Learning Manipulation of a Flashlight

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1 - Project Overview

Robots are slowly becoming more and more capable of completing everyday human tasks. The field of developmental robotics is working to continue this advancement by creating robots that are capable of learning. For example, Vladimir Sukhoy and Alexander Stoytchev [1] created a program by which their upper-torso humanoid robot was able to learn to push doorbell buttons based on audio, visual, and proprioceptive feedback. We are setting out to create a program by which a robot can learn to properly wield a flashlight, shining its beam on a desired location. This could make it possible for a robot to push a doorbell button using Sukhoy and Stoytchev's algorithms in the dark.

1.1 - Motivation

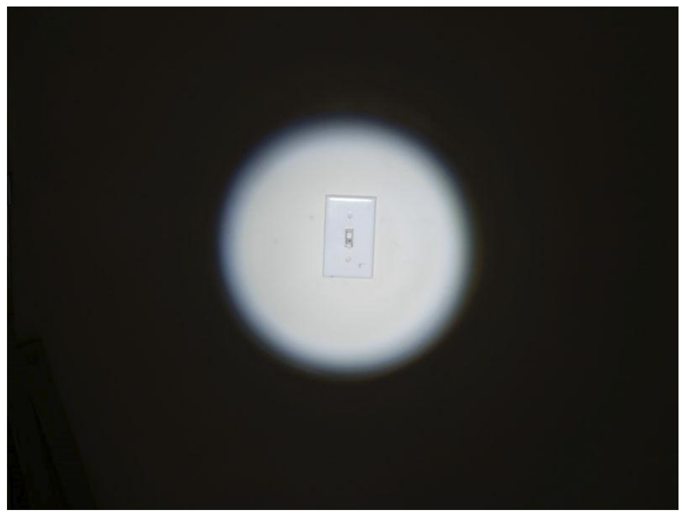

Figure 1 – Illuminated Light Switch

The inspiration for our project came from a poorly designed conference room in Howe Hall at Iowa State University. The light switch is located a good distance from the main entrance, above a counter set into the wall. This makes it nearly impossible to find in the dark when you first enter the room. One day, when meeting in this conference room with Professor Stoytchev, one of our group members quickly got out his keychain flashlight to illuminate the light switch for Professor Stoytchev, who was struggling to turn the lights on in the dark. After turning the lights on, Professor Stoytchev wheeled around, exclaiming how it would be cool to program the robot to learn to do that. Our project was born.

So why use a flashlight? Why not use infrared cameras or laser 3D imaging. Flashlights pose many advantages, one of which is cost. A standard flashlight costs much less than infrared cameras and 3D laser scanners. Another advantage of using a flashlight to illuminate a robot's environment is simplicity. Instead of having to switch to a whole other system for seeing in the dark, a robot using a flashlight needs only pick one up, turn it on, and point it in the desired direction. This would also allow robots to assist humans. We humans lack the capability to see in the dark, so if we require the assistance of a robot in the dark, it should be able to light the way for us.

Another reason for using flashlights to allow robots to see in the dark is for standardization of robotic systems. If robots are built using different methods for seeing in the dark, it will be very hard for them to communicate visual information. By developing robots that use flashlight technology to illuminate their environment, not only will they be able to better communicate with and help humans, they will be able to more effectively communicate with other robots.

1.2 - Audience and Applications

Flashlight use has many practical applications to a wide range of audiences. One day, robots will be "living" with us as assistants and caretakers, especially for the elderly. In case of a power outage or a nighttime emergency, these robots should be able to help their owners in any manner they should require. In one of these situations, an individual will need a flashlight's beam to see, so being able to learn to use a flashlight will be a key skill for caretaker robots. These robots must be able to learn to use flashlights because they will undoubtedly encounter many different kinds of flashlights. With each kind being slightly different, a hard coded "how to use a flashlight" program would certainly fail, so robots will need to be able to adapt to different types of flashlights.

Robots built to work in dark environments will also greatly benefit from flashlight manipulation. For example, a robot working in a coal mine will need to be able to see, and it should also be able to help its human workers to see to. If the robot were trying to point out that it had discovered a crack in the bracing of the mine, it would be hard to point that out to a human without being able to illuminate it with a flashlight beam.

Requiring robots to use visible light to see would also make them more sensitive to visible light. If a robot were able to see in the dark using infrared cameras, it would never be able to understand why a human can't see in the dark. We experience blindness in dark situations quite often, but a robot with the correct sensors may never have this problem. By forcing robots to have limitations similar to ours, it becomes easier for robots to relate to humans and vice versa.

