Graph (Semi-structured) Data

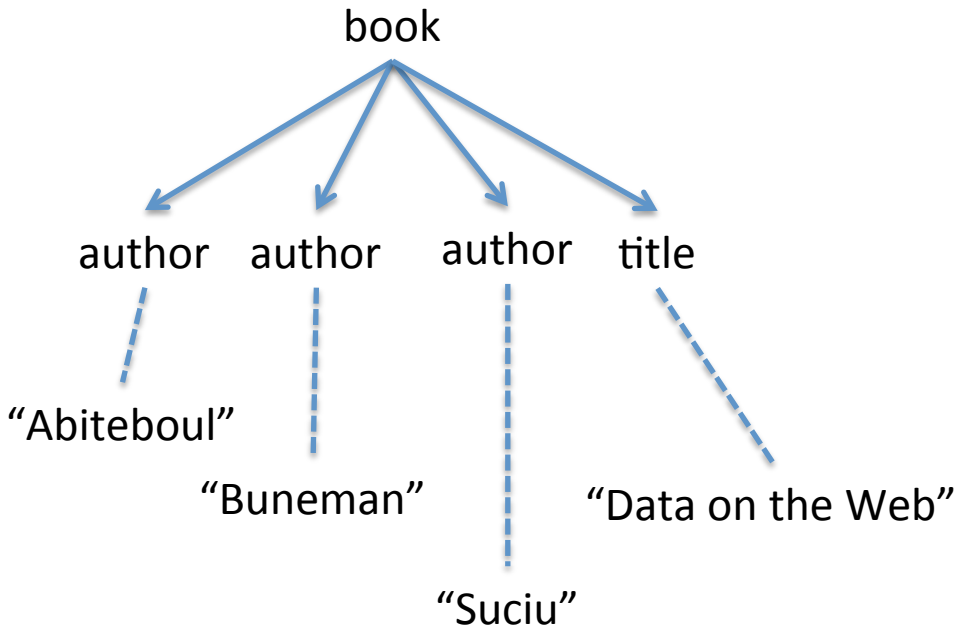
The Data Model

Data Viewed As Graph

- Original intuition:
  - Entities (objects) are represented as nodes
  - Relationships are represented as edges
  - Therefore, nodes and edges have associated types, and attributes

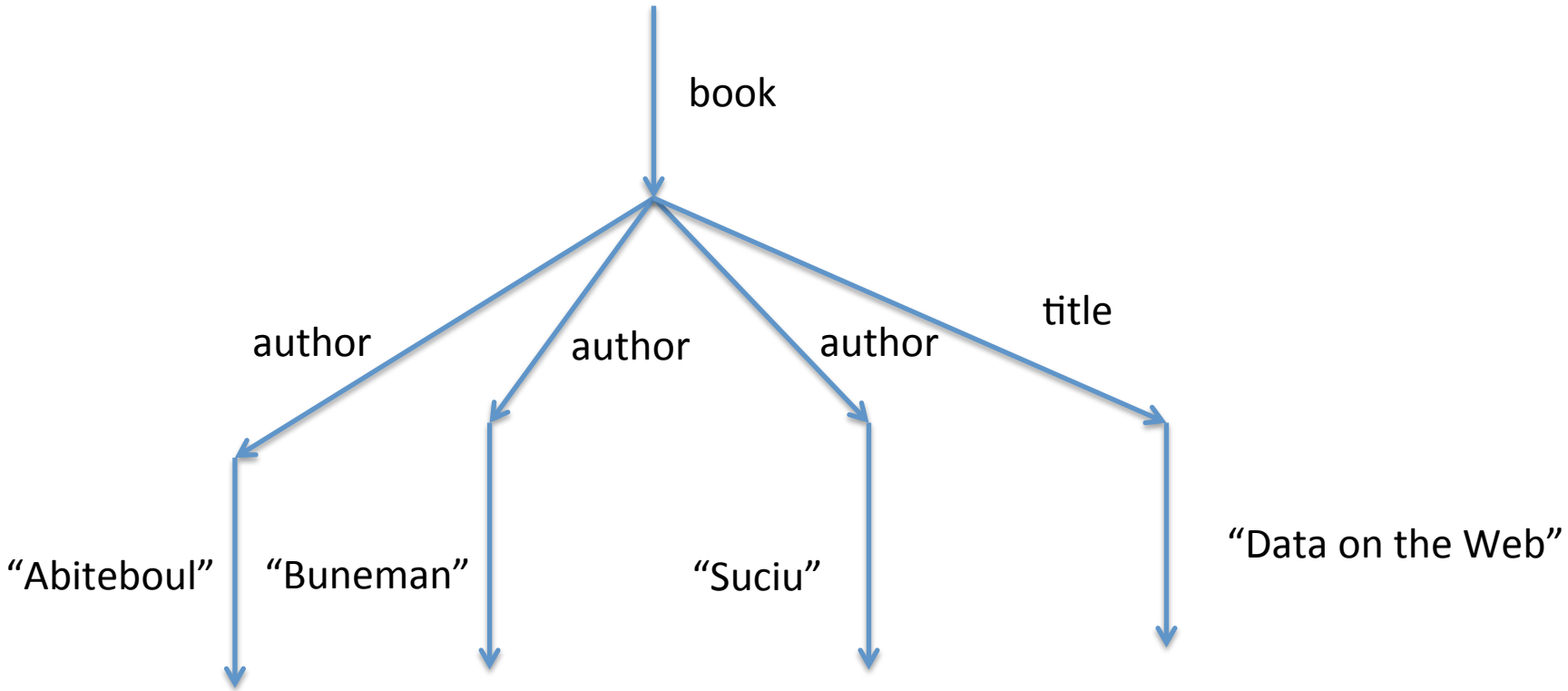
- Many variations in circulation
  - Kind of edges?
    - Directed
    - undirected
  - Where is data?
    - Only on nodes
    - Only on edges
    - On both
  - Shape of graph?
    - Arbitrary (has cycles)
    - Directed Acyclic Graph
    - Tree

