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Processing Keyword Queries under Access Limitations

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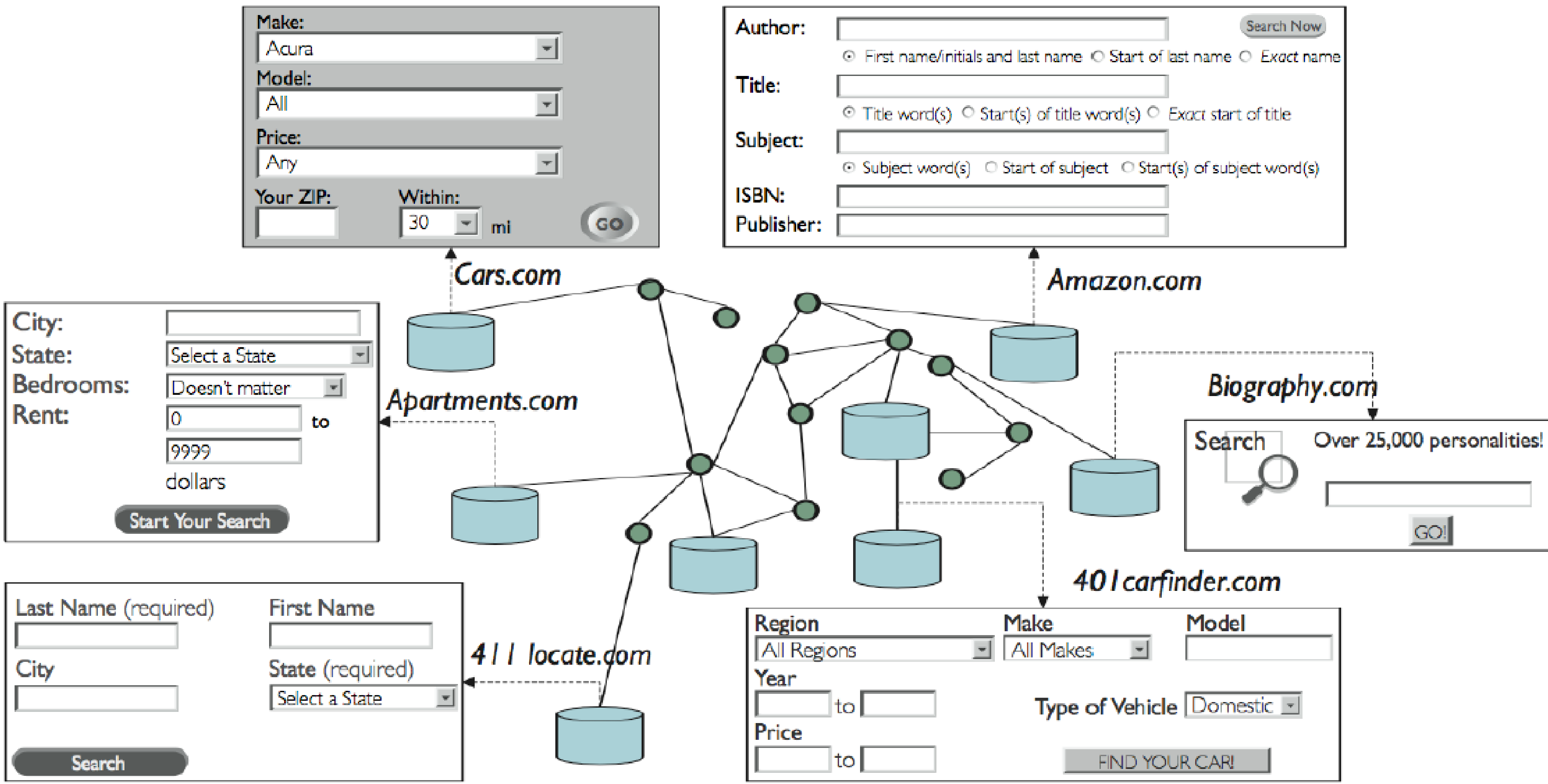
What is the Deep Web?

