Final Report

grade based on completeness (35%)

quality of analysis and research (50%)

adherence to format, grammar

spelling (15%).

Template Follows:

**Social Interactivity Mentor for Youth with Autism using the NAO Robot (SIMYAN)**

**Members: Andrew Nguyen, Bryce George, Colton Homuth, William Ross**

**Sponsor: Dr. Adham Atyabi**

**Advisor: Bill Michael**

**ECE 4890 / CE 4899 -001**

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# Problem Overview [written by William Ross]

*1-2 paragraphs*

*Problem introduction –like an abstract. A high level summary introduction to the problem area and specific problem. What are the objectives? Benefits? Key issues? Is there relevant history?* ***Motivate why this problem is important to work on.*** *Anybody including your parents should be able to read this, and be able to tell you what you are working on. No Jargon. Don’t write: BLE; don’t write: Bluetooth Low Energy; write: ultra-low power wireless communications.*

According to the American Psychiatric Association, “Autism spectrum disorder (ASD) is a complex developmental condition that involves persistent challenges in social interaction, speech and nonverbal communication, and restricted/repetitive behaviors. The effects of ASD and the severity of symptoms are different in each person” (Copeland, 2018). ASD is a relatively common condition in humans that can negatively affect social behavior and development. Children, especially those with ASD may have trouble developing the social skills necessary to find success is our social world. Thus, one proposed solution is the use of “social robotics” or robots aimed towards the development of social skills in humans. Our sponsor’s academic research focus is on children with ASD.

# Problem Statement [written by William Ross]

*This should be the problem statement agreed by you and the sponsor…Did you show them this?*

* *Make sure it is complete—everything the customer needs must be here, no matter how trivial sounding…*
* *Everything must be specifiable—no vague statements like “feels nice” or “looks good”*
* *What are the boundaries of the project? Standards? Size? Location? Power? Operating conditions? Operating life? … but none of these should be specific numbers here— say “outdoors” or “solar power”*
* *Highlight conflicting needs—that’s one place where engineering trade-offs show up. You may want use something like figure 3.9 or figure 3.10 on page 33*
* *Things the customer wants but does not need could be stretch goals (Stretch goal does not mean more work or extra hard to do…it means the customer will be happier if you can do it but satisfied without it)*
* Solution should extend the NAOqi Framework SDK.
* Solution should enable the NAO to initiate an interactive drawing module with social feedback.
* The NAO must be able to draw simple shapes (circle, triangle, square, and rectangle) using a drawing implement on a writing surface.
* The NAO should verbally interact with the user before, during, and after the drawing sequence.
* The solution should include the integration of an external GPU to the NAO for faster on device processing using trained machine learning models.

# Standards Discussion [written by Andrew Nguyen]

*Discuss the standards you have found in your research which apply or may appear to apply to this problem. You may also need to discuss standards which* ***do not*** *apply, in some cases.*

*Standards fall broadly into two categories*

* *Established by industry/government/standards organizations (Example: SuperSpeed USB 10Gbps (USB 3.1 Gen 2) from the USB-IF)*
* *Established by reasonably respected companies as specifications for their products (example: TI MSP430 electrical, programming, mechanical, operating conditions specifications, as found on datasheets, for example)*

*Your literature search should come upon many possible standards which must be adhered to (or which will not be adhered to—you may adhere to USB 2.1 not 3.1 for instance, you should explain why). The customer should agree in all cases. You must discuss each standard in detail, but do not discuss standards which you do not know yet will apply—for instance, if you expect to use an ADC chip, but have not chosen the specific chip yet, you should include a place for the chip standards to be discussed in the final report, but all details should be “TBD” at this point—you could write:*

*ADC Chip – TBD*

**Coding standards:**Standard Python programming. Python code will be written in a PEP 8 formatting style. Each line of code will include 4 spaces instead of a tab. Comments will also be written per function call or block of code in doc-string format. Comments will describe all functions and its parameters. Comments will provide references/inks to documentation when available.  For a possible custom utility is built, provide a command line or GUI interface.

