Query Languages for Semistructured Data

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Outline

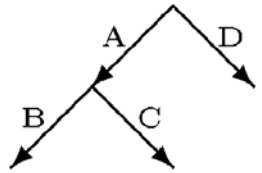
- UnQL
  - Query language for unstructured data
  - UPenn, ACM SIGMOD 96
- Lorel
  - Query language for semistructured data
  - Stanford, JODL 97
- MSL
  - Mediator specification language
  - Stanford, VLDB 96
- WebOQL
  - Query language for documents, databases and webs restructuring
  - UToronto, ICDE 98
- StruQL
  - Language for querying and restructuring semistructured data
  - AT&T Labs, ACM SIGMOD 98

UnQL

Data Model

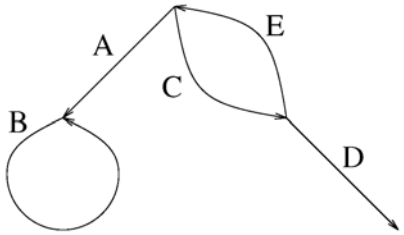
- Rooted edge-labeled directed graph (labeled tree)
  - Fixed-depth, arbitrary-depth, cyclic structures
- Information resides only at labels
- Label types: integers, strings, …, symbols
- Example (trees):

$$\{A \Rightarrow \{B \Rightarrow \{\}, C \Rightarrow \{\}\}, D \Rightarrow \{\}\}$$



- Example (cyclic structures, *tree markers*):

$$X_1 \text{ where } X_1 = \{A \Rightarrow X_2, C \Rightarrow \{D, E \Rightarrow X_1\}\},$$
$$X_2 = \{B \Rightarrow X_2\}$$



UnQL

Characteristics and Expressiveness

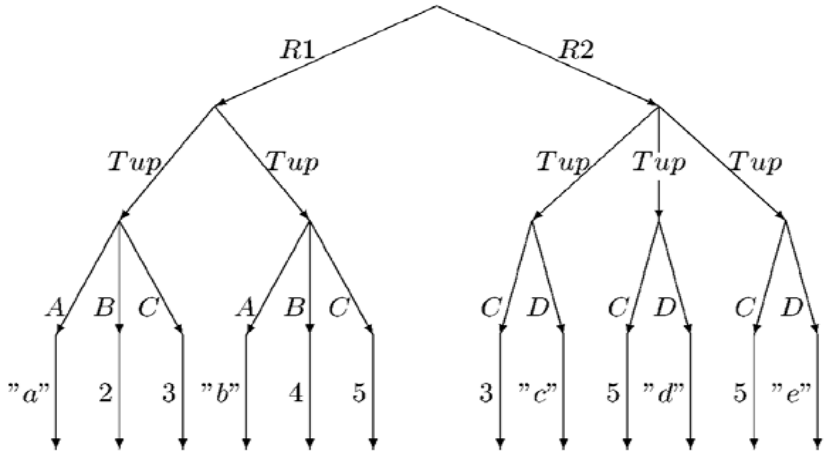
- Tree-traversing pattern-matching-based language
- Two types: Labels and Trees
- A tree is a set of pairs of labels and trees
- Queries defined even on cyclic structures
- Expressive power of relational algebra on fixed-depth structures
- Traversals of arbitrary-depth trees controlled by regular expressions on paths
- Restructuring ability at arbitrary depths
- All queries computable in polynomial time

UnQL

Selection Queries

- Example: Group by C column on R2

```
select {x ⇒ (select y where
                R2 ⇒ Tup ⇒ {C ⇒ x, D ⇒ \y} ← DB)}
where R2 ⇒ Tup ⇒ C ⇒ \x ⇒ {}} ← DB
```



