UC Human Language Technologies

Introduction

This course on **Human Language Technologies** (HLT) explores the rapidly evolving fields of **Natural Language Processing** (NLP) and **Speech Technologies**. Recent advancements, particularly in deep learning and large-scale language models, have revolutionized both areas, enabling machines to better understand, generate, and interact using human language. From breakthrough models like GPT and BERT to state-of-the-art speech recognition systems, the progress has been transformative, pushing the boundaries of what machines can accomplish in interpreting human communication.

These advancements have led to a wide array of applications, including conversational AI, machine translation, sentiment analysis, voice-activated assistants, and accessibility tools. The integration of NLP and speech technologies now plays a critical role in several industries ranging from healthcare and education to finance and entertainment. This course will explore both the underlying theories and practical applications of these technologies, preparing students to contribute to the future of this dynamic field.

Objectives

At the end of the semester the students should be able to:

1. Identify relevant tasks in Human Language Technologies.
2. Identify and use the main methods in solving those tasks.
3. Have an opinion on the capabilities and limitations of state-of-the-art methods for representative tasks in NLP and Speech processing (e.g., NER).
4. Be able to develop a pipeline with current methods to solve a problem.

Syllabus

1) Introduction to Human Language Technologies (HLT)
   a) Overview of HLT and main subareas: Natural Language Processing (NLP), Speech
   b) Historical information
   c) Overview of tasks
   d) Applications
2) Information Extraction (IE)
   a) Pipelines, Tasks, and Applications
      i) IE Pipeline Architectures: Overview of traditional and modern pipelines for information extraction.
      ii) Applications of IE
   b) Named Entity Recognition (NER)
      i) NER with Deep Learning: Approaches using neural networks, transformers, and pretrained language models (e.g., BERT, GPT) for improved NER.
      ii) NER in Low-Resource Languages: Techniques for NER in languages with limited labelled data and resources, including transfer learning and multilingual models.
      iii) Recent work for Portuguese (at IEETA)
   c) IE and Open-IE

   i) Rule-Based IE vs. Open IE: Comparison between traditional, rule-based IE systems and Open Information Extraction (Open-IE) methods that focus on extracting relational triples without predefined schemas.
   ii) Open-IE with Deep Learning: Utilizing deep learning techniques to improve Open-IE systems for extracting more flexible, complex, and domain-agnostic information.
   iii) Relation Extraction: Methods for extracting relationships between entities in a structured format, such as entity-relation triples, and using them to build knowledge graphs.
   iv) Recent work for Portuguese
3) Knowledge Representation
   a) Ontologies and Representation of Domain Knowledge
   b) Knowledge Graphs and Triple Stores - Investigate the use of graph-based structures like RDF and SPARQL for storing and querying knowledge.
   c) Knowledge Representation and Reasoning over Knowledge Bases
   d) Neural Knowledge Representations - Examine distributed knowledge representations in neural networks, such as embeddings and transformer-based models.
4) Speech Technologies
   a) Automatic Speech Recognition
   b) Text-to-Speech (TTS) and Voice Synthesis
5) Dialogue Systems
   a) Dialog and Chat Systems
   b) Task-Oriented Dialogue vs. Open Domain Dialogue
   c) Natural Language Understanding (NLU) and Natural Language Generation (NLG)
   d) Dialogue Management
   e) Examples of Development Tools and Applications
6) Hot Topics
   a) Deep Learning Architectures for NLP
   b) Large Language Models (LLMs) and In-context Learning
   c) Multimodal Systems - Integrating text, speech, vision...
   d) Ethics and Bias - Fairness, transparency, and interpretability

