# Active Learning, Curriculum Learning, & Reinforcement Learning

#### Danna Gurari

University of Texas at Austin Spring 2020



https://www.ischool.utexas.edu/~dannag/Courses/IntroToMachineLearning/CourseContent.html

### Review

- Last week:
  - Machine Learning for Unlabeled Data
  - Autoencoders
  - Clustering
- Assignments (Canvas):
  - Project outline with ML system prototype due yesterday
  - Final project video due in two weeks
  - Final project report due in three weeks
- Questions?

## Paper Writing: Support

- Writing center: <a href="http://uwc.utexas.edu/">http://uwc.utexas.edu/</a>
  - can schedule four individual 45-minutes consultation per month
- Tutoring:
  - <u>https://utdirect.utexas.edu/apps/ugs/my/tutoring/student/tutoring-agreement/</u>

# Plagiarism: Definition

• Material from: https://legacy.lib.utexas.edu/services/instruction/avoidplagiarism.html

#### University of Texas Definition of Plagiarism:

"the appropriation of, buying, receiving as a gift, or obtaining by any means material that is

attributable in whole or in part to another source, including words, ideas, illustrations, structure,

computer code, and other expression

or media, and presenting that material as one's own academic work being offered for credit."

## Plagiarism: Definition

• Material from: https://legacy.lib.utexas.edu/services/instruction/avoidplagiarism.html

#### Plagiarism in Plain English:

Using someone else's work in your own academic work without giving proper credit. Click a button below to see some examples.

Intentional Plagiarism

Unintentional Plagiarism

• Material from: https://legacy.lib.utexas.edu/services/instruction/avoidplagiarism.html

#### Intentional Plagiarism:

- Copying a friend's or classmate's work
- Buying or borrowing papers
- Cutting and pasting blocks of text without providing documentation of the original source
- Borrowing images and other media without documentation of the original source
- Publishing work on the Web without the permission of the creator

• Material from: https://legacy.lib.utexas.edu/services/instruction/avoidplagiarism.html

#### Unintentional Plagiarism:

- Careless paraphrasing
- Poor documentation of sources
- Quoting excessively
- Failure to use your own ideas or words

• Material from: https://legacy.lib.utexas.edu/services/instruction/avoidplagiarism.html

During the course of your research, you come across an idea that you use in your paper. You don't use the author's exact words or even paraphrase -- just the idea. Cite it?

Other people's words aren't the only thing you need to cite. You also need to cite ideas. So in this case, you should give the author credit for the idea by citing them.

• Material from: https://legacy.lib.utexas.edu/services/instruction/avoidplagiarism.html

You are doing a presentation for your Chemistry class and use an image of the Periodic Table you found on a government web site. Cite it?

You should cite images. Even government websites in the public domain need to be cited.

- What can happen if you are accused of plagiarism?
  - Redo assignment
  - Receive a failing grade
  - Be suspended
  - Be expelled
- What resources can help you to avoid plagiarism?
  - Review: <a href="https://legacy.lib.utexas.edu/services/instruction/avoidplagiarism.html">https://legacy.lib.utexas.edu/services/instruction/avoidplagiarism.html</a>
  - Review: <u>https://legacy.lib.utexas.edu/d7/sites/default/files/services/instruction/AvoidingPlagiarism\_guide.pdf</u>
  - Visit writing center: <a href="http://uwc.utexas.edu/">http://uwc.utexas.edu/</a>
- Neither you (I believe) nor I have any desire to talk about plagiarism S
- Play it safe and give credit generously!!!

# Give Credit Generously

- Idea: add credit page to your presentation for resources used
  - e.g., Microsoft Azure
  - e.g., freely-shared code/libraries
  - e.g., links to all images
  - ...

### Today's Topics

- Active Learning
- Curriculum Learning
- Reinforcement Learning
- Guest: Dr. Cheryl Martin from Alegion

## Today's Topics

- Active Learning
- Curriculum Learning
- Reinforcement Learning
- Guest: Dr. Cheryl Martin from Alegion

#### Idea

#### **Passive Learning**



#### **Active Learning**



What is the difference between "passive" and "active" learning?

