What Every Child (and Teacher) Should Know About Artificial Intelligence

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#AI4K12

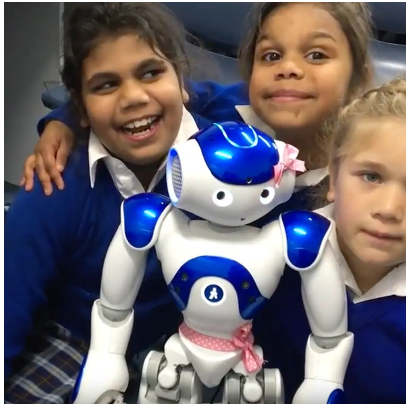
Why should children be learning about AI at all?

1. For the same reason they learn about electricity: *AI is powering the next industrial revolution.*

2. We need informed citizens who understand the issues raised by new technology. AI is bringing huge economic and social changes.

3. Children are growing up with AI all around them. They should not regard it as magic.

4. Encourage thinking about AI-related careers.



The AI4K12 Initiative, a joint project of:

AAAI (Association for the Advancement of Artificial Intelligence)

Association for the Advancement of Artificial Intelligence

CSTA (Computer Science Teachers Association)

CSTA

With funding from National Science Foundation ITEST Program (DRL-1846073)

Carnegie Mellon University
School of Computer Science

K-12 AI Education circa May 2018

- K-12 Computing Education was exploding in the US and abroad.
- We were not as far along when it came to AI, but many countries were trying: China, UK, Thailand, Korea, and EU Countries.

- The 2017 CSTA Computing Standards contained just two sentences about AI.
  - Both were for the 11-12 grade band. Nothing for younger students.

3B-AP-08	11-12	Describe how artificial intelligence drives many software and physical systems.	Algorithms & Programming	Algorithms	Communicating
3B-AP-09	11-12	Implement an artificial intelligence algorithm to play a game against a human opponent or solve a problem.	Algorithms & Programming	Algorithms	Creating

AI4K12.org Initiative: Mission

- Develop national guidelines for teaching AI in K-12
  - Modeled after the CSTA standards for computing education.
  - Four grade bands: K-2, 3-5, 6-8, and 9-12
  - What should students know?
  - What should students be able to do?
- Develop a curated AI resource directory for K-12 teachers
- Foster a K-12 AI Education Research and Practice Community & Resource Developers

AI4K12.org

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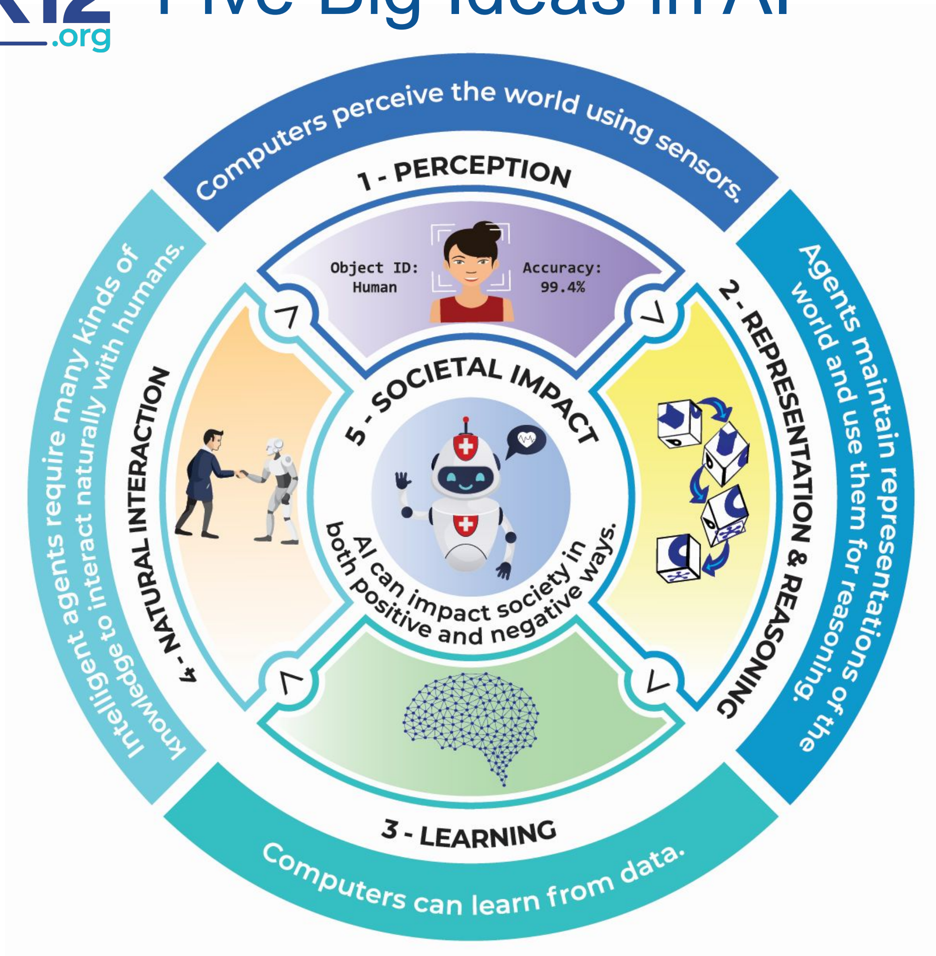
Five Big Ideas in AI

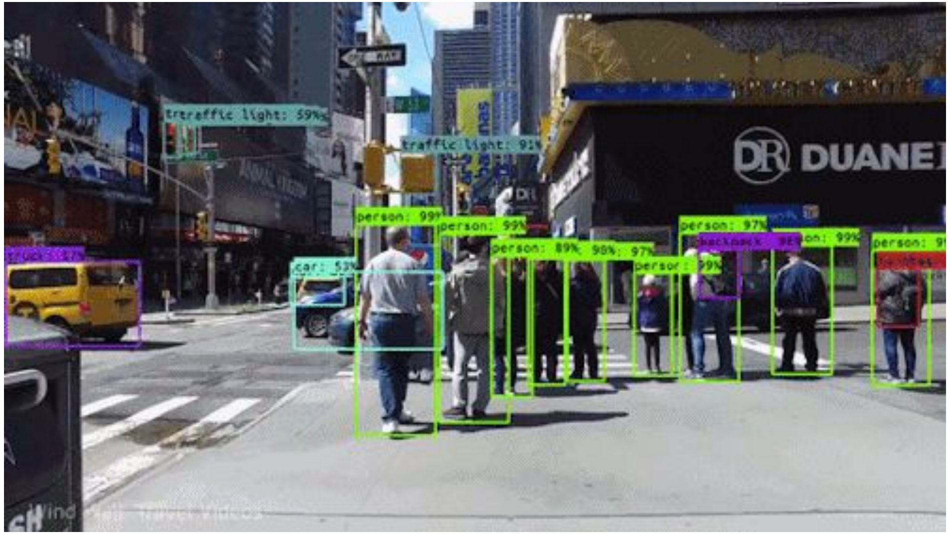


Big Idea #1: Perception

Computers perceive the world using sensors.