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Teaching Team

Prof. António Teixeira

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Full Professor, Department of Electronics Telecommunications and Informatics, University of Aveiro, Portugal, and Leader of the Biomedical Informatics and Technologies (BIT) group of the Institute of Electronics and Informatics of Aveiro. Additionally, he is Chair of the Special Interest Group on Iberian Languages of the International Speech Communication Association (ISCA).
He completed his PhD in Articulatory Speech Synthesis in 2000. Currently his research activity spans Multimodal Human-Machine Interaction, Speech and Language Technologies and new services for Health and Wellbeing. He participated in several national and European research projects.
He was involved in many events related to Iberian languages: one of the General Chairs/Co-chairs of IberSPEECH (2024, Aveiro, Portugal; 2022, Granada, Spain; 2020, Valladolid, Spain; 2018, Barcelona, Spain; 2016, Lisbon, Portugal; 2014, Las Palmas, Spain; 2012, Madrid, Spain), FALA 2010 (Vigo, Spain), I Iberian SLTech (2009) and PROPOR 2008 (The International Conference on Computational Processing of Portuguese, Aveiro, Portugal). Also was one of the Technical Program Committee Chairs of PROPOR 2024 (Santiago de Compostela, Spain) and PROPOR 2012 (Coimbra, Portugal) and Member of the Organizing Committee and Special Sessions Chair of InterSpeech 2005, Lisbon. Will be one of the Technical Program Chairs of InterSpeech 2027 (São Paulo, Brazil).

Prof. Liliana Ferreira

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Full Professor (Invited) at FEUP and Director of Fraunhofer Portugal Research Center for Assistive Information and Communication Solutions (AICOS). Her work spans the fields of Human-Computer Interaction, Natural Language Processing (NLP), and Health Informatics. At Fraunhofer, she leads initiatives aimed at developing AI-powered solutions for healthcare, with a focus on improving the accessibility and efficiency of health services. Professor Ferreira's contributions extend to interdisciplinary projects, combining technology and healthcare to advance patient care and clinical decision-making.
She holds a PhD in Informatics Engineering from the University of Aveiro, obtained in 2010. Her thesis, titled "Medical Information Extraction in European Portuguese", was recognized with the Best Thesis Award at PROPOR (International Conference on Computational Processing of Portuguese) in 2012.

Prof. José João Almeida

Universidade do Minho

Assistant Professor at the Department of Informatics, Universidade do Minho, Portugal. He is a member of the ALGORITMI Research Centre, where he focuses on Natural Language Processing (NLP) and Formal Specification. Professor Almeida has contributed significantly to various projects, including the Natura Project for NLP. He has published numerous papers and is actively involved in research and teaching within his field.

UC Human Language Technologies

Prof. Mário Rodrigues

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Associate Professor (Prof. Coordenador) at the School of Technology and Management of Águeda (ESTGA) at the University of Aveiro. Researcher affiliated with the Institute of Electronics and Informatics Engineering of Aveiro (IEETA) and serves as the Director of ESTGA. His research interests lie in areas such as Natural Language Processing (NLP), Information Retrieval, and Health Informatics. As a leader at ESTGA, he oversees initiatives aimed at integrating technology and innovation into management and business processes, while also driving collaborations that bridge academia and industry.

Professor Rodrigues earned his PhD in Informatics Engineering from the University of Aveiro. His research has focused on advancing methods in text mining, information extraction systems, and knowledge representation, with particular emphasis on methodologies based on graphs and machine learning.

Bibliography

1	*2024*	*Caseli, H.M.; Nunes, M.G.V. (org.) Processamento de Linguagem Natural: Conceitos, Técnicas e Aplicações em Português. 2 ed. BPLN, 2024.*	https://brasileiraspln.com/livro-pln/2a-edicao/
2	*2021*	*Young, Steve* *Hey Cyba - The Inner Workings of a Virtual Personal Assistant* *Cambridge University Press, 2021*	Hey Cyba (cambridge.org)
3	*2015*	*Mário Rodrigues and António Teixeira* *Advanced Applications of Natural Language Processing for Performing Information Extraction* *Springer, 2015*	*https://link.springer.com/book/10.1007/978-3-319-15563-0*
4	*2024*	*Dan Jurafsky and James H. Martin* *Speech and Language Processing (3rd ed. draft)* *20 August 2024*	*Speech and Language Processing (stanford.edu)*
5	*2023*	*A. Bahrini et al., "ChatGPT: Applications, Opportunities, and Threats," 2023 Systems and Information Engineering Design Symposium (SIEDS)*	*https://ieeexplore.ieee.org/document/10137850*