

# Knowledge Representation & Reasoning & Introduction To Knowledge Graphs

Week 1 | Fall 2022 Dr. Amna Basharat



## Importance of 'Knowledge'



## Who's the Creator of Knowledge?

The one who's all knowledgeable



رَبِّ زِدُنِي عِلُمًا



## It Is Impossible To Know Everything

True or False?



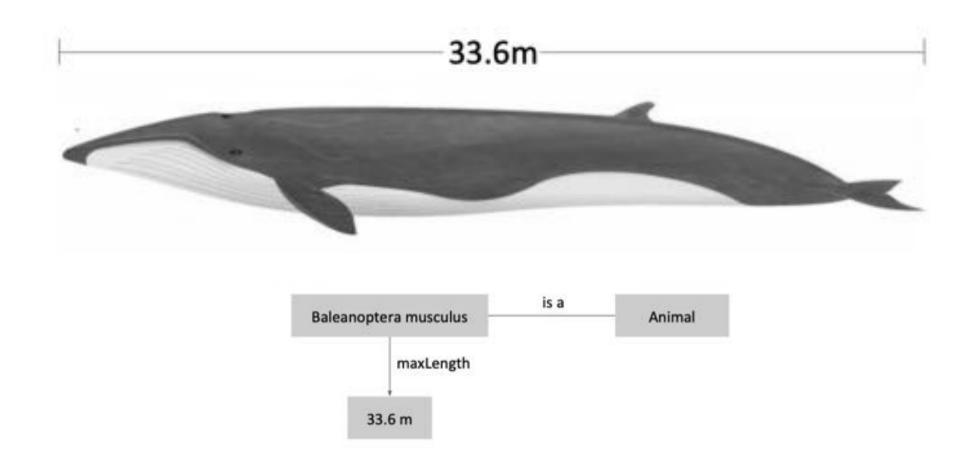
#### All Knowledge Is Beneficial Knowledge?

True or False?



### 33.6

### 33.6 m



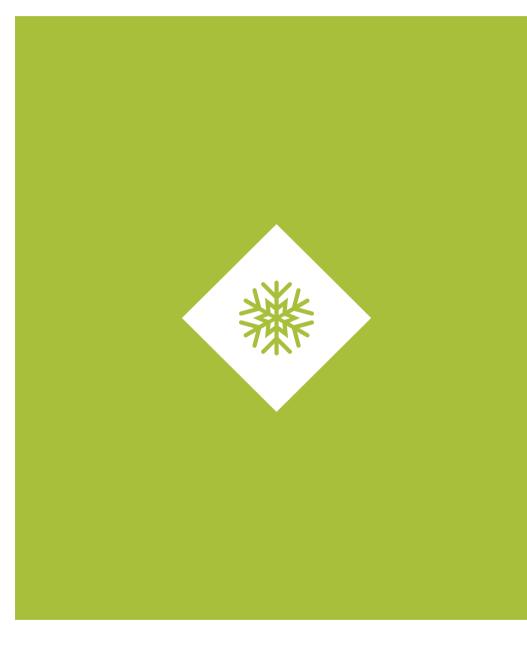
BaleanopteraMusculus 

Animal 

∀maxLength.≤33.6

### Data

- Data is raw.
- It simply exists and has no significance beyond its existence (in and of itself).
- It can exist in any form, usable or not.



#### Information

- Information is data that has been given meaning by way of relational connection.
  - This "meaning" can be **useful**, but does not have to be.
  - Information is contained in descriptions.
- Information answers to questions that begin with such words as who, what, when, where, and how many.

