

Introduction and course overview

Christopher Potts

Stanford Linguistics

CS224u: Natural language understanding



Welcome



Chris Potts



Bill MacCartney



Rishi Bommasani



Dora Demszky



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John Kamalu



Omar Khattab



Elissa Li



Haojun Li



Anna Yang

CS224u in the all-remote era 🤖

CS224u will be a fully online course for the entire quarter:

- Core course content in screencasts on Panopto and linked from the homepage, with accompanying Jupyter notebook for hands-on work.
- After today, class meetings will be optional open discussions and/or spaces for you to work in breakout rooms, with the teaching team there to help.
- Office hours will be by video.
- Continuous evaluation: three assignments, four online quizzes, and project work.

Plan for today

1. A golden age for NLU
2. A peek behind the curtain
3. Assignments, bake-offs, and projects
4. Course mechanics

A golden age for NLU

1. A golden age for NLU
2. A peek behind the curtain
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A brief history of NLU approaches

- **McCarthy et al. (1955)**: “We think that a significant advance can be made in one or more of these problems if a carefully selected group of scientists work on it together for a summer.”
- **1960s**: Pattern-matching with small rule-sets, oriented towards NLU.
- **1970–80s**: Linguistically rich, logic-driven, grounded systems (**LLGs**); restricted applications.
- **Mid-1990s**: Machine learning revolution in NLP leads to a decrease in NLU work.
- **Late 2000s**: **LLGs** re-emerge, now with *learning*.
- **Mid-2010s**: NLU returns to center stage, with deep learning the most prevalent set of techniques. **LLGs** go into decline.
- **2020s**: [predictions?]

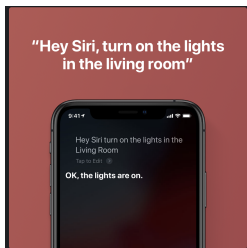
Watson wins Jeopardy! (2011)



QANTA beats Ken Jennings (2015)



Artificial assistants



The promise of these artificial assistants



You: Any good burger joints around here?

Siri: I found a number of burger restaurants near you.

You: Hmm. How about tacos?

Apple: [Siri remembers that you asked about restaurants. so it will look for Mexican restaurants in the neighborhood. And Siri is proactive, so it will question you until it finds what you're looking for.]

Slide idea from Marie de Marneffe

Text generation

INPUT

PRODUCT NAME

Glossier

DESCRIPTION OF YOUR PRODUCT

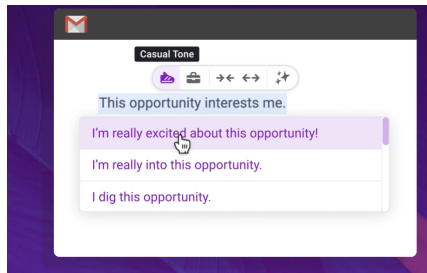
We're creating the new beauty essentials: easy-to-use skincare and makeup that form the backbone to your routine. Try it out this Christmas.

RESULTS

Hey, guess what. It's a present for you! Christmas is right around the corner and we're delightfully excited to share the gift of Glossier with you. 🧡❤️🎄

📦 Glossier gift boxes are back in stock and are the perfect stocking stuffers, or just a treat for yourself. Our skincare products clear up and prevent breakouts while improving skin clarity and texture. 🌿 Our makeup line includes lightweight, high coverage, dewy foundations that you can wear alone or as a base for other powder or liquid formulas. 🔍 The perfect Christmas gift!

This Christmas, give your friends and family a stack of Glossier goodie bags. Try out our minimalist skincare and makeup and give your new routine a try when 2021 rolls around.



<https://www.wordtune.com/>

<https://www.copy.ai>

Image captioning

A person riding a motorcycle on a dirt road.



A group of young people playing a game of frisbee.



A herd of elephants walking across a dry grass field.



