

Developing National Guidelines for K-12 AI Education

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International Workshop on Education in Artificial
Intelligence K-12 (EDUAI-20). July 10, 2020



#AI4K12



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)



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 is exploding in the US and abroad.
- We are not as far along when it comes to AI, but many countries are trying: China, UK, Thailand, Korea, and EU Countries.
- The 2017 CSTA Computing Standards contain just two sentences about AI.
 - Both are 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



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



Steering Committee



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Carnegie Mellon
AI for K-12 Working Group
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University of Florida
AI For K-12 Working
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Grades 3-5

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Grades 6-8

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Grades 9-12

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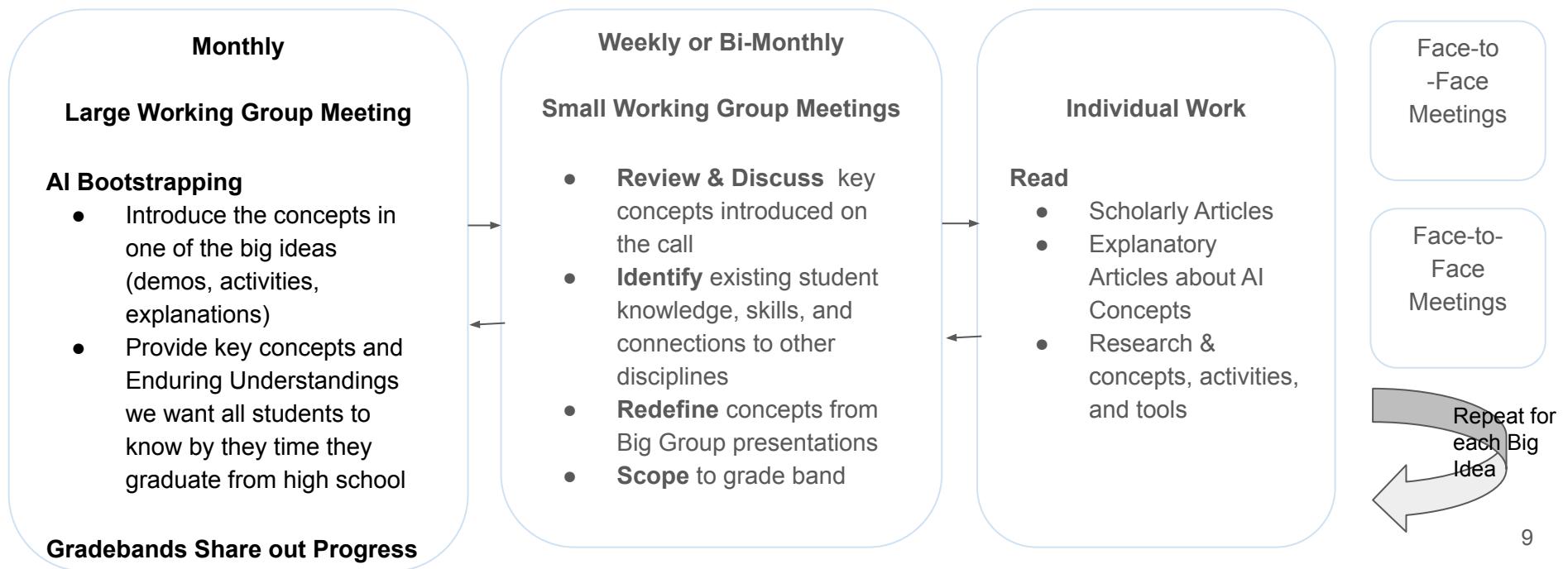
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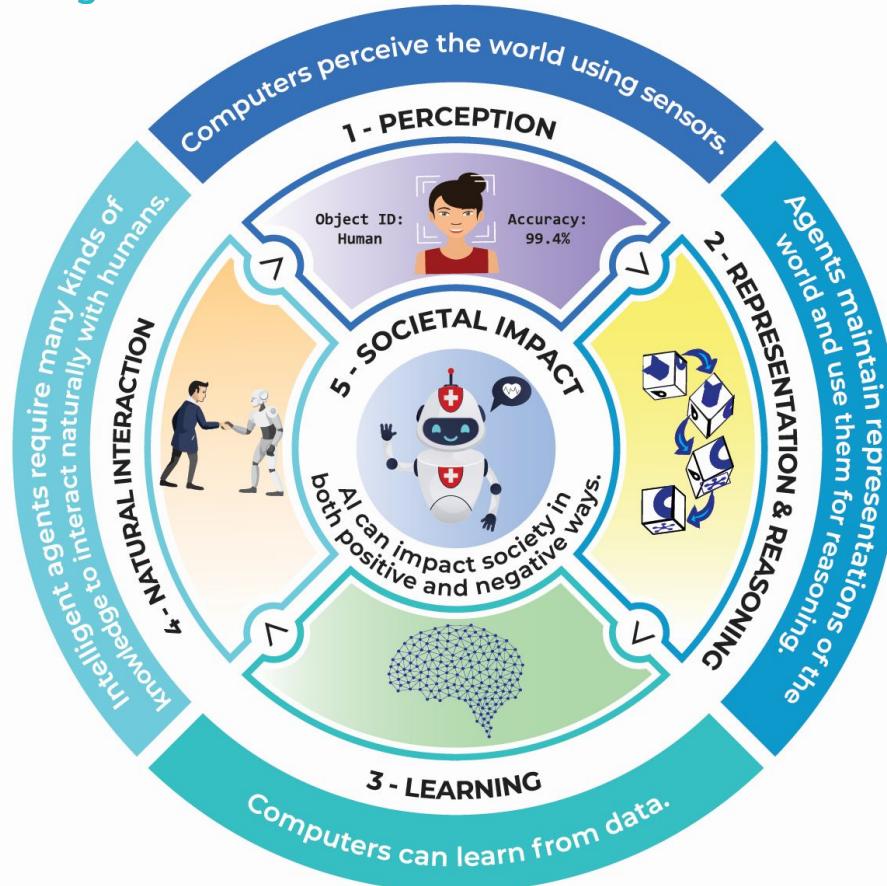
Structure of Working Group & Responsibilities

