Natural Language Processing

Lexical Semantics

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In this lecture:

- Part 1: **Linguistic Ontologies vs. Application Ontologies**
- Part 2: What is Lexical Semantics
- Part 3: What is a Concept
- Part 4: Polysemy and Synonymy
- Part 5: Multilingualism
- Part 6: Distributional Semantics

Reading

[J21] Mustafa Jarrar: **The Arabic Ontology - An Arabic Wordnet with Ontologically Clean Content**. Applied Ontology Journal. IOS, 2019.

https://www.jarrar.info/publications/J21.pdf

Application Ontology vs. Linguistic Ontology

The importance of linguistic ontologies is growing rapidly [J21].

Application ontology

To represent the semantics of a certain domain/application, e.g., the Gene Ontology, the FOAF ontology, the Palestinian e-government ontology.

- Each term convey one concept (no polysemy).
- Represents (/Benchmarked to) application's knowledge.
- Used only by a certain application, or a class of applications.

Linguistic ontology

To represent the semantics of terms in a human language, independently of a particular application.

- Each word may convey several concepts (Polysemy).
- Represents common-sense knowledge (/State-of-art scientific discoveries).
- Can be used for general purposes.

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What is Lexical Semantics?

The study of how and what the words of a language denote [J21].

- Whether the meaning of a *lexical unit* is established by looking at its **neighborhood in the semantic net** (by looking at the other words it occurs with in natural sentences), or if the meaning is already locally contained in the lexical unit?
- There are several **theories of the classification and decomposition of word meaning**, the differences and similarities in lexical semantic structure between **different languages**, and **the relationship of word meaning to sentence meaning** and syntax.

Lexical Semantics ➔ focuses on the mapping of words to concepts.

Lexical item: a single word or chain of words that forms the basic elements of a language's lexicon (vocabulary). E.g., "cat", "traffic light", "take care of", "by-the-way“, etc.

What is Lexical Semantics?

- There are **different theories and approaches** in defining the relation between a lexical unit and its meaning(s). For example: can we understand the meaning independently of a sentence? can we understand the meaning independently of the grammar (morphology)? and so on.

- Such theories and approaches are: Prestructuralist semantics, Structuralist and nostructuralist semantics, interpretative semantics and generative semantics, cognitive semantics.

- **In this lecture,** we don't investigate these theories, but rather, we study the "meaning" from a computational and engineering viewpoints, so to enable computer applications ➔ Based on [J21].

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What is a concept?

ISO TC37 definitions:

تعريف المفهوم حسب مؤسسة المعايير الدولية

3.2.1 concept

unit of knowledge created by a unique combination of **characteristics** (3.2.4)

NOTE Concepts are not necessarily bound to particular languages. They are, however, influenced by the social or cultural background which often leads to different categorizations.

3.2.2 individual concept

concept (3.2.1) which corresponds to only one **object** (3.1.1)

NOTE 1 Examples of individual concepts are 'Saturn', 'the Eiffel Tower'.

NOTE 2 Individual concepts are usually represented by **appellations** (3.4.2)

This ISO definition is based on Eugen Wuster work [W03] who argued: **concepts and objects are both *thoughts* existing in our minds, rather than in reality**.

هذا التعريف منطلق من عمل **إيغن ويستر** الذي يعرف المفهوم والمدلول (الماصدق) أفكار في دماغنا، وليس بالواقع . تم انتقاد هذا التعريف من بعض الفلاسفة، بان هذا غير مفيد لانه لامكن معرفه ما في دماغنا، واقترح باري سمث: استعمال **الكليات** (universal) بدلا من المفاهيم.

This definition was largely criticized [S04, SCT04, S06]: (See [J21])

Constructing concepts as “thoughts” does not help us to benchmark the correctness of our concept system - as we cannot gain access to the interiors of each other’s brains. Smith Suggested to use **Universal** instead of concept.

What is a concept?

