Artificial Intelligence Pathways In 9-12

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The Future of CS: Emerging Concepts in CS Education Conference
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Interactive Slide Deck: http://bit.ly/ai9-12

Beats For Our Session

- Overview of the Big Ideas and the AI4K12 Initiative
  - Frame How to Teach AI and Develop Comfort with the Framework
- Experience an AI Activity Appropriate For All HS Students
- Discuss an AI Lesson Appropriate for Students in CS Courses
- Participate in a Fireside Chat About AI and Machine Learning Courses
- Audience Q&A

Introduce Yourself!

Name

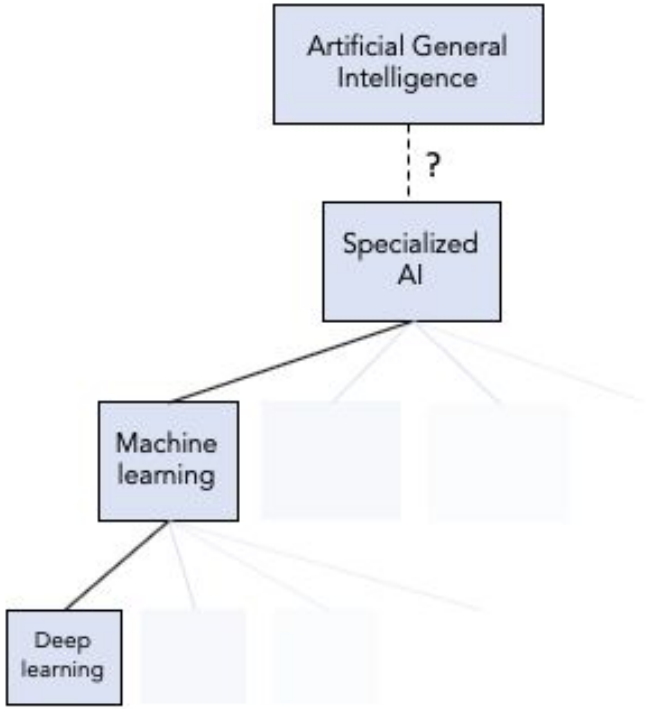
CSTA Chapter

What CS courses do you teach?

Why teach AI in K-12 CS courses?

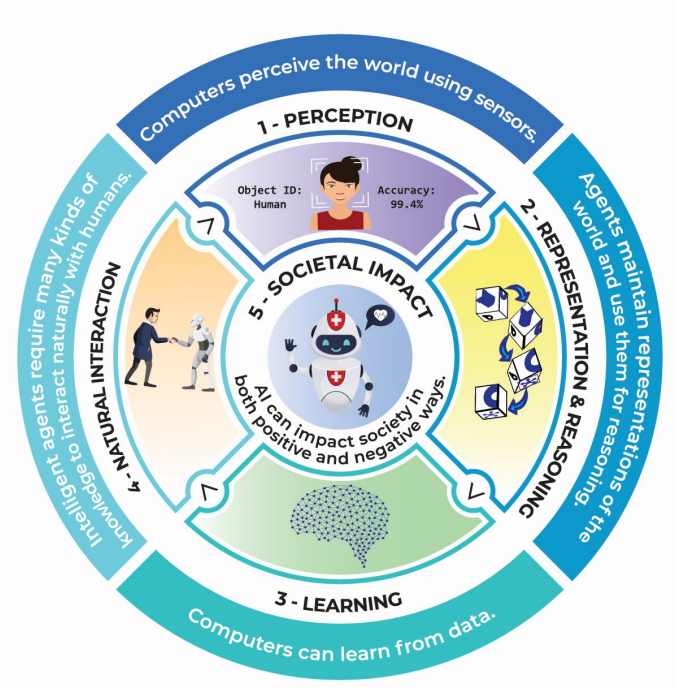
1. AI is a **branch of computer science**.
2. AI technologies are having a profound **impact on society**.
   - Children grow up conversing with Alexa.
   - Self-driving cars, face recognition, machine translation, recommender systems (Netflix), machine learning, deep fakes, and more.
3. Preparation for **future careers**: creating AI and robotic technologies, or working alongside intelligent agents or autonomous robots.

What is AI?



AI is “the science and engineering of making intelligent machines, especially intelligent computer programs”
- John McCarthy

Five Big Ideas in AI



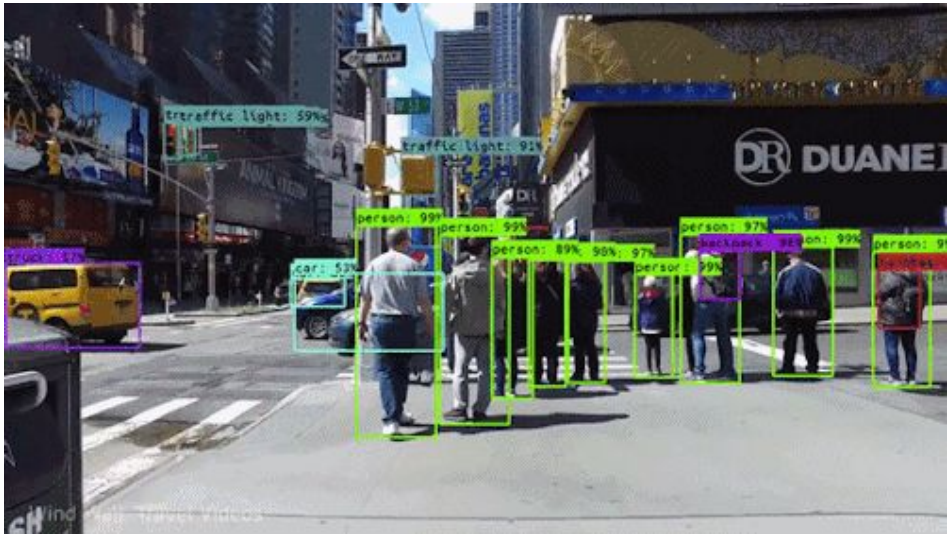
Download a free poster explaining the Five Big Ideas from the website:

AI4K12.org

Big Idea #1: Perception

Computers perceive the world using sensors.