### Passive Learning: Classical ML Approach



Slide Credit: http://www.cs.cmu.edu/~learning/talks-2007-spring/slides/mll0319.active\_learning.ppt

# Active Learning



Slide Credit: http://www.cs.cmu.edu/~learning/talks-2007-spring/slides/mll0319.active\_learning.ppt

### Active Learning



Slide Credit: <u>https://www.cs.utah.edu/~piyush/teaching/10-11-slides.pdf</u>

#### Learning Curves: Active versus Passive Learning



Image Credit: http://burrsettles.com/pub/settles.activelearning.pdf

#### Learning Curves: Active versus Passive Learning



Machines can learn with fewer training instances if they ask questions.

Image Credit: http://burrsettles.com/pub/settles.activelearning.pdf

# Types of Active Learning

#### 1. Stream-Based



#### Consider one example at a time

Image Credit: https://www.cs.utah.edu/~piyush/teaching/10-11-slides.pdf

## Types of Active Learning

#### labeled training set learner label & add to $\langle x_i, y_i \rangle$ Large Pool of training set Unlabeled Data $\langle x_i, ? \rangle$ choose the best query $T_i$ out of the sample pool oracle / expert

2. Pool-Based

#### Consider many examples at a time

Image Credit: https://www.cs.utah.edu/~piyush/teaching/10-11-slides.pdf

## Types of Active Learning

#### Stream-Based

#### Pool-Based



#### Consider one example at a time

#### Consider many examples at a time

Image Credit: https://www.cs.utah.edu/~piyush/teaching/10-11-slides.pdf

### Active Learning Approach

- Active Learning proceeds in rounds
- Each round has a current model (learned using the labeled data seen so far)
- The current model is used to assess informativeness of unlabeled examples
  .. using one of the query selection strategies
- The most informative example(s) is/are selected
- The labels are obtained (by the labeling oracle)
- The (now) labeled example(s) is/are included in the training data
- The model is re-trained using the new training data

Slide Credit: https://www.cs.utah.edu/~piyush/teaching/10-11-slides.pdf

## Active Learning Approach

- Active Learning proceeds in rounds
- Each round has a current model (learned using the labeled data seen so far)
- Approach: query instances based on past queries and their responses (labels)

Problem: how to choose most informative examples to query?

- The (now) labeled example(s) is/are included in the training data
- The model is re-trained using the new training data

Slide Credit: https://www.cs.utah.edu/~piyush/teaching/10-11-slides.pdf

# Uncertainty Sampling: e.g., Logistic Classifier

#### Query instance(s) the classifier is most uncertain about.

True Representation (Assume Labels Are Not Known)



Passive Learner (Random Selection)

Active Learner (Uncertainty Sampling)



Image Credit: http://burrsettles.com/pub/settles.activelearning.pdf

# Uncertainty Sampling: e.g., SVM Classifier

#### Query instance(s) the classifier is most uncertain about.

e.g., strategy 1: request the label of the example closest to the current separator.



Slide Credit: http://www.cs.cmu.edu/~learning/talks-2007-spring/slides/mll0319.active\_learning.ppt

### Query By Committee

#### Query instance(s) different classifiers disagree most about.



Image Credit: http://burrsettles.com/pub/settles.activelearning.pdf

### Group Discussion:

Assume you are hired to build a new face recognition service. How would you design an active learning approach to train an accurate machine learning algorithm while collecting training data efficiently?



Gfycat's facial recognition software can now recognize individual members of K-pop band Twice, but in early tests couldn't distinguish different Asian faces.

https://www.wired.com/story/how-coders-are-fighting-bias-in-facial-recognition-software/

# Today's Topics

- Active Learning
- Curriculum Learning
- Reinforcement Learning
- Guest: Dr. Cheryl Martin from Alegion

