

Introduction and course overview

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Stanford Linguistics

CS 224U: Natural language understanding
April 6



Welcome



Bill MacCartney

COVID-19 accommodations



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

- The class meetings will be video seminars (discussion encouraged!), which will be recorded and put on Canvas.
- Office hours will also be by video using a queue system.
- We will rely even more than usual on our discussion forum to exchange ideas, address challenges, and collaborate with each other.

COVID-19 and NLU

- CORD-19:

<https://pages.semanticscholar.org/coronavirus-research>

- Elsevier Coronavirus Research Repository:

<https://coronavirus.lscience.com/>

- Coronavirus Tweets:

<https://www.kaggle.com/smld80/coronavirus-covid19-tweets>

- CS472 Data science and AI for COVID-19

<https://sites.google.com/view/data-science-covid-19>

- Google's COVID-19 Public Datasets

<https://console.cloud.google.com/marketplace/details/bigquery-public-datasets/covid19-public-data-program>

Plan for today

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

Advances in NLU

1. A brief history of NLU
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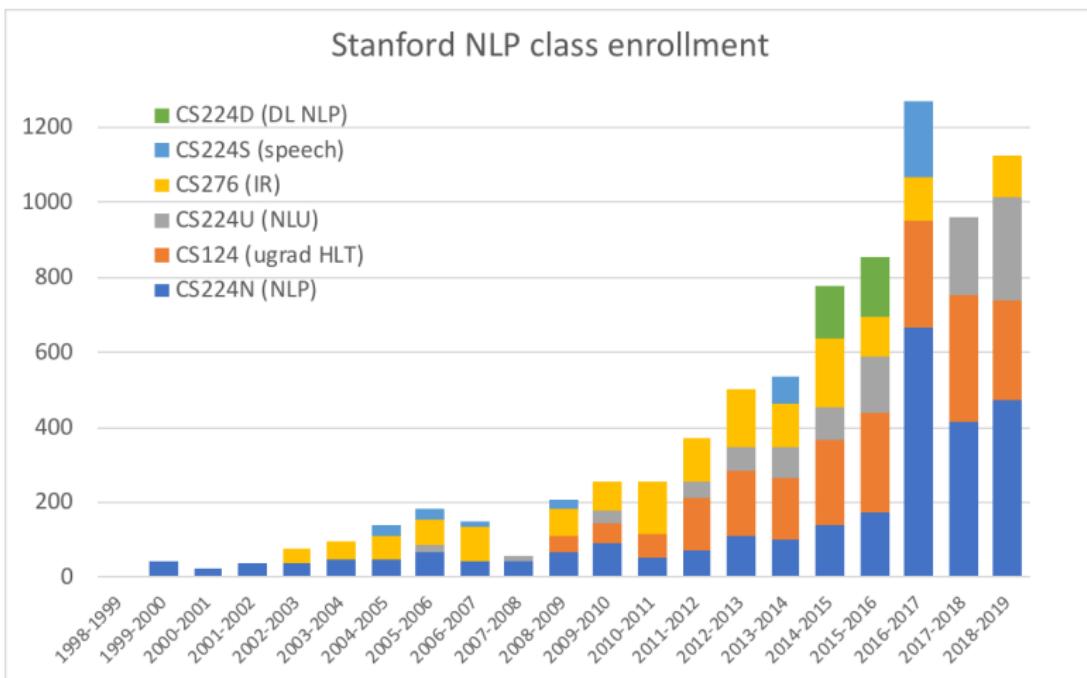
A brief history of NLU approaches

- 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 (**LRLDG**) systems; restricted applications.
- Mid-1990s: Machine learning revolution in NLP leads to a decrease in NLU work.
- Late 2000s: **LRLDG** systems re-emerge, now with *learning*.
- Mid-2010s: NLU returns to center stage, with deep learning the most prevalent set of techniques. **LRLDG** systems go into decline.
- 2020–: [predictions?]