Perception is the extraction of *meaning* from sensory signals based on knowledge.



- Human senses vs. computer sensors
- Types of perception: vision, speech recognition etc.
- How perception works: algorithms

Example Guidelines

- Identify sensors on computers, robots, and intelligent appliances.
- Explain how sensor limitations affect computer perception.
- Explain that perception systems may draw on multiple algorithms as well as multiple sensors.
- Build an application using multiple sensors and types of perception (possibly with Scratch plugins, or Calypso).

Big Idea #2: Representation and Reasoning

Agents maintain representations of the world, and use them for reasoning.

- Types of representations
- Families of algorithms and the work they do
- Representation supports reasoning: algorithms operate on representations

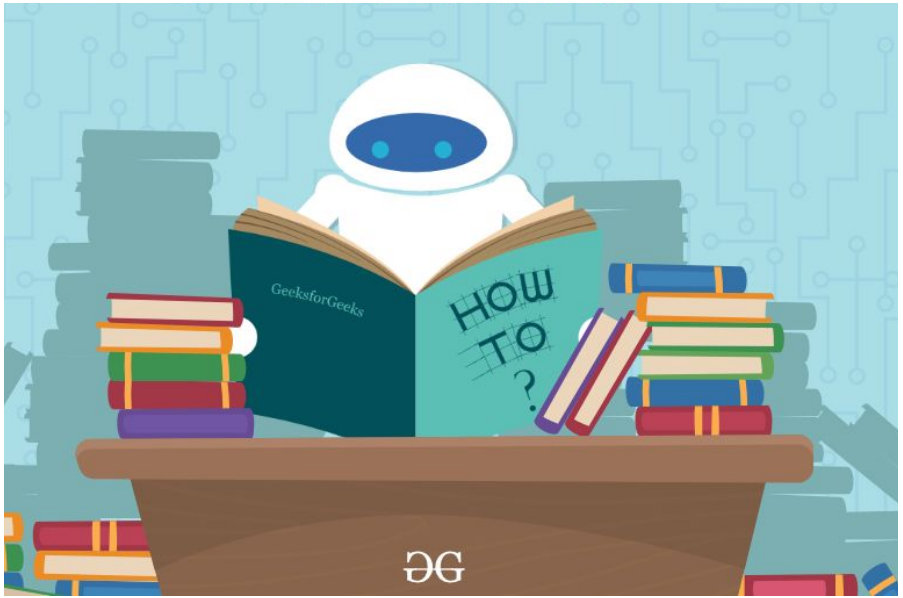
Example Guidelines

- Create/design a representation of an (animal) classification system using a tree structure.
- Draw a search tree for tic-tac-toe
- Describe how AI representations support reasoning to answer questions
- Describe the differences between types of search algorithms

Big Idea #3: Learning

Computers can learn from data.

- Characteristics of learning
- Fundamentals of neural networks
- Data sets



Example Guidelines

- Modify an interactive machine learning project by training its model..
- Describe how algorithms and machine learning can exhibit biases.
- Identify bias in a training data set and extend the training set to address the bias
- Train a neural net (1-3 layers) using *TensorFlow Playground*
- Trace and experiment with a simple ML algorithm

Big Idea #4: Natural Interaction

Intelligent agents require many kinds of knowledge to interact naturally with humans.

- Natural language understanding
- Common Sense Reasoning
- Affective computing & human-machine interaction (facial expressions, gestures, emotion recognition)
- Consciousness and philosophy of mind

Example Guidelines

- Recognize and label facial expressions into appropriate emotions (happiness, sadness, anger) and explain why they are labeled the way they are
- Experiment with software that recognizes emotions in facial expressions
- Construct a simple chatbot
- Describe some tasks where AI outperforms humans, and tasks where it does not
- Explain and give examples of how language can be ambiguous
- Reason about the nature of intelligence, and identify approaches to determining whether an agent is or is not intelligent.

Big Idea #5: Societal Impact

“Artificial Intelligence can impact society in both positive and negative ways.”

- Economic and employment impacts of AI
- Ethics of AI making decisions about people
- AI & Culture

Example Guidelines

- Critically explore the positive and negative impacts of an AI system
- Design and explain how an AI system can be used to address a social issue
- Describe ways that AI systems can be designed for inclusivity
- Understand tradeoffs in the design of AI systems and how decisions can have unintended consequences in the function of a system


An AI Pathway

Three Tiers of AI4K12 in High School

AI User (75%)	CSforAll … AI4All	Voice assistants, recommendations engines, facial recognition- we are all users of AI. Students may learn about the basic principles of AI technologies and the impacts of those technologies on society.
AI Manager (20%)	APCSP/APCSA	As students learn CS, they may create projects and applications that incorporate AI technologies. In our careers, many of us will “manage” AI too
AI Developer (5%)	Capstone Experiences	Students develop and train AI models using industry tools and practices. This experience is likely accompanied with a 4+ year math pathway.

AI User

BOOTSTRAP DATA SCIENCE

ECS Exploring Computer Science

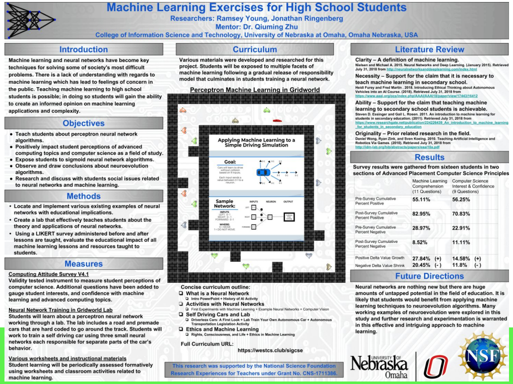
Artificial Intelligence

Alternate Curriculum Unit

IDS

Introduction to Data Science

How to Implement AI in High School?