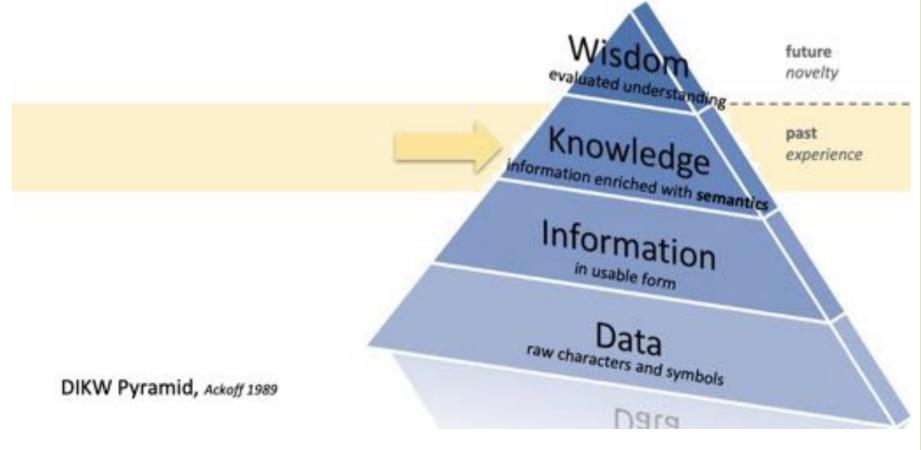


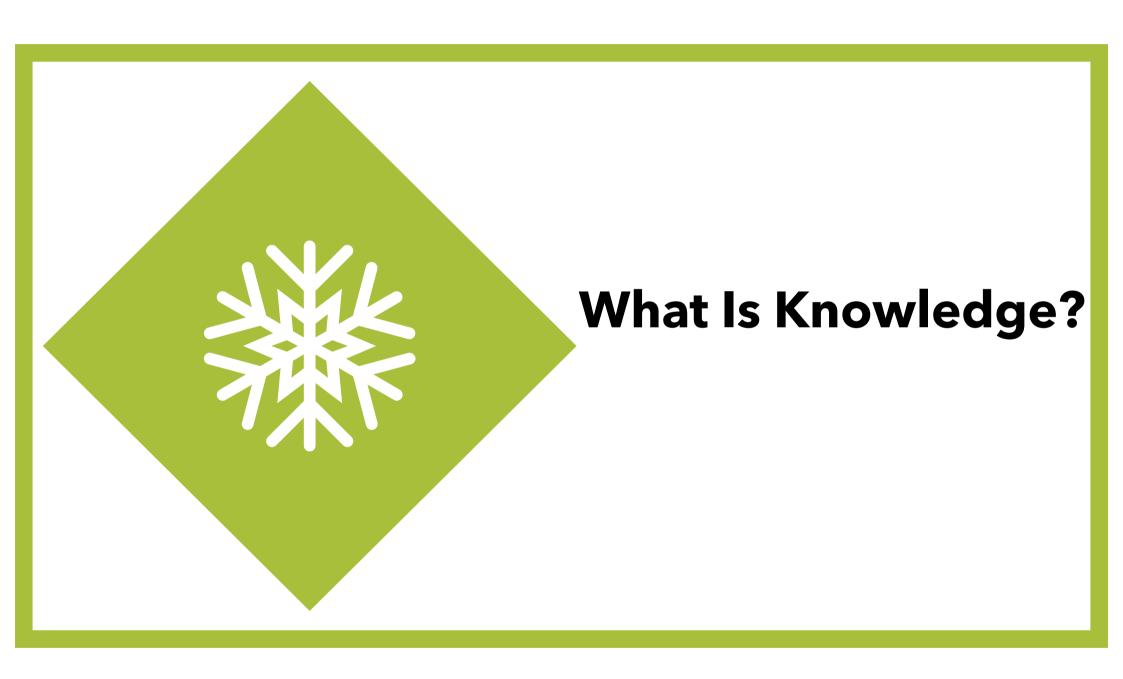
- Knowledge is the appropriate collection of information, such that it's intent is to be useful.
- Wisdom is the ability to make sound judgments and decisions.
- Understanding is a continuum that leads from data, through information and knowledge, and ultimately to wisdom.

Data transforms to information by convention, information to knowledge by cognition, and knowledge to wisdom by contemplation.



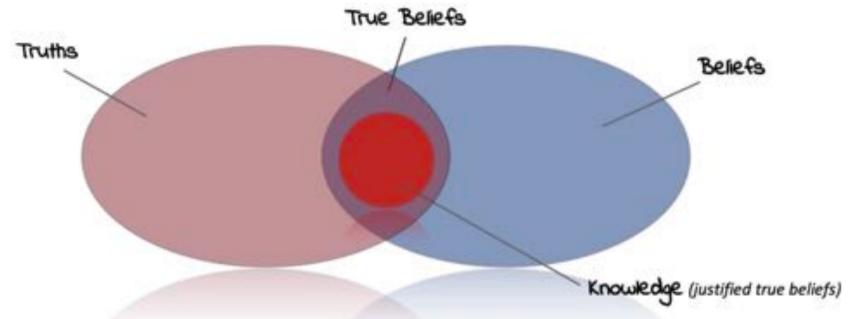
### From Data to Knowledge







### What Is Knowledge?



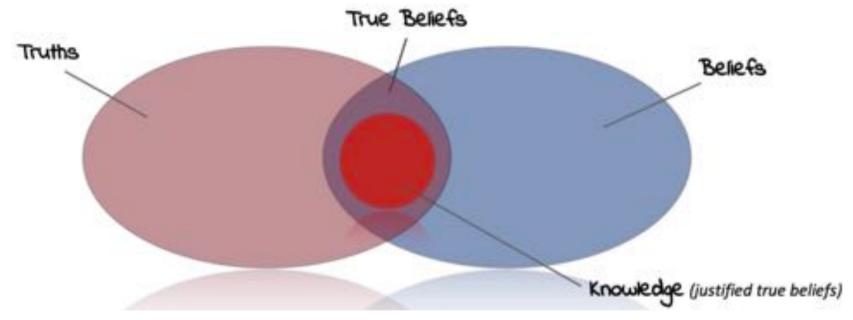
The Tripartite Analysis of Knowledge: S knows that p iff

- p is true;
- S believes that p;
- S is justified in believing that p.

The Analysis of Knowledge, Stanford Encyclopedia of Philosophy, 2001.