A brief history of NLU technologies

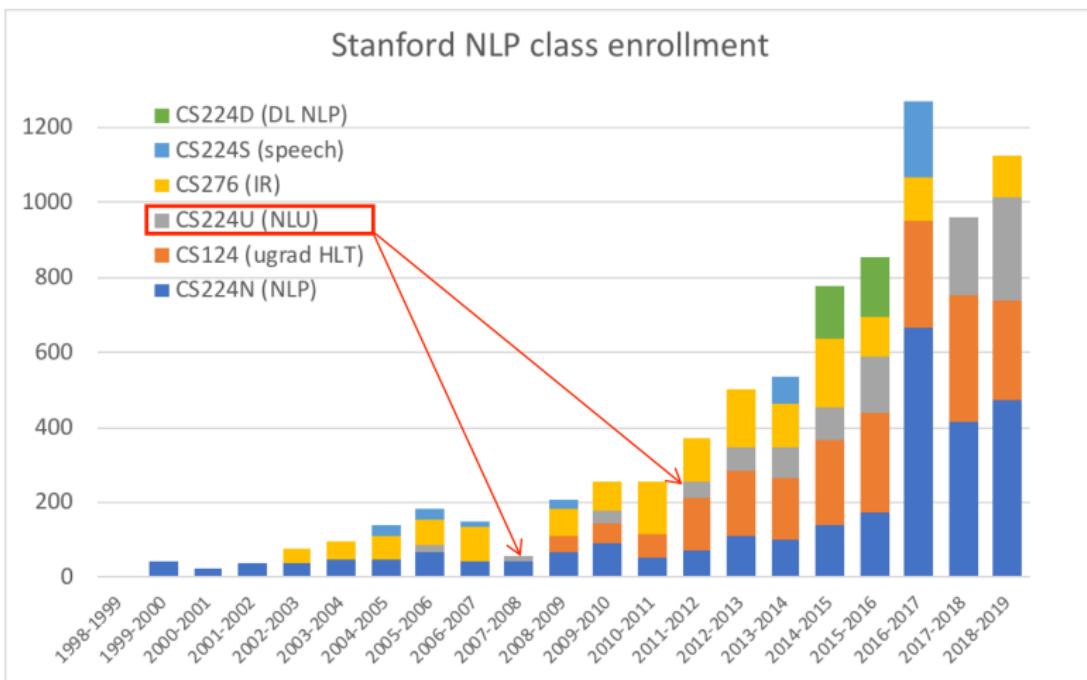
- 1966: Eliza
- 1988: Latent Semantic Analysis patent
- January 2011: IBM Watson beats Jeopardy! champions
- October 2011: Apple Siri launches in beta
- April 2014: Microsoft Cortana demoed
- November 2014: Amazon Alexa
- May 2016: Google Assistant

The history of CS224u enrollments



h/t @StanfordNI P

The history of CS224u enrollments



h/t @StanfordNI P

The history of CS224u topics

2012

1. WordNet
2. Word sense disambiguation
3. Vector-space models
4. Dependency parsing for NLU
5. Relation extraction
6. Semantic role labeling
7. Semantic parsing
8. Textual inference
9. Sentiment analysis
10. Semantic composition with vectors
11. Text segmentation
12. Dialogue

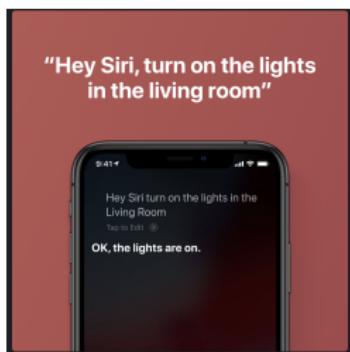
2020

1. Vector-space models
2. Sentiment analysis
3. Relation extraction
4. Natural Language Inference
5. Grounding
6. Contextual word representations
7. Adversarial testing
8. Methods and metrics

A golden age for NLU

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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

Translation

Text Documents

DETECT LANGUAGE ENGLISH SPANISH FRENCH ^ ↔ ENGLISH SPANISH ARABIC v

← Search languages

✓ Detect language + Czech Hebrew Latin Portuguese Tajik

ENGLISH - DETECTED ENGLISH SPANISH FRENCH v ↔ FRENCH ENGLISH SPANISH v

When asked about this, an official of the American administration replied: "The United States is not conducting electronic surveillance aimed at offices of the World Bank and IMF in Washington." x Interrogé à ce sujet, un responsable de l'administration américaine a répondu: "Les États-Unis n'effectuent pas de surveillance électronique à destination des bureaux de la Banque mondiale et du FMI à Washington".