Machine Learning Exercises for High School Students

Researchers: Ramsey Young, Jonathan Ringenberg

Mentor: Dr. Qiuming Zhu

College of Information Science and Technology, University of Nebraska at Omaha, Omaha Nebraska, USA

Introduction

Machine learning and neural networks have become key techniques for solving some of society's most difficult problems. There is a lack of understanding with regards to machine learning which has lead to feelings of concern in the public. Teaching machine learning to high school students is possible; in doing so students will gain the ability to create an informed opinion on machine learning applications and complexity.

Objectives

- Teach students about perceptron neural network algorithms.
- Positively impact student perceptions of advanced computing topics and computer science as a field of study.
- Expose students to sigmoid neural network algorithms.
- Observe and draw conclusions about neuroevolution algorithms.
- Research and discuss with students social issues related to neural networks and machine learning.

Methods

- Locate and implement various existing examples of neural networks with educational implications.
- Create a lab that effectively teaches students about the theory and applications of neural networks.
- Using a LIKERT survey administered before and after lessons are taught, evaluate the educational impact of all machine learning lessons and resources taught to students.

Measures

Computing Attitude Survey V4.1

Validity tested instrument to measure student perceptions of computer science. Additional questions have been added to gauge student interests, and confidence with machine learning and advanced computing topics.

Neural Network Training in Gridworld Lab

Students will learn about a perceptron neural network working through a lab. The lab includes a road and premade cars that are hard coded to go around the track. Students will work to train a self driving car using three small neural networks each responsible for separate parts of the car's behavior.

Various worksheets and instructional materials

Student learning will be periodically assessed formatively using worksheets and classroom activities related to machine learning.

Curriculum

Various materials were developed and researched for this project. Students will be exposed to multiple facets of machine learning following a gradual release of responsibility model that culminates in students training a neural network.

Perceptron Machine Learning in Gridworld

Applying Machine Learning to a Simple Driving Simulation

Goal:

Sample Network:

Concise curriculum outline:

- What is a Neural Network
  - Intro PowerPoint + History of AI Activity
- Activities with Neural Networks
  - First Experiments with Machine Learning + Example Neural Networks + Computer Vision
- Self Driving Cars and Lab
  - Driverless Cars: A First Look + Lab Train Your Own Autonomous Car + Autonomous Transportation Legislation Activity
- Ethics and Machine Learning
  - Rights, Consciousness, and Life + Ethics in Machine Learning

Full Curriculum URL:

https://westcs.club/sigcse

This research was supported by the National Science Foundation Research Experiences for Teachers under Grant No. CNS-1711386.

Literature Review

Clarity – A definition of machine learning.

Nielsen and Michael A. 2015. Neural Networks and Deep Learning. (January 2015). Retrieved July 31, 2018 from http://neuralnetworksanddeeplearning.com/index.html

Necessity – Support for the claim that it is necessary to teach machine learning in secondary school.

Heidi Furey and Fred Martin . 2018. Introducing Ethical Thinking about Autonomous Vehicles into an AI Course. (2018). Retrieved July 31, 2018 from https://www.aaai.org/ocs/index.php/AAAI/AAAI18/paper/view/17443/16412

Ability – Support for the claim that teaching machine learning to secondary school students is achievable.

Steven D. Essinger and Gail L. Rosen. 2011. An introduction to machine learning for students in secondary education. (2011). Retrieved July 31, 2018 from https://www.researchgate.net/publication/224226439_An_introduction_to_machine_learning_for_students_in_secondary_education

Originality – Prior related research in the field.

Daniel Wong, Ryan Zink, and Sven Koeing. 2010. Teaching Artificial Intelligence and Robotics Via Games. (2010). Retrieved July 31, 2018 from http://idm-lab.org/bib/abstracts/papers/eaai10a.pdf

Results

Survey results were gathered from sixteen students in two sections of Advanced Placement Computer Science Principles

	Machine Learning Comprehension (11 Questions)	Computer Science Interest & Confidence (9 Questions)
Pre-Survey Cumulative Percent Positive	55.11%	56.25%
Post-Survey Cumulative Percent Positive	82.95%	70.83%
Pre-Survey Cumulative Percent Negative	28.97%	22.91%
Post-Survey Cumulative Percent Negative	8.52%	11.11%
Positive Delta Value Growth	27.84% (+)	14.58% (+)
Negative Delta Value Shrink	20.45% (-)	11.8% (-)

Future Directions

Neural networks are nothing new but there are huge amounts of untapped potential in the field of education. It is likely that students would benefit from applying machine learning techniques to neuroevolution algorithms. Many working examples of neuroevolution were explored in this study and further research and experimentation is warranted in this effective and intriguing approach to machine learning.

University of Nebraska Omaha

NSF

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Resources for the “AI User” Classroom

- Link to MIT Ethics Activities - Blakely Payne
- Classroom Worksheet
- Student Sample of Speculative Futures: An “AI User” Lesson Experience
- Exploring CS AI Curriculum
- Code.org AI
- ISTE AI Project Guides

Speculative Futures: An “AI User” Lesson Experience

In this experience, you will learn to think about the kind of world we make when we build new technology, and the unintended consequences that can occur when we build that technology. (Big Idea #4 and #5)

Instructions

- Visit the AI Tool linked on your Breakout Room Slide
- Explore with the tool for a little bit!
- On your slide:
  - Briefly describe the tool
  - Identify 3 ways it could do good
  - Identify 3 ways it could harm

Breakout Room #1 - GANpaint

Description:

Draws over original scenes, changing numerous aspects

Doing Good:

1. 1 project effects of weather/environment
2. 2
3. 3

Doing Harm:

1. 1
2. 2
3. 3

Recorder:

Reporter:

Breakout Room #2 - Talk to Transformer

Description:

Takes a phrase then finishes it.

