CS 4803 / 7643: Deep Learning

Website: https://www.cc.gatech.edu/classes/AY2021/cs7643_spring/

Piazza: http://piazza.com/gatech/spring2021/cs48037643a
(code: DL2021)

Canvas: https://gatech.instructure.com/courses/172518 (4803)
https://gatech.instructure.com/courses/172536 (7643)

Gradescope: https://www.gradescope.com/courses/228228 (4803)
https://www.gradescope.com/courses/229744 (7643)

Zsolt Kira

School of Interactive Computing
Georgia Tech

Elephant in the room

- These times are filled with change and uncertainty
- Hope everyone is staying safe and healthy.
- Let’s make the best of it.

Are you in the right place?

- This is CS 4803(DL) / CS 7643
  - “On campus” class

- This is NOT CS 7643-O01/OAN/Q/R
  - Online class for OMSCS program

Spring 21 Delivery Format

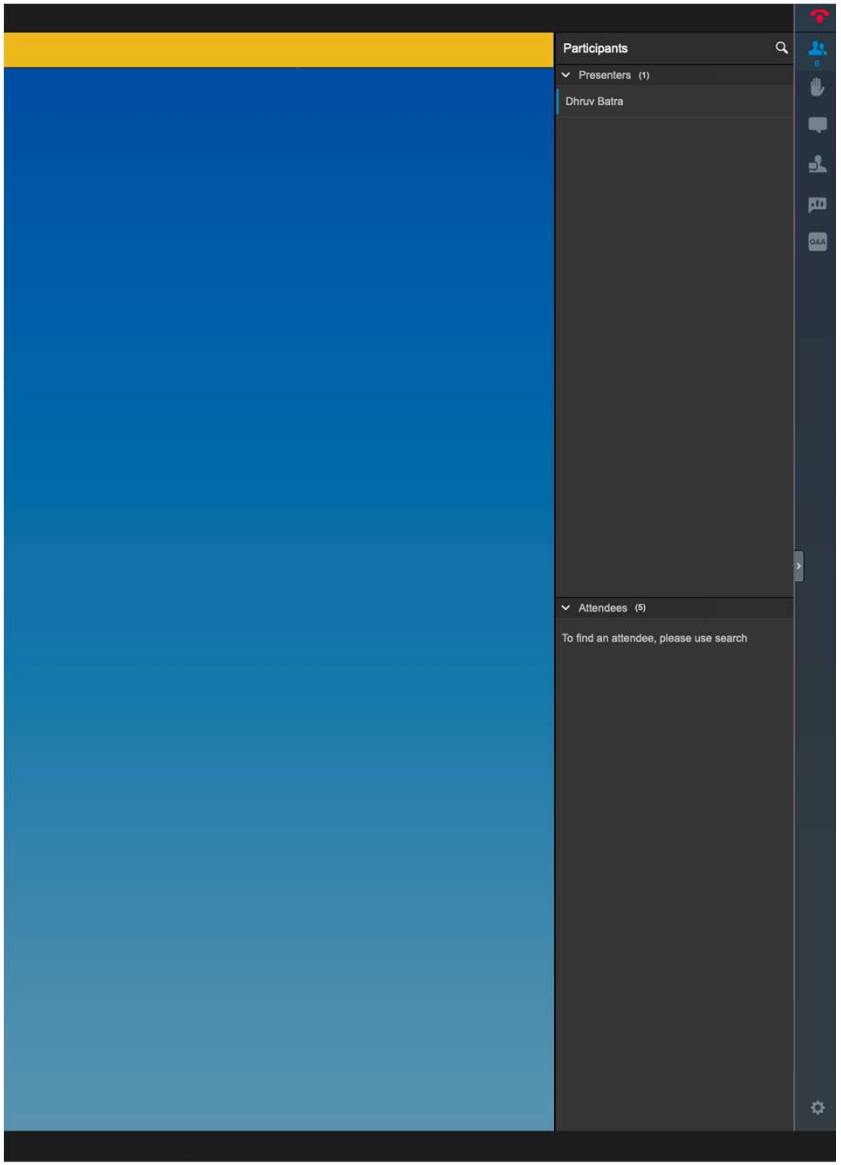
- Remote
  - No in-person interaction
  - Lectures, office hours, HW/project submissions online
    - No exam
- Sync
  - There is a scheduled “live” lecture time
- Recording
  - Lectures are recorded and available for viewing
  - We STRONGLY encourage you to attend the lectures
- **Remember: Content is free online.**
  - **You are here for the interaction and the insight.**

OMSCS Videos

- We will provide dropbox with OMSCS videos
- Nicely produced, clear lectures that allow you to go at your own pace
  - Note slides for this semester will be different from past as a result
- Currently these will be ***supplements*** for those that need it
  - Synchronized lectures will cover the same materials but with a little bit more depth (e.g. a few additional mathematical details/intuitions)
  - These will also be recorded
  - Depending on interest and time available, may experiment with adding research topics
- **Remember: Content is free online.**
  - **You are here for the interaction and the insight.**

How to interact

- Questions
  - Q&A
    - if one-off question
  - Chat
    - for back and forth
  - Raise hand
    - TA will elevate you to participant
  - We'll explicitly stop and take questions periodically
    - But feel free to ask in between
- BlueJeans Event
  - ~10 sec lag



Outline

- What is Deep Learning, the field, about?
  - Highlight of some recent projects from my lab
- What is this class about?
  - What to expect?
  - Logistics
- FAQ

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What are we here to discuss?

Some of the most exciting developments in

Machine Learning, Vision, NLP, Speech, Robotics & AI in general

in the last decade!

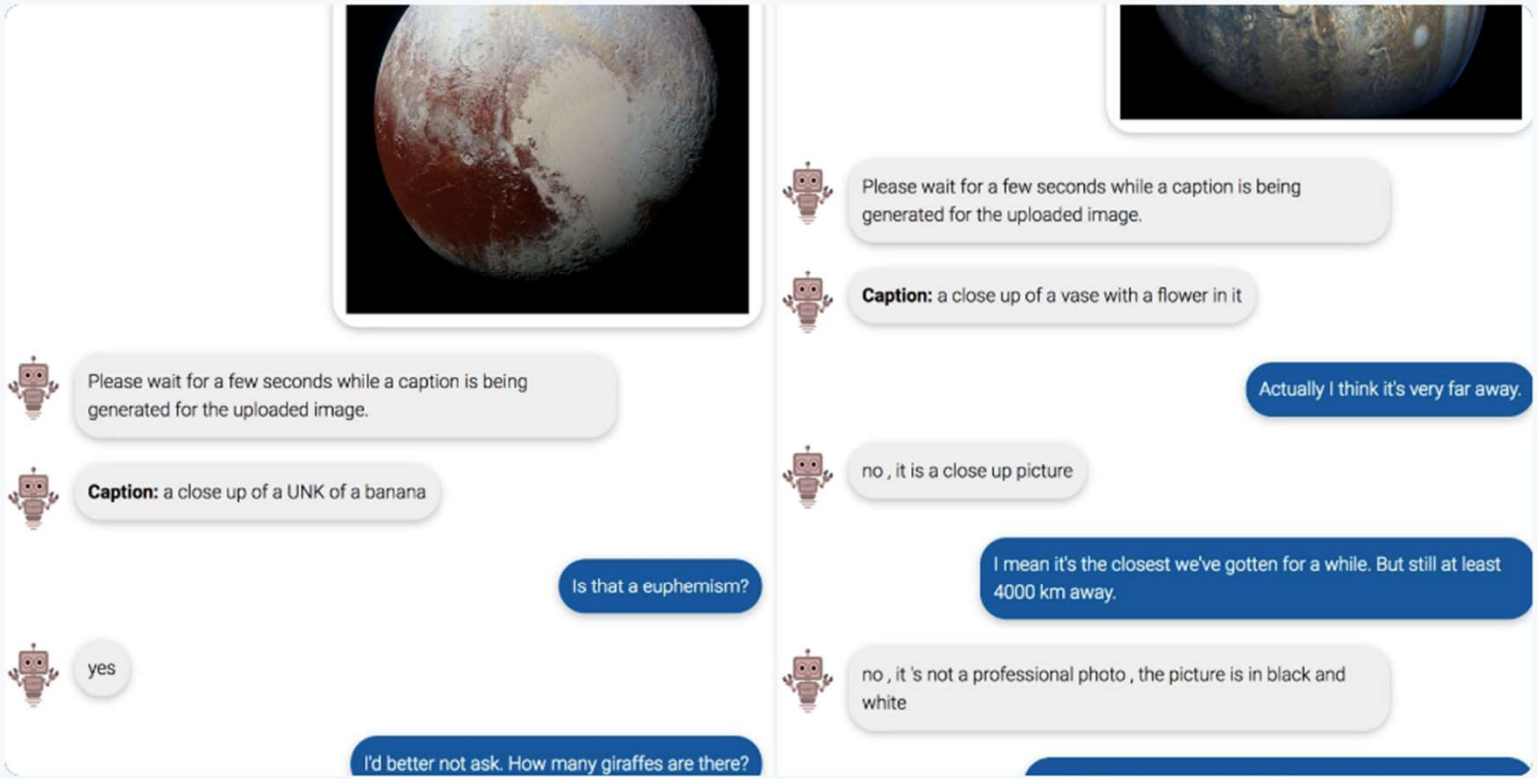
Demo time

vqa.cloudcv.org.

demo.visualdialog.org

Janelle Shane @JanelleCShane · Jun 24

One fun thing I discovered about Visual Chatbot.
It learned from answers that humans gave, and apparently nobody ever asked "how many giraffes are there?" when the answer was zero.
demo.visualdialog.org



