).

Additional Specifications:

- Dimensions: 22.6 x 10.8 x 12.2 inches (574 x 311 x 275 mm)
- Weight: 12.08 pounds (5.48 kg)
- Autonomous Battery Life: 60 minutes active use, 90 minutes stationary use
- Operating System: Linux-Based NAOqi 2.8 (Linux Distro: Gentoo)
- Processor: Intel Atom E3845 @ 1.91 GHz

1.2 WHO MADE NAO?

The initial development of the NAO robot began as early as 2004. NAO was created by a French company known as Aldebaran, who was later acquired by SoftBank Robotics, a company based out of Japan, in 2015. The first public version of the NAO robot was released in 2008, however the version this project will be focusing on (NAO v6, or NAO Next Gen) was released to the public in 2014. Aldebaran also created the "Choregraphe" software that a bulk of the development of custom modules for NAO are made in.

SECTION 2: NAO'S CAPABILITIES

2.1 INITIAL (PRE-BUILT) CAPABILITIES

The original capabilities of the NAO are put on the robot by subscribing to the Aldebaran "Basic Channel." Official documentation on this channel lists and describes its capabilities.[1] Below is a small table listing some of the pre-built phrases that NAO can respond to, most of which are available in English, French, and Japanese Language settings.

[1] http://doc.aldebaran.com/2-1/nao/basic_channel_conversation.html

“How are you?”	“Can you say goodbye?”	“What can you do?”
“Tell me all you can do.”	“How do I install an application?”	“How do I start an application?”
“What did I say?”	“Can you repeat please?”	“What is your IP address?”
“Are you connected to Internet?”	“What languages so you speak?	“Speak French.”
“Can you speak French?”	“Speak Japanese.”	“Speak Chinese”
“Can you speak Chinese”	“Speak softer”	“Speak louder”
“Can you stand up?”	“Can you sit down?”	“Crouch.”
“Lay down”	“Lift your right arm”	“Lay down on your back”
“Lay down on your belly.”	“Stop Looking at me”	“What is your name?”
“Introduce yourself”	“How much do you weigh?”	“How tall are you?”

2.2 VERBAL RESPONSES (Q&A)

CAN YOU DO MY HOMEWORK?

Verbal queues:

- “Can you do my homework?”
- “Can you do my work?”
- “Can you do my math homework?”
- “Can you do my Computer Science homework?”
- Can you do my CS homework?”
- “Can you code for me?”
- “Can you do my lab for me?”

Description: NAO will respond by telling the user that they should do their own work!

CLASS KNOWLEDGE

Verbal queues:

- “Can you tell me about a class?”
- “Tell me about some classes.”
- “Class info.”
- “Class information.”
- “Computer science classes.”
- “Describe the classes.”
- “What classes have you taken?”
- “Have you taken any classes?”

Description: NAO will respond by telling the user that he has taken all of CWU's Computer Science classes, and ask the user for which class they would like information about.

Note: NAO understands classes by having the user either A) individually saying each number of a class number (e.g. "three oh one", or "four ninety two"), or by saying the official class title (e.g., "Programming Fundamentals One", or "Data Structures One")

DEVELOPERS

Verbal queues:

- "Who is developing you?"
- "Who is developing your programs?"
- "Who is programming you?"
- "Who is on your capstone team?"

Description: NAO will list the team members of the AriGato capstone project.

FAVORITE CLASS

Verbal queues:

- "What is your favorite class?"
- "What is your favorite C.S. class?"
- "What is your favorite class at C.W.U.?"
- "What is your favorite class at Central?"

Description: NAO will respond with his favorite computer science class.

FAVORITE COLOR

Verbal queues:

- "Do you like any colors?"
- "Do you have a favorite color?"
- "What is your favorite color?"

Description: NAO will respond with his favorite color.

FAVORITE PROFESSOR

Verbal queues:

- "Who is your favorite professor?"
- "Do you know any professors?"
- "Who is your favorite person?"

Description: NAO will respond stating that his favorite professor is the AriGato group's amazing supervisor, Dr. Davendra!!

FAVORITE SONG

Verbal queues:

- “Do you have a song you like?”
- “Do you like any songs?”
- “Do you like music?”
- “Do you have a favorite song?”
- “What is your favorite song?”

Description: NAO will respond with his favorite song, “Single Ladies”!

HOW OLD ARE YOU

Verbal queues:

- “How old are you?”
- “What is your age?”

Description: NAO will respond with a randomly selected humorous verbal response.

JOKES

Verbal queues:

- “Do you know any jokes?”
- “Tell me a joke.”
- “Can you tell me any jokes?”

Description: NAO will respond with a randomly selected interactive joke.

SEE YOU LATER, ALLIGATOR

Verbal queues:

- “See you later alligator”
- “See ya later alligator”

Description: NAO will respond with “in a while, crocodile”.

SING THE ANTHEM

Verbal queues:

- “Sing the [national] anthem.”
- “Sing [national] anthem.”
- “Can you sing the [national] anthem?”
- “Do you know the [national] anthem?”
- “Sing the Star Spangled Banner.”

Description: NAO will begin to “sing” an auto-tuned version of the American National Anthem (an .mp3 file is played over its loudspeakers) and patriotically place its hand over its heart.

Note: “[national]” in the Verbal Queues section means the word is optional within the command.

WHAT TIME IS IT?

Verbal queues:

- “What time is it?”
- “Do you know the time?”
- “Can you tell me the time?”
- “What is the time?”

Description: NAO will respond with the current Time according to what time zone is given by IP. If Nao is connected to a VPN the time may not be local time.

2.3 INTERNET-BASED REQUESTS & RESPONSES

ROBOT MOVIE INFORMATION

Verbal queues:

- “Tell me about a movie.”
- “Do you know any movies?
- “Do you like movies?”

Description: NAO uses an HTTP request to get information about various robot movies (from a finite list seen below) from the RottenTomatoes.com API, and then repeats the information gathered from the website to the user.

