

AI for Signed Languages: Challenges and Opportunities

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NLP



Berkeley AI
Research

Outline

1. Quick intro to signed languages
2. Current AI progress and challenges
3. Our work: ASL STEM Wiki (dataset and model to support deaf STEM education)
4. Exciting future directions



Nice to meet you! (ASL)

Common misconceptions of signed languages

- ✗ It's just gestures for spoken language
- ✗ It's just hand gestures
- ✗ There's only 1 universal sign language
- ✗ It's slower than speaking

“Name”



American Sign Language



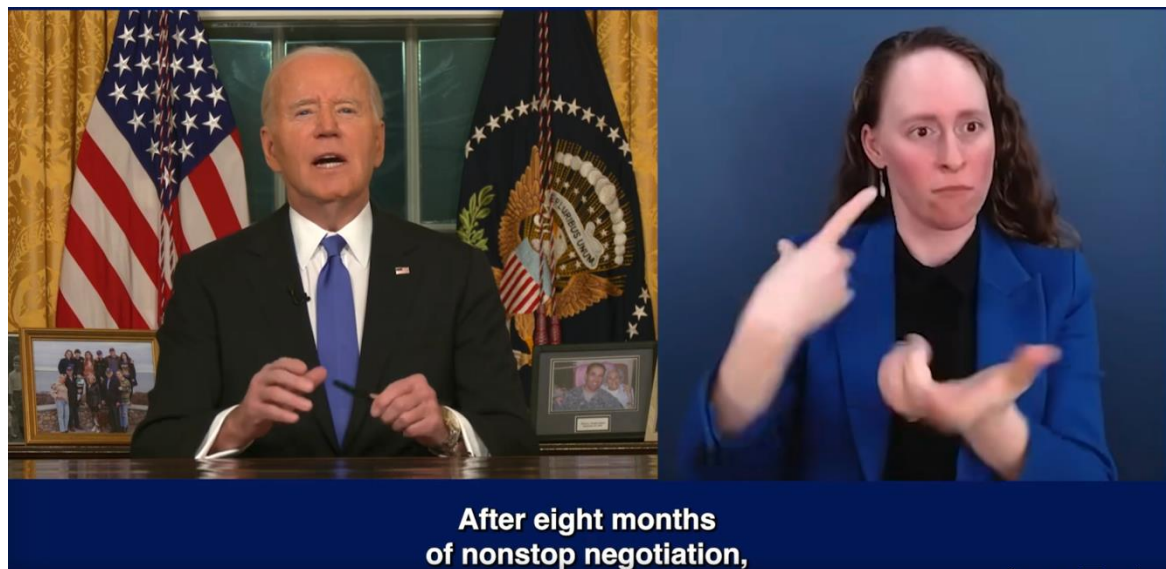
British Sign Language

Signed languages are crucial



- Only 30-40% of English speech can be lipread
- Cochlear implants do not provide complete access to spoken language
- Integral to Deaf culture

Why not just use subtitles / text?

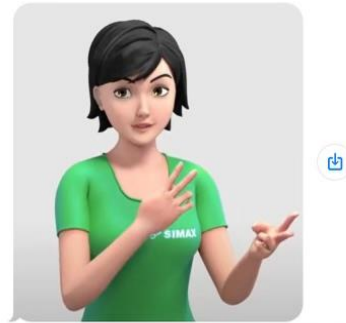


- Convey tone, emotion
- Literacy levels vary among signers
- Primary / most accessible language for many

Possible applications of AI



Translation



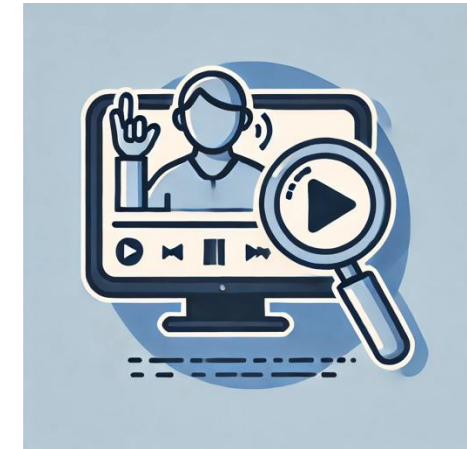
Chatbots



Smart assistants



Education



Information retrieval

Current progress in AI for signed languages

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- 101 papers between 2021-2023 (Desai et al., [2024](#))

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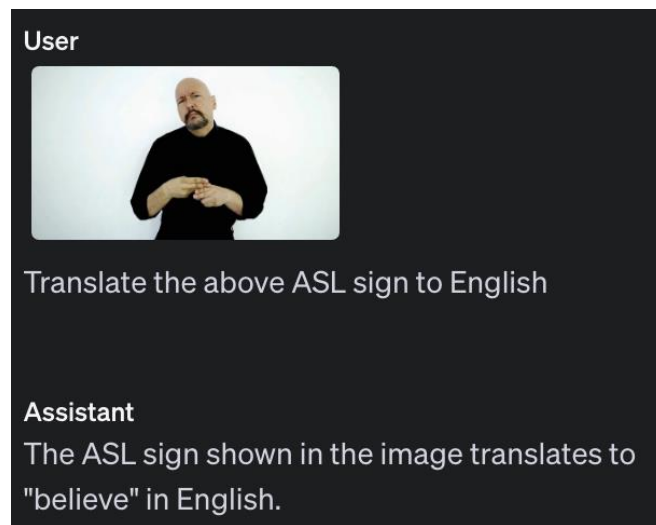
SignLLM
(Fang et al., 2024)

Current progress in AI for signed languages

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SignLLM
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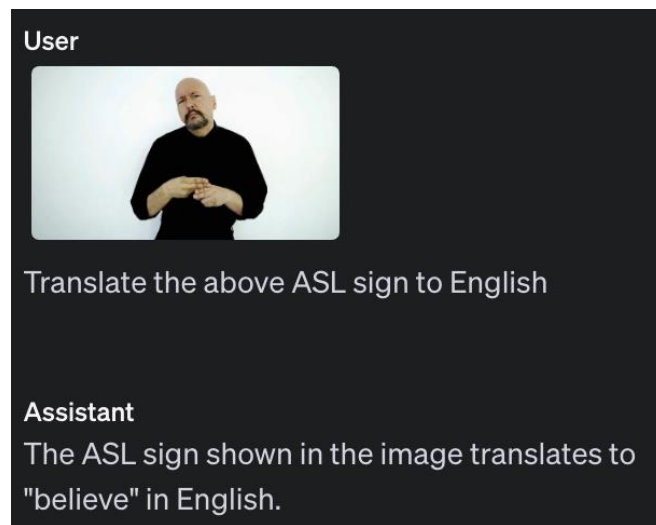
GPT-4o
(OpenAI, 2024)

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SignLLM
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GPT-4o
(OpenAI, 2024)



“Sign language gloves”

