



Universidade de Coimbra
Faculdade de Ciências e Tecnologia
Departamento de Engenharia Informática

Human-Centered Artificial Intelligence
Master in Data Science and Engineering

Human AI Communication

Natural Language Interaction

Hugo Gonçalo Oliveira
hroliv@dei.uc.pt

Overview

- 1 Introduction
- 2 Natural Language Processing
- 3 Conversational Agents
- 4 Approaches

Intelligent Personal Assistants (IPAs)

- Most natural way of communication between humans?
→ **Human Language!**



- IPAs should be able to communicate using this language as well...
→ **Natural Language Understanding**



Cortana.



Siri



amazon echo

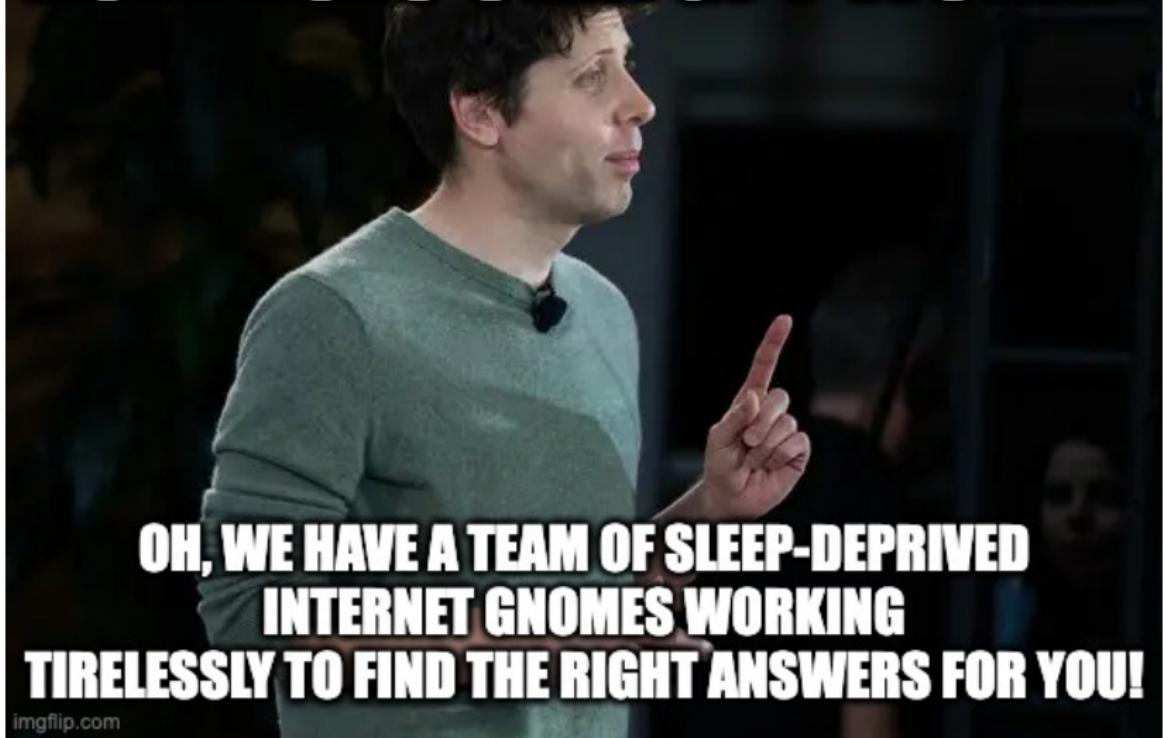


Google now



Facebook M

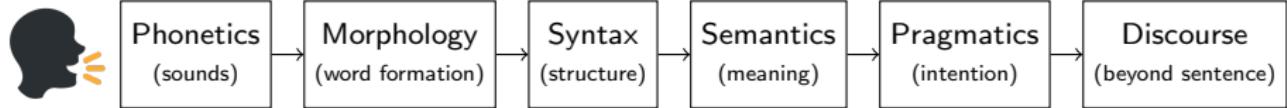
HOW DOES CHATGPT WORK?



imgflip.com

Natural Language Processing [Jurafsky and Martin, 2009]

- Enabling **machines to communicate in human language!**
 - **Artificial Intelligence + Linguistics**
- Knowledge required at several levels...