Complete Movie List:

Astro Boy	Big Hero 6	Blade Runner
Chappie	I Robot	The Iron Giant
Making Mr. Right	The Matrix	Pacific Rim
Real Steel	Robocop	Robot & Frank
Robot Overlords	Robots	Saturn 3
Spare Parts	Surrogates	The Terminator
Transformers	Wall-E	

TEMPERATURE

Verbal queues:

- “What is the current temperature of Ellensburg?”
- “What’s the current temperature?”
- “What is the temperature?”
- “How hot is it outside?”
- “How cold is it outside?”
- “How hot is it?”
- “How cold is it?”
- “What about the weather?”

Description: NAO retrieves weather information from OpenWeatherMap.com and replies with the current temperature in Ellensburg Washington. Due to this module being intended for use in Ellensburg exclusively, if one wants to change the city, they will have to go into the module’s code and change it manually.

WEATHER-BASED CLOTHING RECOMMENDER

Verbal queues:

- “What should I wear outside today?”
- “What should I wear outside?”
- “Should I wear a jacket today?”
- “Should I wear a jacket?”
- “What should I wear today?”
- “What should I wear?”
- “Do I need a jacket today?”
- “Do I need a jacket?”
- “What clothing should I wear today?”
- “What clothing should I wear?”
- “What outfit should I wear today?”
- “What outfit should I wear?”

Description: NAO retrieves weather information from OpenWeatherMap.com and replies with a recommendation for types of clothing to wear outdoors based upon the current weather conditions (e.g., windy weather would cause NAO to recommend a jacket). Due to this module being intended for use in Ellensburg exclusively, if one wants to change the city, they will have to go into the module’s code and change it manually.

2.4 FACIAL DETECTION & RECOGNITION RESPONSES

AGE GUESSER

Verbal queues:

- “Can you guess how old I am?”
- “Guess my age.”
- “How old do you think I am?”

- "What is my age?"
- "How old am I?"
- "How old I am?"

Description: NAO will use its facial detection and mapping abilities to attempt a guess at the user's age. The guesser is not the most accurate, however the module is enjoyable and humorous.

FACIAL RECOGNITION

Verbal queues:

- "Do you know me?"
- "Do you remember me?"
- "Do you know my name?"
- "Do you know who I am?"

Description: Provided that a human face is within view - if NAO can recognize the face within 6 seconds, NAO will greet the person, if not, the module will time out, and NAO will say "Sorry, I do not recognize you".

Note: Learning new faces is currently only possible when the NAO unit is connected to a computer and the "Learn Face" box within Choregraphe is ran (i.e., there is no type of "Learn my face" command to have NAO learn a face on the fly).

MOOD GUESSER

Verbal queues:

- "Can you guess how I'm feeling?"
- "Guess my mood."
- "How do you think I'm feeling?"
- "What is my mood?"

Description: NAO will use its facial detection and mapping abilities to attempt a guess at the user's current mood based upon their facial expression. Similar to the "Age Guesser" module, the guesser is not the most accurate, however the module is enjoyable and humorous.

The moods that NAO recognizes are:

- **Happy** (NAO recognizes a wide smile).
- **Surprised** (NAO Recognizes a shocked looking face, categorized by a wide, open mouth).
- **Sad** (NAO recognizes a frown)
- **Angry** (NAO recognizes a scowl, categorized by a pursed frown, middle-lowered and furrowed eyebrows, flared nostrils).
- **Neutral** (NAO recognizes a straight, bored-looking face with no visible emotion being shown).

2.5 BASIC MOVEMENT OPTIONS

JAZZ HANDS

Verbal queues:

- “Jazz hands.”
- “Do jazz hands.”
- “Be jazzy.”
- “Can you do jazz hands?”
- “Move your arms.”
- “Move your arms for me.”

Description: NAO performs “jazz hands” with its hands, essentially a small wrist motion.

MOVE FINGERS

Verbal queues:

- “NAO, wiggle your fingers.”
- “Move fingers.”
- “Can you wiggle your fingers.”
- “Do your fingers move.”
- “Move your fingers.”
- “Move your hands.”

Description: NAO will open and close its hands to demonstrate the mobility of its hands and fingers.

NOD YES

Verbal queues:

- “Nod yes.”
- “Can you nod for me?”
- “Nod your head.”
- “Nod your head for me.”
- “Do you like Radio Head?”

Description: NAO will move its head up and down to demonstrate the mobility of its head/neck.

RAISE LEFT/RIGHT FOOT

Verbal queues:

- “Raise your left/right foot.”
- “Raise your left/right leg.”

- “Move your left/right foot.”
- “Move your left/right leg.”
- “Balance on your left/right leg.”

Description: NAO will lean to the side and begin to balance on one leg while lifting the corresponding foot in order to demonstrate the mobility of its legs and potential balancing capabilities.

TURN AROUND

Verbal queues:

- “Turn around”
- “Spin around”
- “Can you turn around?”

Description: Nao will turn 180 degrees

TURN HEAD LEFT/RIGHT

Verbal queues:

- “Turn your head left/right.”
- “Turn head left/right.”
- “Head left/right.”
- “Move your head to the left/right.”
- “Look left/right.”

Description: NAO will turn its head to the corresponding direction in order to further demonstrate the mobility of its head/neck.

TURN LEFT/RIGHT

Verbal queues:

- “Turn left/right”
- “Rotate left/right”
- “Can you turn left/right?”
- “Can you rotate left/right?”

Description: Nao will ask the desired degrees to turn, and then turn in the direction and distance accordingly.

WALK FORWARD/BACKWARD/LEFT/RIGHT

Verbal queues:

- “Walk <direction>.”
- “Move <direction>.”

- “Step <direction>.”
- “Take a step <direction>.”
- “Move your legs for me”
- “Move your legs”
- “Step to the left/right.”
- “Walk to the left/right.”
- “Move to the left/right.”

Description: NAO will move 0.2 meters in the desired direction. The last two queues will make Nao walk forward.

Note: Directional options include forward, backward, left, & right.

2.6 ADVANCED MOVEMENT OPTIONS

DANCE MOVES

Verbal queues:

- “Can you dance?”
- “Can you dance for me?”
- “Can you dance like Beyoncé?”
- “Can you dance to Single Ladies?”
- “Do the Beyoncé.”

Description: NAO will do a short dance routine, coordinated to Beyoncé’s “Single Ladies”, which will play over its loudspeakers during the dance.