194/5000

Bulgarian	Georgian	Kannada
Catalan	German	Kazakh
Cebuano	Greek	Khmer
Chichewa	Gujarati	Korean
Chinese	Haitian Creole	Kurdish (Kurmanji)
Corsican	Hausa	Kyrgyz
Croatian	Hawaiian	Lao

Interrogé sur le sujet, un responsable de l'administration américaine a répondu: "les Etats-Unis ne mènent pas de surveillance électronique visant les sièges de la Banque mondiale et du FMI à Washington".

Search, and way beyond search

Google

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

The Google logo is displayed in its characteristic multi-colored letters.A search bar containing the word "parasite".

Search, and way beyond search

Google

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))
```

Stanford Question Answering Dataset (SQuAD)

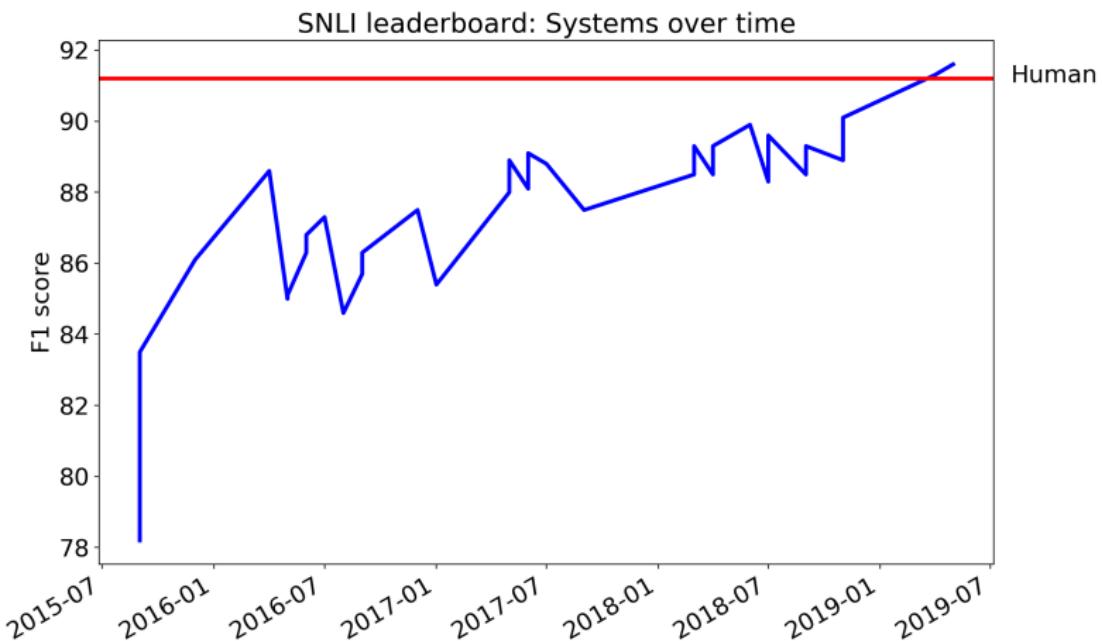
Leaderboard

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-SinTic	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

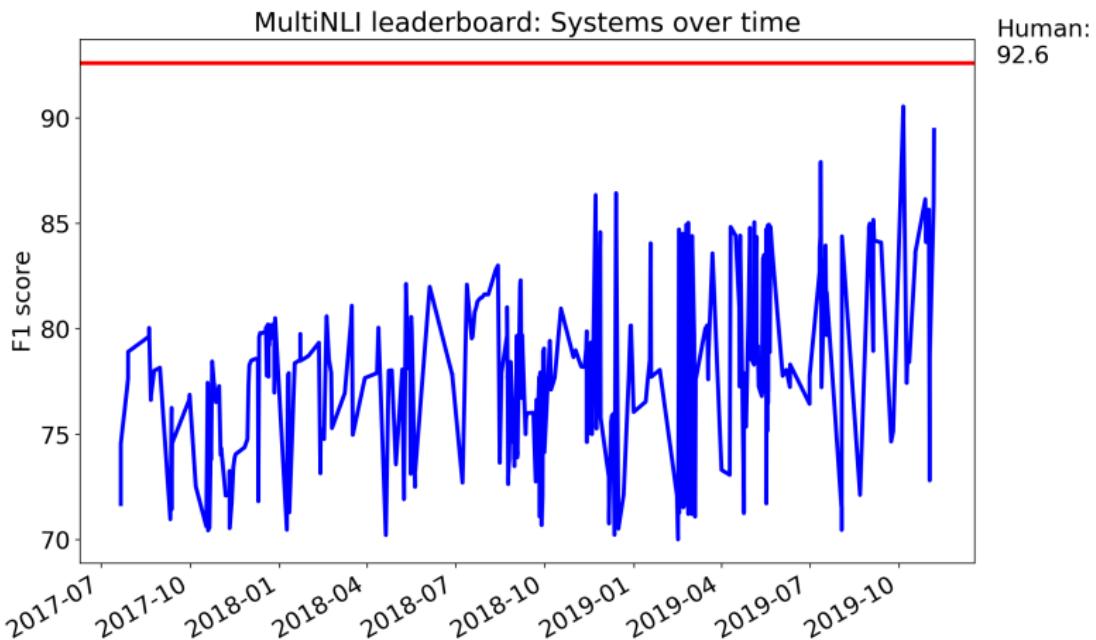
Rajpurkar et al. 2016

Stanford Natural Language Inference (SNLI)



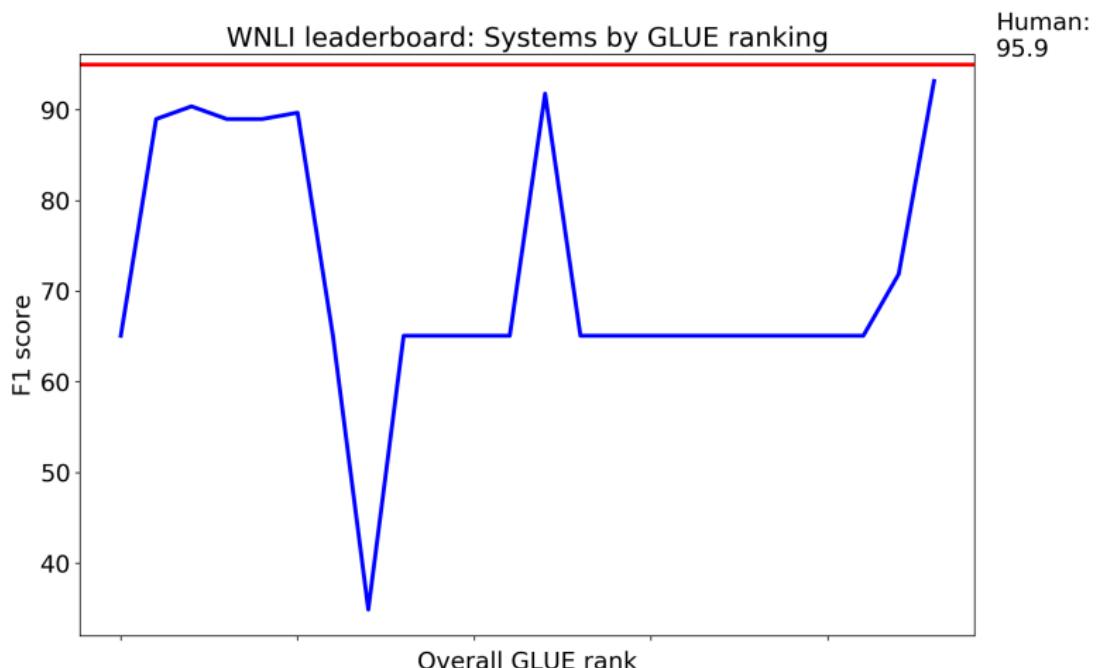
Bowman et al. 2015

MultiNLI



Williams et al. 2018

WinogradNLI



Wang et al. 2018

Forecasting

wisdom formulating intelligent wisdom forecasting contingent wisdom formulating accurate estimations mapping prob sign in or register (\$?)

Metaculus mapping the future delivering probable contingencies composing contingent insights aggregating probable u
rating probable predictions aggregating definitive contingencies delivering defin Find Questions Categories Rankings

Question jump to a random question f t g

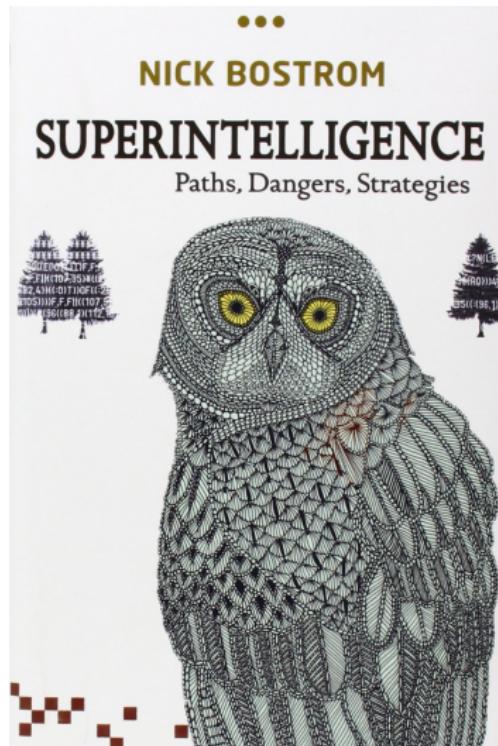
