# Cross-Fertilizing Deep Web Analysis and Ontology Enrichment

**Marilena Oita**, Antoine Amarilli, and Pierre Senellart

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Telecom ParisTech, France

# The Deep Web

dynamically-generated Web pages in response to a user query


HTML forms: intuitive to humans, but hardly understandable by search crawlers

***challenging*** *research topic*: there are (still) no practical ways for search engine crawlers to explore this rich source of data in a meaningful way;

# The Deep Web

*Apps:*

1. focused indexing (vertical search engines)
2. extensional crawling (Web archiving)
3. Semantic Web (ontology enrichment)

*Motivation*:

- IN: deep Web sources are vast repositories of semi-structured data
- IDEA: leverage the *Structured Web* for the expansion of the *Semantic Web*
- OUT: access to the deep Web data in a fully automatic, domain-independent manner

# Outline

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# Form Interface Understanding

ordered list of form elements

- labels
- constraints
- set values, for non-textual input elements

Understanding...

1. how form elements relate to each other
   extract an input schema $\rightarrow$
   - syntactic parsing (as a tree)
   - visual segmentation, etc.
2. which type of input values are valid (e.g., gazeteer)

# Domain Knowledge *Related Work (1)*

→ works rely on a domain knowledge, constructed:

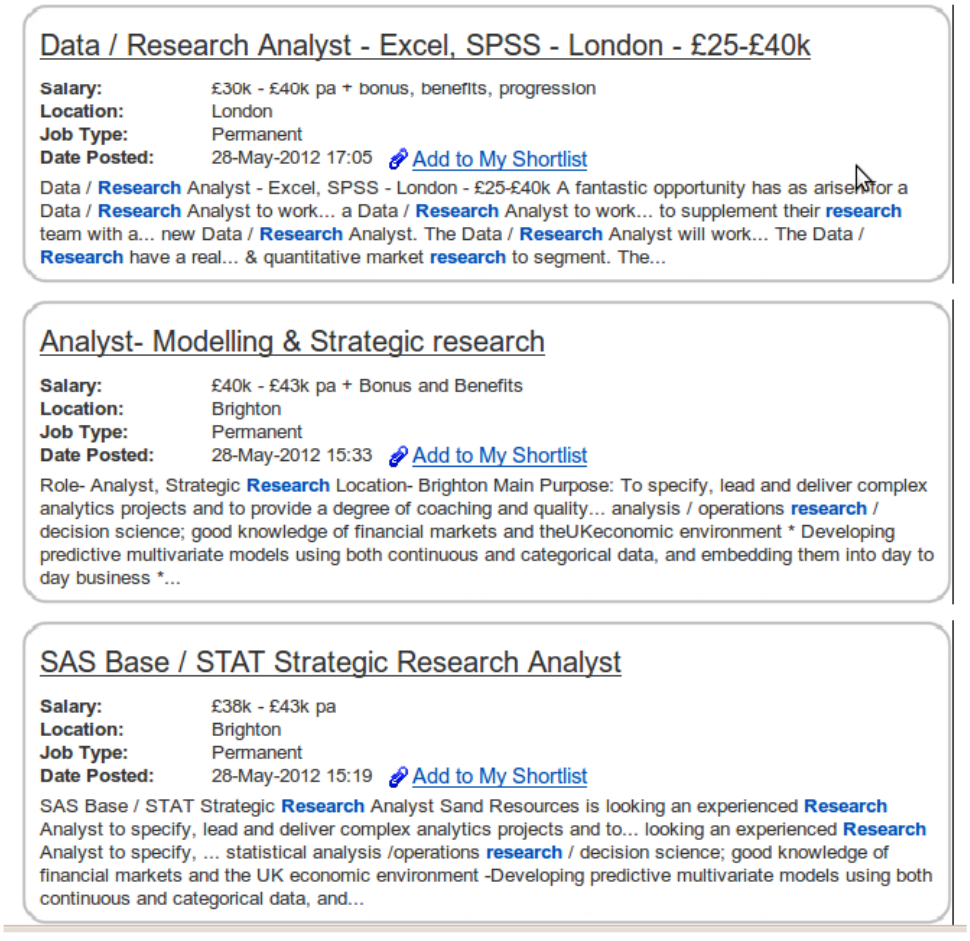
1. manually
2. using machine learning
3. by mapping schemas of different form interfaces (pertaining to the same domain, though)

Shortcomings:

- is highly simplifying the real Web situation, in which a global virtual schema of deep Web entities cannot exist
- approach not scalable
- is segmenting even more the Semantic Web

# Information Extraction from Result Pages

*valid form submission*: Web records



Data / Research Analyst - Excel, SPSS - London - £25-£40k

**Salary:** £30k - £40k pa + bonus, benefits, progression
**Location:** London
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**Date Posted:** 28-May-2012 17:05 Add to My Shortlist

Data / **Research** Analyst - Excel, SPSS - London - £25-£40k A fantastic opportunity has as arisen for a Data / **Research** Analyst to work... a Data / **Research** Analyst to work... to supplement their **research** team with a... new Data / **Research** Analyst. The Data / **Research** Analyst will work... The Data / **Research** have a real... & quantitative market **research** to segment. The...