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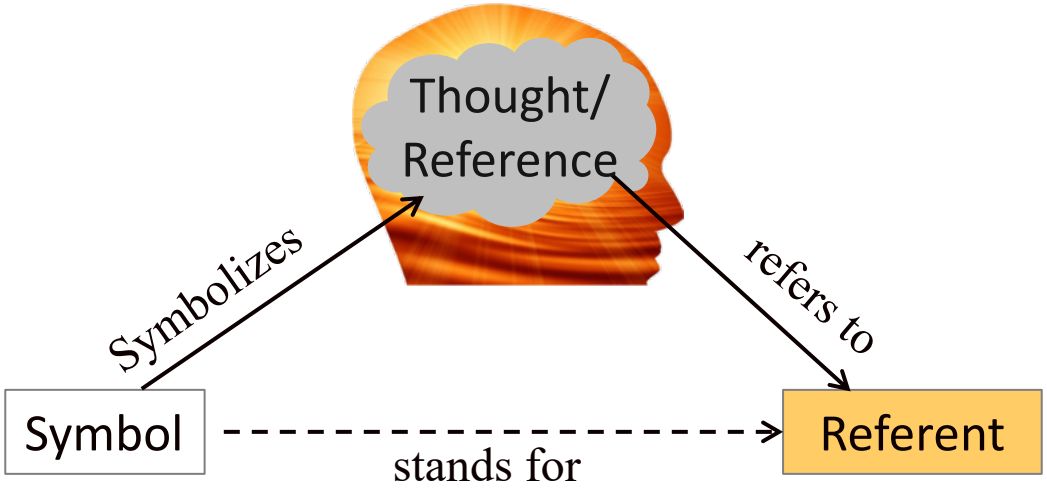
The Semiotic Triangle

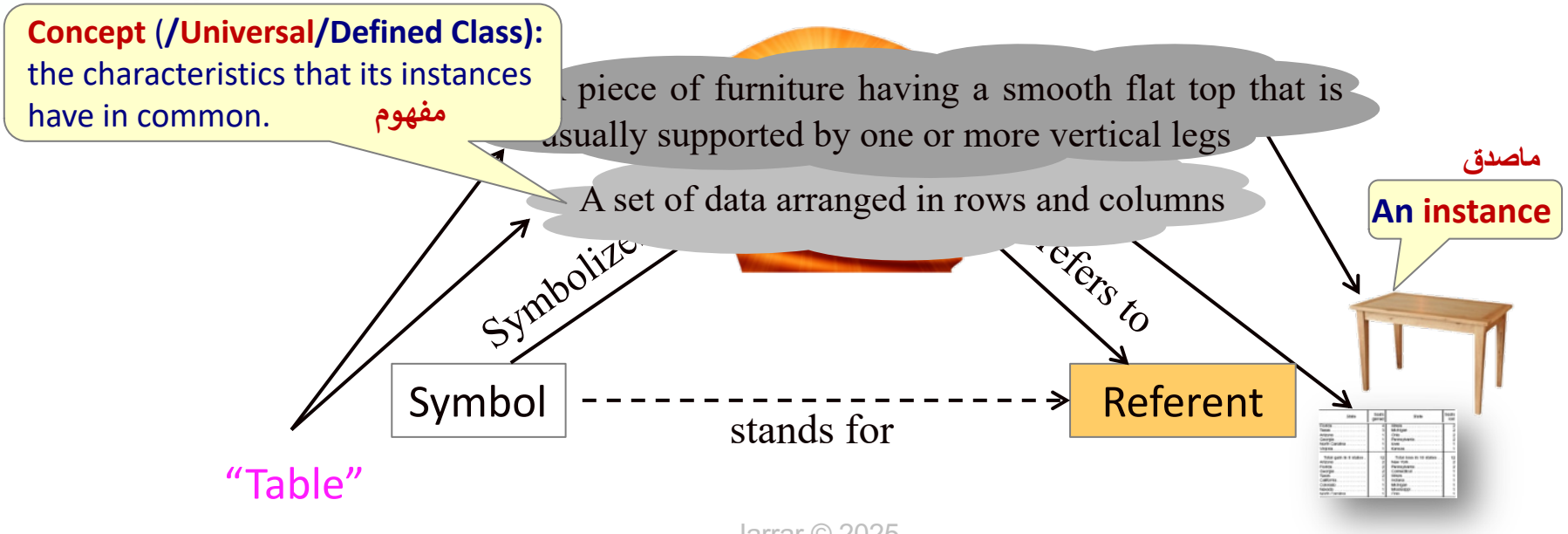
Ogden CK, Richards IA. **The Meaning of Meaning**. 3rd ed. New York, 1930.

- A psychological account (theory of causality)
- A symbolic representation does not refer directly to an object, but indirectly, through a ‘thought or reference’ in mind.



What is a concept

- No concept without instances, and no instance can be a concept at the same time [J11, J05].
- Two concepts with exactly the same extension are the same concept [J11].
- Two terms lexicalizing the same concept (same extension) are synonyms [J05].



