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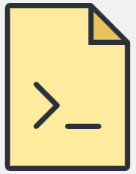

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CS520: KNOWLEDGE GRAPHS

Data Models, Knowledge Acquisition, Inference, Applications

Lectures and Invited Guests

Spring 2021, Tu/Thu 4:30-5:50, cs520.Stanford.edu

Learn about the basic concepts,
latest research & applications

Knowledge Graphs Seminar

- What is a Knowledge Graph?
- How to Create a Knowledge Graph?
- How to Reason with and Access Knowledge Graphs?
- Applications

Knowledge Graphs Seminar

- What is a Knowledge Graph?
- How to Create a Knowledge Graph?
  - How to design the schema?
  - Creating a KG from data
  - Create a KG from text and images
- How to Reason with and Access Knowledge Graphs?
- Applications

Knowledge Graphs

How to Create a Knowledge Graph from Structured Data?

Outline

- Overview
- Schema Mapping
- Record Linkage
- Summary

Overview

- Large organizations have lot of internal data
  - Customer profiles
  - Product offerings
  - Transactions
- They also consume external data from third party providers
  - News reports
  - Funding decisions
  - Supplier relationships

Overview

- 360-degree view of a customer

Financial News

Who supplies to who?

FACTSET

Who are my customers?

INTERNAL COMPANY DATA

Acma Inc filed for bankruptcy
- Suppliers to Acma are facing financial distress
- Stress propagates recursively in the supply chain
  - Credit officers must be alerted
  - Risk analysis must take this into account

Overview

- Knowledge graph by integrating external and internal data
  - Schema design
    - Relating the schema of sources to the knowledge graph schema
  - Record linkage
    - Recognizing if two instances refer to the same object in the real-world

Schema Mapping

- Practical challenges
- Example of schema mapping
- Specifying schema mapping
- Bootstrapping schema mapping

Practical Challenges

- Difficult to understand schema
  - Large tables, unhelpful names (e.g., segment1, segment2, etc.)
- Mappings are not always one-to one
  - Need to apply business logic
- Training data not available
  - Data for schema mappings is even more scarce

Example Schema Mapping

cookware			
name	**type**	**material**	**price**
c01	skillet	cast iron	50
c02	saucepan	steel	40
c03	skillet	steel	30
c04	saucepan	aluminium	20

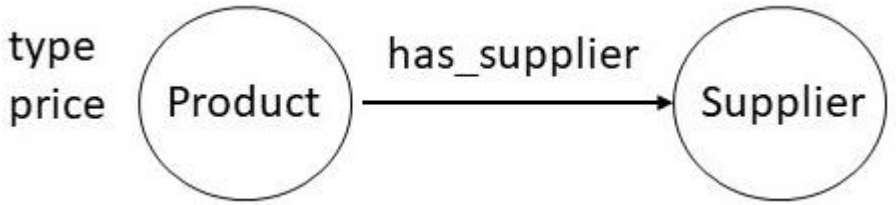
Example Schema Mapping

cookware			
name	**type**	**material**	**price**
c01	skillet	cast iron	50
c02	saucepan	steel	40
c03	skillet	steel	30
c04	saucepan	aluminium	20

kind	
id	**value**
m01	skillet
m02	skillet
m03	saucepan
m04	saucepan

price	
id	**value**
m01	60
m02	50
m03	40
m04	20

Example Schema Mapping



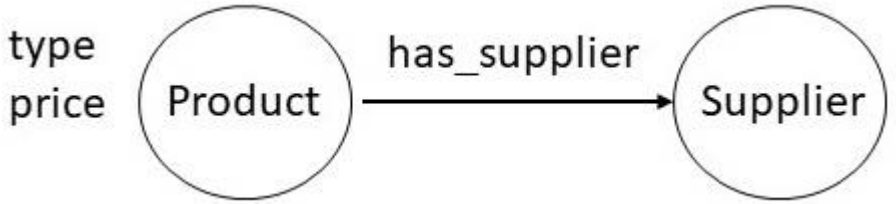
cookware			
name	**type**	**material**	**price**
c01	skillet	cast iron	50
c02	saucepan	steel	40
c03	skillet	steel	30
c04	saucepan	aluminium	20