- Broad range of tasks
- Several challenging phenomena: variability, vagueness, **ambiguity**...
 - Different from programming languages, where each symbol has a **single meaning** or a straightforward disambiguation rule!

Natural Language Processing

Some tasks

Machine Translation

Translation of text in one natural language to another.

Information Extraction

Acquisition of **structured** information from text.

- Named Entity Recognition, Relation Extraction, Temporal Information

Automatic Question Answering

Searching for **answers** to questions posed in a natural language.

- Interpret question, interpret data

Conversational Agents / Dialog Systems

Systems that one can **interact with using natural language**.

- Interpret interactions, interpret data, handle context, generate responses, ...

Conversational Agents

Goals: Companion, Virtual Assistant, Expert

How was your day?

If A = "how was your day?"
then R = "Amazing!"

Amazing!



Switch on
the light



Action: on
Object: lamp



How many movies
did Tarantino direct?

```
SELECT COUNT(*) FROM (SELECT DISTINCT
original_title FROM movies, persons,
activity, activity_codes, jobs WHERE
persons.person_name LIKE "Tarantino" AND
persons.person_id = activity.person_id ...)
```

12

Challenges

Speech recognition

I wish I could be you.



??



??

Weurd wush, but ut's granted now.

Language Modelling

Predicting the probability of a given sequence of words occurring in a sentence.

- $P(\text{you}) > P(u)$?
- $P(\text{be you}) >> P(\text{be u})$

→ Markov assumption: $P(\text{you}|\text{I wish I could be}) \approx P(\text{you}|\text{be})$ (bigrams)

Challenges

Speech recognition



Source: <https://www.facebook.com/PunHubOnline>

Challenges

Language Variability (paraphrases, synonymous)

Switch on the light



Switch the lamp on



Turn on the light

Action: on
Object: lamp



Would you turn on the light, please?

Could you switch on the light?

Synonymy

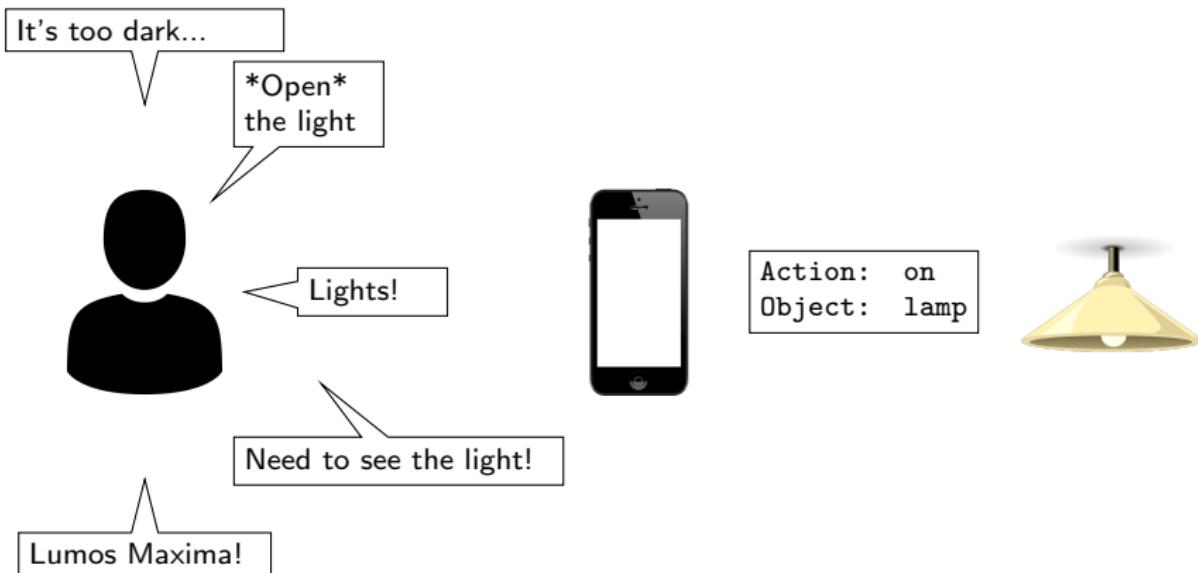
Two different words are synonymous if, in some context, they have the same meaning (e.g., *turn=switch*).