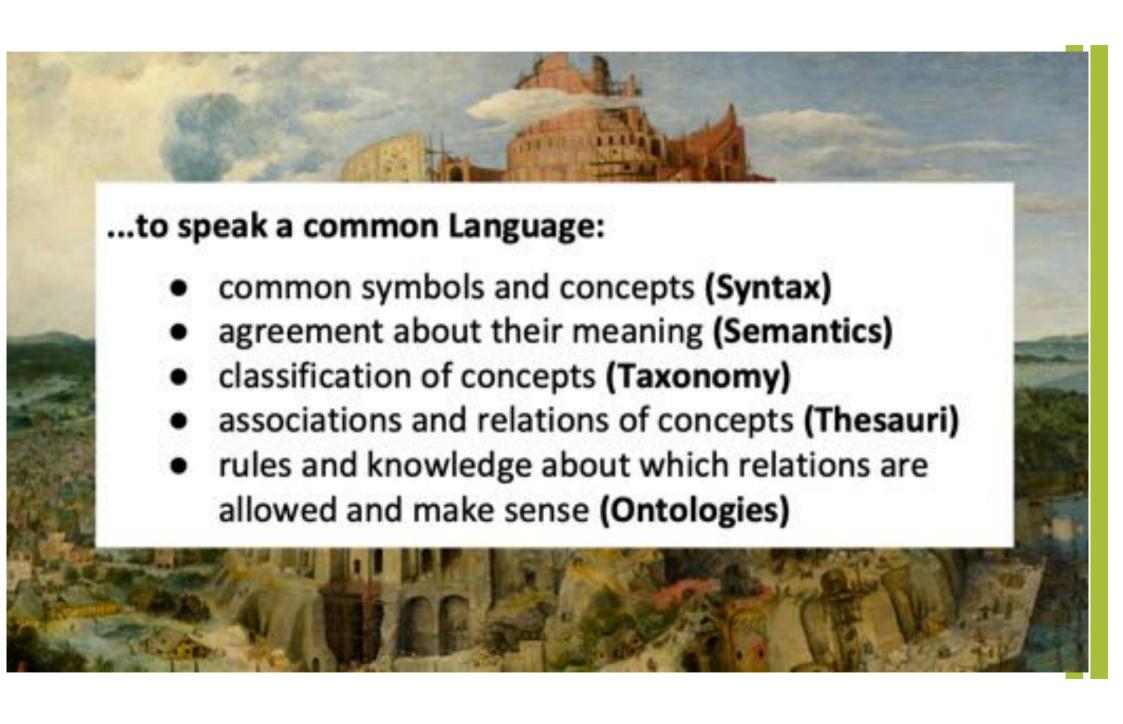
### What Is Knowledge?



Traditional Definition: "Knowledge is a justified subset of all true beliefs"

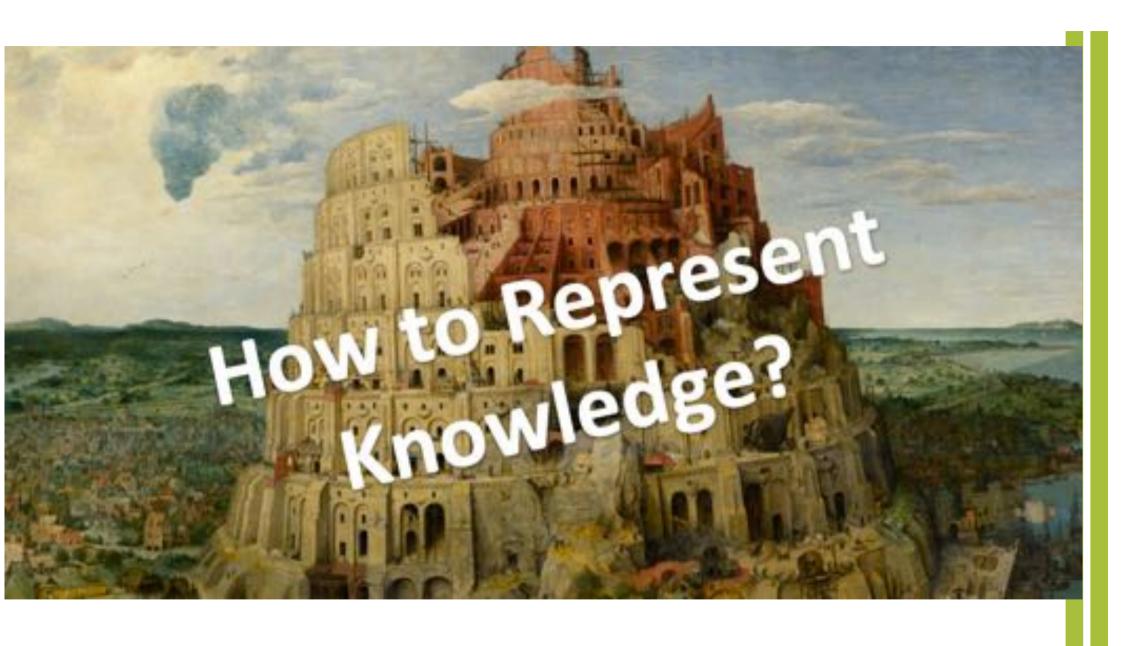
To represent knowledge, we need a **formal** knowledge representation = Ontologies







Knowledge Representation and Reasoning Is at the Heart of the Great Challenge of Artificial Intelligence: To Understand the Nature of Intelligence and Cognition So Well That Computers Can Be Made To Exhibit Human-Like Abilities.