PUSHUPS

Verbal queues:

- “Pushups.”
- “Do pushups.”
- “Do some pushups.”
- “Can you do pushups?”
- “Do you know how to do pushups?”
- “Can you do press-ups?”

Description: NAO will ask how many pushups you would like to be performed (he can do between 1 and 10 inclusive), and will proceed to do that many pushups.

WARNING

NAO **must** have plenty of clear and empty space around, in front, and behind it to do pushups, and must be kept away from any ledges - otherwise damage to the NAO unit is highly possible. Furthermore, making NAO do excessive amounts of pushups without a break can lead to overheating motors and will cause NAO to shut down.

****

2.7 MISCELLANEOUS MODULES

NO SWEARING

Description: NAO listens for swear words or other foul language, and responds to the user telling them that they should not use such language.

Note: This is a persistent module, meaning NAO is running it at all times. There is no specific command to trigger this module, instead NAO listens for words from a list of "bad words" to trigger it.

STOP MODULE

Verbal queues:

- "Stop."
- "Exit."

Description: NAO immediately stops the module it is currently running.

Note: This Feature is only available on the "Anthem" module.

SECTION 3: CREATING YOUR OWN NAO MODULES

3.1 INTRODUCTION TO CHOREGRAPHE

Choregraphe is multi-platform desktop application that allows users to visually program modules for the NAO robot (as well as other robot models created by SoftBank Robotics, such as Pepper). Choregraphe links up with the NAOqi framework (discussed in the following subsection), enabling users to easily create animations and behaviors for NAO, as well as test their creations using a simulated virtual NAO robot, or a physical robot connected via ethernet.

The Choregraphe software comes packaged with a ton of pre-built functions for NAO (known as "boxes" within Choregraphe) such as a "Say Box" which easily allows for text-to-speech programs, or a "Movement Box" which users can take advantage of to have their NAO robot move a specific distance in a specific direction. The biggest draw of Choregraphe however is the ability it gives users to create their own custom boxes, which can be combined to create an entirely custom sequence of events (known as a module) for NAO. These custom boxes can be written in a multitude of programming languages, but this documentation will be focusing on the Python language, as that is what AriGato has solely used in their project.

3.2 THE NAOQI FRAMEWORK

"NAOqi" is the NAO robot's operating system. It is a programming framework that is built and runs off of the Gentoo Linux Distribution. NAOqi is the main software residing in NAO's memory unit,

and controls all of the robot's motors, sensors, and functionalities. According to Aldebaran's documentation, "it answers to common robotics needs including: parallelism, resources, synchronization, [and] events[2]".

NAOqi offers a fully fleshed-out API for both C++ and Python, giving users access and manipulation of the full range of NAO's capabilities. There is a vast library of classes and their respective functions that can be called and expanded upon to create your own modules. A few examples of these classes are "ALTextToSpeech", "ALMotion", and "ALLeds", which each offer a variety of functions related to the class (e.g., ALMotion has a "moveTo" function that enables the NAO to walk). The "boxes" discussed in Section 3.1 rely on these API classes and functions to easily create modules for NAO.

3.3 CREATING YOUR FIRST MODULE

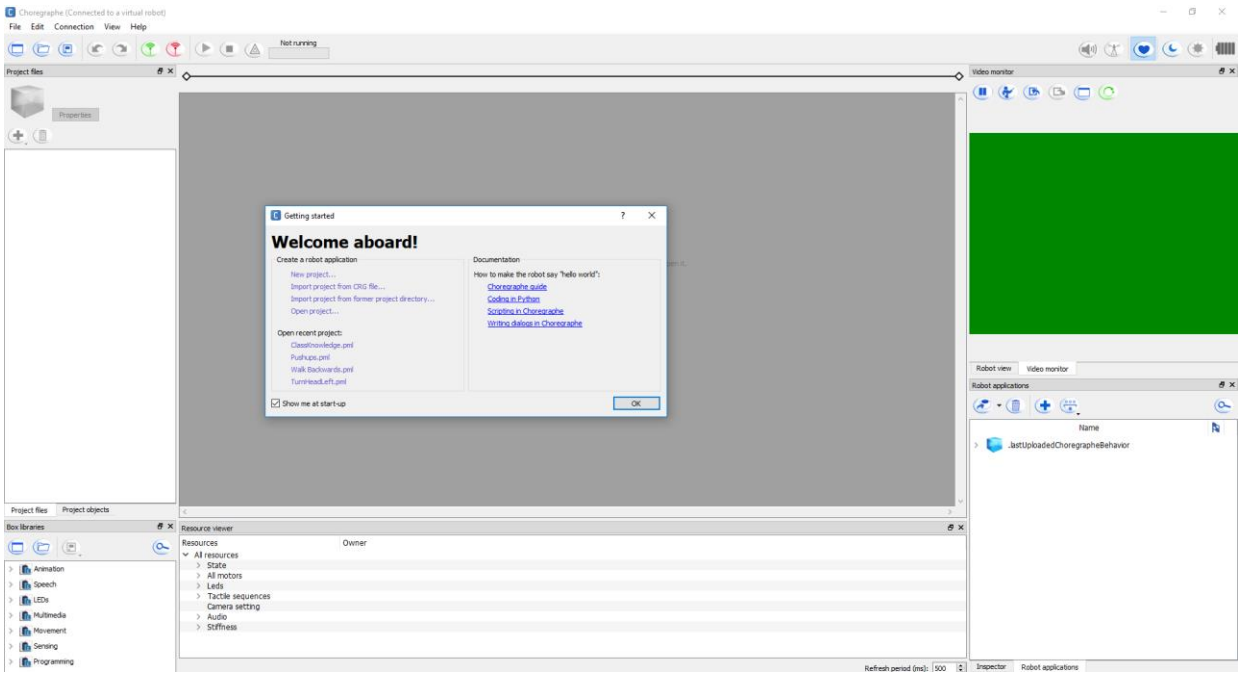

FIGURE 4 - FIRST OPENING CHOREGRAPHE

When first opening Choregraphe a window will pop up saying "Welcome aboard!" It will have a documentation section with a quick "Hello World" tutorial, and links to recent projects if there are any. To begin, either click "New project…" or exit out of the window, which will create a new project anyway. Start by navigating to the "File" menu in the top left corner of Choregraphe, and selecting "Project Properties".