Flashlight manipulation will also carry over to anything else that creates a light beam, like a laser pointer. Tour guide robots and teaching robots would be able to point out items of interest to humans by using a laser pointer much easier than by any other method. For Professor Stoytchev's sake, we will omit the obvious extension to light sabers…

1.3 - Related Work

This section details previous works in robotics and artificial intelligence that are related to our project. However, our proposal is unique in that there have been no attempts at what we are aiming to do.

Self-detection has an important role in tool use. Self-detection is the process through which something can differentiate "self" between other. "Self" is defined through action and outcome pairs in combination with a probability estimate based on the regularity and consistency of these pairs [5]. The approach taken by Alexander Stoytchev [3] first solves the problem of self-detection in robots by estimating the efferent-afferent delay. To find this delay, movement was corresponded with the time after a motor command was issued. Once this delay is found, differentiating "self" from other becomes easier because "self" will only move a certain amount of time after commands are issued.

Tool use is a form of self-detection and has a very important part in our proposal. Stoytchev has defined four things necessarily involved with robotic tool use: a robot, something in the environment labeled as a tool, an object to which the tool is applied, and a tool task [4]. One of the steps taken by Stoytchev was babbling with the tool grasped. The effects of the tool moving through the environment were associated with motor commands. Relating the motor commands to the changes in the environment determined how the tool could be used to best manipulate the environment.

1.4 - Individual Skills

Tanner Borglum

Tanner is a first year student at Iowa State University, sophomore by classification. He has programming experience in C and Java, and is currently learning to program in OpenCV for processing the visual sensory information we will be collecting in our project. His knowledge of the C programming language will also be helpful as the robot is programmed in C.

Nicolas Cabeen

Nicolas is also a first year student at Iowa State University, sophomore by classification. He has programming experience in C and Java, and is currently learning MATLAB for analysis of the processed visual information and proprioceptive data we will be collecting in our project. His knowledge of the C programming language will also be helpful as the robot is programmed in C.

Todd Wegter

Todd is also a first year student at Iowa State University, sophomore by classification. He has programming experience in C and Java, and is currently learning to use UNIX based operating systems, specifically the terminal, as the robot is run out of a UNIX terminal. His knowledge of the C programming language will also be helpful as the robot is programmed in C.

Jivko Sinapov

Jivko is a graduate student at Iowa State University who works in Professor Stoytchev's developmental robotics lab. This means he has lots of experience with the robot. While he is not technically a member of our group, he is the TA for the class and will be helping us with operating the robot and devising analysis algorithms. He has years of programming experience, and his help will be key to the success of our project.