#### Idea

#### How to teach machines to learn faster?

# e.g., How to Teach a Child Math?



#### Random Order of Examples



#### Meaningful Order of Examples

oroduction to feabbles Wig the features in featurement Feddels faces Status in Appropriate Feddels Many Feddels States Frank Fedd for Sec. Frank Fedd for Sec. Frank Fedd for Sec.		Statement Sorger March Austrehum autorg Fuhlahlme Marcher Systeme Warde Kacelow Baugurs anding and Salementry Baugurs and aground Salementry Baugurs Makaging and Decising Radioal Baubary
orderion in faileding With Line Folgenie in Ballinmain?" Polatet Resin Disaring In Appropriate Weighte Ming Bootsectome and Addalar Stagen Pole Foldel Kord Book Folder Book Reset Book Reset Book Pole State	1	Halt Accelers using Foldation Rando Josens Walt Scalars Bager Inspire and good fattering Report Mologing and Driving Rational Random
Wite Lise Polentier on Mallemater's Polatele Reserve Bilanting for Appropriate Weithfor and Voltable Stagen Oraci Feldi Kent Book Fielder Book Reset Book Teater Book Reset Book	117 - 1 - 11	Hack Acceleration Foldoffic Number Systems Which Nucleus Bagers Bagers Bargers Michigang and Selating Regard Michigang and Decking Regard Readors
Fuldate Rein Binaning for Appropriate Possible Mong fortune Rein Inter Folder Stagen Hant Folde Karl Rock Brand Rock Brand Rock Brand Rock		Number System Weise Kacilien Bagert Bagert Bilding out following Bagert Middelping all Driving Radinal Readors
Billioning In Appropriate Heilpfer Mang NoticeClanes Anny Autochile Shapes Hand Heil Kont Heil Konte Heil Konte Heil Konte Heil Konte Heil		Wards Nacions Heighty Integers and eg and failure eng Integers Madophing and Drining Rational Bundwy
dding frothermen daniy folgalar Stagen 1 Anet Feldi Kord Sevic Foldar Davis Romai Rack Transfer Davis	-	Bagary Bagary Bidlag and Salmoving Bargary Multiplying and Draining Rational Resolution
ddaig factur Claure dainty factur Claure I Fact Folds Factor Devic Factor Devic Broad Fork For Ser Band	4	Integral and a solid failure ring Integral Multiplying said Driving Rational Resources
deniy folibelir (Sager 1 Part Frid) Rott Book Folder Book Rotte Book Rotte Book Teo Ser Book		Integers' Multiplying still Driving Rateral Humbers
t Aust Islah Rott Sock Rotat Cook Rotat Rock Tim Tar Book	- 1	Ratenal Robbert
Ruf Bolk Falle Bolk Rosai Bolk Teo Ser Bolk	- 1	
Fotor Book Broad Rock Terr Ser Book	- 7	Rational Numbers, President,
Resaid Rock Time for deale		Estartig Mathem, Two rooms
Teo far deal		Problem of the problem of the second
The of the contraction of the co		Retrie . Construction to the second
		Papinian
3. Pwie vlatki		Institut National Control of Cont
Mayrook.		Real Number System
Parad Rest		Adulture Partners and Sections
Elemen Pold		Case and Factorian
a best holds		Reported and
Catalog Real	10	Francisco
These Test Rent	1.4	baseling.
"Research to Read Variations	14	Second Second
Processed Front in Marian		Relation and Passings
Pleased they be service to contract	1001164	Fundamental States of Contract
it Part Failds		Maladar
Lowers' Look Book	1111 PP	Manager in and Pulsaneous
Fair-Ed Book	1111.08	Preserve and Proposition
Revelops Fill		Supported to a support of the suppor
Noveleg Cali:		Manhatt
First-Deer Serie		- Hereiter
Top Tel Rush		(how dry
Advertise them		Pad-
inco Manufact of Parity		Lines and Line Segments -
The life Back		-Rep
Tables in Faith		Aagini
United Value 1 New or Street		Angle Relationships
Readings of South Later Wanting		Plent
Chemilton	19	This special
Courses Was fired		Trieght
State of the second second	10	Bight Drungles
reserved non-		Right Triangle Tripmenum's
Projects-Inling-Mellin		Qualification
Billiound Peoplet		Papers, Xisistales, and Resaid

#### Big Book of Math; Dinah Zike

# e.g., How to Teach a Child To Read?



#### Random Order of Examples



#### Meaningful Order of Examples





#### Idea: Teach Machines As We Teach Humans

#### Curriculum

# Train with simpler examples first and progressively harder examples over time.

Jeffrey L. Elman. Learning and development in neural networks: The importance of starting small. Cognition, 1993.

### Learning Curves: Shape Variability

*Artificial data*: classify images into 3 shapes (rectangle, ellipse, triangle) *Input*: 32×32 grey-scale image



Yoshua Bengio et al.; Curriculum Learning; 2009.

### Learning Curves: Shape Variability

Artificial data: classify images into 3 shapes (rectangle, ellipse, triangle)

- Training: 3-layer neural network with BasicShapes or GeomShapes (10,000 examples)
- Testing: GeomShapes



What are benefits of curriculum learning?

How long should the algorithm train with easy examples before switching to difficult examples?