[2] NAOqi Documentation Page: http://doc.aldebaran.com/1-14/dev/naoqi/index.html

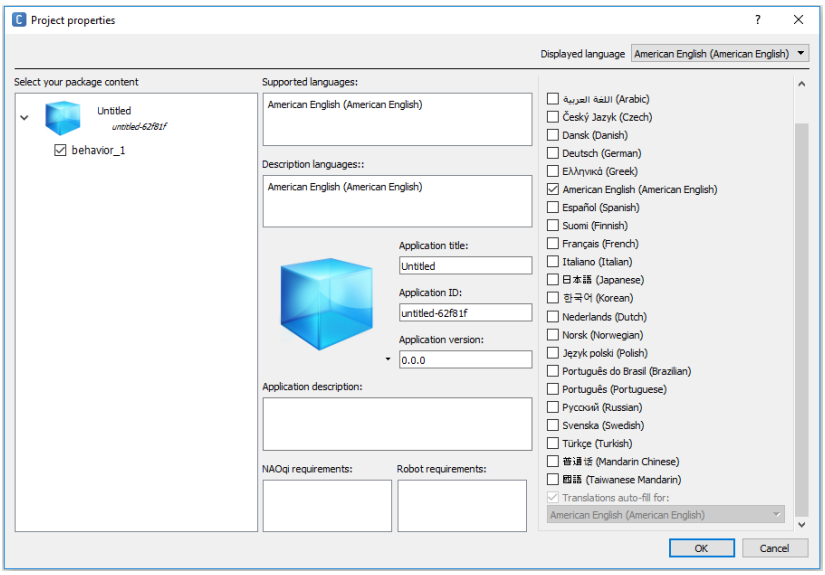

FIGURE 5 - PROJECT PROPERTIES

Fill in the “Application title” section with an accurate and descriptive title, so that when you eventually install your module onto the robot you will know exactly which module it is (it will otherwise be untitled which can become quickly confusing). Next click on the text “behavior_1” under the blue cube in the “Select your package content” section (upper left) of the window in figure 5.

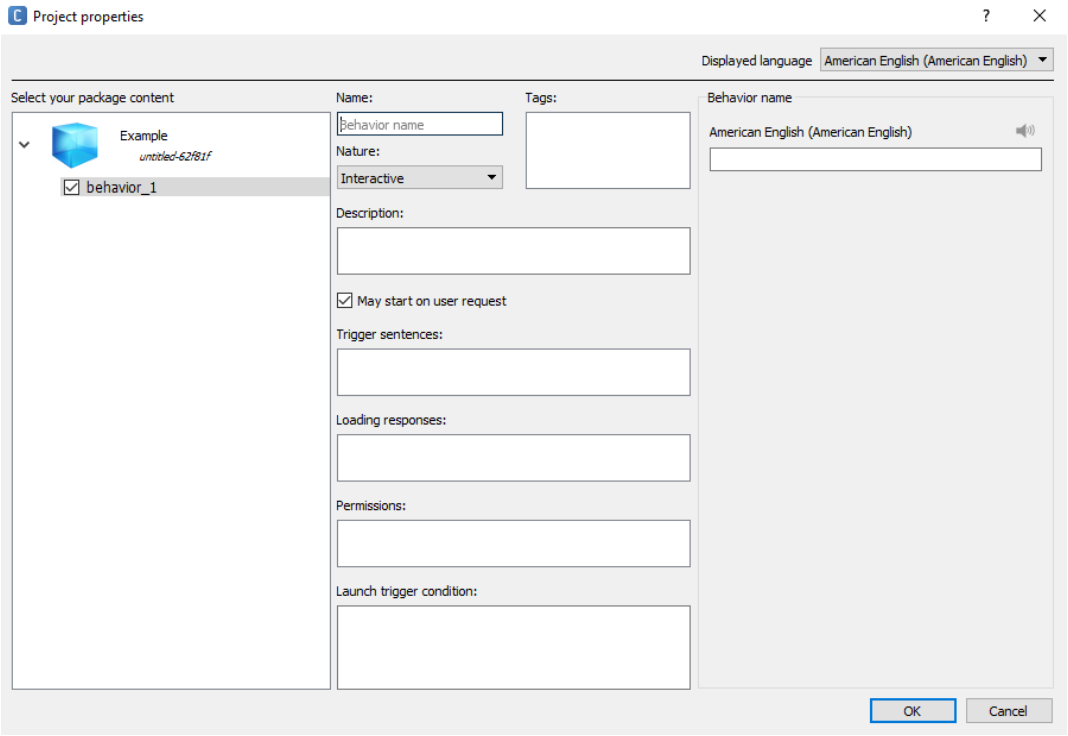

FIGURE 6 - BEHAVIOR PROPERTIES

Fill out the following sections shown in figure 6 after clicking “behavior_1”:

- **Name:** Make sure your module’s name is self-documenting (i.e., The name should be relevant to what the module does). A good example for a simple “Hello World” module would be “hello”, and a bad example would be “module 1”, or “myModule”.
- **Description**: This section will let future users know what your module is supposed to do, and possibly why you have created the module (to serve some certain purpose, for example). It is best to have your description be straight to the point, and not too long – but also informative with all the relevant information for the module included.
- **Nature**: Nature has three possible settings: “Interactive”, “Solitary”, and “No Nature”. **Make sure your module’s nature is set to Interactive**. This means that a user can trigger the module with verbal trigger sentences while NAO’s autonomous life feature is on. Solitary means that NAO will perform the module when he is not being interacted with, and can be interrupted at any time with Interactive modules. There is no available description for No Nature, so it is best not to make use of this mode.
- **Trigger sentences:** Trigger sentences are what NAO listens for to perform a corresponding module. Make sure each trigger sentence is unique, such that they don’t share a phrase with another module that is already on the robot. Additionally, it is important that trigger sentences do not have punctuation in them. It is also good to make a couple of similar trigger phrases for each module, so that the module can be more generally commanded. (Example: For an arm raising module, instead of just saying “lift arm”, also put “lift YOUR arm”, “Can your lift your arm” and “lift your arm please.”)
- **Loading responses:** Loading responses are intended to be what the NAO unit will say after being told a trigger phrase, before the module is actually performed. However, in AriGato’s experience, these loading responses do not actually work, and the robot only ever uses the default phrases of “Okay” and “Let’s go!”.
- **Permissions:** Permissions gives NAO the ability to perform a module while in the process of sitting down, standing up, or sitting in the charging station. The charging station is for NAO models that are not currently in the possession of CWU, thus being not relevant to the AriGato project or this documentation.
- **Launch trigger condition:** Launch trigger conditions gives NAO the ability to perform the module autonomously (i.e., without an user prompting, according to the conditions described). **DO NOT** use trigger conditions on modules that you wish only to be triggered by a user interaction.