Goal: Increase familiarity with AI concepts, and leverage knowledge of students' capabilities in CS and other disciplines and interests, to scope expectations for student learning about AI for their grade band





Five Big Ideas in AI

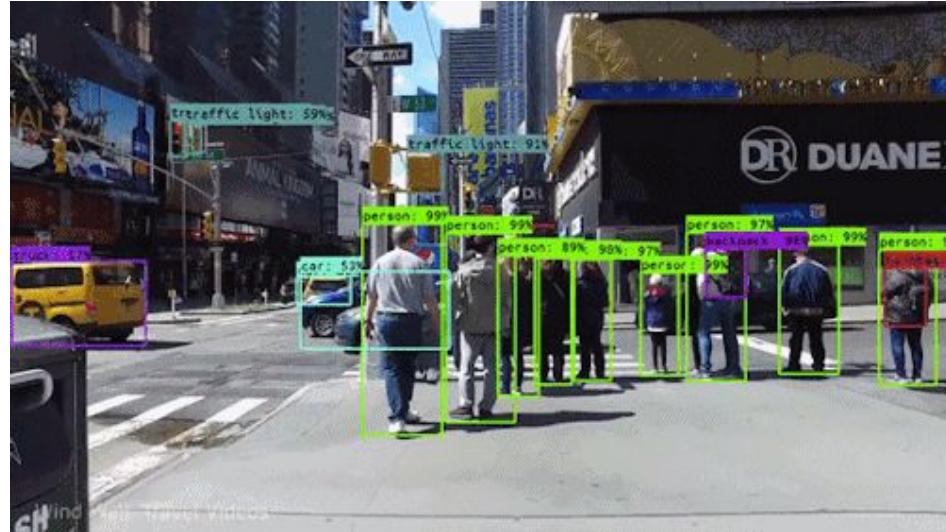


Big Idea #1: Perception

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

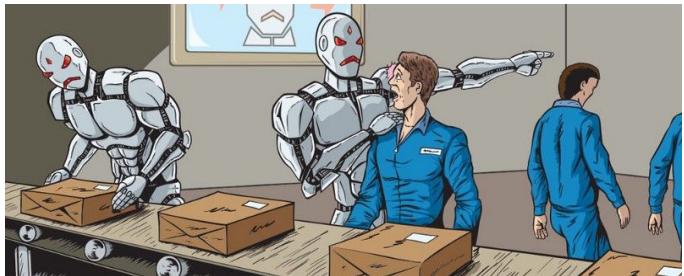
Big Idea #5: Societal Impact (2 of 3)

“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.