Perception is the extraction of *meaning* from sensory signals using 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

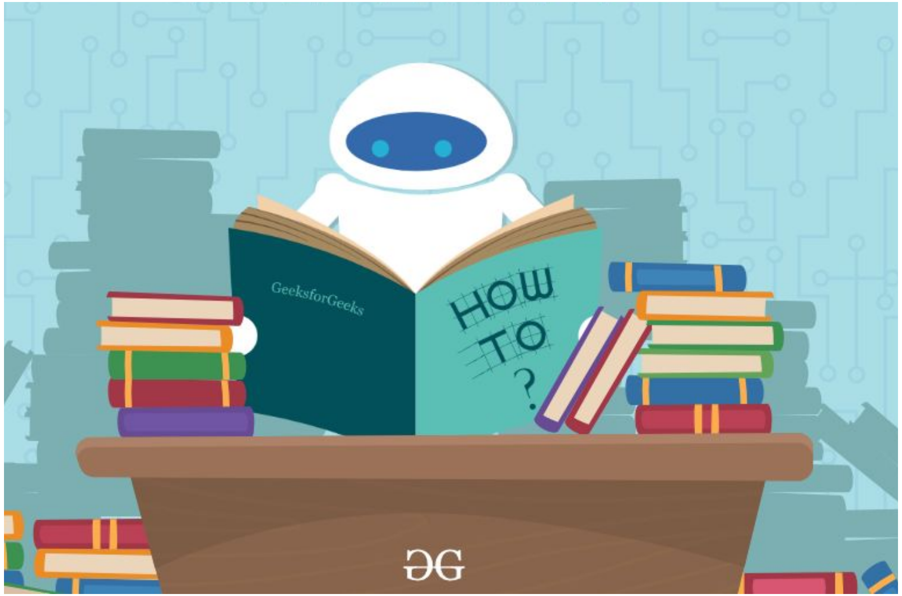
Example Guidelines

- 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.

- Nature 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 & interaction (e.g. with robots, or speech agents)
- 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 (1 of 3)

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

- Ethics of AI making decisions about people
  - Fairness and bias
  - Transparency and explainability
  - Accountability

Example Guidelines

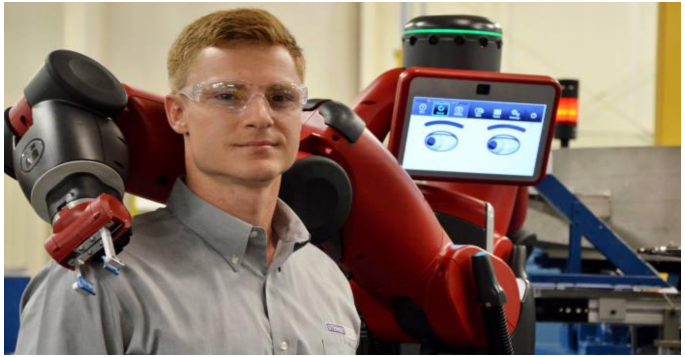
- Critically explore the positive and negative impacts of an AI system.

- Describe ways that AI systems can be designed for inclusivity.

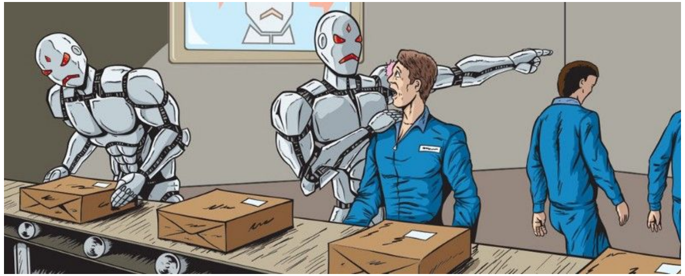
Machine Bias: ProPublica.org

Big Idea #5: Societal Impact (2 of 3)

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



- Economic impact of AI
  - Increased productivity
  - New types of services
  - Reduction in of some types of jobs
  - New career opportunities



Example Guidelines

- Design and explain how an AI system can be used to address a social issue.
- Understand tradeoffs in the design of AI systems and how decisions can have unintended consequences in the function of a system.

Big Idea #5: Societal Impact (3 of 3)

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

- AI & Culture
    - Living with intelligent assistants and robot companions.
    - Would you let your child travel unaccompanied in a self-driving car?
    - New YouTube genre: self-driving car mishaps.

Example Guidelines

- Critically explore the positive and negative impacts of an AI system.

- Describe the debate about whether people should be polite to agents and robots.

Five Big Ideas in Artificial Intelligence

1. Perception

Computers perceive the world using sensors. Perception is the process of extracting meaning from sensory signals. Making computers "see" and "hear" well enough for practical use is one of the most significant achievements of AI to date.

2. Representation & Reasoning

Agents maintain representations of the world and use them for reasoning. Representation is one of the fundamental problems of intelligence, both natural and artificial. Computers construct representations using data structures, and these representations support reasoning algorithms that derive new information from what is already known. While AI agents can reason about very complex problems, they do not think the way a human does.

3. Learning

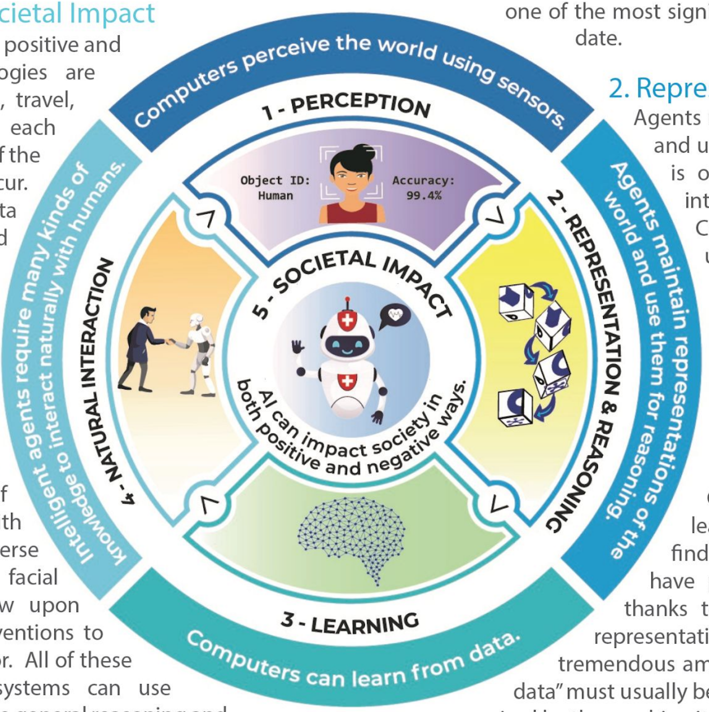
Computers can learn from data. Machine learning is a kind of statistical inference that finds patterns in data. Many areas of AI have progressed significantly in recent years thanks to learning algorithms that create new representations. For the approach to succeed, tremendous amounts of data are required. This "training data" must usually be supplied by people, but is sometimes acquired by the machine itself.