kind	
id	**value**
m01	skillet
m02	skillet
m03	saucepan
m04	saucepan

price	
id	**value**
m01	60
m02	50
m03	40
m04	20

knowledge graph		
subject	**predicate**	**object**
c01	type	skillet
c01	price	50
c01	has_supplier	vendor_1
c02	type	saucepan
c02	price	40
c02	has_supplier	vendor_1
c03	type	skillet
c03	price	30
c03	has_supplier	vendor_1
c04	type	saucepan
c04	price	20
c04	has_supplier	vendor_1
m01	type	skillet
m01	price	60
m01	has_supplier	vendor_2
m02	type	skillet
m02	price	50
m02	has_supplier	vendor_2
m03	type	saucepan
m03	price	40
m03	has_supplier	vendor_2
m04	type	saucepan
m04	price	20
m04	has_supplier	vendor_2

Example Schema Mapping



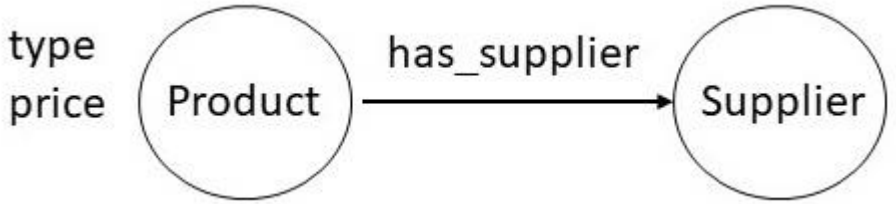
knowledge_graph(ID,type,Type) :- cookware(ID,TYPE,MATERIAL,PRICE)
knowledge_graph(ID,price,PRICE) :- cookware(ID,TYPE,MATERIAL,PRICE)
knowledge_graph(ID,has_supplier,vendor_1) :- cookware(ID,TYPE,MATERIAL,PRICE)

cookware			
name	**type**	**material**	**price**
c01	skillet	cast iron	50
c02	saucepan	steel	40
c03	skillet	steel	30
c04	saucepan	aluminium	20

kind	
id	**value**
m01	skillet
m02	skillet
m03	saucepan
m04	saucepan

price	
id	**value**
m01	60
m02	50
m03	40
m04	20

Example Schema Mapping



knowledge_graph(ID,type,Type) :- kind(ID,TYPE)
knowledge_graph(ID,price,PRICE) :- price(ID,PRICE)
knowledge_graph(ID,has_supplier,vendor_2) :- kind(ID,TYPE)

cookware			
name	**type**	**material**	**price**
c01	skillet	cast iron	50
c02	saucepan	steel	40
c03	skillet	steel	30
c04	saucepan	aluminium	20

kind	
id	**value**
m01	skillet
m02	skillet
m03	saucepan
m04	saucepan

price	
id	**value**
m01	60
m02	50
m03	40
m04	20

Bootstrapping Schema Mapping

- Linguistic Mapping
- Mapping based on instances
- Mapping based on constraints

Bootstrapping Schema Mapping

- Linguistic Techniques
  - Leverage the name
    - Best solution is to use IRIs and sameAs links
  - Stemming, Synonym, Hypernym
    - Cname and Customer Name
    - Automobile and Vehicle
    - Book and Publication
  - Common substrings/pronunciation
    - Amount Received/Amount Receivable
    - Bell vs Belle
  - Leverage documentation string
    - Extract keywords, and check semantic similarity

Bootstrapping based on Instances

- Examine the data
  - If we can recognize the data contain phone number, zip code, ISBN, SSN, Date that can provide strong guidance for which attributes can match

Bootstrapping based on Constraints

- Leverage the constraints
  - Value range constraints, uniqueness, optionality, cardinality