 111 predictions 80% median

By May 2020, will a single language model obtain an average score equal to or greater than 90% on the SuperGLUE benchmark?
Created by ghab. Opened on Aug 9, 2019.
partnered with AI Index
Cross-posted on Metaculus AI Forecasting.

8 interested Open closes Dec 30, 2019

The SuperGlue Benchmark measures progress in language understanding tasks.
The original benchmark, GLUE (General Language Understanding Evaluation) is a collection of language understanding tasks built on established existing datasets and selected to cover a diverse range of dataset sizes, text genres, and degrees of difficulty. The tasks were

Human is 89.8. Current top score: 89.3



A peek behind the curtain

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Translation: Garbage in, fluent text out?

The screenshot shows a machine translation interface. On the left, under the "HAWAIIAN - DETECTED" tab, there is a block of Hawaiian text: "oeuioo aeeui oauieo ui ieuo oioeuaiae aea uaeiaeio uuaaeaoieooiaeaoioauuuu oe aua u oeuueeiieiaeaeiioie eooiu leoaoilaoeluuoi u eauuioeoao i i". To the right of this text is a large "X" icon. In the center, under the "ENGLISH" tab, is the translated text: "The main character can be used as a result of one of the flags in the cycle when it was used to specify the current value of the line." Below the text are several icons: a speaker icon, a progress bar showing "149/5000" with a pencil icon, another speaker icon, and three small icons for copy, edit, and share.

Does Anne Hathaway News Drive Berkshire Hathaway's Stock?

MAR 18 2011, 10:50 AM ET 28

[in Share](#)

257

[Tweet](#)

471

[+1](#)