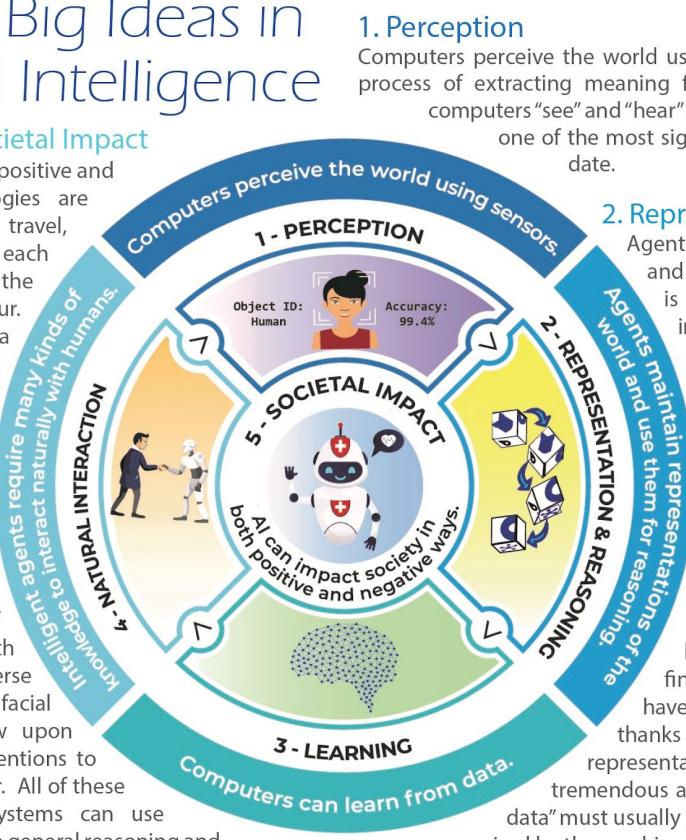
Five Big Ideas in Artificial Intelligence

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.

4. Natural Interaction

Intelligent agents require many kinds of knowledge 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.



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.

Adoption of the Big Ideas

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

Chinese

人工智能的五大理念

5. 社会影响

AI的应用对社会既有正面影响也有负面影响。人工智能技术正在改变我们工作、出行、沟通、和相互照应的方式。但我们必须注意其所能带来的危害。例如，若用于训练人工智能系统的数据存在偏见，可能会导致部分人受到的服务质量低于其他人。因此，讨论AI对我们社会的影响，并根据相关关系在道德层面的设计以及应用来制定标准是重要的。

4. 人机交互

智能代理需要多种知识才能与人类自然交互。为了与人类自然地交互，智能代理必须能够用人类语言交谈，识别面部表情和情感，并利用文化和社会习俗的知识来推断所观察到的人类行为的意图。所有这些问题需要解决都不容易。今天的人工智能系统可以在有意识的程度上使用语言，但其综合推理和会话能力却不如一般的人类儿童。

1. 感知

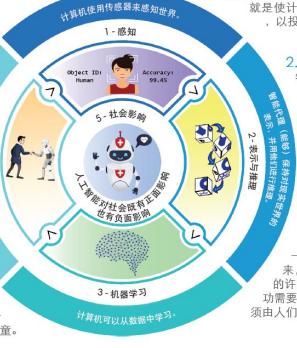
计算机使用传感器来感知世界。感知是从传感器信号中提取意义的过程。AI领域迄今为止最重要的成就之一，就是使计算机能够足够好地去“看”和“听”，以投入实际应用。

2. 表示与推理

智能代理（推理）保持对现实世界的表示，并用他们进行推理。表示是自然智能和人工智能的基本问题之一。计算机使用数据结构来构建表示。这些表示辅助想算法，这些推想算法从从已知信息中推导出新的信息。虽然智能代理可以推理非常复杂的问题，但他们并不像人类一样思考问题。

3. 机器学习

计算机可以从数据中学习。机器学习是一种在数据中找到规律的统计推断。近年来，由于一些学习算法创造了新的表示，AI的许多领域都取得了显著进步。这种方法的成功需要大量的数据。这些“训练数据”通常必须由人们提供，但有时也可以由机器自身获取。



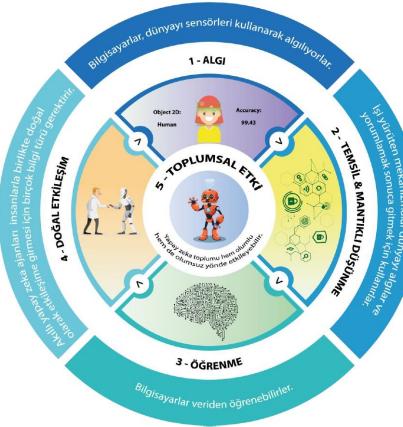
国际中小学人工智能教育指导工作组(AI4K12)与美国人工智能协会(AAAI)与计算机科学教师协会(CSTA)的联合项目。

AI4K12.org
中文翻译由ReadyAI完成

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国际中小学人工智能教育指导工作组

Turkish



Korean

인공지능에 관한 다섯 가지 빅 아이디어

1. 인식(Perception)

컴퓨터는 센서를 이용해 세상을 인식합니다.
인식은 센서에서 감지된 신호로부터 의미를 추출하는 과정입니다. 실제적인 사용을 할 수 있도록 컴퓨터가 충분히 “보고”, “듣도록” 만드는 것은 지금까지 시의 가장 중요한 성과 중 하나입니다.