- Web pages (HTML mostly) have been indexed and searched for many years
- Such pages constitute the so-called Surface Web
    - huge, valuable amount of information
- The web has also continuously “deepened”
    - searchable databases, accessible usually through forms
- The Deep Web (aka Hidden Web or Invisible Web) is not effectively crawlable nor indexeable
    - it is largely unexplored, apart from manual queries issued by users


OPENTEXT
The Deep Web
The Public Web
Only 4% of Web content (~8 billion pages) is available via search engines like Google
7.9 Zettabytes
The Deep Web
Approximately 96% of the digital universe is on Deep Web sites protected by passwords
Source: The Deep Web: Semantic Search Takes Innovation to New Depths

Conceptual view of the Deep Web [He et al. 2007]



Modeling the deep Web

- Each source is modeled as a relational table with access limitations
- Access limitations: input vs output attributes
  - We can only access a table if we can provide a value for every input attribute
  - Access pattern: maps attributes into an access mode: input (i) or output.

People(FirstName,LastName ,State)

Keyword Search in the Deep Web

- Accessing the deep Web:
  - Traditionally, conjunctive queries over data sources with access limitations
- Goal:
  - Provide an high-level access to Deep Web
  - Free the user from the knowledge of:
    - Query languages
    - Structure of data sources
- Approach:
  - Keyword-based queries

Join graph

$r_1 =$

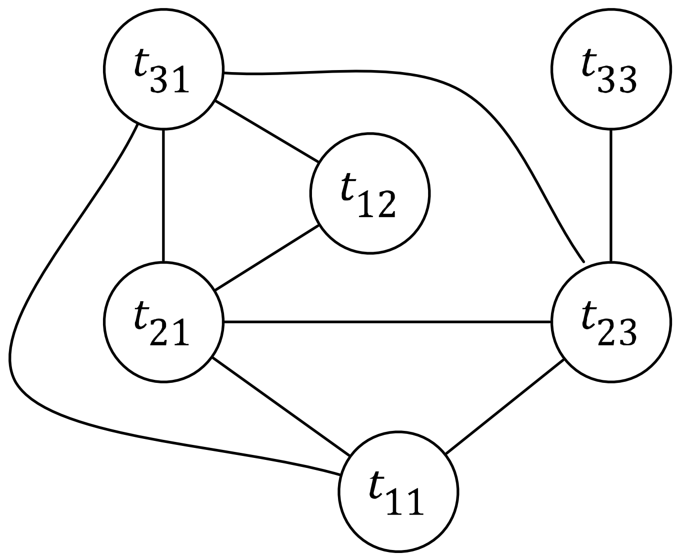
A_1^i	A_2	
c_0	c_1	t_{11}
c_2	c_3	t_{12}