7

[f 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.



Misleading automatic curation

The image displays two separate Google search results side-by-side, illustrating how search engines can present misleading or biased results.

Search 1: King of United States

Google search bar: King of United States

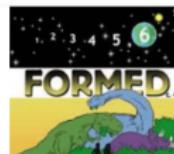
Web results:

- All Hail King **Barack Obama**, Emperor Of The United States Of America! 

Search 2: What happened to dinosaurs

Google search bar: What happened to dinosaurs

Web results:

- All Hail King B www.breitbart.com
- Dinosaurs are used more than almost anything else to indoctrinate children and adults in the idea of millions of years of earth history. However, the Bible gives us a framework for explaining **dinosaurs** in terms of thousands of years of history, including the mystery of when they lived and **what happened** to them. Oct 25, 2007 
- [What Really Happened to the Dinosaurs? | Answers in ...](https://answersingenesis.org/dinosaurs/.../dinosaurs.../wha...)
https://answersingenesis.org/dinosaurs/.../dinosaurs.../wha... Answers in Genesis

<https://searchengineland.com>

Bias perpetuation

Gender Bias in Contextualized Word Embeddings

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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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Jia and Liang 2017

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Jia and Liang 2017

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Answer

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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 entails	A little girl is very sad. A little girl is very unhappy.
