How to Train Your Robot Companion

Developed by the MIT Media Lab & i2 Learning
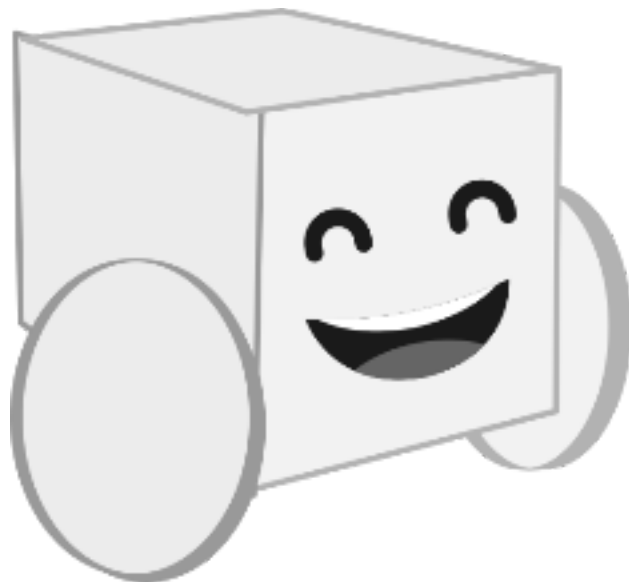
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Learning Goals

Day 1

- Students will learn definitions of Artificial intelligence (AI) and robots
- Students will be able to distinguish machines from robots from artificially intelligent robots
- Students will learn to identify examples of AI in the world
- Discuss different levels of moral and ethical reasoning
- Refresh knowledge of block-based programming in Scratch
- Learn about extensions in Scratch that work with Arduino robot
- Learn about different perceptions of AI that people have in society and in the classroom

Day 2

- Introduce students to machine learning and neural networks
- Students will learn that algorithms do not necessarily give the "right" answer, the answers they give depend on the people who programmed them and what their goals were
- Learn how to train a machine learning system to do image recognition
- Students will learn that algorithms can be helpful and harmful at the same time

Day 3

- Students will be introduced to self-driving cars and some of the issues surrounding the technology
- Students will learn about stakeholders and their interests as they complete an ethical matrix
- Students will use Scratch and Arduino robots to make a self-driving car
- Students will experience some of the challenges of reaching a consensus about technology policy
- Students will do research to find inspiration for final projects
- Students will engage in ideation and brainstorming to choose a few ideas to pursue for their final projects

Day 4

- Open-ended projects help build time-management and planning skills
- Being a user-experience tester is a useful way to learn how to give feedback
- Constructive feedback helps an engineer make improvements to their product
- Reflecting on and synthesizing feedback can help make a project better

Day 5

- Preparing a project for exhibition includes finalizing projects and setting up your exhibition space
- Hard work and playful learning is a way to create a finished product that instills pride
- Divide up roles for explaining the projects to others

Activities Overview

Day 1	Day 2	Day 3
Welcome (15 mins) Students are welcomed to the course and the stage is set for the type of activities they will engage in during the week	**Welcome (15 mins)** Students review what they learned yesterday and go over the activities for today involving machine learning.	**Welcome (15 mins)** Students review what they learned yesterday and go over the activities for today.
What is AI? (30 mins) Students discuss definitions of technology and artificial and intelligence.	**Algorithms as Opinions (30 mins)** Students will do the classic PB&J algorithm example to learn about writing instructions for computers.	**Ethical Matrices (30 mins)** Students will learn about stakeholders and use ethical matrices to guide their moral reasoning about self-driving cars.
Ethical Dilemmas (60 mins) Students will be introduced to moral reasoning with an ethical decision making example.	**Algorithmic Bias (90 mins)** Students will use Google's Teachable Machine to train a biased machine learning system and learn about how algorithmic bias impacts society.	**Self-Driving Robot (90 mins)** Students will learn about closed-loop algorithms to teach their robots to navigate autonomously along a path.
Intro to Scratch and Arduino robots (90 mins) Students will follow tutorials to refresh their knowledge of Scratch and get to know their robotic companions.	**Robot Card Game (90 mins)** Students will teach their robots to use image recognition to play a simple card game.	**Final Project Research (30 mins)** Students will conduct research to do idea generation about their own robot companion projects.
Reflect (30 mins) Students reflect on what they have learned about AI and its role in society today.	**Reflect (30 mins)** Students reflect on what they have learned today about algorithmic bias in AI systems today.	**Reflect (30 mins)** Students reflect on their brainstorming to begin coming up with concrete ideas about what they will build with their robots.

Day 4	Day 5	Notes
Welcome (30 mins) Students will discuss some of their final project ideas and their relationships to some of the ethical concerns they are now aware of.	**Welcome (15 mins)** Students check in with each other about the work they need to do to finish their projects.	
Final Project: Planning (30 mins) Students choose a direction for their final project and develop a plan to determine what the major components of it are.	**Final Project: Finishing Up (120 mins)** Students put the final touches on their projects for the showcase.	
Final Project: Work Time (90 mins) Students start to build a first version of their final projects, inspired by their paper prototypes.	**Final Project: Showcase Preparation (30 mins)** Students prepare for communicating about the work they accomplished this week.	
Final Project: Peer Review (30 mins) Students look at each others' designs and ethical matrices to provide feedback.	**Final Project: Showcase (60 mins)** Students present their robot companions to visitors.	
Reflect (15 mins) Students process the feedback they received and plan the next day's work.	**Reflect (15 mins)** Students reflect on the ethical and technical considerations that went into designing their robot companion.	

Materials

Getting Started

Before the first day, be sure that all laptops are ready by going through the Laptop Setup document. This includes installing Google Chrome, installing the ScratchX robot extension software, making Machine Learning for Kids account for the laptops, and downloading the base code for the robot activities.

Day 1

1. What is Technology handout
2. What is AI handout
3. Ethical Dilemmas handout
4. Ethical Reasoning handout
5. Reflection handout
6. Chart paper
7. Sticky Notes
8. Markers (for teacher)
9. AI vs. Not AI cards
10. Instructor Laptop and Projector (to display video)
11. Student Laptops
12. Robots

Day 2

1. PB&J Algorithm handout
2. Algorithmic Bias handout
3. Reflection handout
4. Cats and Dogs Dataset cards
5. Playing Cards
6. Instructor Laptop and Projector
7. Student Laptops
8. Robots
9. USB Webcams

Day 3

1. Ethical Matrix handouts
2. Final Project Brainstorm handout
3. Final Project Research handout
4. Reflection handout
5. Chart Paper
6. Construction paper
7. Markers
8. Instructor Laptop and projector

9. Student Laptops

10. Robots

11. USB Webcams

Day 4

1. Final Project Planning handout

2. Final Project Peer Review handout

3. Reflection handout

4. Student Laptops

5. Robots

6. USB Webcams

Day 5

1. Final Project Planning handout (from previous day)

2. Reflection handout

3. Student Laptops

4. Robots

5. USB Webcams

Assessments

For more information on assessing your students, see the **Assessment Rubric**, found after this section.

Critical Thinking

When students are working on STEM activities, it is **much more important to assess their critical thinking skills and the ways in which they approach the problem-solving process** rather than assess what they created or their specific coding skills.

⸘ *Discuss* Questions

Embedded throughout the course are opportunities to assess how students are thinking. The bulleted ⸘ *Discuss* questions provide **chances to assess both small-group and whole-class thinking** of either small groups of students or the whole class.

⇔ *Share* Activities

Embedded throughout the course are opportunities to learn about presenting your work, and giving feedback to others. The bulleted ⇔ *Share* activities provide **chances to communicate learnings and build constructive feedback skills** in either pairs of students or as a whole class.

Observing and Listening

As students work through the activities, **listen carefully to their conversations and justifications for their design decisions**. The collaboration and use of science and engineering practices that you see will help you understand how students are approaching problems.

As students become more comfortable working with each other and implementing the engineering design process, **we recommend contrasting what you see at the beginning of the week with what you see later in the course.**

Showcase

Designed to highlight projects creading by groups throughout the week, **the end-of-week Showcase is a great opportunity to assess students by encouraging them to share what they know.**

Assessment Rubric

Students gain positive attitudes and skills		
Goal	**Evidence: I see students...**	**Notes**
Students are engaged	• participate in activities • share ideas during discussion • vocalize enjoyment	
Students apply their knowledge	• share prior knowledge • make connections from one activity to another • relate previously collected data to new contexts	
Students collaborate	• hear and respect the ideas of others • encourage group members and classmates • give thoughtful feedback to others	
Students use programming and engineering practices		
Day 1 Goal	**Evidence: I see students...**	**Notes**
1. Identify AI	• ask about criteria of AI and constraints (i.e. is a toaster AI? Why not?) • notice what is AI in their robots	
2. Programming their robot and using computational thinking	• use indigo blocks • apply math, logic, and abstract thinking to help solve problems or explain observations	
3. Engage in argument from evidence	• support moral argument with logic, observations and findings • discuss the challenges of evaluating ethical decisions	
Day 2 Goal	**Evidence: I see students...**	**Notes**
1. Evaluate an ML system	• identify features (i.e. what to teach) • talk about the challenges of teaching a machine	
2. Understand bias	• make observations about biased and unbiased datasets • talk about solutions in groups or class discussions	
3. Carry out investigations & Build an ML dataset	• discuss evaluation metrics • gather data and build models • support design decisions with evidence	

Day 3 Goal	Evidence: I see students...	Notes
1. Prioritize stakeholders	• discuss roles of different stakeholders • identify constraints and challenges	
2. Use sensors	• identify inputs and outputs • design and improve technologies	
3. Analyze and interpret data	• gather data and observations • talk about data within their groups or class discussions	
4. Engage in argument from evidence	• actively participate in classroom discussion • support argument with logic and observations • identify challenges of AI regulation	
Day 4 & 5 Goal	**Evidence: I see students...**	**Notes**
1. Research and Plan	• generate novel ideas or extensions of existing ideas • create a plan for their idea	
2. Construct explanations and design solutions (for engineering)	• make and test hypotheses • design and improve technologies • talk about solutions in groups or class discussions	
3. Carry out investigations	• identify variables • discuss evaluation metrics • gather data and observations	
4. Obtain, evaluate, and communicate information	• share information during activities • actively participate in showcase	

Welcome

Lesson

15 mins

Objectives

Students will be able to identify examples of technology
Students will learn definitions of Artificial intelligence (AI) and robots
- Artificial intelligence is a program that allows computers to behave in ways that make them seem intelligent (or smart) the same way that humans are intelligent
- Robots are machines that sense their environment, do calculations of some kind, and then perform an action.

Students will be able to distinguish machines from robots from artificially intelligent robots

Introduction

In this course students will build robots that are artificially intelligent. These robots can interact with people and their environment, which means that they can have both good and bad consequences for society. This course will help students think about those consequences and how to design robots that increase good consequences and decrease bad ones.

We will rely a lot on online tools like Scratch which means that students can take what they learn in class and use them for their own projects at home.

Directions

1. Welcome students to Day 1 of How to Train Your Robot Companion. Explain that, in this course, groups of students will work together to design robot companions that solve real-world problems. Along the way, we will learn programming and machine learning to have the robots do things that make them artificially intelligent.