4. Natural Interaction

Intelligent agents require many kinds of knowlege to interact naturally with humans. Agents must be able to converse in human languages, recognize facial expressions and emotions, and draw upon knowledge of culture and social conventions to infer intentions from observed behavior. All of these are difficult problems. Today's AI systems can use language to a limited extent, but lack the general reasoning and conversational capabilities of even a child.

5. Societal Impact

AI can impact society in both positive and negative ways. AI technologies are changing the ways we work, travel, communicate, and care for each other. But we must be mindful of the harms that can potentially occur. For example, biases in the data used to train an AI system could lead to some people being less well served than others. Thus, it is important to discuss the impacts that AI is having on our society and develop criteria for the ethical design and deployment of AI-based systems.



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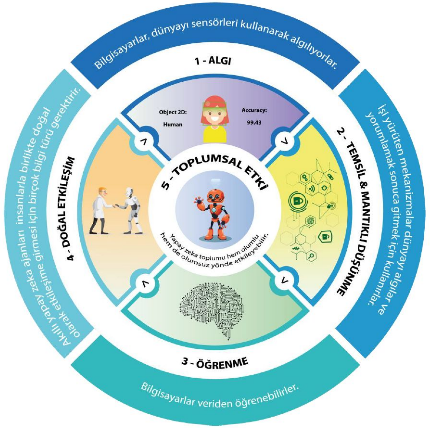
AI4K12.org

11x14 Poster available for free download at AI4K12.org

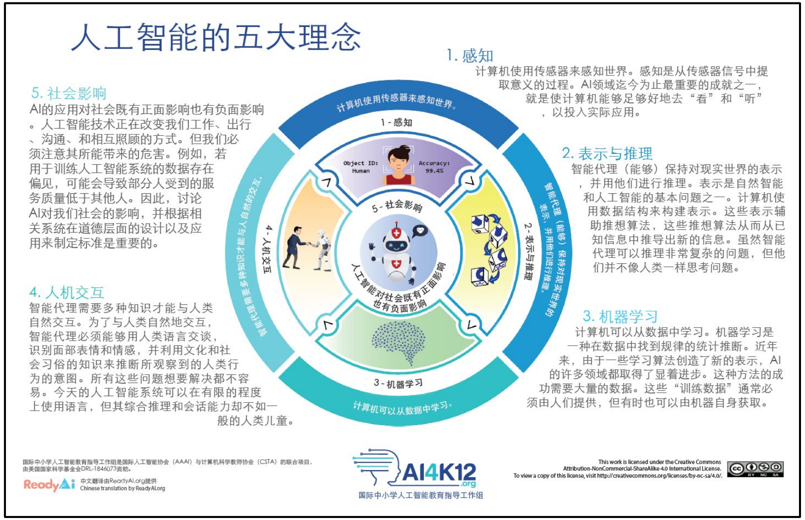
Adoption of the Big Ideas

- Now being adopted by curriculum developers in the US and elsewhere.
- Translations available in Chinese, Korean, Portugese, Hebrew, and Turkish. Spanish is coming soon.