1.5 – Timeline

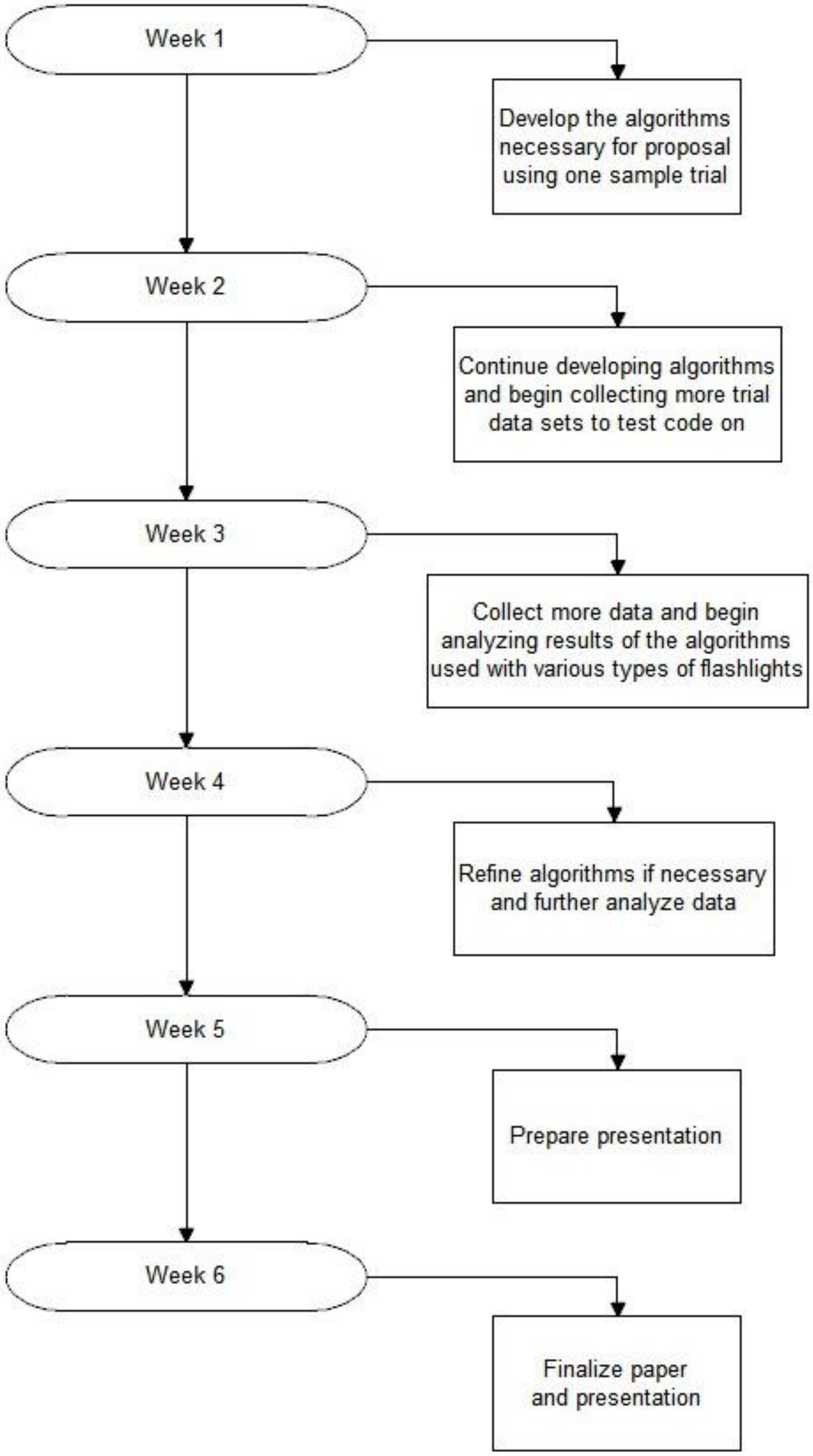

Figure 2 – Project Timeline

2 - Approach

2.1 - Equipment

Robot

The flashlight exploration experiments will be performed with the upper-torso humanoid robot illustrated in Figure 3. Two Barrett Whole Arm Manipulators (WAMs) are used for the robot's arms. Each WAM has seven degrees of freedom. In addition to that, each arm is equipped with a three-finger Barrett BH8-262 Hand as an end effector. Each hand has seven degrees of freedom (two per finger and one that controls the spread of fingers 1 and 2). Because fingers one and two can rotate by 180-degrees, the robot can perform a variety of grasps. In other words, even though the robot has only three fingers it can more than compensate for that because it has not one but two opposable thumbs.

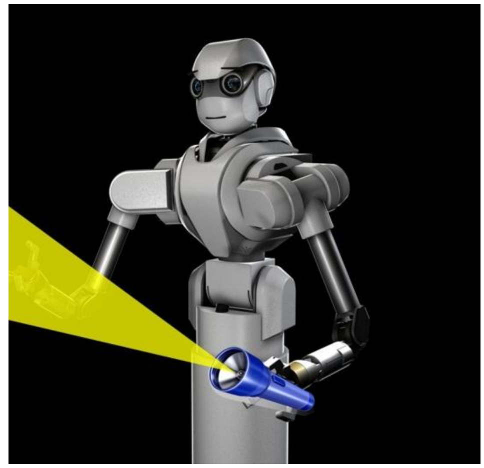

Figure 3 – Simulation of Robot with Flashlight

Flashlights and Batteries

We are currently engaged in the process of acquiring flashlights and batteries for our experiment, so we do not yet have detailed specifications on the specific flashlights that will be used. We intend to utilize standard flashlights that would be expected to be found in everyday situations. The only limitation on our flashlight selection process is the size of the flashlight. The flashlights used in our experiments must be large enough to be grasped with the robot's hand. We will use regular alkaline batteries in our experiments and will vary only the size of the batteries in accordance with the differing specifications of the flashlights.

