



# Sentence-Level NLU

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# What is it in a sentence?

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- Human conversations



**Conversations are Tools  
Humans use to...**





# **Exchange and Manage** Ideas, Opinions, Emotions, Information, Intentions



# What is it in a sentence?

## ■ Humans communicate and execute **speech acts.**

- Generate a sequence of symbols ( tokens from a dictionary ) that belong to a shared code , the natural language.
- Embed the speaker's intentions (e.g., requesting information vs. providing an answer vs. agreeing to a previous statement, etc.)
- Embed expected effect on the hearer ( e.g. satisfying him/her, annoying him/her, etc..)



# In this course

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- We will describe and compute a very common intention in human-machine AI system:
  - **Directive Acts** ( e.g. requesting information)
  - **Expressive acts** (e.g. sharing opinion)
- In the human-machine dialogue course ( 1<sup>st</sup> semester), we will take into considerations the complete set of acts that make up a dialogue.

# Definition of Meaning

## A Starter

- Good for the rest of the course and much more.
- An abstract representation of explicit signals such as speech, text, gestures.
- This abstract representation can be used internally by the machine (e.g. for inference computation) or for computing or explaining machine actions (e.g., **responses**).

# AI System supporting users with flight reservations

This is the ATIS flight information system, how may I help you ?

Show me flights from Seattle to Boston next Monday.



Artificial Intelligent  
System (AIS)



Customer



# AI System supporting users with flight reservations

This is the ATIS flight information system, how may I help you ?

Show me flights from Seattle to Boston next Monday.



Artificial Intelligent  
System (AIS)

Computing the  
Meaning in  
Human-Machine  
Dialogue



Customer

# Natural Language Understanding (NLU)

## Example

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**AIS:** This is ATIS flight information system, how may I help you ?

**Customer:** Show me flights from Seattle to Boston next Monday.

# Natural Language Understanding (NLU)

## Example

**AIS:** This is ATIS flight information system, how may I help you ?

**Customer:** Show me flights from Seattle to Boston next Monday

We need to parse and know about :  
“flight”, “city”, “airport”, “time”, “meal”

# Natural Language Understanding (NLU)

## Example

**AIS:** This is ATIS flight information system, how may I help you ?

**Customer:** Show me flights from Seattle to Boston next Monday.

**AIS:**[Database query] (SELECT DISTINCT flight.flight\_id FROM flight WHERE ( flight.from\_airport IN ( SELECT airport\_service.airport\_code FROM airport\_service WHERE airport\_service.city\_code IN ( SELECT... ) );

Then we can access knowledge resources and from here engage into a dialogue to continue and execute a task

# Outline

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- Natural Language Understanding
  - Concept Sequence Tagging
- Neural Network Architectures

# Sentential Meaning

## Sequence Modeling

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- Word Sequence (X) TO Label Sequence (Y)

X=Show me morning flights from Boston to SF on Tuesday

Y= ????



# Sequence Labeling

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- Word Sequence (X) TO Label Sequence (Y)

X= `Show me morning flights from Boston to SF on Tuesday`

Y= **GOAL**

# Sequence Labeling

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- Word Sequence (X) TO Label Sequence (Y)

X= Show me morning flights from Boston to SF on Tuesday

Y= GOAL      TIME

# Sequence Labeling

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- Word Sequence (X) TO Label Sequence (Y)

X= Show me morning flights from Boston to SF on Tuesday

Y= GOAL      TIME      TOPIC

# Sequence Labeling

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- Word Sequence (X) TO Label Sequence (Y)

X= Show me morning flights from Boston to SF on Tuesday

Y= **GOAL**      **TIME**      **TOPIC**      **ORIGIN**      **DESTINATION**

# Sequence Labeling

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- Word Sequence (X) TO Label Sequence (Y)

X= Show me morning flights from Boston to SF on Tuesday

Y= **GOAL**      **TIME**      **TOPIC**      **ORIGIN**      **DESTINATION**      **TIME**

# Sequence Labeling

- Word Sequence (X) TO Label Sequence (Y)

X= Show me morning flights from Boston to SF on Tuesday

Y= GOAL TIME TOPIC ORIGIN DESTINATION TIME

- Labels in the context of Natural Language  
Understanding may be referred to *concept* (C).