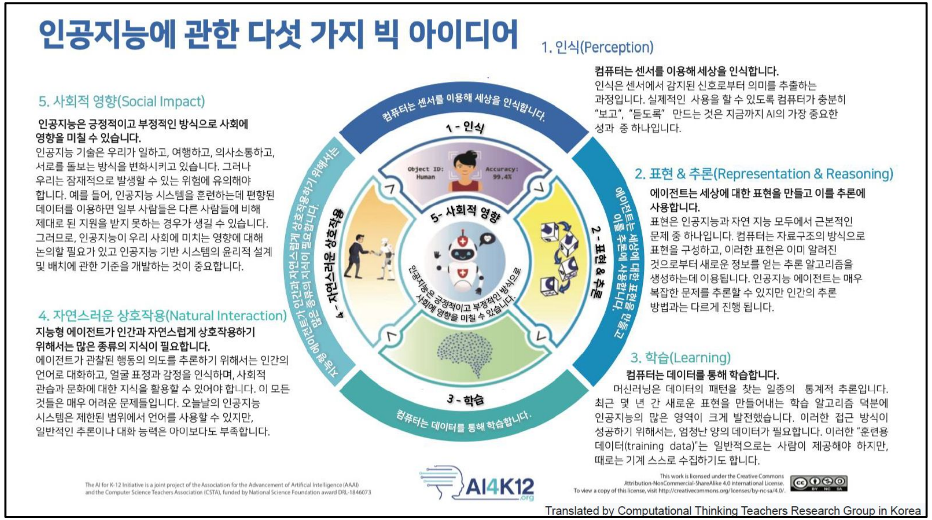
Turkish



Chinese



Korean

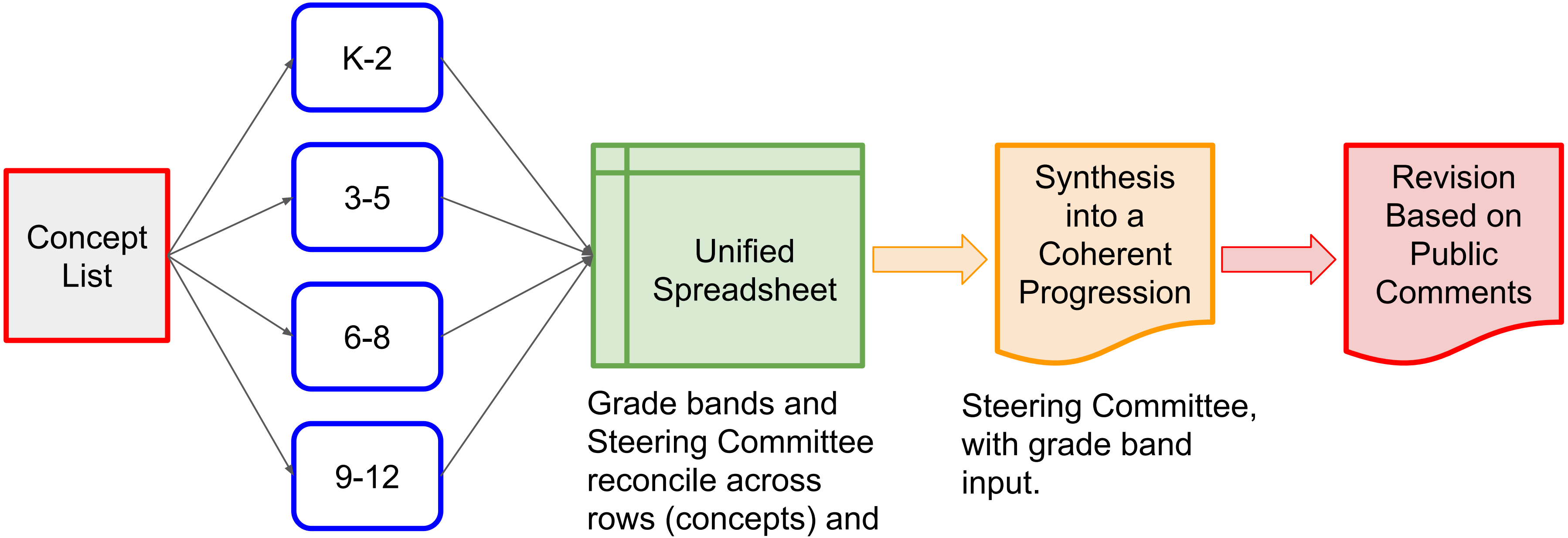


Principles for Refinement & Scoping of Guidelines

Guidelines need to have real-world relevance to enable students to:

- Explain how a self-driving car works and the types AI subsystems involved in its operation.
- Explain the process by which ML models are developed, from data collection to training and testing, sources of bias etc.
- Use, modify, and create AI systems using developmentally appropriate tools .
- Understand the implications of AI for real world issues.

Drafting the Guidelines for One Big Idea

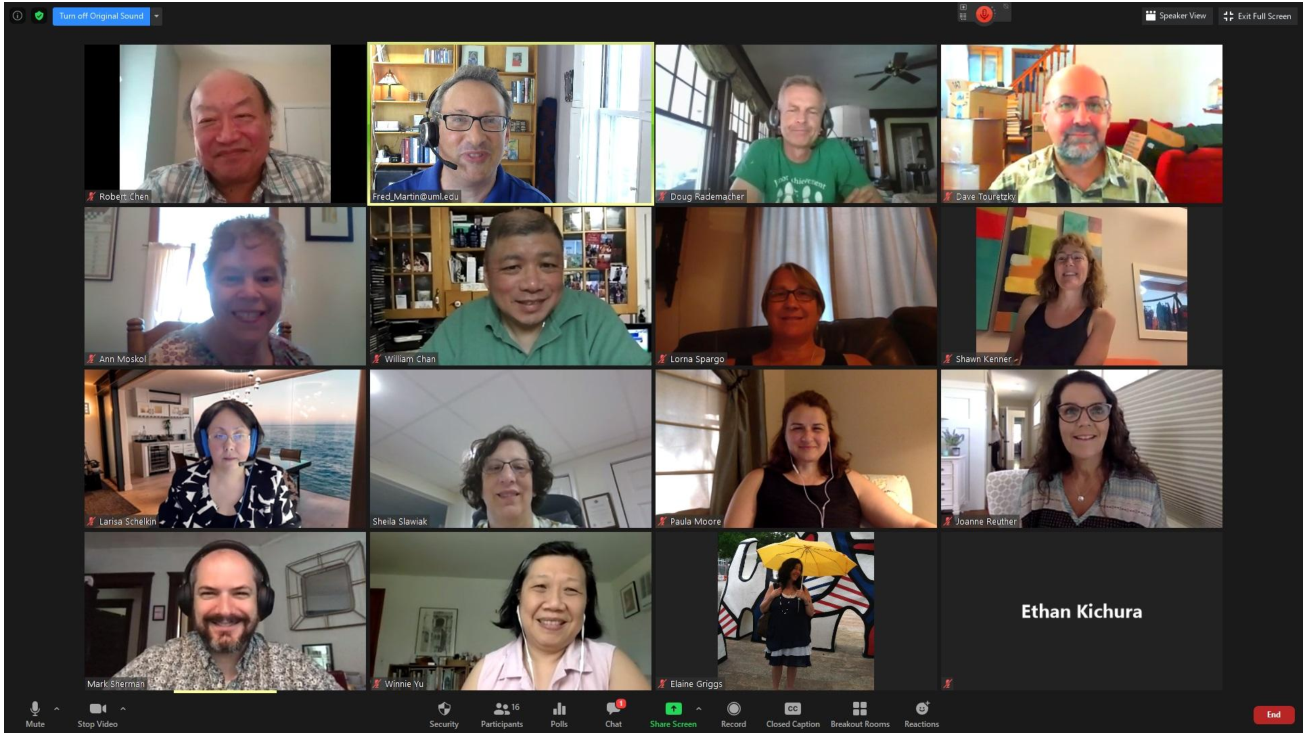


Grade bands develop concept treatments

Grade bands and Steering Committee reconcile across rows (concepts) and columns (grade bands)

Steering Committee, with grade band input.

