CSCI 699: Grounding Natural Language Units: 4 Spring 2022 Tuesdays 2:00-5:20pm Location: Online (Jan 11, 18, 25; Feb 1, 8); WPH B26 (else)

Instructor: Jesse Thomason Office: SAL 244 Office Hours: by appointment Contact Info: jessetho@usc.edu; timeline for replying to emails: within 48 hours.

#### **Course Description**

Advances in representation learning for natural language via lexical embedding techniques, followed by large-scale language modeling via transformers to produce contextual embeddings, have dominated mainstream NLP for years. Yet, large language models and associated, deep contextual language representations remain unable to understand entailments such as "she took three lefts" implies "she went right." Language is grounded in experience with the world and with other speakers, which no scale of text alone can ever convey to a model. This seminar class will explore the ways in which other sensory modalities, especially visual input and embodiment in 3-dimensional space, can influence and guide representation learning for language. We will focus on techniques to jointly learn representations for text and visual modalities (e.g., self-supervised masked-language and masked-region modeling), to translate between single-modality spaces (e.g., projection and manifold alignment), and to use language and vision signals to produce actions in simulated worlds (e.g., vision-and-language navigation and language-guided task execution). Finally, we will explore the use of

dialogue for human-in-the-loop feedback on tasks and resulting language representations.

## **Learning Objectives**

Students will interrogate the question of whether and when language is *enough* for tasks that involve language, and the nature of machine "understanding." Students will achieve an understanding of modern language grounding techniques, their context and historical precedent, and open problems in the field. Students will review and present in detail milestone papers and techniques for class discussion. The hope is that at the end of the course, students will be able to identify shortcomings in single-modality techniques in language and beyond, and be able to develop practical solutions and insights for the application of grounded language.

**Recommended Preparation**: CSCI 544 (Applied Natural Language Processing) or other graduate-level courses in computer vision or machine learning. General background on mathematical notation and optimization; familiarity with programming in Python (pytorch experience can't hurt!), probability, and algorithms.

## **Course Notes**

Lecture notes will be available online after each class.

## **Technological Proficiency and Hardware/Software Required**

Ability to read modern research papers in natural language processing, computer vision, and/or robotics required; this skill will be further developed through the course. For class projects, access to lab compute (i.e., GPUs) is strongly recommended.

## **Required Readings and Supplementary Materials**

All reading material will be posted on the course web page at the beginning of the course. All reading material will be freely and publicly available online.

## **Course Organization Spring 2022**

Course communication planned via slack:

- Workspace: USC Viterbi School of Engineering Classes
  - uscviterbiclass.slack.com
  - Channel: #spring22-csci-699-30118

Course documents shared via Google Drive. Links:

 Paper Presentation schedule: <u>https://docs.google.com/spreadsheets/d/1eFyqX16nM7WRdmKkaE</u> <u>K\_-emXY\_WjzCMMWcp693e8jUU/edit?usp=sharing</u>

#### **Description and Assessment of Assignments**

Each student will present one or two papers from the field of language grounding and complete a research project. There will be no midterm or final examinations. The main assessment will be engagement in class discussions about required paper readings and effort in the development and execution of the research project.

**Paper presentation(s) and discussions.** Students will read a paper and prepare slides to present its core motivations, insights, and conclusions to the class for discussion. The student will be expected to facilitate discussion on the paper, including not just answering class questions but encouraging them through an interrogation of the paper's methods and conclusions. The grade for this assignment will be 15% for the student's own presentation and discussion leadership, and 10% for the student's engagement in discussion of other students' presentations and general helpfulness (*community points*).

**Paper Presentations(s) Rubric.** Presentations should cover the main ideas of the paper(s) and explain how they work together. Presentations and discussions should be about 45 minutes total, so preparing 30-40m of material is expected. Consider answering the following questions with your presentation:

1. What is the main problem/task addressed by each paper?

2. What was done before, and how does each paper improve on that?

3. What is the one cool technique/idea/finding that serves as a takeaway from each paper?

4. What part of each paper was difficult to understand, and what could be done better in presenting it?

5. What are possible generalizations, extensions, and applications of the findings in each paper? What are the potential positive and negative downstream effects, and on whom?