Paraphrase

Two sentences paraphrase each other if they can have the same meaning.

Challenges

Language Variability (non-literal interpretations)



Challenges

Vagueness



Switch on the light



?

Action: on
Object: lamp1



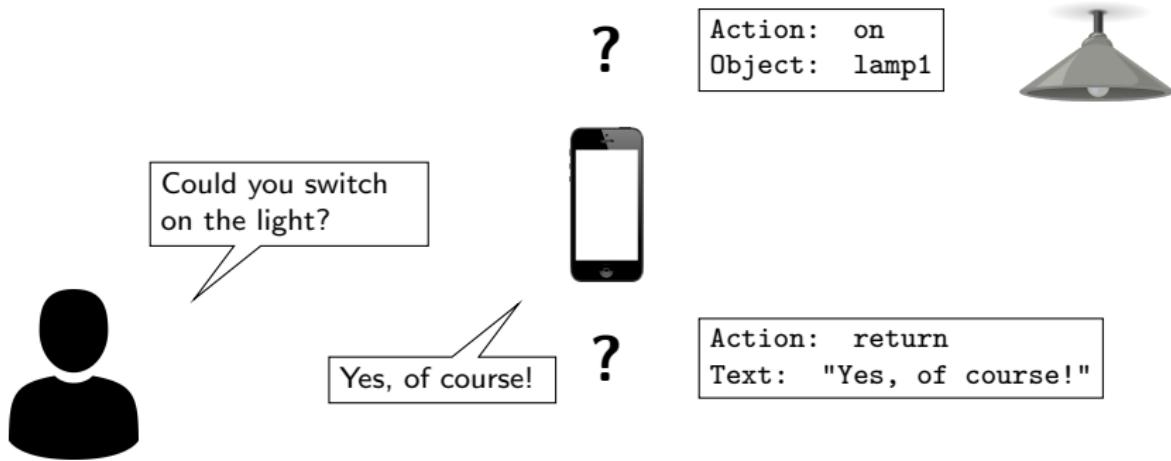
?

Action: on
Object: lamp2



Challenges

(Semantic) Ambiguity



Ambiguity

An ambiguous expression might have **two or more possible interpretations**.

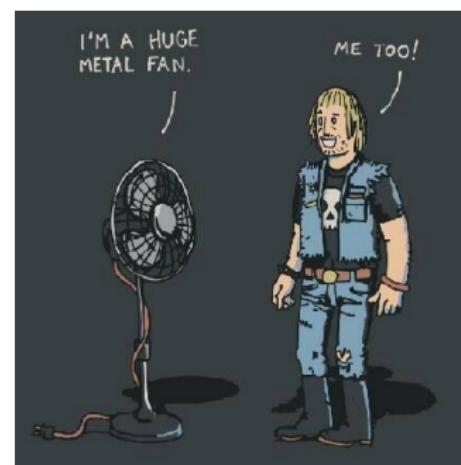
In natural language, ambiguities can be phonological, lexical, syntactic, semantic, ...