Teacher Feedback Session on Big Idea #1



Online feedback form available at http://AI4K12.org

Page 1 (of 4) of the draft guidelines for Big Idea #1: Perception

AI4K12.org

Draft Big Idea 1 - Progression Chart

www.AI4K12.org

Big Idea #1: Perception	*Computers perceive the world using sensors.*	**Perception is the extraction of meaning from sensory information using knowledge.**	**The transformation from signal to meaning takes place in stages, with increasingly abstract features and higher level knowledge applied at each stage.**	**LO** = Learning Objective: what students should be able to do. **EU** = Enduring Understanding: what students should know.
Concept	**K-2**	**3-5**	**6-8**	**9-12**
Sensing (Living Things) **1-A-i**	**LO:** Identify human senses and sensory organs. **EU:** People experience the world through sight, hearing, touch, taste, and smell.	**LO:** Compare human and animal perception. **EU:** Some animals experience the world differently than people do. **Unpacked:** Bats and dolphins use sonar. Bees can see ultraviolet. Rats are have no color vision; dogs are red-green colorblind. Dogs and rats can hear higher frequences than humans.	**LO:** Give examples of how humans combine information from muliple modalities. **EU:** People can exploit correlations between senses, such as sight and sound, to make sense of ambiguous signals. **Unpacked:** In a noisy environment, speech is more understandable when the speaker's mouth is visible. People learn the sounds associated with various actions (such as dropping an object) and can recognize when the sound doesn't match their expectation.	N/A – for AI purposes, this topic has already been adequately addressed in the lower grade bands. *Other courses, such as biology or an elective on sensory psychology, could go into more detail about topics such as taste, smell, proprioception, and vestibular organs.* *Possible enrichment material: look at optical illusions (Muller-Lyer illusion, Kanizsa triangle) and ask which ones are computer vision systems also subject to.*
Sensing (Computer Sensors) **1-A-ii**	**LO:** Locate and identify sensors (camera, microphone) on computers, phones, robots, and other devices. **EU:** Computers "see" through video cameras and "hear" through microphones.	**LO:** Illustrate how computer sensing differs from human sensing. **EU:** Most computers have no sense of taste, smell, or touch, but they can sense some things that humans can't, such as infrared emissions, extremely low or high frequency sounds, or magnetism.	**LO:** Give examples of how intelligent agents combine information from multiple sensors. **EU:** Self driving cars combine computer vision with radar or lidar imaging. GPS measurement, and accelerometer data to form a detailed representation of the environment and their motion through it.	**LO:** Describe the limitations and advantages of various types of computer sensors. **EU:** Sensors are devices that measure physical phenomena such as light, sound, temperature, or pressure. **Unpacked:** Cameras have limited resolution, dynamic range, and spectral sensitivity. Microphones have limited sensitivity and frequency response. Signals may be degraded by noise, such as a microphone in a noisy environment. Some sensors can detect things that people cannot, such as infrared or ultraviolet imagery, or ultrasonic sounds.
Sensing (Digital Encoding) **1-A-iii**	N/A	**LO:** Explain how images are represented digitally in a computer. **EU:** Images are encoded as 2D arrays of pixels, where each pixel is a number indicating the brightness of that piece of the image, or an RGB value indicating the brightness of the red, green, and blue components of that piece.	**LO:** Explain how sounds are represented digitally in a computer. **EU:** Sounds are digitally encoded by sampling the waveform at discrete points (typically several thousand samples per second), yielding a series of numbers.	**LO:** Explain how radar, lidar, GPS, and accelerometer data are represented. **EU:** Radar and lidar do depth imaging: each pixel is a depth value. GPS triangulates position using satellite signals and gives a location as longitude and lattitude. Accelerometers measure accleration in 3 orthogonal dimensions. **Unpacked:** Radar and lidar measure distance as the time for a reflected signal to return to the transceiver. GPS determines position by triangulating precisely timed signals from three or more satellites. Accelerometers use orthogonally oriented strain gauges to measure acceleration in three dimensions.

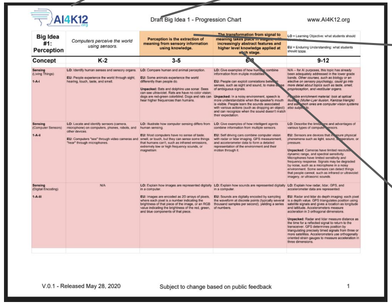
V.0.1 - Released May 28, 2020

Subject to change based on public feedback

1

Big Idea #1: Perception

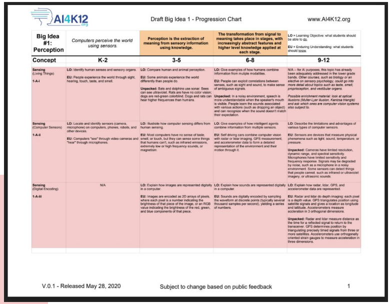
Computers perceive the world using sensors.



Perception is the extraction of meaning from sensory information using knowledge.

The transformation from signal to meaning takes place in stages, with increasingly abstract features and higher level knowledge applied at each stage.

Big Idea #1 Concept List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Draft Big Idea 1 - Progression Chart

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Concept	K-2	3-5	6-8	9-12

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1-A: Sensing

- 1-A-i: Living Things
- 1-A-ii: Computer Sensors
- 1-A-iii: Digital Encoding

1-B: Processing

- 1-B-i: Sensing vs. Perception
- 1-B-ii: Feature Extraction
- 1-B-iii: Abstraction Pipeline: Language
- 1-B-iv: Abstraction Pipeline: Vision

1-C: Domain Knowledge

- 1-C-i: Types of Domain Knowledge
- 1-C-ii: Inclusivity

1-A-i: Sensing in Living Things

K-2	3-5
LO: Identify human senses and sensory organs. **EU:** People experience the world through sight, hearing, touch, taste, and small.	**LO:** Compare human and animal perception. **EU:** Some animals experience the world differently than people do. **Unpacked:** Bats and dolphins use sonar. Bees can see ultraviolet. Rats have no color vision...

LO (Learning Objective): What students should be able to <u>do</u>.
EU (Enduring Understanding): What students should <u>know</u>.

1-A-ii: Computer Sensors

K-2

LO: Locate and identify sensors (camera, microphone) on computers, phones, robots, and other devices.

EU: Computers “see” through video cameras and “hear” through microphones.

9-12

LO: Describe the limitations and advantages of various types of computer sensors.

EU: Sensors are devices that measure physical phenomena such as light, sound, temperature, or pressure.

Unpacked: camera resolution, spectral sensitivity, etc.

1-A-iii: Digital Encoding

3-5

LO: Explain how images are represented digitally in a computer.

EU: Images are encoded as 2D arrays of pixels, where each pixel is a number indicating the brightness of that piece of an image, or an RGB value indicating the brightness of the red, blue, and green components...

6-8

LO: Explain how sounds are represented digitally in a computer.

EU: Sounds are digitally encoded by sampling the waveform at discrete points (typically several thousand samples per second), yielding a series of numbers.

1-B-i: Sensing vs. Perception

K-2

LO: Give examples of intelligent vs. non-intelligent machines and explain what makes a machine intelligent.

EU: …

Unpacked: Cameras and phones can record and play back images and sounds, but extracting meaning from these signals requires a computer with artificial intelligence.

6-8

LO: Give examples of different types of computer perception that extract meaning from sensory signals.

EU: There are specialized algorithms for face detection, facial expression recognition, object recognition, obstacle detection, speech recognition, vocal stress measurement, music recognition, etc.

Are Supermarket Doors Intelligent?

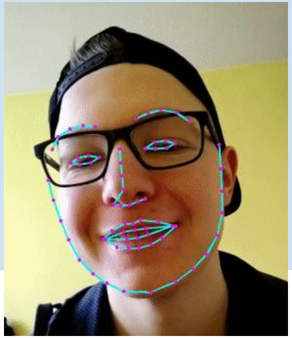
This is what you get when your automatic doors have sensing but not perception.