Analyst- Modelling & Strategic research

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Role- Analyst, Strategic **Research** Location- Brighton Main Purpose: To specify, lead and deliver complex analytics projects and to provide a degree of coaching and quality... analysis / operations **research** / decision science; good knowledge of financial markets and theUKeconomic environment * Developing predictive multivariate models using both continuous and categorical data, and embedding them into day to day business *...

SAS Base / STAT Strategic Research Analyst

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SAS Base / STAT Strategic **Research** Analyst Sand Resources is looking an experienced **Research** Analyst to specify, lead and deliver complex analytics projects and to... looking an experienced **Research** Analyst to specify, ... statistical analysis /operations **research** / decision science; good knowledge of financial markets and the UK economic environment -Developing predictive multivariate models using both continuous and categorical data, and...

# Information Extraction *Related Work (2)*

→ works suppose valid response pages and extract the data values from records through IE processing *Aim*:

1. building/enriching ontologies or gazetteers
2. expanding sets of entities

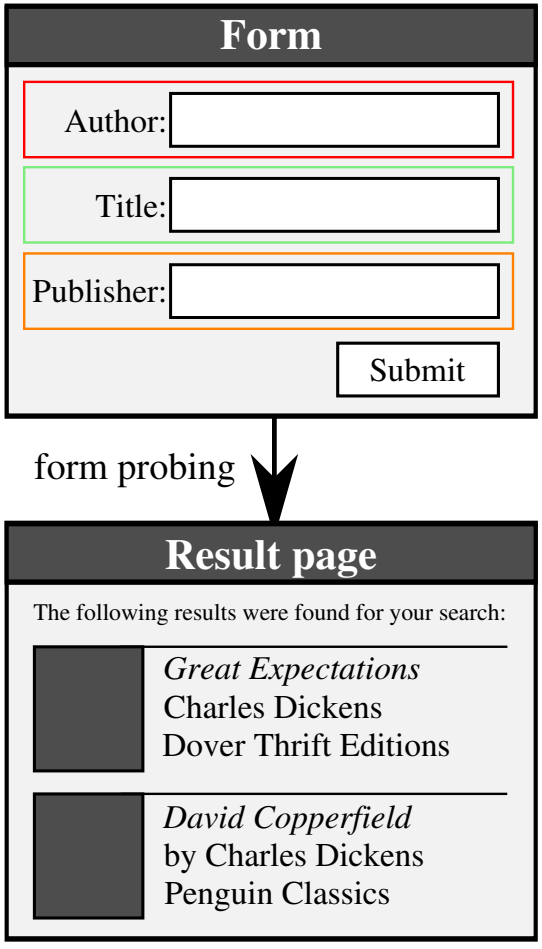
Shortcomings: isolated works that do not involve the form understanding

# Holistic Approach

*Motivation:*

- (complementarity): the form interface and the response pages represents facets of the same conceptual object
- (interconnection): the output of each step is useful for the next;
- (*late* ontologic use): a source of knowledge is inevitable – relax the domain specificity constraint by adapting to the data context;

# Domain-Agnostic Form Probing




Purpose: $\rightarrow$*bootstrap* some initial response pages

- fill out a textual input with a stop word or a contextual term (possibly, use the AJAX auto-completion facilities)
- select or check non-textual input elements

# Record Identification

1. 


**The Adventures of Tom Sawyer (Dover Thrift Editions)** by Mark Twain (Jan 27, 1998)

(440 customer reviews)

| Formats | Price | New | Used | Collectible |
|---|---|---|---|---|
| **Paperback**<br>Usually ships in 1 to 4 weeks<br>Eligible for **FREE** Super Saver Shipping and<br>1 more promotion | **$3.50** | $0.45 | $0.01 | $2.83 |
| **Kindle Edition**<br>Auto-delivered wirelessly | **$2.97** | | | |

Other Formats: Hardcover; Paperback; Mass Market Paperback; Audio CD ; See All.

**Excerpt** - Front Cover: "**MARK TWAIN** The Adventures of Tom Sawyer" See a random page in this book.

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2. 


**Life on the Mississippi** by Mark Twain (Nov 5, 2011)

(51 customer reviews)

| Formats | Price | New | Used | Collectible |
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**Excerpt** - Front Cover: "LIFE ON THE MISSISSIPPI **MARK TWAIN**" See a random page in this book.