Challenges

Ambiguity in Natural Language



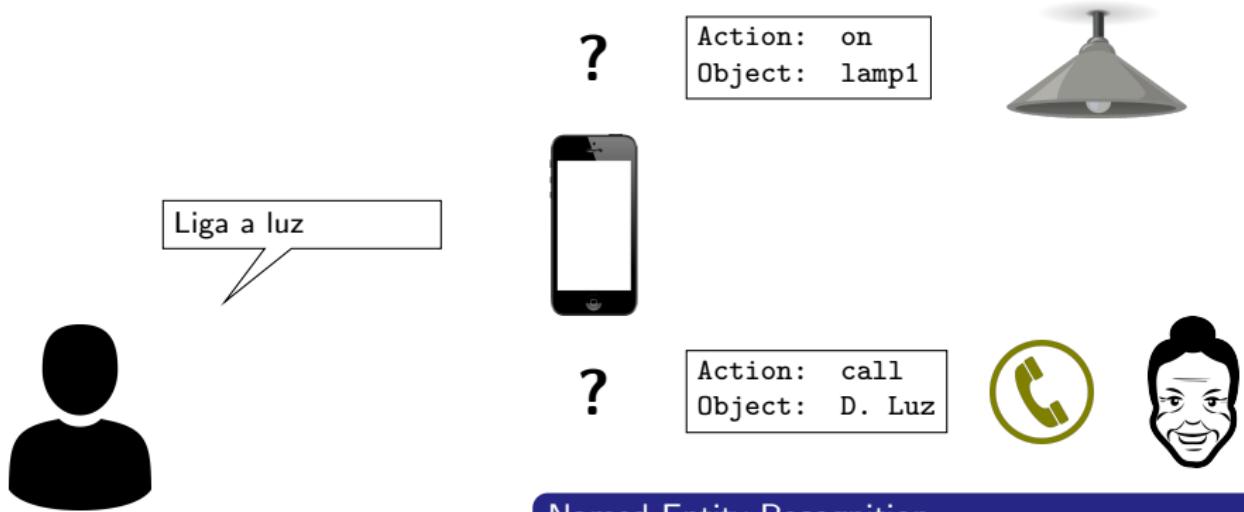
Structural / syntactic ambiguity



Semantic ambiguity

Challenges

(Semantic) Ambiguity (2)



Named Entity Recognition

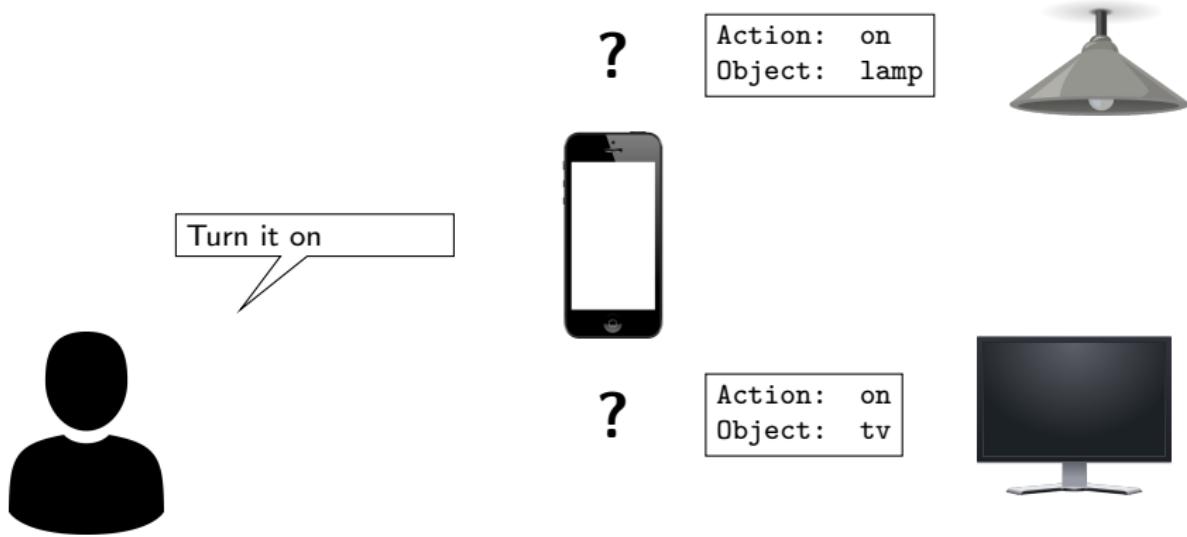
- Locate **mentions to entities** that contribute to understanding the meaning of text
- **Classify** such mentions according to pre-defined categories
- **Entity Linking:** link entity mentions to their entries in a knowledge base.