1-B-ii: Feature Extraction

3-5

LO: Illustrate how face detection works by extracting facial features.

EU: Face detectors use special algorithms to look for eyes, noses, mouths, and jawlines.

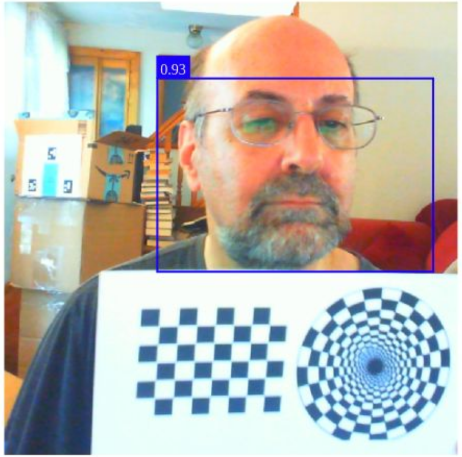


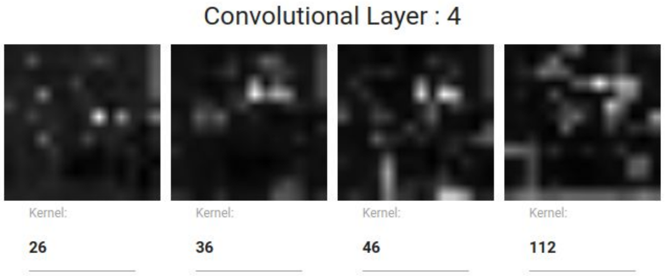
6-8

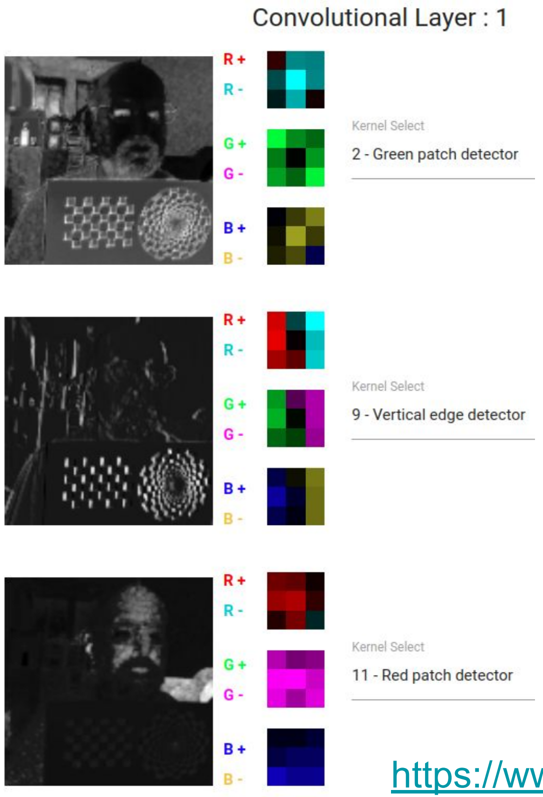
LO: Illustrate the concept of feature extraction from images by simulating an edge detector.

EU: Locations and orientations of edges in an image are features that can be extracted by looking for specific arrangements of light and dark pixels in a small (local) area.

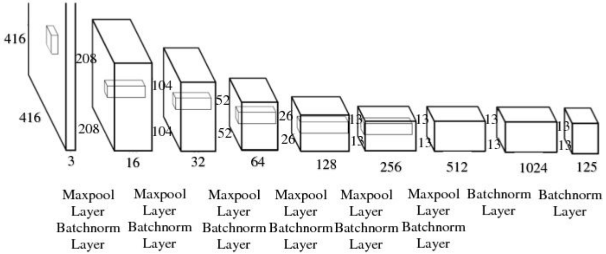
Edge and Face Detection Demo







Real-time face detection by a deep neural network (TinyYoloV2)



https://www.cs.cmu.edu/~dst/FaceDemo

1-B-iii: Abstraction Pipeline: Language

K-2

LO: Describe the different sounds that make up one's spoken language, and for every vowel sound, give a word containing that sound.

EU: For a computer to understand speech it must be able to recognize the sounds from which words are constructed.

9-12

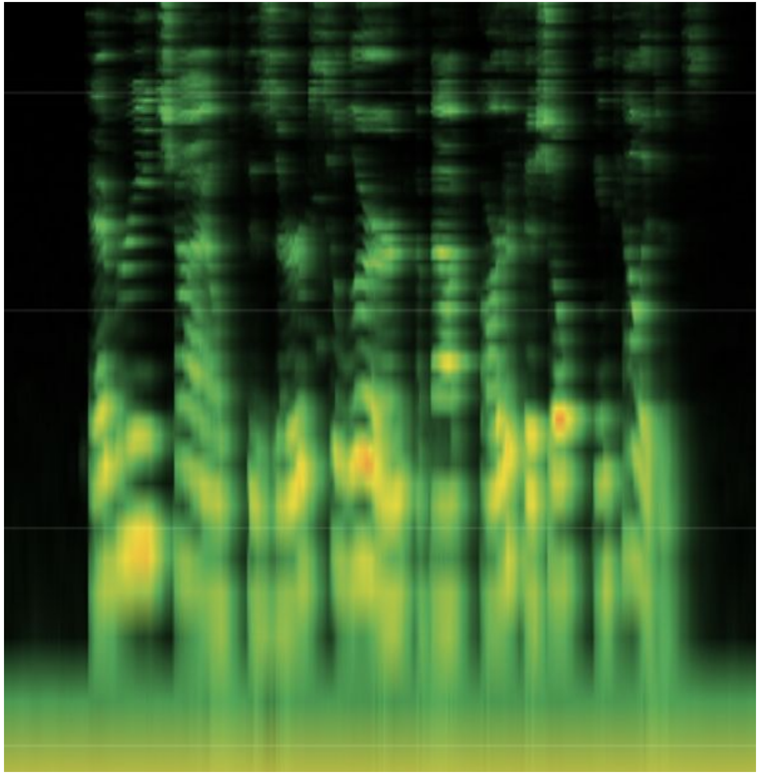
LO: Illustrate the abstraction hierarchy for speech, from waveforms to sentences, showing how knowledge at each level is used to resolve ambiguities in the levels below.