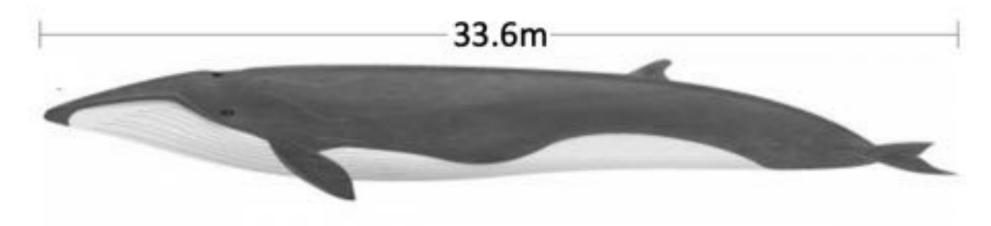


### 33.6

33.6 is a number

### 33.6 m

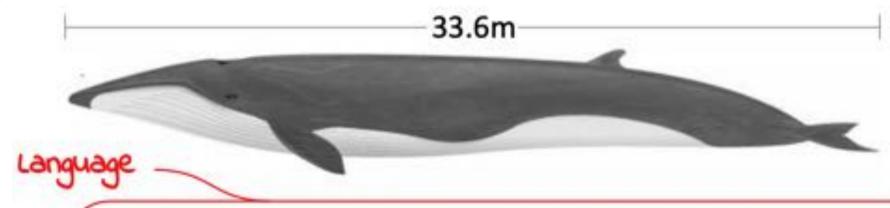
- 33.6 is a number
- 33.6 m is a length



- 33.6 is a number
- 33.6 m is a length
- 33.6 m is the length of a Blue Whale.



#### Data, Information & Knowledge



- We want to express more:
  - The blue whale is a whale. A whale is a mammal. A mammal is an animal.
  - The whale lives in the oceans. An ocean is a body of water.
  - This is 'Moby', a specific blue whale. He lives in the Atlantic Ocean.
  - The longest ever measured blue whale had a length of 33.6 m
  - This means that up to now and unless we may find a longer one the largest blue whale measures 33.6 m, or no blue whale is longer than 33.6 m.
  - Moby is not longer than 33.6 m.
  - If you happen to find a longer whale, then either it is no blue whale or we have to change our previous assumptions.



#### **Home Work**

- Represent this knowledge using 3 existing representation formats including XML and Object Oriented paradigm
  - e.g. JSON
  - .CSV etc



#### Review

- What is the relationship between data, information and knowledge?
- What is knowledge?
- What is the DIKW pyramid?
- Getting from Data to Information requires \_\_\_\_\_\_?
- Getting from Information to Knowledge requires \_\_\_\_\_\_\_
- Getting from Knowledge to Wisdom requires \_\_\_\_\_\_?
- What are the key elements necessary to speak a common language?
- What is an ontology?

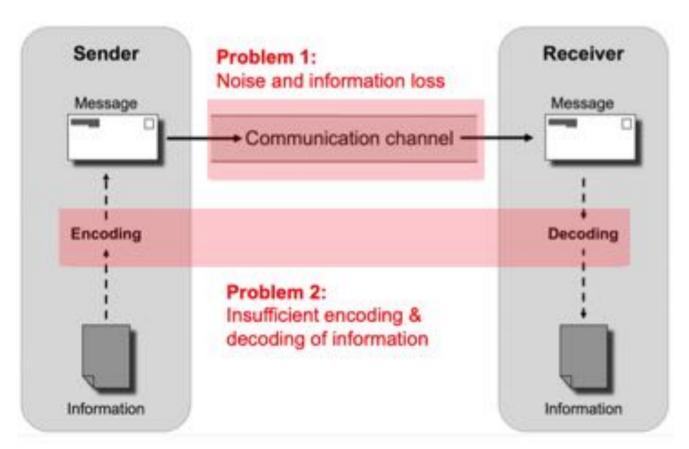


### Language as Knowledge Representation

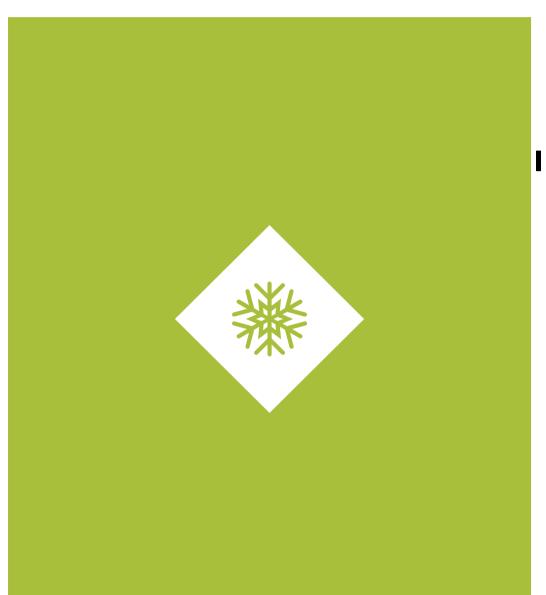
- (Natural) Language can be a way to represent knowledge
- What is Language?
  - Language is a system of conventional **spoken, manual, or written symbols** that combine to **convey meaning**, and by means of which human beings, as members of a social group and participants in its culture, **express** themselves.
  - One of the most important functions of language is **communication**.



### Language of Communication



Ch. Meinel, H. Sack: Digital Communication -Communication Multimedia, Security, Springer, 2014.