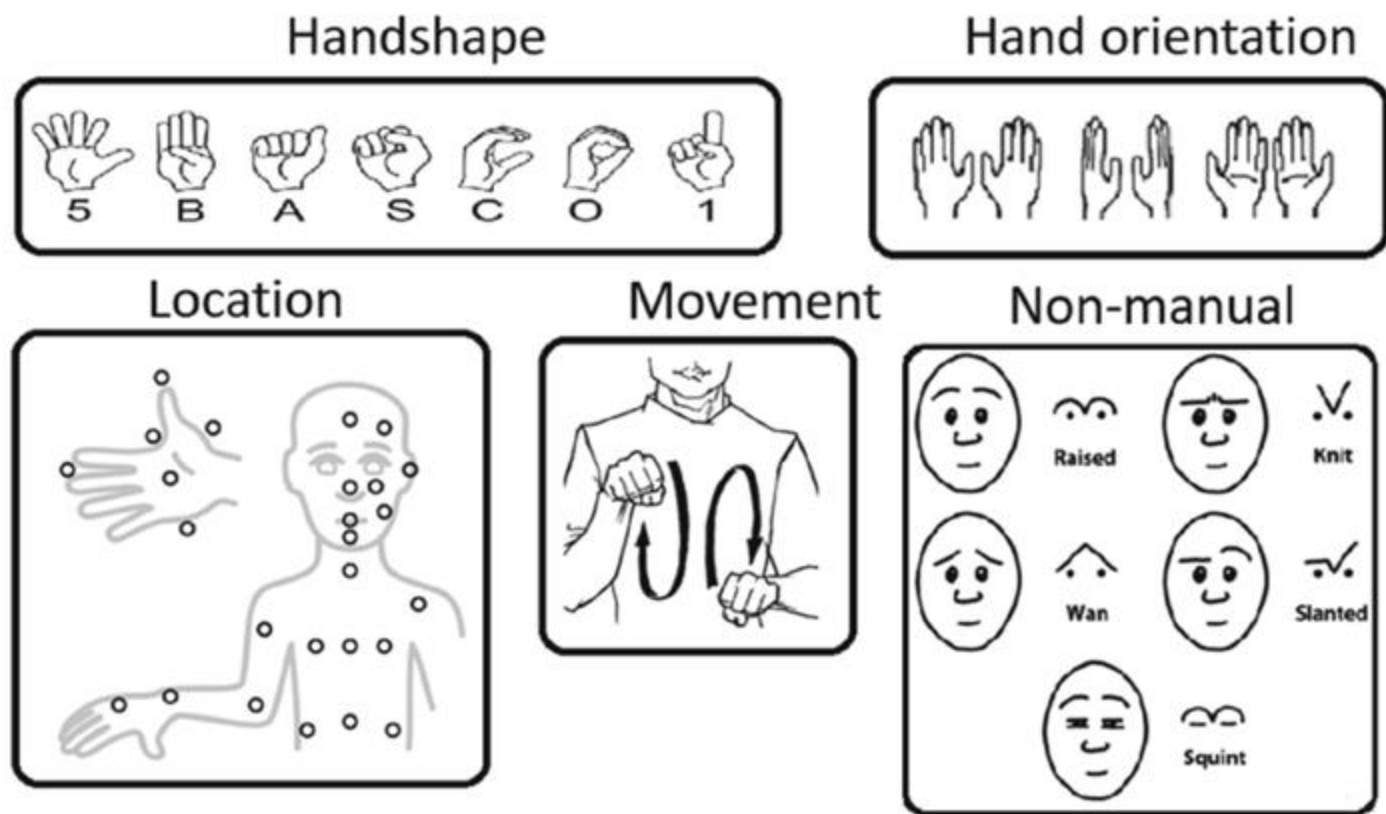
Challenge: data

- ~ 40 public datasets
 - Largest: ~1000 hours
- Gap between training data and target users
- 1 min of annotated data = 600 hours of collection
- Consent and privacy?



BOBSL dataset
(Albanie et al., 2021)

Challenge: simultaneous channels



5 phonological parameters of ASL

- Hands, face, body all express meaning
- Subtle, fine-grained visual signal
- Continuous, complex video modality

Challenge: spatial dependencies



Directional verbs in ASL

- Space expresses grammar, relationships, storytelling
- Pointing, eye gaze, head tilt, body shift, hand path
- Long spatial context
- Intentional vs. random motion?

Challenge: Deaf-centric design

April 12, 2016

UW undergraduate team wins \$10,000 Lemelson-MIT Student Prize for gloves that translate sign language



Wearable-tech glove translates sign language into speech in real time

The device is inexpensive, flexible and highly durable, UCLA bioengineers say

Matthew Chin

June 29, 2020

Hand-ear co-ordination: Interactive glove translates sign language into speech

Infinity Glove, a Lebanon-based start-up, seeks to help translate sign-language into speech by using a high tech glove solution. Cody Combs / The National



Cody Combs

Feb 21, 2024



Listen In English



Listen in Ar

Powered by automated trans

Challenge: Deaf-centric design

Why Sign-Language Gloves Don't Help Deaf People

Wearable technologies that claim to translate ASL overlook the intricacies of the language, as well as the needs of signers.

By Michael Erard



Sign Language Translating Devices Are Cool. But Are They Useful?



Emily Matchar

Innovation Correspondent

February 26, 2019

News & Views | Published: 15 July 2020

WEARABLE TECHNOLOGY

Do deaf communities actually want sign language gloves?

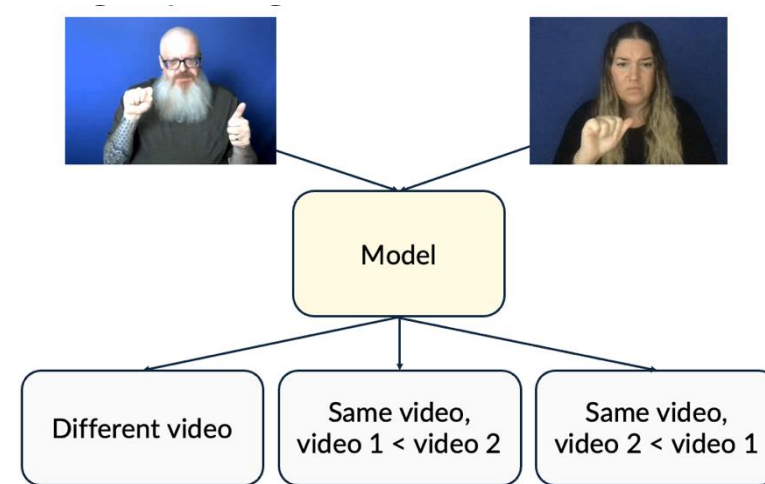
[Joseph Hill](#) 

Addressing these challenges: ASL STEM Wiki



Dataset to support
DHH students in STEM

Addressing these challenges: ASL STEM Wiki



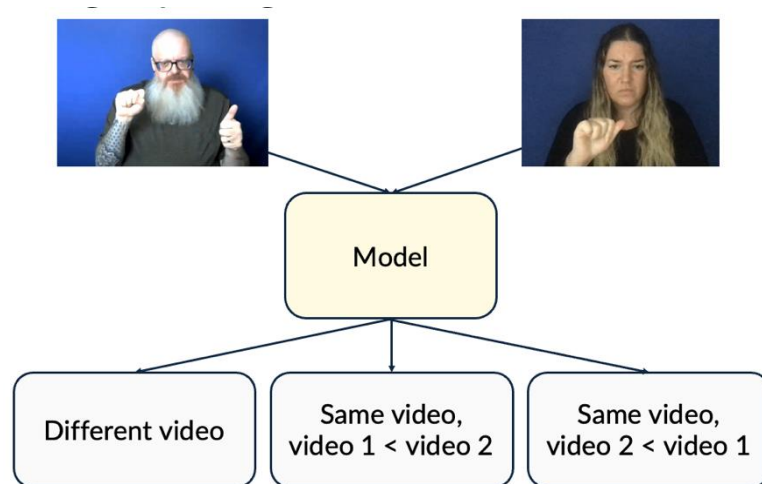
Dataset to support
DHH students in STEM

Self-supervised sign
language modeling

Addressing these challenges: ASL STEM Wiki

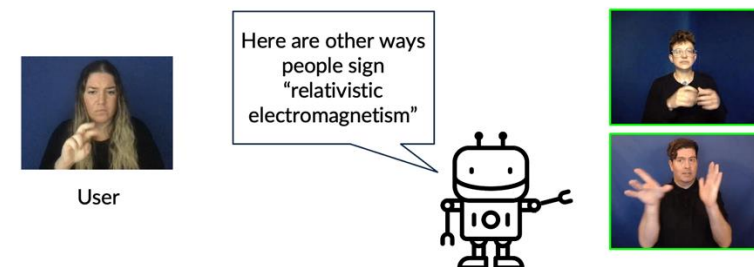


Dataset to support
DHH students in STEM



Self-supervised sign
language modeling

Automatic sign suggestion



Tool to assist ASL interpreters



ASL STEM Wiki

Dataset and Benchmark for Interpreting STEM Articles

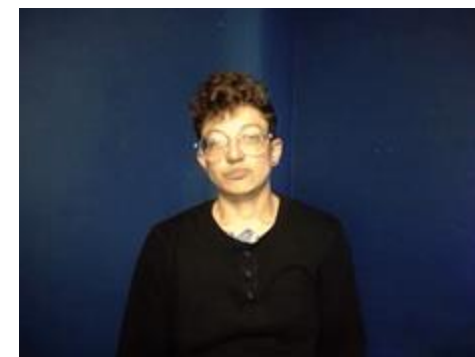
Kayo Yin, Chinmay Singh, Fyodor O. Minakov, Vanessa Milan