Bootstrapping Schema Mapping

- Bootstrapping results
  - are inexact
  - need human verification
- Can save some effort
- Lead to a better story

Outline

- Overview
- Schema Mapping
- Record Linkage
- Summary

Record Linkage

- An Example Problem
- An approach to record linkage
  - Blocking followed by Matching
    - Random forests
    - Active learning
    - Rule application

Example

	Table A		
	Company	**City**	**State**
a_1	AB Corporation	New York	NY
a_2	Broadway Associates	Washington	WA
a_3	Prolific Consulting Inc.	California	CA

	Table B		
	Company	**City**	**State**
b_1	ABC	New York	NY
b_2	Prolific Consulting	California	CA

a1=b1
a3=b2

Inexact Inference

In practice, millions of records

Approach

- Blocking Followed by Matching

	Table A		
	Company	**City**	**State**
a_1	AB Corporation	New York	NY
a_2	Broadway Associates	Washington	WA
a_3	Prolific Consulting Inc.	California	CA

	Table B		
	Company	**City**	**State**
b_1	ABC	New York	NY
b_2	Prolific Consulting	California	CA

Blocking
<a1,b1>
<a3,b2>

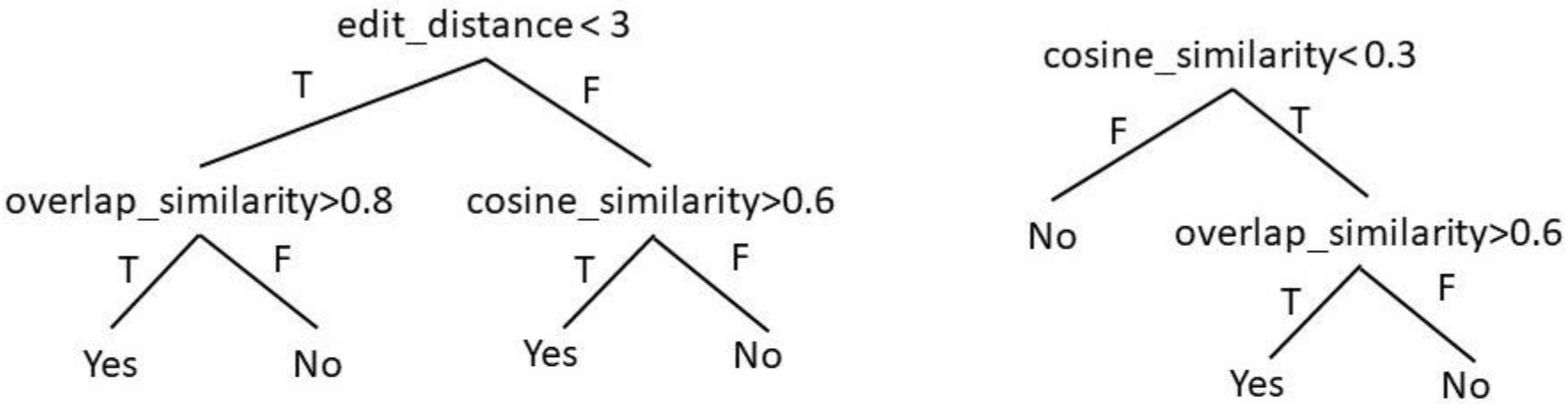
Overview of the algorithm

- Express the blocking/matching rules as a random forest
- Use Active Learning to build the random forest
- Efficient application of rules through indexing

Random Forest

- Consists of a set of set of rules
- Each rule selects records based on (inexpensive) similarity functions
  - Edit distance
  - Overlap similarity
  - Cosine similarity

Random Forest



r_1: (edit_distance ≥ 3) and (cosine_similarity > 0.6) $\rightarrow$ match

r_2: (edit_distance < 3) and (overlap_similarity > 0.8) $\rightarrow$ match

r_3: (cosine_similarity ≥ 0.3) and (overlap_similarity > 0.6) $\rightarrow$ match