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Concepts

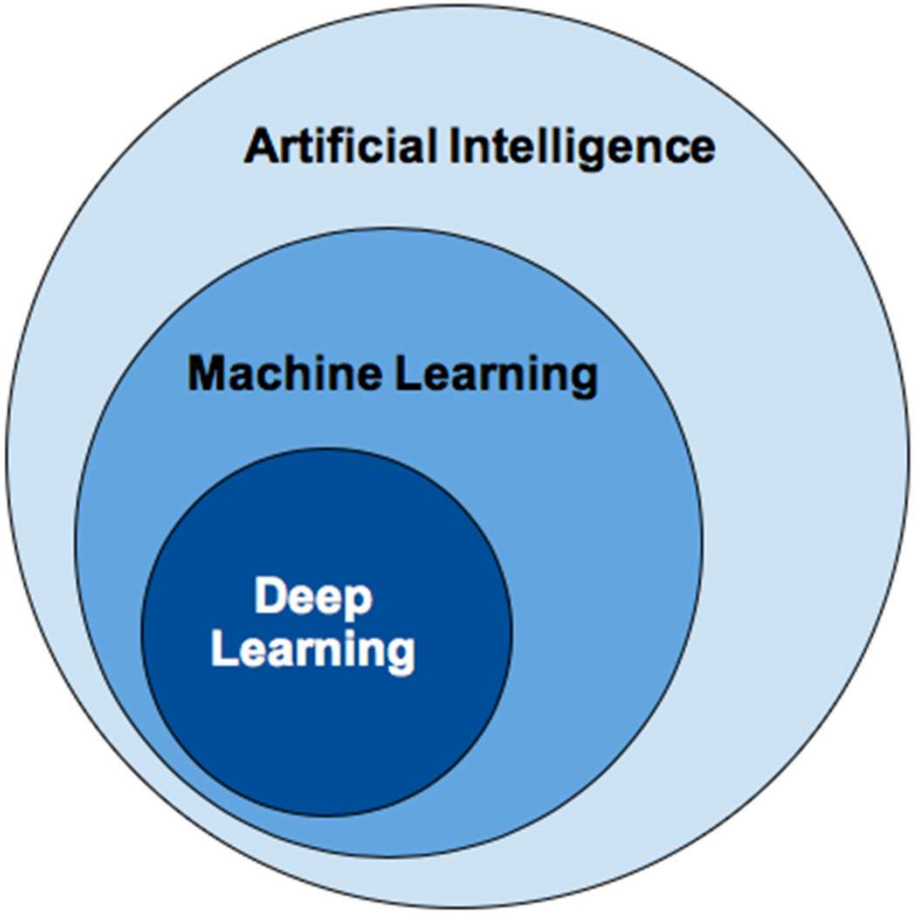


Image Credit: https://www.sumologic.com/blog/machine-learning-deep-learning/

What is (general) intelligence?

- Boring textbook answer

The ability to acquire and apply knowledge and skills

  – Dictionary

- A favorite

The ability to navigate in problem space

  – Siddhartha Mukherjee, Columbia

What is artificial intelligence?

- Boring textbook answer

Intelligence demonstrated by machines

  – Wikipedia

- A favorite:

The science and engineering of making computers behave in ways that, until recently, we thought required human intelligence.

  – Andrew Moore, CMU

What is machine learning?

- A favorite

Study of algorithms that
improve their performance (P)
at some task (T)
with experience (E)

  – Tom Mitchell, CMU

So what *is* Deep (Machine) Learning?

- Representation Learning
- Neural Networks
- Deep Unsupervised/Reinforcement/Structured/ <insert-qualifier-here> Learning
- Simply: Deep Learning

So what *is* Deep (Machine) Learning?

- A few different ideas:

- (Hierarchical) Compositionality
  - Cascade of non-linear transformations
  - Multiple layers of representations

- End-to-End Learning
  - Learning (goal-driven) representations
  - Learning to feature extraction

- Distributed Representations
  - No single neuron “encodes” everything
  - Groups of neurons work together

Hierarchical Compositionality

VISION

pixels → edge → texton → motif → part → object

SPEECH

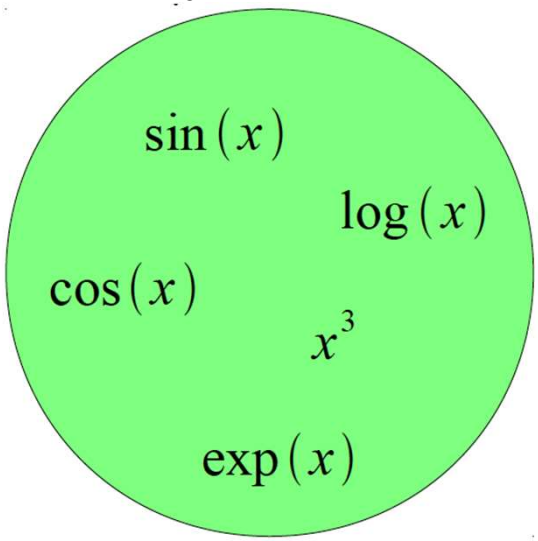
sample → spectral band → formant → motif → phone → word

NLP

character → word → NP/VP/.. → clause → sentence → story

Building A Complicated Function

Given a library of simple functions



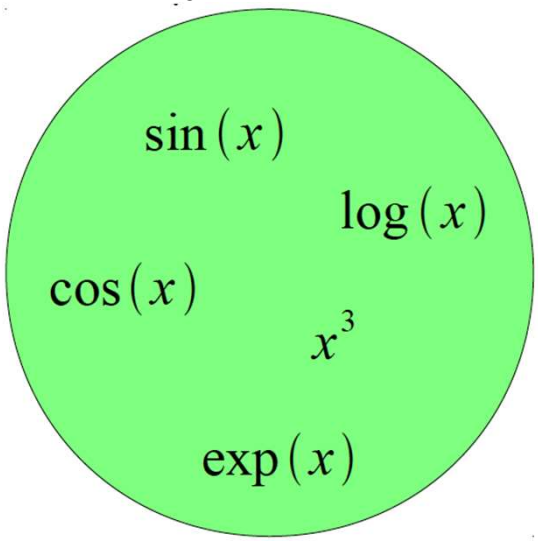
Compose into a

complicate function

Slide Credit: Marc'Aurelio Ranzato, Yann LeCun

Building A Complicated Function

Given a library of simple functions



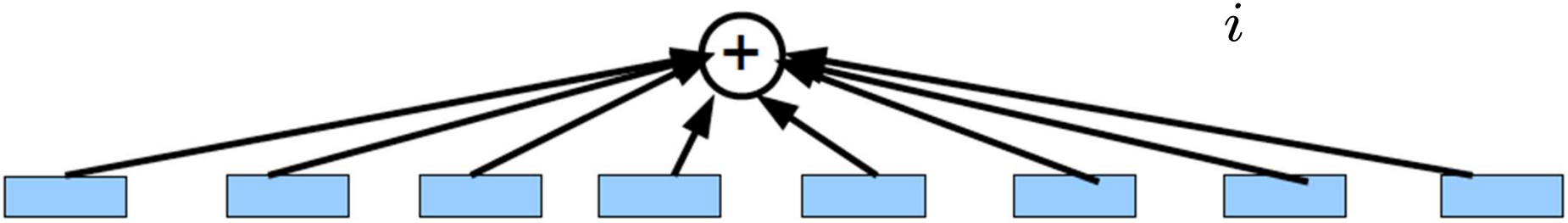
Compose into a

complicate function

Idea 1: Linear Combinations

- Boosting
- Kernels
- …

$$f(x) = \sum_i \alpha_i g_i(x)$$



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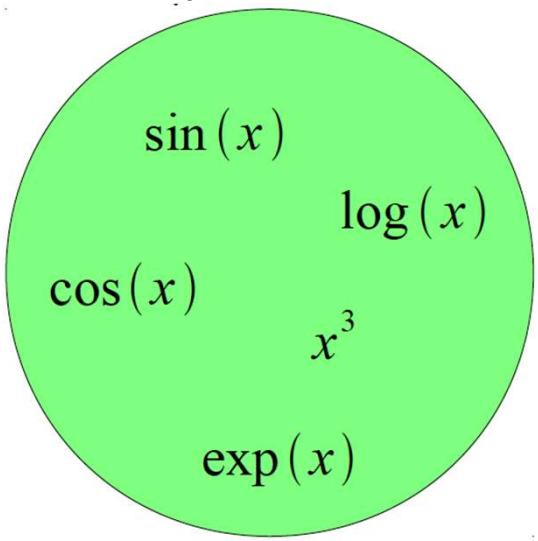

Compose into a

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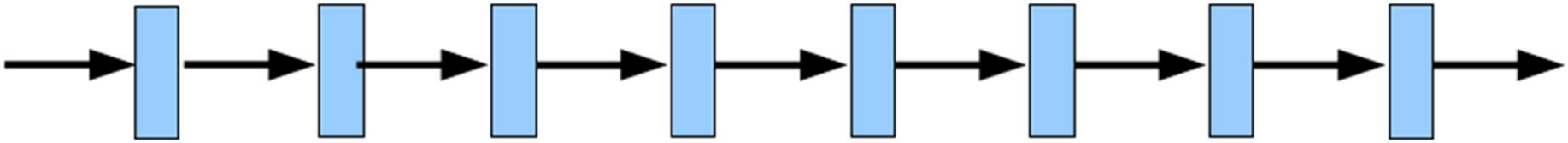
Idea 2: Compositions

- Deep Learning
- Grammar models
- Scattering transforms…

$$f(x) = g_1(g_2(\ldots(g_n(x)\ldots))$$



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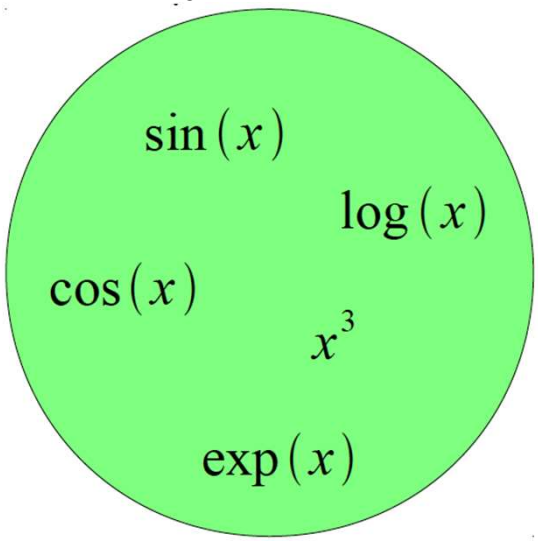
Given a library of simple functions