6. What is the relationship between the two papers? Does one set the groundwork for the other? Do they complement or contradict one another? How does each speak to a common theme?

**Community Points Rubric.** Students can earn 5 Community Points (up to 100 total) for individual actions such as:

- Asking an engaging question during another person's paper presentation.
- Offering insights during paper discussion to *another* student's question as part of a dialogue with the presenter and class.
- Helping debug or resolve issues from another team's project in Slack or on Github.
- Making impactful suggestions to course or project structure to improve the experience for future students.

This list is non-exhaustive. If you've helped out or engaged with the class in a way you feel should be credited, please let me know.

**Project proposal slides.** Students will brainstorm a project idea *individually* or in teams of 2 in the space of language grounding. Students will prepare 5-6 slides articulating the objective of their project, how the problem is approached currently, how the proposed approach addresses the limitations of existing work, and what success would contribute to the field, including considerations of the ethical implications of the contribution's deployment. These proposal slides are not awarded points, but should be thought of as an early way to scope the project for the remainder of the semester so as not to commit to too much or too little.

**Project themes.** Students may scope a project related to grounding natural language on their own, and can also choose to select a project related to one of the following themes. Project themes are associated with datasets/tasks, and working within a theme will allow for some information sharing and debugging between projects within that theme.

Theme Paper	Resources	Domain
ALFRED	<u>Home</u>	Natural language instructions to take discrete actions in a visual simulation.
Pose, Audio, Transcript, Style (PATS)	<u>Home</u>	Spoken language with aligned video pose tracking and ASR transcripts.
<u>Room Across</u> <u>Room</u>	<u>Code</u>	Multilingual language instructions for discrete navigation in a visual simulation.
Social IQ	<u>Home</u>	Video Question Answering focused on social interactions.
TEACh	Code	Language dialogue interaction to take discrete actions in a visual simulation.

**Project survey report.** A literature survey, analogous to the Related Work section of a conference paper, will be prepared by each project group. This survey will cover the same core topics as the proposal slides, digging deeper into literature to understand and contextualizing existing work, what challenges remain to be solved, insights drawn from other work and how they might apply to a new method, and ethical implications of success. This stage may require refining the proposal to differentiate it further from existing work, if the student finds that their novel insight or new idea has been previously explored. The survey will be formatted as a 2 page literature review write-up. A template will be provided.

**Project mid-term presentation.** The student will deliver a 5 minute presentation with accompanying slides to overview their proposed approach, early stage results so far, analysis of any interesting findings, and a concrete set of next steps achievable before the end of the semester.

**Project mid-term report.** The student will first run one or more state-of-the-art and baseline methods for their proposed problem and analyze the performance of these methods. Error analysis of existing methods will provide quantitative insight into what the proposed method can and should address in achieving better results. Additionally, writing analysis and comparison code now will enable faster and more effective benchmarking of the new method against baseline and current approaches. This report will be about 5 pages, where the first few are a revised survey report. Build on the template provided with the survey report.

**Project final presentation.** The student will deliver a 10 minute presentation with accompanying slides, analogous to a conference talk, with 5 minutes for questions after. The presentation will briefly introduce

the problem and the current approaches to that problem, then the insights and implementation of the proposed new approach, followed by experimental results and analysis of the proposed method's performance.

**Project final report.** The student will present their findings, either a new method for an existing problem or a new analysis, technique, or benchmark for a novel problem. The writeup will be 8 pages in total, with up to 5 pages recycled from the survey report (Introduction and Related Work) and mid-term report (Problem/Task and Baselines). Possible additional content would be the analysis of model performance from the mid-term report can be expanded to include the new method, a new or interesting problem formulation can be evaluated against existing models, and discussions about what interesting questions the research raises. Students will return to the ethical implications of their methods, whether successful or not; considering questions or applications?" and "how could systemic failure of my model on some parts of this data affect downstream applications and users?" Build on the template provided with the survey report.