Node-labeled

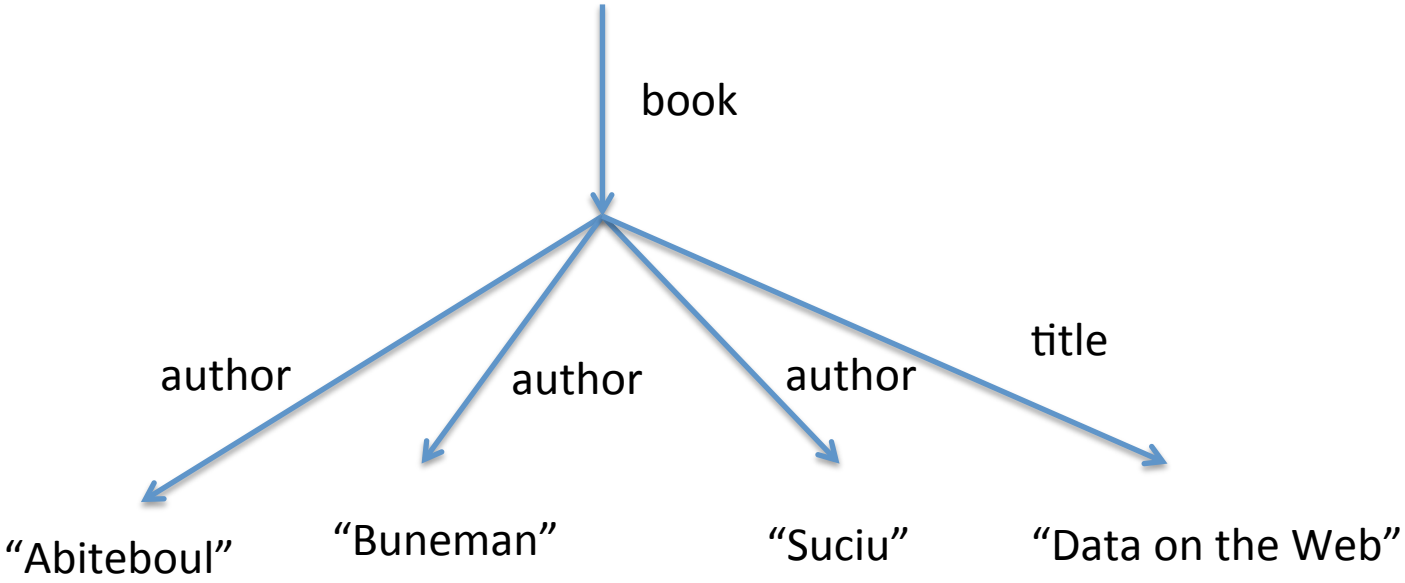


Nodes are labeled with types (book, author, title) and/or data (strings)