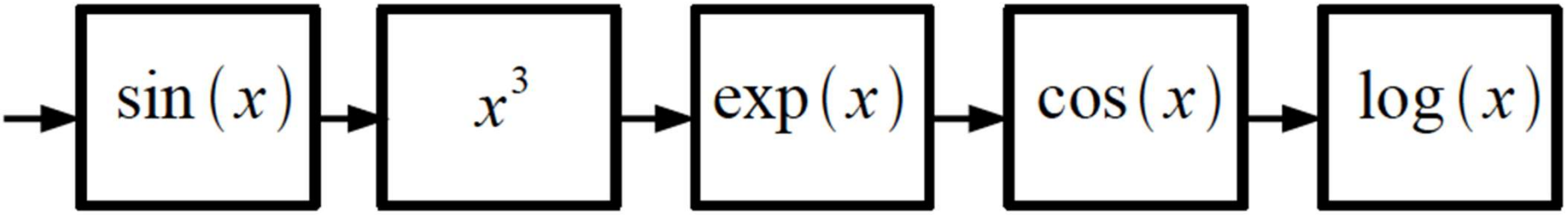
Compose into a

complicate function

Idea 2: Compositions

- Deep Learning
- Grammar models
- Scattering transforms…

$$f(x) = \log(\cos(\exp(\sin^3(x))))$$



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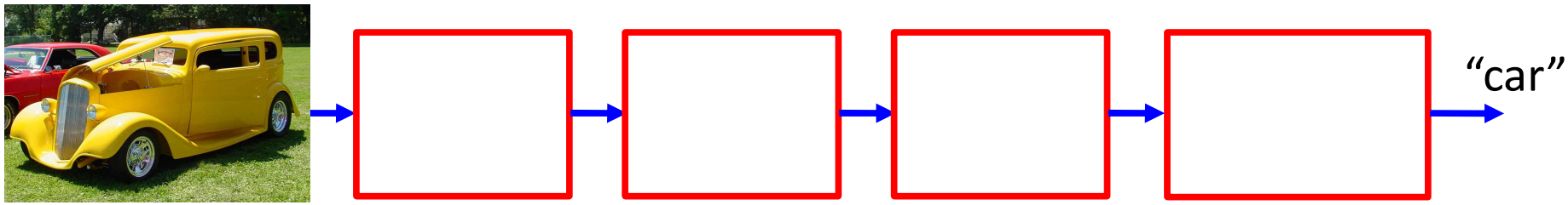
Deep Learning = Hierarchical Compositionality



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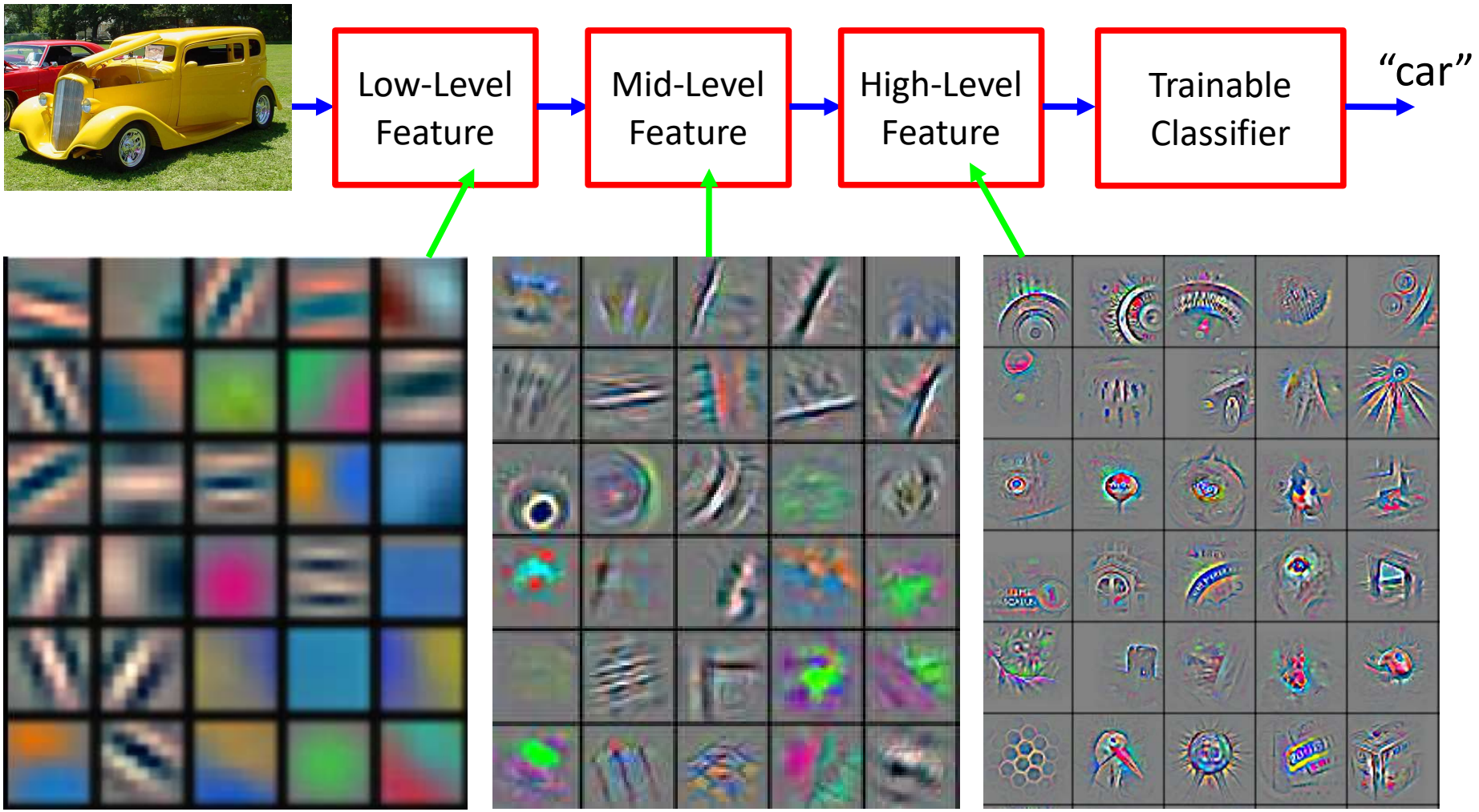

Feature visualization of convolutional net trained on ImageNet from [Zeiler & Fergus 2013]

So what *is* Deep (Machine) Learning?

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Traditional Machine Learning

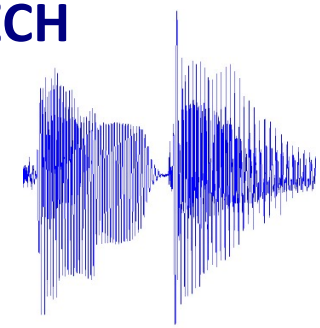
VISION

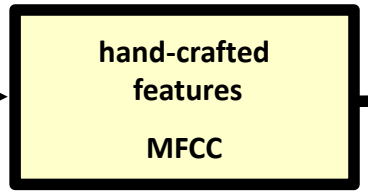
fixed

learned

"car"

SPEECH





fixed

learned

\ˈd ē p\

NLP

This burrito place

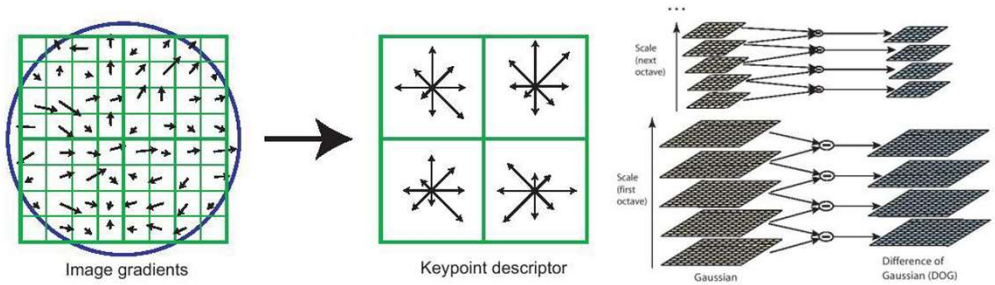
is yummy and fun!

fixed

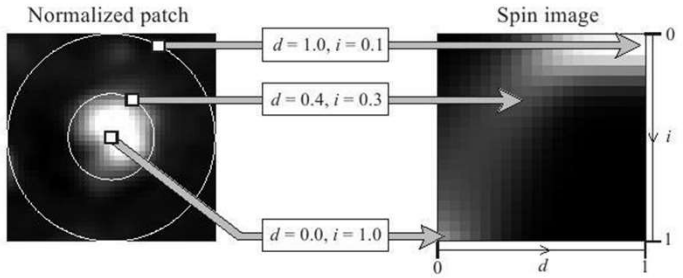
learned

"+"