Word Sense Disambiguation

Determining which of the possible **meanings** of a word is activated by a particular **context**.

Challenges

Anaphora



Anaphora

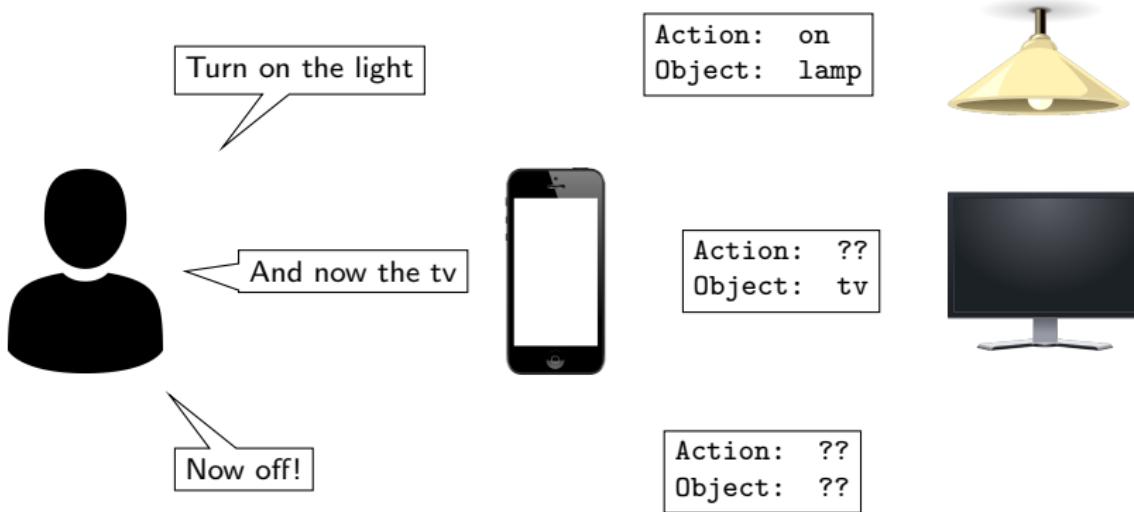
The use of an expression whose interpretation depends upon another expression in context.

Coreference resolution

Finding all expressions that refer to the same entity in a text.

Challenges

Ellipsis



Ellipsis

The omission of a word or phrase that has to be inferred for proper understanding.

Approaches

Keyword-based / Pattern-matching

Switch on the light



Patterns	Intent
"switch * on", "turn * on", ...	Action: on
lamp, light, ...	Object: lamp
tv, television, ...	Object: tv
...	...

Action: on
Object: lamp



ELIZA [Weizenbaum, 1966]

A computer program that simulated conversation through “pattern matching” and substitution, that gave users an illusion of understanding, but had no built in framework for contextualizing events.

```

ELIZA: Is something troubling you ?
YOU: Men are all alike.
ELIZA: What is the connection, do you suppose ?
YOU: They're always bugging us about something or other.
ELIZA: Can you think of a specific example ?
YOU: Well, my boyfriend made me come here.
ELIZA: Is it important to you that your boyfriend made you come here ?
YOU: He says I'm depressed much of the time.
ELIZA: I am sorry to hear that you are depressed.
YOU: It's true. I am unhappy.
ELIZA: Can you explain what made you unhappy ?
YOU:
    
```

* Chat with ELIZA: <http://psych.fullerton.edu/mbirnbaum/psych101/eliza.htm>

Approaches

Retrieval-based

turn on the light



Similarity function

Index	
Entries	Intent
"switch on the light "	Action: on, Object: lamp
"turn off the light "	Action: off, Object: lamp
"switch on the tv "	Action: on, Object: tv
"turn off the tv "	Action: off, Object: tv
"call my mother "	Action: call, Object: mother
...	...

Action: on
Object: lamp



Information Retrieval [Manning et al., 2008]

The activity of obtaining information resources automatically in large collections of unstructured text (e.g. the Web), relevant to an information need.