Now that you have set all of the relevant project properties, navigate back to the main screen (known as the “workbench”) of Choregraphe. **Note:** For this tutorial we will be showing you have to create custom boxes using Python code, but will also make short mention of how to find and use the pre-built functions that are packaged with Choregraphe.

Right click anywhere within the empty workbench, and hover your mouse over the “Create a new box” option, inside of the submenu that appears, select “Python…”. Your screen should open a new dialog box called “Edit box”, and look the same as below in Figure 7:

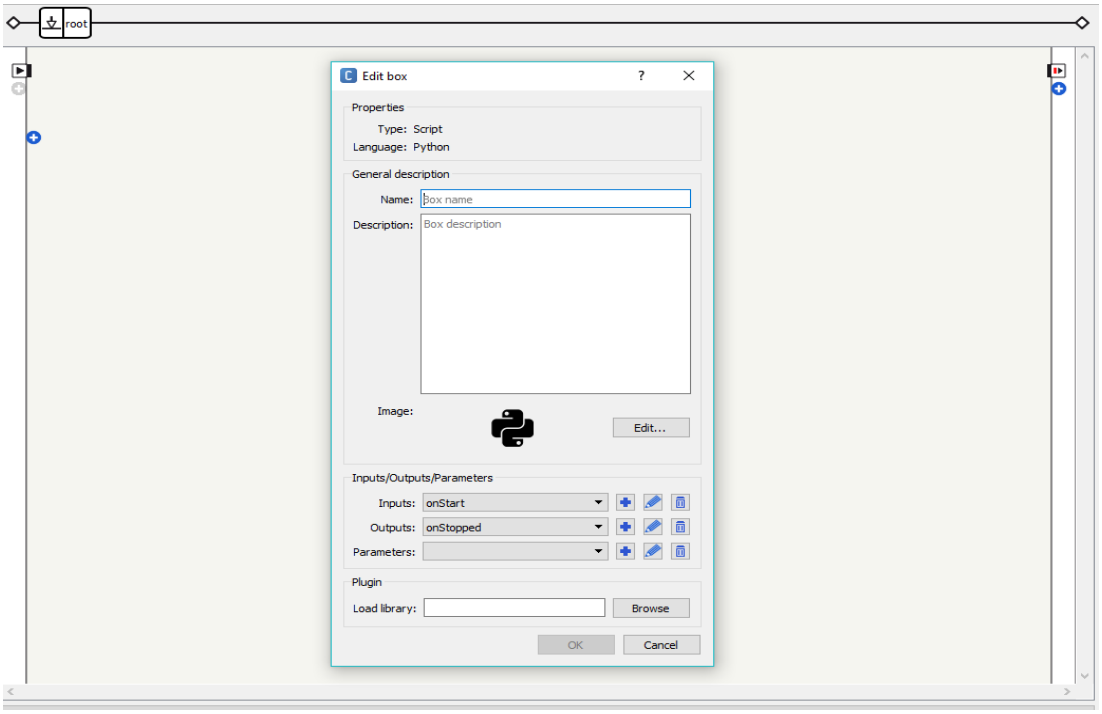

FIGURE 7 - EDIT BOX

Fill out the following sections shown in figure 7 after clicking "Python…":

- **Name:** Your box's name should follow suit with the module and application names you've previously set, in other words, it should be self-documenting and accurate to what the box will be doing. Think of this like a function name while programming. As previously stated, a good box name for a simple Hello World code would be something like "TextToSpeechBox", or "SayHelloBox".
- **Description**: Similar to the project description that you've already written, this section should be a relatively short, but informative definition of what it is that your newly created box will be doing.
- **Input**: Allows the user to add multiple start inputs.
- **Output**: Allows different outputs to be added to the module
- **Parameters**: Allows parameters to be added to the module that can be used within the module.
- **Plugin**: If your module is dependent on third-party libraries, you can add them in the load library section, under "Plugin".

To add the script into the module, double click your python box, and a python script window will open, as shown in figure 4. Your code will be written in the *onInput_onStart* function. Delete the "pass" from this function, and uncomment the "on_Stopped()"