**Documentation Standards:**For each code committed to the GitHub directory, UCCS-Social-Robotics/docs, it must include a Wiki page or markdown for each module. The codes must also include author(s), GitHub username, and date information at the top of documentation files and Wiki pages.

**Safety Standards:**IEC 60601 international standards for the basic safety and essential performance of medical electrical equipment. Provide safe interactions between the NAO robot and the user.

# Constraints Discussion [written by Colton Homuth]

*Discuss each of the following constraints which may limit your proposal and project in some way. If a constraint does not apply, state there is no constraint and give a reason. It is expected that constraints do exist for most of these issues for your project, you may need to think deeply and consider the problem widely. There may be additional constraints for your problem which you should add to this discussion. (note: you don’t need to start each section with “For this Project”)*

## Economic

The largest constraint in this case would be the budget. We need to acquire a depth sensor which might be lower quality than desired with the current budget, however this will not be a huge problem.

## Environmental

For this project, we are not sure any environmental constraints would apply since this project takes place in a controlled, indoor environment without any other outside factors.

## Social

Since this project is meant to promote social interaction within ASD children, it must be designed for this purpose. Mainly, we must avoid changing it explicitly into any particular therapeutic experience or anything else outside of our scope since we are not experts when it comes to working with ASD children.  Moreover, no testing will be performed with ASD individuals at any point during this project.

## Political

For this project, political forces should not be too much of a factor since all we are trying to do is create a safe, interactive space for ASD children.

## Ethical

When dealing with ASD children, they must always be treated with respect and this would be our biggest ethical constraint. Since we’re dealing with a user and one user alone, we must focus on them being treated well and not being used or mistreated in any way.

## Health and Safety

For this project, since we are only dealing with one specific user, a big constraint would be making sure NAO programming does not prompt it to do anything dangerous. We must also consider the general closures and restrictions as a result of the COVID-19 pandemic, as well as the safety regulations for physically interacting with one another.

## Manufacturability

Since project is adding software to existing hardware, we are only limited by the hardware on the NAO robot and the software we write to program its behaviors.

## Sustainability

For this project, we will not have any problems with sustainability, as long as nothing is changed on the NAO robot and Python version that we are running.

# Requirements Analysis and Literature Search [written by Bryce]

Explain your process for developing the requirements specification. This process necessarily includes an extensive literature search and survey of existing solutions and technology. Use figures and words from the text liberally. Answer these questions where appropriate and expand on them (not just yes/no answers); these are example topics for discussion, you should include other suitable topics. Remember, this is about what the customer needs, not about the design of the solution.

* Are you working with an informed or a frontier customer? What important points result from this?
* Analyze important points of how this problem is solved by others, if no similar solution, analyze why not.
* What existing technology could be useful?
* Summarize how your real-world constraints influence the requirements. How do they influence your specifications?
* List the needs and wants
* What are the project boundaries?
* Do you have an input/output analysis?
* Can you preview the user interface?
* Have you surveyed design attributes?
* Do you have conflicting needs?

Explain how you translated important and special things from the requirements analysis to the requirements specification

# Requirements Specification [written by All]

Preferably in table format.

Re-read sections 3.2—3.4 in the text!

These should be the specifications agreed to by you and the sponsor—

Quantify the problem statement—“outdoors” becomes -20C--+50C, 5%--95% humidity, etc.

How will you know when you are done?

What tests must be passed?

Everything you need to design needs to be specified, even if the customer doesn’t know it

This is not where you detail your solution!