2. Begin the class with an icebreaker question. If the class does not know each other well, make sure that they all share their names. Here are some ideas of icebreaker questions:
- Can you give an example of something that is AI?
- What is the coolest example of technology you have seen or heard about?

What is AI?

Materials and Preparation

Chart paper
Colored markers
What is Technology handout
What is AI handout
AI vs Non-AI Cards

Vocabulary

Artificial Intelligence - a program made by people that makes computers do things that seem intelligent (or smart) in the same way that humans are intelligent.
> With AI, computers and machines can _understand_ their environment, _learn_ more about it, _make decisions_ and plans, and then _interact_ with humans and the environment.

Machine - any moving mechanical device that does work

Robots - machines that sense their environment, do calculations of some kind, and then perform an action.
> Without AI, robots can sense but not understand, they can do calculations but they cannot learn and make decisions, and they can do actions but they cannot interact.

Technology - knowledge that we use to invent new tools or devices

Directions

1. Ask students to turn to their 'Technology is...' handout'. Use the following discussion questions to guide students to come up with some ideas so that they can fill out the handout.

Note: Rather than using the handouts, you can have students make posters or recreate the handout in a course notebook.

⠇ Discuss

What do you think the term technology means? Work with students to come up with a definition. An example definition is that technology is every tool made by people that solves a problem or does something new.

What are examples of technology that you have seen or used? Answers can range from very exciting things - virtual reality headsets, genetically engineered food, spaceships that land straight up and down - to very mundane things - ponytail holders, pencils, rubberbands.

2. As students begin discussing examples of technology, try and find words that might fill in the blanks with the sentence starter handout. Then, have them choose an example of technology that is important to them to draw in the blank.

Technology is _____ (noun) made by _____ (noun) in order to _____ (verb).

3. Explain to students that throughout the course (and beginning today) they will have the chance to think about how technology might cause harm, but can be designed to be reduce this harm.

⋮ Discuss

What are some ways that technology might cause harm? There are a couple of big ethical concerns with technology. Prompt students with these ideas and see if they can come up with examples.

Unintended consequences, someone might build something that unintentionally hurts someone else. An example is a farmer up the river builds a dam to better water his crops. What he doesn't know is that he keeps water from everyone else down the river.

Security, new technologies always come with new vulnerabilities. An example is that as cars become more electronic it becomes easier to "hack" them with a computer. People do not need direct access to your car anymore.

Fairness, having a technology might give some people an unfair advantage over others. An example is that a lot of teachers assign homework where students need a computer because students can do research and learn more. However, only about half of students in the United States have computers at home. It's a lot harder for students without computers at home to get their homework done.

Environmental impact, new technology can harm the environment. An example is that phones are built to last for about two years, then most people go and buy a new one. The problem is that this has led to a lot of hard to recycle e-waste.

4. Have students use the 'Technology is...' handouts to come up with a few ways that their technology can be used to do helpful things or abused and have bad consequences.
5. Explain to students that the technology that we will focus on in this class is artificial intelligence. Start by creating a working definition of AI with the students.

⋮ Discuss

What do you think the term "artificial intelligence" means? Work with students to come up with a definition. Encourage students to break this term down by first defining "artificial" and "intelligence".

*The term **artificial** is an adjective used to describe that which is not natural and is usually made by people. **Have class share out examples of things that are "artificial".** If no one brings it up, make sure that technology, machines, and robots come up.*

***Intelligence** is something related to using your mind to do things like understand what is going on, apply knowledge, solve problems, and be creative (there are no simple definitions of intelligence!) **Have class share out actions they would describe as intelligent.** It might be useful to think of things that they can do*

which babies, animals, and even computers cannot do. Some important ideas are being good at puzzles, being creative, knowing the right thing to do, being able to talk.

*Students should understand the term "**artificial intelligence (AI).**" AI is **a program made by people that makes computers do things that seem intelligent (or smart) in the same way that humans are intelligent.***

6. If you are using the "AI is…" handout, then have students fill in the blanks for the definition of AI. AI is <u>a program</u> made by <u>people</u> that <u>makes computers do things that seem intelligent in the same way that humans are intelligent</u>

7. Now, draw on the board or chart paper, create a large table with three columns: 'Examples of AI' 'How can we use AI?' leave the third column blank. Eventually, we will fill in the third column with 'How can we abuse AI?'.

8. Next, have students call out different examples of AI. You can use the four topics of AI (along with posters) to guide their thinking. We will use these examples in the next activity.

⋮ Discuss

Four Topics of AI: understand/perceive, learn, make decisions/plans, interact.

With AI, computers and machines can understand their environment, learn more about it, make decisions and plans, and then interact with humans and the environment.

- **Understand/Perceive:** *Face filters (Snapchat or Facebook), chatbots (Siri, Alexa), toy robots*
- **Learn:** *Netflix and YouTube learn what kinds of videos you like to recommend more*
- **Decide/Plan:** *DeepBlue AI that beat the world's best chess player, AlphaGo AI that beat the world's best Go players, self-driving cars*
- **Interact:** *Chatbots (Siri, Alexa), DeepBlue and AlphaGo, self-driving cars,*

Note: If you are using the 'AI is…' worksheet then have students pick one example of AI to draw. This can be done in notebooks or students can make posters for the wall.

9. Test students' understanding of AI by passing out the "What is AI" cards. Ask students to work in groups to sort the cards into things that are AI and things that are not AI. If there are any disagreements, discuss them with the class.

Not AI	**AI**
Toaster	Autonomous robot dog
Automatic door	Chatbots
Car (old school)	Self-driving car
Remote control robot	Snapchat face filter

10. Now fill in the second column with ideas about ways that AI can be used. This will come back when students begin brainstorming for their final projects.

⋮ Discuss

Why might we want to develop artificial intelligence? How might AI be helpful to us?

We can make AI that...

- **Entertains:** *AIBO robot dog, Cozmo robot, Sophia android*
- **Goes where humans can't:** *NASA Helicopter, Curiosity, Valkyrie*
- **Help people:** *NAO therapy robot, PARO therapy robot, Huggable*
- **Explore the world:** *Self-driving cars, Roomba vacuums*

11. Finally, tell students that just like any other technology, AI can be used for good things. But it might have some bad consequences for individual people or society as a whole. Write the final column header 'How can we abuse AI?' This is an idea that we'll explore throughout the week.

Ethical Dilemmas

Materials and Preparation

Laptops and Wifi connection
Ethical Dilemmas handouts
Ethical Reasoning handout

Websites
https://www.youtube.com/watch?v=zPsoFhUDLuU

Vocabulary

Morality	The difference between good and bad, wrong and right, following the rules and breaking the rules
Ethics	Moral guidelines for how people in society should behave if they want to be fair

Lesson

1 hour

Objectives

Discuss different levels of moral and ethical reasoning

Introduction

As we mentioned in the Welcome, every technology has good and bad consequences. We not only want to teach students about technology, we also want them to be able to think carefully about those consequences of the technology. In this lesson we will introduce ethical dilemmas and equip students with some tools to think about them carefully.

Directions

1. Have students watch the following video about ethical dilemmas together https://www.youtube.com/watch?v=zPsoFhUDLuU.

⋮ Discuss

What are ethics? Ethics are a set of moral guidelines that individuals in society follow to be fair to one another. **Who decides these guidelines?**

What was the first ethical dilemma that Tim described? The girl in the video was paid to mow her neighbor's lawn. It took the girl about half an hour less to mow the lawn than usual. The amount that the neighbor paid was most likely related to how long it thought it would take. This means that the girl was given too much money to mow her neighbors lawn. **What strategies did Tim employ to discuss the ethical dilemma?** Tim suggested

that the girl put herself in her neighbor's shoes and considered the consequences of each action. **What advice would you give the girl and why?**

What was the second ethical dilemma that Tim described? A boy's friend cheated off of his test. The friend asked the boy not to tell the teacher about it. **What strategies did Tim employ to discuss the ethical dilemma?** Tim made a pro/con list for the different consequences of each of the actions. **What advice would you give the boy and why?**

Would you expect everyone to have the same advice for these situations? What does that mean?

2. Different people may have different opinions about the right thing to do. Different people may also have the same opinion about what to do, but have different reasons for wanting to do it. **The important thing** is to learn how to understand different opinions and to make the best decision possible.
3. Have students look at the three ethical dilemmas on their AI ethical dilemma reading page. Students should work with another person to look at the different sides of the ethical dilemma. Students can use the pro-con list and/or perspective taking from different sides to help with their reasoning. Give students 20-30 minutes to work on them.
4. Ask students to share their reasoning with the class.

Ethical Dilemmas
A. Joe is a fourteen-year-old boy who wanted to go to camp very much. His father promised him he could go if he saved up the money for it himself. So Joe worked hard at his paper route and saved up the forty dollars it cost to go to camp, and a little more besides. But just before camp was going to start, his father changed his mind. Some of his friends decided to go on a special fishing trip, and Joe's father was short of the money it would cost. So he told Joe to give him the money he had saved from the paper route. Joe didn't want to give up going to camp, so he thinks of refusing to give his father the money. Should Joe refuse to give his father the money?
B. Two young men, brothers, had got into serious trouble. They were secretly leaving town in a hurry and needed money. Karl, the older one, broke into a store and stole a thousand dollars. Bob, the younger one, went to a retired old man who was known to help people in town. He told the man that he was very sick and that he needed a thousand dollars to pay for an operation. Bob asked the old man to lend him the money and promised that he would pay him back when he recovered. Really Bob wasn't sick at all, and he had no intention of paying the man back. Although the old man didn't know Bob very well, he lent him the money. So Bob and Karl skipped town, each with a thousand dollars. Which is worse, stealing like Karl or cheating like Bob?