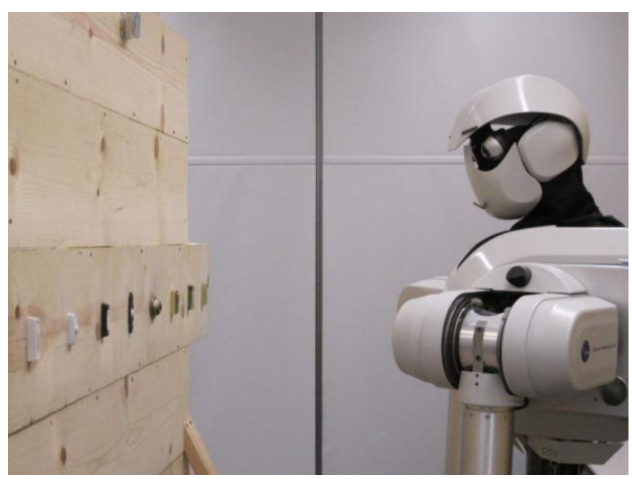

Figure 4 – Robot with Button Panel

Experimental Fixture with Doorbell Buttons

Seven different doorbell buttons were mounted on a wooden fixture as shown in Figure 4. The middle segment of the fixture could slide horizontally, which allowed different buttons to be placed in front of the robot without moving the fixture or the robot. The buttons can be connected to a buzzer, which produces loud auditory feedback, located on the upper part of the fixture by the robot was connected to a buzzer [1][2]. However, the sliding functionality and the buzzer will not be necessary for our experiment but provide conveniences for future research opportunities (See Section 3.3). We plan on using shining the robot's flashlight beam on this surface. It could also be used in future research to try pushing the buttons in little or no light situations.

Software

The robot is controlled using C++ on a UNIX platform. OpenCV, an open-source library, will be used for image processing. MatLab will be used to handle post-experiment data analysis. To develop an adequate knowledge of this software, we have devised a plan to divide the learning load among the group as described in Section 1.4.