Hal Daumé III, Cyril Zhang, Alex X. Lu, Danielle Bragg



Barriers to STEM education for DHH students

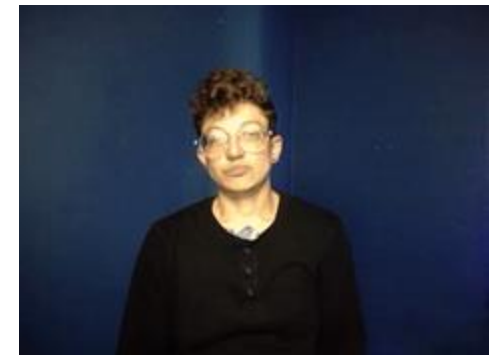
- ASL -> primary and most accessible language for many deaf and hard-of-hearing (DHH) students in the US



“Relativistic electromagnetism”

Barriers to STEM education for DHH students

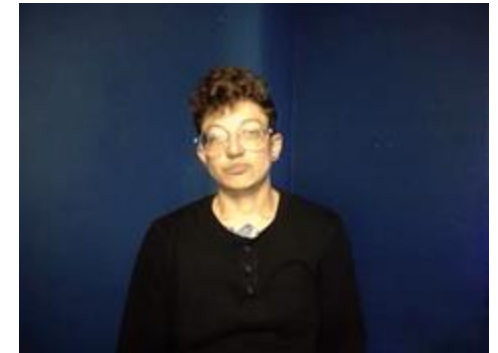
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- Deaf students score higher on science with direct instruction in ASL ([Kurz et al., 2015](#))



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Barriers to STEM education for DHH students

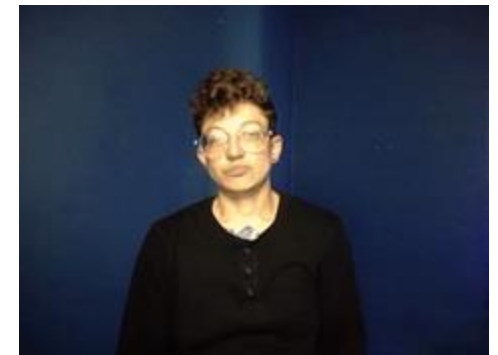
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- STEM resources in ASL are **scarce**



“Relativistic electromagnetism”

Barriers to STEM education for DHH students


- ASL -> primary and most accessible language for many deaf and hard-of-hearing (DHH) students in the US
- Deaf students score higher on science with direct instruction in ASL ([Kurz et al., 2015](#))
- STEM resources in ASL are **scarce**
- Lack of **standardized ASL signs** for technical words



“Relativistic electromagnetism”

ASL STEM Wiki

- 254 Wikipedia articles
 - Science, technology, mathematics, medicine, geography
- 300+ hours
- 37 certified ASL interpreters



Wiki Home [Having trouble?](#)

Photosynthesis

Having problems with this content? [Please let us know](#)

Article <https://en.wikipedia.org/wiki/Photosynthesis>

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0.0 Photosynthesis is a process used by plants and other organisms to convert light energy into chemical energy that can later be released to fuel the organisms' activities.

0.1 This chemical energy is stored in carbohydrate molecules, such as sugars, which are synthesized from carbon dioxide and water – hence the name photosynthesis, from the Greek *phōs*, "light", and *sunthesis*, "putting together".

0.2 In most cases, oxygen is also released as a waste product.

0.3 Most plants, most algae, and cyanobacteria perform photosynthesis; such organisms are called photoautotrophs.

0.4 Photosynthesis is largely responsible for producing and maintaining the oxygen content of the Earth's atmosphere, and supplies most of the energy necessary for life on Earth.

0.5 Although photosynthesis is performed differently by different species, the process always begins when energy from light is absorbed by proteins called reaction centres that contain green chlorophyll pigments.

0.6 In plants, these proteins are held inside organelles called chloroplasts, which are most abundant in leaf cells, while in bacteria they are embedded in the plasma membrane.

0.7 In these light-dependent reactions, some energy is used to strip electrons from suitable substances, such as water, producing oxygen gas.

0.8 The hydrogen freed by the splitting of water is used in the creation of two further compounds that serve as short-term stores of energy, enabling its transfer to drive other reactions: these compounds are reduced nicotinamide adenine dinucleotide phosphate (NADPH) and adenosine triphosphate (ATP), the "energy currency" of cells.

0.9 In plants, algae and cyanobacteria, long-term energy storage in the form of sugars is produced by a subsequent sequence of light-independent reactions called the Calvin cycle; some bacteria use different mechanisms, such as the reverse Krebs cycle, to achieve the same end.

0.10 Using the ATP and NADPH produced by the light-dependent reactions, the resulting compounds are then reduced and removed to form further carbohydrates, such as glucose.

0.11 The first photosynthetic organisms probably evolved early in the evolutionary history of life and most likely used reducing agents such as hydrogen or hydrogen sulfide, rather than water, as sources of electrons.

0.12 Cyanobacteria appeared later; the excess oxygen they produced contributed directly to the oxygenation of the Earth, which rendered the

00:01:350

Continuous Play

Videos

[mixey](#) 04-27-2022

Contributions

1. First dataset of continuous signing for STEM: **ASL STEM Wiki**
2. Linguistic analysis & appropriate use cases
3. New AI tool: **automatic sign suggestion**
4. New modeling technique: **contrastive learning** for signed language

Linguistic analysis – fingerspelling in ASL STEM Wiki

High rate of fingerspelling in ASL STEM Wiki



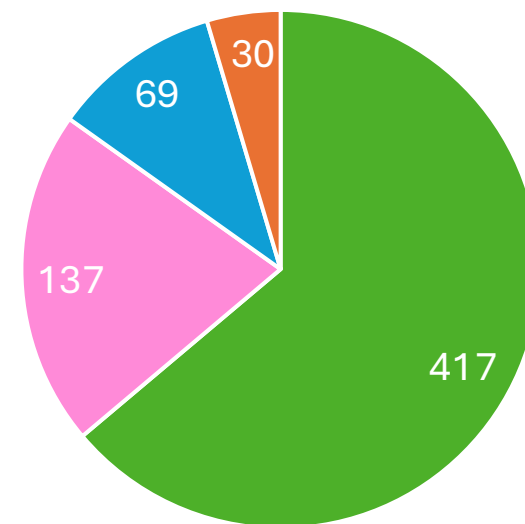
- **Fingerspelling:** spell out an English word using letter signs
- ~6.4% of ASL (Morford and MacFarlane, 2003)
- **~31.5%** of ASL STEM Wiki

“Relativistic electromagnetism”

High rate of fingerspelling in ASL STEM Wiki

- **63.9%** of fingerspelling is **STEM** words
- Interpreters often resort to fingerspelling when a technical sign is not known

Categories of fingerspelled words



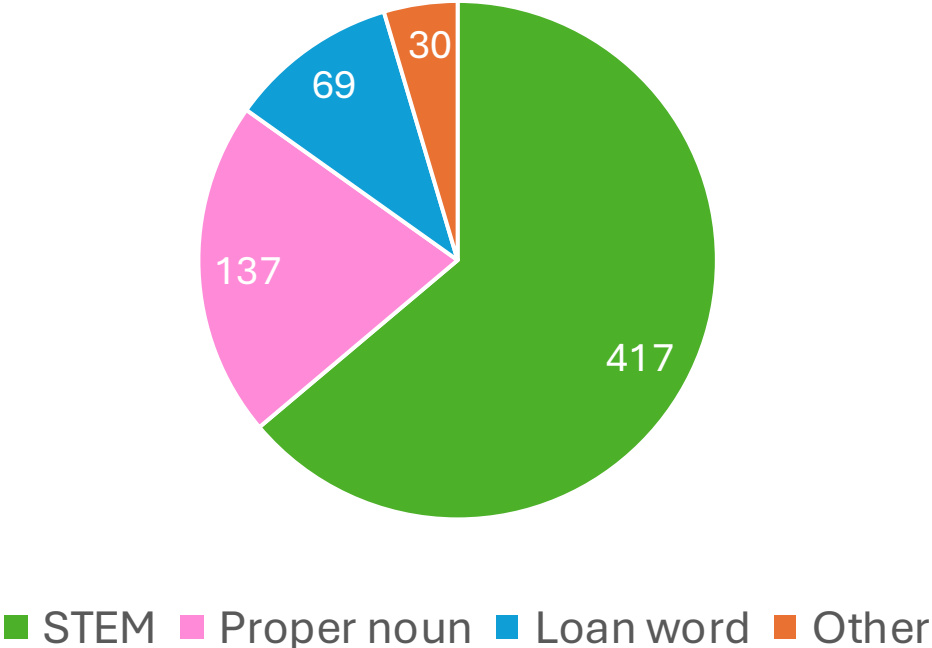
■ STEM ■ Proper noun ■ Loan word ■ Other

High rate of fingerspelling in ASL STEM Wiki

- 63.0% of the words in the ASL STEM Wiki are fingerspelled.
- “[Deaf] students prefer that terms either be signed in ASL, or signed and fingerspelled, as opposed to just fingerspelled.”