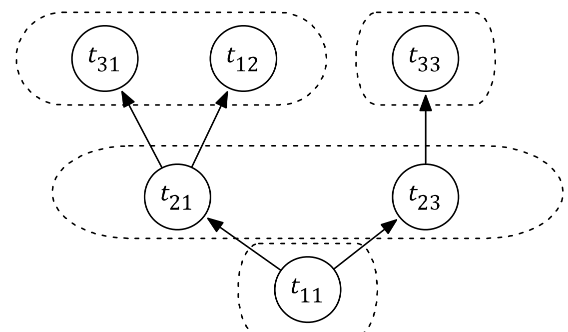
$r_2 =$

A_2^i	A_1	
c_1	c_2	t_{21}
c_4	c_2	t_{22}
c_1	c_6	t_{23}

$r_3 =$

A_1^i	A_2	A_3	
c_2	c_1	c_9	t_{31}
c_5	c_4	c_9	t_{32}
c_6	c_7	c_9	t_{33}



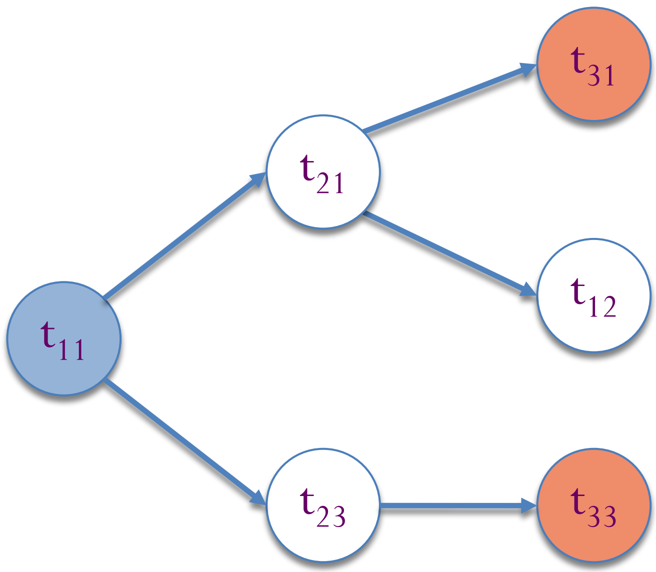


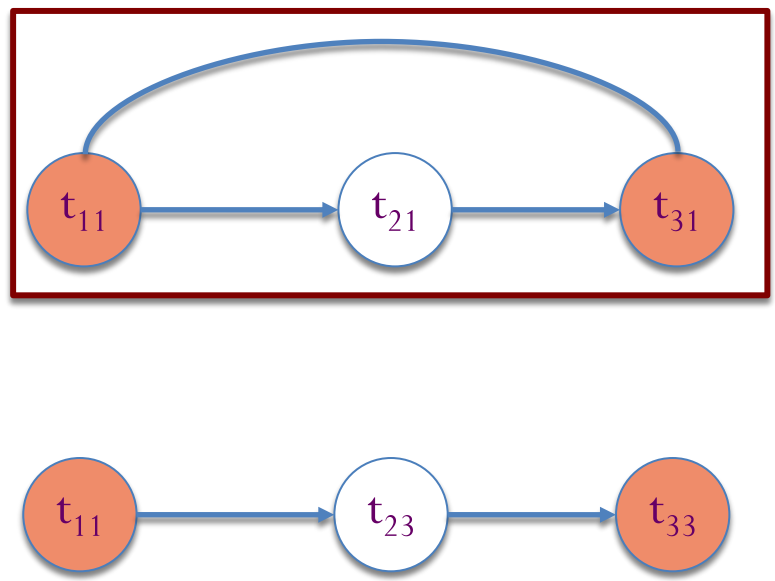
Answers to keyword queries

- A keyword query is a set of constants called keywords
- An answer to a keyword query q against a database instance r over a schema R with access limitations is a set of tuples A in the reachable instance such that:
    1. Each keyword in q occurs in at least one tuple t in A;
    2. the join graph of A is connected;
    3. for every subset A’ of A such that A’ enjoys Condition 1, the join graph of A’ is not connected.
- An answer is optimal if it has minimum size.

Computing an optimal answer

$$r_1 = \begin{array}{|cc|l} \hline A_1^i & A_2 & \\ \hline k_1 & c_1 & t_{11} \\ c_2 & c_3 & t_{12} \\ \hline \end{array} \qquad r_2 = \begin{array}{|cc|l} \hline A_2^i & A_1 & \\ \hline c_1 & c_2 & t_{21} \\ c_4 & c_2 & t_{22} \\ c_1 & c_6 & t_{23} \\ \hline \end{array} \qquad r_3 = \begin{array}{|ccc|l} \hline A_1^i & A_2 & A_3 & \\ \hline c_2 & c_1 & k_2 & t_{31} \\ c_5 & c_4 & k_2 & t_{32} \\ c_6 & c_7 & k_2 & t_{33} \\ \hline \end{array} \qquad q = \{k_1, k_2\}$$





A method for computing an answer

A brute-force approach:

1. Extract the reachable portion
2. Find an optimal (or at least minimal) answer in the reachable instance

Data complexity

1. Extraction of the reachable instance
   - It can be implemented by a Datalog program P over the input database d,
   - P can be evaluated in polynomial time in the size of d [Vardi 82].
2. Determining an optimal answer from the reachable instance
   - It corresponds to finding a Steiner Tree (ST) of its join graph, i.e., a minimal-weight subtree of this graph involving a subset of its nodes.
   - STs can be enumerated in ranked-order with polynomial delay, i.e., the time for printing the next optimal answer is polynomial in the size of d [Kimelfeld and Sagiv 2006].

An optimal answer to a keyword query against a database instance with access limitations can be efficiently computed under data complexity

Conclusions

- Formalization of keyword-based query answering in the Deep Web
- Preliminary insights on possible methods for computing optimal answers
- It turns out that:
    - The problem it is not easy to solve even over a few data sources
    - Traditional techniques for query answering in the Deep Web need to be revised
    - Even in the worst case the problem remains tractable

Current and Future work

- Optimization strategies for query answering
    - conditions under which an optimal answer can be derived without extracting the whole reachable instance;
- Implementation
    - based on the Dataplex framework
- Adoption of schema-based techniques
    - e.g, when the domains of the keywords are known in advance
- Take into account source availability and proximity
    - they can be modeled as weights on nodes and arcs, respectively