Typically two main components:

- (Inverted) index (tokens → documents / actions)
- **Similarity** function, either supervised (closed domains) or unsupervised (similarity metrics, possibly exploiting pre-trained language models (e.g., BERT [Devlin et al., 2019]))

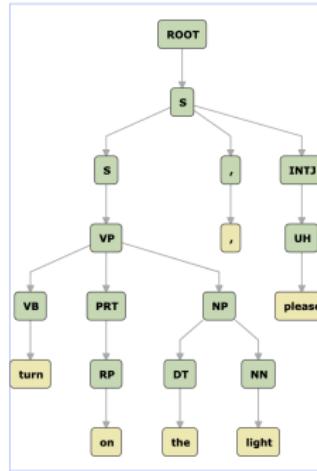
Approaches

Semantic Parsing

turn on the light, please



Lexicon	PoS	Synonyms	Intent
turn	VB	switch	turn(x, y)
on	RP		on_{r1}
light	NN	lamp	$light_{n2}$



$\lambda x \times \lambda y \text{ turn}(x, y)$

$x = \text{lamp}, y = \text{on}$

Action: on
Object: lamp



Rule-based

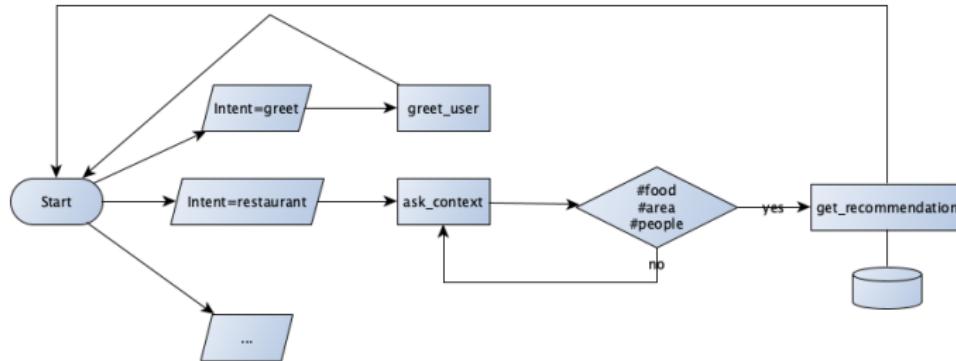
- From parsing tree to intent

Supervised Learning

- Learn from...
 - Utterance + meaning representation
 - Utterance + answer [Berant et al., 2013]

Approaches

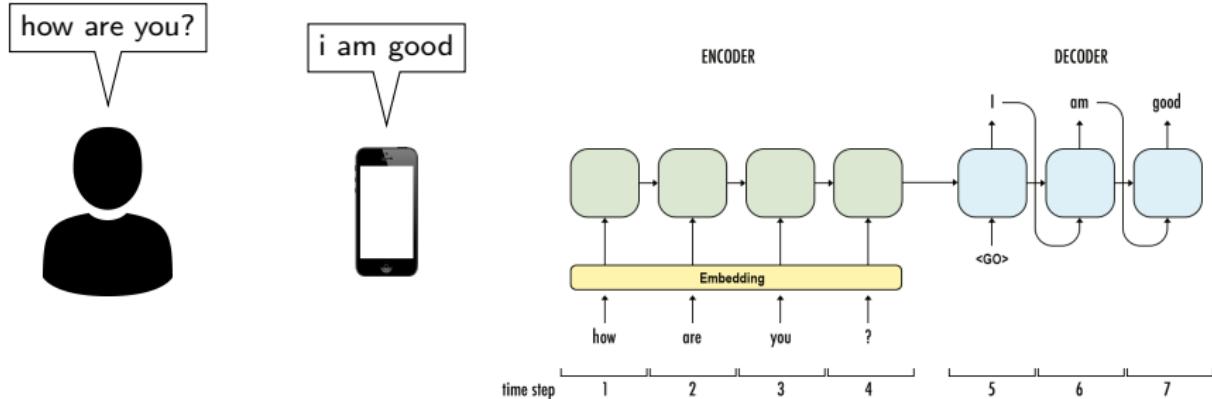
Dialogue Flows



- Regardless of the approach for finding suitable responses, several conversation agents are based on dialogue flows
 - At each turn, the dialogue is in a specific state, associated with an action
 - Natural Language Understanding: **intent** recognition, **entity** extraction
 - Often predefined by humans
 - Interpretable