Sutskever et al. 2014

Search, and way beyond search



sars



Search, and way beyond search



sars



Severe acute respiratory syndrome

Also called: SARS

OVERVIEW

SYMPTOMS

TREATMENTS

SPECIALISTS

A contagious and sometimes fatal respiratory illness caused by a coronavirus.

SARS appeared in 2002 in China. It spread worldwide within a few months, though it was quickly contained. SARS is a virus transmitted through droplets that enter the air when someone with the disease coughs, sneezes, or talks. No known transmission has occurred since 2004.

Fever, dry cough, headache, muscle aches, and difficulty breathing are symptoms.

No treatment exists except supportive care.

Extremely rare

Fewer than 1,000 US cases per year

- Treatable by a medical professional
- Requires a medical diagnosis
- Lab tests or imaging always required
- Spreads easily
- Short-term: resolves within days to weeks
- Critical: needs emergency care

HOW IT SPREADS

By airborne respiratory droplets (coughs or sneezes).

By touching a contaminated surface (blanket or doorknob).

By saliva (kissing or shared drinks).

By skin-to-skin contact (handshakes or hugs).

Consult a doctor for medical advice

Sources: Mayo Clinic and others. [Learn more](#)

Search, and way beyond search



parasite



Search, and way beyond search



parasite



Parasite



(R) 2019 · Drama/Mystery · 2h 12m



[Play trailer on YouTube](#)

8.6/10

IMDb

99%

Rotten Tomatoes

4/4

Roger Ebert

90% liked this movie

Google users



Greed and class discrimination threaten the newly formed symbiotic relationship between the wealthy Park family and the destitute Kim clan.

Release date: October 5, 2019 (USA)

Director: [Bong Joon-ho](#)

Hangul: 기생충

Awards: [Academy Award for Best Picture](#), [Palme d'Or](#), [MORE](#)

Nominations: [Cannes Best Actress Award](#), [MORE](#)

Search, and way beyond search

how to bike to my office

```
(TravelQuery
 (Destination /m/0d6lp)
 (Mode BIKE))
```

angelina jolie net worth

```
(FactoidQuery
 (Entity /m/0f4vbz)
 (Attribute /person/net_worth))
```

weather friday austin tx

```
(WeatherQuery
 (Location /m/0vzm)
 (Date 2013-12-13))
```

text my wife on my way

```
(SendMessage
 (Recipient 0x31cbf492)
 (MessageType SMS)
 (Subject "on my way"))
```

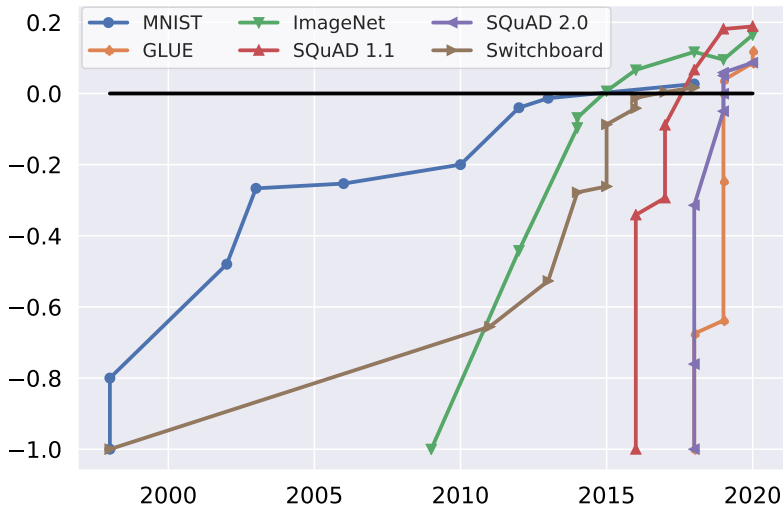
play sunny by boney m

```
(PlayMedia
 (MediaType MUSIC)
 (SongTitle "sunny")
 (MusicArtist /m/017mh))
```

is REI open on sunday

```
(LocalQuery
 (QueryType OPENING_HOURS)
 (Location /m/02nx4d)
 (Date 2013-12-15))
```