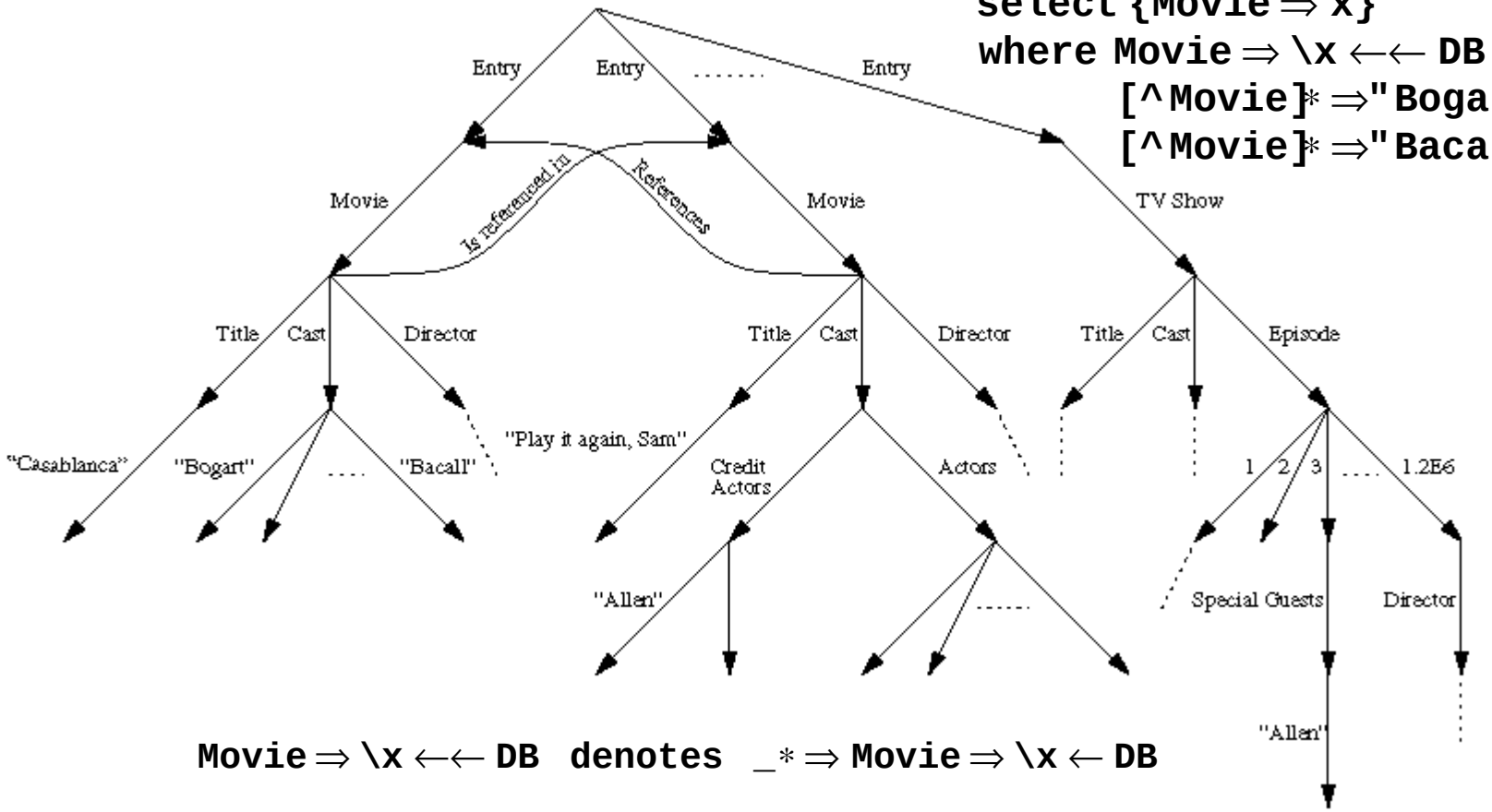

```
{3 ⇒ {"c"}, 5 ⇒ {"d","e"}}
```

UnQL

Deep Queries

- Example: Find all movies involving "Bogart" and "Bacall"

```
select {Movie ⇒ x}
where Movie ⇒ \x ←← DB
      [^Movie]* ⇒"Bogart"⇒ _ ← x,
      [^Movie]* ⇒"Bacall"⇒ _ ← x
```