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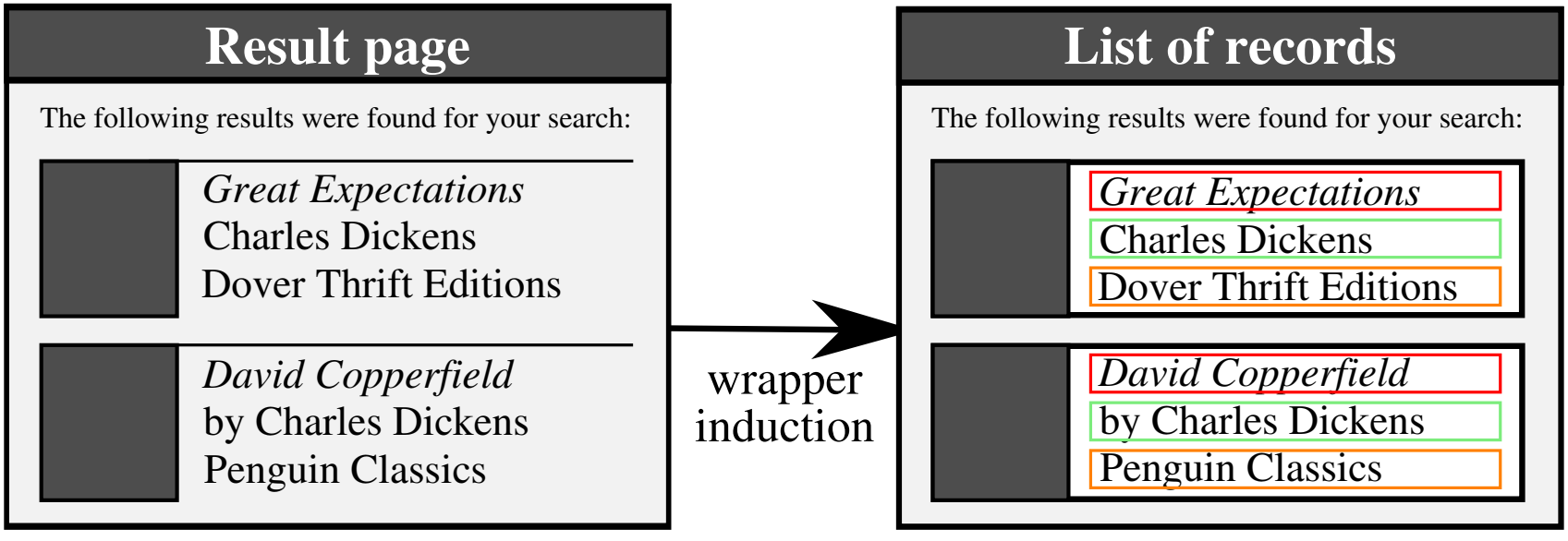
# Record Identification

typically, wrapper induction techniques

→ FOREST: identify the location of records using the keywords used during form submission to identify their common XPath in the DOM



# Attribute Alignment

Web records = structurally-similar DOM subtrees:

1. extract the values of textual leaf nodes
2. group values based on their record internal path

*Example*

//[div[class="data"]/h3[class="title"]/a[class ="title"] {The Adventures of Tom Sawyer (Dover Thrift Editions); Life on the Mississippi}