2. 표현 & 주문(Representation & Reasoning)

에이전트는 세상에 대한 표현을 만들고 이를 추론에 사용합니다.
보통은 인공지능과 같이 모든에서 구본적인 문제 중 하나입니다. 컴퓨터는 자료구조와 방식으로 표현을 구성하고, 이러한 표현은 이미 알리진 것으로부터 새로운 정보를 얻은 후에 알리려면 성장하는데 이용됩니다. 인공지능 에이전트는 매우 복잡한 문제를 주문할 수 있지만 인간의 주문 방식과는 다르게 진행 됩니다.

3. 학습(Learning)

컴퓨터는 데이터를 통해 학습합니다.
마이크로프로세서의 페인을 찾는 일종의 통계적 추론입니다. 최근 몇 년 간 새로운 표현을 만들어내는 학습 알고리즘 덕분에 인공지능의 많은 영역이 크게 발전했습니다. 이러한 접근 방식이 성공하기 위해서는, 엄청난 양의 데이터가 필요합니다. 이러한 ‘운행 데이터(training data)’는 일반적으로 사람에 제공해야 하지만, 예를 들어 기기 스스로 수집하도록 합니다.

4. 자연스러운 상호작용(Natural Interaction)

지능형 에이전트는 인간과 자연스럽게 상호작용하기 위해서는 많은 종류의 자산이 필요합니다.
에이전트는 관찰된 행동의 의도를 추론하기 위해서는 인간의 언어로 대화하고, 행동의 표정과 감정을 인식하여, 사회적 관습과 문화에 대한 지식을 활용할 수 있어야 합니다. 이 모든 것들은 매우 어려운 사항들입니다. 오늘날의 인공지능 시스템은 세밀한 범위에서 인간과 상호작용할 수 있지만, 일반적인 주문이나 대화 능력은 아직까지는 부족합니다.

The AI for K-12 Initiative is a joint project of the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA), funded by National Science Foundation award DRL-184603.

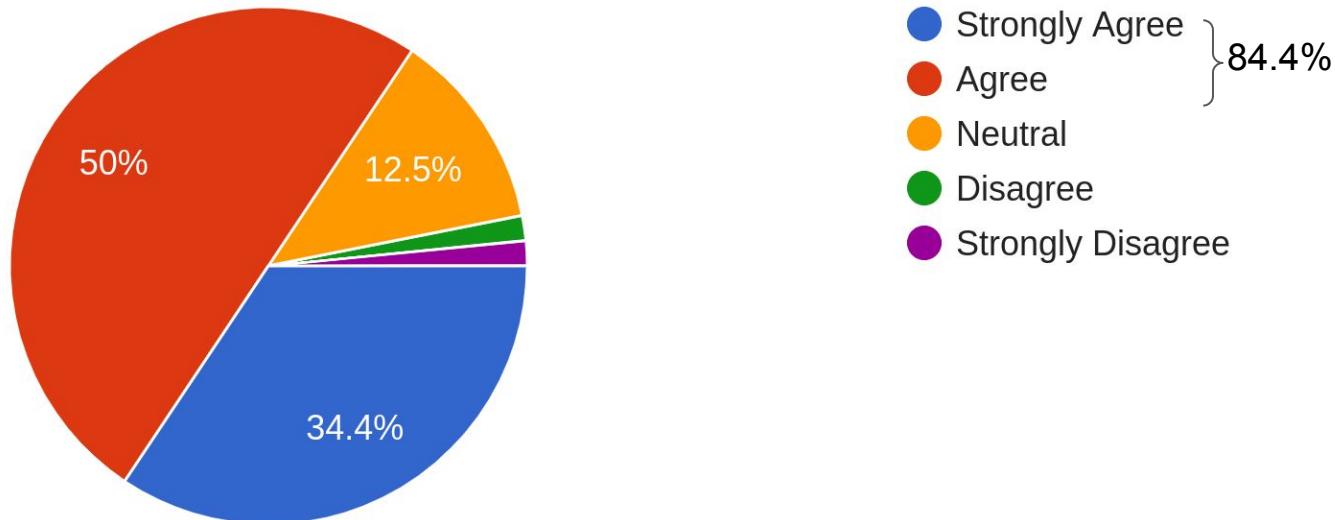


Translated by Computational Thinking Teachers Research Group in Korea
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Results of AAAI Members Survey in Nov./Dec. 2019

The "5 Big Ideas in AI" capture the essence of AI.