Development of American Sign Language Guidelines for K-12 Academic Assessments

Categories of fingerspelled words

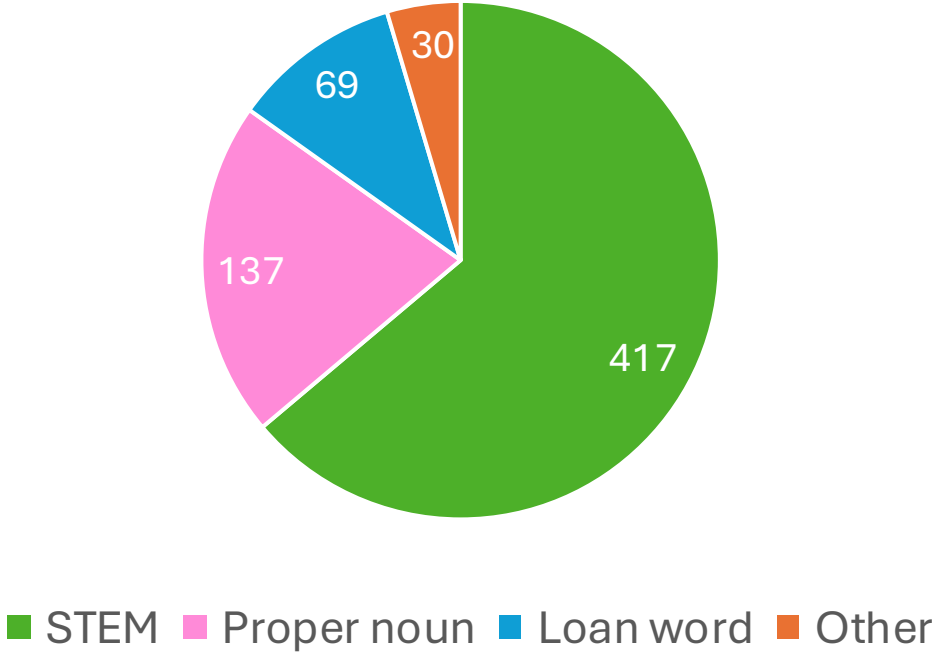


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Development of American Sign Language Guidelines for K-12 Academic Assessments

Categories of fingerspelled words



-> Use AI to address the high rate of fingerspelling in STEM

Automatic sign suggestion: task setup

Automatic sign suggestion



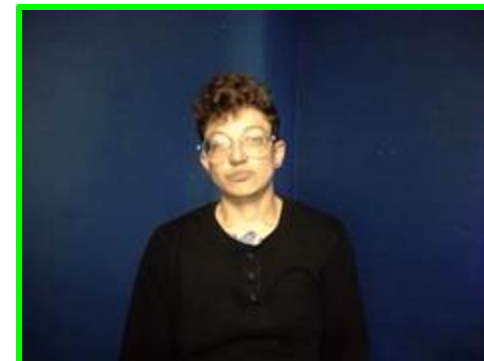
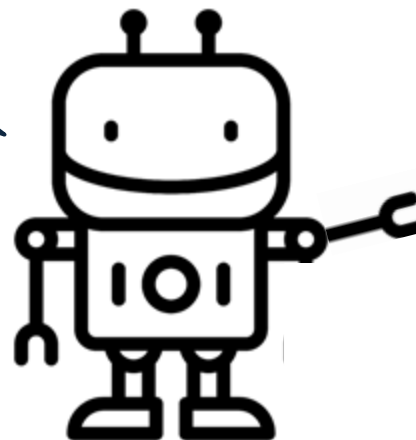
User

Automatic sign suggestion



User

Here are other ways
people sign
“relativistic
electromagnetism”

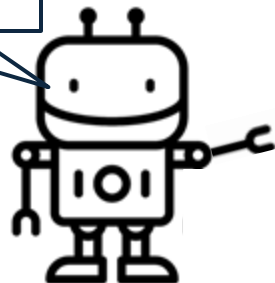


Automatic sign suggestion



User

Here are other ways
people sign
"relativistic
electromagnetism"



3 steps:

1. Fingerspelling detection
2. Fingerspelling alignment
3. Sign retrieval

Automatic sign suggestion

1. Fingerspelling detection
2. Fingerspelling alignment
3. Sign retrieval



Relativistic electromagnetism is a physical phenomenon due to Coulomb's law and Lorentz transformations.

1. Fingerspelling detection

Automatic sign suggestion

1. Fingerspelling detection
2. Fingerspelling alignment
3. Sign retrieval



Relativistic electromagnetism is a physical phenomenon due to Coulomb's law and Lorentz transformations.

1. Fingerspelling detection

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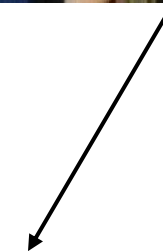
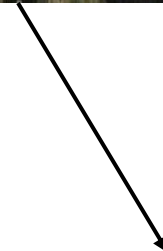


Relativistic electromagnetism is a physical phenomenon due to Coulomb's law and Lorentz transformations.

2. Fingerspelling alignment

Automatic sign suggestion

1. Fingerspelling detection
2. Fingerspelling alignment
3. Sign retrieval



Relativistic electromagnetism is a physical phenomenon due to *Coulomb's* law and *Lorentz* transformations.

2. Fingerspelling alignment

Automatic sign suggestion

1. Fingerspelling detection
2. Fingerspelling alignment
3. Sign retrieval

Relativistic electromagnetism

3. Sign retrieval

Automatic sign suggestion

1. Fingerspelling detection
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Relativistic electromagnetism



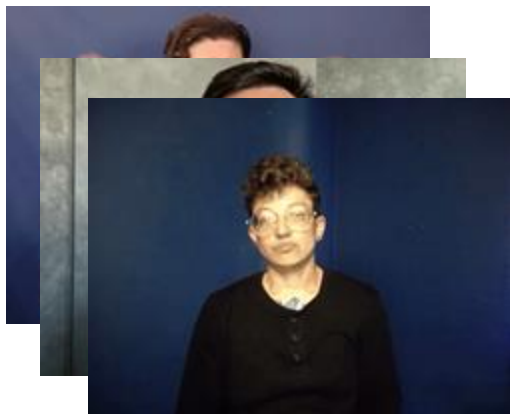
ASL database

3. Sign retrieval

Automatic sign suggestion

1. Fingerspelling detection
2. Fingerspelling alignment
3. Sign retrieval

Relativistic electromagnetism



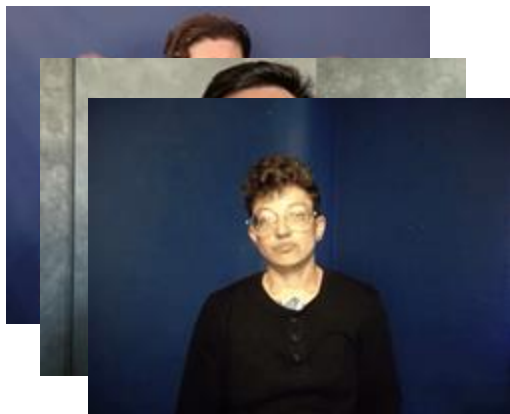
ASL database

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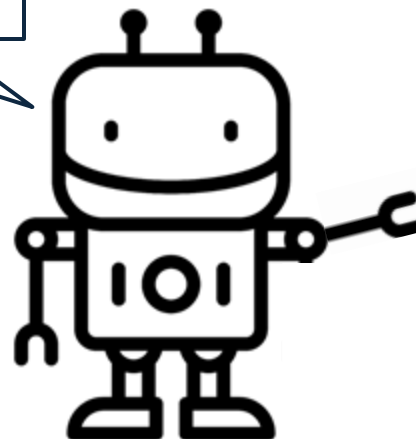
Automatic sign suggestion