Intro to Scratch and Arduino Robots

Materials and Preparation

Sticky notes
Laptops and Wifi connection required
robots

Websites
https://machinelearningforkids.co.uk/scratchx/?url=https://mitmedialab.github.io/arduino-scratch2/Chromebook/arduino_extension.js#scratch

Vocabulary

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Coding	assembling a set of instructions that tells a computer how to do something you want it to
Backdrop	a picture or drawing that can be placed in the background of a scene in Scratch
Block Palette	the part of the Scratch editor all the way to the left where you can see the different types of code blocks that can be used in the Workspace
Script	a set of blocks that are linked together in order to have a set of actions happen in sequence
Sprite	a character that can be coded in a scene in Scratch
Stage	the area of the Scratch editor interface where the animations happen
Workspace	the part of the Scratch editor interface in which to place code blocks you want to use to code your animation

Lesson

1 hr 30 mins

Objectives

Refresh knowledge of block-based programming in Scratch
Learn about extensions in Scratch that work with arduino robots

Introduction

Scratch is an online tool that we can use to program games, animations, and videos. The programming tools are blocks that snap together. The different colors of the blocks distinguish the kind of block it is and what it can do.
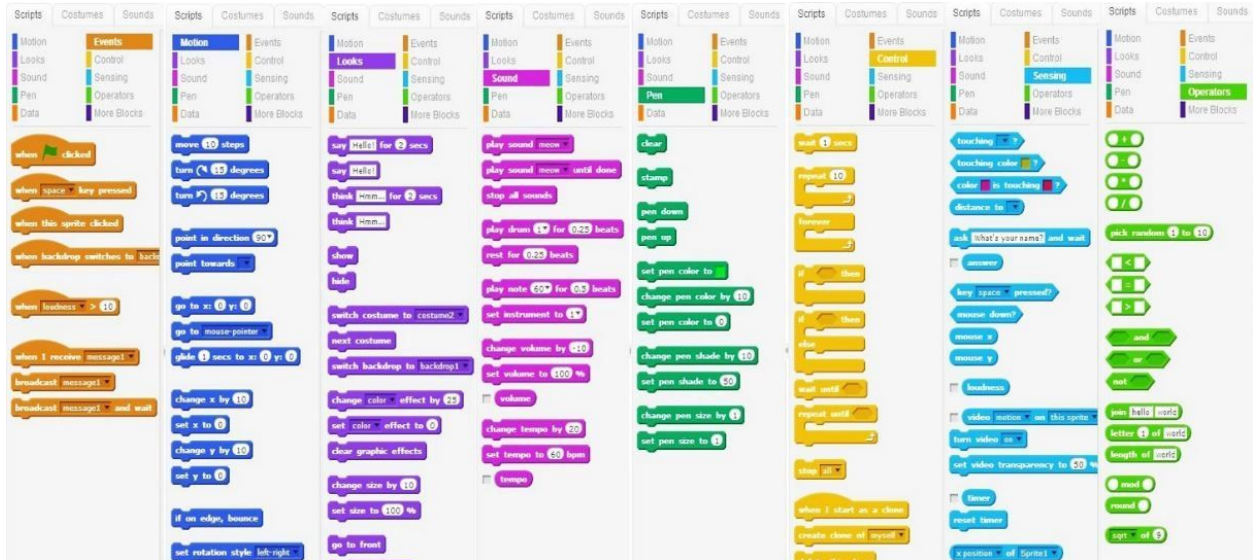
We will be using Scratch to program our robot companion. In order to program our robots we will need special dark indigo blocks. Today we will go through tutorials to get more familiar with Scratch and with Arduino robots.

Directions

1. Have students take out their robots.
2. Have students find the Google Drive document that shows all of the guiding pages for using Scratch and Arduino robots.
3. Instruct students to get to know thier Go through the different things that the robot can do - measure distance, see colors beneath it, make sounds, do animations, flash a colorful LED.
4. Robot Activities
   a. Make a police car (LED lights, sounds, animations)
   b. Drive in a square (Motors)
   c. Navigate a maze (IR sensors, motors)
   d. Chase after objects if they get too close (Ultrasonic distance sensor, Motors, Animations)
   e. Do a skit that uses all of the blocks

Note: If students need inspiration for the last activity, they can check out the following video https://www.youtube.com/watch?v=7X64DsFN8gE.

⋮ Discuss

Would you consider the things you built AI? What would have to be different for it to be AI?

Reflect

Materials and Preparation

Reflection handout

Lesson

30 mins

Objectives

Learn about different perceptions of AI that people have in society and in the classroom

Introduction

To end the first day, students will reflect on the role of AI and technology in their lives.

Directions

1. For this activity, students will get up and move around the room to vote about their opinion of AI. Explain to students that they should group in different parts of the room according to their opinions. First, we will do a test. Have students go to one corner if they love pizza, the other corner if they love ice cream, and the middle if they don't know or they are somewhere in the middle.
2. Next question: What is the role of technology in your life (can't live without it -> it scares me)? Feel free to let students explain their reasoning.
3. Ease - AI might make our day-to-day lives easier because we could ask computers to do more tasks for us
    a. I am very excited by this possibility -> I am very concerned about this possibility
    b. I think this is very likely to come true -> I think this is very unlikely to come true
4. Obsolescence - AI might mean we become over reliant on machines and replace the need for humans in jobs, relationships, and socializing
    a. I am very excited by this possibility -> I am very concerned about this possibility
    b. I think this is very likely to impact me in my lifetime -> I think this is very unlikely to impact me in my lifetime
5. Gratification - AI might become the perfect friend, there to listen whenever we need and ready to meet our every desire
    a. I am very excited by this possibility -> I am very concerned about this possibility
    b. I think this is very likely to impact me in my lifetime -> I think this is very unlikely to impact me in my lifetime
6. Alienation - AI might cater to all our desires so well that we prefer AI interaction to human interaction
    a. I am very excited by this possibility -> I am very concerned about this possibility
    b. I think this is very likely to come true -> I think this is very unlikely to come true
7. How strongly do you feel you are able to influence how AI develops in the future (strongly agree -> strongly disagree)

End the day by having students use the Reflection handout to write down either: something they learned about AI, something AI is useful for, someway AI might cause harm, or a question they have about AI.

Give students the opportunity to share if they would like to.

Day 2

Welcome
Materials and Preparation

Laptops with Internet

Websites
https://quickdraw.withgoogle.com/

Vocabulary

|	
Machine Learning	Computer applications, or apps, that learn about the world without being programmed with instructions
Neural Network	A way to do machine learning, loosely modeled after a human brain, that uses patterns to figure out how to label an input
Dataset	A collection of information, for machine learning this information is usually pairs of objects and their labels
Features	Characteristics of objects that machine learning algorithms use to make decisions about how to label them

Lesson

15 mins

Objectives

Introduce students to machine learning and neural networks

Introduction

Machine learning is a hot topic in AI. Recently, faster and more powerful computers as well as easier access to large datasets have made it easier to develop machine learning systems. Today, students will go through several machine learning algorithms, beginning with neural networks.

A neural network is a computer system roughly modeled on the functions of the human brain. The basic idea is that brains use networks of neurons, a basic cell in the brain, to process information from input (i.e. one of the five senses) to output (i.e. a thought in the brain or action for the nervous system to execute). Each neuron can only do a tiny bit of work before propagating information to the next neuron. However, all of the neurons together can do incredible feats like translate visual information into recognition of objects. Here is a visualization of neural networks implemented in computers:
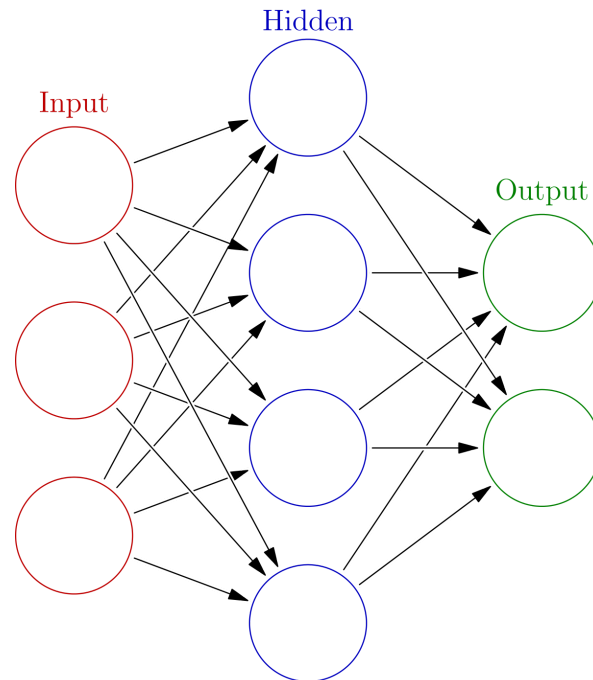
In neural networks, there can be as many layers as necessary to do the work. The harder the problem, the more neural networks you will need.

To give you an idea, here are some common neural networks:

- Written number recognition (MNIST) http://yann.lecun.com/exdb/mnist - 2 layers
- Credit card fraud detection https://blog.usejournal.com/credit-card-fraud-detection-by-neural-network-in-keras-4bd81cc9e7fe - 2 layers
- Facebook Auto-tagging https://computer.howstuffworks.com/internet/tips/facebook-photo-tags.htm - 9 layers

Directions

1. Welcome students to the second day of learning about AI and ethics. Explain that today students will learn about different AI algorithms - their uses and their pitfalls. First, we will play with an AI that recognizes drawings.
2. Have students spend some time playing the QuickDraw game at https://quickdraw.withgoogle.com/

Note: If time is a concern, this activity can be done with one laptop and you can choose students to come up and play different rounds. Let students know that they can continue to play later or they can access the website from any other device outside of the classroom.

⋮ Discuss

What was your strategy for drawing? Time crunch aside, students most likely used a strategy where they tried to include the most important parts of what they were drawing. Like if they were told to draw an elephant they focused on the trunk and the ears. **Why do you think using this strategy was important for the computer? Were you ever surprised**

that the computer did not recognize something? When the computer got things wrong, how did you feel? Neural nets are one of the most opaque algorithms. When it gets things wrong, it's not entirely clear why or how to fix it. In this game, getting things wrong is a bit annoying. However, there are application spaces where neural nets get things wrong with very important consequences.

How do you think the computer learned to recognize so many different drawings?

3. Explain to students that the computer learned to recognize drawings by looking at lots and lots of drawings. Does anyone want to guess how many? The computer learned from looking at 50 million drawings of 345 different items done by more than 15 million people. That would be every person in New York City, Los Angeles, and Chicago submitting 3 drawings for the computer to learn from. That's a lot of drawings!
4. Explain neural nets to students: the computer was using an algorithm called a neural net that is based on the neurons in people's brains. Students can refer to the 'Neural Net' reading page that shows how neural nets recognize dogs

    However, although the algorithm is based on human brains it works much differently than our brains. After all, we certainly don't need to see 50 million examples to learn to recognize drawings well! Still, neural nets are very powerful - if you have the data to train it, that is.
5. Look at the dataset visualization https://quickdraw.withgoogle.com/data and investigate one of the categories, such as the bowtie https://quickdraw.withgoogle.com/data/bowtie. Here students can see all of the example drawings that the system learned from.

⋮ Discuss

What kinds of things does it look like the system is learning about bow ties? Two triangles on either side and a circle in the middle. However, you can see that sometimes people drew just two triangles, without the circle or one triangle and the circle and that's it. If you look closer you can see that some people drew a necktie or even just scribbles. What are some things the system might get confused with bow ties depending on how someone drew it? If someone just drew one triangle and a circle, it looks a lot like a fish. If someone drew two rectangles with a square in the middle, it looks like a belt.

Investigate some of the things that the computer might confuse with a bow tie. Use the dropbox at the top left of the page to look at the data for fish or any other object.
6. Now that we've talked about neural nets, how they are trained, how much data they need, and how accurate they are we can continue to learn about new algorithms. Today we're going to train neural nets, learn about another machine algorithm, and think about the consequences of AI algorithms being wrong.