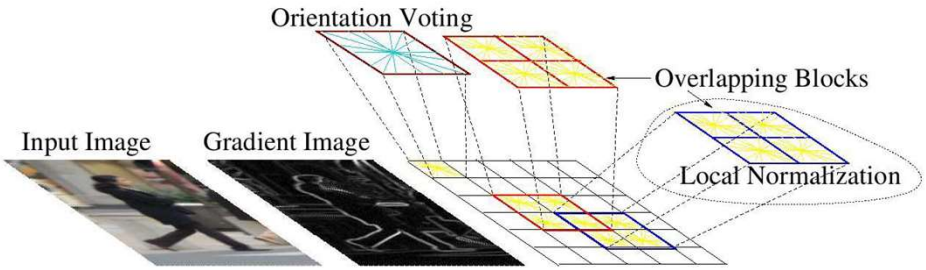
Feature Engineering



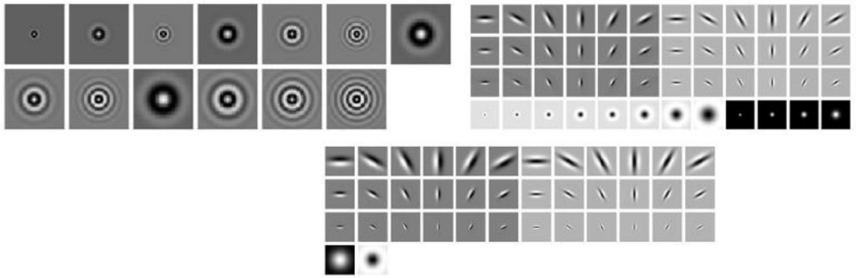
SIFT



Spin Images



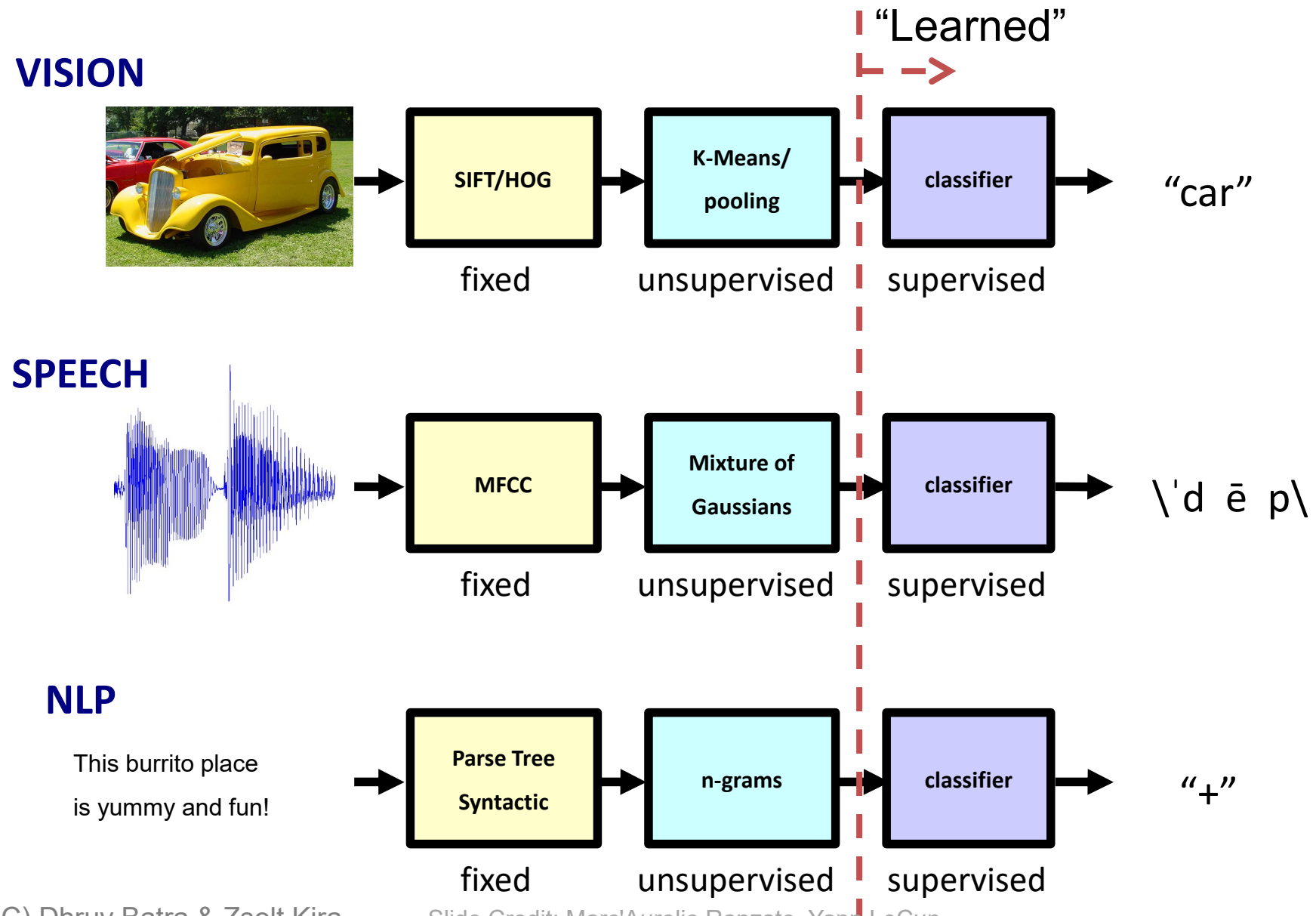
HoG



Textons

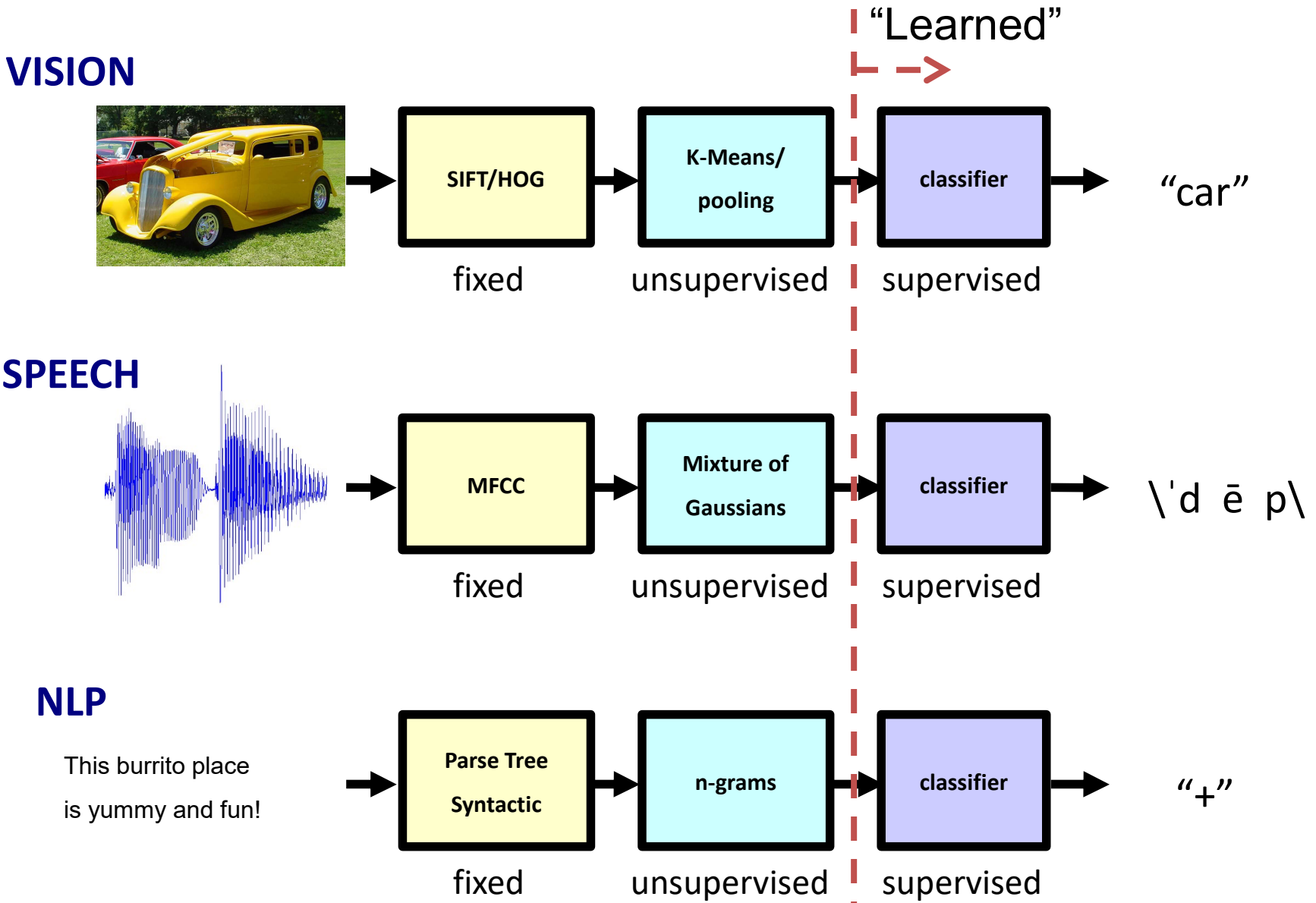
and many many more….

Traditional Machine Learning (more accurately)



Slide Credit: Marc'Aurelio Ranzato, Yann LeCun

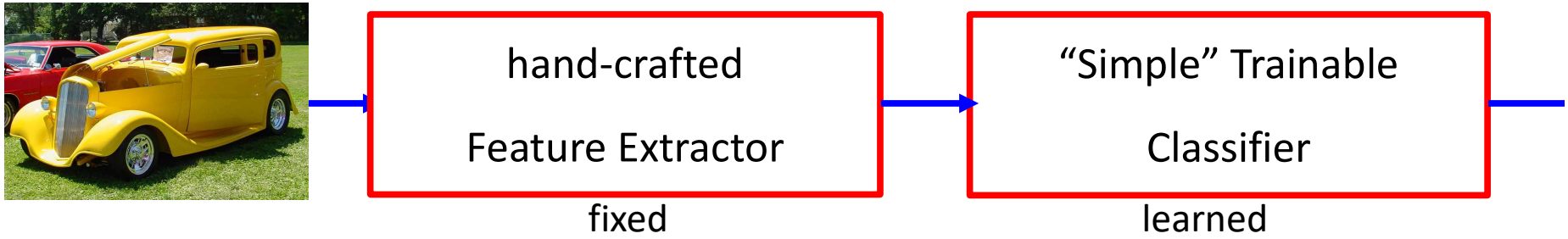
Deep Learning = End-to-End Learning



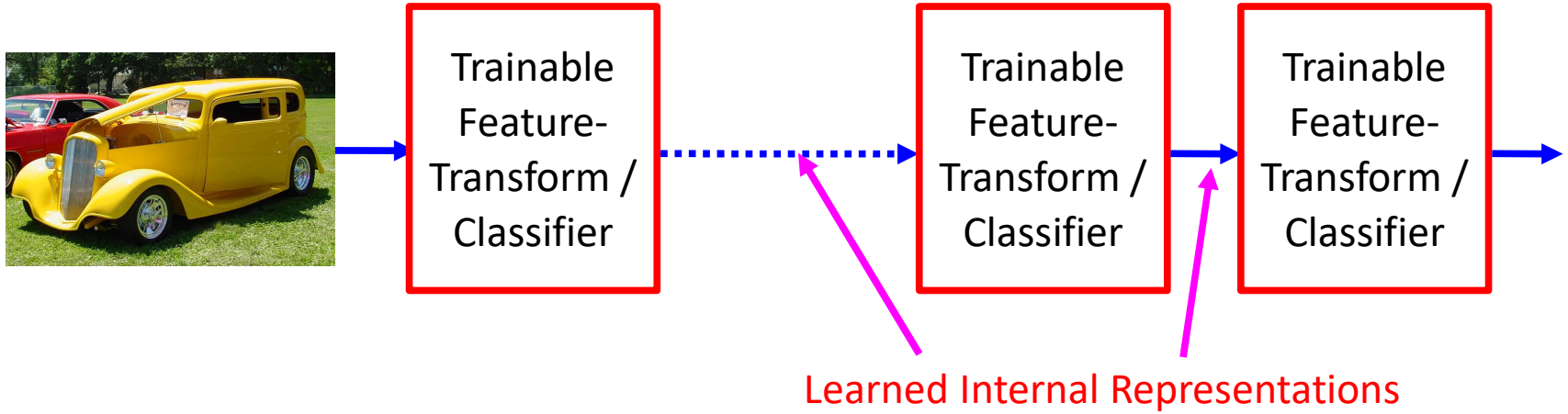
Slide Credit: Marc'Aurelio Ranzato, Yann LeCun

“Shallow” vs Deep Learning

- “Shallow” models



- Deep models



Slide Credit: Marc'Aurelio Ranzato, Yann LeCun

So what *is* Deep (Machine) Learning?