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3. Sign retrieval

Relativistic electromagnetism



Here are other ways people sign "relativistic electromagnetism"



3. Sign retrieval

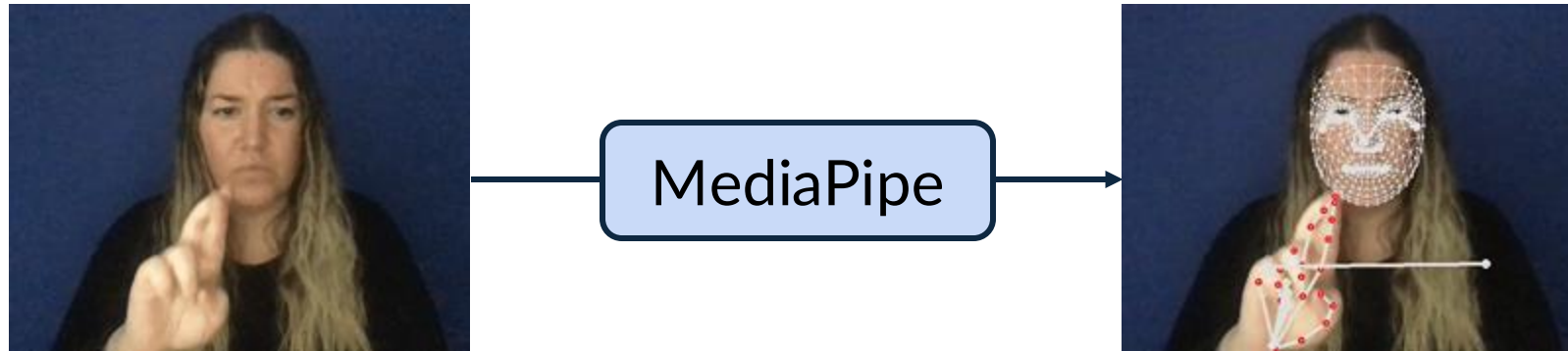
Methods deep-dive: fingerspelling detection

Fingerspelling detection



Relativistic electromagnetism is a physical phenomenon due to...

Fingerspelling detection



Relativistic electromagnetism is a physical phenomenon due to...

Fingerspelling detection



Graph convolutional
network

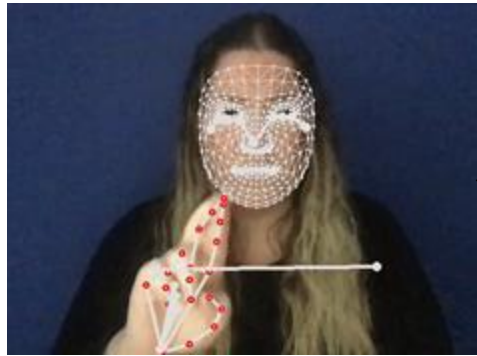


CANINE
(Clark et al., 2022)

*Relativistic electromagnetism is a
physical phenomenon due to...*

Pre-trained character-level English LM

Fingerspelling detection



Graph convolutional network



CANINE
(Clark et al., 2022)

Relativistic electromagnetism is a physical phenomenon due to...

Fingerspelling detection

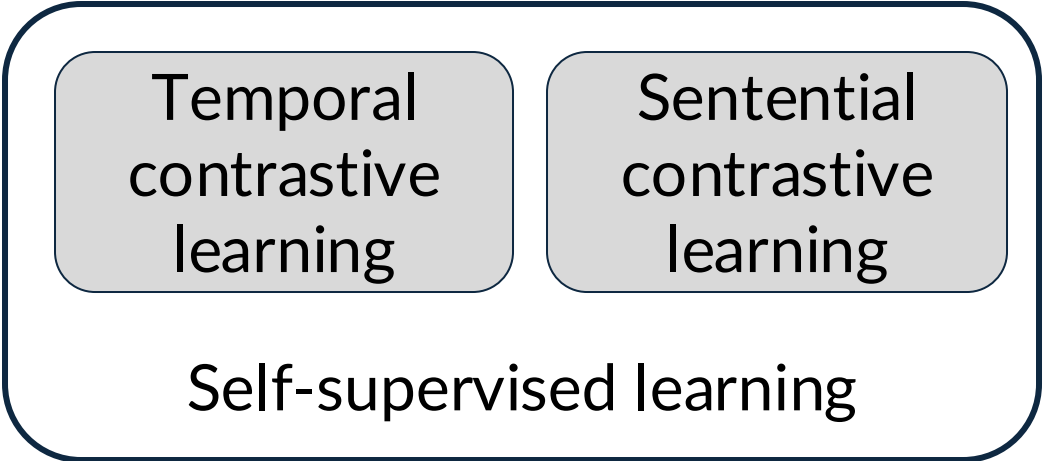


Graph convolutional network



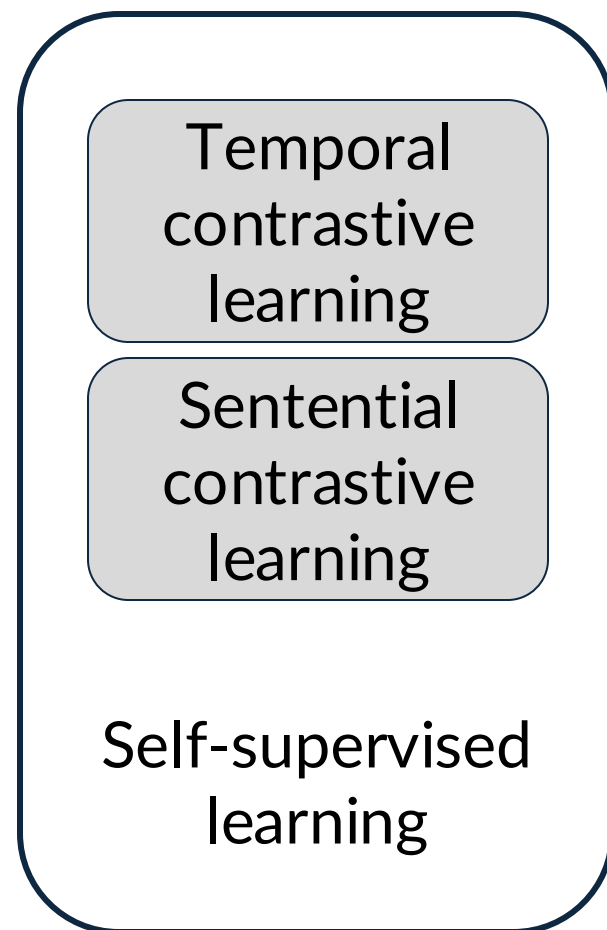
CANINE
(Clark et al., 2022)

Relativistic electromagnetism is a physical phenomenon due to...