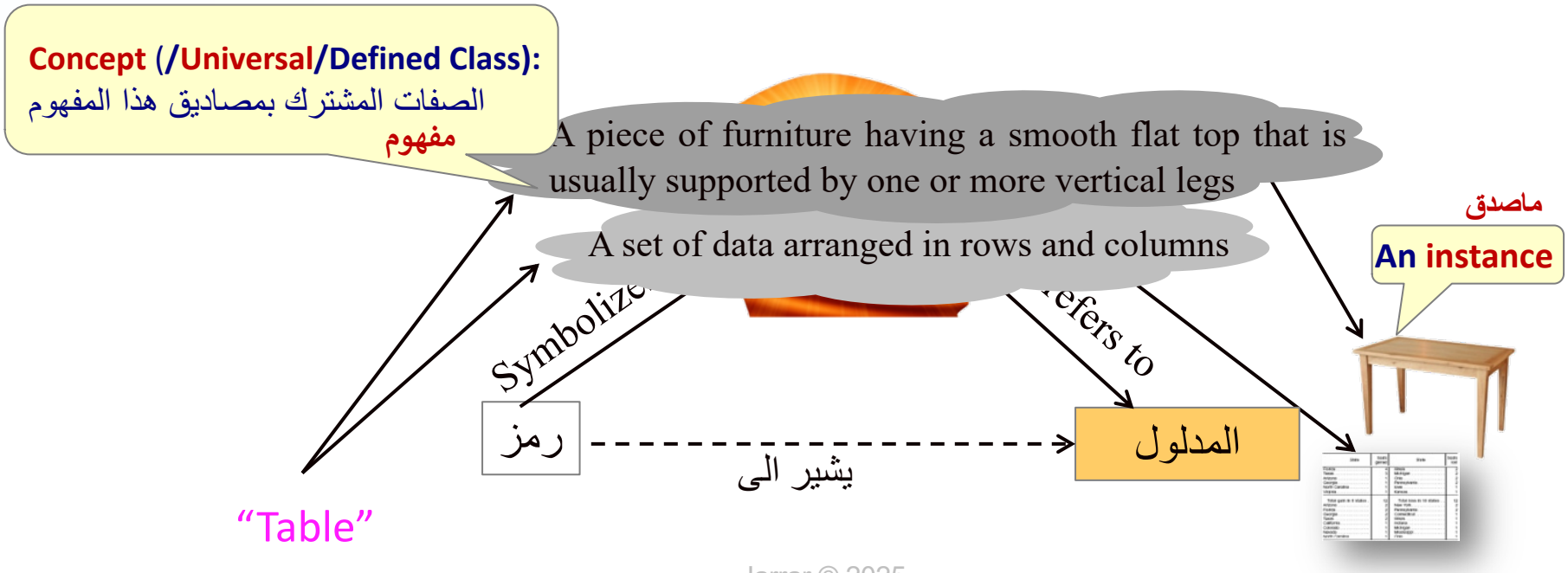
المفهوم والماصدق (Concept vs Instance)

المفهوم هو مجموعة من المصاديق (لها صفات مشتركة).

لا يوجد مفهوم لا يوجد له ماصدق. والماصدق لا يمكن ان يكون مفهوم.

اذا وجد مفهومين لهما نفس المصاديق فهما نفس المفهوم.