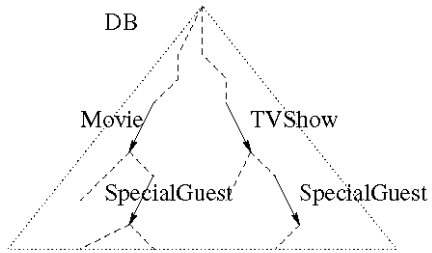
`Movie ⇒ \x ←← DB` denotes `_* ⇒ Movie ⇒ \x ← DB`

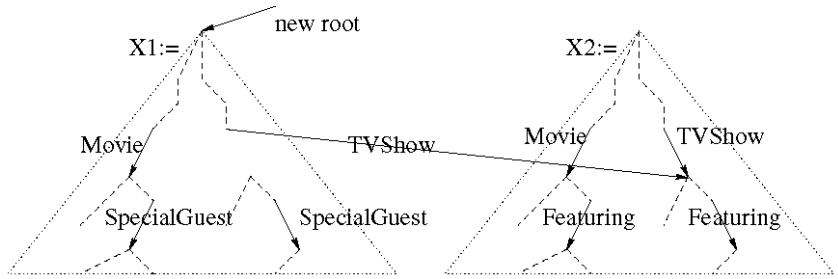
UnQL

Restructuring Queries

- Example: Replace every *SpecialGuest* edge with a *Featuring* edge, but only in *TVShows*

```
traverse DB giving X1,X2
        case TVShow ⇒ _          then X1 :={TVShow ⇒ X2}
        case SpecialGuest ⇒ _    then X2 :={Featuring ⇒ X2}
        case \l ⇒ _              then X1 :={l ⇒ X1}, X2 :={l ⇒ X2}
```