Yoshua Bengio et al.; Curriculum Learning; 2009.

### Learning Curves: Word Prediction

Wikipedia: predict next word in a sentence

- Curriculum: grow vocabulary size; 5k most frequent words, then 10k most frequent words, etc
- Target: final vocabulary size is 20, 000 words



What are benefits of curriculum learning?

How long should the algorithm train with easy examples before switching to difficult examples?

Yoshua Bengio et al.; Curriculum Learning; 2009.

#### Group Discussion: Curriculum Learning

#### Task: train algorithm to read text in images taken by people who are blind





#### **Questions**

What criteria should be used to order examples?
 What batches would you use when changing the available data?
 How often would you make updates?

# Today's Topics

- Active Learning
- Curriculum Learning
- Reinforcement Learning
- Guest: Dr. Cheryl Martin from Alegion

### Reinforcement Learning Overview

Agent takes actions in an environment so as to maximize the total reward.



Figure Credit: https://towardsdatascience.com/applications-of-reinforcement-learning-in-real-world-1a94955bcd12

### Intuition: Learning to Walk by Trial-and Error



https://en.wikipedia.org/wiki/Crawling\_(human)

#### Reinforcement Learning Applications

#### Learning to Walk in 20 Minutes

Russ Tedrake Brain & Cognitive Sciences Center for Bits and Atoms Massachusetts Inst. of Technology Cambridge, MA 02139 russt@csail.mit.edu Teresa Weirui Zhang Mechanical Engineering Department University of California, Berkeley Berkeley, CA 94270 resa@berkeley.edu H. Sebastian Seung Howard Hughes Medical Institute Brain & Cognitive Sciences Massachusetts Inst. of Technology Cambridge, MA 02139 seung@mit.edu



# Reinforcement Learning Applications Autonomous reinforcement learning on raw visual input data in a real world application

Sascha Lange, Martin Riedmiller Department of Computer Science Albert-Ludwigs-Universität Freiburg D-79110, Freiburg, Germany Email: [slange,riedmiller]@informatik.uni-freiburg.de Arne Voigtländer Shoogee GmbH & Co. KG Krögerweg 16a D-48155 Münster, Germany Email: arne@shoogee.com



Fig. 1. The visual slot car racer task. The controller has to autonomously learn to steer the racing car by raw visual input of camera images.

# **Reinforcement Learning Applications**





https://www.tastehit.com/blog/google -deepmind-alphago-how-it-works/

https://web.stanford.edu/class/psych209/Readings/MnihEtAlHassibis15NatureControlDeepRL.pdf

### e.g., Pong Game - Learning Example

-1 if missed the ball

+1 reward if ball goes past opponent

0 otherwise



#### Move "up" or "down"



http://karpathy.github.io/2016/05/31/rl/

### e.g., Pong Game: Policy Network



Game State

http://karpathy.github.io/2016/05/31/rl/

### e.g., Pong Game: Training Protocol



- Play 100 games of Pong; i.e., policy "rollouts" (200 images/game); Suppose: win 12 games, lose 88
- # Winning Decisions = 200\*12 = 2400 decisions; positive update (fill in a +1.0 in the gradient for the sampled action, do backprop, and parameter update to encouraging the actions)
- # Losing Decisions: 200\*88 = 17600; negative update (as above, but fill in -1.0 in the gradient)

http://karpathy.github.io/2016/05/31/rl/

### e.g., Pong Game: Trained for Three Nights

Demo: https://www.youtube.com/watch?time\_continue=16&v=YOW8m2YGtRg

#### e.g., Learning Dexterity

Demo: https://www.youtube.com/watch?v=jwSbzNHGflM

#### e.g., Learning to Flip Pancakes

Demo: https://www.youtube.com/watch?v=W\_gxLKSsSIE&list=PL5nBAYUyJTrM48dViibyi6 8urttMlUv7e

#### e.g., Learning to Walk

Demo: https://www.youtube.com/watch?v=gn4nRCC9TwQ

# Google Form: Guest Speaker & Class Feedback

- Google form:
  - Guest: Dr. Cheryl Martin, Chief Data Scientist at Alegion (<u>https://www.alegion.com/company/leadership</u>); list one question for her for today's visit
- Then, take a short break.
- Class resumes at 4:50pm CST.

# Today's Topics

- Active Learning
- Curriculum Learning
- Reinforcement Learning
- Guest: Dr. Cheryl Martin from Alegion