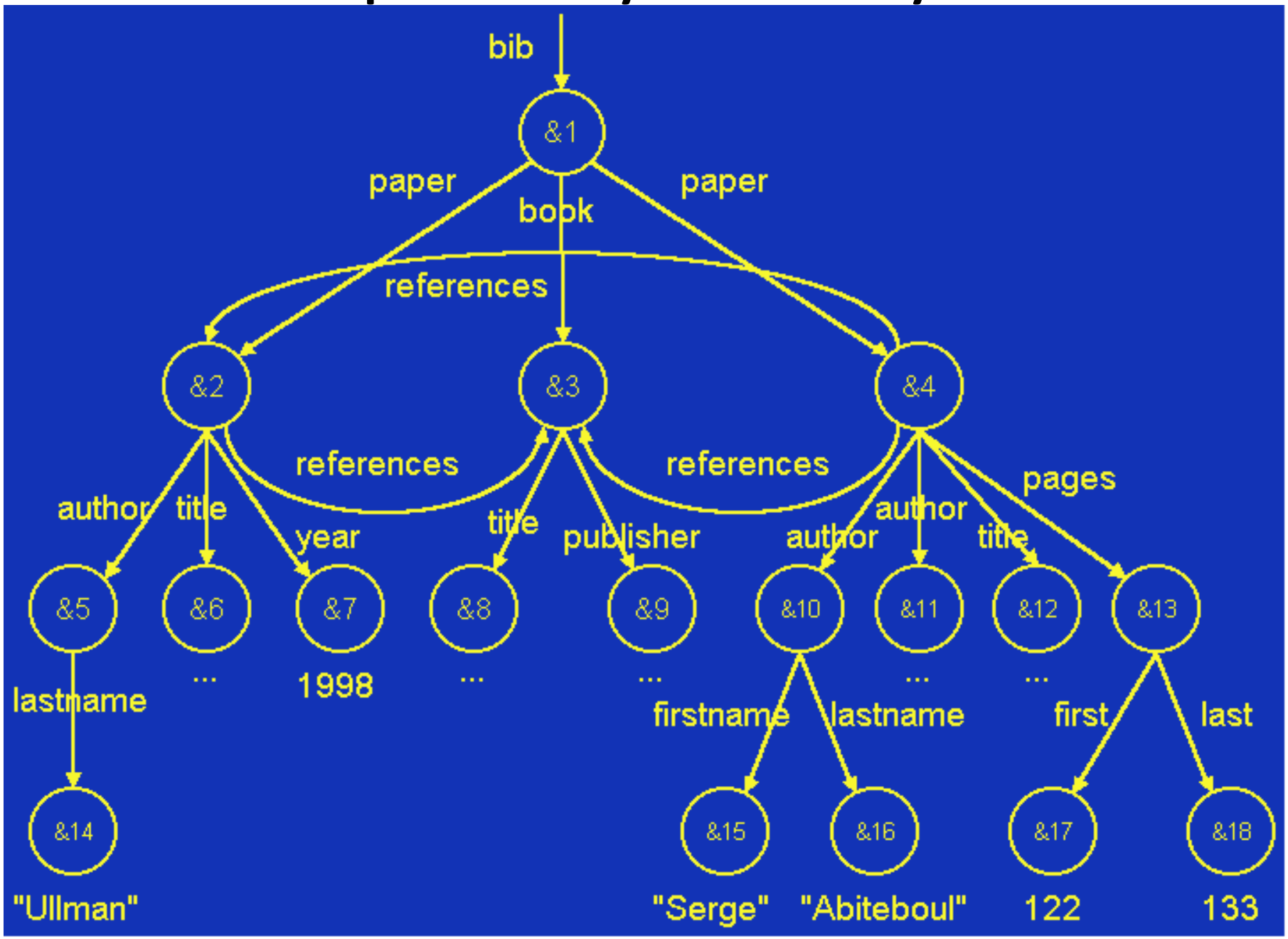
Edge-labeled



Nodes labeled with Data, Edges with Type



Graphs May Have Cycles



OEM (Object Exchange Model): a reference serialization format

```
bib: &1
  { paper: &2 { ... },
    book:  &3 { ... },
    paper: &4
        { author: &10
              { firstname: &15 "Serge",
                lastname: &16 "Abiteboul" },
          author: &11 { ... }
          title: &12 { ... }
          pages: &13
              { first: &17 122,
                last: &18 133 },
          references: &2,
          references: &3
        }
  }
```

