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Machine Learning in Robotic Locomotion

Problem

As the field of robotics continues to grow with applications in fully autonomous locomotion (i.e. self-driving vehicles), control theory has grown with it. One common use is with machine learning where robots are able to take inputs from their surroundings and "learn" from the data to map out and maneuver through a previously undetermined course. In this lesson, students will build a vision kit to be introduced to convolutional neural networks and machine learning. In addition, the students are expected to build on their CAD experience to build a case for the vision kit.

Abstract

Machine learning has become increasingly important in robotics as scientists and engineers look to create fully autonomous robots that can generalize their actions to various environments and inputs.. This lesson starts with an introductory discussion on machine learning and how it is applied in different fields. The second part of the lesson is to act as a first exposure for students to build a Google AIY vision kit and begin working with basic terminal commands to run various machine learning demos. In addition, a sub-component of the lesson is for the group to design and 3D print a customized case for the vision kit.

Alignment with Standards

SCSh1. Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.

a. Exhibit the above traits in their own scientific activities.
b. Recognize that different explanations often can be given for the same evidence.
c. Explain that further understanding of scientific problems relies on the design and execution of new experiments which may reinforce or weaken opposing explanations.

SCSh3. Students will identify and investigate problems scientifically.

a. Suggest reasonable hypotheses for identified problems.
b. Develop procedures for solving scientific problems.
c. Collect, organize and record appropriate data.
d. Graphically compare and analyze data points and/or summary statistics.
e. Develop reasonable conclusions based on data collected.
f. Evaluate whether conclusions are reasonable by reviewing the process and checking against other available information.

SCSh4. Students will use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

a. Develop and use systematic procedures for recording and organizing information.
b. Use technology to produce tables and graphs.
c. Use technology to develop, test, and revise experimental or mathematical models.

Next Gen Science Standards

Engineering Design

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Common Core State Standards Connections:
ELA/Literacy -
RST.11-12.7
Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1),(HS-ETS1-3)

RST.11-12.8
Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-1),(HS-ETS1-3)

RST.11-12.9
Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1),(HS-ETS1-3)
Mathematics -
MP.2
Reason abstractly and quantitatively. (HS-ETS1-1),(HS-ETS1-3),(HS-ETS1-4)

Objectives

The objective of the lesson is to act as a introductory lesson for students to be exposed to machine learning and neural networks. In addition, the students should be able to display their progress in applying the engineering design process to build a 3D-printed case that is able to house the vision kit hardware.

Anticipated Learner Outcomes

Students should:

1.) Be inspired interest in the world of robotics research, particularly being exposed to machine learning
2.) Understand the engineering design process and how it is applied to robotics
3.) Design and build a vision kit
4.) Program a robot to complete a given task through a machine learning algorithm
5.) Design and 3D print a customized part for their robot using CAD software

Assessment & Rubrics

A copy of the student handouts can be found in the Appendix of this document. A recommended rubric can be found for the machine learning and CAD stations.

Built in formative assessments can be done during the design and build process with the summative assessment being skill set test and quiz on various concepts and terms. Further homework, in-class assignments or test questions relating to the design process with a focus on machine learning and CAD can and should relate to the Anticipated Learner Outcomes.

Background

The background of this lesson plan is from research done for biologically inspired quadruped robot that was built for the purposes of invoking cat-like motion to test various predictive algorithms that would be implemented in autonomous robot movement.

Materials & Supplies

1. Download Autodesk Inventor here:

http://www.autodesk.com/education/free-software/inventor-professional

2. VEX EDR Robotic parts and curriculum guides:

http://curriculum.vexrobotics.com/home

3. Google AIY Vision Kit

https://aiyprojects.withgoogle.com/vision/#meet-your-kit

4. 3D Printer (Statasys F170 was used for the purposes of this lesson)

Plan

The lesson will be embedded as two stations within a five station rotation. Students will spend one week at each rotation with the stations covering the following five topics A) Mechanical systems, B) Fluid power systems, C) AC/DC Electronics, D) CAD, and E) Machine Learning with Google AIY Vision Kits.

1. Start with the opening question (3 minutes)
2. Introduce the idea machine learning in robotics (5 minutes)
3. Discussion question: How does the Google Self-Driving car work? (3 minutes in groups, 5 minutes as a class depending on how many topics are brought up)
4. Discuss sensor inputs, neural networks and transition learning (10 minutes as a class)
5. Start building Vision Kit (30 minutes)

The lesson is placed after the classes are already familiar with the robot components and programming and will be focused on the 3D CAD portion of the class.

1. Allow students to finish building Vision Kits and playing with default demos (90 minutes)
2. Require checkpoints for specific tasks (See handout in
3. Introduce challenge to customize Vision Kit to accomplish task base on image classifier or face detection (i.e. robot moves toward specific objects or robot follows a specific face/person)

Integrate lessons as needed to focus on specific tools in machine learning or to help troubleshoot issues that are arising with robot mechanics, electronics, or programs.