Adversarial			

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.
	A child is pulling a woman on a sled in the snow.	neutral	

SIRI on The Colbert Show

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

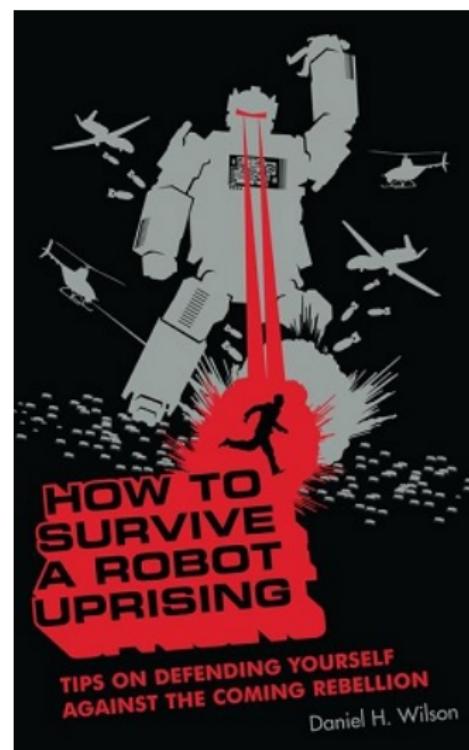
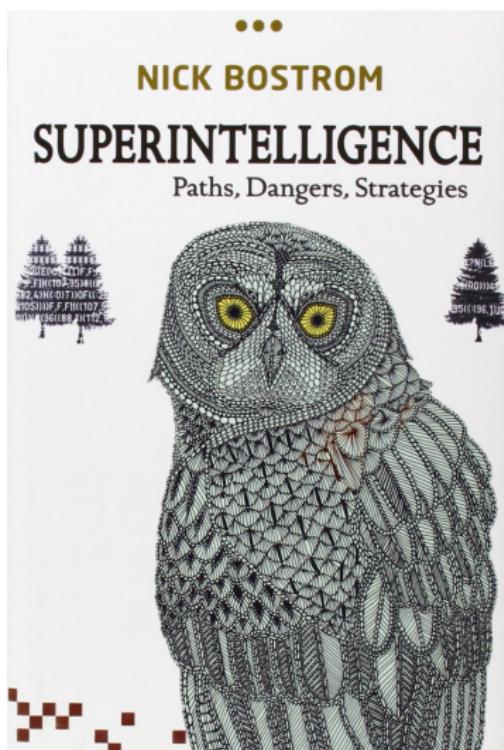
Siri: What kind of place are you looking for? Camera stores or churches?
[...]

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."



Two perspectives



Levesque (2013)

- “This paper is about the science of AI. Unfortunately, the technology of AI that gets all the attention.”
- “AI is the study of intelligent behaviour in computational terms.”
- “Should baseball players be allowed to glue small wings onto their caps?”
- “We need to return to our roots in Knowledge Representation and Reasoning for language and from language.”

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.

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**

Assignments, bake-offs, and projects

1. A brief history of NLU
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High-level summary

Topics

1. Vector-space models
2. Sentiment analysis
3. Relation extraction
4. NLI
5. Grounding
6. Contextual word representations
7. Adversarial testing
8. Methods and metrics

Assignments/bake-offs

1. Word similarity
2. Relation extraction with distant supervision
3. Word-level entailment
4. Generating color descriptions in context

Final projects

1. Literature review
2. Experiment protocol
3. Short video presentation
4. Final paper

Assignments and bake-offs