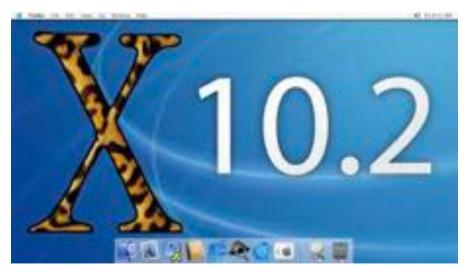
I Am Always Dreaming About my Jaguar!

Or

I Love my Jaguar

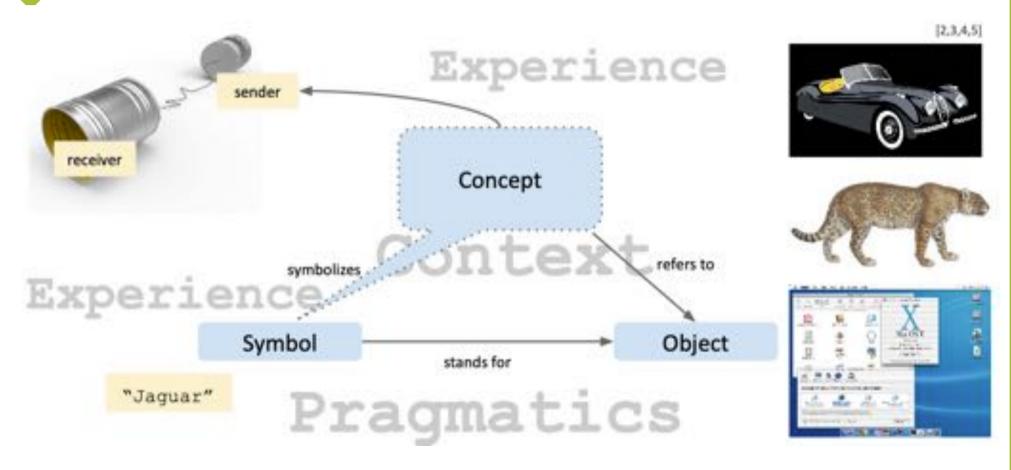








### **Communication of Meaning**





## Why (Natural) Language Is Difficult?

- Paraphrasing
- Ambiguity



#### Formal Knowledge Representation

- Formal Knowledge Representation
  - is a field of artificial intelligence (AI),
  - which (unambiguously) captures the semantics (meaning) of concepts, properties, relationships, and entities
  - of specific knowledge domains, i.e., fields of interest or areas of concern,
  - as structured data.
- Machines (computers) must be able to understand formal knowledge representations.
- To "understand" a knowledge representation, the machine must be able to interpret it correctly.





### Meaning and Comprehension

- Understanding is the ability to grasp the meaning of information
- Information is conveyed in a message using a specific language
- Information is understood by the receiver of the message, if the receiver **interprets** the information **correctly**



## **Meaning and Comprehension**

- Correct interpretation depends on:
  - Syntax
  - Semantics
  - Context
  - Pragmatics
  - Experience



## **Syntax**

- =[greek] Arrangement, Ordering
- In **grammatics** syntax denotes the study of the principles and processes by which sentences are constructed in particular languages.
- In **formal languages,** syntax is just a set of rules, by which well formed expressions can be created from a fundamental set of symbols (alphabet).
- In **computer science**, syntax defines the normative structure of data.



#### **Semantics**

- =[greek] pertains to the character, the study of meaning
- Is part of the linguistics focused on the **Sense and Meaning** of language or symbols of language.
- Is the **study of interpretation of signs or symbols** as used by agents or communities within particular circumstances and **context**.
- Semantics ask, how sense and meaning of complex concepts can be derived from simple concepts based on the **rules of syntax.**
- The Semantics of a message depends on **context** and **pragmatics.**



#### Context

- [lat.] contextus = interweaved
- Denoted the surrounding of a symbol (concept) in an expression resp. its relationship with surrounding expressions (concepts) and further related elements,
- Contexts denotes all elements of any sort of communication that define the interpretation of the communicated content.
- We distinguish
  - General contexts: place, time, interrelation of action in a message
  - Personal or social contexts: relation between sender and receiver of a message



## **Pragmatics**

- [greek] = action
- Reflects the **intention by which the language is used** to communicate a message.
- In linguistics pragmatics denotes the **study of applying language in different situations.**
- It also denotes the intended purpose of the speaker.
- Pragmatics studies the ways in which context contributes to meaning.



## Experience

- **Experience** considers all information that you have learned and put in context with the world you are living in.
- Experience in this sense also often is referred to as **common sense knowledge** or **world knowledge**.



## **Successful Communication**

- For successful communication,
  - Information has to be correctly transmitted (**Syntax**)
  - The meaning (**Semantics**) of the transmitted information must be interpreted correctly (= **understanding**)
- Understanding depends on
  - The context of both sender and receiver and
  - The **pragmatics** of the sender
- Context of sender and receiver depend on
  - The **experience** (knowledge of the world) of both sender and receiver.