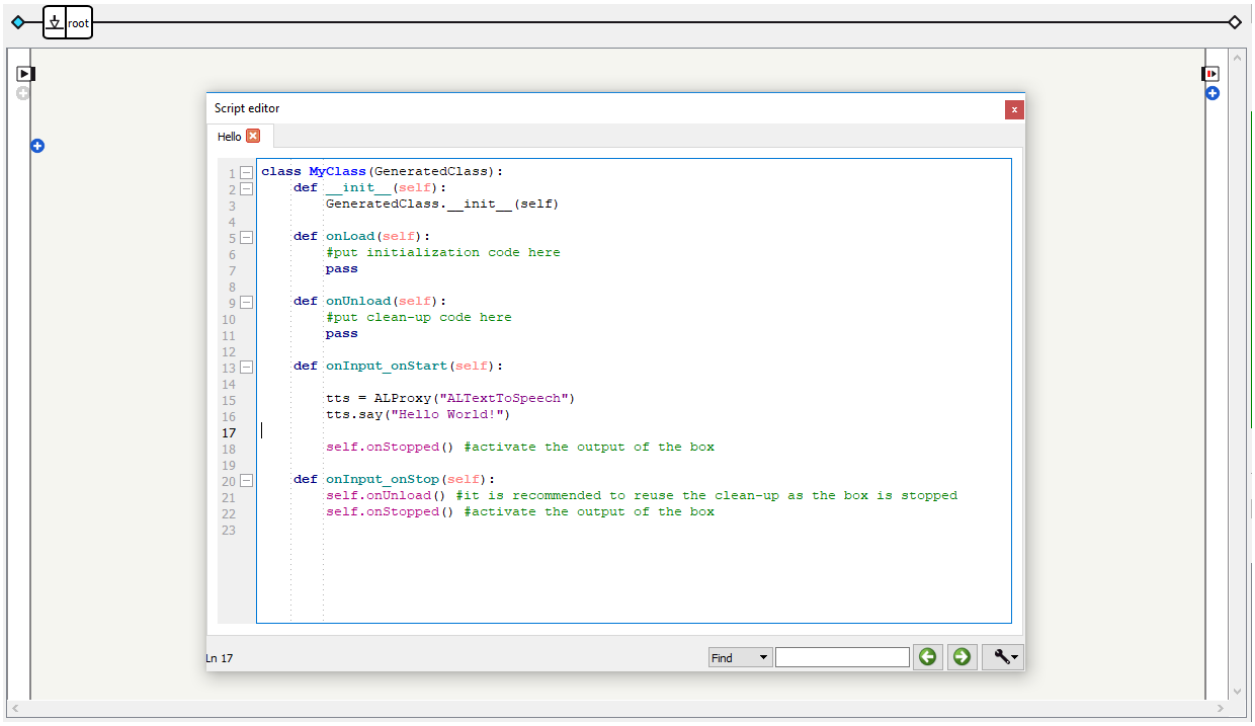

FIGURE 8 – SCRIPT EDITOR

The first line in out function in figure 8 (line 15), “tts = ALProxy("ALTextToSpeech")”, creates a proxy, or a link, using the “ALProxy” function provided in NAO’s API. This function takes a string as its parameter, describing what the proxy is for. “ALTextToSpeech” for instance, converts text to speech, and “ALMotion” has functions that gives you the ability to control NAO’s motions.

The second line (line 16), “tts.say(“Hello World!”)”, uses the text to speech proxy that we just made, and calls its function “say()”, using the String parameter “Hello World!”. When this is called, it will make NAO say “Hello World!”

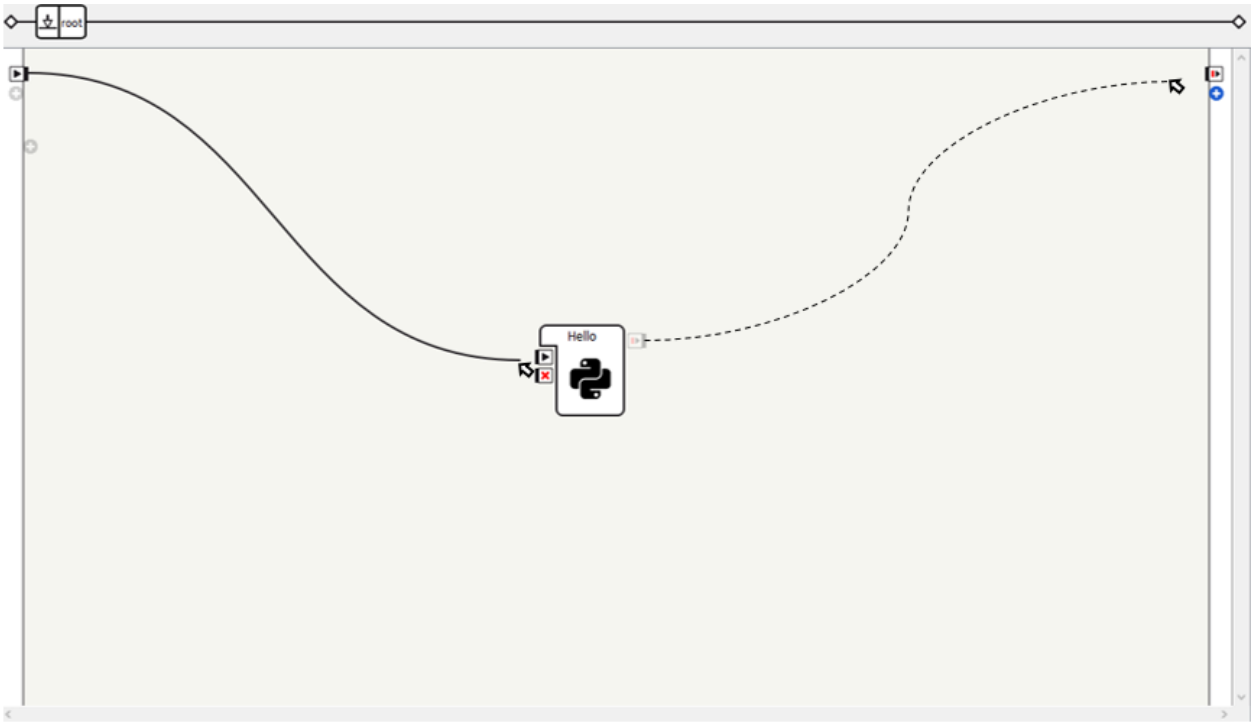

FIGURE 9 - DRAW THE LINES

To finish your project, create a connection from on start in the upper left corner to the on start on your python box as shown in figure 9. This starts your function when the behavior starts. If there is no connection from the on start in the upper left corner to any of your functions, your module will do nothing, and run infinitely. Drawing an arrow from the on stop on your function to the on stop in the upper right corner, as shown in figure 9, will exit the module after the Python script has finished.

It is important to remember to connect something to the on stop in the upper right corner, so that there is some exit condition, however if the on start signal hits a dead end in your code it will just exit, so it is not completely necessary.

3.4 INTEGRATING YOUR MODULE ONTO NAO

To integrate your module, first you must connect NAO to your computer via Ethernet cable. Then, hit the green connection button in the upper left corner of Choregraphe, which will bring up a list of connections. Click your NAO robot, and then click the select button. You may have to wait for a moment while NAO connects to your computer.

