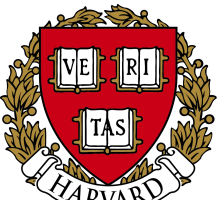
Approximating Intelligence:

An Introduction to Machine Learning Driven Artificial Intelligence

Spandan Madan,
SEAS Fellow @ Harvard
Research Assistant @ MIT
smadan@mit.edu
Spandan_madan@g.harvard.edu



Wikimedia commons

SITN
science in the news

The broad goal

- What does the talk hope to achieve?
- Who is this talk for?

Wikimedia commons
Pixabay
Flickr

SITN
science in the news

Roadmap for the evening

1. **Section I:** What is AI? What is Machine Learning and how are they related?

2. **Section II:** How does Machine Learning *really* work?

3. **Section III:** Why did AI suddenly become so popular? What are some examples of things it still can't do?

SITN
science in the news

An artificially intelligent robot

https://www.youtube.com/watch?v=QHH3iSeDBLo

SITN
science in the news

Some capabilities WALL-E must have

- Recognizing the cockroach
- Communicating using gestures
- Walking around the rugged terrain
- Being curious (he observed many objects)
- Learning to operate a new object(Fire extinguisher)
- Knowing how to get back home

What makes WALL-E intelligent?

SITN
science in the news

What is Artificial Intelligence (AI)?

- Is Apple's Face ID artificially intelligent?
- Facebook's language translation system? Siri?

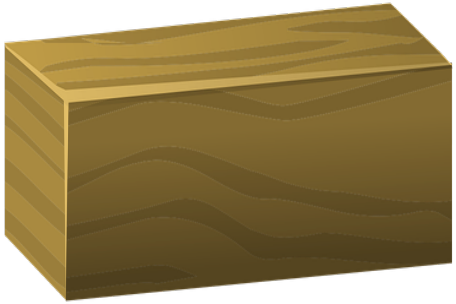
No clear definition of what Artificial Intelligence is.

An artificially intelligent system has similar characteristics, and can do similar tasks as intelligent beings can.

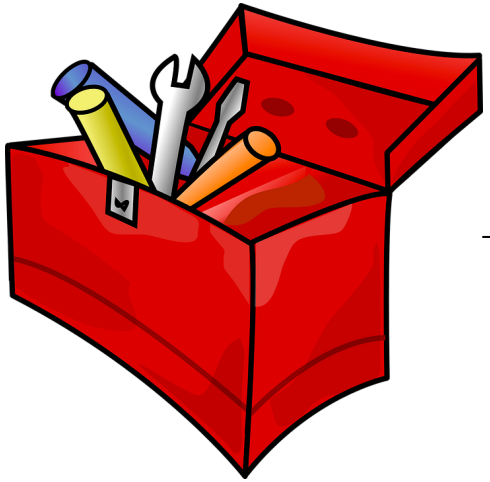
We need to give the capability to do intelligent tasks to robots!

SITN
science in the news

Machine Learning



Unprocessed things



Tool-Kit

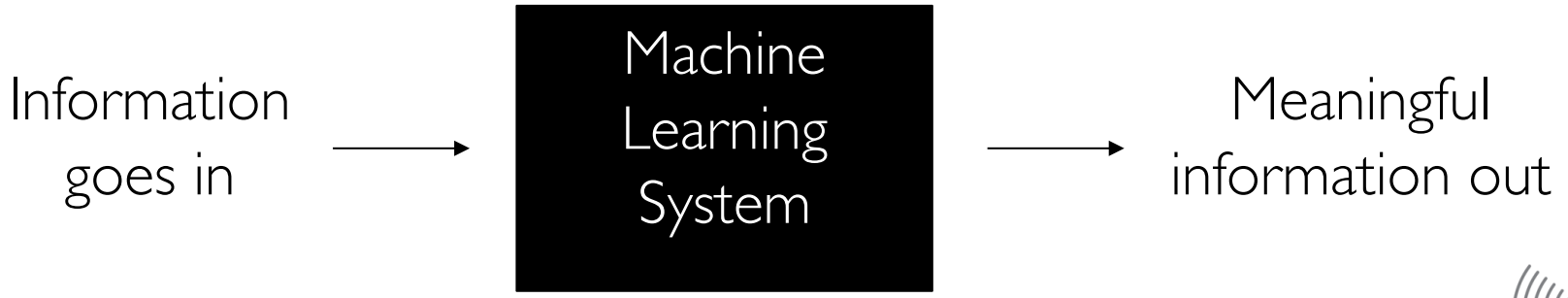
More useful thing

Wikimedia commons
Pixabay
Flickr
https://www.publicdomainpictures.net/en/view-image.php?image=246541&picture=wooden-chair

SITN
science in the news

What ***really*** is Machine Learning?