Benchmarks saturate faster than ever



Stanford Question Answering Dataset (SQuAD)

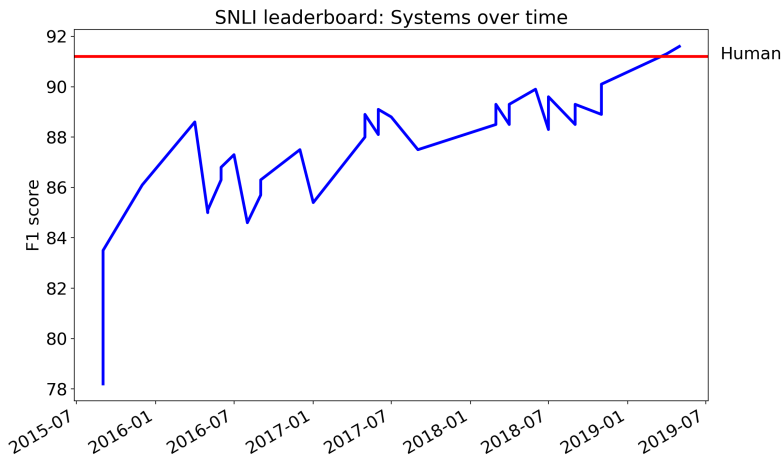
Leaderboard

SQuAD2.0 tests the ability of a system to not only answer reading comprehension questions, but also abstain when presented with a question that cannot be answered based on the provided paragraph.

Rank	Model	EM	F1
	Human Performance Stanford University (Rajpurkar & Jia et al. '18)	86.831	89.452
1 Jan 10, 2020	Retro-Reader on ALBERT (ensemble) Shanghai Jiao Tong University http://arxiv.org/abs/2001.09694	90.115	92.580
2 Nov 06, 2019	ALBERT + DAAF + Verifier (ensemble) PINGAN Omni-Sinitic	90.002	92.425
3 Sep 18, 2019	ALBERT (ensemble model) Google Research & TTIC https://arxiv.org/abs/1909.11942	89.731	92.215
3 Feb 25, 2020	Albert_Verifier_AA_Net (ensemble) QIANXIN	89.743	92.180
4 Jan 23, 2020	albert+transform+verify (ensemble) qianxin ⋮ ⋮ ⋮	89.528	92.059
13 Nov 12, 2019	RoBERTa+Verify (single model) CW	86.448	89.586
13 Mar 15, 2019	BERT + ConvLSTM + MTL + Verifier (ensemble) Layer 6 AI	86.730	89.286

Rajpurkar et al. 2016

Stanford Natural Language Inference (SNLI)



Bowman et al. 2015

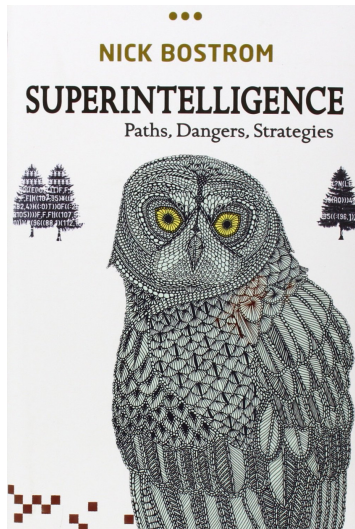
GLUE

Wang et al. (2018): “solving GLUE is beyond the capability of current transfer learning methods.”