Seems to be

“Searching” as if you typed in a phrase in Google

Doing Good:

1. Birdwalking in meetings
2. Generate creative responses to questions

Doing Harm:

1. Could say something useless or offputting
2. Generate “fake news”

Ie. The South African-born billionaire has taken the stage in a music festival event in California to perform a live version of his recent single “On The Run,” as first reported by Spin.

Recorder: Jared

Reporter: Nate

Breakout Room #3 - Affectiva

Description:

Facial recognition tracking 9 different facial expression while viewing a video. Tracks each expression and graphs for you. It also includes a comparative feature looking at your response compared to others

Doing Good:

1. Couple Therapy
2. Efficacy of virtual lesson
3. Helping autistic students interpret expressions

Doing Harm:

1. Advertising manipulation
2. 2
3. 3

Recorder:

Reporter:

Breakout Room #4 - Deep Angel

Description:

Learning about the uses of AI while testing your ability to recognize deep fakes

Doing Good:

1. 1
2. 2
3. 3

Doing Harm:

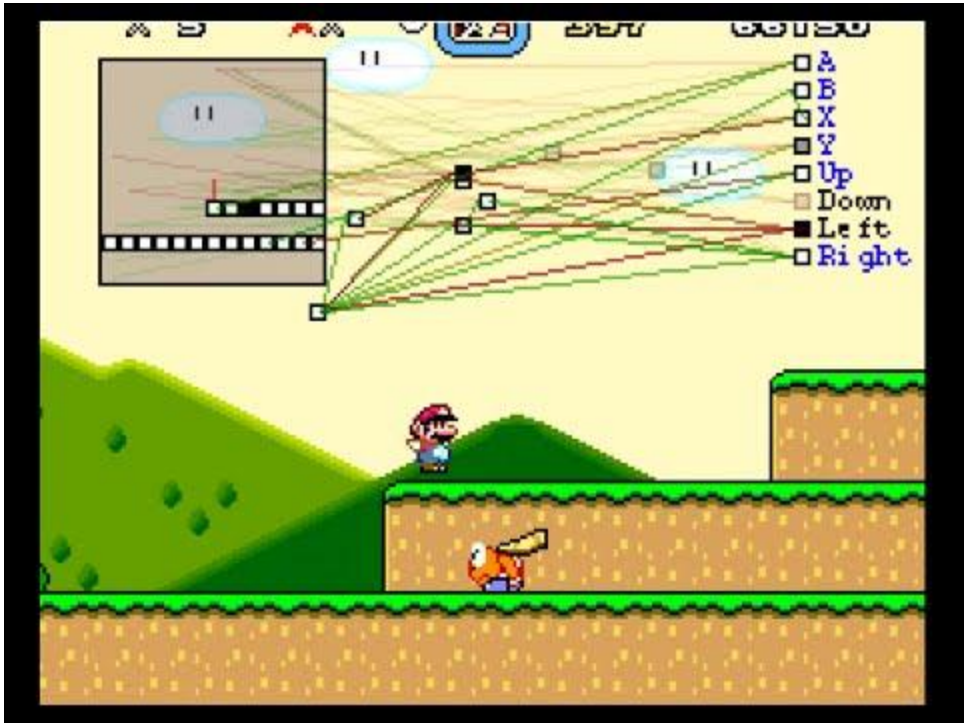
1. 1
2. 2
3. 3

Recorder:

Reporter:

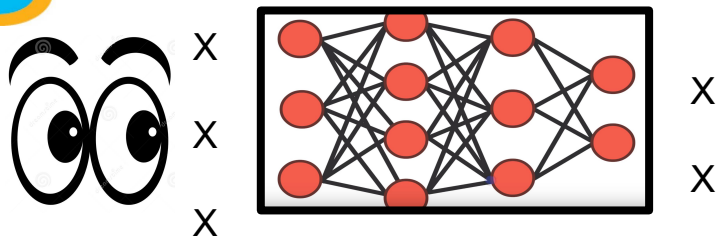
AI Manager

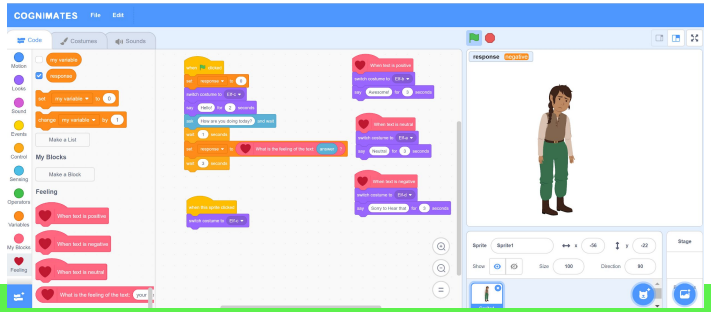
Bringing AI Into The CSP Classroom … A Call to Action



“AI Manager” Classroom Considerations

1. **Use transparent AI demonstrations** *that help students see what is going on inside the black box: it’s not magic!*
2. **Help students build mental models** of *what is happening under the hood in AI applications.*
3. **Encourage students to develop AI applications** *using AI services.*





AI Manager Student Activity Considerations

- **Experiment with AI agents** to investigate their behavior
- **Hand simulate** AI algorithms
- Encourage students to **build their own AI applications**
- **Explore case studies of AI-related societal issues** from multiple perspectives

These activities promote understanding of:

- How AI works
- Limitations of AI
- Systems thinking (AI systems are built from smaller components)
- Sources of bias in AI
- Societal impacts of AI systems

AI-Powered Players in Video Games

Adapted by from the ISTE AI Guide Written By Mark Gerl, Nancye Blaire Black, and Susan Brooks Young

What games do you play that have a computer player, either when you play against the computer, or when you have computer characters as teammates or opponents?