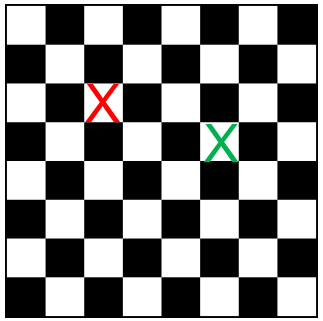
- A system which takes in some **information/data, and transforms it into more meaningful information** using mathematics.



SITN
science in the news

Examples!

→ Machine Learning System → Chair YES/NO



→ Machine Learning System → 3 right + 1 down

21 year old, speaks english, likes pop → Machine Learning System → Ed Sheeran

Intelligent tasks are often involve transforming one information to another

Wikimedia commons
Pixabay
Flickr

SITN science in the news

Machine Learning learns to approximate an intelligent task

- Intelligent tasks are often involve transforming one information to another

For Ex: Picture of chair to label, Map to path.

- By approximating this transformation, machine learning lets us perform an intelligent task!

SITN
science in the news

AI-Machine Learning bridge

- We defined AI as the capability of performing intelligent tasks.
- Machine Learning lets us approximate an intelligent task.
- Thus, Machine Learning systems are the toolkit that is used for AI!

SITN
science in the news

Why do we even need Machine Learning to learn an intelligent task?

Every "computer program" is a list of instructions.

Example:

- Open facebook.com
- Download a picture, open it.
- Add two numbers for me.

So, we need to define what a chair is!

Pixabay

SITN science in the news

How would you define a chair?

Pixabay

SITN
science in the news

But none of these chairs have 4 legs!

How about a surface on which we can sit?

Publicdomainpictures.com
Wikimedia commons
flickr

SITN
science in the news

How about a surface on which we can sit?

We can't give a clear definition!

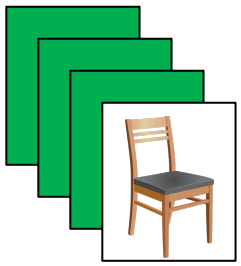
Wikimedia commons

SITN
science in the news

Defining is hard!!

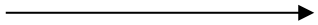
- We can't define, so we can use Machine Learning to approximate this relationship.

- Information 1: Picture
- Information 2: Does it contain chair? (label)



Pictures

YES
or
NO!



Machine Learning System

Wikimedia commons
Pixabay
Flickr

SITN
science in the news

Why is it called "learning"? what is being *learned?*

Machine Learning System = Approximate process which transforms one information to the other one.

Examples:

Information In	Information out
Picture	Does it contain a chair?
Rough map of a city	Best way from work to home?
Someone's age, language	Their music preferences

SITN science in the news

The two steps of Machine Learning

- Training/Learning: The machine looks at examples of pictures and their labels (content), and learns the transformation/relationship

- Testing/Prediction: The machine has learned, and it can be used now to test or predict the content of new pictures.

SITN
science in the news

Summary: Section I

- **AI** → A system with the same capabilities, and characteristics as intelligent beings.
- **Machine Learning** → The mathematical toolkit used for AI. Helps approximate intelligent tasks.
- So, Machine Learning systems together can help further Artificial Intelligence!

SITN
science in the news

Section II

- Section 1: What is AI? What is Machine Learning? How is Machine Learning related to AI?

- This section**: How** does a machine learning system *learn?*

SITN
science in the news

Imagine you wanted to learn woodwork

- How would you learn to do woordwork?
- From a teacher (By Example)
- Take tools, and start building yourself and understand what tool does what **(By Exploration)**
- Without any tools, just identifying patterns in catalogues of furniture **(By Observation)**

SITN
science in the news

Popular ways to teach machines

- By Example → **Supervised Learning**
- By Exploration → **Reinforcement Learning**
- By Observation → **Unsupervised Learning**

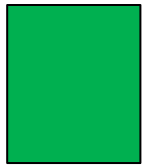
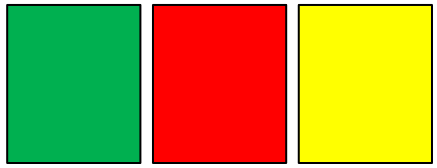
SITN
science in the news

Recap: 3 important capabilities of WALL-E needed

- Identifying the cockroach
- Knowing how to get back home at the end of the day
- Identifying SO many other objects!