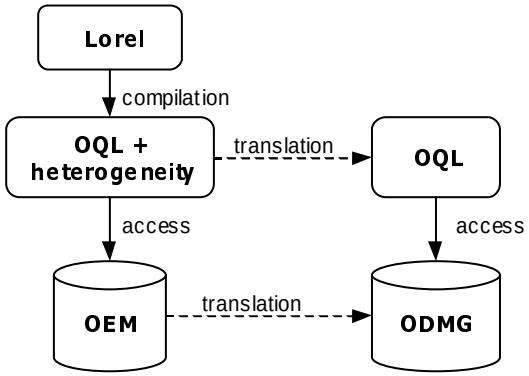


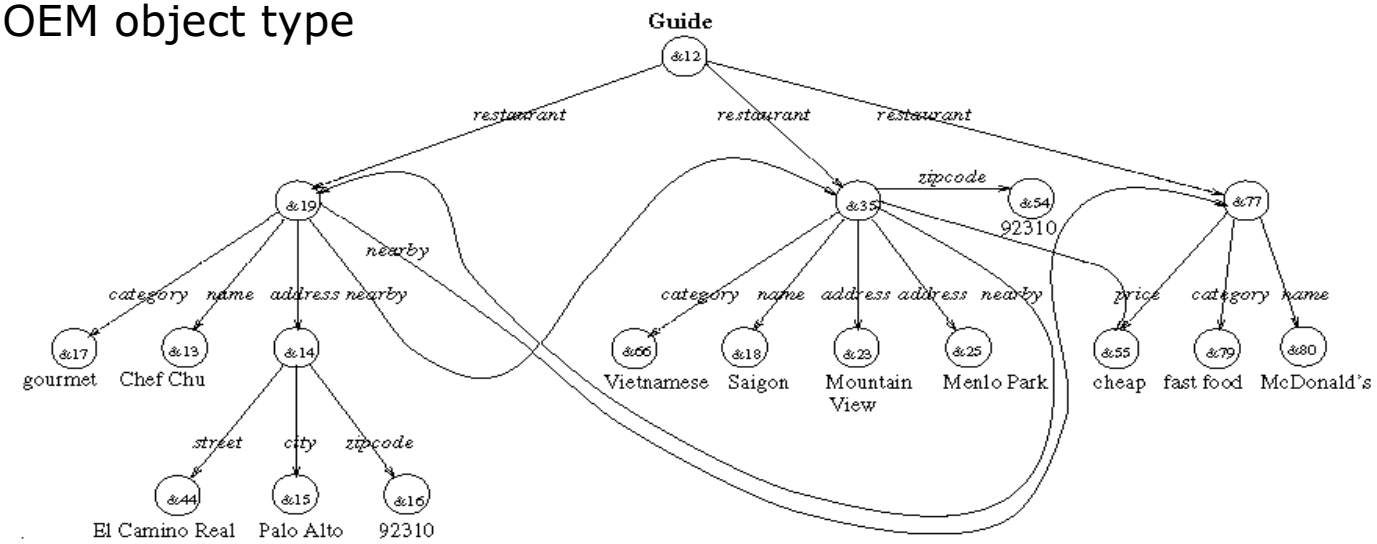


Lorel

Data Model

- OEM (Object Exchange Model)
  - Labeled Directed Graph
  - Objects at vertices, Labels at edges
  - Atomic and complex objects
  - Object names
- Extension of the ODMG data model
  - OEM object type





Lorel

Characteristics and Expressiveness

- User-friendly, pattern-matching-based language
- Extension of OQL
- Extensive use of coercion (relax strong typing)
- Declarative navigational access using path expressions
- Four types: atomic values, atomic objects, set of objects, complex object

Lorel

Coercion

- Example: Find the addresses of all restaurants with zipcode 92310

```
select X.address
from Guide.restaurant X, X.zipcode Y
where Y = 92310
```

- Rules provided for atomic types, predicates and functions
- Comparing values and atomic objects

arg1 \ arg2	*string*	*real*	*int*
string	–	*string* → *real*	*both* → *real*
real		–	*int* → *real*
int			–

- Comparing objects and sets of objects
  - Two types of equality: "=" and "=="

arg1 \ arg2	*value*	*atomic object*	*set of objects*	*complex object*
value	*coerce*	*dereference*	*existential with ==*	*false*
atomic object		*value =*	*existential with ==*	*false*
set of objects			*existential with == on both sides*	*false*
complex object				*value =*

Lorel

Simple Path Expressions

- Can be translated to OQL queries
- Example: Select prices more than 25

```
select Guide.restaurant.price
from Guide.restaurant
where Guide.restaurant.price > 25
```

```
select (select P from R.price P)
from Guide.restaurant R
where exist Q in R.price : Q > 25
```

WRONG

```
select (select P from R.price P where P > 25)
from Guide.restaurant R
where exist Q in R.price : Q > 25
```

CORRECT

```
Guide &12
   restaurant &19
      category &17 "gourmet"
      name &13 "Chef Chu"
      address &14
         street &44 "El Camino Real"
         city &15 "Palo Alto"
         zipcode &16 92310
      nearby_eating_place &35
      nearby_eating_place &77
   restaurant &35
      category &66 "Vietnamese"
      name &18 "Saigon"
      address &23 "Mountain View"
      address &25 "Menlo Park"
      nearby_eating_place &19
      zipcode &54 "92310"
      price &55 "cheap"
   restaurant &77
      category &79 "fast food"
      name &80 "McDonald's"
      price &55
      price &10
```

Lorel

General Path Expressions

- Cannot be translated to OQL queries
- Allow regular expressions and label completion
- Examples:

```
Guide.restaurant(.address)?.zipcode
Guide.restaurant.#@P.comp%.name
Guide.restaurant(.nearby)*{R}.name
```