“An artificial intelligence (AI) is a computer program that can intelligently respond to the player’s moves”
- Al Sweigart

Let’s Try It Out!

Play 10 games on Version 1

Based on Sweigart’s definition, did you play against an AI agent?

Another Version

Play 10 games on Version 2

Based on Sweigart's definition, did you play against an AI agent?

ISTE's Hands-On AI Projects Guides

Download these and other ISTE AI Explorations resources at:

http://iste.org/ai and http://www.edsurge.com/research/guides/ai-is-for-everyone-everywhere

Resources for the “AI Manager” Classroom

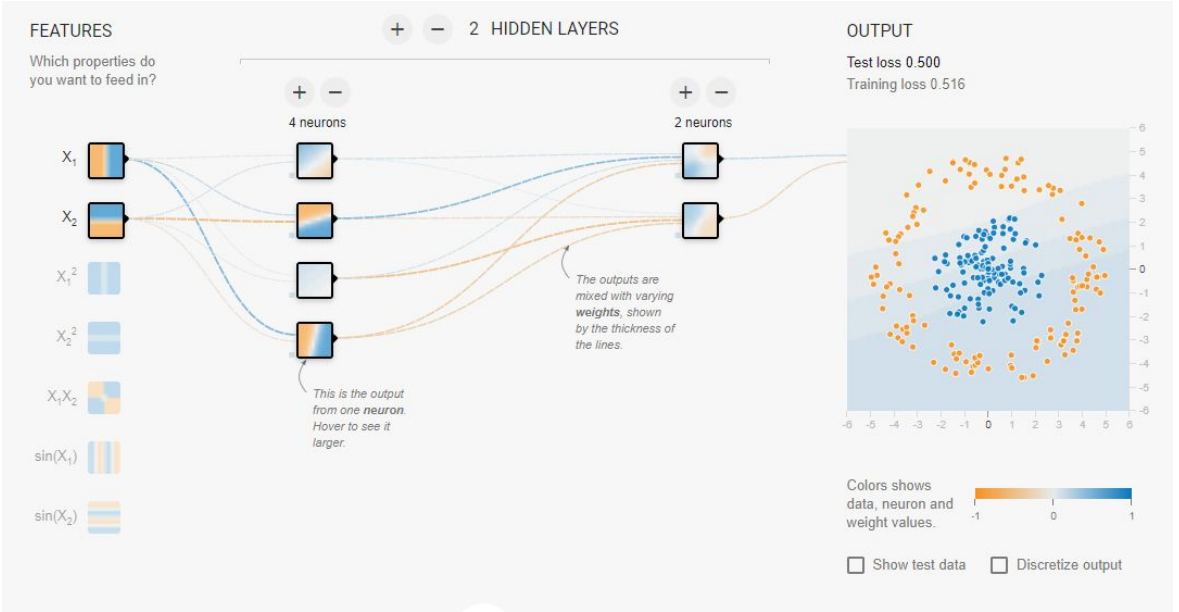
- ISTE AI Project Guides
- Ramsey Young’s and Jonathon Ringenberg’s Machine Learning Unit for CSP
- Machine Learning for Kids Python Lessons

AI Developer

Algorithmic/Programming

- Why we teach how
  - Our type of students
- Overview of Course
- Example of a lesson
- Resources
  - How we learned
  - Lesson Materials
  - Hardware and software we used
  - Links to resources
    - Videos
    - Datasets

Algorithmic - Teach How



TensorFlow Playground

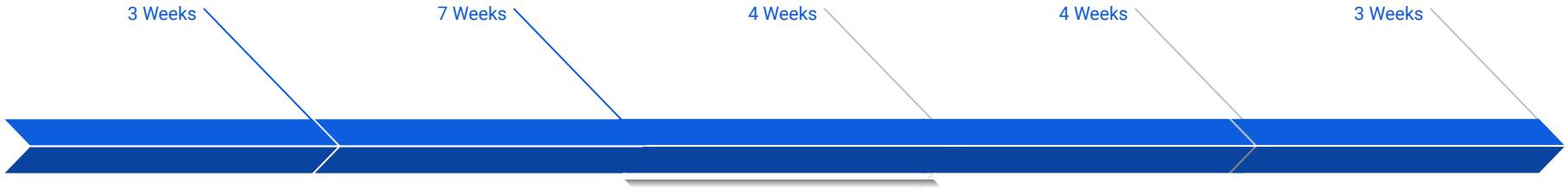
Why teach “How” in High School?

- Students are starting to take AP CS A earlier
  - 49% are 9-11th grade.
- Students are using it for other classes (like Biology)
  - Science fair
  - They are going to try to learn it with you or without you.
- Tools are more powerful and free
  - Python, Anaconda, Spyder all free, AWS and Google Colaboratory
  - Need a basic graphics card

Why teach “How” at Academies of Loudoun?