SITN
science in the news

Some terminology

-  = Picture
-  = Pictures of different things

For ex: dog vs cat,

or conference room vs outdoors

SITN
science in the news

Teaching WALL-E what a cockroach is

- Same as teaching what a chair is!

- We need lots of pictures of cockroaches, and machine learning learns to approximate the relationship between:

Information 1: given picture

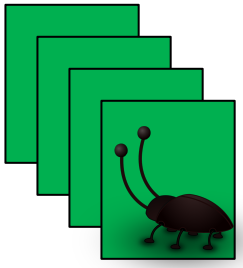
Information 2: Does it contain a cockroach?

SITN
science in the news

Supervised Learning: Learning from Examples

- Step 1: Training/Learning

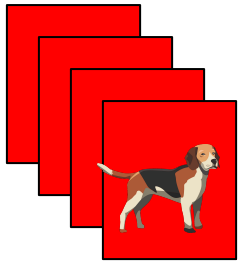
Pictures of cockroaches, YES



YES!

Machine Learning System Training

Pictures of other things, NO



NO!

Machine Learning System Training

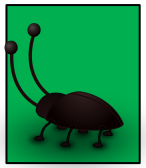
SITN science in the news

- Step 2: Once it learns the approximate relationship, using the trained system for predictions about new samples

New picture:
We DON'T know
Cockroach or not

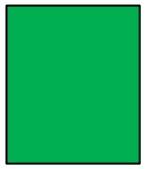
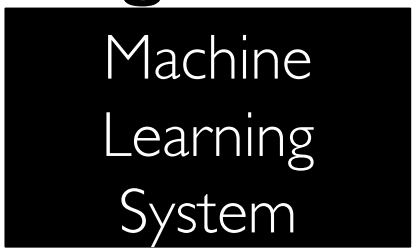
YES
or
NO

- **Training/Learning:**

We have: 1)  , 2) Contains cockroach or not.

Machine learning system learns the transformation or relationship between the picture and the label using math.

- **Testing/Predicting:**

We have: 1)  , 2) 

We don't know the contents of the picture, BUT our trained system can tell us what it contains!

SITN
science in the news

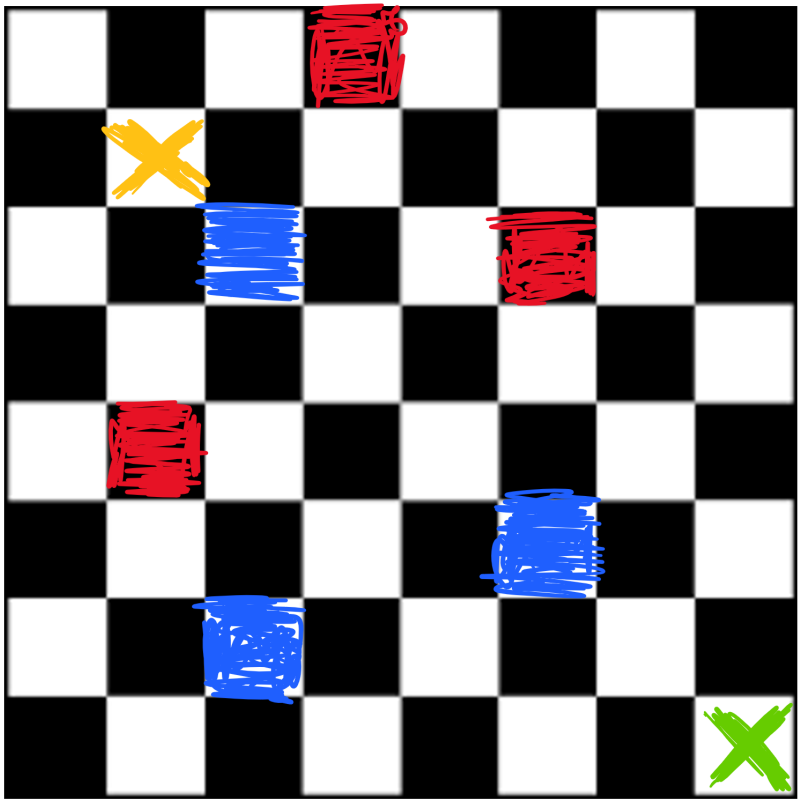
WALL-E : 1/3 capabilities done!