//[div[class="data"]/span[class="ptBrand"]/a[href=...] {Mark Twain}

//[div[class="data"]/span[class="bindingAndRelease"] {Jan 27, 1998; 2011}

# Attribute Alignment

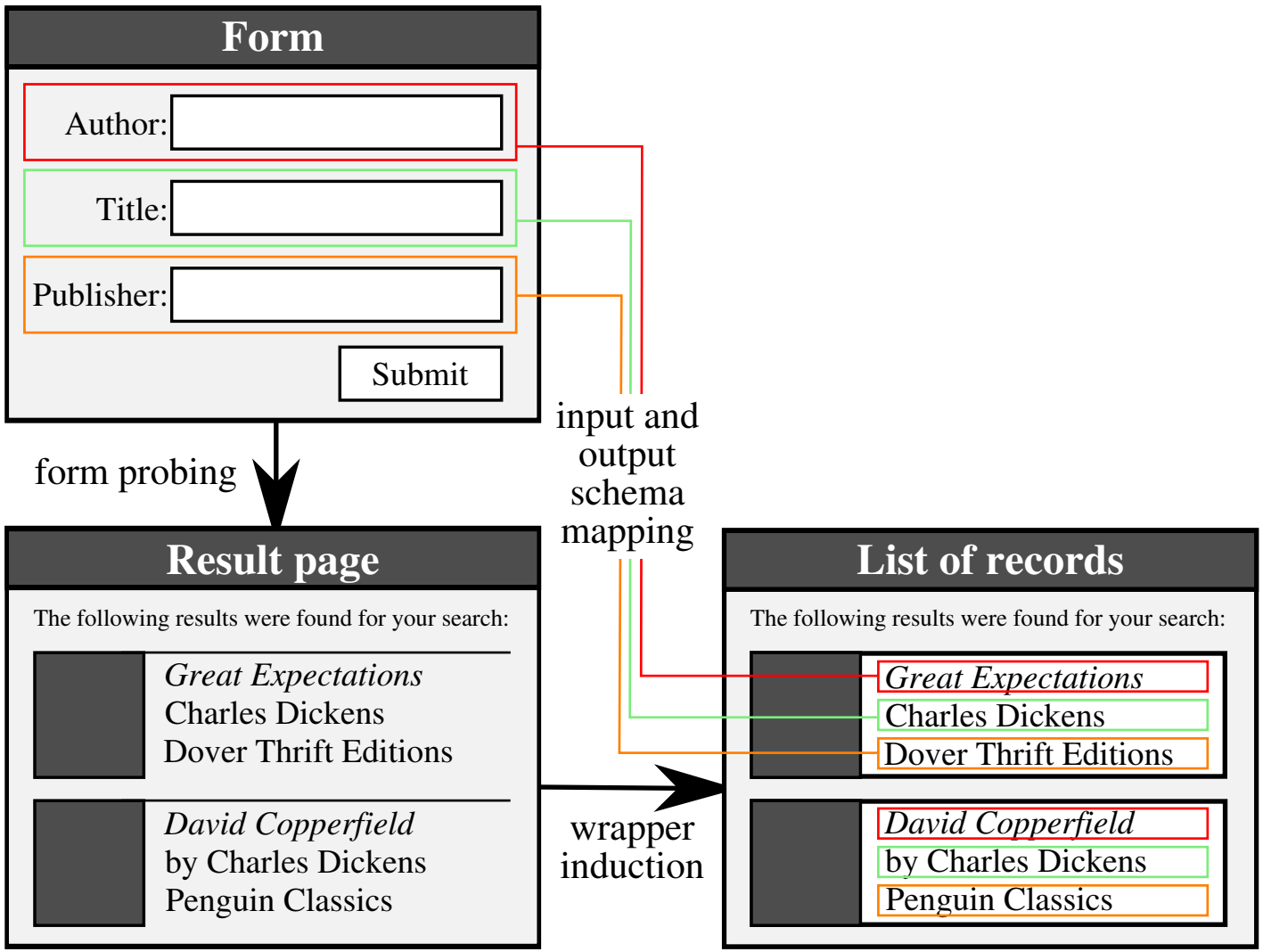
record feature=<record internal path, cumulated bag of instances>

Used for:

1. constructing the output schema (:= the ordered sequence of record features)
2. generation of RDF triples

# Input-Output Schema Mapping

## align input fields of the form with record features of response pages



# Input and Output Schema Mapping

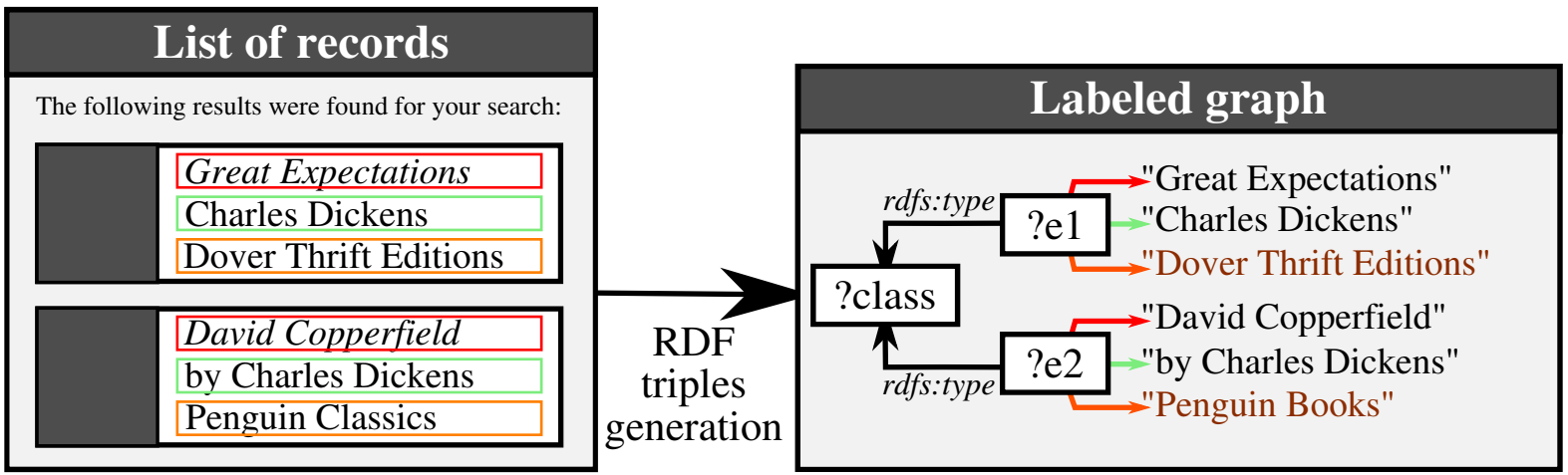
*Idea*: the form as an instrument of validating mapping hypothesis:

1. use extracted values as query instances
2. verify the record internal path where they will apear in the responses

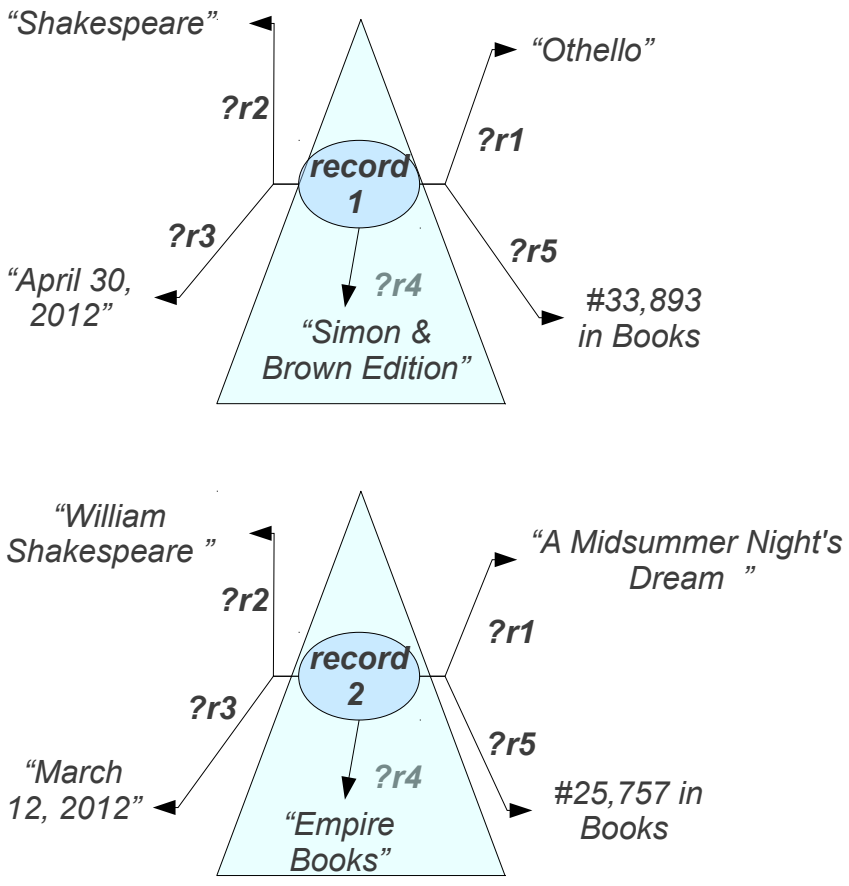
$\rightarrow$ the same values will appear consistently in all the records, under its expected record internal path