- We are a STEM magnet School in Northern Virginia
  - Students take 4 years of Computer Science
- Machine Learning Course -
  - 42 students - Post AP CS
  - Currently taking Calculus
  - In Junior Year
  - Prepare for Senior Research project
  - Goal - Capstone project at end of semester is ISEF project

How Did We Progress Students



Foundation

Python

Matrix Algebra

Introduction to ML

Perceptron, Linear Regression, Cost Function, Gradient Descent, Normalization, Write python code for basic functions

Deeper Dive

Logistic Regression, Categorical data, Missing data, Basic Neural Net, Hand Calculate BackPropogation

Neural Networks

Multi-Layer Perceptron, Keras, CNN, KNN, Random Forest, LSTM

Capstone Project

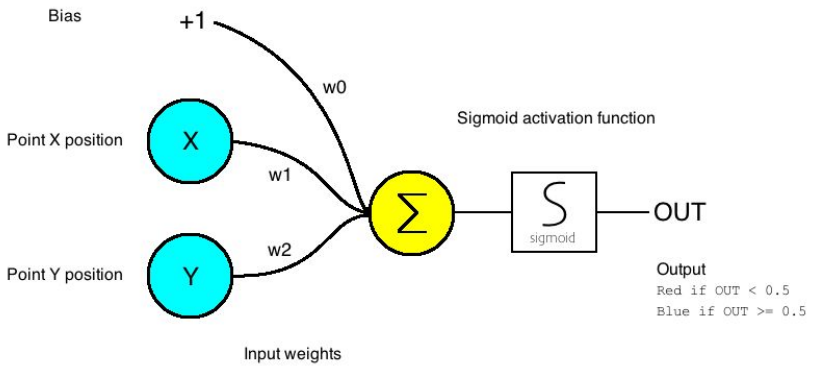
ISEF format for capstone project using any model previously leanred

Foundation

- Review of Matrix Algebra
  - Add, subtract, multiply, inverse
  - Properties
- Python
  - Summer assignment completion – Python 3 tutorial – sololearn.com Data structures: lists, tuples, dictionaries
  - Data Input - Parsing files in CSV and JSON formats
  - Plotting - Matplotlib
  - Vector (Array) Programming
    - Splicing, adding columns, removing columns
    - Numpy vector programming

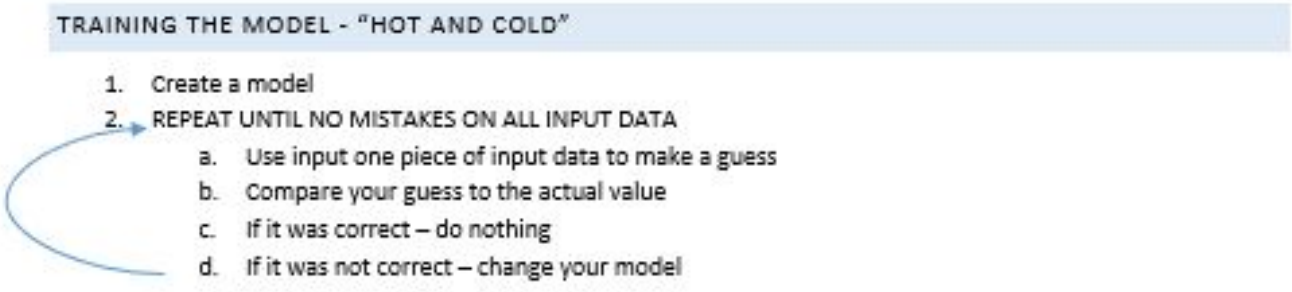
Introduction to ML - Perceptron

- Concepts
  - Iterative Process
  - Learning Rate
  - Cost Function/Error
  - Weights
  - Simple matrices, vectorization
- Hand Calculate
  - Truth Table - 2 Iterations of adjusting weights
- Projects
  - Linear Separable Truth Tables



Typical Lesson - Concept Introduction

- **Iterative Process**
  - **Hot/Cold -**
    - Learning Rate
    - Iterative Process

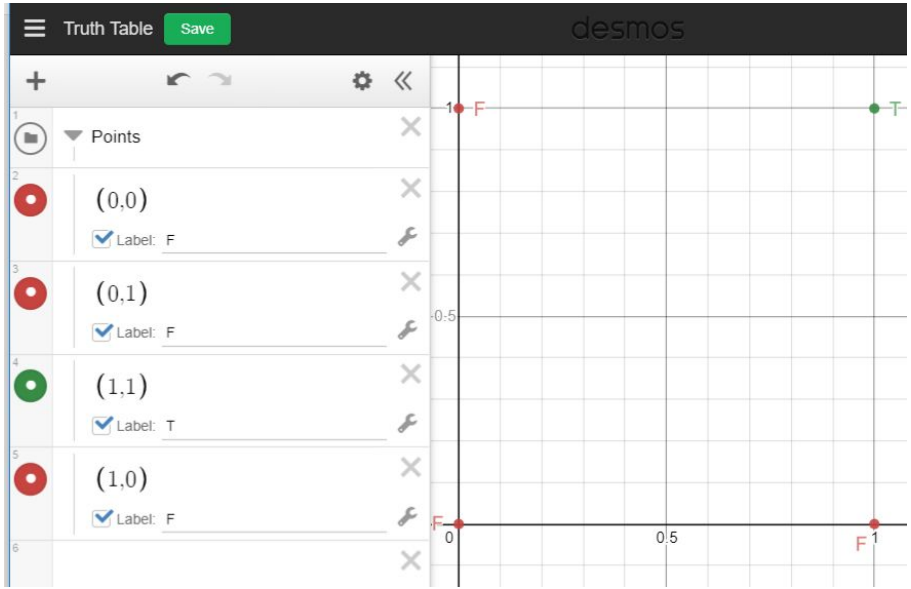


Linear Classification – Truth Table

AND	X_1	X_2	Y
	0	0	0
	0	1	0
	1	0	0
	1	1	1

$X_1 * w_1 + X_2 * w_2 = val$

```
if (val > 0)
    predict 1
else
    predict 0
```



Hand Calculation – Math Abstraction

- **Mathematical abstraction of process – Linear Decision Boundary**

CREATE THE MODEL -

Equation of a line:

Goal – find Y=mx + b

Point on the line:

The weight of each feature times the value of each feature.