- ~~Identifying the cockroach~~
- Knowing how to get back home at the end of the day
- Identifying SO many other objects!

SITN
science in the news

Teaching WALL-E to get back home

Wall E's world:



WATER PUDDLE

POTHOLE

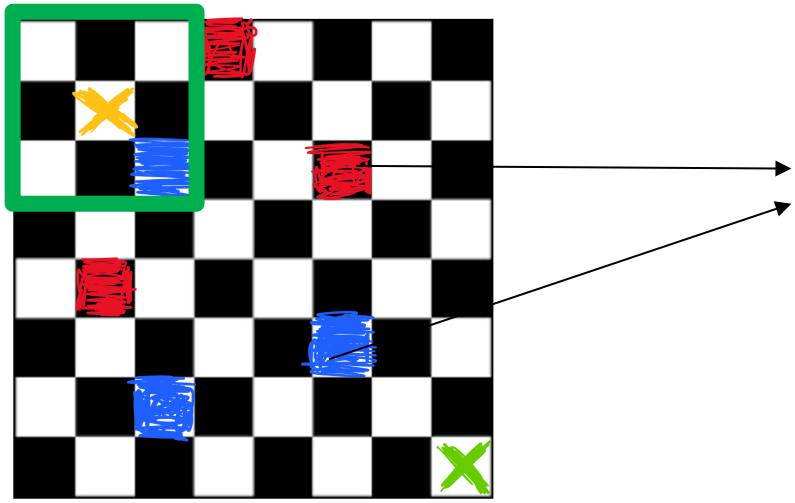
WORK

HOME

SITN
science in the news

Teaching WALL-E to find it's way back home with minimum cost of fuel and repair

- Can we use **supervised learning**?
- WALL-E must take action based on vicinity & goal. Potholes, water puddles may change.



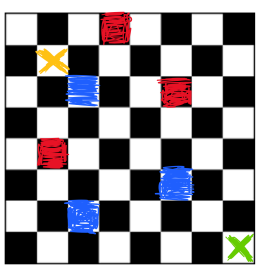
SITN
science in the news

How do humans handle such situations?

- By exploring, taking a risk and trying to maximize the reward.
- When there's no way to get all the information beforehand, you must explore with a risk/reward balance.
- Balancing the risk/reward = Hallmark of reinforcement learning.

SITN
science in the news

Reinforcement Learning: Learning from Exploring



Machine Learning System

Right, left, up or down action at every step

Every day, at every step, he decides where to turn next.
Some times, it tries to go through water puddles/potholes if he thinks there's a shorter path available!

Over time, he learns to navigate this path!

SITN science in the news

Comparison between Supervised Learning and Reiforcement Learning

Machine Learning: Learning transformation/relationship between 2 pieces of information.

For ex: Picture to it's label, or map of city to best path home.

Supervised Learning: We have both pieces of information.

Information 1: picture, Information 2: label)

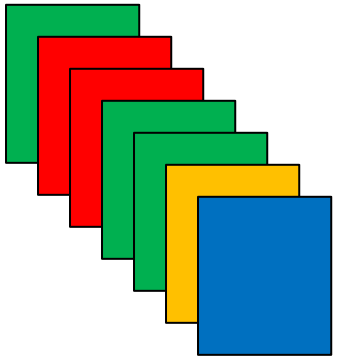
SITN
science in the news

- **Reinforcement Learning:** Incomplete access to information (map). We get to know cost only for path that we try, and we balance risk/reward.
- Information 1: one of the many possible paths, Information 2: cost

What if we have no access to information 2 at all?

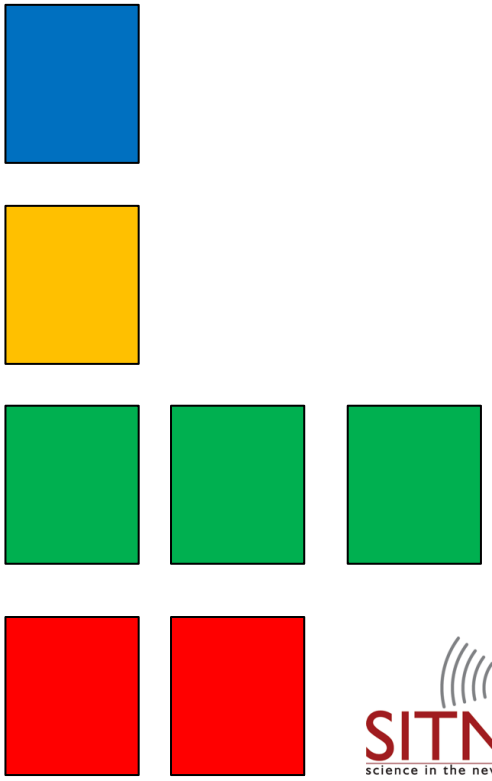
Say, we're given only pictures and never told what they contain. Or a map, but never told the final cost?