اذا وجد كلمتين تشيرا الى نفس المفهوم – أي نفس المصاديق – فهما مترادفتان

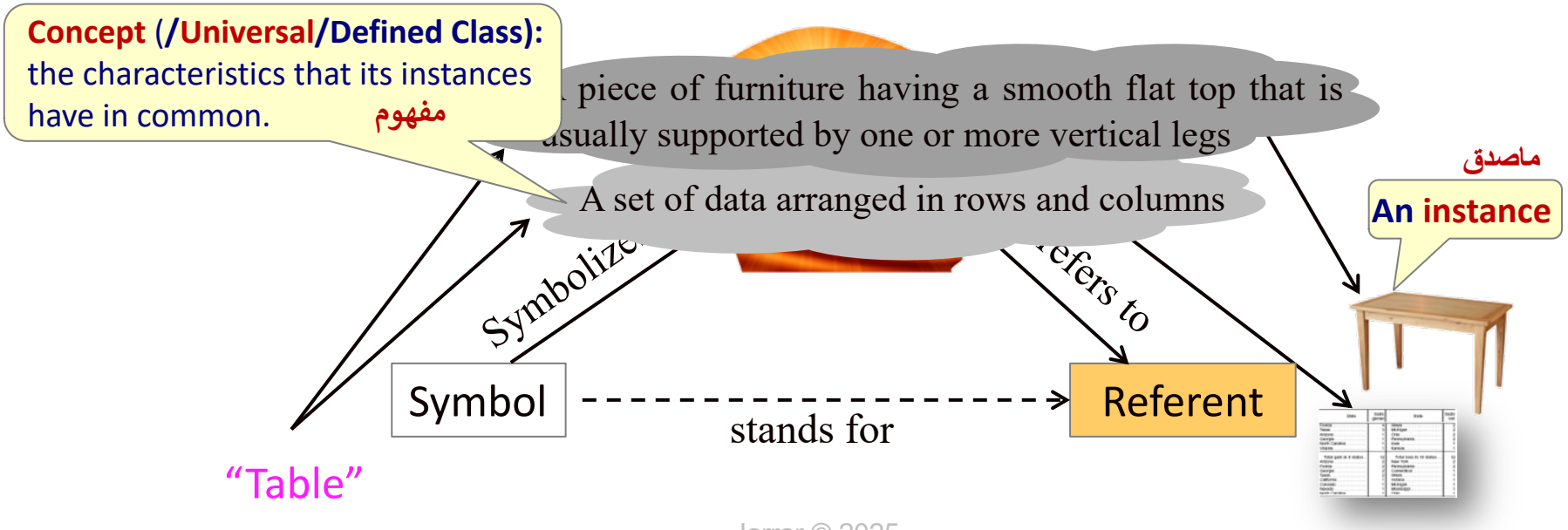


Benchmarking Concepts

How to judge whether the content of the ontology is correct? [J21]

(e.g., Fungus *IsA* Organism? Virus *IsA* Organism? Democracy is political System? …)

- Wusteren/**conceptualist** viewpoint: benchmarked to your *perception*.
- **Realist** Viewpoint: benchmarked to scientific discoveries.



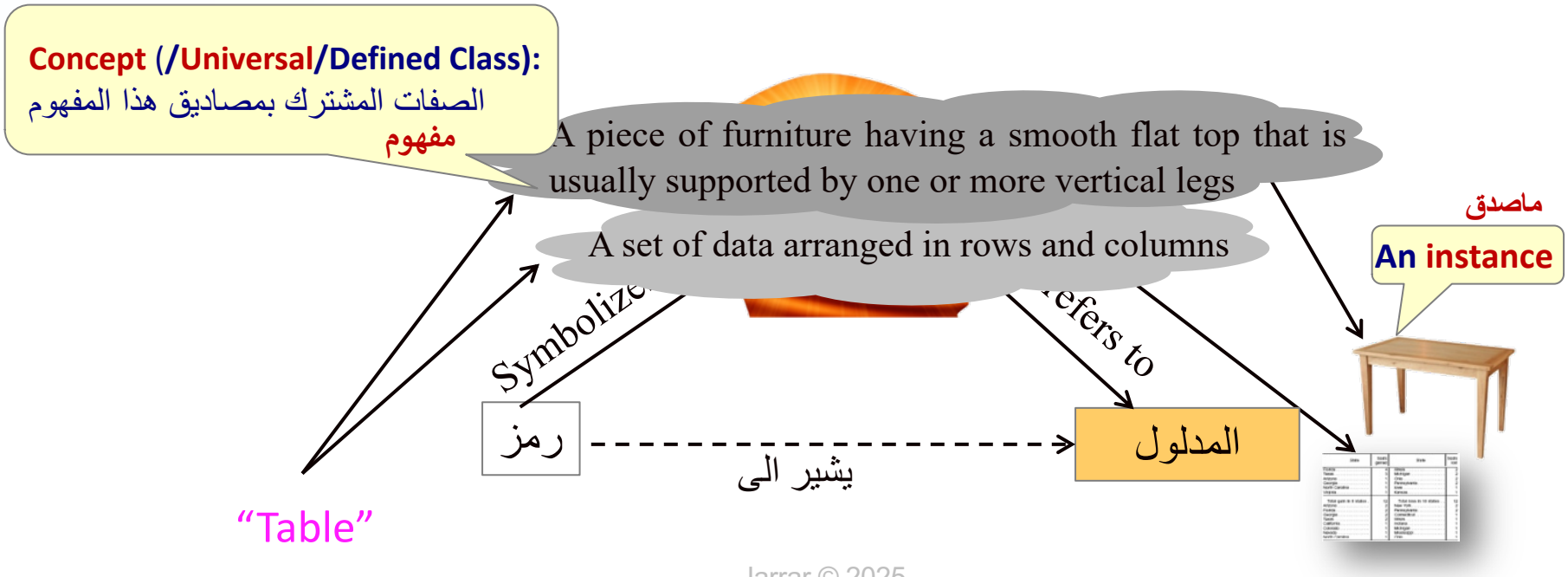
مرجعية العريف المعنى

كيف نحكم ما اذا كان (تعريف المعنى) فعلا صحيح؟ انظر ([J21])