$w_1x_1 + w_2x_2 + w_0b = 0$

Solving for x_2

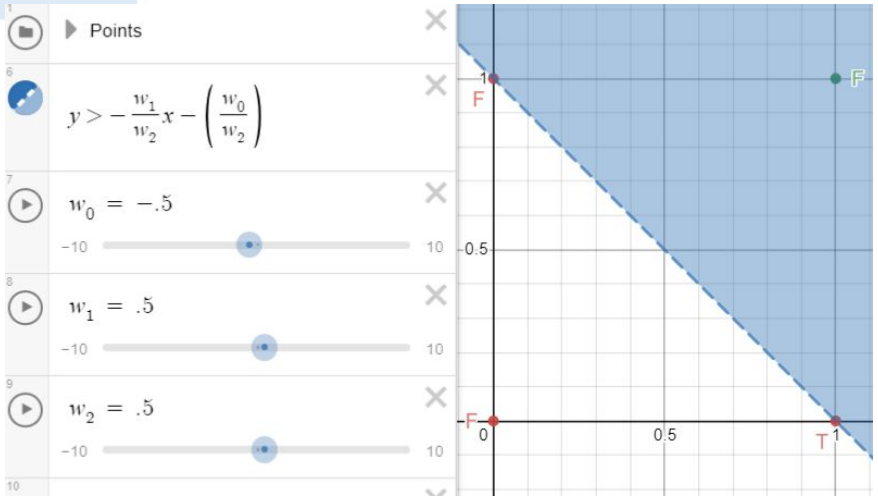
$$x_2 = -\left(\frac{w_1}{w_2}\right)x_1 - \left(\frac{w_0}{w_2}\right)b$$

Slope = $-\left(\frac{w_1}{w_2}\right)$

Bias (y-intercept) = $-\left(\frac{w_0}{w_1}\right)$ because b is typically set to 1.

All x_2 values ABOVE the line then adhere to the following equation

$$x_2 > -\left(\frac{w_1}{w_2}\right)x_1 - \left(\frac{w_0}{w_2}\right)b$$



Typical Lesson - Hand Calculate on Whiteboard

- **Create Initial Data**
- **Calculate Predicted Value**
- **Adjust weights if needed**

3) IF THE PREDICTED VALUE (P) IS NOT EQUAL TO ACTUAL VALUE (Y) ADJUST THE WEIGHTS ACCORDING TO

1) Calculate new weights
   a. Set a learning rate (= .5,
   b. For the first data point Y = false = 0, and P = 1
      i. For $x_0 = 1$ and $w_0 = 1$
         1. $w_0 = 1 + .5(0-1)(1) = .5$ so the new weight is .5
      ii. For $x_1 = 0$ and $w_1 = 1$
         1. $w_1 = 1 + .5(0-0)(1) = 1$ so the new weight is 1
      iii. For $x_2 = 0$ and $w_2 = 1$
         1. $w_2 = 1 + .5(0-0)(1) = 1$ so the new weight is 1

Typical Lesson - Excel and Visualize with Desmos

1) Calculate the Predicted Value and compare to Y

	(w0 * bias)	+ (w1* x1) +	(w2 * x2) =	Calculate	Prediction - Heaviside Activation	Compare to Expected Value (Y)
F or F = F	-0.5	1	1	0	1	1	0.5	1	0

2) Adjust Weights if prediction <> Expected value

New weight = old weight + learning Rate *(Expected value - prediction) * x where x is the value in the array the weight is multiplied by

LR 0.5

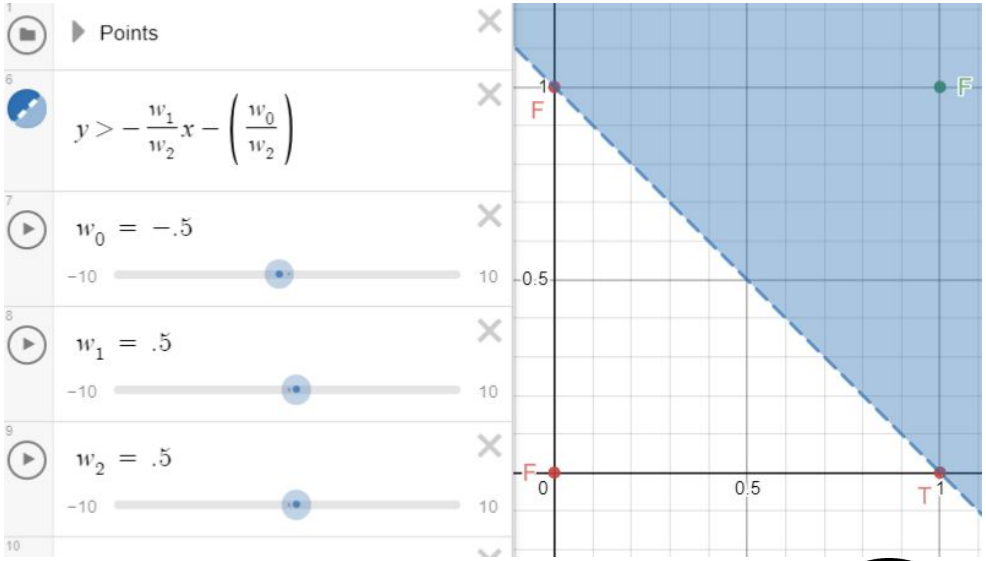
New w0 =	w0	+ LR *	(Y-	P)	* bias
-1	-0.5	0.5	0	1	1

New w1 =	w1	+ LR *	(Y-	P)	* x1
1	1	0.5	0	1	0

New w2 =	w2	+ LR *	(Y-	P)	* x2
1	1	0.5	0	1	0

2) Graph the line using the new weights on Desmos

1) Activation Function - converts output to binary
2) Learn Rate
3) Understand details, and then trust that it works