2.2 – Algorithms

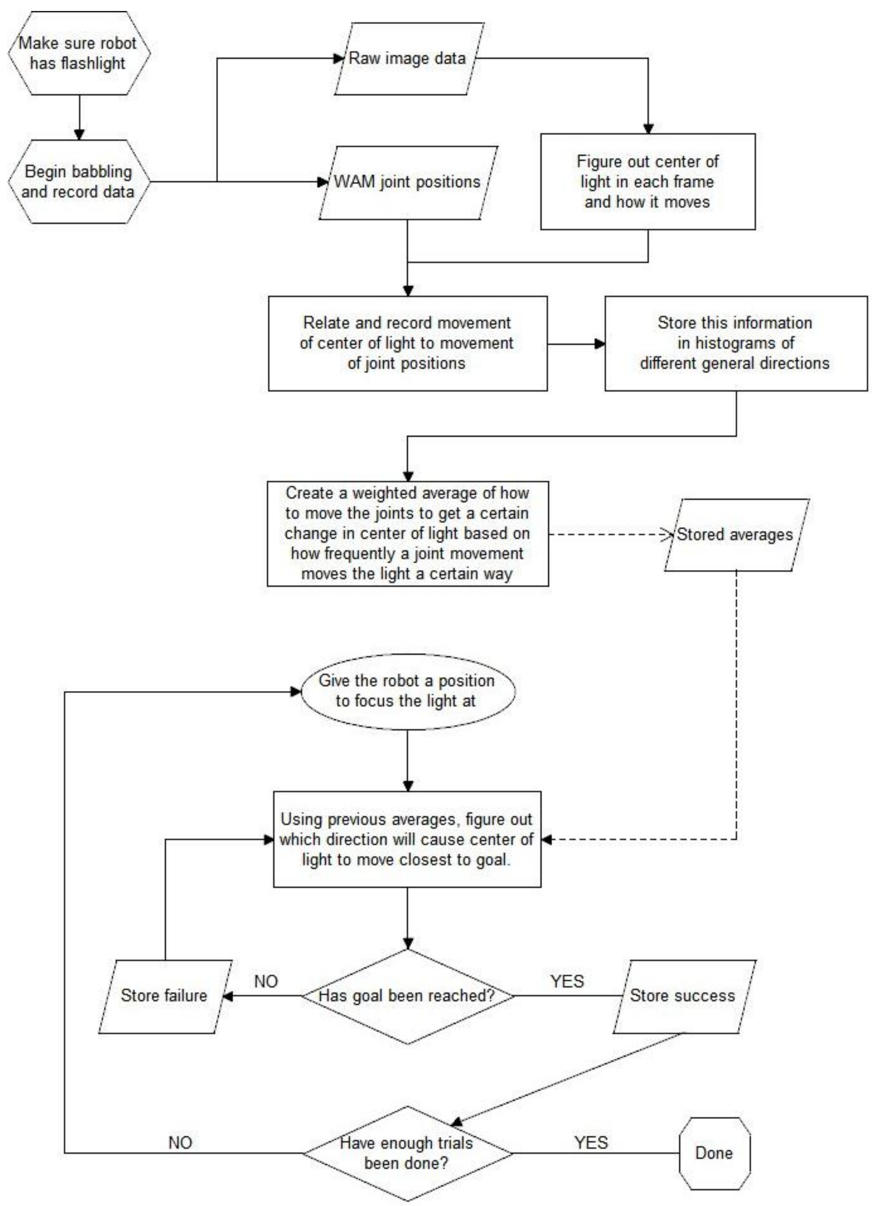

Figure 5 - Algorithms and Data Flow

3 - Evaluation

3.1 – Goals

The goals for this project are developmental in nature and build off each other.

Goal 1) Have the robot grasp a flashlight when it is placed in its palm and babble its arm randomly within given joint constraints.
Goal 2) Have the robot self-detect control of the changing light in its field of vision.
Goal 3) Have the robot be able to shine the light beam on a given position.
Goal 4) Repeat the process with different flashlights and bulb types.

3.2 – Success

Goal 1:

Success for Goal 1 is easily definable. Either the robot will grasp the flashlight or will fail to make a secure grip. Without too much difficulty, success rates for this procedure should be at least ninety percent.

Figure 6 – Example of Visual Data

Goal 2:

With real-time analysis of visual and proprioceptive data, we will develop algorithms to relate joint positions to visual changes caused by the moving light beam. From this data, we should be able to obtain consistent estimates of the time difference between motor commands (efferent signals) and visual movements (afferent signals) to find the efferent-afferent delay [3].

Goal 3:

Our algorithms from Goal 2 will be applied to complete Goal 3. With the gained knowledge of the relationship between proprioceptive data and visual data from previous experiments, the robot will be able to adjust the joint positions to direct the light beam to illuminate the goal point. By considering the location of the beam to be the center of the light, the algorithms will permit for a fairly large margin of error.

Goal 4:

Goal 4 ensures the universal applicability of our algorithms since the different bulbs will alter RGB values of illuminated areas. In this stage in particular, we will make any modifications in the algorithms as necessary to solve problems we will surely encounter during the experiments. Success will be defined as the ability for the robot to complete Goal 3 with different flashlights with different bulb types.

3.3 - Future Work

Short-Term Research:

This research can be combined with the button recognition and button pressing algorithms to allow the robot to use one hand to hold a flashlight to guide its other hand to press doorbells in low light to no-light conditions [1][2].

Another possibility is to expand the target-illuminating algorithm to follow moving targets. In everyday life, it is common to not only find stationary objects in the dark, but also to find and thereafter follow a moving object.

As described in Section 1.1, it is not always ideal to have a single robot perform an operation independently. Research could be done in having multiple robots working together to accomplish an objective. For example, give one robot a flashlight to illuminate a button or switch across the lab while another robot handles pressing the button or switching the switch.

Long-Term Extensions:

A long-term extension for this research, with application of future research topics discussed above, would be the utilization of full humanoid robots to assist police officers in chasing and apprehending fugitives in nighttime scenarios.

Another similar extension would be the use of robots for search and rescue missions. A robot with only night vision and infrared sensors would likely frighten the victim and increase the likelihood of injury or death. The ability to utilize flashlights would make the robots seem more familiar and would likely make the victim more comfortable and calm.

4 - References

[1] Sukhoy, V. and Stoytchev, A., "Learning to Detect the Functional Components of Doorbell Buttons Using Active Exploration and Multimodal Correlation," In Proceedings of the 10th IEEE International Conference on Humanoid Robots (Humanoids), Nashville, Tennessee, December 6-8, pp. 572-579, 2010.

[2] V. Sukhoy, J. Sinapov, L. Wu, and A. Stoytchev, “Learning to press doorbell buttons,” in Proc. of ICDL, 2010, pp. 132–139, 2010.

[3] Stoytchev, A., "Self-Detection in Robots: A Method Based on Detecting Temporal Contingencies", *Robotica*, volume 29, pp. 1-21, 2011.

[4] Stoytchev, A., "Behavior-Grounded Representation of Tool Affordances," In Proceedings of IEEE International Conference on Robotics and Automation (ICRA), pp. 3071-3076, Barcelona, Spain, April 18-22, 2005.

[5] Lewis, Michael, and Jeanne Gunn. *Social Cognition and the Acquisition of Self*. New York: Plenum Press, 1979.