Algorithms as Opinions

Materials and Preparation

PB&J Algorithm handout
Pens
For teacher:
> Loaves of bread (or colored paper representing bread in slices)
> Plastic knives
> Jar of peanut butter (or colored paper representing peanut butter in a jar or other container)
> Jar of jelly (or colored representing jelly in a jar or other closed container)

Vocabulary

Algorithms   A set of instructions that computers follow to do work

Lesson

30 minutes

Objectives

Students will learn that algorithms can have various goals and motives; they do not magically give the "right" answer

Introduction

An algorithm is a set of instructions that computers follow to do work. Computers use algorithms programmed by computer scientists to complete tasks. However, unlike people, computers are very literal. The programs that computer scientists write have to be very specific because the computer will follow exactly what they say. To demonstrate, the instructor will pretend to be a computer and the students will write a program to make a peanut butter and jelly sandwich.

Directions

1. Tell students that algorithms are kind of like recipes. You have a list of ingredients, or the input data, instructions for making the recipe, or code, and then you have the output! The trick with recipes for computers, though, is that they have to be very specific in order for the computer to get them right.
2. Have students go to the 'Peanut Butter and Jelly Algorithm' handout in their student pages. Students should take 5-10 minutes to come up with an algorithm, or recipe, to make _the best_ peanut butter and jelly sandwich.
3. After students finish, have them turn to someone else in the classroom to describe their algorithm.

⋮ Discuss

What things did you have in common with your friend's algorithm? What things were different?

If you had to give your algorithm a title like "How to make the ___ PB&J" what adjective would you use? You cannot use "best." Most students will say "yummiest" or "tastiest" to describe their algorithm.

Did anyone include instructions to put away ingredients after you used them? Then you might have been writing the "tidiest" PB&J algorithm. Did anyone write an algorithm that included cutting the sandwich into fun shapes? Then maybe you made the "most artistic" PB&J algorithm.

4. Share that your doctor's P&J algorithm included putting PB&J on slices of banana rather than bread. Your doctor's goal was to make the "healthiest" PB&J algorithm. Just like with PB&J algorithms, computer algorithms also have different definitions for "best."

    Deciding which "best" to design an algorithm for depends on who will use the computer and what is important to them. This is an ethical decision that designers have to make.

⋮   Discuss

When you search on Google, it gives everyone different results according to an algorithm that searches through all of the websites on the Internet. What might be the goal of Google's search algorithm? Students might say that Google is giving the right answer or as close to the right answer as possible. Really, algorithms give answers that are unique to the person that is searching. Ultimately, their goal is to get people to click on links - specifically advertiser's links.

5. Open up Google search under two different accounts (or one under an account that is logged in, and one in an incognito browser). Search for some of the following items: pizza place, best movie, news.

⋮   Discuss

What kinds of things might the search algorithm take into account when giving personalized results? Things that Google knows about: location, previous searches, and previously clicked links.

Algorithmic Bias

Materials and Preparation

Laptops with Internet
Algorithmic bias handout
Projector with Internet, or download video in advance

Websites

Vocabulary

Training	Giving a machine learning system a dataset with input and expected output so that it can learn the patterns that relate the two of them
Testing	Giving a machine learning system just the input of a dataset and measuring to see how accurate the outputs are so that you can evaluate how well the system learned

Lesson

60 mins

Objectives

Learn how to train a machine learning system to do image recognition
Learn that machine learning algorithms focus on certain parts of data, or features to make decisions
Students will learn about Algorithmic Bias and how to mitigate it
Students will learn that algorithms can be helpful and harmful at the same time

Introduction

Now we're going to use what we learned about machine learning to train our own system. This system does not use a neural network, but an algorithm called nearest neighbors. That means that the system learns how to classify objects by comparing it to objects that it already knows.

In the picture below, the system is trying to decide if the green circle is supposed to be with the red triangles or the blue squares. If we look at green circle's nearest neighbor, we see that it is much closer to a red triangle than a blue square so it might be a good idea to say the green circle is with the triangles. But we can look for more information. If we look at the 3 neighbors closest, again there are more red triangles close to the green circle than squares. However, we can still look for more information. If we look at the 5 neighbors closest to the green circle, then we see three blue squares and two red triangles, so then again maybe the green circle is really supposed to be a blue square.

k-nearest neighbor rule
- Choose k odd to help avoid ties (parameter!).
- Given a query point x_q, find the sphere around x_q enclosing k points.
- Classify x_q according to the majority of the k neighbors.

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We can choose how many neighbors to look at by testing lots of data, lots of green circles, rather than just one and seeing whether looking at 4 neighbors vs two neighbors gives us a better result.

At the end of the activity, students will discuss algorithmic bias. Algorithmic bias is a tricky, but important topic for students to be aware of. The input data for a machine learning algorithm is extremely important for reducing algorithmic bias. If a system has too few or too many examples, then it might not work as expected.

Directions

1. Make sure that students have webcams and Internet enabled on their laptops.
2. Have students navigate to the Teachable Machine www.teachablemachine.withgoogle.com website and go through the quick tutorial.
3. The tutorial should have students training algorithms fairly quickly. Challenge them to make a classifier that can distinguish rock, paper, and scissors hand signs, then say the name of each out loud.
4. To introduce the idea of features, have students train one class in front of a wall with one background and another class in front of a different background. For example, have students do train the rock class in front of the whiteboard/blackboard and the paper class in front of a window or door (or some other surface that looks very different).
5. When students test their machine, they'll find that the machine cares more about the background behind them rather than the shapes their hands are making. The background in the image is a feature that the machine is using unintentionally!
6. To help the machine learn that the background should not be an important feature, make sure to train classes with multiple different backgrounds and other conditions like how close the object is to the camera, the amount of light, and the people pictured in the image.

⋮ Discuss

What surprised you about teaching the machine to recognize different objects?
Students should say things like again they had to be very careful because the computer would take the image too literally and not know exactly what to pay attention to. Also, they

had to give the computer a lot of examples for it to work. The machine required at least 30 examples!

7. Now we're going to train a classifier to recognize cat and dog images. Point students to the biased cat-dog dataset to train a class for cats and dogs and have them cut out the images. Do not tell the students, but the data is biased such that there are many more cats than dogs and a wider variety of cats than dogs.
8. After students finish training their system, give them the unbiased cat-dog dataset to test their system on. Students should find that their system is much more accurate for cats than dogs. See if students can look at the biased cat-dog dataset to see why (i.e. there are many more cats than dogs, there are much better examples of different kinds of cats than dogs, some of the dogs look like cats!)
9. Now ask students to use the biased and unbiased examples to make their own unbiased dataset to train their cat-dog classifier.
10. Watch the "AI Ain't I A Woman?" video by Joy Buolamwini (Bowl-Lum-Wee-Knee).

⋮ Discuss

What issue in facial recognition technology does Joy identify? That facial recognition systems are very good at recognizing males with white skin, but not as good at recognizing females with dark skin.

Why is this a problem? Think of some ways that facial recognition is used (Snapchat/camera filters, Google searches, self-driving cars). It's not fair that technology that is advertised as being built for everyone does not work as well for some people.

For example, if people with darker skin can't use fun camera filters or if automatic cars have a hard time seeing people with darker skin. There are some positive effects: if cameras have a harder time seeing people with darker skin then there's less of a chance of their privacy being breached by surveillance. However, this also has some risks—what if an innocent person is accused of a crime because of a bad recognition system?

Based off what you know about training algorithms, how could this problem be fixed? Have students think about how they improved the cat-dog classifier. They included many more examples and made sure they were balanced in all of the important classes. In the case of cats and dogs this means including lots of different breeds of each.

What are some rules we might want to put in place about using this kind of technology fairly and safely? Should we put rules in place about how much and what kind of testing to before selling a technology? Should outside organizations (like another version of the FDA) help provide oversight to make sure that everyone is doing a good job testing. Companies could apply for certification to prove their product is fair.

Robot Card Game

Materials and Preparation

Playing cards
Arduino robot
USB webcam
Laptops with Internet and webcams

Website
https://machinelearningforkids.co.uk/scratchx/?url=https://mitmedialab.github.io/arduino-scratch2/Chromebook/arduino_extension.js#scratch

Lesson

1 hr 30 mins

Objectives

Students will design their own dataset for an image recognition system
Students will apply their lessons about algorithmic bias to carefully design and implement their machine learning system
Students will learn how to identify stakeholders

Introduction

In this activity, students use image recognition to make a card game where you challenge the computer to recognize that two cards have the same suit. This is based off of a Machine Learning for Kids activity called Snap!.

In order to train the computer to recognize the cards, they will take pictures of the cards to upload to the computer. The neural net will require at least 10 examples of each class. Students may wonder why they don't need the millions of examples that other systems need. The truth is that IBM Watson, the interface that they are building their algorithm on top of, did train their neural net on millions of examples. Then, in order to make it possible for other people to train their own neural nets, they removed the last layer (the output layer) and replace it with the training data supplied by the students.
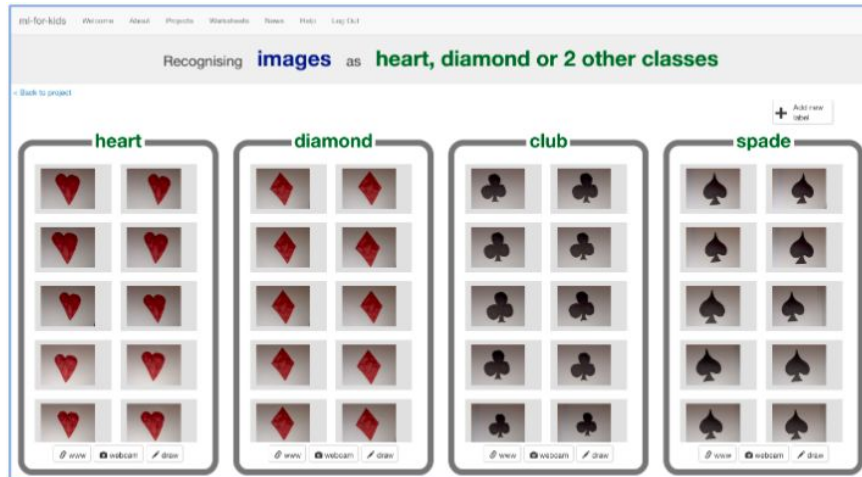
The game works where students will flip over cards one at a time in front of their Arduino robot. If the card's suit matches the suit that the robot randomly picks, then the student must yell "Snap!" Whoever says "Snap" first, the student or the robot, will get one point.

Directions

1. Now students are going to use image recognition to use image recognition to make a card game where you can challenge the computer to recognize that two cards have the same suit.
2. First, have students set up the external camera so that it looks down on the playing space. The robot and a stack of playing cards should be in the scene.
3. Sort the cards into suits. This will make it easier to train.
4. Train your machine learning algorithm! Take pictures of each card and label them by their suit, spades, diamonds, hearts, or clubs, in the image labelling workspace. Click the train button to let your algorithm train.

⋮ Discuss

What kinds of things did you take into consideration to make the card recognizer work well? Students should be sure to get lots of different examples of each card suit, to rotate some of the cards, and use training images that are similar to the testing environment.

How would you advertise your project? What information would you give a user in terms of how it should be used? Students should tell the user about the training data that was used, what things it should be able to do well and what might not work. For example, if the user's cards are very different from the training cards then the project might not work as well.