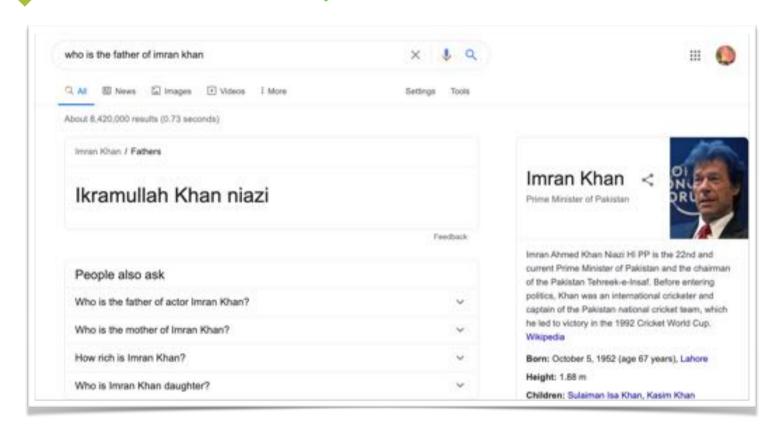


# The Age of Intelligent Agents

Knowledge Graphs, Ontologies, Semantics are some of the key enablers!



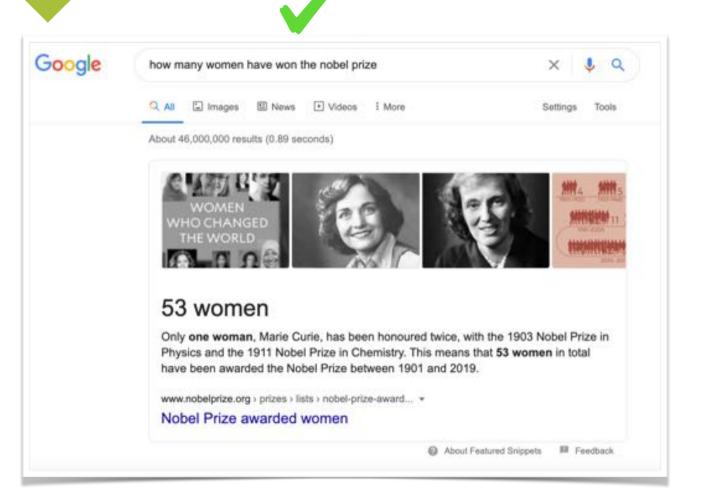
Google vs Siri

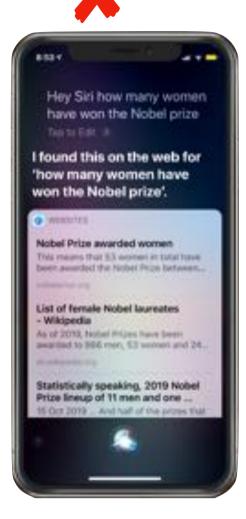






## Google vs Siri



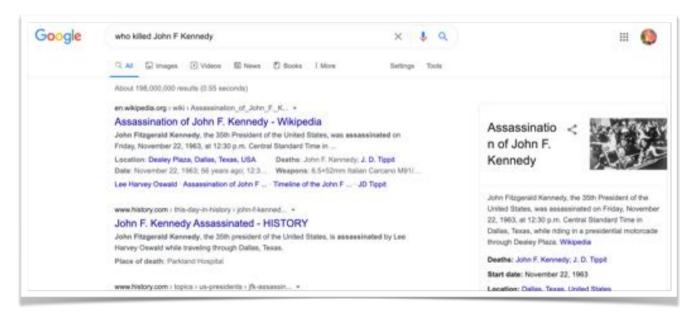


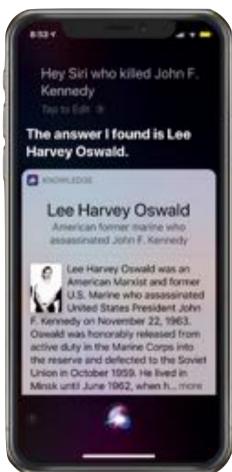


## Google vs Siri











## **IBM Watson**







# The Knowledge Graph

By Google!



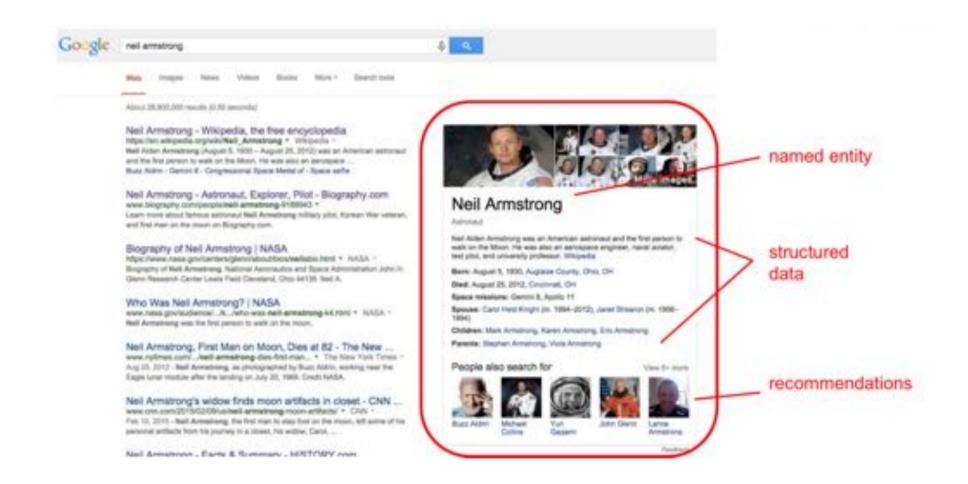
## The Google Knowledge Graph

An"ontology about everything

• Identifying entities in queries and presenting data about those entities as results