We have lots of pictures, but no labels! What can we do?



LOTS of pictures,
don't know of what

Meaningful information



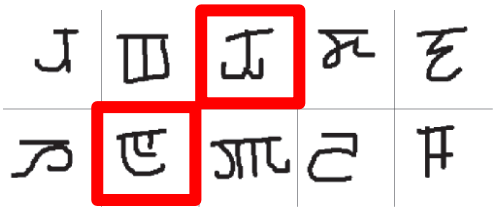
SITN
science in the news

Teaching WALL-E all the objects in the world

WALL-E, just like humans, should be able to recognize objects with a few examples, otherwise teaching all examples will be hard!

SITN
science in the news

Let's do an experiment right now!

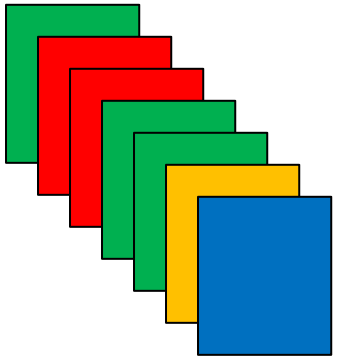


We want machines to be able to identify "similar" things!

SITN
science in the news

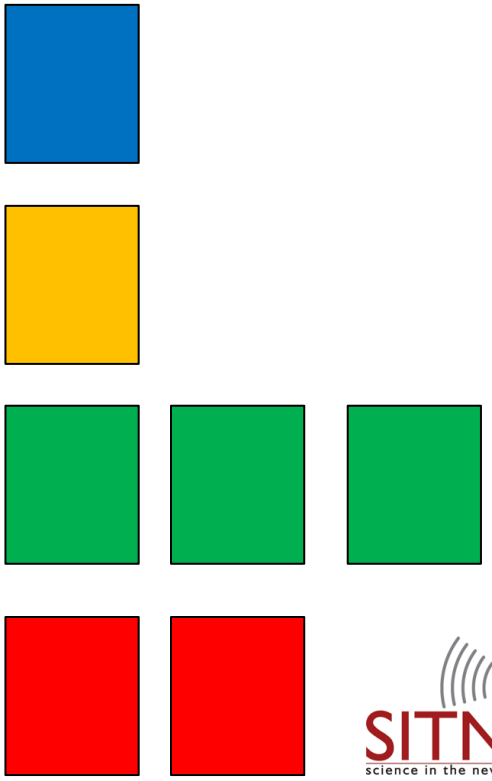
Unsupervised Learning: Learning by Observing

LOTS of pictures of multiple things

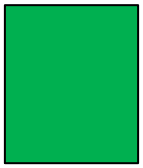


Machine Learning System

Pictures of similar things together



SITN science in the news

 = DOG

Now, a few days into your trip of earth, if you overheard someone referring to the green picture as a dog, you'd know that all of them are dogs!

With just one sample, you will learn how to tell if a picture is of a dog or not!

SITN
science in the news

Identifying patterns is the big win

- Let WALL-E walk around the world, understand patterns and identify groups of objects.
- Then, it can ask you for a name for one example of each group.
- Now it knows all objects!

SITN
science in the news

Summary: Section II

3 ways machines can learn:

I) By Example: **Supervised Learning**

Ex: What is a cockroach, using lots of cockroach pics.

II) By Exploration: **Reinforcement Learning**

Ex: How to get home, by exploring the right amount.

III) By Observation: **Unsupervised Learning**

Ex: How to group objects without being told what objects

SITN
science in the news

Section III

- Section 1&2: What is AI? How do we build AI systems using Machine Learning?
- Section 3: Why is AI so popular suddenly?
- There was a major technological challenge in machine learning that was solved.

SITN
science in the news

The problem with Machine Learning

- The system "learns" with experience.
- Just like a student, it's important to give the "right" amount of information. Neither to little, nor too much.
- What seems simple to us, can be very complicated information to a computer.

SITN
science in the news

Can someone tell me what this is?