#### **Grading Breakdown**

Assessment Tool (assignments)	Points	% of Grade
Paper presentations	100	15%
Community points	100	10%
Project survey report	100	15%
Project mid-term report & pres	100	20%

Project final presentation	100	20%
Project final report	100	20%

Final grades will be binned into letters (e.g., A+, A, etc.) with adjustments made for overall point distributions.

## **Assignment Submission Policy**

Upload/email to be decided, encouraged by 6pm (aka "quittin' time") on the due date; accepted until 11:59pm on the due date.

## **Grading Timeline**

Assignments will be graded within one week of the due date.

## **Additional Policies**

This is a discussion-based course, hence consistent attendance is expected. Lack of attendance will affect the class participation score. Missed classes with a valid excuse are allowed. Class participation will be scored based on engagements in course discussions.

The course will allow for a budget of 5 *Late Day Tokens* per student. These tokens can be expended on project deliverables (NOT presentations) to extend the deadline for a student. These tokens should be used with no justification or explanation for taking the late time required (i.e., you do not need to explain your reasoning to me). Going over budget (e.g., turning things in late with no Late Day Tokens to expend) will incur grade penalties of 5% per day late. For project teams, each member must expend a Late Day Token for a single day extension to a project-related deadline (i.e., for a team of 2 to push back their project deadline, both team members must expend a Late Day Token). There are no refunds for late days: unused late days cannot be converted into credit of any kind. Use them.

## **Project Schedule:**

Week 3: Proposals due Jan 27 [Thursday] Week 5: Surveys due Feb 10 [Thursday] Week 11: Midterm Reports due March 24 [Thursday] Final Report due May 5 [University-scheduled Final Exam Day]

	Agenda
Week 1 Jan 11 (Online)	Class introduction, planned daily agenda setup, syllabus breakdown, paper presentation scheduling.
(,	Lecture: The Symbol Grounding Problem (in brief)
<b>Week 2</b> Jan 18	Lecture: History of "Meaning" for AI in NLP
(Online)	Theme: Why Ground Language?
	Presenter 1:
	<u>The Symbol Grounding Problem</u> . S. Harnad. Physica D 1990. <u>Climbing towards NLU: On Meaning, Form, and Understanding in the Age of Data</u> . Emily M. Bender and Alexander Koller. ACL 2020.
	Presenter 2:
	Experience Grounds Language. Yonatan Bisk, Ari Holtzman, Jesse Thomason, Jacob Andreas, Yoshua Bengio, Joyce Chai, Mirella Lapata, Angeliki Lazaridou, Jonathan May, Aleksandr Nisnevich, Nicolas Pinto, and Joseph Turian. EMNLP 2020.
	Recommended Reading:
	The Development of Embodied Cognition: Six Lessons from Babies. Linda Smith and Michael Gasser. Artificial Life 2005.
Week 3	[Proposals due Jan 27]