Advantages of graph data model:

- easy to discover new data and load it
- easy to integrate heterogeneous data
- easy to query without knowing data types

Disadvantages:

- loses type information
- lack of schema makes optimisation harder

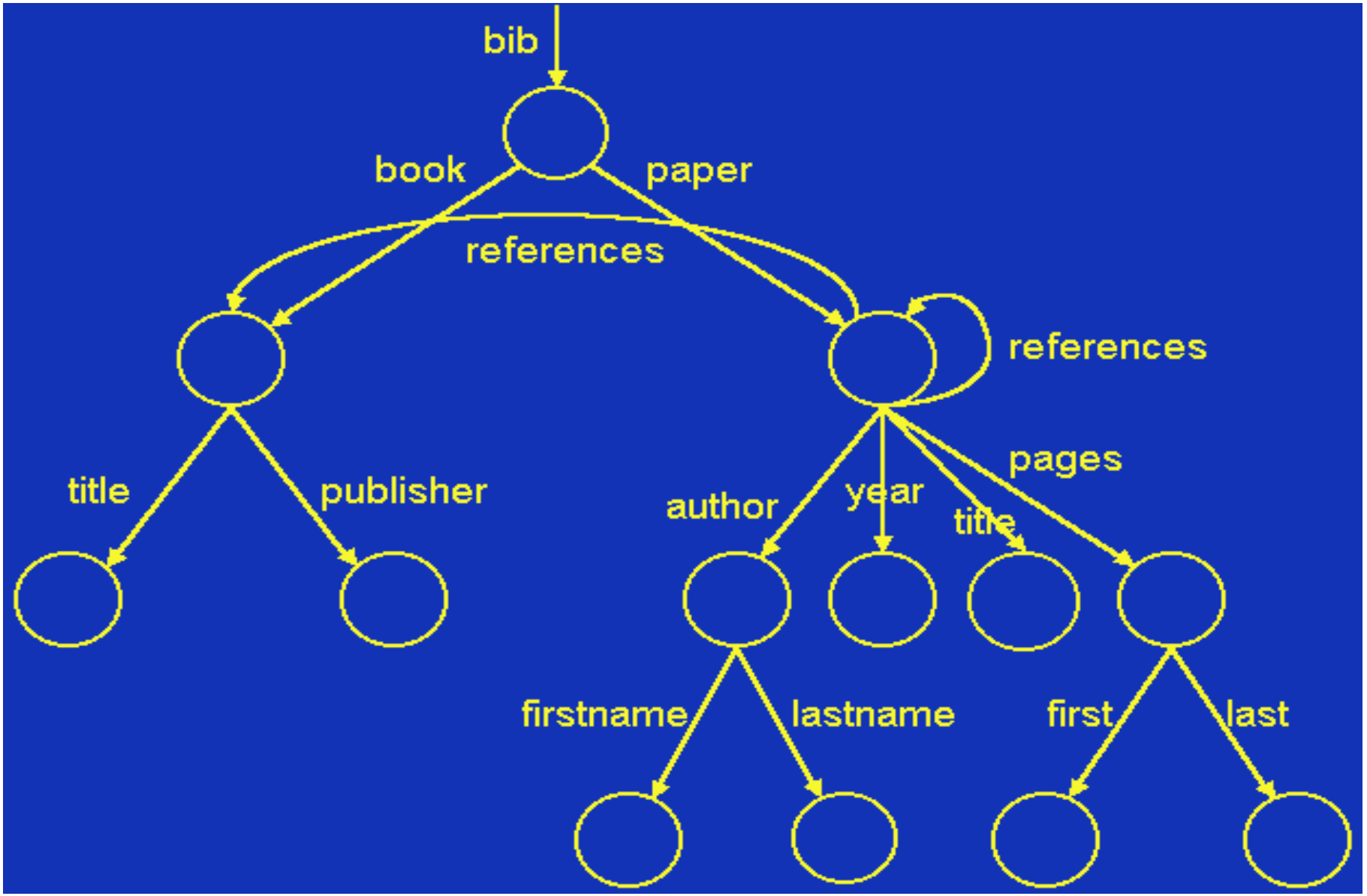
Graph Schemas

- given some semi-structured data, might want to extract a schema that describes it
- useful for
  - browsing the data by types
  - optimizing queries by reducing the number of paths searched
  - improving storage of data