64 responses

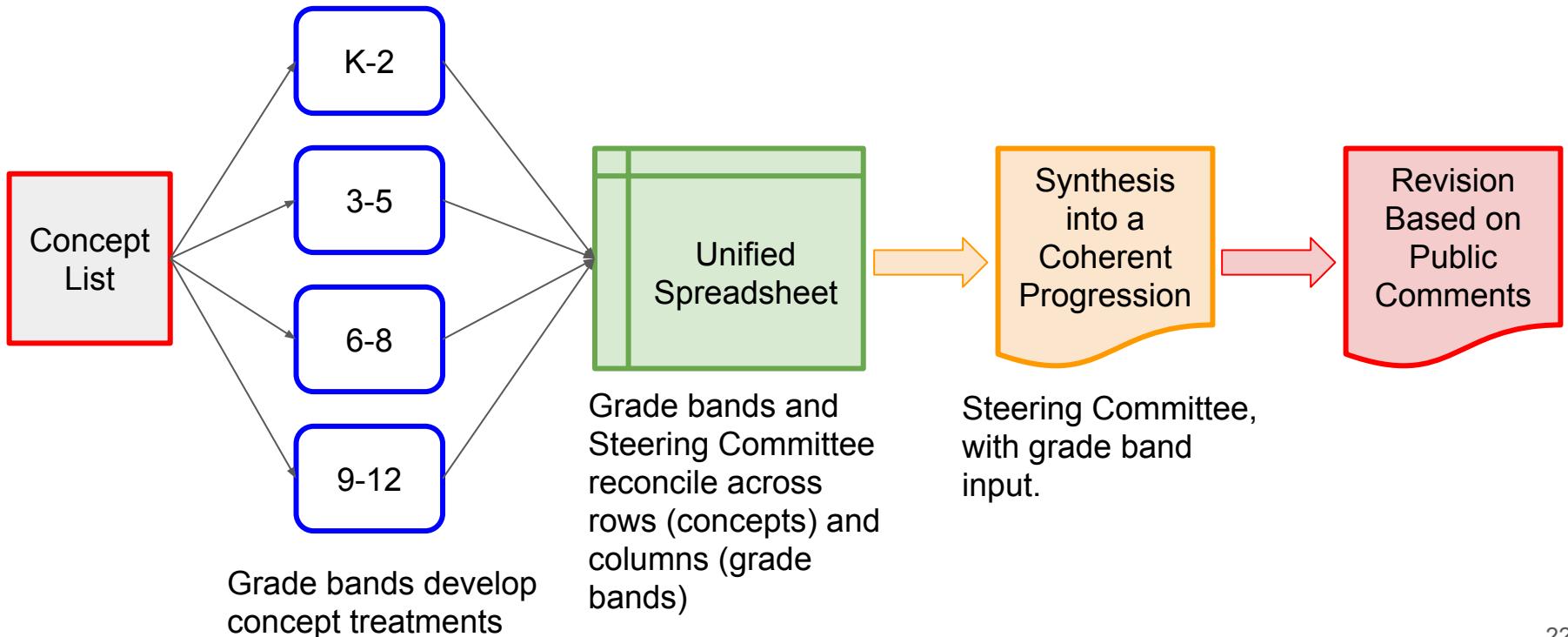


Principles for Refinement & Scoping of Guidelines

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.