Self-supervised learning

- Self-supervised learning
 - Learn patterns from unannotated data
- Need fingerspelling labels
 - We annotated 507 videos
 - 63,759 unannotated videos



Self-supervised learning

Temporal
contrastive
learning

Sentential
contrastive
learning

Self-supervised
learning

Self-supervised learning

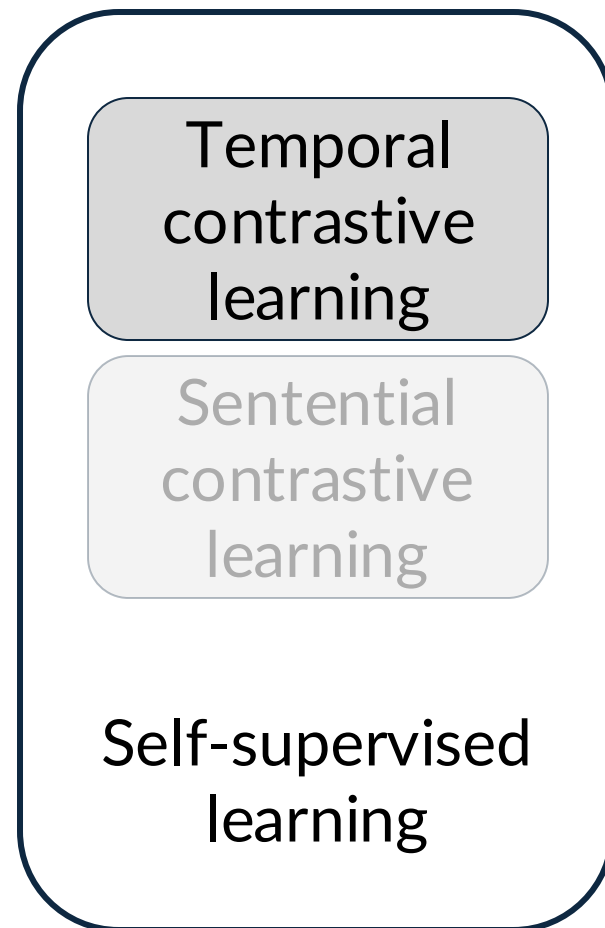
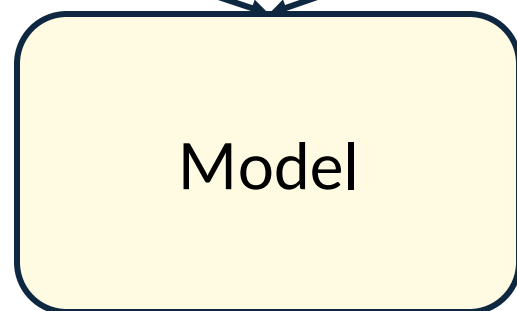


Temporal
contrastive
learning

Sentential
contrastive
learning

Self-supervised
learning

Self-supervised learning



Self-supervised learning



Model

Different video

Same video,
video 1 < video 2

Same video,
video 2 < video 1

Temporal
contrastive
learning

Sentential
contrastive
learning

Self-supervised
learning

Self-supervised learning



Learn representations of the structure and timing of signs

Different video

Same video,
video 1 < video 2

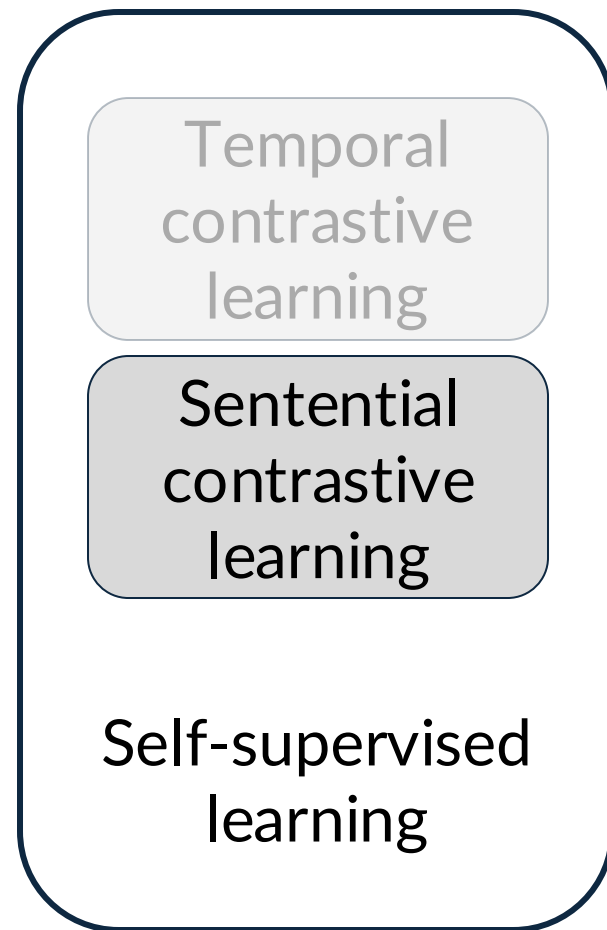
Same video,
video 2 < video 1

Temporal
contrastive
learning

Sentential
contrastive
learning

Self-supervised
learning

Self-supervised learning



Self-supervised learning



*Relativistic
electromagnetism is a
physical phenomenon
due to...*

*An observer at rest with
respect to a system of
static, free charges will...*

Temporal
contrastive
learning

Sentential
contrastive
learning

Self-supervised
learning

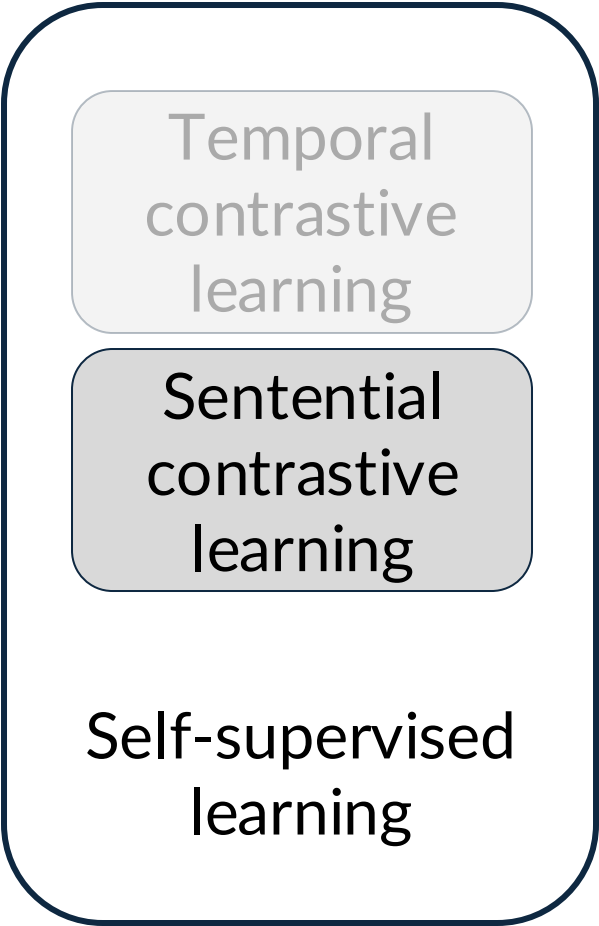
Self-supervised learning



*Relativistic
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Model



Self-supervised learning



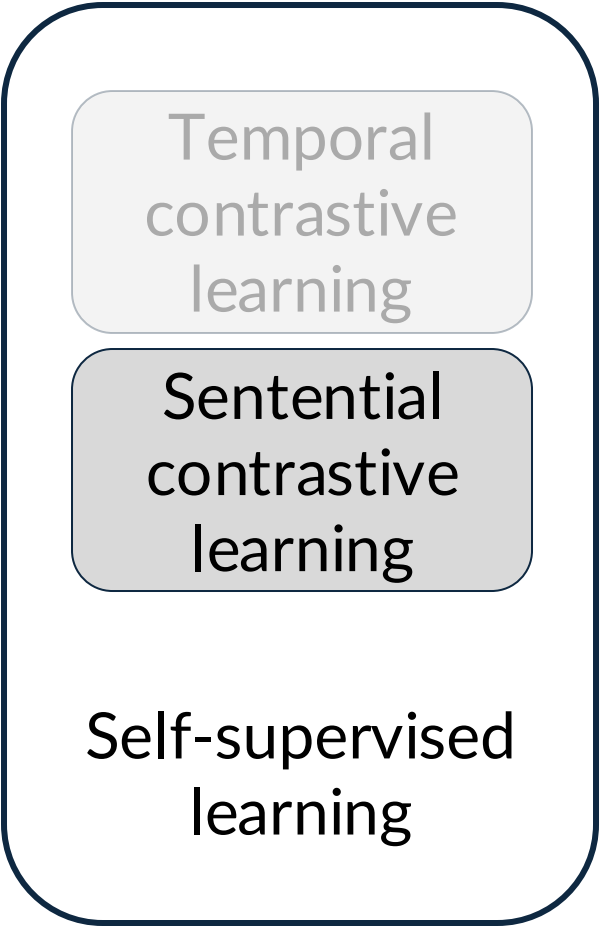
Relativistic electromagnetism is a physical phenomenon due to...