EU: waveforms -> spectrograms -> articulatory gestures -> sounds -> morphemes -> words -> phrases -> sentences

Real-Time Spectrogram Demo

Speech spectrogram of me saying *“Every child deserves to learn about artificial intelligence.”*

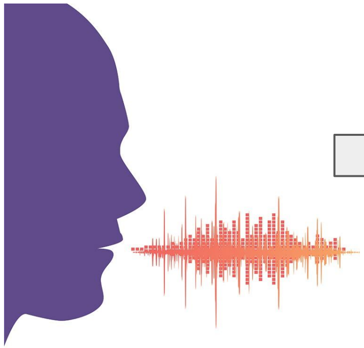
https://creatability.withgoogle.com/seeing-music

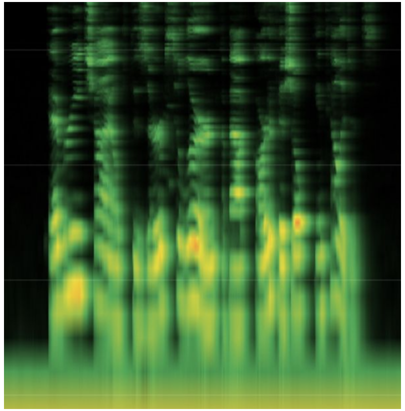


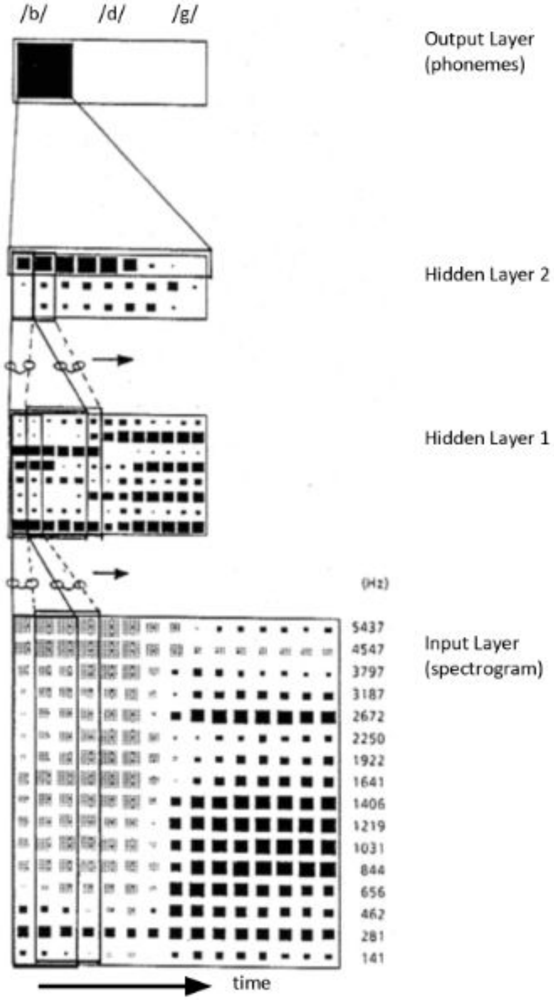
Time Delay Neural Network

Early convolutional neural net from 1980s.

Spectrograms go in; phonemes come out.

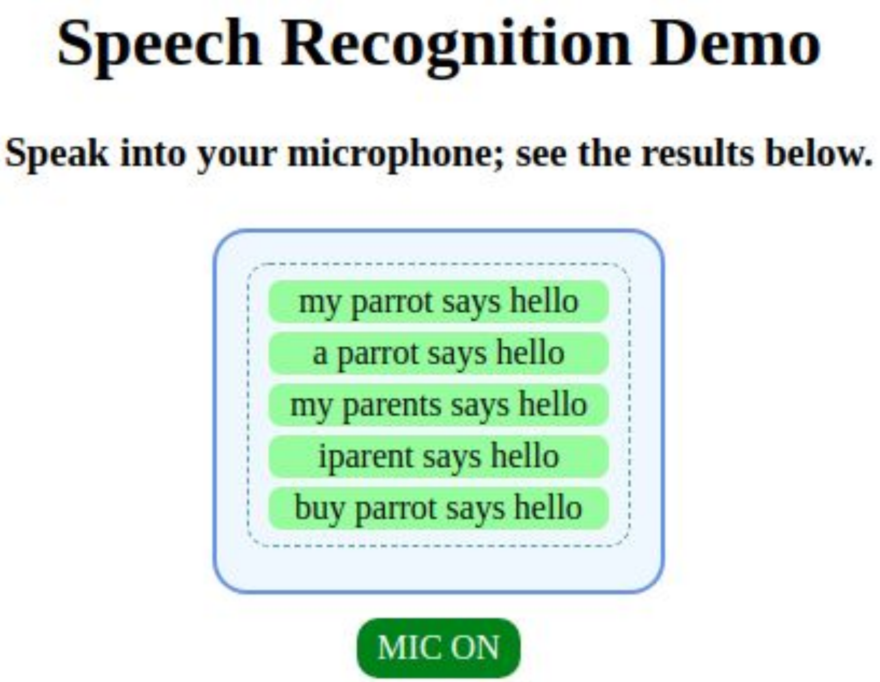






Google Speech API: Embrace the ambiguity!

https://www.cs.cmu.edu/~dst/SpeechDemo

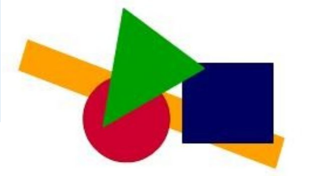


1-B-iv: Abstraction Pipeline: Vision

3-5

LO: Illustrate how outlines of partially occluded (blocked) objects differ from the real shapes of the objects.

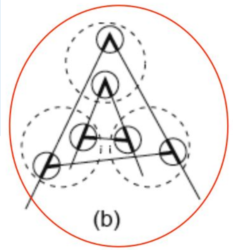
EU: Understanding complex scenes requires taking into account the effects of occlusion when recognizing objects.



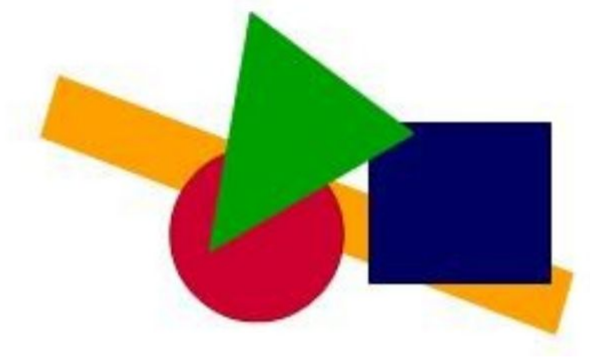
6-8

LO: Describe how edge detectors can be composed to form more complex feature detectors for letters or shapes.

EU: The progression from image to meaning takes place in stages, with increasingly complex features extracted at each stage.