Summary

To emphasize the importance of robotics and to introduce students to the world of machine learning, this lesson plan seeks to put students in the shoes of an engineer who is tasked with developing autonomous locomotion. In small groups, students are given the task of either having a robot that moves to specific objects or to track a face. To complete the task, students will design, build, program and test their own robot for a 2 week period and have specific criteria to determine the best robot design and performance.

Appendix

Meet your kit

1. Welcome! Let's get started

The AIY Vision Kit from Google lets you build your own intelligent camera that can see and recognize objects using machine learning. All of this fits in a handy little cardboard cube, powered by a Raspberry Pi.

These instructions show you how to assemble your AIY Vision Kit, connect to it, and run the Joy Detector demo application.

Time required: 1.5 hours

available at target.com

If you have any issues while building the kit, check out our help page or contact us at support-aiyprojects@google.com.

2. Check your kit version

These instructions are for Vision Kit 1.1. Check your kit version by looking on the back of the white box sleeve in the bottom-left corner.

If it says version 1.1, proceed ahead! If it doesn't have a version number, follow the assembly instructions for the earlier version.

Figure 1. Screenshot of Build, Connection and Demo Instructions found at https://aiyprojects.withgoogle.com/vision/

Skill Assessment Record Sheet

MACHINE LEARNING

Student Name: ____

STEP NO.	SKILL TITLE	PTS	TEACHER INIT.
Machine Learning – Google AIY Vision Kit Build Instructions			
75	Run Joy Detector – Return 8 Bit Sound with Yellow Light		
98-99	Run the image classification camera demo		
101-102	Run the face detection camera demo with at least 3 faces detected		
106	Display a picture of yourself on the monitor		
107-108	Display a picture of your group, entitled 'Group Shot'		
109-110	Run the face detection demo on your 'Group Shot' image from Step 107 and achieve a joy score of 0.8 or above		
	TOTAL SCORE	**/24**	

Evaluation Rubric

0. **Not Mastered, Cannot Perform Skill**
1. **Not Mastered, Can Only Perform Minimal Portions of Skill**
2. **Not mastered, Can Perform Skill with Assistance** - Completed skill with some assistance from the instructor
3. **Not Mastered, Can Perform Skill Given Time** - Completed skill with no assistance, but excessive time was required.
4. **Mastered Skill** - Completed skill with no assistance in a timely manner

Figure 2. Skill Assessment Record Sheet and Rubric for Machine Learning Station

Day 1

Google Vision Kit – Build Instructions (https://aiyprojects.withgoogle.com/vision/ for interactive directions)

- **Complete All Steps 1-75**
- **Step 2**
  - **We will be connecting using Step 2, Option 2**
  - What are the additional items needed with the Google AIY Vision Kit in Option 2
- **Step 25**
  - How many pins does the Raspberry Pi header have?
- **Skill 74**
  - How much time does it take for the device to boot up the first?
  - How long should it take in the future to turn on?
- **Skill 75**
  - What color does the light turn on a frown? How about a smile?
  - How far should the camera be held in order to read correctly?

Day 2

Connect & Demos ((https://aiyprojects.withgoogle.com/vision/ for interactive directions)

- **SKIP Steps 76 - 87**
- **Complete Steps 88-1**
- **Step 88**
  - What are the peripherals to gather?
- **Step 92**
  - Do NOT change the password
    - **Demonstrate for instructor**
- **Step 94**
  - What prompt should you see in the terminal to confirm you are connected?
- **Step 95**
    - What command do you type to stop the joy detector?
    - What could you type to disable the joy detector from starting on default?
- **Step 96**
  - What does the 'cd' command do?
  - How do you Copy and Paste in terminal?
- **Step 97**
  - What does the 'ls' command do?
  - What's python?
- **Step 98**
  - What does "./" do?
    - **Demonstrate for instructor that Image Classification is working**
- **Step 99**
  - How do you stop the demo?
- **Step 101**

            - **Demonstrate for instructor that 3 faces are detected**
- **Step 105**
            - What command do you type if you want to rename the last image so that you don't overwrite it?
- **Step 106**
    - What command do you type if you are connected via mouse and keyboard?
    - What is gpicview?
        - **Demonstrate for instructor that you have a picture of yourself on the monitor**
- **Step 107**
    - What does the command 'raspistill' do?
    - How long does the camera wait after you press enter to take an image?
    - What does the –w flag, -h flag and –o flag tell you?
        - **Demonstrate for instructor that you have a 'Group Shot' image taken**
- **Step 110**
    - What does the face score and joy score tell you?
    - What does bbox tell you?
        - **Demonstrate for instructor that you achieved a joy score of 0.8 or above**
- **Step 117**
    - **What command shuts down your kit?**
    - **What should you see before you unplug your kit?**

Day 3 & 4

Makers guide ((https://aiyprojects.withgoogle.com/vision/ for interactive directions)

- **Tensorflow Model Compiler**
    - What is TensorFlow?
    - What is a compiler?
    - What are constraints?
- **Extension to Poet Tutorial**
    - Use Linux machine to run TensorFlow Poet tutorial properly
- **How to use the compiler**
    - **DO NOT run compiler on Vision Kit**

OR

Build a custom case for the Google AIY Vision Kit using CAD and 3D-Print