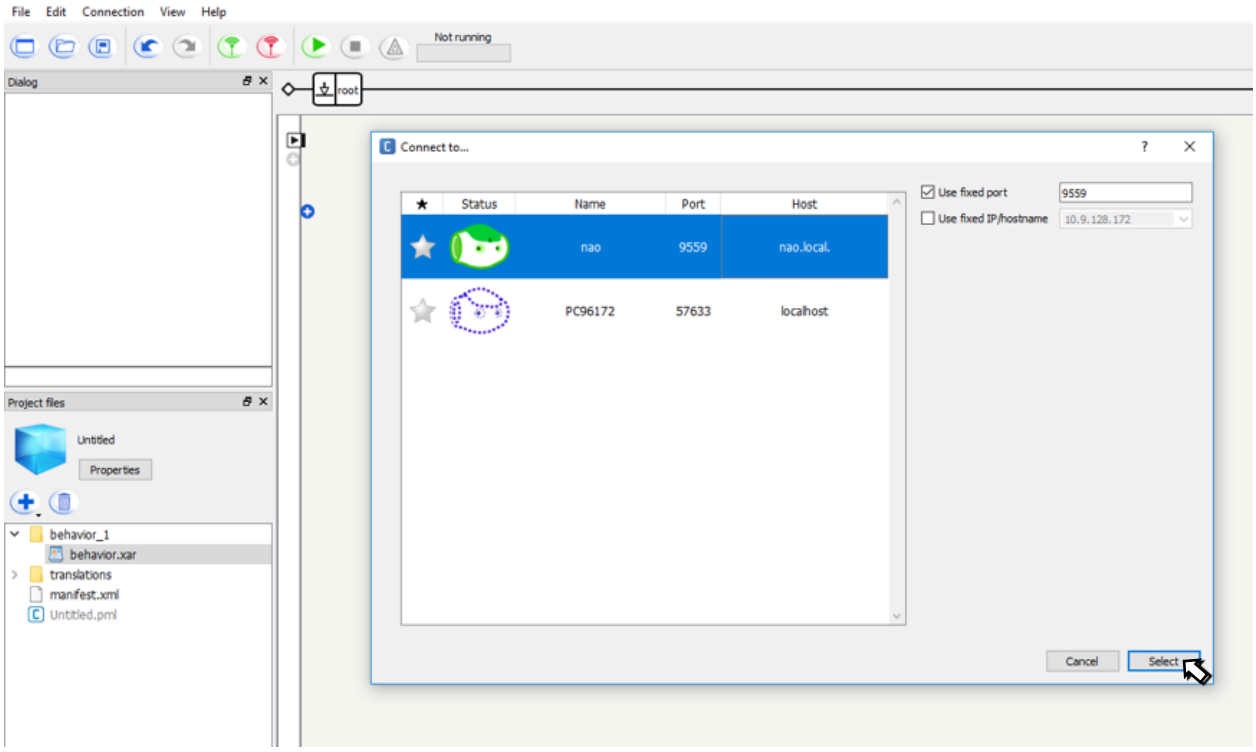

FIGURE 10 - CONNECTING YOUR ROBOT

Now adding your module should be simple. In the view tab, make sure "Robot Applications" is turned on. Then, click robot applications tab in the lower right corner, or wherever else it may appear, to open it. Now all you need to do is click the button with NAO's head on it in the upper right corner of the robot application box shown in figure 11, and the module will be loaded and ready to go.

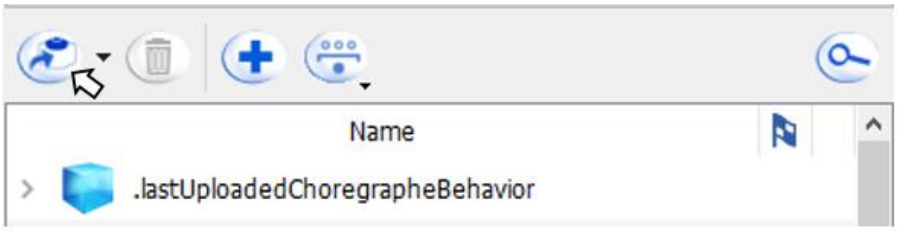

FIGURE 11 - ROBOT APPLICATIONS

SECTION 4: HELP

4.1 GENERAL FAQS

Is Choregraphe available on all Operating Systems?

- Choregraphe is available with full support on Windows and MacOS, as well as limited support on Linux.

Which programming languages can I use with Choregraphe?

- The NAOqi API has full support with Python and C++, so AriGato recommends using either of these languages. There are limited support options with other languages, such as Java.

What is a “Box” in Choregraphe?

- Boxes house the scripts that written and used to have NAO perform actions. You can make use of pre-created boxes from Aldeberan, or make your own boxes with Python or C++. For a full tutorial, visit the “Creating Your Own Module” section of this document.

Can a module have multiple trigger phrases?

- Yes, and it highly recommended!

How does NAO’s speech recognition work?

- Using its microphones, NAO looks for trigger phrases/words from its currently-installed list of modules. NAO **cannot** parse just any words said to it (similar to Google Assistant, or Apple’s Siri which have full speech recognition capabilities), only the finite list of trigger phrases/words can be recognized by NAO.

4.2 TROUBLESHOOTING

NAO unit overheating:

- This is a commonly documented problem with many models of the NAO robot. Strenuous physical activities, or activities that push NAO’s CPU to its limits can cause the robot to get too hot, and shut itself down before any damage occurs to the hardware.
- **Solution**: If your robot seems to be randomly shutting off after performing tasks, feel around its chest and head areas for warmth, and then let the robot sit while turned off for 30 minutes to an hour to let it cool down before resuming use.

NAO unit segmentation faulting:

- This is a problem that AriGato faced quite frequently while developing modules for their NAO. There does not seem to be an exact cause for this problem, as it happens randomly when NAO has been used extensively. While testing, AriGato noticed that once this problem occurs once in a session, it tends to occur repeatedly in increasing amounts if NAO is not given a break.
- **Solution:** If your NAO unit seg-faults, indicated by a red light on its chest, hold down NAO’s chest button until it turns off, then press it again to turn NAO back on. AriGato recommends letting NAO “rest” for 30 minutes to an hour if this error occurs, to avoid it happening repeatedly.

Choregraphe Error Message “Cannot Load 3D” Upon Startup:

- This error message occurred for all AriGato members when starting up the Choregraphe software on their CWU-provided Windows computer.
- **Solution:** However, it seems that simply selecting “Ignore” on the error message that appears allows the Choregraphe software to startup completely normally, with no issues affecting the 3D NAO model within the software. It appears that this error can be ignored without issue.