Schema Graph

- specifies schema as a graph itself
- schema graph specifies what edges are *permitted* in a data graph
- every path in the data graph occurs in the schema graph

Schema Graph Example



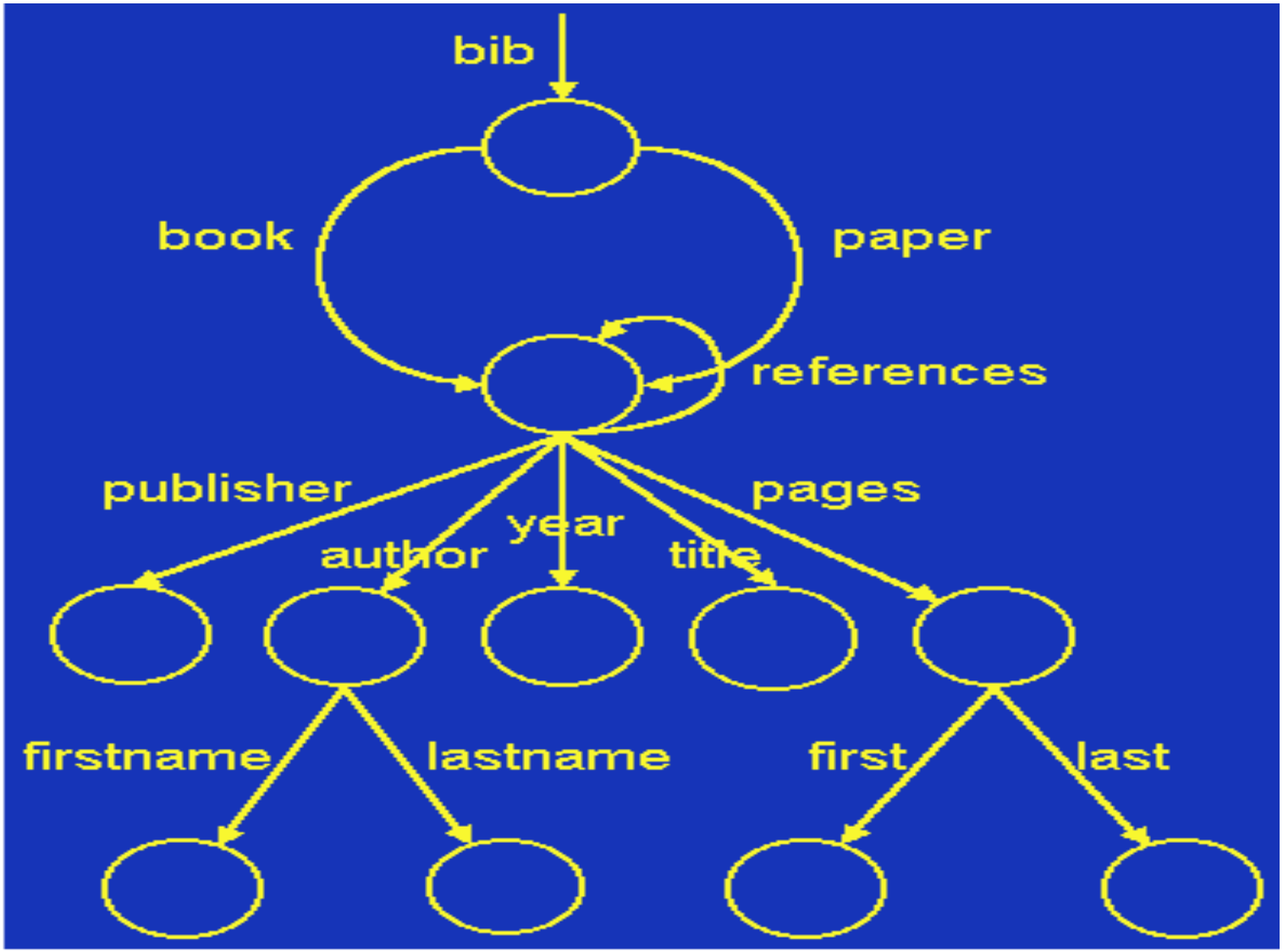
Data Graph Satisfying a Schema Graph

- given data graph *D* and schema graph *S*
- *D* is an *instance of S* (or *D satisfies S*) if there exists a *simulation R* from *D* to *S* such that *(root(D), root(S))* is in *R*
- a *simulation* is a relation *R* between nodes:
  - if *(u,v)* is in *R* and *(u,x)* labeled *l* is in *D*
    then there exists *(v,y)* labeled *l* in *S*
    such that *(x,y)* is in *R*