1. There are four regular assignments. The first is due April 20, and they are weekly after that.
2. Each assignment culminates in a bake-off: 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 bake-off entries earn the additional point.
5. Winning bake-off 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/Bake-off: Word similarity

	against	age	agent	ages	ago	agree	ahead	ain't	air	aka	al
against	2003	90	39	20	88	57	33	15	58	22	24
age	90	1492	14	39	71	38	12	4	18	4	39
agent	39	14	507	2	21	5	10	3	9	8	25
ages	20	39	2	290	32	5	4	3	6	1	6
ago	88	71	21	32	1164	37	25	11	34	11	38
agree	57	38	5	5	37	627	12	2	16	19	14
ahead	33	12	10	4	25	12	429	4	12	10	7
ain't	15	4	3	3	11	2	4	166	0	3	3
air	58	18	9	6	34	16	12	0	746	5	11
aka	22	4	8	1	11	19	10	3	5	261	9
al	24	39	25	6	38	14	7	3	11	9	861

Assign/Bake-off: Word similarity

Reweighting

probabilities

length norm.

TF-IDF

O/E

PMI

Positive PMI

:

Assign/Bake-off: Word similarity

Reweighting

probabilities
length norm.

TF-IDF

O/E

PMI

Positive PMI

:

Dimensionality reduction

LSA

GloVe

word2vec

autoencoders

:

Assign/Bake-off: Word similarity

Reweighting

probabilities
length norm.

TF-IDF

O/E

PMI

Positive PMI

:

Dimensionality reduction

LSA
GloVe
word2vec
autoencoders

:

Vector comparison

Euclidean
Cosine
Dice
KL

:

Assign/Bake-off: Word similarity

sun	sunlight	50
automobile	car	50
river	water	49
food	gull	20
gate	hotel	20
dessert	head	7
born	hockey	7

Assign/Bake-off: Word similarity

Dataset	Pairs	Task-type	Best score	Paper
WordSim-353	353	Relatedness	82.8	Speer et al. 2017
MTurk-771	771	Relatedness	81.0	Speer et al. 2017
MEN	3,000	Relatedness	86.6	Speer et al. 2017