Facial Recognition-Based Modules Running Infinitely/Not Responding:

- A commonly occurring problem discovered during testing was the NAO robot being asked to complete a module that included facial recognition (e.g. “AgeGuesser”), and then the NAO unit would stare infinitely at the user without speaking any output.
- **Solution:** Make absolutely sure that there is only one face within NAO’s view. When there are multiple, even if NAO is locked onto the face of the commanding person, NAO will get confused when trying to use its facial mapping capabilities, and run modules infinitely until it can properly find a singular face (only one face in its field-of-view). Additionally, make sure you are around 1-1.5 feet away from the NAO unit when giving this command, as too much distance also confuses the robot.

“Stop” Module Not Working:

- A “Stop” command has been implemented on the “Sing the Anthem” module, as the song that NAO plays during this module is quite lengthy, and typically will be desired to be shut off early. Occasionally, saying “Stop” while this module is running does not work, or needs to be repeated.
- **Solution:** The reason for this occasional error is due to NAO’s loudspeakers being placed right next to its microphones in its head. The song that plays during the Anthem module partially drowns out NAO’s microphones, meaning that “Stop” must be said loudly and also at a close proximity to the robot in order to be accurately heard and acted upon.

NAO randomly says “and lets go has been too”?:

- As discussed in the “Problems Encountered” section of this documentation, the exact cause or a solution to this mystery dialog has yet to be discovered. It seems that NAO will occasionally say this phrase, or a similar one that does not make any grammatical sense.
- **Solution:** AriGato was unable to track down the cause of this bug, and chocked it up to being a small quick/annoyance from NAO’s programming. Thankfully, this audio bug has no affect on any behavior’s performance, so it is best to just ignore it.

AriGato

NAO Documentation Part 6:

Final Report

The AriGato team had a simple task at hand for their senior capstone project: implement exciting and meaningful human-to-robot interaction onto an Aldebaran NAO robot. This task was at its core, a blank slate – AriGato essentially had full control over what to make their capstone, only being limited by the physical and computational constraints of the NAO robot, and their own imaginations. Knowing this, the members of the team ran wild with the potential possibilities of what they could make NAO do, writing up huge lists of possible commands and questions to have the NAO unit act upon, and eventually shortening the list down to a refined yet wide-range set of behaviors.

AriGato's research for this project began in late November 2018, where each member performed individualized self-study of the NAO robot's documentation pages provided by Aldebaran, as well as what other academic groups around the world who had similar projects had completed. This research, combined with weekly meetings with the group's supervisor and client helped AriGato rule out what sorts of behaviors would be in-scope, and which would be out-of-scope; for example, one of the first ideas that an AriGato team member had was to have NAO recognize hand gestures, or American Sign Language (ASL). Though this concept would've definitely fit the bill of "exciting and meaningful interaction", it turned out that there was no native support for NAO to recognize hand/finger gestures, meaning that AriGato would've had to code the hand-recognition by themselves – a task that would certainly take longer than a couple of months.

After the initial researching phase concluded, and the team had regrouped after CWU's Winter break through December 2018, AriGato began working on the set of basic level behaviors for NAO, also known as the project's "Functional Requirements" (FRs). These basic behaviors include things such as moving various appendages and simple text-to-speech programs, things that are not necessarily the most grand of scale, but were necessary to implement to learn the fundamentals of coding in Python (a language that none of AriGato was too familiar with), and taking control of the NAO unit. After about three weeks, the functional requirements were completed, and AriGato had around 12 completed modules, all of which revolved around having NAO perform a small movement, or respond to a command/question.

Once the basics of coding for NAO had been fully understood, it was time for AriGato to move into the next phase of their project's development: "Non-Functional Requirements" (NFRs), or requirements that built upon the functional side of things, and would be used to eventually judge the project's completeness and the team's effectiveness. Some of the core NFRs included facial detection and recognition, advanced movement options, and internet-based behaviors. Developing and integrating the NFRs took up the bulk of the project's lifetime, as they required the most amount of research and testing to successfully complete. It was also at this point in the project that AriGato began to fully understand how NAO's speech recognition capabilities worked. The team initially figured that NAO would work in a similar way to Google Assistant, or Apple's Siri: meaning that a user could verbally tell the speech

recognizer any sentence, and it would accurately parse the spoken phrase and act upon it accordingly. As it turned out, this is not how NAO robots work; NAO's are only capable of recognizing words/phrases from the finite list that they are programmed to listen for. This put a hold on many of AriGato's planned modules, as they relied on essentially having unlimited cases for speech recognition. The workaround that AriGato found for this issue came in the form of using "case statements" within the Choregraphe software, which would be implemented on any modules that would take variable input (e.g., MovieInformation). Though these case statements are only capable of finite inputs, they proved to be a suitable replacement for the original way that AriGato thought that NAO's speech recognition worked.

Come late February, AriGato wrapped up development on the remaining NFRs and began numerous rounds of testing with largely varied groups, ranging from university professors, to students from various non-STEM related departments, to elementary aged children. The results from testing were fruitful, as testers would frequently give ideas to AriGato of new modules that should be implemented (e.g., Favorite Color, Jokes), as well as ideas for new trigger phrases to be added to the currently integrated modules, such that NAO could more easily be interacted with. The AriGato team members are extremely grateful to all of those who took time out of their schedules to help them test their project, and help it be fully realized as the finished product that it is today!

In conclusion, throughout their senior capstone project, all members of the AriGato Robotics Group have learned the power of teamwork and collaboration in the software development setting. The things accomplished in the project would not have been possible without the weekly meetings, constant daily communication through Slack, and the guidance from the team's supervisor and client. Whenever a new problem or bug arose, all members of the team were quick to spring onto it and help one-another out to solve the issue so that development could smoothly continue. Though at times the project proved to be extremely frustrating due to poor documentation and community support online, AriGato put forth their best efforts to work past these things, and became better software developers as a result. The team fully believes that they have delivered a successful senior capstone project based upon the assigned requirements.

"Thank you to supervisor Dr. Donald Davendra, the team's client, Dr. Szilard Vajda, and the entire Central Washington University Computer Science department for the opportunity to work on this meaningful and exciting project!" – AriGato Robotics

AriGato