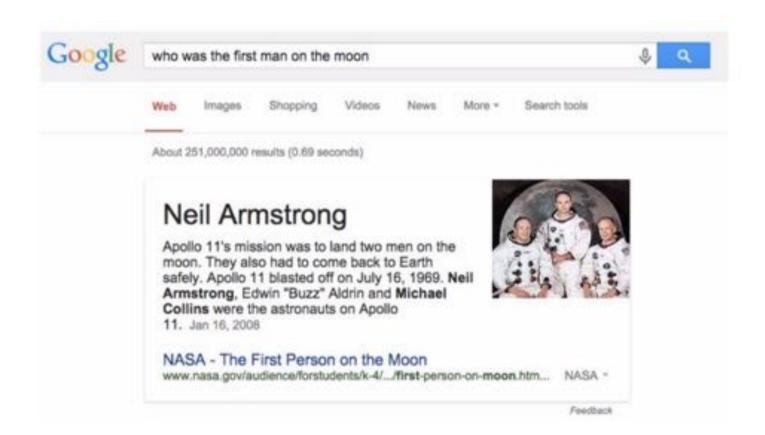


#### **Document Retrieval and Knowledge Graphs**





#### From Document to Fact Retrieval



From an Information Engine ....to a .... Knowledge Engine!



#### From Document to Fact Retrieval







# Knowledge Graphs Constitute the Backbone of Today's State-of-the-Art Information Systems & Intelligent Agents

From improving search results over question answering and recommender systems up to explainable AI systems, the applications of knowledge graphs are manyfold.



## Knowledge Graphs - the Hype

- Knowledge graphs have emerged as a compelling abstraction for organizing world's structured knowledge over the internet
  - capturing relationships among key entities of interest to enterprises
  - a way to integrate information extracted from multiple data sources
- Knowledge graphs have also started to play a central role in machine learning and natural language processing
  - as a method to incorporate world knowledge
  - as a target knowledge representation for extracted knowledge
  - and for explaining what is being learned



## Knowledge Graphs - Emerging on the Hype Cycle

 Getting the Semantic Web and Knowledge Graph researchers excited!

#### Gartner Hype Cycle for Emerging Technologies, 2019





## **Course Dynamics**



## Join Google Classroom

Via Email



#### **Course Overview**

- In this course you will learn what is necessary to design, implement, and use knowledge graphs for the purpose of knowledge representation and reasoning
- The focus of this course will be on basic knowledge representation technologies including the principles of knowledge representation and symbolic AI.
  - Information encoding via RDF triples
  - Knowledge representation via ontologies with OWL
  - Efficiently querying knowledge graphs via SPARQL
  - Knowledge graph applications in innovative information systems, as e.g., semantic and exploratory search



## Requirements

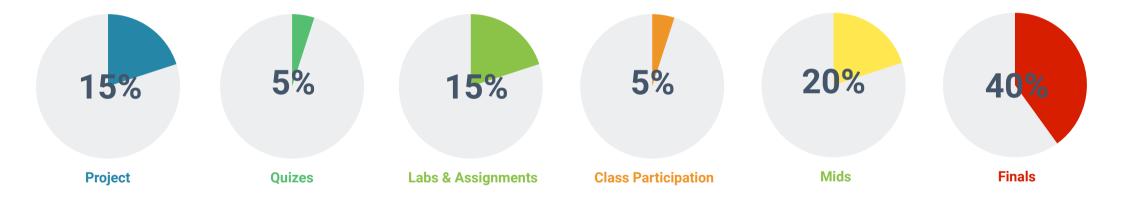
- Discrete Structures, Propositional and First Order Logic
- Basic understanding of web technologies, such as URL and HTTP
- Basic knowledge of database technology, such as relational databases and SQL query language
- No prior knowledge of ML, AI, DM required as such, though it will be of benefit in helping co-relate and better appreciate the use of KGs