- Path Variables and path distinguishers
- Example: Select restaurants with two distinct paths to the same nearby restaurant

```
select R
from Guide.restaurant R
where R(.#.nearby)@P = R(.#.nearby)@Q and P <> Q
```

MSL

Data Model

- OEM
  - Schema-less, self-describing, object-oriented model
  - Same as Lorel, but labels are migrated to nodes
  - OEM objects have object-id, label, type and value
  - Three types: Atomic value, atomic object, set of objects

```
<&r1, report, set, {&r1n, &r1a, &r1t, &r1y, &r1r}>
      <&r1n, report_num, string, 'AB-123-456'>
      <&r1a,authors, set, {&b1a1}>
            <&r1a1, author, string, 'John Patriot'>
      <&r1t, title, string, 'UN Conspiracies'>
      <&r1y, year, string, '1995'>
      <&r1r, related, set, {&r2}>
             ⋮
<&r2, report, set, {&r2n, &r2a, $r2t, &r2y, &r2r}>
```

MSL

Characteristics and Expressiveness

- Mediator specified by a set of non-procedural rules
- Each rule maps a set of objects at a source
- Additional sources require more rules for a specification
- Assignment of semantically meaningful object ids at the mediator using Skolem functions
- Fusion operations specified non-procedurally
- Removal of redundancies and resolution of inconsistencies between sources
- Integration of nested and cross-referenced objects (Web)

MSL

Object Fusion

- Example: Fuse reports that have the same report number from sources s1 and s2

```
(MS1) (R1.1) <trep(RN) techreport {<title T>}>@simple :-
                    <report {<report_num RN> <title T>}>@s1
      (R1.2) <trep(RN) techreport {<postscript P>}>@simple :-
                    <report {<report_num RN> <postscript P>}>@s2
```

- Rules can incrementally and independently insert information into a semantically identified mediator object
- Example: Retrieve all data of techreports's with object-id trep('123')

```
(Q1) <trep('123') techreport V> :- <trep('123') techreport V>@simple
```

MSL

Removing Redundancies

- Example: Group all information about reports into techreports objects

```
(MS2)(R2.1) < trep(RN) techreport {< rnOID(RN) report_num RN > < O1 L1 X1 >} > @nored :-
                < report {< report_num RN > < O1 L1 X1 >} > @s1 AND NOT L1 = report_num
     (R2.2) < trep(RN) techreport {< rnOID(RN) report_num RN > < O2 L2 X2 >} > @nored :-
                < report {< report_num RN > < O2 L2 X2 >} > @s2 AND NOT L2 = report_num
```

- The structure of the source reports is not required

MSL

Resolving Inconsistencies

- Blocking sources at various levels of granularity
- Example: s1 is accessed for free, s2 is not

```
(MS3) (R3.1) < trep(RN) techreport V >} > @save :-
             < report V :{< report_num RN >} > @s1
      (R3.2) provides(RN) :- < report {< report_num RN > < author A >} > @s1
      (R3.3) < trep(RN) techreport V > @save :-
             NOT provides(RN) AND < report V :{< report_num RN >} > @s2
```

- Dynamic priority assignment
- Fine-grained blocking at subobjects level

MSL

Handling References

- Solution 1 (inexpensive, weak):
  - Subobjects that contain references must be known

```
(MS4)(R4.1) <trep(RN) techreport {L X}>@ref :-
            <report {<report_num RN> <L X>}@s1 AND NOT L = related
     (R4.2) <trep(RN) techreport {related {<trep(REL) techreport {}>}>}>@ref :-
            <report {<report_num RN> <related {<report_num REL>}>}>}>@s1
```

- Solution 2 (expensive, powerful):
  - Copies needed
  - If references between sources exist, more copies are needed

```
(MS5)(R5.1) <trep(RN) techreport {L X}>@ref :-
            <report {<report_num RN> <L X>}@s1
     (R5.2) <O techreport V :{report_num RN}>@ref :-
            AND <O report {<report_num RN>}>@s1
```