For Our Running Example

- node *&1* in *D* related under *R* to node at target of *bib* edge in *S*
- *&2* and *&4* related to node at target of *paper* edge
- *&3* related to node at target of *book* edge
- note that above two cases need to satisfy requirements of edges labeled *references* as well
- *&10* and *&11* related to node at target of edge labelled *author*
- ...

A Less Specific Schema Graph



Data Guide

data guide is a concise and accurate summary of a data graph

- *accurate*: every path in the data occurs in the data guide, and vice versa
- *concise*: every path in the data guide occurs exactly once

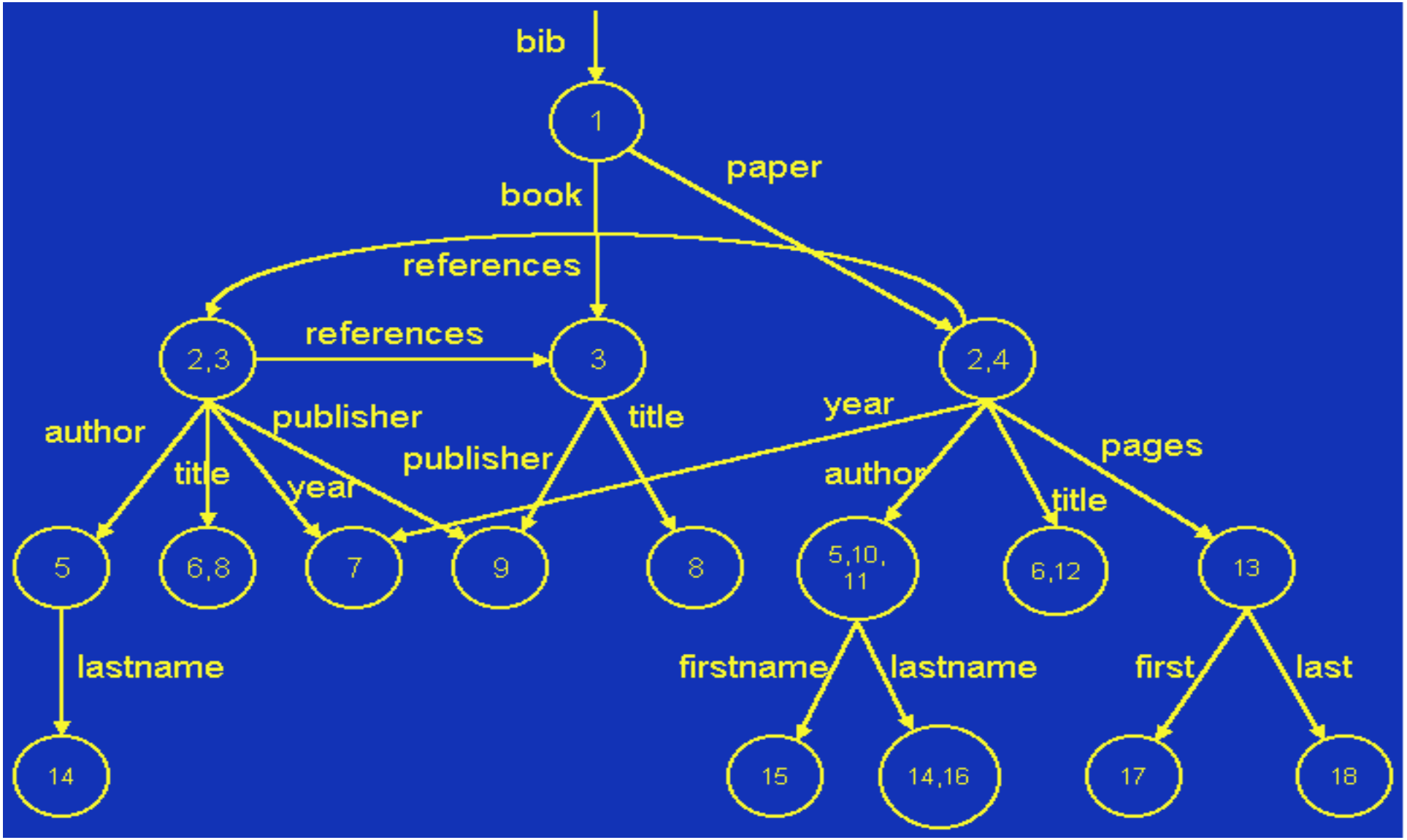
data guide is the *most specific* schema graph for a given data graph