مثلا: الفطر: هو كائن حي ....؟ الفيروس: هو كائن حي: ... ؟ الديمقراطية: نظام حكم ....؟

من وجهة نظر الذهنين (conceptualist) وحسب ويستر: المرجع هو فهمنا (ما في دماغنا)

من وجهة نظر واقعية (Realist) وحسب سمث: المرجع هو ما توصلت اليه العلوم (بالتجارب العلمية)



Number of Terms vs Concepts in a Language

How concepts are named and communicated?

ركوع

قرفصاء

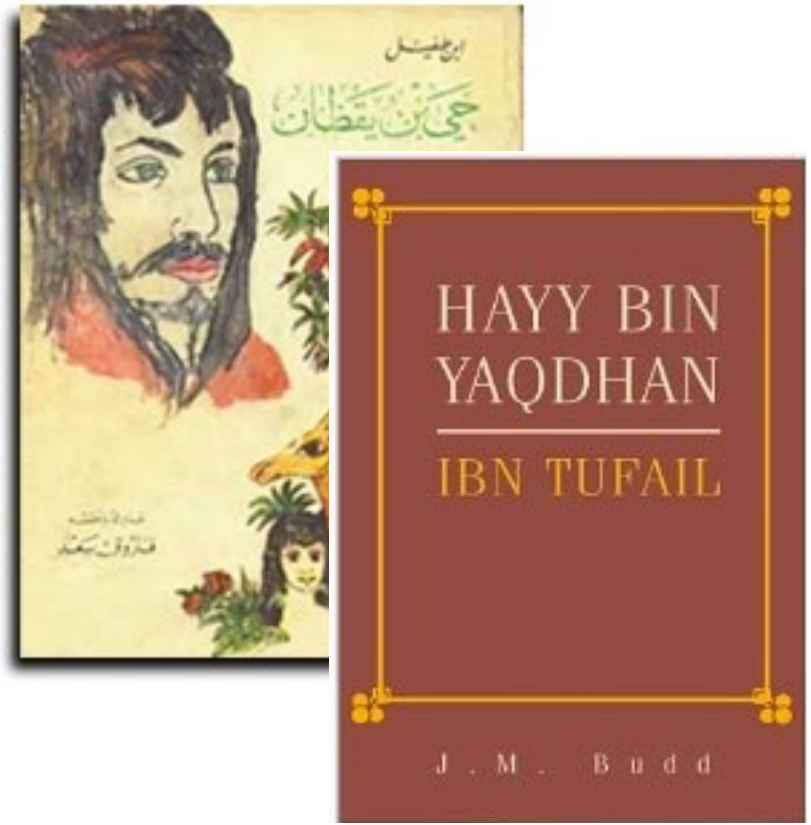
سجود

??

Why there is no word in Arabic to describe this situation?

We give names to the concepts we use more.
Some societies love to give/invite names to concepts (as Arabs in the past)

Recommended Reading



Ḥayy Bin Yaqdhan Novel

Ḥayy ibn Yaqẓān (Arabic: حي ابن يقظان"Alive, son of Awake"; Latin: Philosophus Autodidactus "The Self-Taught Philosopher"; English: The Improvement of Human Reason: Exhibited in the Life of Hai Ebn Yokdhan), the first Arabic novel, was written by Ibn Tufail (also known as Aben Tofail or Ebn Tophail), a Moorish philosopher and physician, in early 12th century Islamic Spain. The novel was itself named after an earlier Arabic allegorical tale and philosophical romance of the same name, written by Avicenna (Ave Cena) in early 11th century,[SO96] though they had different stories.[D92]
-wikipedia