An observer at rest with respect to a system of static, free charges will...

Model

Video = sentence 1

Video = sentence 2



Self-supervised learning



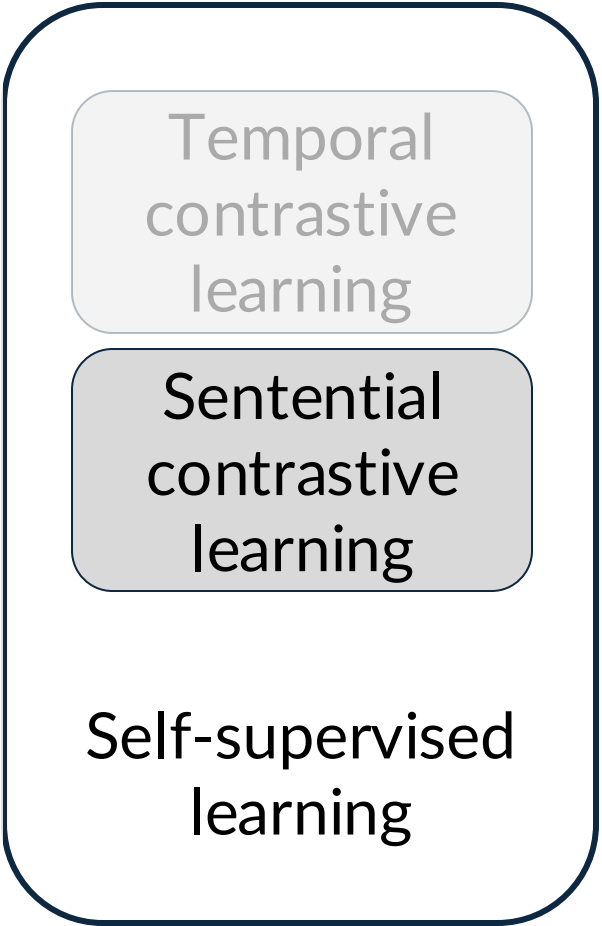
*Relativistic
electromagnetism is a
physical phenomenon
due to...*

*An observer at rest with
respect to a system of
static, free charges will...*

Learn associations between ASL videos and English text
Model

Video = sentence 1

Video = sentence 2



Fingerspelling detection



Graph convolutional network



CANINE
(Clark et al., 2022)

Relativistic electromagnetism is a physical phenomenon due to...

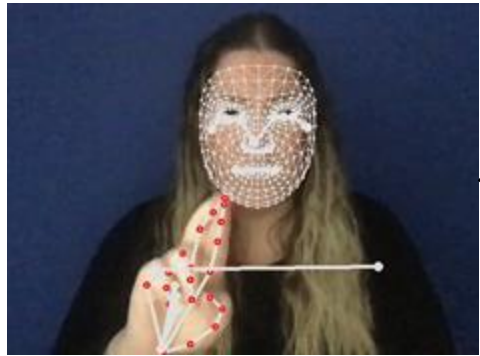
Temporal contrastive learning Sentential contrastive learning

Self-supervised learning

Fingerspelling detection

Fine-tuning

Fingerspelling detection



Graph convolutional network

\oplus

CANINE
(Clark et al., 2022)



Relativistic electromagnetism is a physical phenomenon due to...

Fingerspelling detection



Graph convolutional network



CANINE
(Clark et al., 2022)



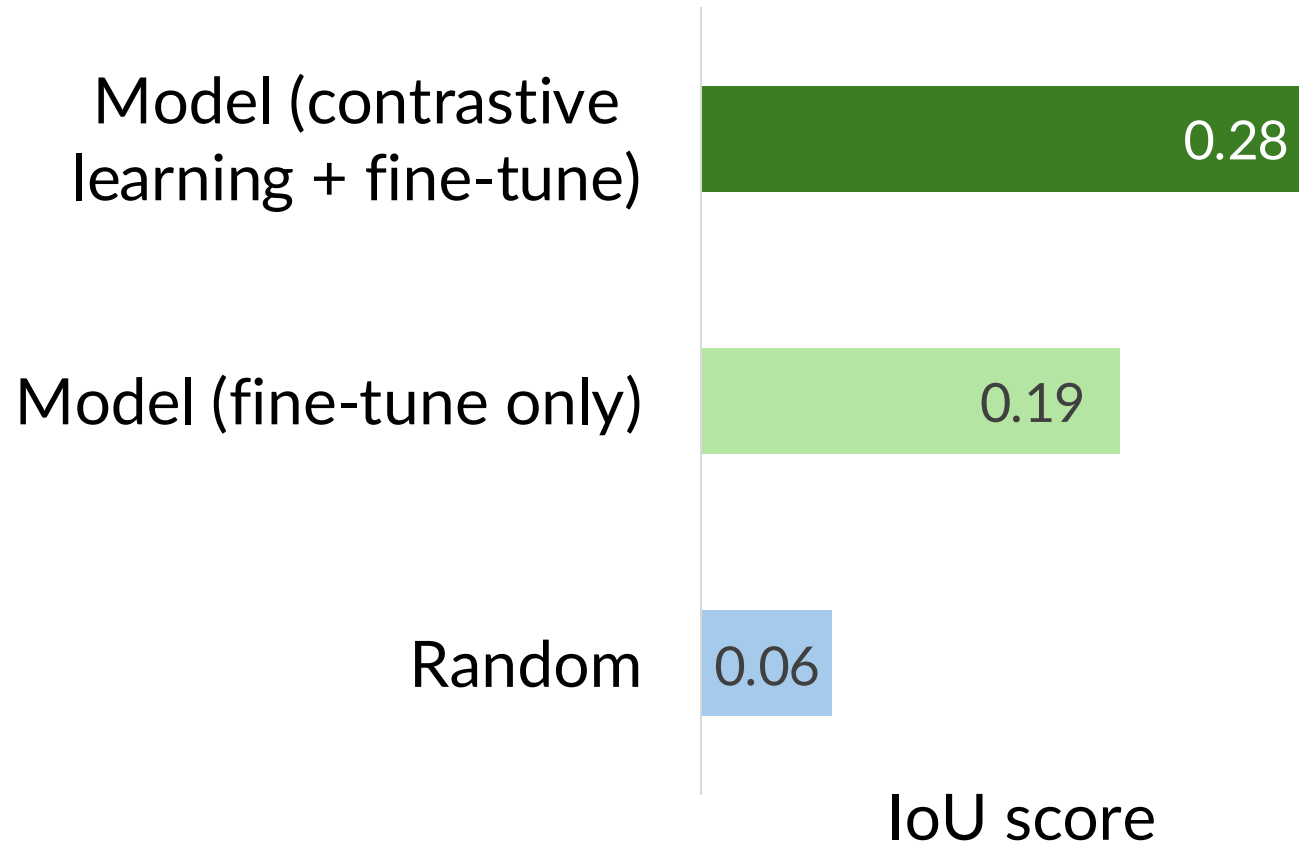
| |
|---|
| 1 |
| 0 |
| 0 |
| 1 |
| 0 |
| 1 |
| 0 |

Relativistic electromagnetism is a physical phenomenon due to...