SimVerb-3500-dev	500	Similarity	61.1	Mrkšić et al. 2016
SimVerb-3500-test	3,000	Similarity	62.4	Mrkšić et al. 2016

And two held-out datasets for bake-off assessment

Assign/Bake-off: Relation extraction

Obama was born in Honolulu, Hawaii

From 1964 to 1967, former President Barack Obama resided in Honolulu's Manoa neighborhood.

Barack Obama, the 44th president of the United States, was born on August 4, 1961 in Honolulu, Hawaii to Barack Obama, Sr., and Stanley Ann Dunham.

President Barack Obama holds hands with daughters Malia and Sasha during a family vacation in Honolulu.

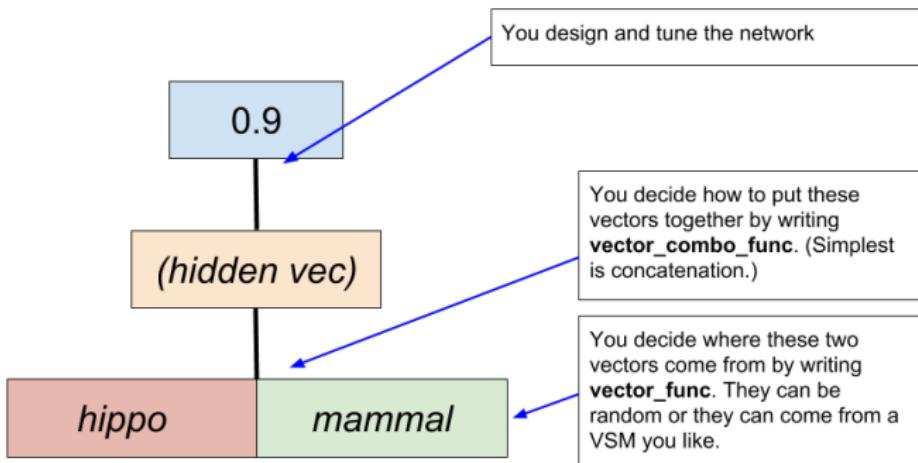
(**Barack Obama**
R
Honolulu)

Assign/Bake-off: Word-level entailment

Train		
turtle	animal	1
turtle	desk	0
ingredient	element	1
pain	joint	0
⋮		
Test		
dog	mammal	1
grenade	cycling	0
⋮		

Train and test have disjoint *vocabs*.

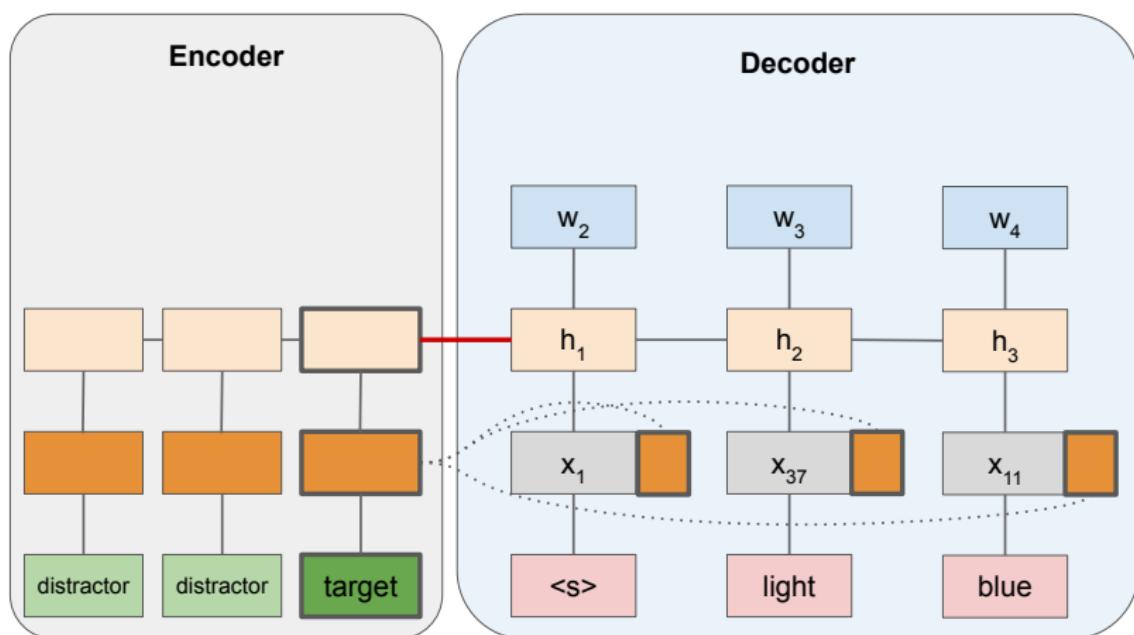
Assign/Bake-off: Word-level entailment



Assign/Bake-off: Contextual color descriptors

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

Assign/Bake-off: Contextual color describers



Monroe et al. 2017, 2018

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. Short video presentation
 - d. Final paper
4. Exceptional final projects (and some videos) from past years (access restricted):
[https://web.stanford.edu/class/cs224u/
restricted/past-final-projects/](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](https://github.com/cgpotts/cs224u/blob/master/projects.md)

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.
5. Next time: vector space models of meaning!

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