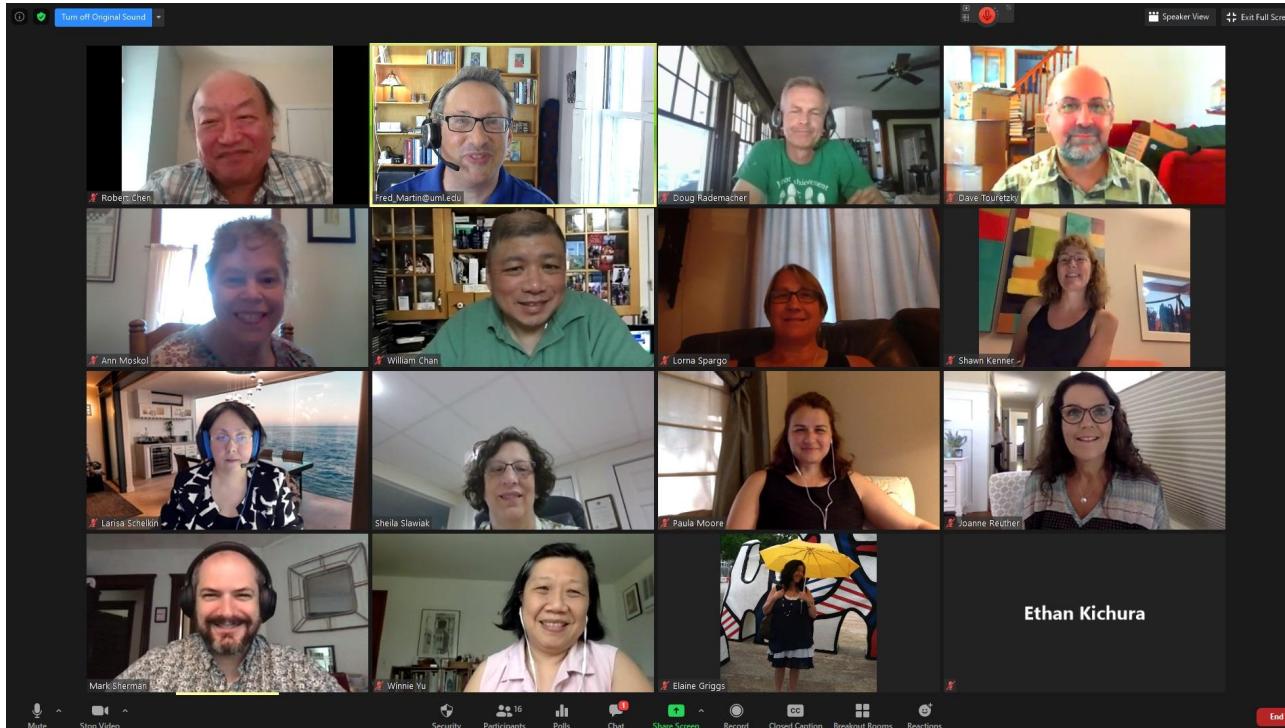
Drafting the Guidelines for One Big Idea



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

Big Idea #1: Perception	<i>Computers perceive the world using sensors.</i>	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 color blind. Dogs and rats can hear higher frequencies than humans.	LO: Give examples of how humans combine information from multiple 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. <i>Possible enrichment material: look at optical illusions (Muller-Lyer illusion, Kanizsa triangle) and ask which ones are computer vision systems also subject to.</i>
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 latitude. Accelerometers measure acceleration 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.

Teacher Feedback Session on Big Idea #1



Online feedback form available at <http://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.

Big Idea #1 Concept List

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

LO: Identify human senses and sensory organs.

EU: People experience the world through sight, hearing, touch, taste, and smell.

3-5

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 do.

EU (Enduring Understanding): What students should know.

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.

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.

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 -> articulatory gestures -> sounds -> morphemes -> words -> phrases -> sentences

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.

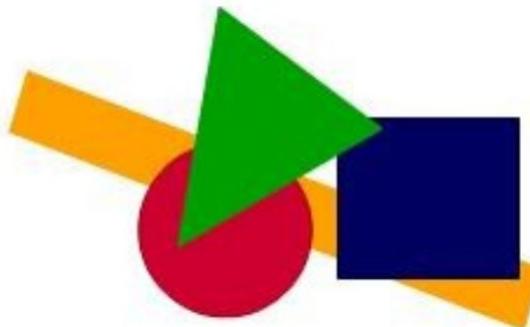
EU: Understanding complex scenes requires taking into account the effects of occlusion when recognizing objects.

6-8

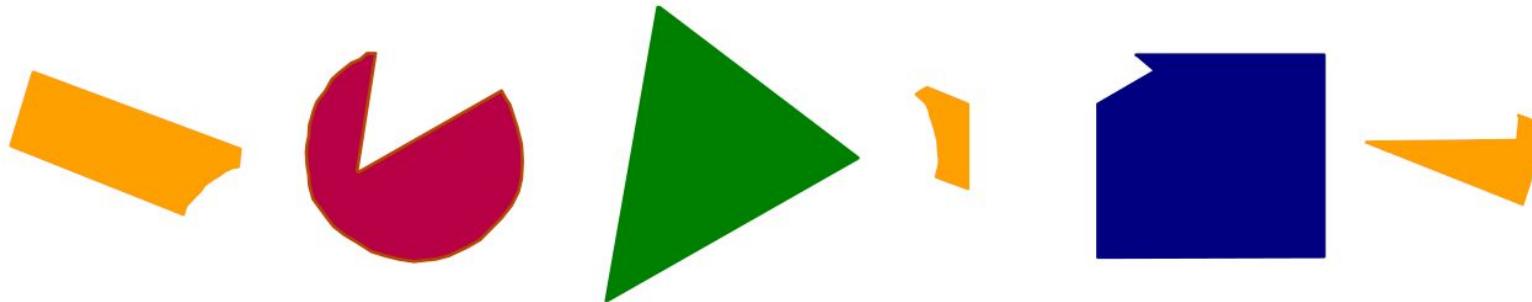
LO: Describe how edge detectors can be composed to form more complex feature detectors for letters or shapes.