5. Have students load the base code for the game in Scratch. Next, have students load their model in Scratch by following the instructions on the reading page. Use the Scratch project to see how well our algorithm does recognizing cards. Retrain if needed.

The game works where students will flip over cards one at a time in front of their Arduino robot. If the card's suit matches the suit that the robot randomly picks, then the student must yell "Snap!" Whoever says "Snap" first, the student or the robot, will get one point.

6. Remix the project! Add features such as having the robot speak it's suit out loud, drive over the card rather than just saying "Snap!", or use LED lights and music to make the game more interactive.

⋮ Discuss

Who is this project appropriate for and who might be left out? What if users are too young to read, speak different languages, only have black-and-white cameras, or do not have access to cards.

Reflect

Artificial unintelligence and adversarial patches

Materials and Preparation

Laptops and Wifi connection

Websites
https://www.youtube.com/watch?v=i1sp4X57TL4
https://www.youtube.com/watch?v=piYnd_wYlT8

Vocabulary

Lesson

30 mins

Introduction

Artificial unintelligence is a term that describes that in the field of AI, machines have many limitations and can be fooled. Sometimes when AI algorithms fail they can cause harm and injustice, like in the case of algorithmic bias. Other times, AI algorithms may get intentionally hacked.

An example of hacking machine learning algorithms is in the creation of adversarial patches.

Directions

1. Today we learned about machine learning algorithms and that they do not always give the "right" answer. They are designed to answer certain questions well. When algorithms are used in ways they are not designed for, then there are possible harmful effects that result.

   ⋮ Discuss

   What are some ways that you've seen algorithms fail in your own experience? Voice personal assistants don't understand what you say, cannot answer your question, cannot understand the voice of someone with an accent. YouTube's recommendation algorithm sometimes recommends videos that seem strange or that you're not interested in.

2. Tell students that there is a field of research (called 'artificial unintelligence') dedicated to exploring how to trick AI and make it more robust. Load the first video about adversarial stickers. Then load the second video about adversarial textures.

   ⋮ Discuss

   How do you think the adversarial stickers were made? Adversarial stickers were made with AI! Researchers used an algorithm where they adjusted the way the toaster looked slowly over time to increase the system's confidence that it was seeing a toaster.

You can still see some characteristics of a toaster within the image of the adversarial sticker. Do you think that is important for adversarial stickers to work? No. Adversarial stickers have actually been produced where, to the human eye, the image is clear. However, the algorithm still gets confused.

"panda"
57.7% confidence

"gibbon"
99.3% confidence
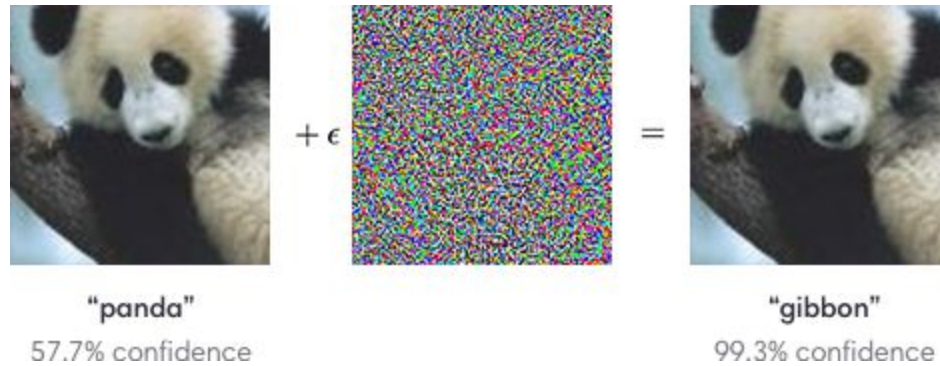
3. Surveillance is also a big concern for people using AI. What if you don't want any camera on the street to see and record all of your actions? Researchers have developed an adversarial patch where the algorithm cannot recognize humans in the scene.

4. Adversarial patches have also been created to "hack" future self-driving cars by confusing them.

5. This technology clearly has some positive and some negative uses.

⋮ Discuss

Now that you know more about the risks and problems with AI, does that change your opinion about using it? Students should reflect on Algorithmic Bias (Can we build AI that's fair for everyone) as well as the new security concerns raised by technologies like adversarial patches. Allow students to express their fears, then balance them out with their hopes about AI to come to a final conclusion about using AI in society.

Welcome

Materials and Preparation

Ethical Matrix handouts

Vocabulary

Stakeholders	People, either individuals or groups, who care about a technology
Ethical matrix	A tool that we can use to think about stakeholders and the reasons they are interested in a technology

Lesson

15 mins

Objectives

Stakeholders are people, individuals or groups, who care about a technology
Ethical matrices can help us understand how technology impacts different people in society

Introduction

Ethical matrices are tools for ethical analysis where students identify the stakeholders in an issue and their varying interests. Stakeholders go down the first column, different areas of interest they may have go across the first row. Then, the cells in the middle are filled in with the major concerns each stakeholder has with respect to each topic. Here is an example of an ethical matrix for agricultural policies.

Example: Food Industry

	Wellbeing	Autonomy	Justice
People in the industry	Income & working conditions	Freedom of action	Fair trade
Citizens	Food safety & quality	Informed choices	Availability & Affordability
Farm Animals	Animal welfare	Behavioural freedom	Intrinsic value
The environment	Conservation	Biodiversity	Sustainability

Directions

1. Welcome students to the third day of learning about AI and algorithms. Explain to students that over the past two days they have learned about how AI collects data and learns from that data. Today, they will learn about how to use these kinds of AI to interact with humans and the environment. By the end of the day, they will begin to think about what they want to build.
2. Ask students to recall their PB&J algorithms from the first day.

⋮ Discuss

What were some of the goals that our algorithms had in the PB&J activity? Students should recall things like they made the tastiest, quickest, tidiest, or healthiest PB&J sandwiches. These are words that we used to fill in the blank "Recipe for the _____ PB&J Sandwich."

If we have to make a sandwich, how do we decide which goal is most important? Students may suggest that if they are eating the sandwich they would prioritize their own preferences, regardless of healthiness or cleanliness. However, if a busy parent is making the sandwich for them then the quickest sandwich might be the goal. More diplomatic students may suggest that we choose the sandwich recipe that makes the most people happy.

3. Explain to students that ethical matrices are a tool that ethical analysts, such as themselves, can use to think about who is affected by technology and what is in the best interest of all of those people. Just like the different perspectives and pros and cons examples that we did the first day, this is another method of ethical reasoning. We can use it to decide what goals to prioritize.
4. Have students look at their first 'Ethical Matrix' handout. First, we are going to fill out the stakeholders. They go down the first column. Explain to students that stakeholders are all of the people who care about something because they are impacted by it in some way.

⋮ Discuss

Who are some people or groups who might care about your PB&J recipe? Who cares about what you have for lunch and what you eat? Direct stakeholders: me, my parents, my siblings, my grandparents, my doctor/dentist, teacher, classmate, babysitter, sports coach.

5. Now, we are going to fill out the things that each of these stakeholders are concerned about. Have students write tastiness, healthiness, and cleanliness across the top. This should leave 1-2 spaces to add more concerns.
6. Now, go through the first stakeholder with the students and put an 'X' in a space where that stakeholder has a concern. For example, "Me," the person eating the sandwich, definitely cares about tastiness and speed (if they're really hungry). They might also care about healthiness and they might care about cleanliness too.

   Note: The goal of this activity is not to make sure that X's are in certain spaces, but to make sure that students are thinking about the perspective of the stakeholders and able to justify the X's they place.
7. Have students go through the other stakeholders and to fill out the matrix.

Example PB&J Ethical Matrix

	Tastiness	Healthiness	Speed	Cleanliness
PB&J Eater	X The eater definitely cares how tasty the sandwich is. The tastier the better.	x Small x - The eater might not care how healthy the sandwich is.	X Hungry PB&J eaters might also want a quick and easy sandwich to make.	The eater might not care how clean the sandwich is. Especially if they can leave it to their parents to clean.
Parent of PB&J Eater	x Small X - because the parent would want the eater to be happy. But This isn't a primary concern.	X The parent cares a lot that the sandwich is healthy.	X Parents might appreciate PB&J sandwiches that are faster and easier to make.	X If a parent has to clean up the mess, they would really prefer the cleaner sandwich.
Dentist of PB&J Eater	Dentists don't care how tasty the sandwich is.	X Dentists care a lot that you eat things that are good for you. Especially good for your teeth.	Dentists don't really care how long it takes.	Dentists don't really care how clean a sandwich is.

Bus Driver	Bus drivers don't care how tasty the sandwich is.	Bus drivers don't care how healthy the sandwich.	Bus drivers don't care how long it took someone to make the sandwich.	X If someone brings the sandwich on the bus, the bus driver really cares that it's not messy.

⋮ Discuss

Where did you put X's on your matrix and why? As students start sharing where they put their X's, press them to think about their reasons for putting the X's there. Justification is important.

8. Explain to students that we can now use the ethical matrix to think about what sandwich to make. Ideally, we want to go with a sandwich that makes as many people as possible as happy as possible. However, there are bound to be conflicts of interest. A conflict of interest is a place where one stakeholder wants one things and another person wants the opposite thing.

⋮ Discuss

Now that we see what everyone cares most about, can we see stakeholders with conflicts of interest? There is a conflict of interest for healthiness and tastiness. The tastiest PB&J is a fried PB&J (coated with butter and fried like a grilled cheese) however this is definitely not healthy. Another conflict is healthiness vs. speed. The healthiest PB&J might use banana slices instead of bread. However, it takes longer to slice up a banana and to add PB&J to the slices.

How might we resolve these conflicts of interest to make the best sandwich for everyone? We might go interview different stakeholders about what is most important to them and try to prioritize what is most important to them and have them compromise on things that are less important. We might hold a discussion where all the stakeholders can look at different options and vote on their favorites.

Optional Extended Activity
After the ethical matrix is complete, assign different groups to different stakeholders and ask them to design the perfect PB&J for them. Think about how which of these sandwiches might work for different groups of stakeholders. Assign groups to another stakeholder and have them adjust their design to now meet more of the needs of that stakeholder.