Approaches

Generative



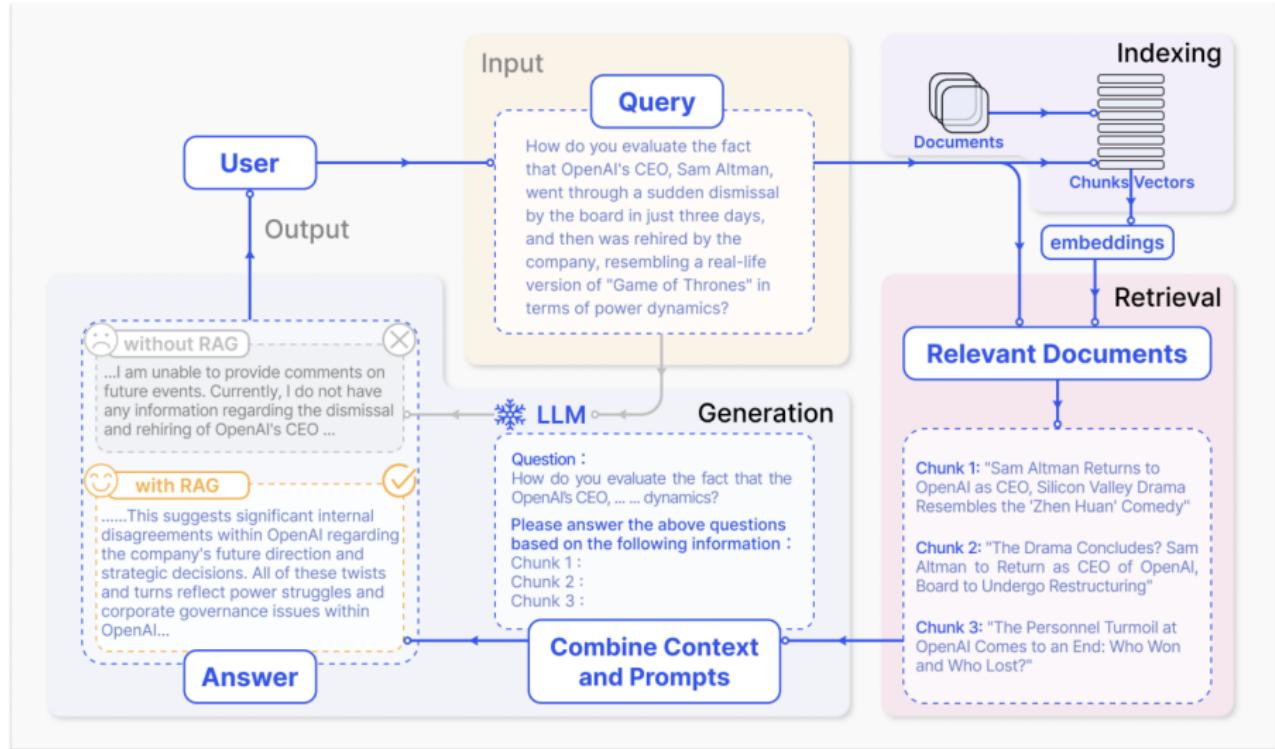
Encode-decoder architectures

- Learn to translate interactions into responses
- Supervised by available data
 - Human-human conversations in social networks, movie subtitles, FAQs, ...
- Currently based on LLMs [Dam et al., 2024]
 - e.g., ChatGPT is a chatbot based on the GPT LLM

Approaches

Generative + IR

Retrieval Augmented Generation [Gao et al., 2024]



Questions?



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