(Note: in later presentations and reports you may need to expand or adjust the requirements specification with items from 3.4.1—3.4.4 such as analysis of a similar design or results from testing prototypes or requirements which are excessive or impossible, any of which leads to a modification of the requirements specifications)

# Team Organization [written by Bryce George]

*Your team must have somebody with overall responsibility for an area—an area manager. This does not mean the manager must do all of the tasks, or even any of the tasks, but if there are problems in that area, it’s their responsibility to resolve, and they take the primary blame. For instance, the Design Manger will most likely be doing part of the design but not all of it; there could be one or two people working on hardware design, and another working on software design, for instance. The Design Manager needs to know what each member is doing, are they on schedule, how to resolve issues, and communicates with the project manager. It doesn’t need to be formalized in that way in a group with 5 people, but there needs to be somebody who can stand up and take responsibility for the good and the bad. For teams with less than 5 members, some people may have 2 or 3 manager roles to fill.*

**Project Manager:**

Bryce George

**Communications Manager:**

William Ross, Colton Homuth

**Logistics Manager:**

Colton Homuth, William Ross

**Test Manager:**

Andrew Nguyen

# Team Constraints [written by Bryce George]

*Survey the landscape you are in*

* *Each team member, 1-2 sentences: degree major, skills, interests, future plans (job, startup, grad school…)*
* *Missing skills you need*
* *Anything else?*

*Do not solve these issues here—just say what they are*

Andrew Nguyen is a Data Analytics and Systems Engineering major. He has skills in Python and software engineering. He is pursuing a job in Data Analytics. Limited knowledge in machine/deep learning.

Bryce George is pursuing B.S. degrees in Computer Science as well as Data Analytics and Systems Engineering and is also employed as a Software Engineer at Eclypses, a cyber security company located in Colorado Springs. He has considerable background in the .NET ecosystem as well as experience with the software engineering process, agile development, software security and computational cryptography, applied deep learning methods for object detection and tracking, IoT systems, and some exposure to robotics.

Colton Homuth is a 4th year Computer Engineering student mostly invested in software engineering. His plan is to take a software engineering job after graduation. In terms of this project, the area where he is most limited would be machine learning however he is excited to learn.

William Ross is an electrical engineering major in his 5th year. He is interested in software engineering and has some experience with python and deep learning research.

Overall, our team has limited experience with both Python and robotics, which will certainly be key areas of focused research and improvement for all team members. Several team members also have limited exposure to machine learning algorithms and the processes required for their development and application. In addition, developing familiarity and understanding of the proprietary NAO Framework will require a significant investment from the team and will be necessary in order to understand both its native capabilities, as well as how to implement the advanced social behaviors planned for this project. Finally, we will need to rely on the input of our sponsor and our own research to design the robot’s behaviors and interactions to be as natural and effective as possible when working with ASD children.

# Operational Description [written by Bryce George]

*Describe roughly how it will be operated, what are the things humans and/or other machines must do for your project to function. This is not how your project responds to the environment—the sun will rise in the morning whether you want or not, and your project will start recharging a battery if so designed; the human merely must orient it towards the sun. Additional requirements may be derived from the operational description.*

Given that the modules developed for this project are intended to provide children with ASD an opportunity for developmental social interactions, the robot must be responsive to many natural human stimuli such as verbal instructions and visual cues, as well as being capable of performing many of its functions autonomously. In general, the robot should be placed in a room, directly in front of a drawing surface, and a number of colored writing implements should be available in the nearby vicinity. The person interacting with the robot should then enter the room and approach the robot, optionally offering a greeting. The interactive drawing session should begin either with the person verbally instructing the robot to draw a picture, or with the person agreeing to the robot’s suggestion that they draw a picture together. If the picture to be drawn has not been specified, the robot will ask to clarify what picture should be drawn. From there, the robot will ask the person to place the writing implement of the person’s desired color into its hand. Once the person has placed the writing implement in the robot’s hand, the hand will close to grip it and the robot will begin drawing the desired picture on the drawing surface. Once complete, the robot will ask the person if they like the picture and respond to their feedback, whereafter, it shall await further instruction.