//[div[class="data"]/span[class="ptBrand"]/a[href=...] {Mark Twain}

# Triples Generation

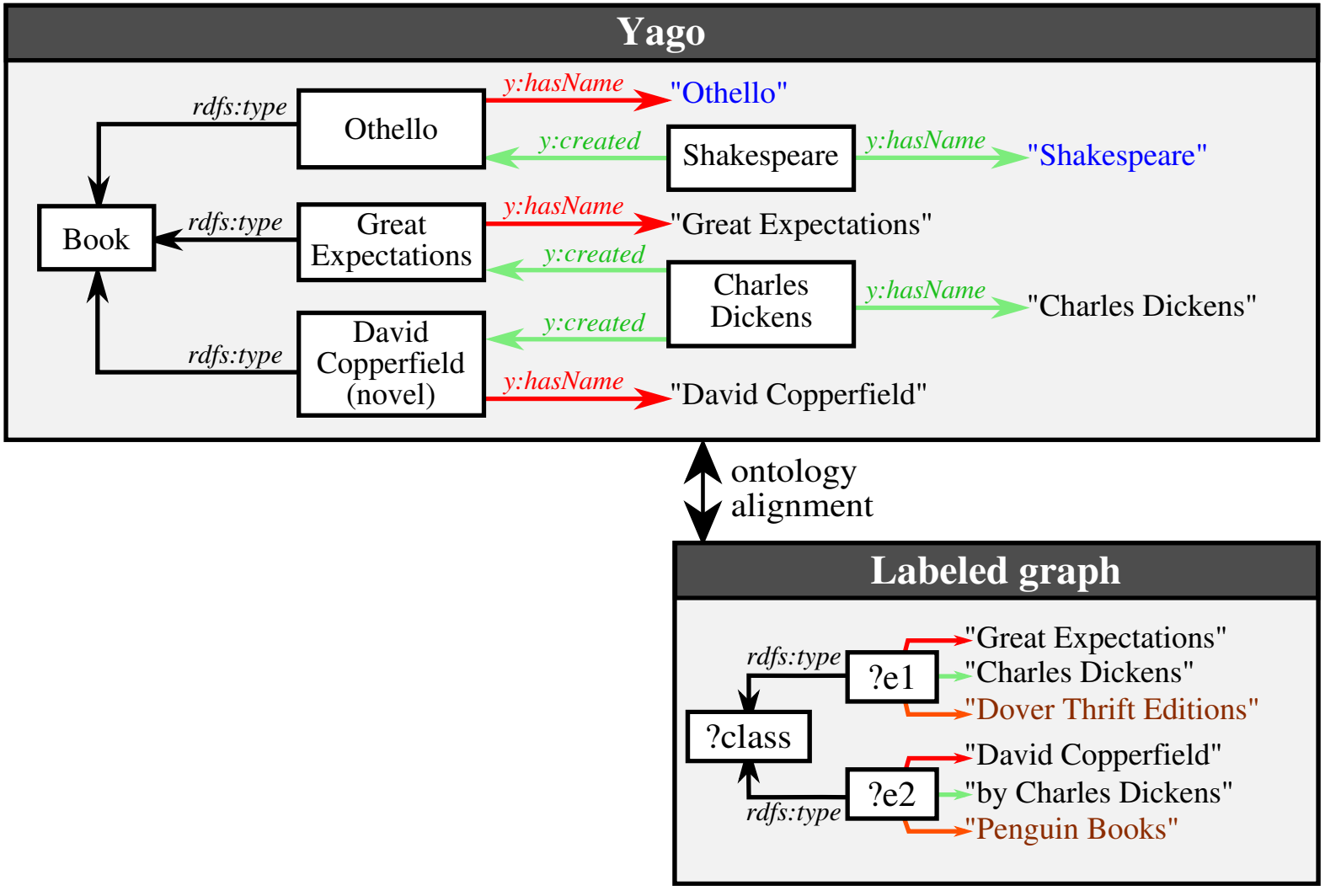


# Labeled Graph Construction




1. entities := records
2. all records are of the same `rdf:type`
3. literals := extracted data values
4. for each record feature, attribute values are of the same `rdf:type`
5. the relation (i.e., predicate) := record internal path

# Deep Web Data Alignment



# Deep Web Data Alignment

*Components:*

1. labeled graph
2. generic reference ontology: YAGO
3. alignment system: PARIS (VLDB '12) aligns both entities and relations by:
   - matching literals
   - propagating evidence based on relation functionalities

*Purpose* obtain the missing:

- relations
- the class of entities (e.g., book)
- the meaning of record attributes (data type, domain and range)

# Preliminary Experiments using PARIS

approach prototyped for the Amazon advanced search form for books

1. similarity computation: **Hamlet (French Edition)** $\equiv$ *Hamlet*
2. compute the transitive closure of the ontology graph – to answer reachability questions regarding relation mappings

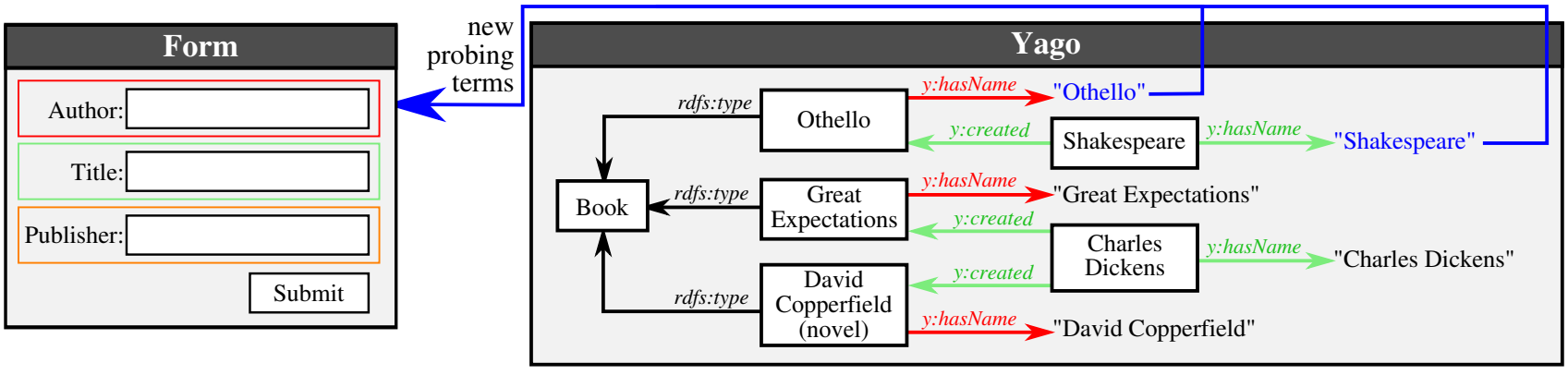
$\rightarrow$ in practice: limit the exploration depth to 2