WebOQL

Data Model

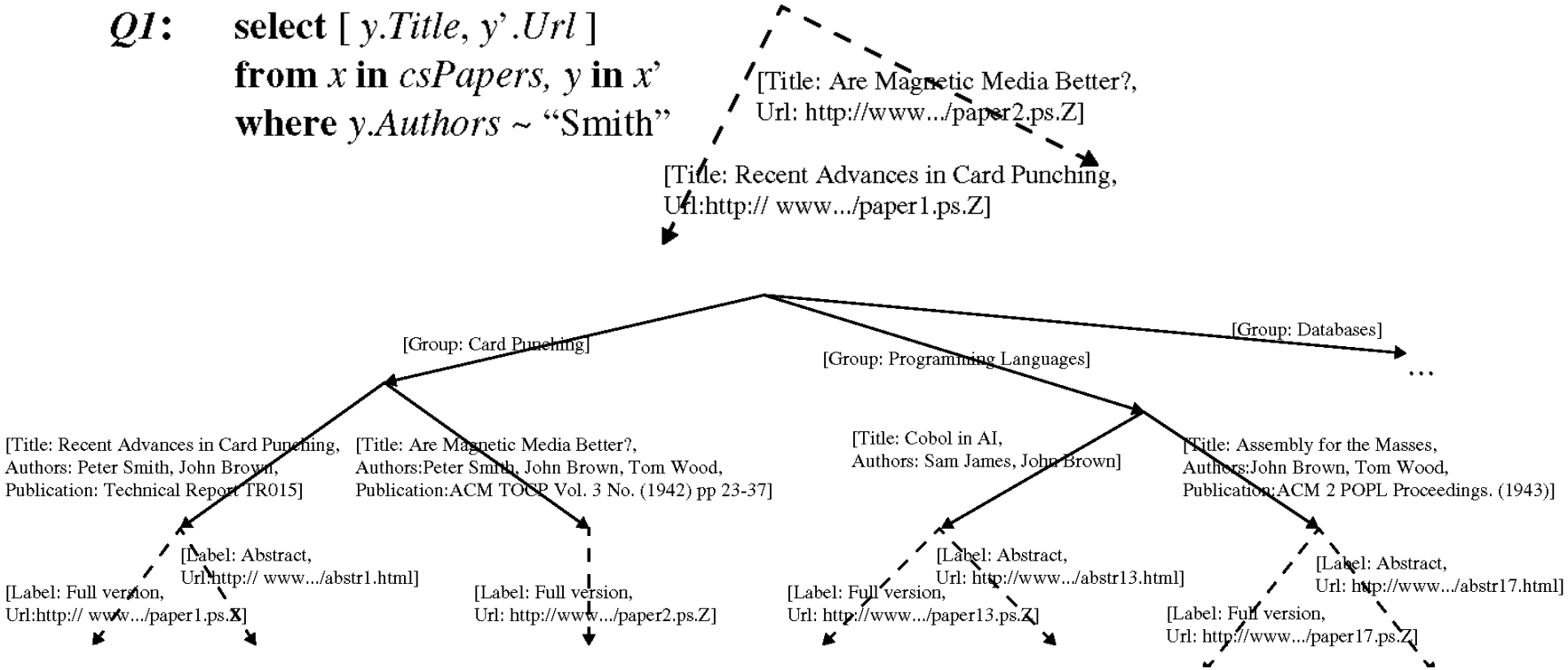
- Hypertrees
  - Ordered arc-labeled trees
  - Contains internal (structured objects) and external (references) arcs
  - Represents a document or a relation
  - Three abstractions: collections, nesting, ordering, references
- Webs
  - Models a set of related hypertrees
  - Consists of a hypertree t (schema) and a function F that maps URLs to hypertrees (browsing function)
  - The browsing function defines a graph of hypertrees (pages)
  - The schema provides entry points to the graph
  - URL dereferencing using the browsing function (F(u) is the content of the page, u is a URL)