## Course Schedule: A Weekly Breakdown

Jan 25 (Online)	Lecture: Symbol Grounding without "Connectionist" Networks Theme: Language for Vision and Vision for Language
	Presenter 1: Is this a wampimuk? Cross-modal mapping between distributional semantics and the visual world. A. Lazaridou, E. Bruni and M. Baroni. ACL 2014. Unified Visual-Semantic Embeddings: Bridging Vision and Language with Structured Meaning Representations. Hao Wu, Jiayuan Mao, Yufeng Zhang, Yuning Jiang, Lei Li, Weiwei Sun, Wei-Ying Ma. CVPR 2019.
	<ul> <li>Presenter 2:</li> <li>Word sense disambiguation with pictures. Kobus Barnard and Matthew Johnson. Al 2005.</li> <li>Learning Transferable Visual Models From Natural Language Supervision. Alec Radford, Jong Wook Kim, Chris Hallacy, Aditya Ramesh, Gabriel Goh, Sandhini Agarwal, Girish Sastry, Amanda Askell, Pamela Mishkin, Jack Clark, Gretchen Krueger, Ilya Sutskever. 2021.</li> </ul>
	Recommended Reading: Resolving Language and Vision Ambiguities Together: Joint Segmentation & Prepositional Attachment Resolution in Captioned Scenes. Gordon Christie and Ankit Laddha and Aishwarya Agrawal and Stanislaw Antol and Yash Goyal and Kevin Kochersberger and Dhruv Batra. EMNLP 2016.
<b>Week 4</b> Feb 1	Lecture: Symbol Grounding with "Connectionist" Networks
(Online)	Theme: Language as Image Understanding
	Presenter 1: VQA: Visual Question Answering. Stanislaw Antol and Aishwarya Agrawal and Jiasen Lu and Margaret Mitchell and Dhruv Batra and C. Lawrence Zitnick and Devi Parikh. ICCV 2015. Neural Module Networks. Jacob Andreas, Marcus Rohrbach, Trevor Darrell, Dan Klein. CVPR 2016.

	<ul> <li>Presenter 2:</li> <li>Information Maximizing Visual Question Generation. Ranjay Krishna and Michael Bernstein and Li Fei-Fei. CVPR 2019.</li> <li>Grounded Situation Recognition. Sarah Pratt and Mark Yatskar and Luca Weihs and Ali Farhadi and Aniruddha Kembhavi. ECCV 2020.</li> <li>Recommended reading:</li> <li>Bottom-Up and Top-Down Attention for Image Captioning and Visual Question Answering. Peter Anderson, Xiaodong He, Chris Buehler, Damien Teney, Mark Johnson, Stephen Gould, Lei Zhang. CVPR 2018.</li> </ul>
Week 5	[Surveys due Feb 10]
(Online)	Lecture: Learning Vision and Language Representations
	Theme: Language and Vision Transformers
	<ul> <li>Presenter 1:</li> <li>A Joint Model of Language and Perception for Grounded Attribute Learning. Cynthia Matuszek and Nicholas FitzGerald and Luke Zettlemoyer and Liefeng Bo and Dieter Fox. ICML 2012.</li> <li>ViLBERT: Pretraining Task-Agnostic Visiolinguistic Representations for Vision-and-Language Tasks. Jiasen Lu, Dhruv Batra, Devi Parikh, Stefan Lee. NeurIPS 2019.</li> </ul>
	Presenter 2: Vokenization: Improving Language Understanding with Contextualized. Visual-Grounded Supervision. Tan, Hao and Bansal, Mohit. EMNLP 2020. ViLT: Vision-and-Language Transformer Without Convolution or Region Supervision. Kim, Wonjae and Son, Bokyung and Kim, Ildoo. ICML 2021.
Week 6	Lecture: Embodied Language Understanding I
	Theme: Vision and Language Model Analysis
	Presenter 1:

	<ul> <li>Shifting the Baseline: Single Modality Performance on Visual Navigation &amp; QA. Jesse Thomason, Daniel Gordon, and Yonatan Bisk. North American Chapter of the Association for Computational Linguistics (NAACL), 2019.</li> <li>Vision-and-Language or Vision-for-Language? On Cross-Modal Influence in Multimodal Transformers. Stella Frank, Emanuele Bugliarello, Desmond Elliott. EMNLP 2021.</li> <li>Presenter 2: Can Language Models Encode Perceptual Structure Without Grounding? A Case Study in Color. Mostafa Abdou, Artur Kulmizev, Daniel Hershcovich, Stella Frank, Ellie Pavlick, Anders Søgaard. CoNLL 2021.</li> <li>The World of an Octopus: How Reporting Bias Influences a Language Model's Perception of Color. Cory Paik, Stéphane Aroca-Ouellette, Alessandro Roncone, Katharina Kann. EMNLP 2021.</li> </ul>
Week 7 Feb 22	Lecture: Embodied Language Understanding II Theme: Language for Action: Navigation <i>Presenter 1:</i> Learning to Interpret Natural Language Navigation Instructions from Observations. David L. Chen and Raymond J. Mooney. AAAI 2011. Listen, Attend, and Walk: Neural Mapping of Navigational Instructions to Action Sequences. Hongyuan Mei, Mohit Bansal, and Matthew R. Walter. AAAI 2016. <i>Presenter 2:</i> Vision-and-Language Navigation: Interpreting visually-grounded navigation instructions in real environments. Peter Anderson, Qi Wu, Damien Teney, Jake Bruce, Mark Johnson, Niko Sünderhauf, Ian Reid, Stephen Gould, Anton van den Hengel. CVPR 2018. Improving Vision-and-Language Navigation with Image-Text Pairs from the Web. Arjun Majumdar and Ayush Shrivastava and Stefan Lee and Peter Anderson and Devi Parikh and Dhruv Batra. ECCV 2020.
<b>Week 8</b> Mar 1	Lecture: Embodied Language Understanding III Theme: Language for Action: Interactive Worlds <i>Presenter 1:</i>

	Toward Interactive Grounded Language Acquisition. Kollar, Thomas and Krishnamurthy, Jayant and Strimel, Grant. RSS 2013. Grounding Language in Play. Corey Lynch and Pierre Sermanet. 2020. <i>Presenter 2:</i> Learning interpretable spatial operations in a rich 3d blocks world. Bisk, Yonatan and Shih, Kevin J and Choi, Yejin and Marcu, Daniel. AAAI 2018. Learning Language-Conditioned Robot Behavior from Offline Data and Crowd-Sourced Annotation. Suraj Nair and Eric Mitchell and Kevin Chen and Brian Ichter and Silvio Savarese and Chelsea Finn. CoRL 2021.
<b>Week 9</b> Mar 8	Lecture: Slot-based Dialogue Agents Theme: Social grounding: common ground
	<ul> <li>Presenter 1:</li> <li>Logic and Conversation. Paul Grice. Syntax and Semantics 3: Speech Acts. Academic Press 1975.</li> <li>Learning to Mediate Perceptual Differences in Situated Human-Robot Dialogue. Liu, Changsong and Chai, Joyce Yue. AAAI 2015.</li> <li>Presenter 2:</li> <li>What You See is What You Get: Visual Pronoun Coreference Resolution in Dialogues. Xintong Yu, Hongming Zhang, Yangqiu Song, Yan Song, Changshui Zhang. EMNLP 2019.</li> <li>Executing Instructions in Situated Collaborative Interactions. Alane Suhr, Claudia Yan, Jacob Schluger, Stanley Yu, Hadi Khader, Marwa Mouallem, Iris Zhang, Yoav Artzi. EMNLP 2019.</li> </ul>
<b>Week 10</b> Mar 15	No class; Spring Recess
<b>Week 11</b> Mar 22	Project mid-term presentations
<b>Week 12</b> Mar 29	Lecture: Grounded Dialogue Agents