Talking points: how do we decide which sandwich to make and "score" the fairness of a solution

Ethical Matrices

Materials and Preparation

Large paper
Pen
Ethical matrix handouts for every student
Computer with projector

Websites
https://www.youtube.com/watch?v=FCdYq3AhCFc

Vocabulary

Autonomous   Able to work without input from a human or others

Lesson

30 mins

Objectives

Students will be introduced to self-driving cars and some of the issues surrounding the technology
Students will learn about stakeholders and their interests as they complete an ethical matrix
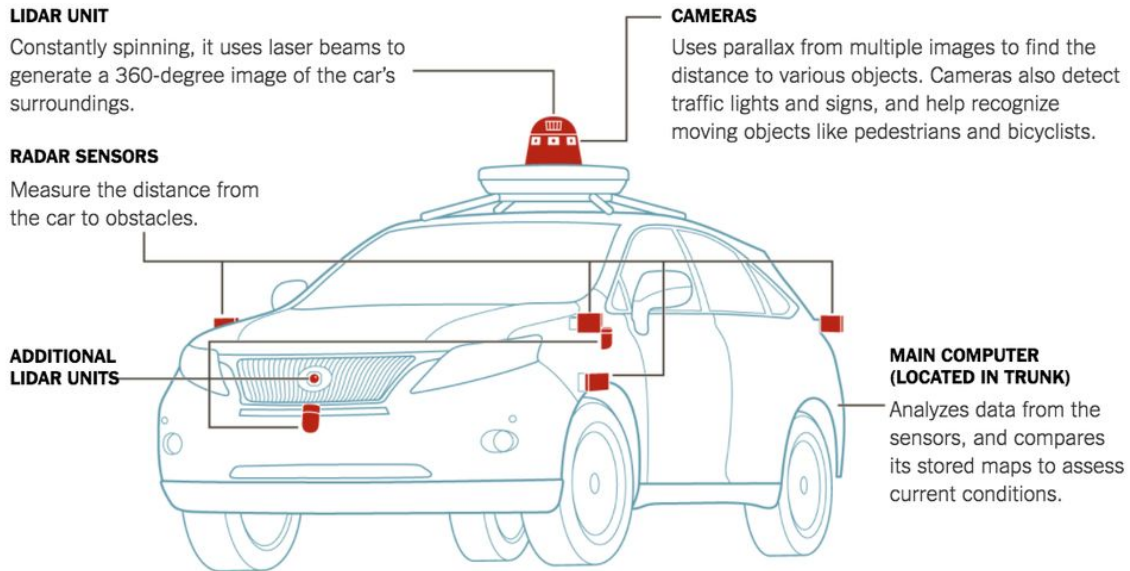Students will use ethical matrices to make design decisions

Introduction

Self-driving cars are an exciting technology and one of the most popular and futuristic applications of AI that is within reach today. So far, we do not have "fully autonomous" self-driving cars. However, we are on our way.

Levels of Self-Driving Cars
- Level 0: No automation. Everything that the car does must be handled by the human.
- Level 1: Car assists driver. The car can do things like control the steering or the vehicle speed of the car. However, the driver has full responsibility for being in control of the car and taking over if something goes wrong. Example: cruise control.
- Level 2: Low automation. The car can do things like steer and control speed by itself. The driver still has to pay close attention and has to do more complex things like paying attention to traffic signals or making turns. Example: autopilot in some higher end cars. This mostly only works on the highway.
- Level 3: Driver assists car. The car can do most maneuvers by itself. If it encounters a scenario that it is uncertain it can handle, the driver must be paying attention so they can take over. Example: Tesla cars.
- Level 4: High automation. The car can operate without human control, however it must be in very controlled surroundings like a test road. Example: Google's Firefly pod-car that was partially used to help create maps for Google Maps. It did not have pedals or a steering wheel, but its top speed was 25 mph.

- Level 5: Fully autonomous. The car can drive itself without humans. It can drive in any surroundings as well as a human. Example: None yet! But many companies are working on it.

Basic Algorithm

LIDAR UNIT
Constantly spinning, it uses laser beams to generate a 360-degree image of the car's surroundings.

RADAR SENSORS
Measure the distance from the car to obstacles.

ADDITIONAL LIDAR UNITS

CAMERAS
Uses parallax from multiple images to find the distance to various objects. Cameras also detect traffic lights and signs, and help recognize moving objects like pedestrians and bicyclists.

MAIN COMPUTER (LOCATED IN TRUNK)
Analyzes data from the sensors, and compares its stored maps to assess current conditions.

Most self-driving cars have sensors like:
- Radar - to detect objects next to them
- Lidar - to create a 360 image of things around the car
- Cameras - to detect objects on the road and to recognize pedestrians and other vehicles
- Internal sensors - to understand the performance of the car (Is it driving as expected? Are the roads more slippery or is the wind very strong?)

Self-driving cars will use all of these systems to make a **map** of its environment.
Then, without human input, the computer on the car will plan a path to navigate its map.
Finally, the computer will send commands to the wheels and brakes to operate the car.

Directions

1. Using information from the introduction, explain the different levels of self-driving cars, the sensors they have, and their basic algorithm. Do students understand why self-driving cars are AI and not programming?

⋮ Discuss

What are all of the different road conditions that a self-driving car might have to handle on a normal drive? Nearby obstacles, the speed of the car, weather, the type of road, and information about a car such as its weight and age. There are millions of factors to take into account.

How do we know that self-driving car algorithms are AI and not programming? Given all of the different combinations of factors that a self-driving car might have to deal with, it is not feasible to write a program that can handle each and every single possibility. The car must have the ability to adapt to situations it has not encountered before.

Think about the decision tree that we made about self-driving cars earlier this week. One of the aspects of that tree was that the computer could "adapt to different situations" and that "it did not need a human in control at all times." Normal programs cannot do this

2. Now have students think about the robots they have been programming.

⋮ Discuss

How do the sensors on the robot compare to the ones on a standard self-driving car?
Our robot has an optional camera - self-driving cars have cameras

Our robot has an ultrasonic distance sensor - self-driving cars have LIDARS which are more accurate distance sensors. Also, our robot only has one distance sensor and self-driving cars have them all over.

Our robot has infrared sensors to do line detection - self-driving cars often use extra sensors to figure out where the lines in the road are. However, the ideas are similar.

3. Show students a video of how self-driving cars work on YouTube:
https://www.youtube.com/watch?v=FCdYq3AhCFc
4. Now that students understand a lot about self-driving cars, it is time to discuss ethical issues surrounding the technology. Introduce that we will be doing an ethical matrix for this technology so that we can think about how this technology should be designed.

⋮ Discuss

What are some good uses of self-driving cars? Self-driving cars can be much safer than humans driving. Humans get tired, are susceptible to emotions, and get distracted which can cause accidents. Self-driving cars are always paying attention.

People who have lost their ability to drive (for whatever reason) will have another option for getting around which greatly increases their independence.

Can you think of any negative effects this technology might have? If anyone can drive a car, this could lead to some dangerous or scary situations. Computer controlled cars might be hacked, introducing a new security risk. If an accident happens involving a self-driving car, it will be harder to place assign blame - is it the people in the car, the people in the other car, the programmers who made the car, or someone else who is to blame? People who drive for a living will have their jobs threatened.

5. Now that students have thought about some of the good and bad consequences, have them start filling out the ethical matrix with stakeholders and their interests.

⋮ Discuss

Who are the stakeholders for self-driving cars? Car companies, passengers, pedestrians, governments, taxi cab drivers, etc.

What kinds of things do the stakeholders care about? Pedestrian safety, passenger safety, the law, making money, jobs.

6. Now, ask students to fill in their ethical matrices with X's in the blocks that represent things that individual stakeholders care about.

⋮ Discuss

What kinds of things do the stakeholders care about? Where are the conflicts of interest? There's a scary conflict of interest between passenger safety and pedestrian safety. Sometimes cars may be in an impossible situation where it's difficult to protect both. There is also the conflict between car companies who want to make a lot of money and professional drivers who do now want to lose their job. There's also a conflict between the car companies who make self-driving cars and those who don't. As soon as one company successfully make self-driving cars then all of the other car companies will have to rush to keep up so that they can stay in business. This rush could also jeopardize safety.

What happens when we prioritize the interests of some stakeholders, but ignore the interests of others? Just like with the algorithmic bias example we looked at yesterday, it is important to take in everyone's perspective when building new technologies. When we leave people out then we create technologies that are not fair. It's important to come up with solutions that work well for everyone.

At what point might we say that technology is not appropriate and should not be built? Unfortunately, a solution that works for everyone is not always possible. Therefore, we have to have some hard rules. If something puts people in danger, causes irreversible harm to the environment, or causes a societal injustice we have to choose to not use the technology.

Self-Driving Robot

Materials and Preparation

Laptops with Wi-Fi
Arduino robot
USB webcam
Construction paper
Chart paper (several different colors)
Thick markers (several different colors)

Vocabulary

Simultaneous Localization and Mapping (SLAM)
Controls

Lesson

1 hr 30 mins

Objectives

Students will use Scratch and Arduino robots to make a self-driving car
Students will learn about localization and mapping to understand how machines position themselves in the world
Students will learn about decision making algorithms that leverage machine vision (or other sensing) algorithms to function

Introduction

Explain this simplified version of how self-driving cars work.

Software Block Diagram of Self-Driving Cars
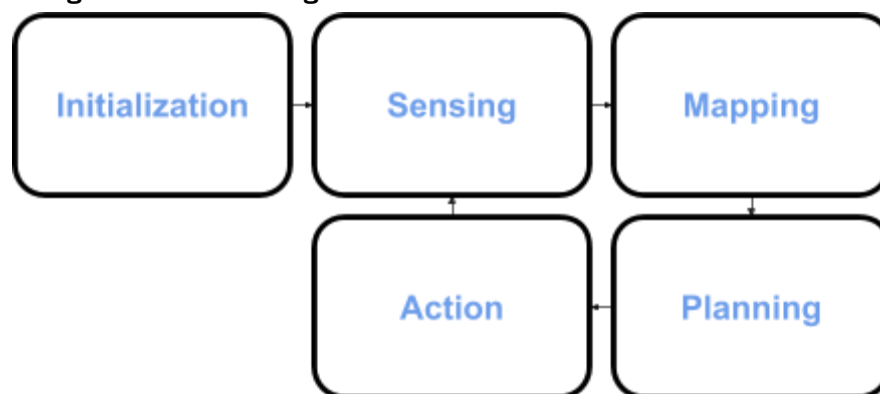
Initialization - Calibrating the robot and creating the datasets that are necessary to get the robot ready to drive
Sensing - Have the robot take a reading from the infrared sensors, ultrasonic distance sensor, and take a picture with the camera
Mapping - Have the robot use the sensor readings to recognize what is around it

Planning - Have the robot decide which motors to turn or keep still
Action - Have the robot do the action
Repeat from Sensing

Directions

How might you get a self-driving car to work?
Introduce the overall code for self-driving cars.
Give students robots and laptops and have them set up everything.
First, students need to teach their robot to recognize the color of the pen to follow of the path. This is done by testing the infrared sensor. Students must calibrate their robot to recognize the color of the pen that they have for drawing a path.

Pseudocode - 2 Infrared Sensors
If the left sensor detects black line, turn left
If the right sensor detects black line, turn right
Repeat

Next, students need to teach their robot to recognize obstacles that are in its way. Use the ultrasonic distance sensor to detect when there is an object in front of the robot. Use Machine Learning for Kids to take pictures of the obstacles that the vehicle can encounter.

Pseudocode
When the obstacle is in the camera scene, stop

Have students create a map to demonstrate that their robot can navigate itself in the map. They should draw a path for the robot to follow with pop-up obstacles.
Have students "travel" to a new environment to try their robots on the maps that different groups created.

Discussion:
What happened when the robot was placed in a new environment? Did it do well or poorly?
What are some of the benefits of self-driving cars?
What does it mean when one environment can enjoy self-driving cars, but others cannot?
How might we work together as a team to build a self-driving car that works in many environments. We want students to see that collaboration is a good path for solving some of the problems with translating to new environments and dealing with unfairnesses.
What issues might arise from trying to collaborate this way?