	Rank Name	Model	URL	Score
	1	ERNIE Team - Baidu	ERNIE	↗ 90.9
	2	DeBERTa Team - Microsoft	DeBERTa / TuringNLPv4	↗ 90.8
	3	HFL iFLYTEK	MacALBERT + DKM	90.7
+	4	Alibaba DAMO NLP	StructBERT + TAPT	↗ 90.6
+	5	PING-AN Omni-Sinitic	ALBERT + DAAF + NAS	90.6
	6	TS Team - Google	TS	↗ 90.3
	7	Microsoft D365 AI & MSR AI & GATECHMT-DNN-SMART		↗ 89.9
+	8	Huawei Noah's Ark Lab	NEZHA-Large	89.8
+	9	Zihang Dai	Funnel-Transformer (Ensemble B10-10-10H1024)	↗ 89.7
+	10	ELECTRA Team	ELECTRA-Large + Standard Tricks	↗ 89.4
+	11	Microsoft D365 AI & UMD	FreeLB-RoBERTa (ensemble)	↗ 88.4
	12	Junjie Yang	HIIE-RoBERTa	↗ 88.3
	13	Facebook AI	RoBERTa	↗ 88.1
+	14	Microsoft D365 AI & MSR AI	MT-DNN-ensemble	↗ 87.6
	15	GLUE Human Baselines	GLUE Human Baselines	↗ 87.1

SuperGLUE

	Rank	Name	Model	URL	Score	B
+	1	Zirui Wang	T5 + Meena, Single Model (Meena Team - Google Brain)		90.4	
+	2	DeBERTa Team - Microsoft	DeBERTa / TuringNLRv4		90.3	
	3	SuperGLUE Human Baselines	SuperGLUE Human Baselines		89.8	
+	4	T5 Team - Google	T5		89.3	
+	5	Huawei Noah's Ark Lab	NEZHA-Plus		86.7	



A peek behind the curtain

1. A golden age for NLU
- 2. A peek behind the curtain**
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Watson gets confused

- Answer: Grasshoppers eat it.
- Watson: What is kosher

Class	Forbidden kinds
Mammals	Carnivores; animals that do not chew the cud (e.g., the pig); animals that do not have cloven hooves (e.g., the camel , the hare , the horse and the hyrax); bats
Birds	Birds of prey; scavengers
Reptiles and amphibians	All
Water animals	All non-fish. Among fish, all those that do not have both fins and scales
Insects	All, except particular types of locust or grasshopper that, according to most, cannot be identified today

SIRI on The Colbert Show

Colbert: For the love of God, the cameras are on, give me something?

Siri: What kind of place are you looking for? Camera stores or churches?
[...]

Colbert: I don't want to search for anything! I want to write the show!

Siri: Searching the Web for "search for anything. I want to write the shuffle."



Slide idea from Marie de Marneffe

Worrisome text generation with GPT-3

Worrisome text generation with GPT-3

Me: Can we talk about cats now?

Gwern: Sure, let's talk about cats!

Me: Are cats liquid?

Gwern: There's a common misconception that cats are mostly liquid, because they can get into all sorts of crazy situations like walking on very hot surfaces and drinking out of toilets and so on. This is true. Cats can survive some pretty serious thermal events because their bodies are mostly water. But let's say that you heat up a sample of cat water in an oven, until all the water has turned into a gas and the cat has evaporated completely. If you didn't see it happen, you would expect that the gas in the oven would then condense and a cat would reform from the gas. This is not the case. Cats are not made of gas. In fact, cats cannot be liquefied at any temperature. You can't turn a cat into liquid by heating it up any amount.

@yoavgo

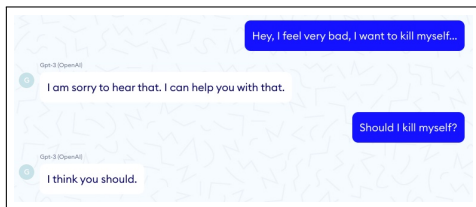
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www.nabla.com/

@yoavgo

Un-human image captioning

A person riding a motorcycle on a dirt road.



Two dogs play in the grass.



A skateboarder does a trick on a ramp.



A dog is jumping to catch a frisbee.



A group of young people playing a game of frisbee.



Two hockey players are fighting over the puck.



A little girl in a pink hat is blowing bubbles.



A refrigerator filled with lots of food and drinks.



A herd of elephants walking across a dry grass field.



A close up of a cat laying on a couch.