*William Shakespeare* `y:created` *Hamlet*
*William Shakespeare* `y:hasPreferredName` **Shakespeare**

# Alignment Consequences

1. propagate discovered knowledge back to the input schema
   - discovered relations are mapped to the record internal paths of attributes
   - attribute types propagate to form input fields
2. incrementally infer new representative instances to fill in the form

# New Probing Terms



# Ontology Enrichment

## possibilities

1. set of entities expansion
2. add facts (triples) that are missing in YAGOattribute values
3. add the relation types that did not align

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1. set of entities expansion
2. add facts (triples) that are missing in YAGOattribute values
3. add the relation types that did not align $\rightarrow$ more challenging

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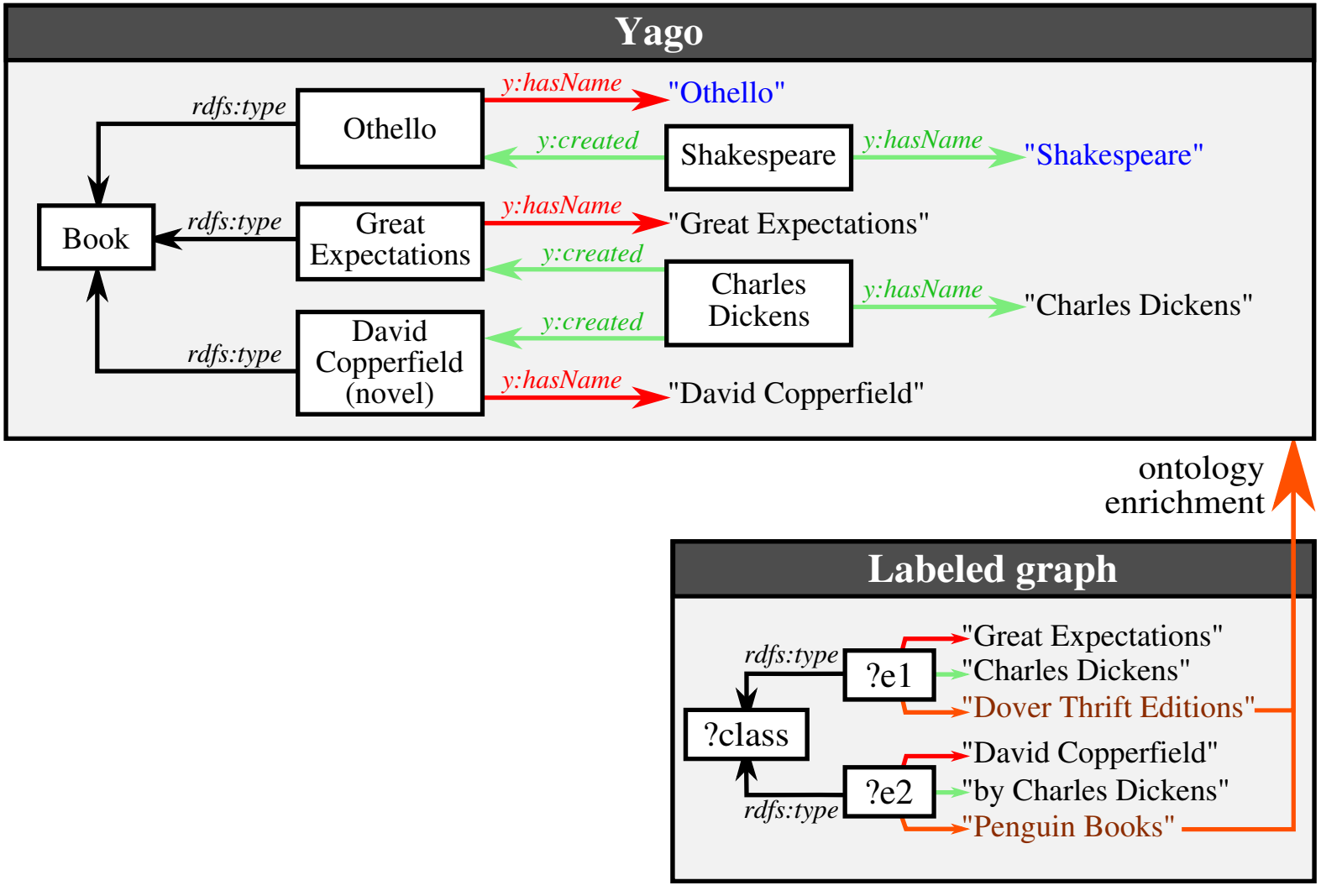
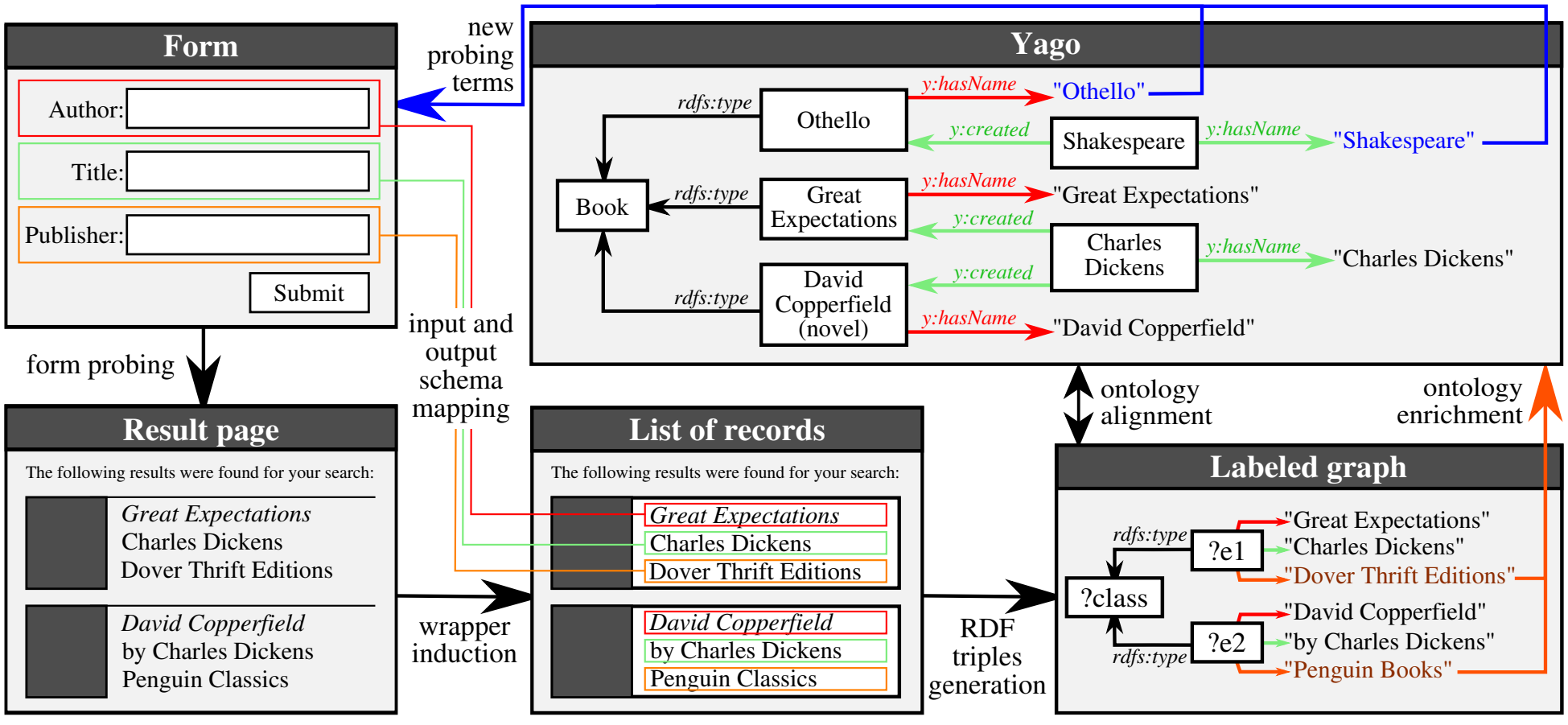


# Holistic Approach



# Conclusions

*advantages*

1. fully automatic
2. domain-independent
3. focused on knowledge discovery

*further experiments:*

1. more sophisticated strategy for the I/O schema matching
2. test forms from various domains (YAGO coverage)
3. multiple settings for PARIS (e.g., vary the exploration depth)

# Challenges

- identification of new relation types of interest among those extracted
- domain identification (through form object description)
- resilience to outliers and noise resulting from imperfect literal matching
- proper management of the confidence in the results of each automatic task (cascade behavior)

# Thank You

## Questions