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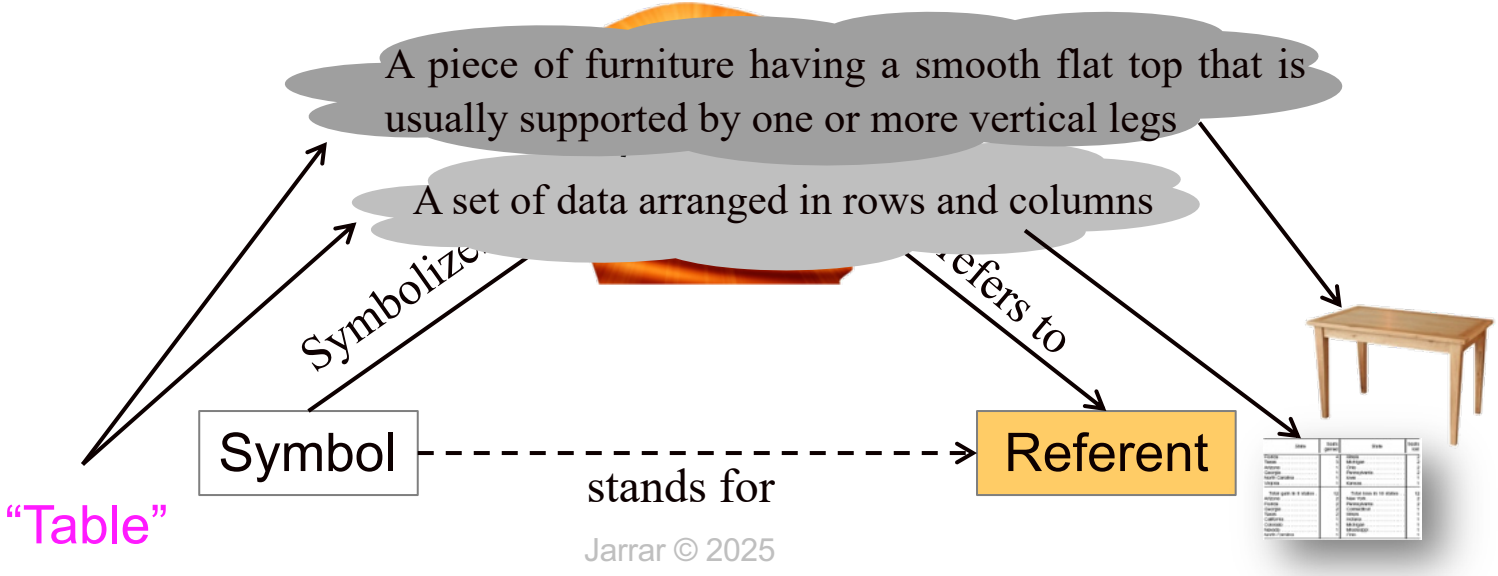
Polysemy

المشترك اللفظي

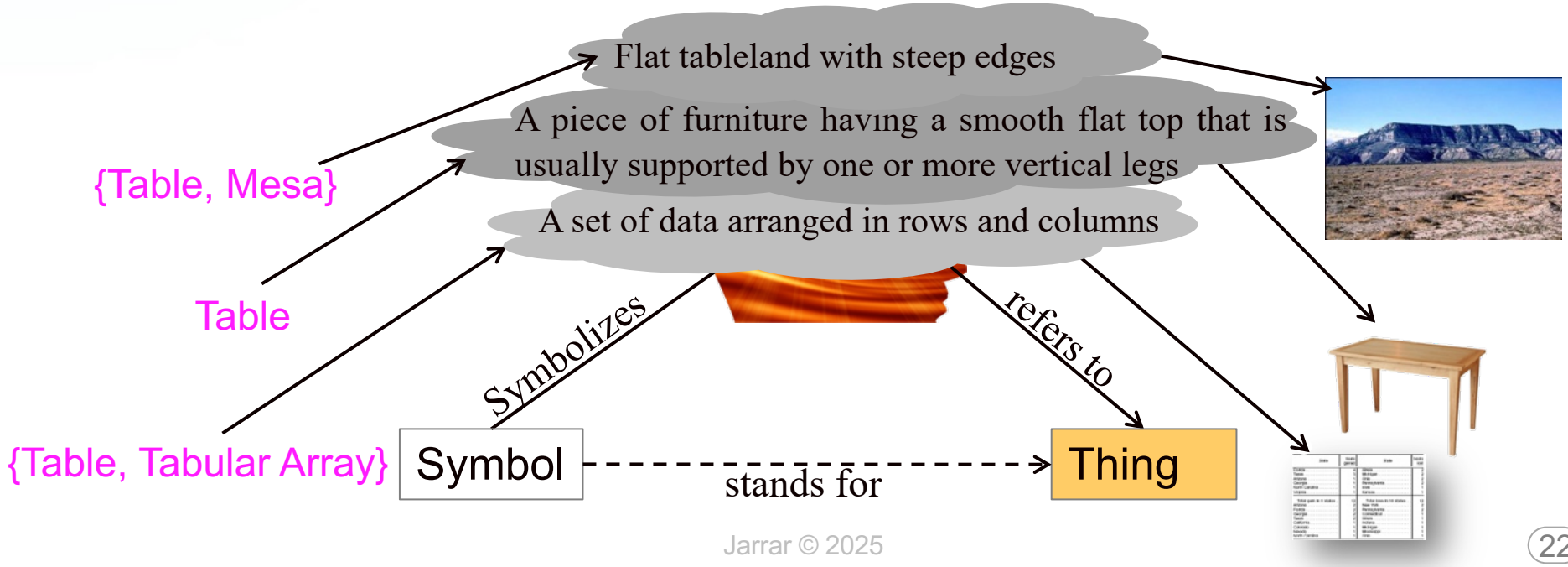
- **Polysemy**: is the capacity of a lexical unit to refer to multiple meanings/concepts. These meanings can be related or different.
- **Polysemy is the consequence of meaning evolution**. The constant discussion over how to name and what words mean is in the discourse of a community and implies language evolution. [T97]
- Note: the most frequent word forms are the most polysemous! [F]