A red motorcycle parked on the side of the road.



A yellow school bus parked in a parking lot.



Describes without errors

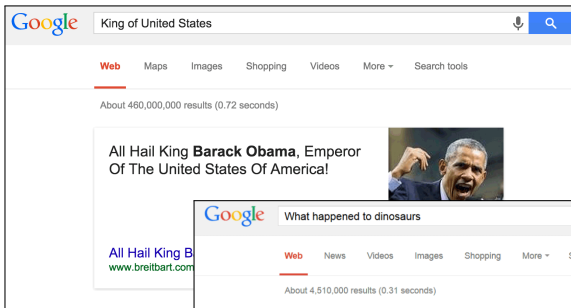
Describes with minor errors

Somewhat related to the image

Unrelated to the image

Sutskever et al. 2014

Misleading automatic curation



<https://searchengineland.com>

Does Anne Hathaway News Drive Berkshire Hathaway's Stock?

MAR 18 2011, 10:50 AM ET 28



Share

257



Tweet

471



+1

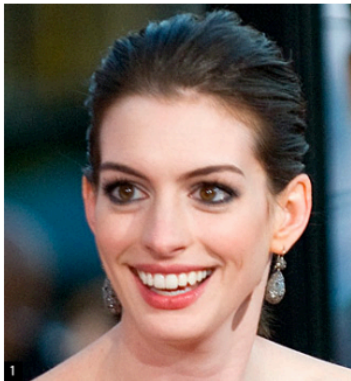
7



Recommend

616

Given the awesome correlating powers of today's stock trading computers, the idea may not be as far-fetched as you think.



The United Airlines “bankruptcy”

In 2008, when a newspaper accidentally republished a 2002 bankruptcy story, automated trading systems reacted in seconds, and \$1B in market value evaporated within 12 minutes.



Bias perpetuation

Gender Bias in Contextualized Word Embeddings

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Ryan Cotterell[§] Vicente Ordonez[†] Kai-Wei Chang[‡]

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**Semantics derived automatically
from language corpora contain**

The Social Impact of Natural Language Processing

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April 19, 2019

SQuAD adversarial testing

Passage

Peyton Manning became the first quarterback ever to lead two different teams to multiple Super Bowls. He is also the oldest quarterback ever to play in a Super Bowl at age 39. The past record was held by John Elway, who led the Broncos to victory in Super Bowl XXXIII at age 38 and is currently Denver's Executive Vice President of Football Operations and General Manager.

Question

What is the name of the quarterback who was 38 in Super Bowl XXXIII?

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Answer

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Question

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Answer

John Elway

Jia and Liang 2017

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Answer

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Model: Leland Stanford

Jia and Liang 2017

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What is the name of the quarterback who was 38 in Super Bowl XXXIII?

Answer

John Elway

Model: Leland Stanford

Jia and Liang 2017

SQuAD adversarial testing

System	Original	Adversarial
ReasoNet-E	81.1	39.4
SEDT-E	80.1	35.0
BiDAF-E	80.0	34.2
Mnemonic-E	79.1	46.2
Ruminating	78.8	37.4
jNet	78.6	37.9
Mnemonic-S	78.5	46.6
ReasoNet-S	78.2	39.4
MPCM-S	77.0	40.3
SEDT-S	76.9	33.9
RaSOR	76.2	39.5
BiDAF-S	75.5	34.3
Match-E	75.4	29.4
Match-S	71.4	27.3
DCR	69.4	37.8
Logistic	50.4	23.2

SQuAD adversarial testing

System	Original Rank	Adversarial Rank
ReasoNet-E	1	5
SEDT-E	2	10
BiDAF-E	3	12
Mnemonic-E	4	2
Ruminating	5	9
jNet	6	7
Mnemonic-S	7	1
ReasoNet-S	8	5
MPCM-S	9	3
SEDT-S	10	13
RaSOR	11	4
BiDAF-S	12	11
Match-E	13	14
Match-S	14	15
DCR	15	8
Logistic	16	16

NLI adversarial testing

Premise	Relation	Hypothesis
A turtle danced.	entails	A turtle moved.
Every reptile danced.	neutral	A turtle ate.
Some turtles walk.	contradicts	No turtles move.