Occlusion: How many rectangles in this image?



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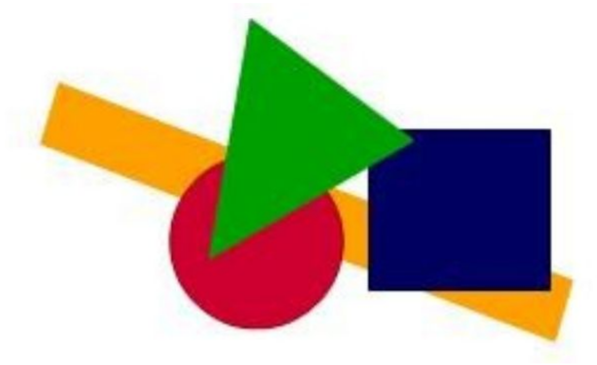
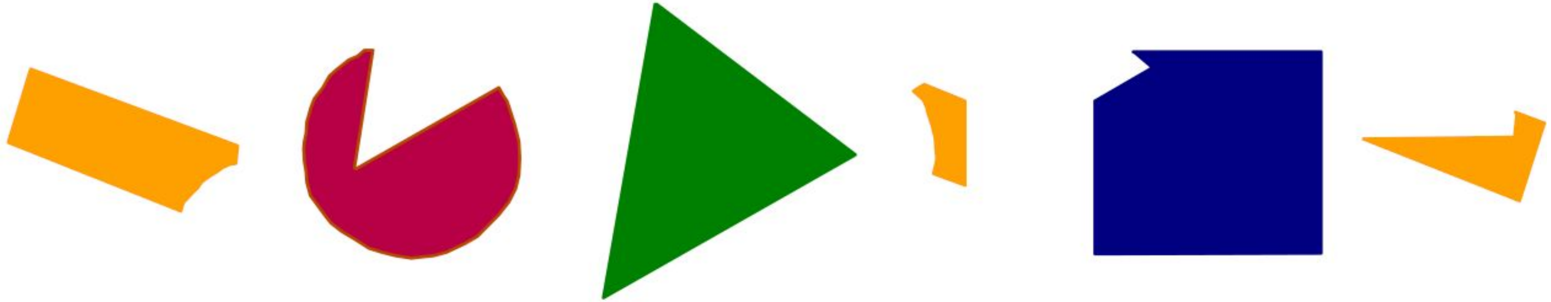
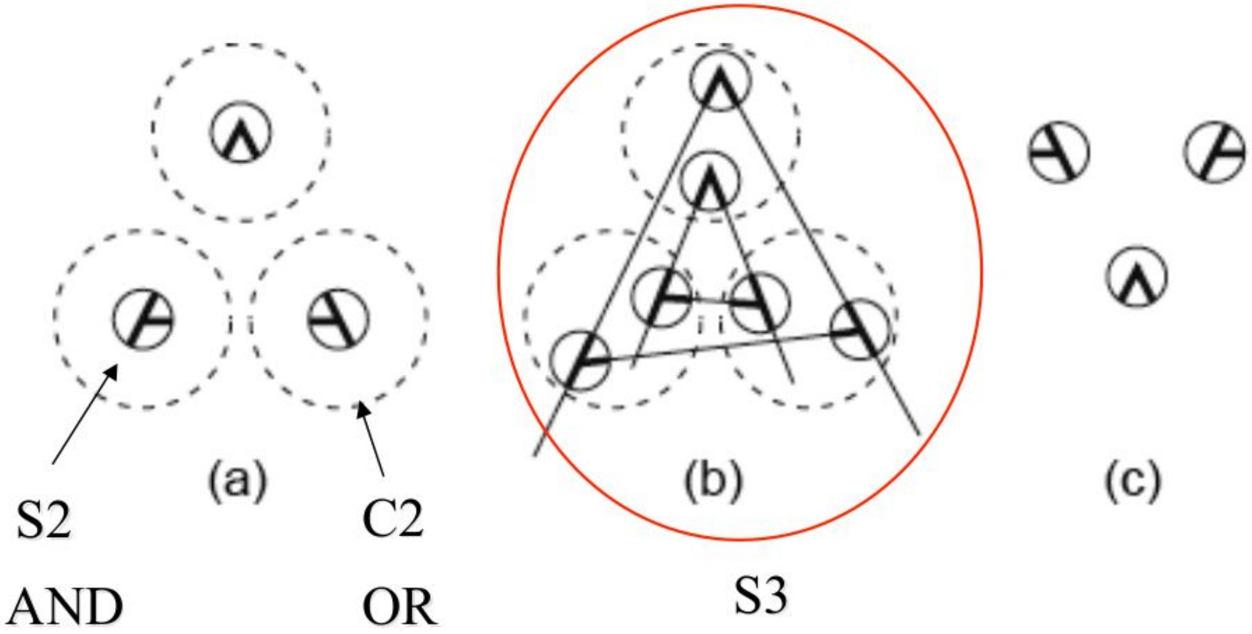


None!



Detecting an “A” with position & scale invariant features



1-C-i: Types of Domain Knowledge

3-5

LO: Demonstrate how a text to speech system can resolve ambiguity based on context, and how its error rate goes up when given ungrammatical or meaningless inputs.

EU: Speech recognition systems are trained on millions of utterances … which helps them select the most likely interpretation of the signal.

9-12

LO: Analyze one or more online image datasets and describe the information they provide and how this can be used to extract domain knowledge for a vision system.

EU: Domain knowledge in AI systems is often derived from statistics collected from millions of utterances or images.

Unpacked: Can use ImageNet, Coco...

1-C-ii: Inclusivity

K-2

LO: Discuss why intelligent agents need to understand languages other than English.

EU: Speech recognition systems need to accommodate different languages because many different types of people will use them.

9-12

LO: Describe some of the technical difficulties in making computer perception systems function for diverse groups.

EU: Dark or low contrast facial features are harder to recognize than high contrast features. Children's speech is in a higher register and less clearly articulated than adult speech.

What’s Next?

- August 2020: First release of Big Idea #3 progression chart for public comment.

- September 2020: Revised Big Idea #1 progression chart.

- Fall 2020: drafts of progression charts for Big Ideas #4, 5, and 2.

- February 2021: EAAI-21 will have a special track: “Demos, Software Tools, and Activities for Teaching AI in K-12”.

Big Idea #3: Learning

Computers can learn from data.

Machine learning allows a computer to acquire behaviors without people explicitly programming those behaviors.

Learning of new behaviors is brought about by changes in internal representations.

Large amounts of training data are required when the space of possible behaviors that could be learned is large.

Join Us in Developing the Guidelines

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