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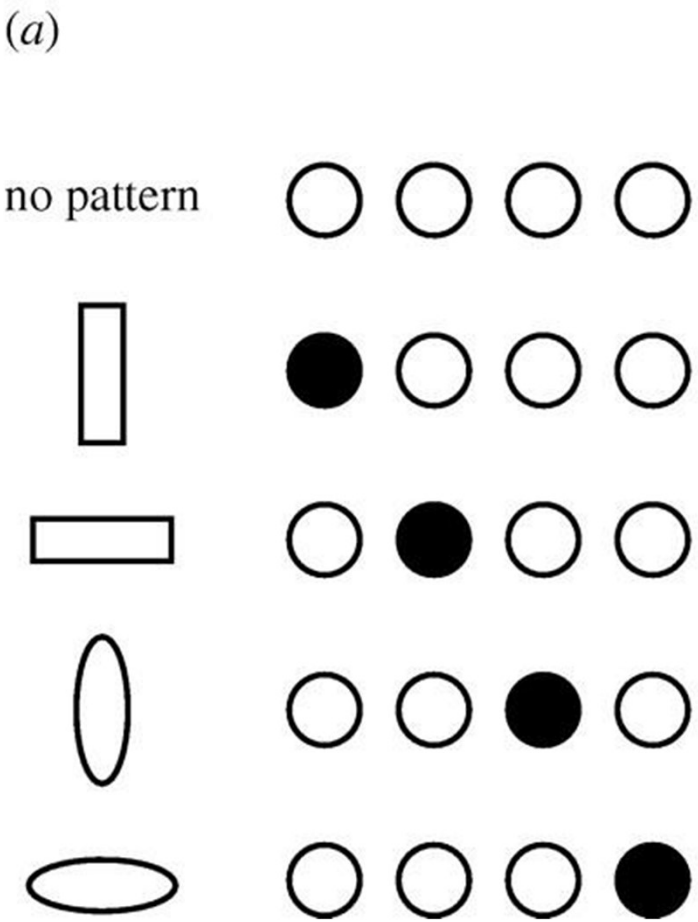
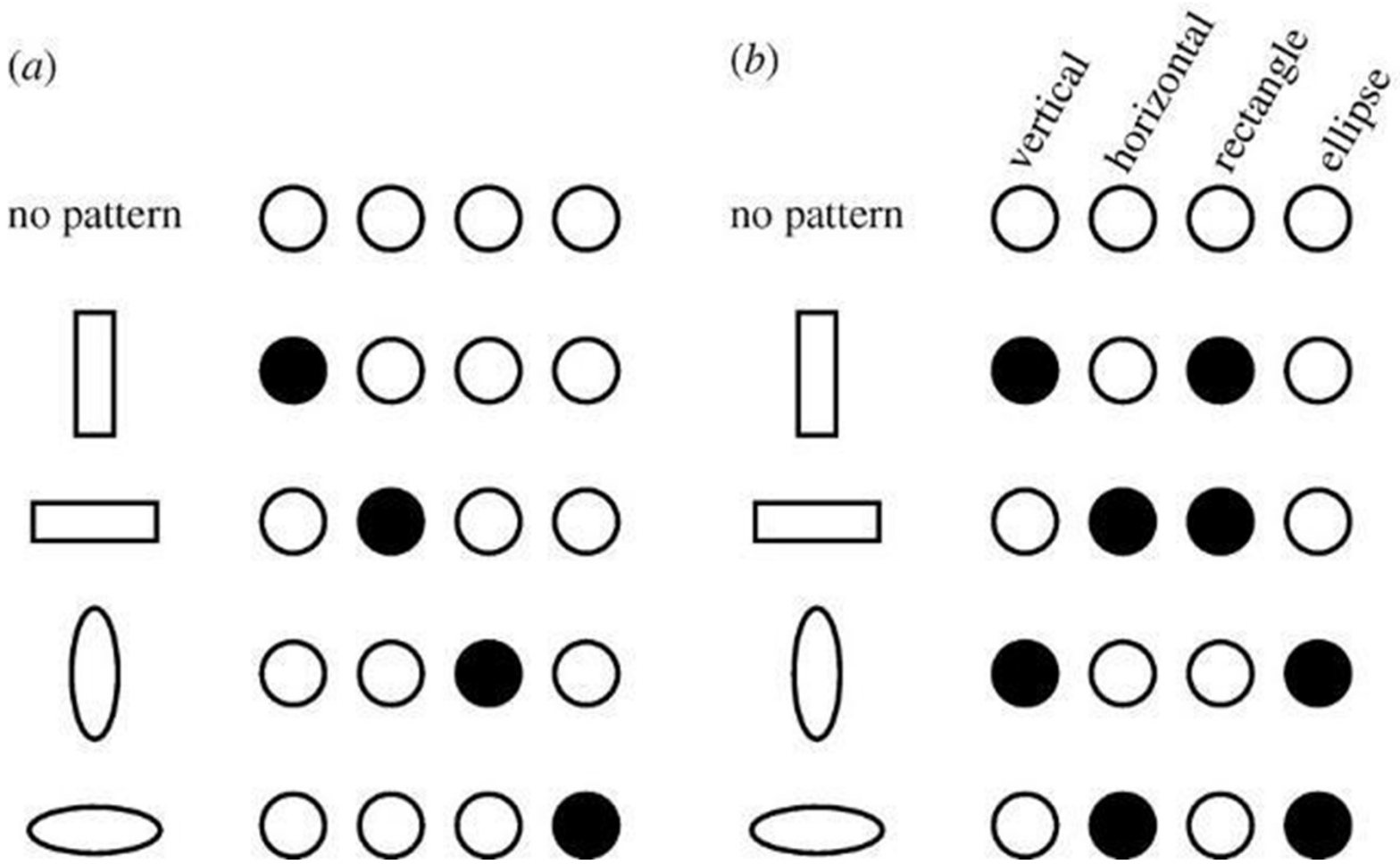
Distributed Representations Toy Example

- Local vs Distributed

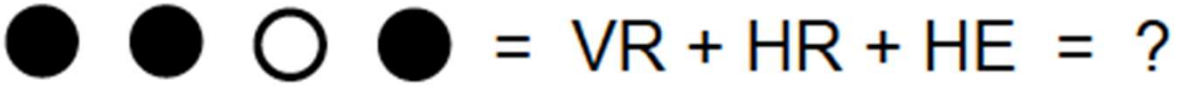


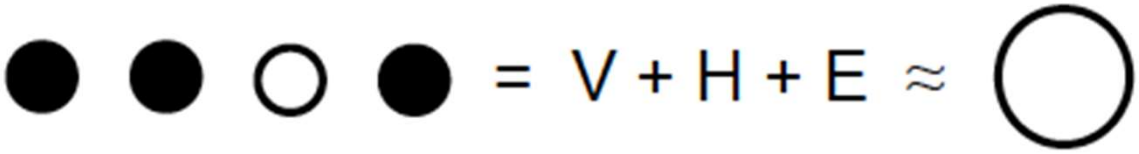
Distributed Representations Toy Example

- Can we interpret each dimension?