	Theme: Social grounding: language fidelity and dialogue cooperation.
	Presenter 1: <u>Towards Ecologically Valid Research on Language User Interfaces</u> . Harm de Vries and Dzmitry Bahdanau and Christopher Manning. 2020. <u>Unnatural Language Processing: Bridging the Gap Between Synthetic and Natural</u> <u>Language Data</u> . Alana Marzoev, Samuel Madden, M. Frans Kaashoek, Michael Cafarella, Jacob Andreas. 2020.
	Presenter 2: <u>Vision-and-Dialog Navigation</u> . Jesse Thomason, Michael Murray, Maya Cakmak, and Luke Zettlemoyer. CoRL 2019. <u>Collaborative dialogue in Minecraft</u> . Anjali Narayan-Chen, Prashant Jayannavar, Julia Hockenmaier. ACL 2019.
Week 13 Apr 5	Lecture: Transformers Lite Theme: Language grounding with vision and time
	Presenter 1: Language2Pose: Natural Language Grounded Pose Forecasting. Chaitanya Ahuja, Louis-Philippe Morency. 2019. <u>MERLOT: Multimodal Neural Script Knowledge Models</u> . Rowan Zellers, Ximing Lu, Jack Hessel, Youngjae Yu, Jae Sung Park, Jize Cao, Ali Farhadi, Yejin Choi. NeurIPS 2021.
	Presenter 2: <u>Verb Physics: Relative Physical Knowledge of Actions and Objects</u> . Maxwell Forbes and Yejin Choi. ACL 2017. <u>PIQA: Reasoning about Physical Commonsense in Natural Language</u> . Yonatan Bisk and Rowan Zellers and Ronan Le Bras and Jianfeng Gao and Yejin Choi. AAAI 2020.
<b>Week 14</b> Apr 12	Lecture: Transformers and States Theme: Language grounding beyond vision: audio and
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	<ul> <li>Presenter 1:</li> <li>Multi- and Cross-Modal Semantics Beyond Vision: Grounding in Auditory Perception.</li> <li>Douwe Kiela and Stephen Clark. EMNLP 2015.</li> <li>Jointly Discovering Visual Objects and Spoken Words from Raw Sensory Input. David Harwath, Adrià Recasens, Dídac Surís, Galen Chuang, Antonio Torralba, James Glass. ECCV 2018.</li> <li>Presenter 2:</li> <li>Learning Multi-Modal Grounded Linguistic Semantics by Playing "I Spy". Thomason, Jesse and Sinapov, Jivko and Svetlik, Maxwell and Stone, Peter and Mooney, Raymond. IJCAI 2016.</li> <li>The Lancaster Sensorimotor Norms: multidimensional measures of perceptual and action strength for 40,000 English words. Dermot Lynott, Louise Connell, Marc Brysbaert, James Brand &amp; James Carney. Behavior Research Methods 2020.</li> </ul>
Week 15 Apr 19	Lecture: Steps Towards Social Grounding Theme: Physical grounding; sensory modalities; robotics <i>Presenter 1:</i> Mapping Navigation Instructions to Continuous Control Actions with Position Visitation Prediction. Valts Blukis and Dipendra Misra and Ross A. Knepper and Yoav Artzi. CoRL 2018. Sim-to-Real Transfer for Vision-and-Language Navigation. Peter Anderson and Ayush Shrivastava and Joanne Truong and Arjun Majumdar and Devi Parikh and Dhruv Batra and Stefan Lee. CoRL 2020. <i>Presenter 2:</i> Asking for Help Using Inverse Semantics. Stefanie Tellex and Ross Knepper and Adrian Li and Daniela Rus and Nicholas Roy. RSS 2014. CLIPort: What and Where Pathways for Robotic Manipulation. Mohit Shridhar, Lucas Manuelli, Dieter Fox. CoRL 2021.
<b>Week 16</b> Apr 26	Project final presentations
FINAL	Final Report [Due May 5]

## **Statement on Academic Conduct and Support Systems**

## Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, policy.usc.edu/scientific-misconduct.

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Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call suicidepreventionlifeline.org

Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call studenthealth.usc.edu/sexual-assault

Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED) - (213) 740-5086 | Title IX – (213) 821-8298

#### equity.usc.edu, titleix.usc.edu

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

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#### usc-advocate.symplicity.com/care report

Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity |Title IX for appropriate investigation, supportive measures, and response.

## The Office of Disability Services and Programs - (213) 740-0776 dsp.usc.edu

Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Campus Support and Intervention - (213) 821-4710 campussupport.usc.edu

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101 diversity.usc.edu Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call

dps.usc.edu, emergency.usc.edu

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