Synonymy

الترادف

- **Synonymy**: different lexical units denoting the **same concept**
- Two lexical units are said to be **synonyms if they can be used interchangeably** in a certain context (/refer to the same extension).
- Mostly, synonyms are generated by the **parallel use**.
- Some lexicographers claim that no synonyms have exactly the same meaning (in all contexts or social levels of language)!!!!.



Synonymy

Synonymy in Wordnet

two expressions are synonymous in a linguistic context C if the substitution of one for the other in C does not alter the truth value" (Miller et al., 1990).

{motorcar | machine | car | automobile | auto سيارة | مركبة}

He needs a car to get to work
He needs a motorcar to get to work
He needs an auto to get to work

Synonymy in Ontology Engineering

alternative labels/names of concepts

Definition: Synonymy Relation (see [J01])
Given two terms t_1 and t_2 lexicalizing concepts c_1 and c_2, respectively, then t_1 and t_2 are considered to be synonymous *iff* $c_1 = c_2$. In this way, synonymy can be defined as an equivalence relation $=_c$ between terms lexicalizing the same concept, thus it is a reflexive, symmetric and transitive relation.

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Multilingually

The language- independency of Concepts is problematic (See [J21]):

- Concepts/universals (that are benchmarked to scientific discoveries) **are language independent**.
- Concepts (that are benchmarked to *perceptions) are* **not totally language-independent**, as they typically depend on the perceptions and culture of the language-speakers.
- Many concepts are **shared cross languages**, especially if the speakers of these languages interact with each other.
- **The more interaction** between two communities speaking different languages, **the more shared concepts** can be found.

Multilingually

The language- independency of Concepts is problematic:

- Concepts/universals (that are benchmarked [illegible] discoveries) **are language independent**.
- Concepts (that are benchmarked [illegible] **language-independent**, as they typically de[illegible]re of the language-speakers.
- Many concepts are **shared cross**[illegible]s of these languages interact with ea[illegible]
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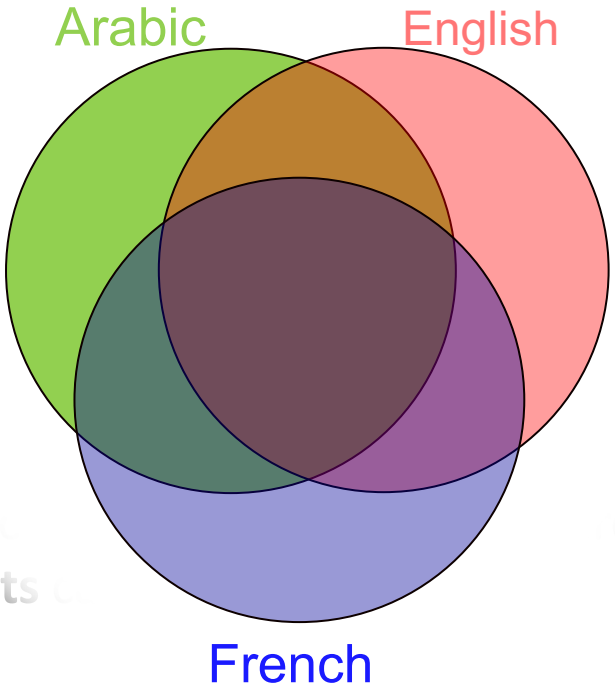

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Distributional Semantics

الدلالة الاحصائية

Distributional Hypothesis:

Linguistic items with similar distributions have similar meanings

In other words, words that are used and occur in the same contexts tend to purport similar meanings (Harris 1954).