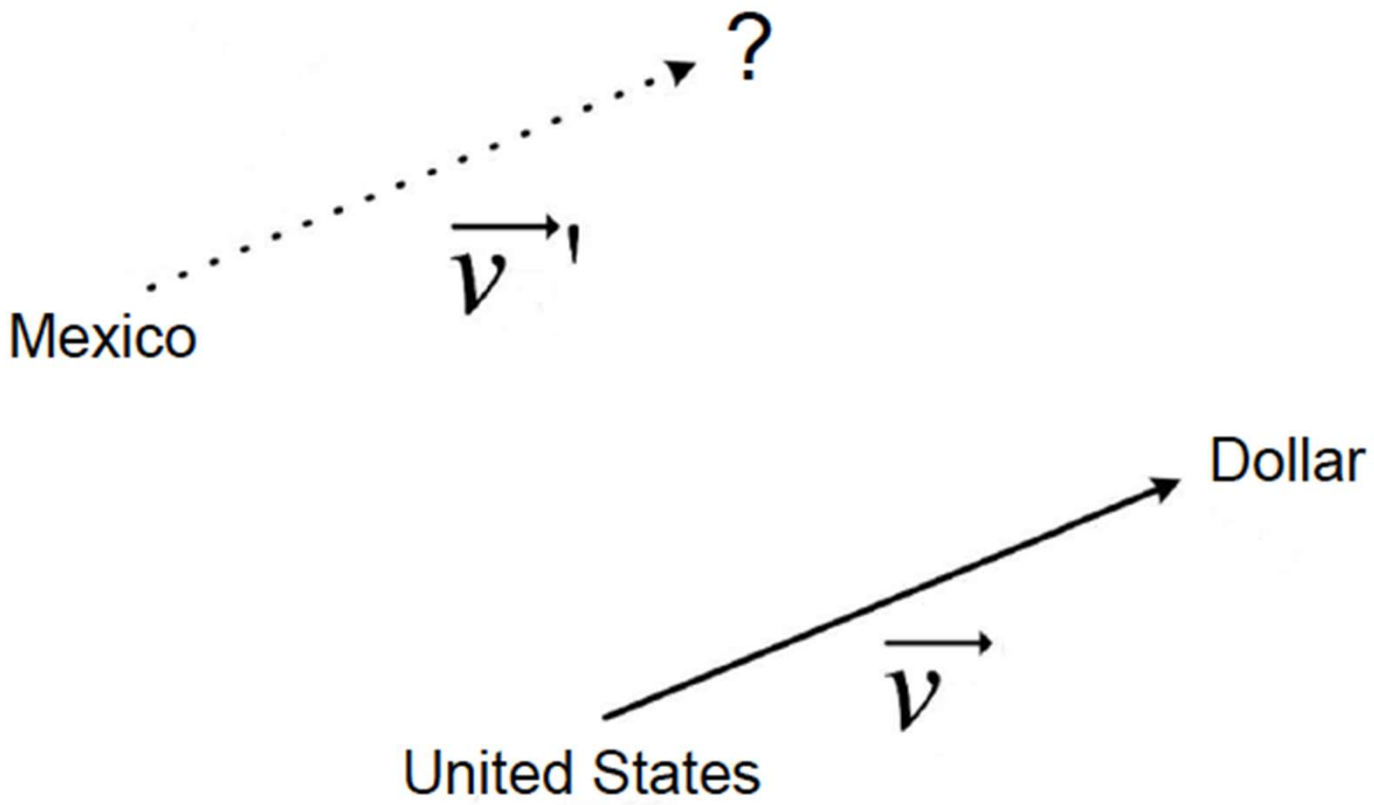
Power of distributed representations!

Local 

Distributed 

Power of distributed representations!

- United States:Dollar :: Mexico:?



ThisPlusThat.me

Image Credit: http://blog.kiradatascience.com/blog/thisplusthat_a_search_engine_that_lets_you_add_words_as_vectors.html

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Benefits of Deep/Representation Learning

- (Usually) Better Performance
  - Caveats: given enough data, similar train-test distributions, non-adversarial evaluation, etc, etc.

- New domains without “experts”
  - RGBD/Lidar
  - Multi-spectral data
  - Gene-expression data
  - Unclear how to hand-engineer

“Expert” intuitions can be misleading

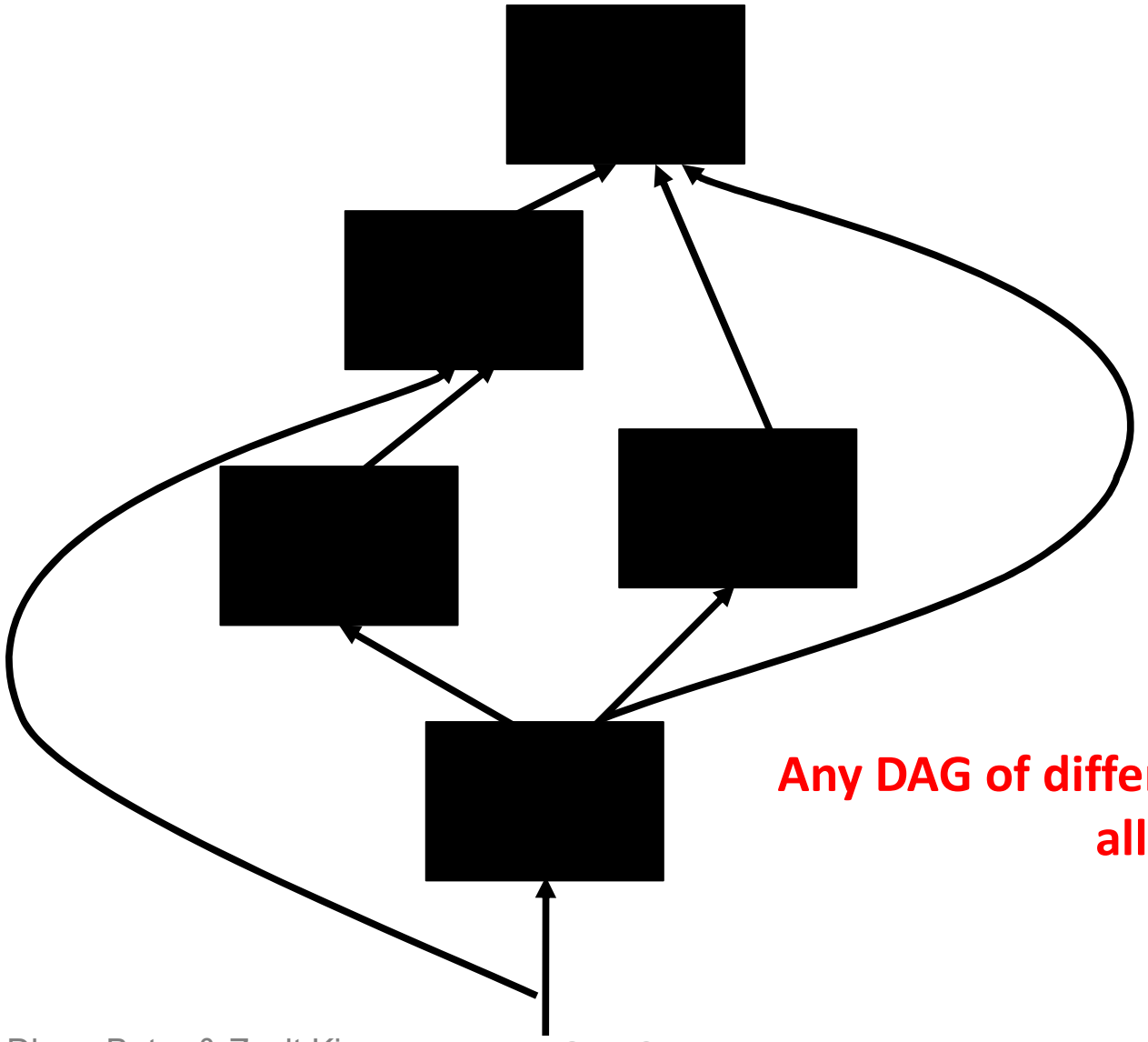
- *“Every time I fire a linguist, the performance of our speech recognition system goes up”*
  - Fred Jelinik, IBM ’98

- *“Because gradient descent is better than you”*
  - *Yann LeCun,* CVPR ‘13

Benefits of Deep/Representation Learning

- Modularity!
- Plug and play architectures!

Differentiable Computation Graph



Any DAG of differentialble modules is allowed!

Slide Credit: Marc'Aurelio Ranzato

Problems with Deep Learning

- Problem#1: Lack of a formal understanding
  - Non-Convex! Non-Convex! Non-Convex!
    - Depth>=3: most losses non-convex in parameters
  - Worse still, existing intuitions from classical statistical learning theory don't seem to carry over.
  - Theoretically, we are stumbling in the dark here

- Standard response #1
  - "Yes, but this just means there's new theory to be constructed"
  - "All interesting learning problems are non-convex"
    - For example, human learning
      - Order matters → wave hands → non-convexity

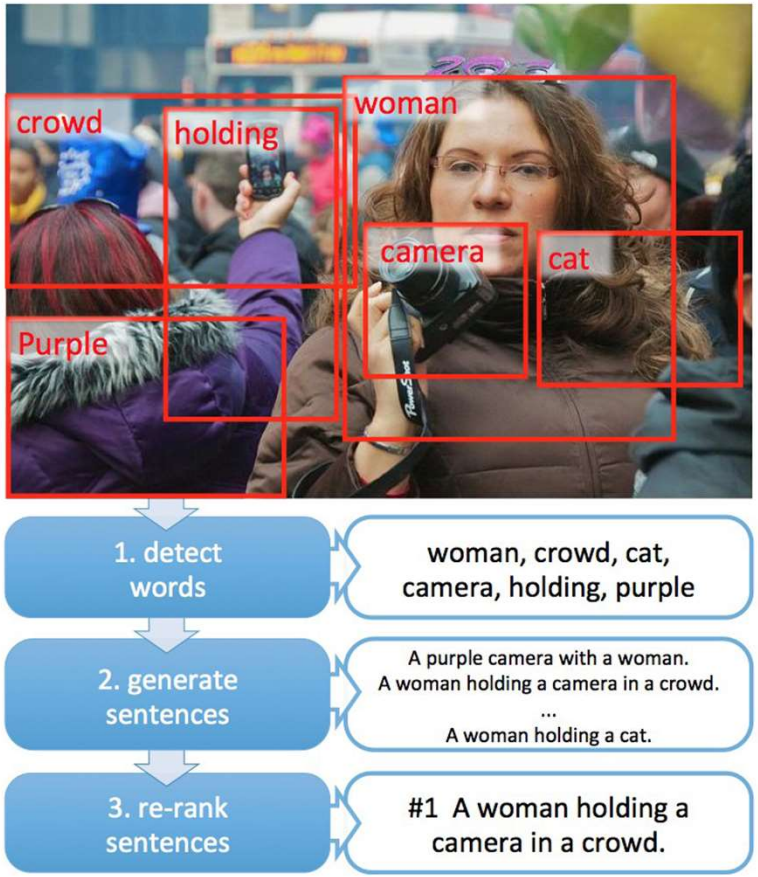
- Standard response #2
  - "Yes, but it often works!"