Final Project Research
Materials and Preparation

Final Project Research Handout
Pens

Resource Website
https://montessori-mun.org/committee-in-the-classroom/

Lesson

30 mins

Objectives

Students will do research to find inspiration for final projects
Students will engage in ideation and brainstorming to choose a few ideas to pursue for their final projects
Students will discuss some of the ethical dilemmas involved in their final projects

Introduction

In order to have students begin to think about their showcase projects, they will look at existing examples of AI and consider ethical concerns related to them. Here is the list of seven major ethical concerns with AI: unemployment, inequality, humanity (definition and addiction), artificial unintelligence, algorithmic bias, security, unintended consequences, singularity, robot rights.
1. **Uneployment**. Self-driving trucks taking the jobs of people
2. **Inequality.** Algorithm that helps developed countries make new computers faster. Makes it harder for others to keep up
3. **Humanity.** Robot companions for children
4. **Artificial unintelligence.** Artificial vision system deployed for individuals with vision impairments. Sometimes messes up.
5. **Algorithmic bias.** Police department buys face classification software. It has a 99% accuracy on white males and 87% accuracy overall. However, for individuals with darker skin tones it often calls women men and misclassified the age of people.
6. **Security.** Widespread adoption of AI agents that listen in the home. Has some vulnerabilities.
7. **Unintended consequences**. Self-driving cars are used everywhere. Someone cuts in front of a car, breaking the traffic rules. The self-driving car swerves to avoid the person and smashes a light pole. Who is at fault?

Directions

1. Direct students to form pairs or small groups to watch the collection of final project videos (link).
2. Tell students they are free to watch as many videos as they would like, but they *must* watch all of the videos in one category.
3. For the videos in this category, have the students fill out the Final Project Research handout for one category. Allow students to spend 20-25 minutes watching videos and filling out the handout.

4. Finally, go through each category and ask students to share what they learned about the robots.

Reflect

Materials and Preparation

Final Project Brainstorm worksheet

Lesson

15 minutes

Introduction

Now it is time for students to begin discussing final project ideas. They should look back at the examples in the brainstorming to guide their thinking.

Directions

1. Have students work individually to write down some ideas about what they want to build with their robot. Encourage them to come up with as many ideas that are as different as possible. Allow them to spend 5-10 minutes doing this.
2. Have students discuss their ideas with the people around them.

Welcome

Materials and Preparation

Paper Prototyping handouts
Pens

Lesson

30 minutes

Introduction

Now, students will begin thinking about their final projects and the kind of companion they want to create, building off of the final project ideation done the previous day.
Have students get into groups of 2-3 based on their preferred partners. Have all of the groups sit close to one another.

Directions

1. Introduce the paper prototyping handouts. Ask students to spend 5-10 minutes filling in as many words on the worksheet as possible.
2. Now, on the other side of the paper prototyping handout, have students envision what the robotic system looks like all together by drawing or writing stories about their robot companion. Students will need 10-15 minutes to sketch out a few ideas.
3. Within their groups, have students present their ideas to one another and share feedback. Student's feedback should be in the form of "I wish...I like...What if."

    For example:
    I wish the robot was more like a real animal.
    I like that the robot has floppy ears and a tail.
    What if the robot responded to voice commands.

    Allow time for everyone in each group to share.
4. As a class, bring the discussion together and offer students a chance to share their ideas with the larger class. If students are hesitant, ask them if there is work from someone in their group that they would like to share with the class.

Note: Sharing with the class allows groups to both narrow down to a few favorite ideas and get more ideas from the broader classroom. Also encourage groups with overlapping ideas to consider one another a resource for figuring out trickier problems.

Final Project Planning

Materials and Preparation

Project Planning handout

Lesson

30 mins

Objectives

Open-ended projects help build time-management and planning skills

Introduction

In the project planning stage, groups should come together to decide on which idea they want to implement in their project. Students should break down their project into a few big goals, then break down the big goals into smaller tasks. Students can begin to think about how they will divide the work and who will work on each task too.

Directions

1. Share the Project Planning handout with students. Explain to students that they will use this document to start organizing their thoughts about the companion they want to build.
2. Give groups time to think about their overall goal and to write down a few words (or pictures) to describe it in the big box.
3. Next, give groups time to think about the 4-6 big components they need to accomplish that goal. The handout already suggests students break the project down into programming, AI/machine learning, construction, and societal impact analysis. Check to make sure that every project covers all of these topics.
4. Have groups break down their major goals into specific tasks. Explain to groups that everyone should try very different tasks. For example, if one person really likes programming then they should do some of the programming tasks, but be sure to share too. Have students think about how they will balance limited resources like only one person working on the computer at a time or one person working with the physical robot at a time. Which tasks need multiple people on them?
5. Have groups retain their plan (or the teacher can retain them). They should update the plan as they go along.

Final Project Work Time

Materials and Preparation

Robots
Laptops with Internet
Craft materials

Websites
https://machinelearningforkids.co.uk/scratchx/?url=https://mitmedialab.github.io/arduino-scratch2/Chromebook/arduino_extension.js#scratch

Lesson

90 mins

Introduction

Now it's time for students to spend time executing on their plan. Provide students with a plethora of resources such as LEGOs and craft materials to begin designing, building, and programming their companion.

Directions

1. Have students start working on their final projects, following their project plan.
2. After 45 minutes - 1 hour of work, have students stop and do peer review.
3. Be sure to have students save their work on their laptops or Google Drive whenever they get to a significant milestone.

Final Project Peer Review
Materials and Preparation

Peer Review handouts

Lesson

30 mins

Objectives

Being a user-experience tester is a useful way to learn how to give feedback
Constructive feedback helps an engineer make improvements to their product

Introduction

Now students will be user testers for each other. Have students upload their projects to a class Google Drive folder so that anyone in the class can access them. Make sure students have saved their work before they load another group's project into Scratch.

Directions

1. Have groups stop their work in whatever state it is currently in.
2. Ask students to go to the Google Drive folder and load their project as it is.
3. Have groups answer the following questions on a sheet of paper:
    a. What have you done so far?
    b. What do you have left to do?
    c. What things have you been stuck on?
    d. What are some issues with your project that you are already aware of?
4. Explain to students that now they will be doing user testing on each other's projects using the Peer Review handout.
5. Have pairs (or sets of 3) of groups partner to discuss each other's projects.
6. Before showing others how their robot works, have groups explain what they have done so far and what they have left to do to give context.
7. Remind students to give constructive feedback. This means that they should share things that they liked as well as things they think could be better. If something could be better, they should share concrete ideas about how to make it better.
8. Each group should take about 5 minutes to show their project and 5 minutes to get feedback from others both spoken and written down on the handouts.
9. Ask the entire class to share one piece of feedback they heard that they found particularly helpful or creative. Reinforce that peer review, giving and receiving constructive feedback, is an important part of being an engineer.
10. Allow students to continue working on their projects.

Reflect
Materials and Preparation

Project Planning handout from earlier
Peer Review Handouts from last activity

Lesson

15 mins

Objectives

Students will reflect on and synthesize feedback to help make their project better

Directions

1. After students receive feedback, give them time to go through and read the feedback they were given. Any questions they have about the feedback they can write down.
2. Next, have students write down or highlight something that they received feedback on that they would like to implement in their project.
3. Finally, have students revise their Project Plan to decide what they will accomplish on the last day.

Welcome

Materials

Project Planning handouts from previous day

Lesson

15 mins

Introduction

For students to finish up their projects strong, they may need to ask for help or reduce the scope of their project a bit. Have students spend some time thinking about their major goals and any help they might need to achieve them.

Directions

1. As a class, have each group give a status update:
   a. How are they feeling about their progress on their project?
   b. What is the most important, achievable goal they want to accomplish and showcase
   c. Is there anything they would like help on?
2. Remind students to ask for help if they feel like they are currently stuck on something.

Final Project Finishing Up

Materials and Preparation

robots
Laptop with Internet

Website

Lesson

2 hours

Objectives

Preparing a project for exhibition includes finalizing projects and setting up your exhibition space

Directions

1. Allow groups this time to focus on finishing up their projects. Remind them of the goals for the project: to program, use AI, and to analyze the impact that their project will have on the world in terms of the stakeholders.

Final Project Showcase Preparation

Materials and Preparation

Chart paper
Pens
Laptop with Internet

Lesson

30 minutes

Objectives

Preparing a project for exhibition includes finalizing projects and setting up your exhibition space

Introduction

Students should now prepare their project for exhibition. Depending on the personality of your classroom, you can ask groups to give presentations, you can arrange a "science fair" style exhibition, or a combination of the two!
Final project showcases should include anything students need to present including a poster and set-up props. Students will use this time to prepare and rehearse their showcase.

Directions

1. Instruct students that they will now be showcasing their projects. This will occur in whichever format (formal presentations vs. science fair exhibitions, see 'Introduction') that you think suits them best.
2. Tell students they should focus on creating a poster - like an advertisement or brochure - about their project and rehearsing what everyone will say. Some important questions to answer are:
   a. What was the inspiration for your robot project?
   b. What was the most challenging thing in the project? What was most rewarding?
   c. How do you think your robot will positively impact society? What are some possible negative impacts and how will you respond to them?

3. Towards the end, have students do final tests on their project. It may be a good idea to video record at this time before the showcase begins.

Final Project Showcase
Materials and Preparation

Chart Paper
Markers
Crayons
robots
Laptop with Internet

Website
https://machinelearningforkids.co.uk/scratchx/?url=https://mitmedialab.github.io/arduino-scratch2/Chromebook/arduino_extension.js#scratch

Lesson

1 hour

Objectives

Hard work and playful learning is a way to create a finished product that instills pride
Divide up roles for explaining the projects to others

Directions

1. Welcome visitors to the Showcase! Orient visitors by explaining how the Showcase is structured.
2. Encourage visitors to ask questions about the projects students made, what they learned throughout the week, and anything that surprised them about what they learned.
3. Make sure that students are taking turns visiting others' projects too!
4. Thank everyone for coming.

Reflect

Lesson

15 mins

Objectives

Reflecting on the design process involves synthesizing learning experiences for future designs

Introduction

Now that the showcase is over, give students time to share highlights and low points from the week.

Directions

Questions to ask:
1. How do they feel about thier final project?
2. What is one thing they would like to learn about or build if they had more time?
3. What is one thing they are excited to teach other people about what they learned?

AI Scavenger Hunt

Materials and Preparation

Chart paper
Colored markers
Laptops with Internet and/or projector

Lesson

30 mins

Objectives

Students will learn to identify examples of AI in the world
Students will be able to identify the differences between machines, robots, and artificially intelligent
robots

Introduction

AI is a very popular topic today. We have things like conversational agents on our phone, object
detection algorithms on cameras, and self-driving cars being tested on the street. People often think of
AI as a very futuristic thing. However, AI has been around for a long time - since the 1950s. Today, we
find AI used in many more systems than initially come to mind. It is important to think about all the
places that AI is used in our society and to reflect on how widely it is used in our society.