## The Driving Forces!



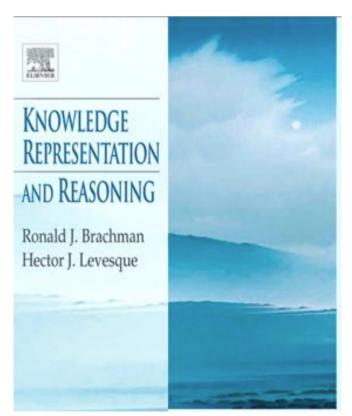
## The Key Driving Forces...?\*



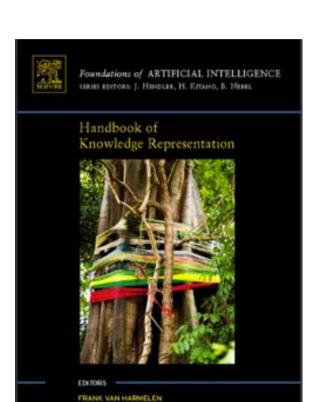
<sup>\*</sup>Subject to Revision



#### **Books & Resources**





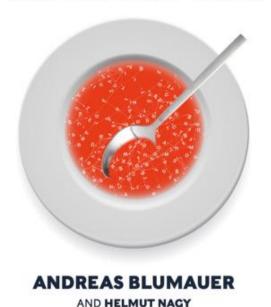


VLADIMIR LIFSCHITZ BRUCE PORTER



## The Knowledge Graph Cookbook

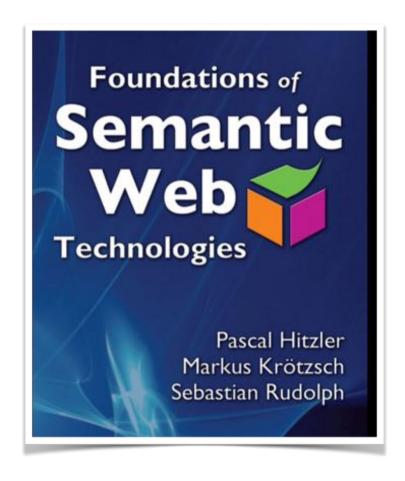




1st edition, 2020



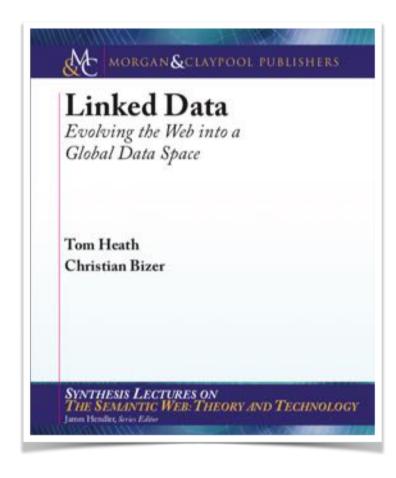
#### **Foundations of Semantic Web**







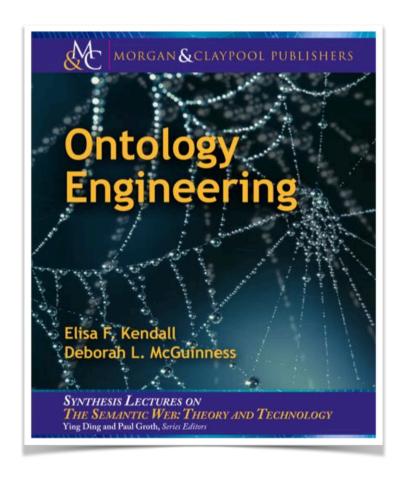
## **Linked Data**







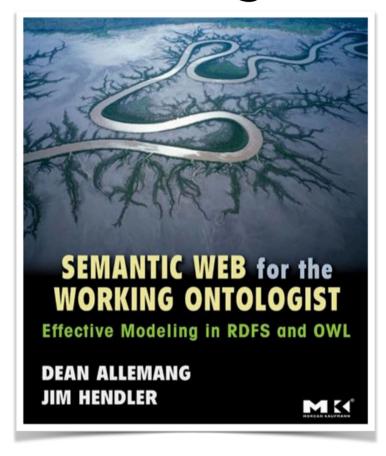
## **Ontology Engineering**







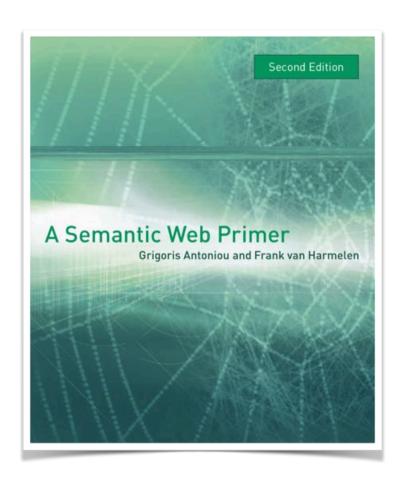
## Semantic Web for Working Ontologist







### **Semantic Web Primer**



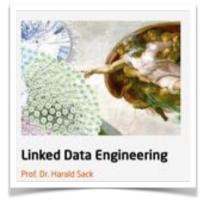


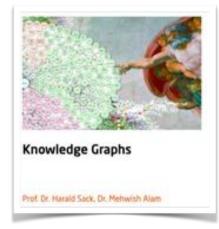


#### **Other References:**

- Lecture Material (Including slides) derived/taken from:
  - OPEN HPI MooC (<a href="https://open.hpi.de">https://open.hpi.de</a>)
    - Knowledge Engineering with Semantic Web Technologies
    - Linked Data Engineering
      - by Prof Dr. Herald Sack
  - Semantic Web Course 2018 by Linkopings Universitet (<a href="https://www.ida.liu.se/research/semanticweb/events/SemWebCourse2018/">https://www.ida.liu.se/research/semanticweb/events/SemWebCourse2018/</a>)









#### Resources

**CS 520** 

#### **Knowledge Graphs**

How should AI explicitly represent knowledge?

Department of Computer Science, Stanford University, Spring 2020

- This class is a graduate level research seminar featuring prominent researchers and industry practitioners working on different aspects of knowledge graphs. It will showcase how latest research in AI, database systems and HCI is coming together in integrated intelligent systems centered around knowledge graphs.
- https://web.stanford.edu/class/ cs520/