Problems with Deep Learning

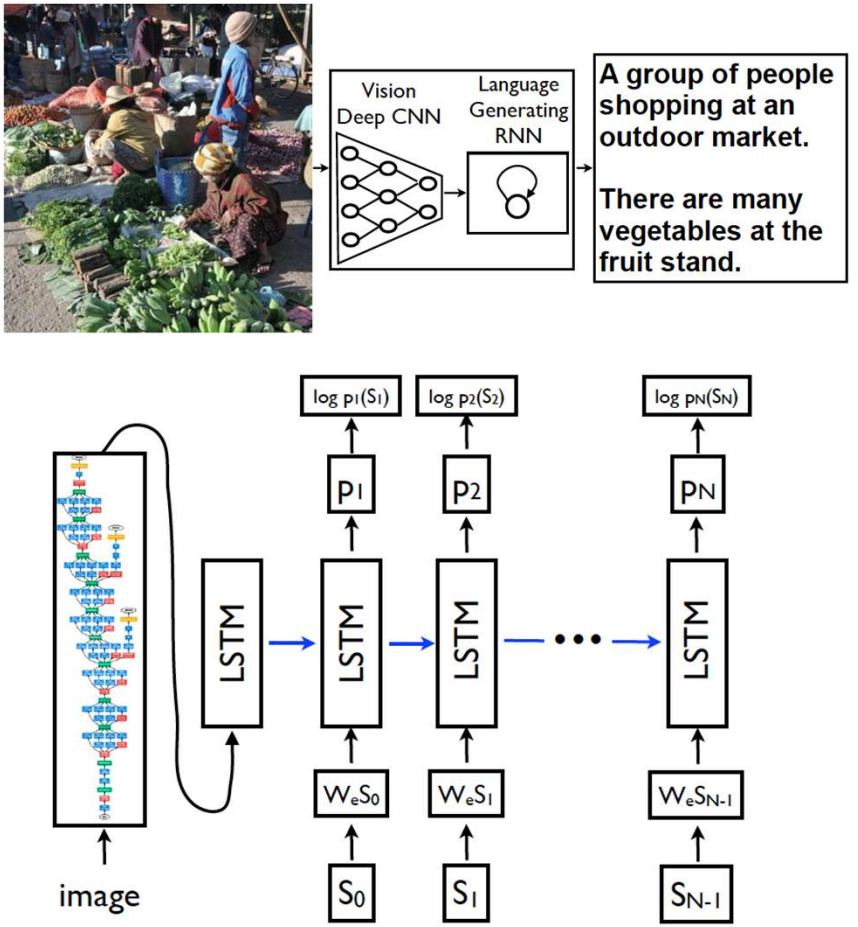
- Problem#2: Lack of interpretability
  - Hard to track down what's failing
  - Pipeline systems have expected performances at each step
  - In end-to-end systems, it's hard to know why things are not working

Problems with Deep Learning

- Problem#2: Lack of interpretability



[Fang et al. CVPR15]



[Vinyals et al. CVPR15]

Pipeline

End-to-End

Problems with Deep Learning

- Problem#2: Lack of interpretability
  - Hard to track down what's failing
  - Pipeline systems have "oracle" performances at each step
  - In end-to-end systems, it's hard to know why things are not working

- Standard response #1
  - Tricks of the trade: visualize features, add losses at different layers, pre-train to avoid degenerate initializations…
  - "We're working on it"

- Standard response #2
  - "Yes, but it often works!"

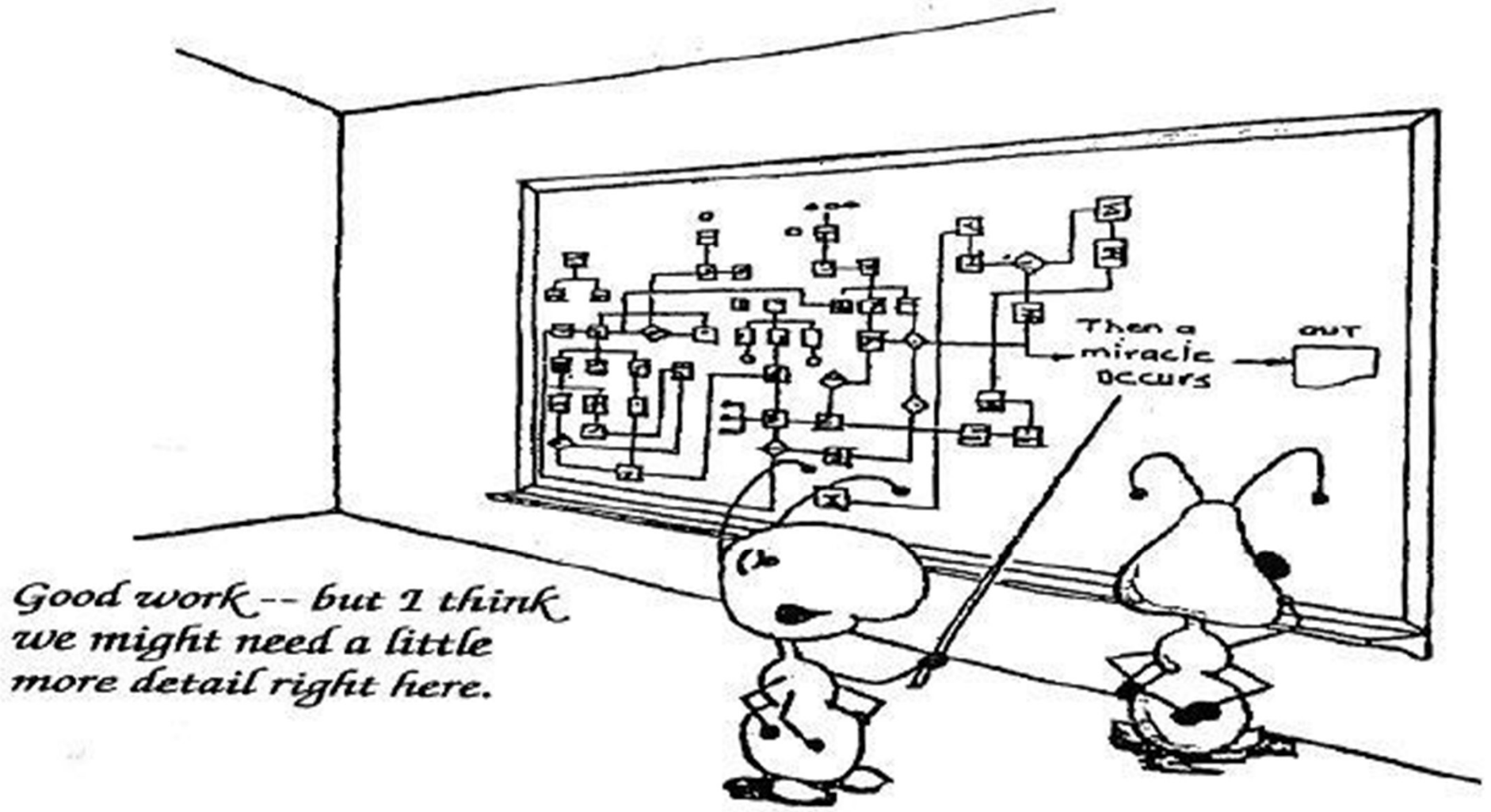
Problems with Deep Learning

- Problem#3: Lack of easy reproducibility
  - Direct consequence of stochasticity & non-convexity
    - different initializations → different local minima

- Standard response #1
  - It's getting much better
  - Standard toolkits/libraries/frameworks now available
  - PyTorch, TensorFlow, MxNet…

- Standard response #2
  - "Yes, but it often works!"

Yes it works, but how?



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What is this class about?

- Introduction to Deep Learning

- Goal:
  - After finishing this class, you should be ready to get started on your first DL research project.
    - CNNs
    - RNNs / Transformers
    - Deep Reinforcement Learning
    - Generative Models (VAEs, GANs)

- Target Audience:
  - Senior undergrads, MS-ML, and new PhD students

What this class is NOT

- NOT the target audience:
  - Advanced grad-students already working in ML/DL areas
  - People looking to understand latest and greatest cutting-edge research (e.g. GANs, AlphaGo, etc)
  - Undergraduate/Masters students looking to graduate with a DL class on their resume.
- NOT the goal:
  - Teaching a toolkit. “Intro to TensorFlow/PyTorch”
  - Intro to Machine Learning