# Segmentation and Labeling

- Word Sequence (X) TO Label Sequence (Y)



- **Segmentation**: Grouping words that are mapped into the same concept
- **Labeling**: Assign a label to the group of words
- **Extensions** : concept sequences to semantic parse trees to graphs

# Human Knowledge Approach

## Grammar Writing

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- *Human experts* write grammar rules ( e.g. context free grammar )
  - Terminal rules map into the language tokens
  - Non-terminal rules may be purely syntactic or semantic ( domain ontology ) or hybrid.

# Descriptive Solution

## Grammar Writing

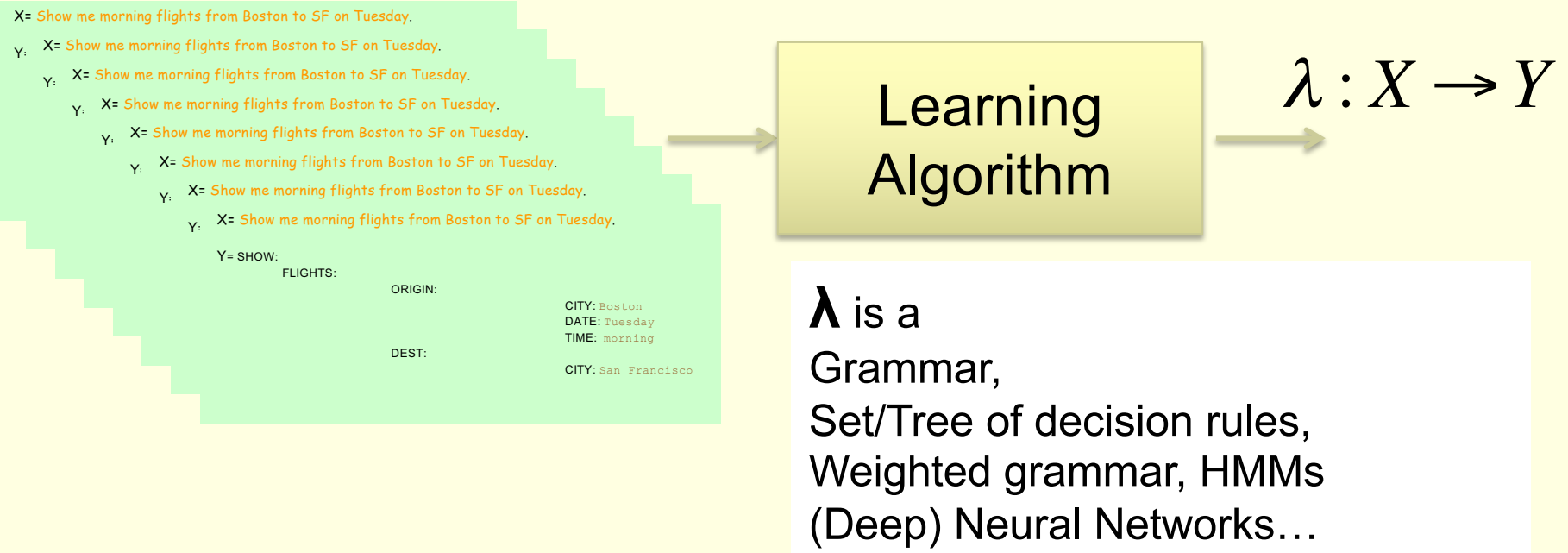
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- *Human experts* write grammar rules ( e.g. context free grammar )
  - Terminal rules map into the language tokens
  - Non-terminal rules may be purely syntactic or semantic or hybrid.
- **Example:** ATIS corpus ( flight information retrieval task )
  - 3K non-terminals, 13K grammar rules
- **Balancing act** btw coverage and complexity and cost and accuracy !