Example: “Car” and “Taxi”
“Solder and “Army”
“Boy” and “Gril”

Children can figure out how to use words they've rarely encountered before by generalizing about their use from distributions of similar words (Gleitman 2002).

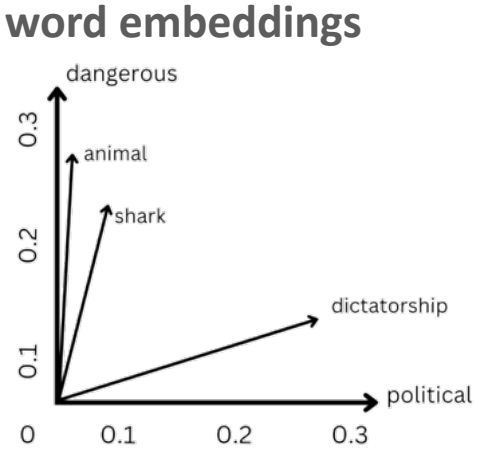
Distributional Semantics

الدلالة الاحصائية

Can we quantify semantic similarities between linguistic items based on their distributional properties in large samples of language data?

Distributional semantic similarity can be represented in different ways, including latent semantic analysis (LSA),Hyperspace Analogue to Language (HAL), syntax- or dependency-based models, random indexing, semantic folding and various variants of the topic model.

Semantic similarity between words using Word Embeddings

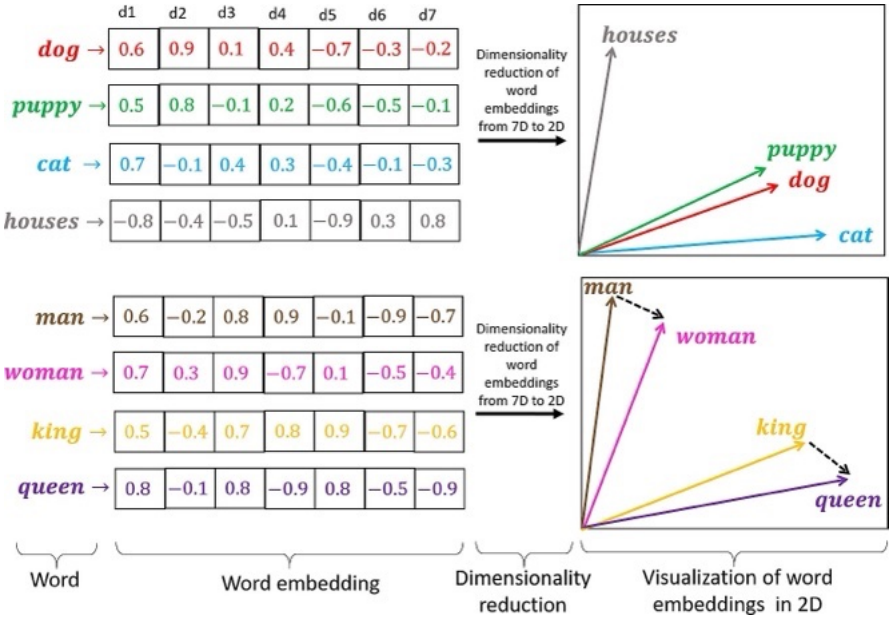


Word Embedding

الدلالة الاحصائية

Word Embedding:
A vector that encodes the meaning of the word in such a way that the words that are closer in the vector space are expected to be similar in meaning (Jurafsky et a., 2000).

can be obtained using language modeling and feature learning techniques (neural models), where words are mapped to vectors of real numbers.



Word Embedding

الدلالة الاحصائية

Word and phrase embeddings, when used as the underlying input representation, have been shown to boost the performance in NLP tasks, such as: syntactic parsing, **sentiment analysis**, **automatic creation of thesauri**, **word sense disambiguation**, **paraphrasing**, and others.

Underlying representation in:

- Word2Vec
- BERT
- GPT
- …

Read More: **A Compositional Distributional Model of Meaning**, by Stephen Clark Bob Coecke Mehrnoosh Sadrzadeh

https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=f86ef3e7b856d61ade62e643d87d288fef8827dd

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