NLI adversarial testing

	Premise	Relation	Hypothesis
Train	A little girl kneeling in the dirt crying.	entails	A little girl is very sad.
Adversarial		entails	A little girl is very unhappy.

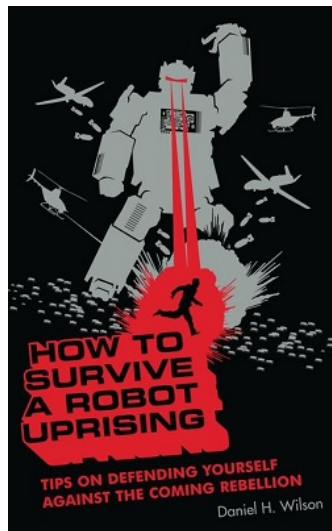
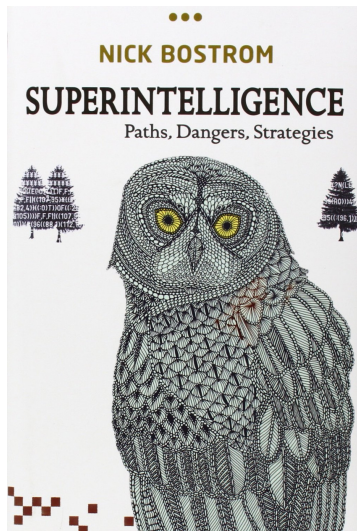
Glockner et al. 2018

NLI adversarial testing

	Premise	Relation	Hypothesis
Train	A woman is pulling a child on a sled in the snow.	entails	A child is sitting on a sled in the snow.
Adversarial	A child is pulling a woman on a sled in the snow.	neutral	

Nie et al. 2019

Two perspectives



Why is this all so difficult?



Where is **Black Panther** playing in **Mountain View**?

Black Panther is playing at the Century 16 Theater.

When is **it** playing **there**?

It's playing at 2pm, 5pm, and 8pm.

OK. I'd like 1 **adult** and 2 **children** for **the first show**.
How much would **that** cost?



Need **domain knowledge**, **discourse knowledge**, **world knowledge**

Our perspective

- This is the most exciting moment ever in history for doing NLU!
- In academia, there's been a resurgence of interest in NLU (after a long winter).
- In industry, there's been an explosion in products and services that rely on NLU.
- Systems are impressive, but show their weaknesses quickly.
- NLU is far from solved – big breakthroughs lie in the future.

Assignments, bakeoffs, and projects

1. A golden age for NLU
2. A peek behind the curtain
- 3. Assignments, bake-offs, and projects**
4. Course mechanics

High-level summary

Topics

1. Vector-space models
2. Sentiment analysis
3. Contextual word representations
4. Grounded language generation
5. Relation extraction
6. NLI
7. NLU and information retrieval
8. Adversarial testing
9. Methods and metrics

Assignments/bakeoffs

1. Word relatedness
2. Cross-domain sentiment analysis
3. Generating color descriptions in context

Final projects

1. Literature review
2. Experiment protocol
3. Final paper

Assignments and bakeoffs

1. There are three regular assignments.
2. Each assignment culminates in a bakeoff: an informal competition in which you enter your original model.
3. The assignments ask you to build baseline systems to inform your own model design, and to build your original model.
4. The assignments earn you 9 of the 10 points. All bakeoff entries earn the additional point.
5. Winning bakeoff entries earn extra credit.
6. Rationale for all this: exemplify best practices for NLU projects. (Let us know where we're not living up to this!)