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

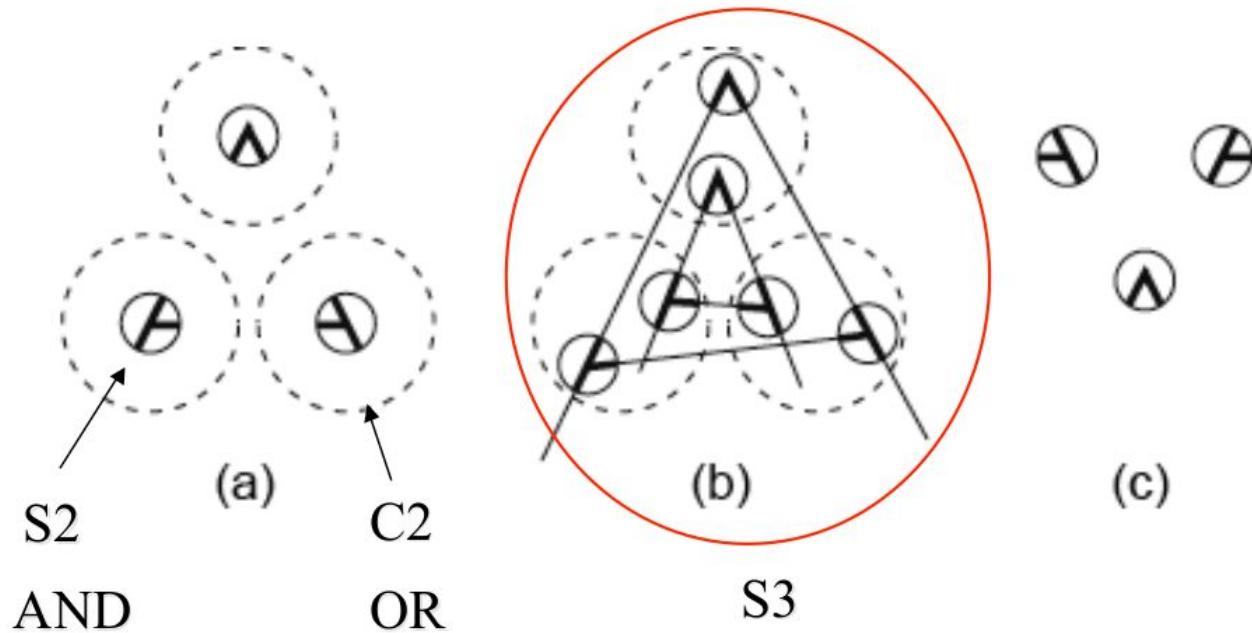
Occlusion: How many rectangles in this image?



None!



Detecting an “A” with position & scale invariance



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

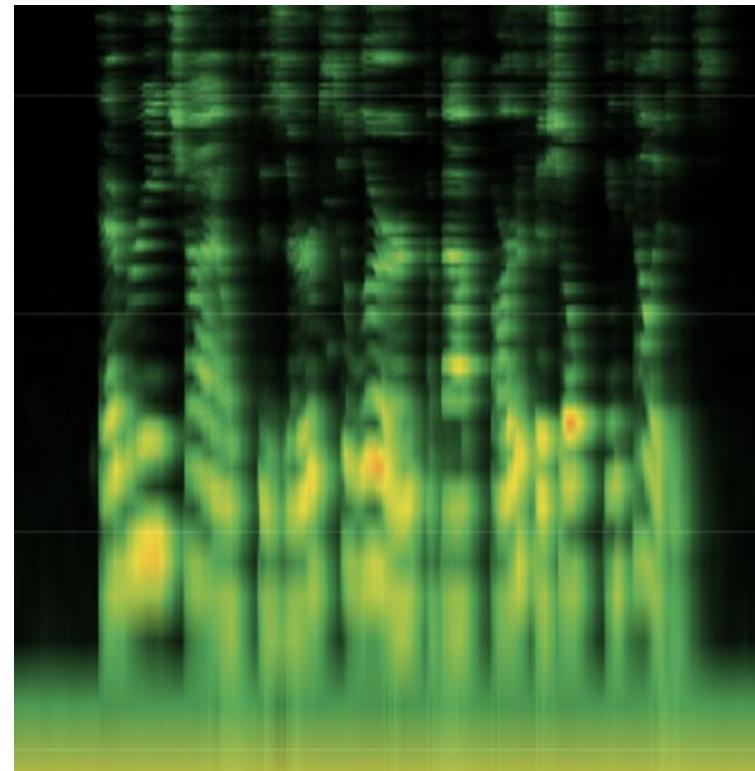
LO: Describe some of the technical difficulties in making computer perception systems function for diverse groups.