Direction

1. Have students think about different examples of AI by walking around the classroom or thinking
   about what technology they use throughout their day.
2. Record student responses on the board or chart paper.

⋮ Discuss

Do any of the examples of AI surprise you?

3. Have students explore other items that may not necessarily be inside of the classroom.
   Encourage them to consider things outside or on the internet. Do students think of examples like
   YouTube recommendation? SnapChat filters? Google searches? Ads?

⋮ Discuss

Do any of the new examples of AI surprise you?

Is there anything we might need to add to the class [decision tree](#) to include these new examples?

Do you think it's important for AI to be obvious/for people to know what is AI and what is not?

1. Give students pen and paper. Have them create two lists: all the ways that computers are better than humans and all the ways that humans are better than computers.
2. After 5 minutes, Discuss.
3. For the items in the "humans are better" category, do Internet searches to see if programs or robots exist that can do that function

Discussion

Did any of the AI examples surprise you? Why?
Do you think it's important for AI to be obvious/for people to know what is AI and what is not?

Decision Trees
Materials and Preparation

AI Examples Worksheet
AI Decision Tree Worksheet
Optional Laptop and projector

Websites
www.google.com

Vocabulary

Algorithm	A process, whether a set of instructions or calculation, that computers follow to solve a problem
Decision Tree	A graph that uses its branches to reason about a subject

Lesson

30 mins

Objectives

Students will think about the ways that artificial intelligence is similar to and different from their own intelligence
Students will be able to identify the differences between machines, robots, and artificially intelligent robots

Introduction

Sometimes it is difficult to tell the difference between programming and AI. When you program something you write code, or instructions, to tell it exactly what to do. With AI, you do not give the computer instructions, you teach the computer what to do in those kinds of situations and allow it to come up with instructions on its own.

It becomes confusing when you come across very complex programs that seem to do something very intelligent. However, if the actions of the computer can be traced back to instructions a programmer writes then it is still not considered AI.

The first AI algorithm students will learn about is decision trees. Decision trees are useful tools for classifying objects or picking a next action. They can be used both by humans and computers. We will use a decision tree to decide what is AI and what is not. This will help us make simple rules about what AI must have and what it might have, but does not necessarily need. Here's an example of a decision tree for classifying fruits and vegetables. Students have this diagram in their student pages.
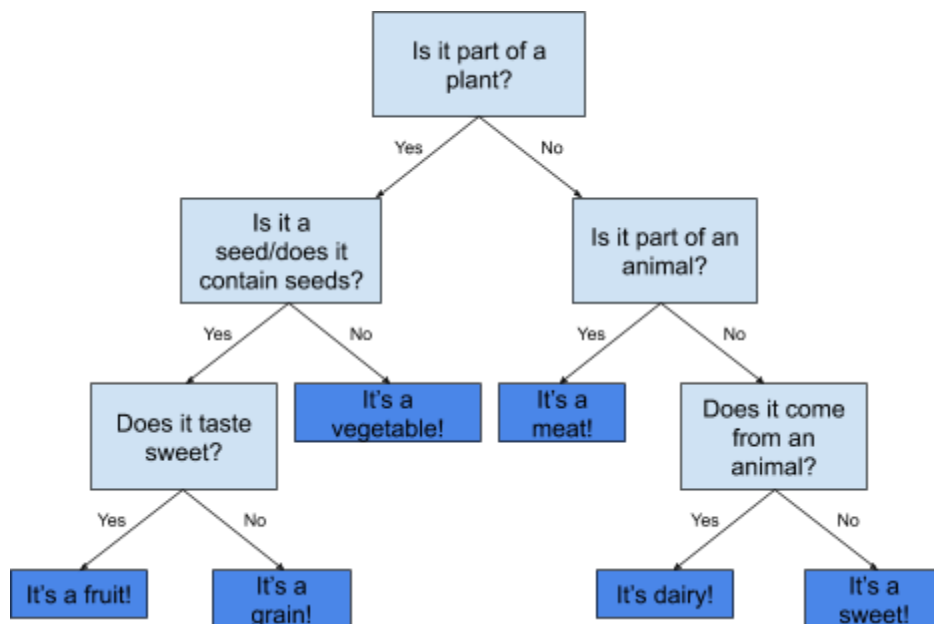
So let's think about an orange. The top of the decision tree asks if the food is part of a plant. Oranges are parts of plants, so we move down the 'Yes' branch on the left to the next rectangle. This rectangle asks if the food is a seed or contains seeds. Oranges do have seeds, so we move down the 'Yes' branch on the left again. Do oranges taste sweet? They do! So our decision tree tells us that oranges are sweet.

We can use our decision tree not only to classify all different kinds of foods, we can also learn information about the different kinds of foods. For example, we learn from the tree that fruits are parts of plants that contain seeds or are seeds and taste sweet. Vegetables, on the other hand, are parts of plants that are not seeds.

You may notice that this decision tree is not perfect. For example, eggplants and squash do not fit nicely into the tree. When this happens we can adjust our decision tree. In the activity with the students we will build a decision tree that may not be perfect. Finding **counterexamples** that don't fit in the tree will help students solidify their understanding of AI.

Directions

1. Tell students that we are going to learn about an AI algorithm that is used to make decisions. We will use it to decide if something is AI or if it is just a program.

⋮ Discuss

Who has heard the word algorithm before? Does anyone know what it means?
Algorithms are processes that computers follow to solve a problem. In the case of programming, an algorithm is the set of instructions, called code, for the computer to follow exactly.

How is AI different from programming or robots? AI has different algorithms from normal programs or robots with AI. Instead of getting step-by-step instructions from code, AI solves problems by itself by recognizing patterns, using logic, or doing calculations.

What are some examples of programs robots that do not have AI? What are some examples of AI that is not a robot? There are a lot of robots that are used in factories to make cars. These robots do the same thing over and over again, so it is easy to write code for them. These robots do not use AI.

Chatbots like Google Home, Siri, and Alexa are all AI because they can have conversations with people. However, even though some of them work on a phone or smart speaker, the program does not on any body. So these are examples of AI that are not robots.

2. Point out to students that the line between programming and AI can be a little difficult to comprehend since lots of examples of AI include programming. A good example is Google Voice Search. The speech recognition can understand, for the most part, whatever anyone says to it even if they say something strange or use an accent.

   After Google understands what you say, it is *programmed* to start a Google search for the thing you asked about. Different chatbots, like Siri, either open an app, do a search, or tell you one of it's programmed responses (like if you ask for a joke). Even though these chatbots have programming in them, we still consider them an AI.

Note: If you have a laptop and projector available, take a second to let students play around with Google and convince themselves that speech recognition was not done by simple coding.

3. Tell students that next we will create a decision tree to determine if some uses AI or not. First, we need to explain what a decision tree is. In the student handouts, there is an example decision tree for classifying foods. Walk students through the decision tree so that they can see how it works.
4. Now it's time to make our own decision tree to sort out what is AI and what is not. Here are some examples of both that we can use to help us decide:
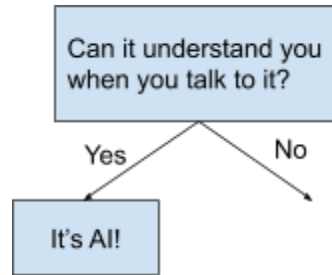   **Not AI**
   > Toaster
   > Automatic-opening doors (like at grocery stores)
   > Car
   > Programmable or remote control robot (Dash and dot/Atom robot from Real Steel)

   AI Examples
   > Snapchat Face filters
   > Chatbots (Siri, Alexa, Google Home)
   > Robot dog (AIBO)
   > Self-driving cars

5. Start a decision tree on the board by drawing a "decision leaf", a rectangle with two branches coming out of it. In the first leaf, write 'Can it understand you when you talk to it?' For chatbots and robot dogs, the answer is 'Yes' so everything on the left branch is AI!

6. Have the class try and come up with decision leaves that divide up the rest of the examples into 'AI' and 'Not AI'. Here are some ideas:
    a. Does it collect information to understand the world? (Cars and toasters do not)
    b. Can it do things without being told to by human? (Programmable robots, toasters, and cars cannot)
    c. After it's turned on, does a person have to always be in control of it for it to work? (Cars and programmable robots cannot)
    d. Can it adapt to its environment and do different things if its surroundings change? (Automatic doors and programmable robots cannot)
7. Use some of the prompts above as the decision leaves in the tree. As you build the tree, show which of our examples end up on each side of the examples. Stop when you get to a point where all of the AI examples are separated from the Not AI examples.
8. Now let's compare our tree to some other AI examples (talking doll, Google search engines) and Not AI examples (washing machines, remote control cars).

⋮ Discuss

How do the definitions of AI that we started with compare to the decision tree that we created?

Is there anything that we would add to the definition of AI now that we know more?

How might decision trees be helpful when designing intelligence?

Model UN Game
Objectives

Students will experience some of the challenges of reaching a consensus about technology policy

Introduction

Have students prepare for Model UN by making placards. The placards should have the name of the student and a color or sticker for the stakeholder they represent. Have students make their own placards to use for volunteering to speak and taking votes.

Directions

Position Forming
1. Explain that we are a special UN committee convening to decide on the future of self-driving cars.
    > We have to decide whether or not we will allow self-driving cars, what laws we will pass about the price of cars, who will develop them, and where they will be allowed to operate.
2. Assign students with different roles based on the stakeholders and the interests of the stakeholders that we discussed
    a. Car company - profit, long-term success (fewer people will want cars), safety, liability
    b. Passengers/People who can afford car - safety, cost, performance of cars, control
    c. Pedestrians - safety
    d. People who cannot afford car - resource usage
    e. Government - planning for traffic change, liability for accidents, planning for economic change, society safety (hackers, surveillance)
    f. Professional drivers (taxis, limos, bus, truck) - loss of customer base
    g. Driving companies - profit
    h. Insurance companies - liability of insuring machine,
3. Within their groups, have students think about the laws and policies that suit them best and how the self-driving car should be designed and used.
4. Within groups, choose a delegate to represent the position of the stakeholder. To the class, have delegates give a two-minute speech outlining their position.

Classroom Discussion
1. Open the classroom to discussion for 15 minutes. The goal is to decide what laws to pass regulating self-driving cars.
    > Begin with "Greetings, distinguished delegates. I am your Chair, and I now call this committee to order. Today, we are discussing the topic of self-driving car regulation. Each speaker will have one minute to speak. All those wishing to speak, please raise your placards at this time."
2. If someone would like to speak, they must raise their placard. Delegates have one-minute to speak.
    > If one minute expires and the delegate is still speaking, then kindly cut him or her off by saying, "Excuse me, distinguished delegate. Thank you for your speech, but your time has expired. You may now sit down."

3. Repeat the process by asking "All those wishing to speak, please raise your placards at this time." Delegates must raise their placards to speak. After several speeches ask if there are any motions on the floor. Motions include:
   a. Break for informal discussion
   b. Asking Chair for information
   c. Calling a vote on a particular law
4. Within groups, have students write a summary about the laws that were passed. What things work well for their stakeholders and what are some concerns?
5. To the class, have each delegate give a two-minute summary.

Discussion

What were some of the challenges and opportunities in coming to an agreement?