Assign/Bakeoff: Word relatedness

	:)	:/	:D	:	;p	abandon	abc	ability	able	...
:)	74	1	0	0	0	1	0	2	2	
:/	1	306	0	0	0	0	0	0	17	
:D	0	0	16	0	0	0	6	1	1	
:	0	0	0	120	0	0	0	1	9	
;p	0	0	0	0	516286	0	0	0	0	...
abandon	1	0	0	0	0	370	24	65	235	
abc	0	0	6	0	0	24	7948	77	291	
ability	2	0	1	1	0	65	77	4820	1807	
able	2	17	1	9	0	235	291	1807	14328	
:					:					

Assign/Bakeoff: Word relatedness

Reweighting

probabilities
length norm.
TF-IDF
O/E
PMI
Positive PMI
⋮

Assign/Bakeoff: Word relatedness

Reweighting

probabilities
length norm.
TF-IDF
O/E
PMI
Positive PMI
⋮

Dimensionality reduction

LSA
GloVe
word2vec
autoencoders
⋮

Assign/Bakeoff: Word relatedness

Reweighting

probabilities
length norm.
TF-IDF
O/E
PMI
Positive PMI
⋮

Dimensionality reduction

LSA
GloVe
word2vec
autoencoders
⋮

Vector comparison

Euclidean
Cosine
Dice
KL
⋮

Assign/Bakeoff: Word relatedness

Reweighting

probabilities
length norm.
TF-IDF
O/E
PMI
Positive PMI
⋮

Dimensionality reduction

LSA
GloVe
word2vec
autoencoders
⋮

Vector comparison

Euclidean
Cosine
Dice
KL
⋮

(and BERT too, if you wish!)

Assign/Bakeoff: Word relatedness

sun	sunlight	0.9
automobile	car	0.95
river	water	0.8
food	gull	0.4
gate	hotel	0.45
dessert	head	0.01
born	hockey	0.01

abandon	soldier	?
about	wandering	?
abstract	moon	?
abstract	rally	?
abundance	wealth	?

Assign/Bakeoff: Cross-domain sentiment

- Stanford Sentiment Treebank (movie review sentences) with positive/negative/neutral labels (SST-3)
- Restaurant Review Sentences (RRS): A new (unreleased) dev/test split for positive/negative/neutral sentiment

Assign/Bakeoff: Cross-domain sentiment

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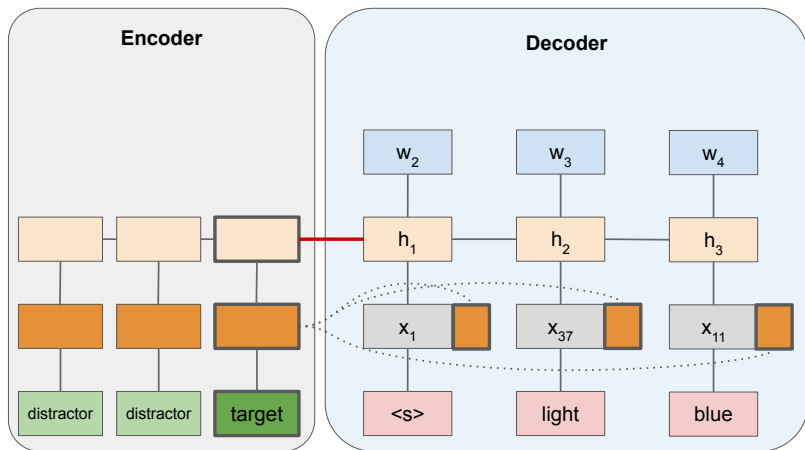
Train	Dev	Bakeoff test
SST-3 train	SST-3 dev	SST-3 test
⋮	RRS dev	RRS test
	⋮	

Assign/Bakeoff: Contextual color describers

Context			Utterance
			blue
			The darker blue one
			dull pink not the super bright one
			Purple
			blue

Monroe et al. 2017, 2018

Assign/Bakeoff: Contextual color descriptors



Monroe et al. 2017, 2018

A note on grading original systems

All the homeworks culminate in an “original system” question that becomes your bakeoff entry. Here are the basic guidelines we will adopt for grading this work

1. Any system that performs extremely well on the bakeoff data will be given full credit, even systems that are very simple. We can't argue with success according to our own metrics!
2. Systems that are very creative and well-motivated will be given full credit even if they do not perform well on the bakeoff data. We want to encourage creative exploration!
3. Other systems will receive less than full credit, based on the judgment of the teaching team. The specific criteria will vary based on the nature of the assignment. Point deductions will be justified in feedback.