Frame-level detection predictions

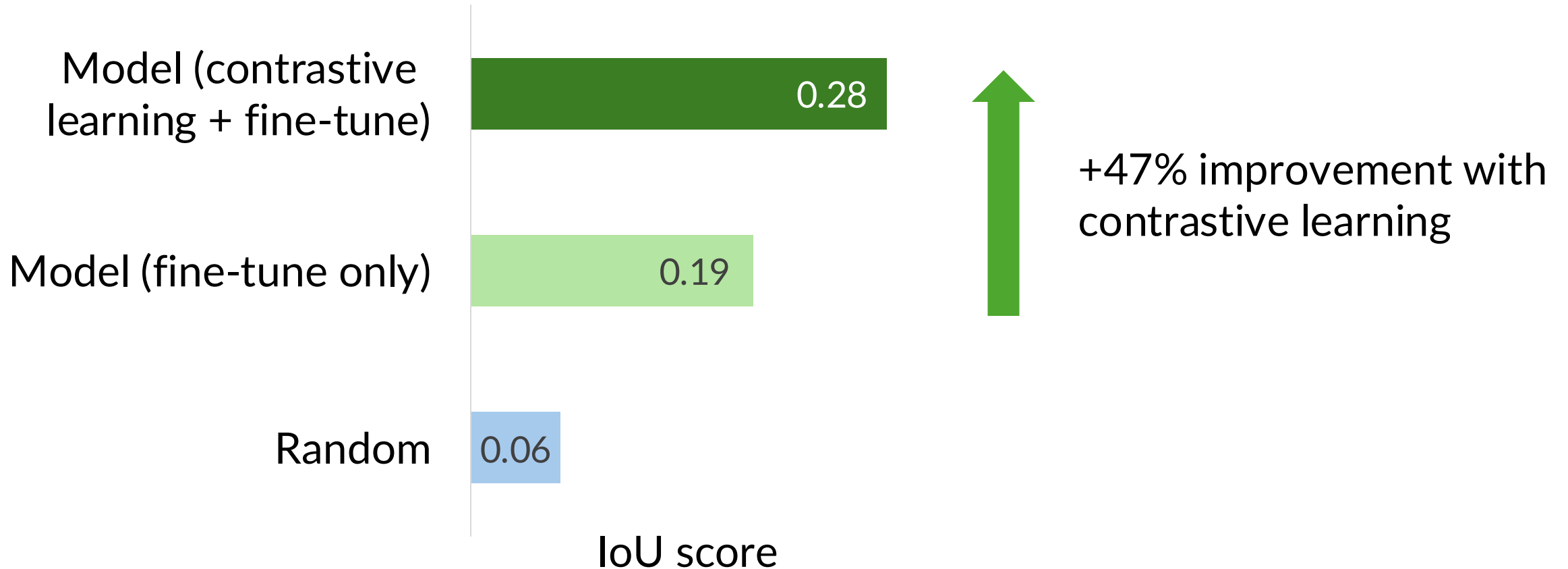
Does contrastive learning work?

Fingerspelling detection



Does contrastive learning work?

Fingerspelling detection



Summary

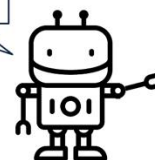


Automatic sign suggestion



User

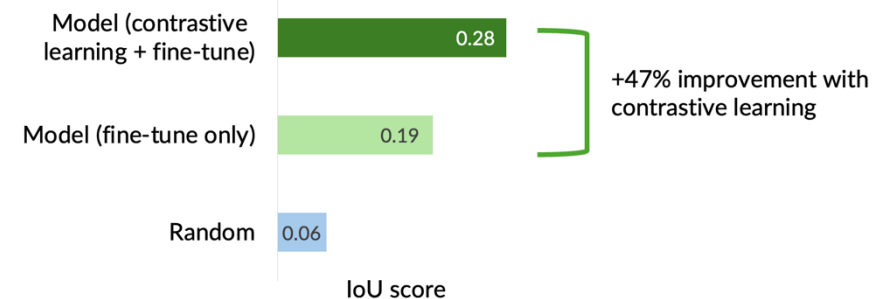
Here are other ways people sign "relativistic electromagnetism"



New dataset to support DHH students in STEM

New task to enhance ASL STEM interpretations

Fingerspelling detection



Contrastive learning for sign language modeling

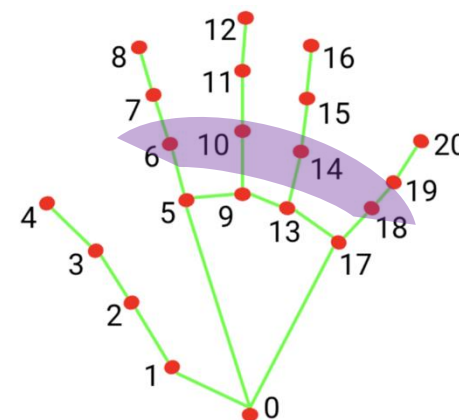
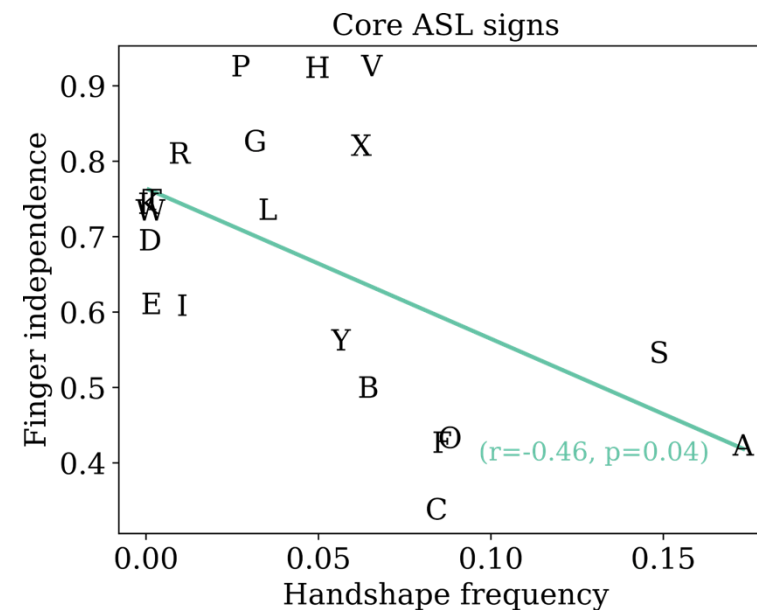
Future directions



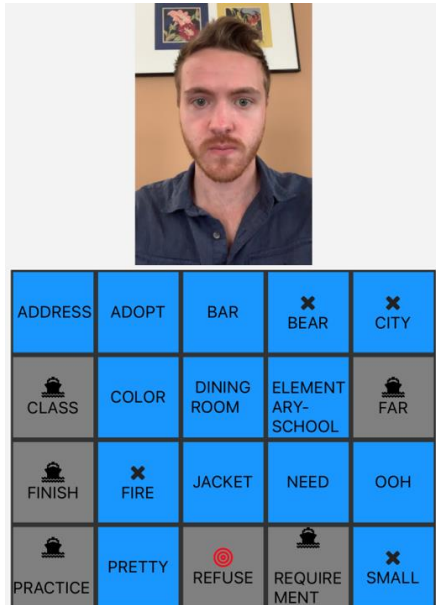
“Future” in ASL

I'm currently working on:

- NLP to verify sign linguistic theories
- Examining representations learned by sign language models
- Evaluation of sign language models



Data collection

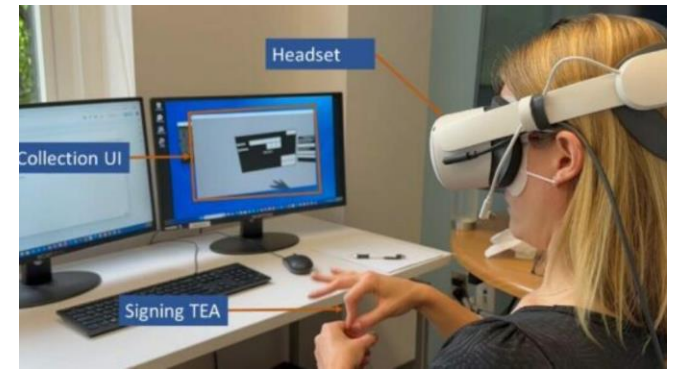


ASL Sea Battle
(Bragg et al., 2021)

- HCI interfaces for data collection
- AI tools to assist data annotation
- AI video anonymization
- Data augmentation

Education

- What environment to learn signed language digitally?
- Adaptive AI for personalized learning
- Educational content delivery, real-time classroom support



ASL Champ
(Gallaudet, 2024)

Signed language generation



Here Comes Mavo!
(Gallaudet, 2025)

- What does a good signing avatar look like?
- Translation between signed languages
- Storytelling

The end!

Road trip to Gallaudet University (Dec. 2021)



CMU SCS The Link (Winter 2021)



Some highlights from my time researching signed languages at CMU 😊