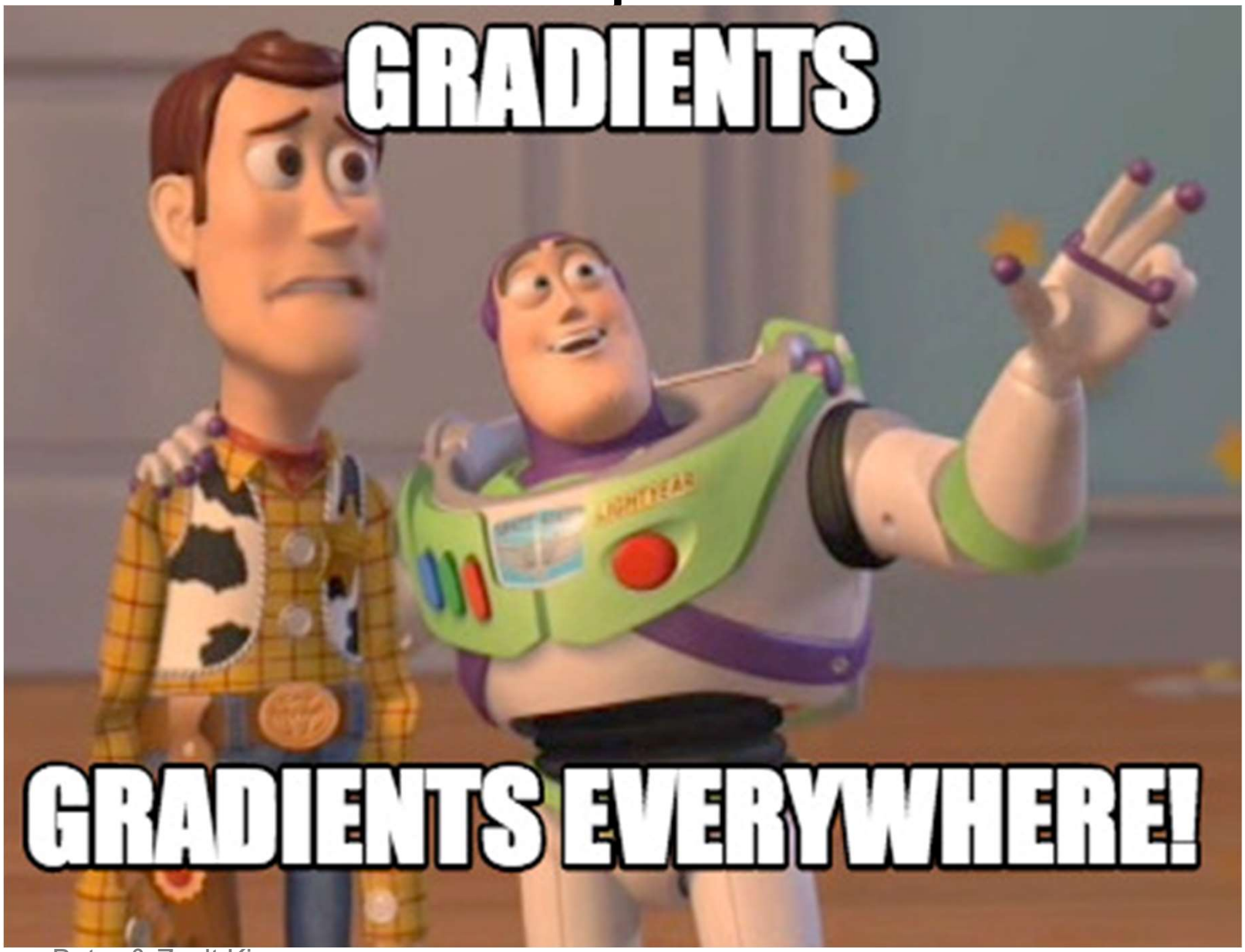
Caveat

- This is an ADVANCED Machine Learning class
  - This should NOT be your first introduction to ML
  - You will need a formal class; not just self-reading/coursera
  - If you took CS 7641/ISYE 6740/CSE 6740 @GT, you're in the right place
  - If you took an equivalent class elsewhere, see list of topics taught in CS 7641 to be sure.

Prerequisites

- Intro Machine Learning
  - Classifiers, regressors, loss functions, MLE, MAP
- Linear Algebra
  - Matrix multiplication, eigenvalues, positive semi-definiteness…
- Calculus
  - Multi-variate gradients, hessians, jacobians…
- Must read (on W3 reading list): Matrix calculus for deep learning
  - https://explained.ai/matrix-calculus/index.html

Prerequisites



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  - Matrix multiplication, eigenvalues, positive semi-definiteness…
- Calculus
  - Multi-variate gradients, hessians, jacobians…
- Programming!
  - Homeworks will require Python!
  - Libraries/Frameworks: PyTorch
  - HW0+5 (pure python), HW1 (python + PyTorch), HW2+3+4 (PyTorch)
  - Your language of choice for project

Course Information

- Instructor: Zsolt Kira
  - zkira@gatech dot edu **(use piazza for most things!)**

TAs

Manas Sahni (Head TA)

Yihao Chen

Rahul Duggal

Program: PhD CS (3rd Year)
Research Interests: Model compression, Neural architecture search.

Hrishikesh Kale

Man Xie

PhD in Interactive Computing, working with Dr. Frank Dellaert

Michael Piseno

- 5th year studying CS and Math
- Third semester TAing for 4803/7643
- Research interests are multi-agent RL and robotics

Interests: Snowboarding, Learning Languages

Zhuoran Yu

Organization & Deliverables

- 4 problem-sets+homeworks (80%)
  - Mix of theory (PS) and implementation (HW)
  - First one goes out next week
    - Start early, Start early, Start early, Start early, Start early, Start early, Start early, Start early, Start early, Start early
- Final project (20%)
  - Projects done in groups of 3-4
- (Bonus) Class Participation (3%)
  - Contribute to class discussions on Piazza
  - Ask questions, answer questions

Plenty of “buffer” built in

- Grace period
  - 2 days grace period
    - Intended for *checking* submission NOT to replace due date
    - No need to ask for grace, no penalty for turning it in within grace period
    - Can NOT use for PS0
  - After grace period, you get a 0 (no excuses except medical)
    - Send all medical requests to dean of students (https://studentlife.gatech.edu/)
    - Form: https://gatech-advocate.symplicity.com/care_report/index.php/pid224342?
  - **DO NOT SEND US ANY MEDICAL INFORMATION!** We do not need any details, just a confirmation from dean of students

PS0

- Out today; due Wed. Jan 20th
  - Will be available on class webpage + Canvas
- Grading
  - Not counted towards your final grade, but required
  - <=75% means that you might not be prepared for the class
  - If you submit after Wed. we will not grade before registration ends
- Topics
  - PS: probability, calculus, convexity, proving things

Computing

- Major bottleneck
  - GPUs
- Options
  - Your own / group / advisor's resources
  - Google Colab
    - jupyter-notebook + free GPU instance
  - Google Cloud credits (details TBD)

4803 vs 7643

- Level differentiation
- HWs
  - Extra credit questions for 4803 students, necessary for 7643
- Project
  - Higher expectations from 7643

Outline

- What is Deep Learning, the field, about?
  - Highlight of some recent projects from my lab
- What is this class about?
  - What to expect?
  - Logistics
- FAQ

Waitlist / Audit / Sit in

- Waitlist
  - Class is full. Size will not increase further.
  - Do PS0. Come to first few classes.
  - Hope people drop.
- "I need this class to graduate"
  - Talk to your degree program advisor. They control the process of making sure you have options to graduate on time.
- Audit or Pass/Fail
  - No. We will give preference to people taking class for credit.
- Sitting in
  - Welcome to. Talk to instructor.

What is the re-grading policy?

- Homework assignments
  - **Within 1 week** of receiving grades: see the TAs

- This is an advanced grad class.
  - The goal is understanding the material and making progress towards our research.

What is the collaboration policy?

- Collaboration
  - Only on HWs and project (not allowed in PS0).
  - You may discuss the questions
  - Each student writes their own answers
  - Write on your homework anyone with whom you collaborate
  - Each student must write their own code for the programming part

- Zero tolerance on plagiarism
  - Neither ethical nor in your best interest
  - Always credit your sources
  - Don’t cheat. We will find out.

How do I get in touch?

- Primary means of communication -- Piazza
  - No direct emails to Instructor unless private information
  - Instructor/TAs can provide answers to everyone on forum
  - Class participation credit for answering questions!
  - No posting answers. We will monitor.
  - Stay respectful and professional

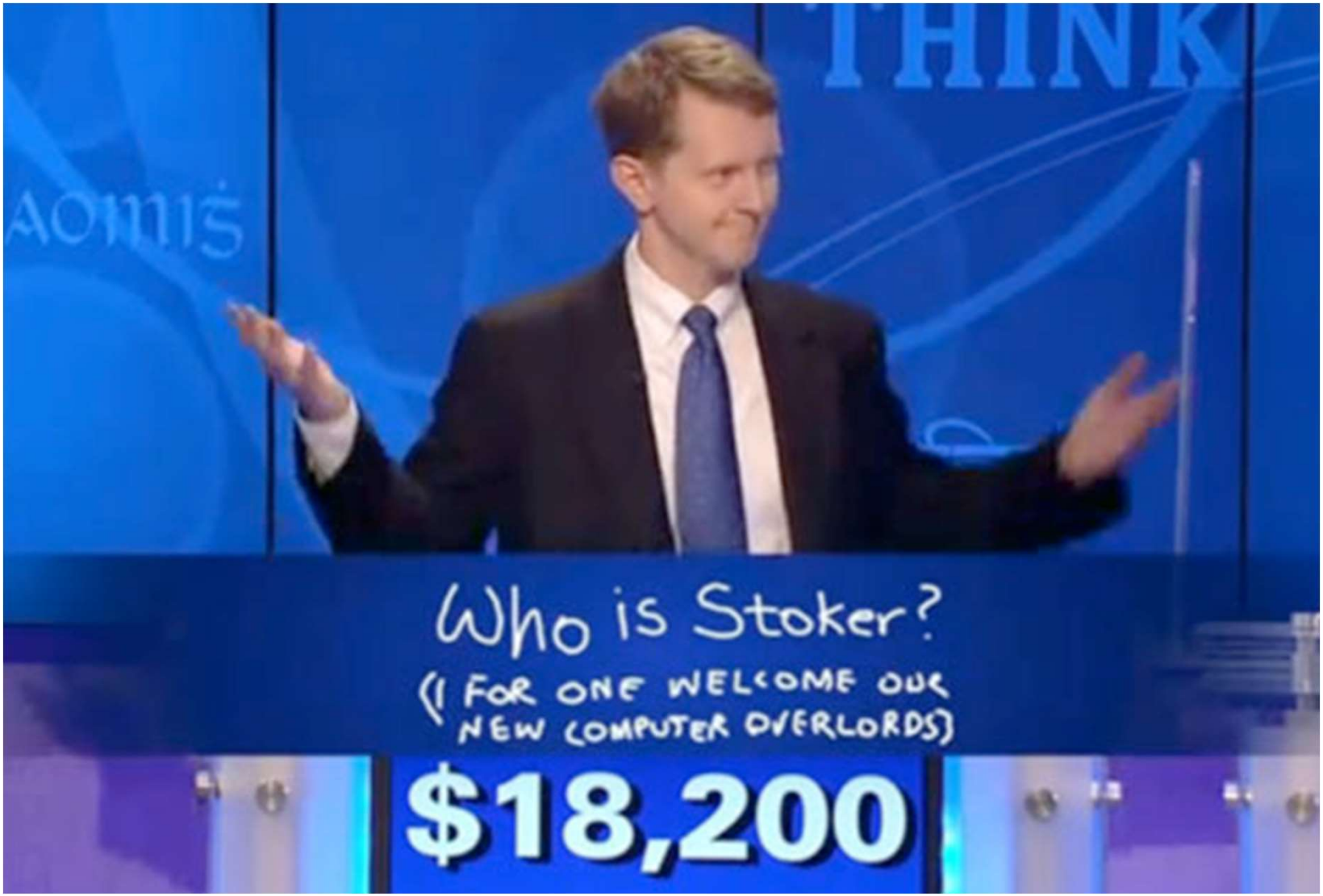
Research

- "Can I work with your group for funding/credits/neither?"
  - I am not taking new advising duties.
  - If you can find one of my students to supervise you, I am happy to sign off on the paperwork.
  - Your responsibility to approach them and ask. It will help if you know what they are working on.

Todo

- PS0
  - Due: Jan 20 11:59pm

Welcome


THINK
Who is Stoker?
(I FOR ONE WELCOME OUR NEW COMPUTER OVERLORDS)
$18,200