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.

Demos Make Concepts Real to Students

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

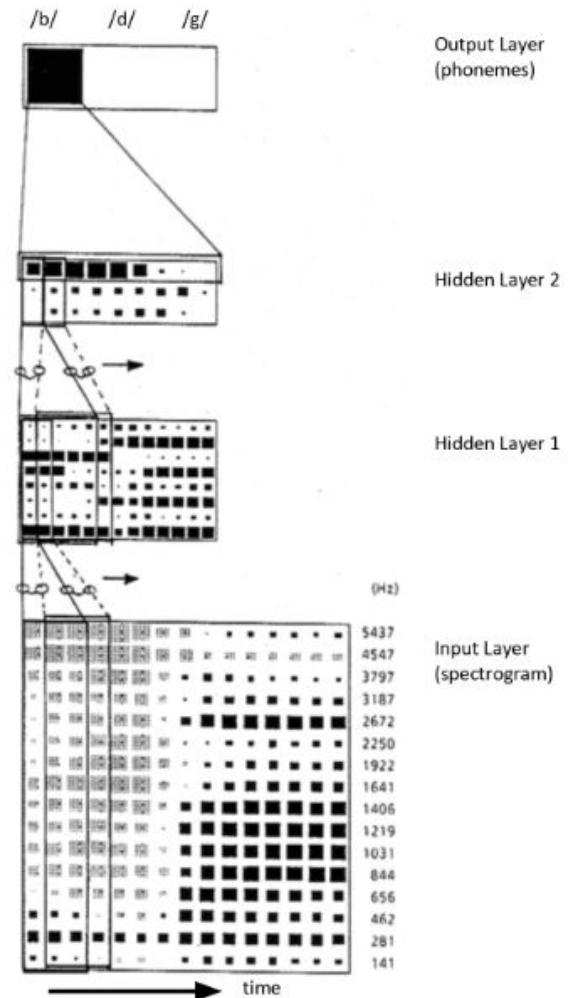
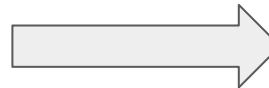
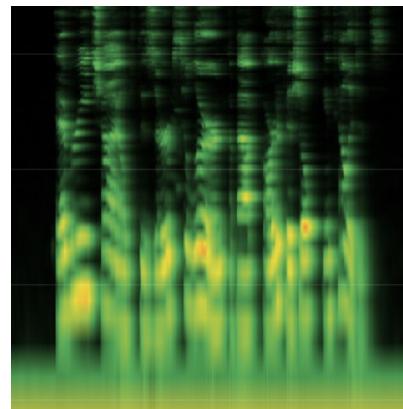
<https://creativity.withgoogle.com/seeing-music>



Time Delay Neural Network

Early convolutional neural net from 1980s.

Spectrograms go in; phonemes come out.

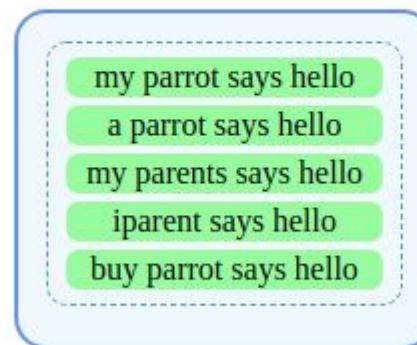


Google Speech API: Embrace the ambiguity!

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

Speech Recognition Demo

Speak into your microphone; see the results below.



MIC ON

Real-time face
detection by a
deep neural net.

Show the image
maps for selected
kernels.



What's Next?

- July 2020: Revised version of Big Idea #1 progression chart.
- July/August 2020: First release of Big Idea #3 progression chart for public comment.
- 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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<http://AI4K12.org>

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