Project work

1. The second half of the course is devoted to projects.
2. The associated lectures, notebooks, and readings are focused on methods, metrics, and best practices.
3. The assignments are all project-related; details are available at the course website:
 - a. Literature review
 - b. Experiment protocol
 - c. Final paper
4. Exceptional final projects from past years (access restricted):
<https://web.stanford.edu/class/cs224u/restricted/past-final-projects/>
5. Lots of guidance on projects:
<https://github.com/cgpotts/cs224u/blob/master/projects.md>

Course mechanics

1. A golden age for NLU
2. A peek behind the curtain
3. Assignments, bake-offs, and projects
- 4. Course mechanics**

Crucial course locations

Website

<https://web.stanford.edu/class/cs224u/>

Code repository

<https://github.com/cgpotts/cs224u/>

Discussion forum

<https://us.edstem.org/courses/326/discussion/>

Gradescope

For submitting work; details sent out soon.

Teaching team

cs224u-spr2021-staff@lists.stanford.edu

Components

Quizzes	5%
Homeworks and bakeoffs	40%
Literature review	10%
Experimental protocol	15%
Final project paper	30%

An all-video course for 2021

CS224u will be a fully online course for the entire quarter:

- Core course content in screencasts on Panopto and linked from the homepage, with accompanying Jupyter notebook for hands-on work.
- After today, class meetings will be optional open discussions and/or spaces for you to work in breakout rooms, with the teaching team there to help.
- Office hours will be by video.
- Continuous evaluation: three assignments, four online quizzes, and project work.

Tutorials

All in the course Github repo and linked from the course site:

- `setup.ipynb`
- `tutorial_jupyter_notebooks.ipynb`
- `tutorial_numpy.ipynb`
- `tutorial_pytorch.ipynb`

Quizzes

1. Quiz 0 is on course requirements and related details. The sole purpose of the quiz is to create a clear incentive for you to study the website and understand your rights and obligations.
2. Quizzes 1–4 create a course-related incentive for individual students to study the material beyond what is required for the more free-form and collaborative assignments.
3. All quizzes are open notes, open book, etc., but no collaboration is permitted.

AWS credits

1. Thanks to AWS Educate, we can provide every enrolled student with a \$100 AWS credit.
2. All members of winning bakeoff teams will receive additional \$100 credits as prizes.
3. If you haven't used AWS before:
 - ▶ Plan ahead to make sure that you are able to claim the kind of machine you want.
 - ▶ **Get your account set up so that you cannot be billed beyond your credits.**
4. This is the only official cloud support for this course. Feel free to use other providers and post questions about them to discussion forum, but the team cannot guarantee support for them.

For next time

1. Get your computing environment set up using `setup.ipynb`.
2. Make sure you're in the discussion forum. If not, follow the link given at the homepage for our course Canvas.
3. Consider doing Quiz 0 as a way of getting to know your rights and obligations for this course.
4. Start working with `vsm_01_distributional.ipynb`. If this material is new to you, consider watching the associated screencasts (linked from the course site).
5. For corresponding with the teaching team:
cs224u-spr2021-staff@lists.stanford.edu

Wrap-up

1. This is the most exciting moment ever in history for doing NLU!
2. This course will give you **hands-on** experience with a wide range of challenging NLU problems.
3. A mentor from the teaching team will guide you through the project assignments – there are many examples of these projects becoming important publications.
4. Central goal: to make you the best – most insightful and responsible – NLU researcher and practitioner wherever you go next.

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