WebOQL

Restructuring Simple Trees

- Example: Retrieve the title and URL of the full version of papers authored by "Smith"

***Q1*:** **select** [*y.Title, y'.Url*]
from *x* **in** *csPapers, y* **in** *x'*
where *y.Authors* ~ "Smith"

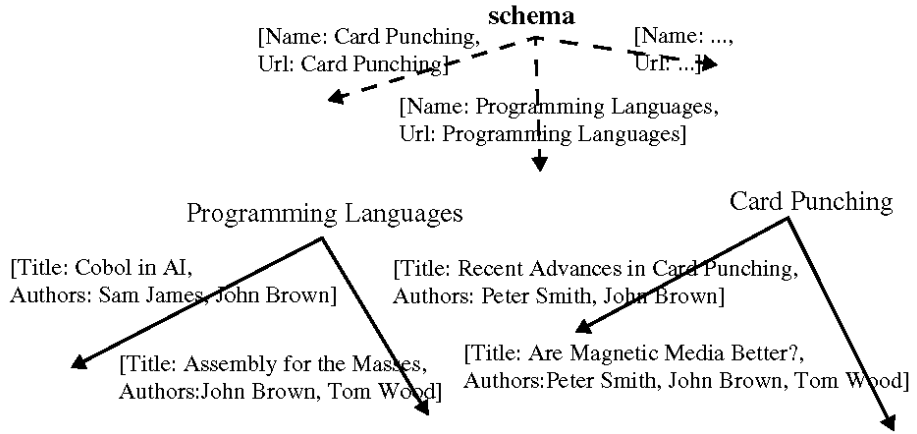


WebOQL

Restructuring Webs

- How to map one web into another
- New schema, redefined browsing function
- Example: Create a new web containing one page per group (title,author/publication) and an index page

Q11: *newWeb* ← **select unique**
[*Name*:*x.Group*,*Url*:*x.Group*] **as schema**,
[*y.Title*, *y.Authors*] **as** *x.Group*
from *x* **in** *csPapers, y* **in** *x'*



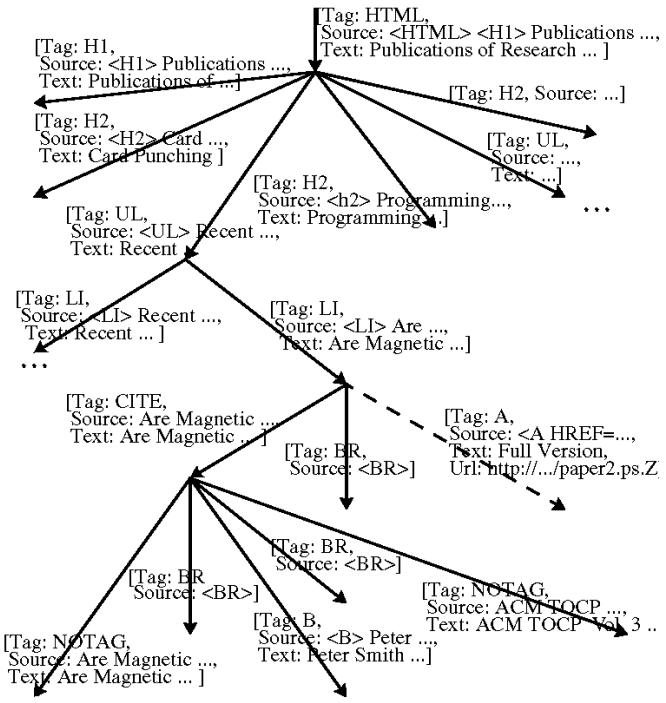
WebOQL

Annotated Abstract Syntax Trees (ASTs)