# Data Driven Learning

- Learn from annotated examples
  - $(X,Y) = (\text{Word Sequence}, \text{Label Sequence})$

# Annotated Corpus



# Learning from data

- Learn from annotated examples

- $(X, Y) = (\text{Sentence}, \text{Frame})$

$X =$  Show me morning flights from Boston to SF on Tuesday.

$Y =$  SHOW:

FLIGHTS:

ORIGIN:

CITY: Boston

DATE: Tuesday

TIME: morning

DEST:

CITY: San Francisco

**Frame**

# Semantics of Labels

What do they mean

- Labels are leaves drawn from a dictionary or structure
- **Ontology** : system of concepts describing objects ( degrees of abstractness )
- **Frames** : linguistically motivated.  
Connecting a linguistic scene with abstract objects
  - Predicates (**reserve**)
  - Entities ( **flight** )



# In Practice

What do they mean

- Practice= Conversational AI platforms
  - Amazon, Google, Apple, et al.

# Intents in Conversational Agent Dev Platform

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- In most development platform for Conversational Agent ( Amazon, Google, MS ) one of the key construct they will provide is the intent-slot structure of an utterance.
- The motivation and definition is similarly ambiguous in all platforms.

# Intents : Example

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In Amazon Alexa's development framework\* intent is defined as "A representation of the action that fulfills a customer's spoken request":

\*Source: [Amazon Alexa Developer website](#)

# Intents : Example

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In Amazon Alexa's development framework\* intent is defined as "A representation of the action that fulfills a customer's spoken request":

Given a sentence like:

I am going on a trip on Friday

They would suggest the intent *PlanMyTrip*.

\*Source: [Amazon Alexa Developer website](#)

# Intents : Example

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In Amazon Alexa's development framework\* intent is defined as "A representation of the action that fulfills a customer's spoken request":

Given a sentence like:

I want to visit Portland

What would be the intent ?.

\*Source: [Amazon Alexa Developer website](#)

# Intents : Example

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In Amazon Alexa's development framework\* intent is defined as "A representation of the action that fulfills a customer's spoken request":

Given a sentence like:

I want to travel from seattle to  
portland next Friday

What would be the intent ?.

\*Source: [Amazon Alexa Developer website](#)



# Intents : Example

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In Amazon Alexa's development framework\* intent is defined as "A representation of the action that fulfills a customer's spoken request":

Given sentences like:

I am going on a trip on Friday

I want to visit Portland

I want to travel from seattle to portland next Friday

They would be mapped in the intent *PlanMyTrip*.

\*Source: [Amazon Alexa Developer website](#)

# More on Terminology

What do they mean

- Practice= Conversational AI platforms
- Domain
  - *restaurant, hotel*
- Slots
  - *Guests, ArrivalDate*
- Values
  - *6, 20220601*
- Intent
  - *ReserveDinner, MakeReservation*
  - Fuzzy definition and prone to over or under generalization
  - No universal lexicon, poor reusability and extendability

# Dismissing Intents Towards Linguistic Theory

- In the next semester, we will introduce a discourse analysis of natural language
    - Course: Human-Machine Dialogue
  - Different layers of interpretations that take into account the speaker and the hearer's point of view
- ➔ Speech and Dialogue Acts

# Segmentation and Labeling Problem

- Word Sequence (X) TO Label Sequence (Y)

X= Show me morning flights from Boston to SF on Tuesday.  
Y= **GOAL** **TIME** **TOPIC** **ORIGIN** **DESTINATION** **TIME**

- General Problems:
  - Which computational models ?
  - Which labels ? How Many ?
  - Which words ?
  - How much data ?

# Observe-Collect-Model-Verify



# Segmentation and Labeling Problem

X= Show me morning flights from Boston to SF on Tuesday

Y= GOAL TIME TOPIC ORIGIN DESTINATION TIME



- Word Sequence (X) TO Label Sequence (Y)

# Outline

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- Natural Language Understanding
  - Concept Sequence Tagging
- Generative Models for NLU
- Discriminative models for NLU
  - Conditional Random Fields
- **Neural Network Architectures**

# Questions ?