0	12	231	123	33	112	97	67	218	211
677	81	68	769	80	70	123	34	123	111
98	231	122	123	108	156	187	107	187	63
81	68	769	187	107	187	63	67	218	33
70	123	34	123	111	68	769	80	70	122
187	107	12	231	34	123	111	68	12	231
81	68	769	80	70	122	108	156	187	33
68	769	80	63	67	70	123	63	67	218
123	111	68	81	68	769	187	769	80	70
187	107	187	63	67	81	68	769	80	70

Nothing sensible!

SITN
science in the news

How computers see the world

=

112	231	151	181	111
131	156	211	253	234
171	181	187	191	141
122	200	234	234	255
142	100	103	233	243

Computers see pictures as a very large grid of numbers.

A picture is TOO complicated information for machine learning to learn from. We need to find the "right" subset of this grid!

SITN
science in the news

The right subset of information from the grid is called the "representation" of the grid

The right information from the grid

Machine Learning System

chair

Scientists spend many years

What is the right representation?

- Depends on the intelligent task!
- Deciding what's "right" took scientists years! For every single task!

For ex: Telling if a picture contains a chair,

If a face picture is of you or someone else.

- Even such similar tasks have different "right" information subset.

SITN
science in the news

Enter Deep Learning!

- Picks the right information subset using math.

Machine Learning

Deep Learning

- A lot recent AI advancements rely on Deep Learning.

SITN
science in the news

Deep Learning finds the right representation automatically!

- It (intelligently) tries out a bunch of mathematical operations on an image. Requires a LOT of calculations.

- Techniques were around since 80s, we didn't have strong enough computers to do this.

- The grid of values get's simplified in a manner we don't understand, but the computer does.

SITN
science in the news

So, how does Deep Learning do this?

Put lots of simple things together to get something complicated

SITN
science in the news

Complicated calculations

The right information from the grid

Machine Learning System

chair

- A combination of simple calculations can approximately do the same.
- This correct combination of easy calculations is called a “Neural Network”.
- When “learning”, the system is learning what combination of calculation works!

SITN science in the news

Summary: Section III

Machine Learning systems, just like students need to be given the right amount and kind of information while teaching.

Scientists spent years to find the right representation for different problems like comparing people's faces, comparing pictures of scenes, or of objects.

Deep Learning automatically picks representation using math.

SITN
science in the news

Bonus:
Artificial General Intelligence vs Artificial Intelligence

Microsoft's LineBackBot

They also say I may become irrelevant
You are slowly becoming intelligent.
(by Katy Perry and spanmad)

There's a rumour, there's a rumour
My bot has got humor!
(by Donna Summer and ri_deckard)

Recap: An artificially intelligent system has similar characteristics, and can do similar tasks as intelligent beings can.

Achieving this goal = Artificial General Intelligence.

SITN
science in the news

How close are we really to this goal?

- Not very.

- AI is still very much in it's infancy, and true intelligence is far.

SITN
science in the news

Current systems are "task specific"

- Have little "understanding" beyond the task.

a woman riding a horse on a dirt road

an airplane is parked on the tarmac at an airport

a group of people standing on top of a beach

Pictures from Professor Josh Tenenbaum, MIT

Progress is fast…

https://www.youtube.com/watch?v=wXxrmussq4E

SITN
science in the news

But there is a LOT left to do!

- https://www.youtube.com/watch?v=JzIsvFN_5HI

SITN
science in the news

Making sense of the news

- Every time you hear the phrase "Google built an AI that does….", re-read it in your mind as "Google made a Machine Learning system that …"

- Read a news article that surprised you? Take a moment to read the original source.

- Media can some times sensationalize things, and now we are equipped to make sense of it without being biased by the article!

SITN
science in the news

Summary

AI — **Needs understanding**

Giving an exact definition is hard

So we use Machine Learning to approximate it

To learn by example, exploration or observation.

This requires giving the “right amount” of info.

SITN
science in the news

Summary

Deep Learning automatically finds this representation.

Major Success for AI!

But, we are still far from true AI.

News may sensationalize it

But you now have the tools to be understand it for yourself!

SITN
science in the news

Thank you!

SITN would like to acknowledge the following organizations for their generous support.

Harvard Medical School
Office of Communications and External Relations
Division of Medical Sciences

The Harvard Graduate School of Arts and Sciences (GSAS)

The Harvard Graduate Student Council (GSC)

The Harvard Biomedical Graduate Students Organization (BGSO)

The Harvard/MIT COOP