Depending on the extension features which are able to be developed in the time allotted, the following additions to the previous scenario may also be viable: The robot may not need to be placed directly in front of the drawing surface in the room. Instead, it might be positioned some ways away from it and be able to locate and move to the drawing surface on its own once the interactive drawing sequence has begun. Additionally, the robot may be capable of locating writing implements in its vicinity and picking them up on its own, in which case, the robot will do so instead of requesting for the person to put one in its hand. The robot may also be capable of selecting a color on its own, wherefore it would ask the person whether they would like for it to use a different color before proceeding—using the color it selected itself unless directed otherwise. In order to accomplish these tasks which rely on the robot’s visual perception, the robot will need to use a GPU to process the images so they can be analyzed by deep learning models trained to detect the relevant features. The scope of pictures which the robot can draw may also be broadened to include a larger number of pre-defined objects, pictures composed of multiple objects, and possibly the ability to reproduce a line-drawn version of an image it sees using its own camera in real time. For more complex pictures, the robot may be able to differentiate between different objects and ask for or select different colors for each. The robot may also be capable of identifying more opportunities for social interaction with the person during the drawing process. In such cases, the robot will be able to generate the correct phrases and body language to initiate and maintain the conversation for its natural duration, selecting appropriate actions at each stage.

# Block Diagram [written by Andrew Nguyen]

*Very rough at this point—Inputs, outputs, blocks of basic function, not specific devices or programs*

Graphical user interface

Description automatically generated

# System Design Expectations [written by Colton Homuth]

*What needs to be designed? Where do you expect to make your mark on this project? What will you synthesize, what are the questions you need to find the right answers for? Don’t answer yet, but show what the unknowns are, what are the things which could have a big impact?*

The NAO robot must be able to create a drawing using a dry erase marker on a whiteboard. On top of this, it needs to be able to communicate with a person in order to help promote social interaction. There are many steps that need to be taken to accomplish this, as it can be separated into many sub-tasks. The most important being the creation of a drawing algorithm able to make use of a predefined motor control module to make precise movements. It must also be able to hold a writing utensil (dry erase marker), respond to verbal commands, recognize a writing surface (whiteboard), as well as interact with another person throughout the activity. The NAO robot has built-in capabilities that support most of these tasks using their NAOqi SDK. Our biggest task will be figuring out what complex algorithms we can implement to both assist this framework and supplement it as needed to complete our goals.

# Draft Budget [written by William Ross]

*Can be very rough, but try to list what needs to be purchased and costs as you think they may be, as well as sources of income. A range is OK. Where you receive donations, write that—for instance, if you will receive IC’s free note that and the sources*

Project funding will be a total of $400 provided by the ECE department.

Items:

* Jetson Nano GPU
* Remote access equipment: camera, “play pen” fence, and padding
* 3D printed materials: utensil holder, backpack (to hold GPU)
* Depth sensor (LiDAR, Infrared)

Cost Allocation:

* GPU – free, borrowed from advisor Bill Michael
* Depth sensor - $300
* Remaining materials - $100

# Deliverables [written by Bryce George]

*What will be on the table at the front of the room in May?*

The primary deliverable for this project will be the software developed to allow a NAO robot to perform the desired interactive drawing exercise. The software will include a custom SDK containing modules that provide the generic support components for implementing advanced social behaviors in the NAO robot, as well as a social interactive drawing module that implements the SDK in order to accomplish that use case. Software documentation will also be delivered to explain the code and support future developments, as well as a manual for integrating and utilizing a Jetson Nano GPU within the NAO Framework. A mechanism for attaching the GPU to the robot will also be developed. Another mechanism may also be provided for affixing a writing implement to the robot’s hand/arm if it is found that the robot cannot maintain adequate hold on the writing implement during drawing.

* Software
  + SIMYAN SDK
  + SIMYAN SDK Documentation
  + Social Interactive Drawing Module (SIDM)
  + SIDM Documentation
* Jetson Nano GPU Integration Manual
* A mechanism for attaching the Jetson Nano GPU to the NAO robot
* A mechanism for attaching a writing implement to the NAO robot’s hand or arm *(Only if the robot is found to be incapable of holding the writing implement on its own)*

# Appendix [written by All]

Original problem statement for the RFQ

<Use Cases>

# Compiled by Bryce George

# References

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