Random Forest

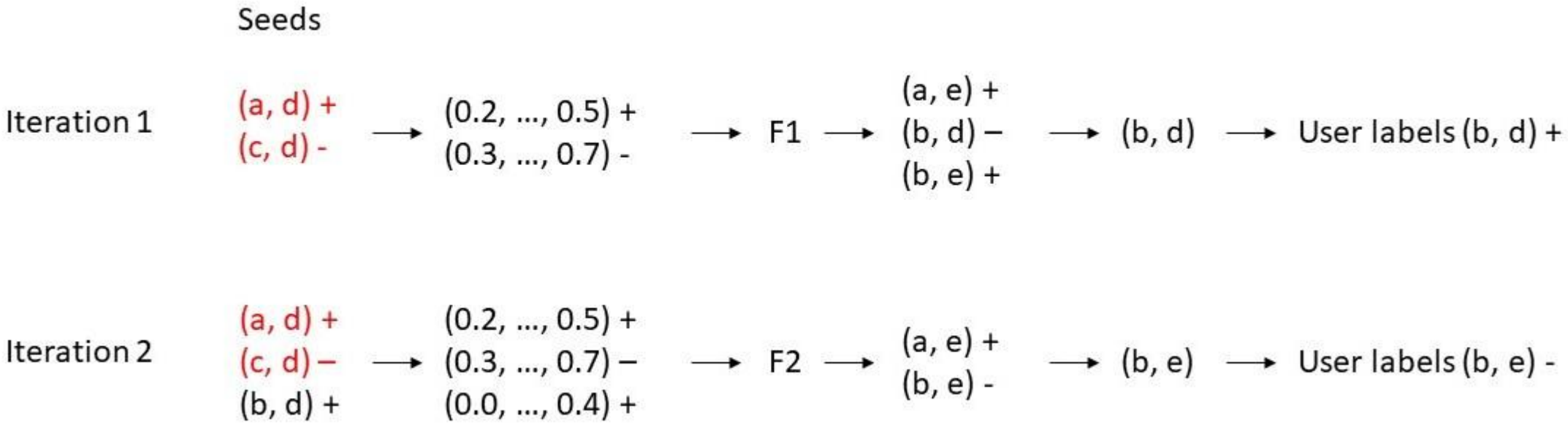
- General principles for selecting similarity functions
  - Numeric-valued attributes such as age, weight, price, etc.
    - exact match, absolute difference, relative difference, and Levenstein distance
  - String-valued attributes
    - edit distance, cosine similarity, Jaccard similarity, and TF/IDF functions.

Active Learning

- Randomly select pairs from the two data sets
  - Ask the users to label them
- Use similarity functions to obtain features
- Learn random forest
- Apply the learned rules to new selected pairs
  - Evaluate the rules
- Iterate

Active Learning

- Source 1: (a,b,c) Source 2: (d,e)



Active Learning

- Once the learning algorithm converges, present the rules to the user
- Retain the rules validated by the user

Rule Application

- Leverage indexing for efficient application of rules
  - Suppose we need to check Jaccard similarity to movie “Sound of Music”
  - If the similarity needs to be greater than 0.7, we need to consider only those movies with length between 3*0.7, and 3/0.7, ie, between 2 and 4
  - An index on the length of movies can help us select which movie records to consider

Blocking vs Matching

- Same algorithmic outline is used except
  - The matching rules are more exact/price
  - The matching is usually verified through human intervention

Summary

- Creating KG from structured sources is a data integration problem
  - Target schema is a knowledge graph
- Schema Mapping Problem
  - Even though bootstrapping is possible, but it is still labor intensive
- Record Linkage Problem
  - Efficiency is a key consideration
  - Two-step approach with blocking and matching
    - Leverage random forests and active learning

Structured Data Cleaning

Ihab Ilyas
U. Of Waterloo

Lauren Orr
Self-Supervised Entity Disambiguation

Mayank Kejriwal
Entity Resolution in Web Scale KGs

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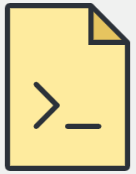

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