- i.e., there is a simulation from the data guide to every other schema graph the data graph satisfies

connection to Finite State Automata:

- data graph is analogous to a *nondeterministic finite state automaton* (NFA)
- given NFA *N*, data guide is analogous to a *deterministic finite state automaton* (DFA) equivalent to NFA *N*
- conversion from NFA to DFA can result in exponential increase in size

Data Guide Example



Example Discussed

- provides a classification of nodes/objects in the data
- *2* and *4* are papers
- *5*, *10* and *11* are authors of papers
- *2* and *3* are referenced by papers
- *6* and *8* are titles of objects referenced by papers
- *3* is both a book and an object that is referenced by an object that is referenced by a paper

Representative Query Paradigms

Philosophy: Patterns

- Inspired by relational QBE formalism
- Basic pattern: matches against a single edge

_s – E -> _t

_s,_t: node variables, E: edge type label

- Example:
  find endpoints of paths crossing an E edge, then an F edge

  Q1(_s,_t) :- _s – E -> _x, _x – F -> _t

- Find nodes with an outgoing D edge whose target has an outgoing E edge and an outgoing F edge. Return source node and the two target nodes.

Q2(_s,_e,_f) :- _s – D -> _x, _x – E -> _e, _x – F -> _f

Note use of variable _x to match against the fork node

Regular Path Patterns: Concatenation

- When intermediate nodes on path do not need to be named:

Q1(_s,_t) :- _s – E -> _x, _x – F -> _t

Expression E.F expresses edge concatenation :

Q1’(_s,_t) :- _s – E.F -> _t

Regular Path Patterns: Disjunction

- Find endpoints of E or F edges:

  Q3(_s,_t) :- _s – E|F -> _t

- Find endpoints of paths strting with an E edge, followed by an F or G edge, then by an H edge:

  Q4(_s,_t) :- _s – E.(F|G).H -> _t

Regular Path Patterns: Wildcard

- Find endpoints of all edges, regardless of edge type

```
Q5(_s,_t) :-  _s - _ -> _t
```

- Endpoints of paths of length 3

```
Q6(_s,_t) :-  _s - _._._ -> _t
```

- Nodes involved in self-loops

```
Q7(_n) :-  _n - _ -> _n
```

Regular Path Patterns: Kleene Star

- p*

Specifies arbitrarily many (including 0) repetitions of path pattern p

- Pairs of connected nodes

Q8(_s,_t) :- _s -_* -> _t

- Pairs of nodes connected only by red or blue edges

Q9(_s,_t) :- _s – (red|blue)* -> _t

- Connected by an alternation of red and blue edges, starting with red

Q10 (_s,_t) :- _s – (red.blue)* -> _t

Regular Path Patterns: Syntax

- p := T
  | ‘_’
  | p ‘.’ p
  | p ‘|’ p
  | p ‘*’
  | ‘(‘ p ‘)’

where T is any edge type label

Node Construction

- So far, queries have only extracted sets of tuples of nodes
- What if we wish to construct new nodes?
- Need to specify
  - Node identity
  - New edges connecting newly created nodes

Generating Node Identities: Skolem functions

- A Skolem Function associates with its arguments the identity of a node.
- When called for the first time with a certain argument, the function creates a fresh node and returns its identity
- Subsequent calls with the same argumet return the identity of the previously created node

Representative QL: StruQL

- For each author of a referenced book, create a “citedAuthor” edge, emanating from a fresh “Result” node

from bibGraph _r

where _r – bib.book -> _b,
_b – author -> _a,
_a – lastname -> _l,
_a – ssn -> _s,
_r -_*.references -> _b

create Result (), Aut (_s), LN (_s,_l)

link Result () – CitedAuthor -> Aut (_s),
Aut (_s) – LastName -> LN (_s,_l)