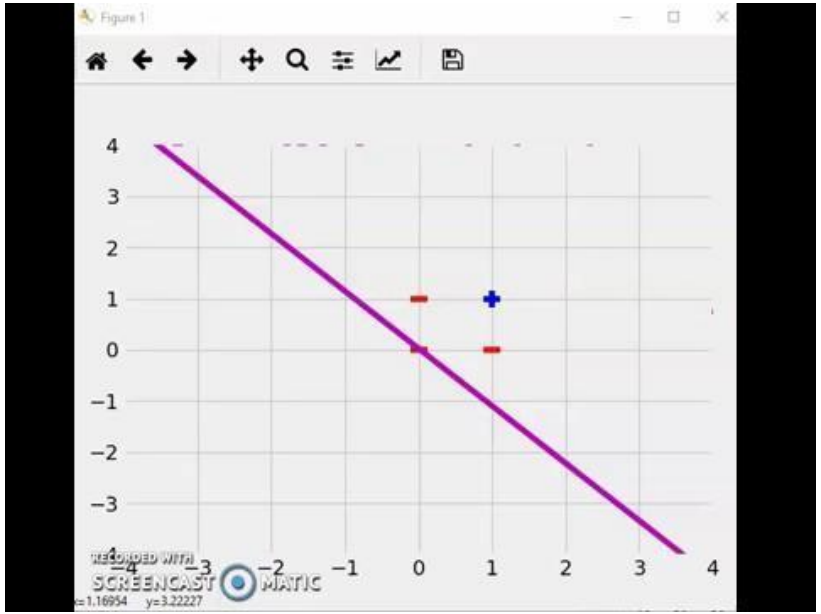
Typical Lesson – Perceptron and Truth Table

```
while (notFinished and (count< maxIter)):
    notFinished = False
    #Process each test value adjusting weights if need be
    for testNumber in range(len(X)):
        #totWeight is hypothesis
        summation = np.dot(weights,X[testNumber])

        #Heaviside function
        if(summation > 0):
            prediction = 1
        else:
            prediction = 0

        #update weights if hypothesis is wrong
        if (prediction != Y[testNumber][0]):
            notFinished = True
            for weightNum in range(paramNum):
                xVal = X[testNumber][weightNum]
                yVal = Y[testNumber][0]
                curWeight = weights[weightNum]

```



Linear Regression

- Concepts
  - Cost Function -Mean Squared Error - How far is our prediction from the expected value
  - Gradient Descent - How do we find the minimum value of the cost function
  - Iterative calculation
    - Adjusting the weights
    - Learning Rate
  - Vectorization - Dot product and Numpy
  - Standardardization/Normalization
  - Stochastic Gradient Descent
- Hand Calculate
  - 2 Iterations of adjusting weights

Linear Regression - cont.

- Projects
  - 1 Variable - Random Data,Cricket Chirp
  - Multi-Variable - Random, Housing Data, Age/blood pressure, murders/unemployment, movie theatre earnings, psychology exams, basketball points/game

Logistic Regression

- Concepts
  - Cost Function - Logarithmic
  - Processing Data
    - Test Vs. Training Data
    - Categorical Data - One Hot Encoding
    - Overfitting/Underfitting (bias/variance)
  - Activation Function - Sigmoid
  - Multiple Classification
- Projects
  - Single Output Classification - Titantic(who lives or dies), 1994 Census(who makes more than 50K)
  - Multiple Output Classification - Iris Dataset - Random, Housing Data,
- Hand Calculate
  - Logistic Regression - Sigmoid

Neural Networks

- Concepts
  - Perceptron - non linearly separable truth tables (XOR)
  - Activation Function - Relu vs. Sigmoid, Softmax
  - Neural Networks
    - BackPropogation
  - Keras (Tensorflow more involved)
- Projects
  - Multiple node perceptron - XOR Truth table
  - Images - MNIST
  - IMDB
  - BikeShare
- Hand Calculate
  - Backpropogation - 3blue1brown YouTube videos (2 on backprop)

Actual Student Projects

- Detect Malaria
- Detect Skin Cancer
- Identify Airplane Type
- Detect HandWriting
- Predict probability of Breast Cancer
- Predict Energy Usage
- Predict Animal Shelter length of Stay
- Predict Climate Change impact
- Predict Women’s Human Freedom Index
- Diabetes Prediction
- Predict Airport Delay
- Identifying Malware
- Predicting Size of Forest Fires
- Identifying specific Humpback whales
- Predict whether person will donate blood
- Predict PUBG Rank
- Predict Life Expectancy by Country

Rewards and Challenges

Rewards

- Students understand the “black box” of ML
- Students work on solving real-world problems
- Students gain deep understanding of how to understand and use data

Challenges

- Rapidly changing technology
- Scaffolding - No readily available curriculum - for HS students
- Programming/debugging in a new language with extensive libraries

How to learn about Machine Learning

- John and Jared background
  - Did not Python
  - Did not know ML
- How we learned ML
  - Online Course - Andrew NG Coursera
  - Books - Keras
  - Relationship with Janelia Research Campus
- How we learned Python
  - Runestone online book
  - Automate The Boring Stuff
- Good ML website links - CHECK THIS OUT
- Mind Map of ML Concepts, Math and Programming prereq's

What Software Do You Need?

Code manager

ANACONDA.

- Manages versions

IDE - Browser

jupyter

- Google Colab
- Displays text and code
- Easy to run

IDE - StandAlone

- Spyder
- Displays variable for debugging nicer
  - Easy if used to other ide's

Languages

- Python 45%
- R 11.2%
- MatLab

Questions?

Stay Involved!

Visit us:

http://AI4K12.org

Join the mailing list:

Send mail to ai4k12@aaai.org

Provide feedback on the AI4K12 Framework:

https://github.com/touretzkyds/ai4k12/wiki

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