- HTML documents are modeled with their annotated abstract suntax trees (ASTs)

```
<HTML>
<H1>Publications of Research Groups at CS Department</H1>
<H2> Card Punching </H2>
<UL>
<LI>
    <CITE> Recent Advances in Card Punching <BR>
    <B> Peter Smith, John Brown </B> <BR>
    Technical Report TR015 </CITE> <BR>
    <A HREF="http://.../paper1.ps.Z"> Full version </A>
    <A HREF="http://.../abtstr1.html"> Abstract </A> <BR>
</LI>
<LI>
    <CITE> Are Magnetic Media Better? <BR>
    <B> Peter Smith, John Brown, Tom Wood </B> <BR>
    ACM TOCP Vol. 3 No.1 (1942) pp 23-37</CITE> <BR>
    <A HREF="http://.../paper2.ps.Z"> Full version </A>
</LI>
</UL>

<H2> Programming Languages </H2>
<UL>
<LI>
    <CITE> Cobol in  AI <BR>
    <B> Sam James, John Brown </B> <CITE> <BR>
    <A HREF="http://.../paper13.ps.Z"> Full version </A>
    <A HREF="http://.../abstr13.html"> Abstract </A> <BR>
</LI>
...
<H2> Databases </H2>
...
</HTML>
```



WebOQL

Restructuring Documents

- Navigation patterns (NPs)
  - Variables can range over linked hypertrees
  - Example: Extract the names of all research groups (tagged with H2)

```
Q13:  select [ x.Text ]
      from x in "papers.html" via ^*[Tag = "H2"]
```

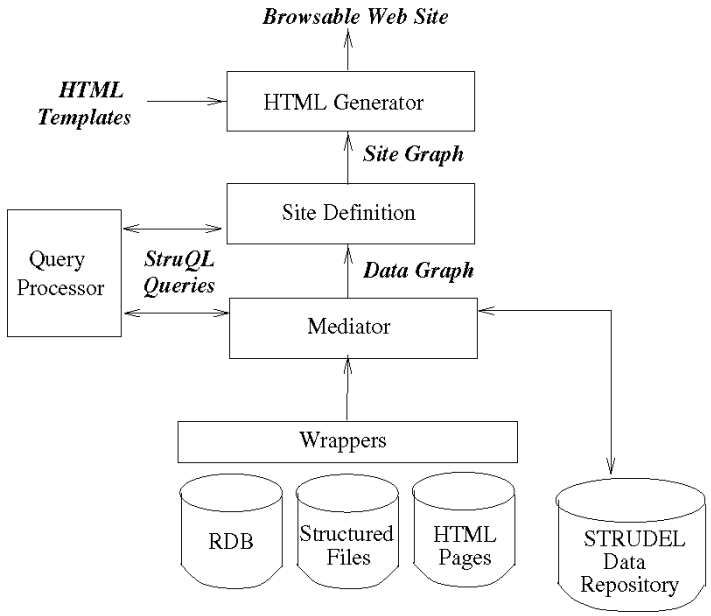
- Tail Variables
  - Example: Restructure the list of papers for a group into an HTML ordered list

```
Q15:  [ Tag: "OL" /
            select [ Tag: "LI" / X&3 ]
            from X in browse("Card Punching.html")!
            where X.Tag = "H3"
      ]
```

StruQL

Characteristics

- Strudel Web-Site Management System
  - Three independent phases
  - Labeled directed graph data model
- StruQL
  - Declarative specification of a web site's content (datagraph) and structure (site-definition query)
  - Restructuring operations on graphs



References

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- *"The Lorel Query Language for Semistructured Data"*, S. Abiteboul, D. Quass, J. McHugh, J. Widom, J. Wiener *(JODL 97)*
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- *"WebOQL: Restructuring Documents, Databases and Webs"*, G. Arocena, A. Mendelzon (ICDE 98)
- *"Catching the boat with Strudel: Experiences with a Web-Site Management System"*, M. Fernandez, D. Florescu, J. Kang, A. Levy, D. Suciu (ACM SIGMOD 98)