Finding the Best Probabilistic Schema for an XML Corpus

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Webdam Seaminar, 4 March 2011

XML Schemas vs Probabilistic XML

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- Compact description of a (possibly infinite) set of XML documents
- Nondeterministic generator

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Question

Can we transform an XML schema into a probabilistic XML document by learning the optimal probabilities (w.r.t. a corpus)?

Same-Structure Inference Problem

Given:

- an XML corpus, i.e., multiset of documents $\{|d_1 \dots d_n|\}$
- an XML Schema schema, i.e., a top-down deterministic tree automaton with primary keys and foreign keys
- Some class of probabilistic distributions (e.g., Gaussian, uniform...) for data values

Find the best probabilistic XML generator, as a recursive Markov chain [Benedikt et al., 2010] (i.e., probabilistic tree automaton) extended with:

- Continuous probability distributions [Abiteboul et al., 2010]
- Long-distance constraints

... that has the same structure as the schema.

Motivating Applications

- Sampling of XML documents similar to a corpus: testing
- Analysis of a corpus, and display to a user
- Evaluating the respective quality of two XML schemas
- Concise summary of a corpus, on which statistics can be gathered (e.g., through aggregate queries)

Outline

Introduction

Basic Case

Adding Constraints

Conclusion

Basic Setting: No Constraints

- We have: a top-down tree automaton and a corpus
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```
<!ELEMENT directory (person*)>
<!ELEMENT person (name,phone*)>
```

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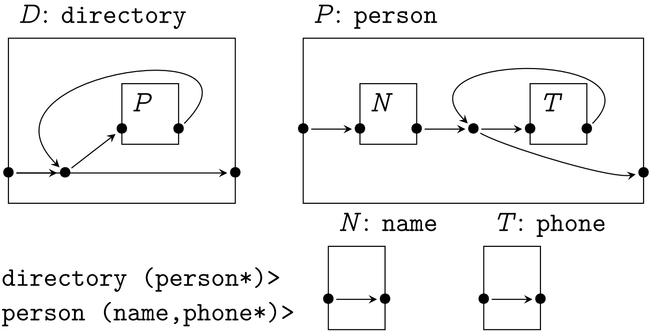


```
<!ELEMENT directory (person*)>
<!ELEMENT person (name,phone*)>
```

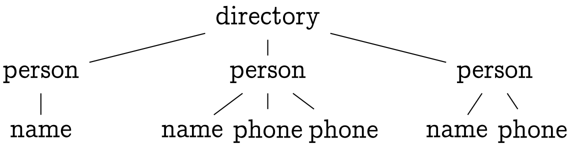
Algorithm

Very simple algorithm:

1. For each document of the corpus, run the automaton it, and for each state encountered:
   1.1 Increment a counter for the state
   1.2 Increment a counter for the outgoing transition
2. Normalize each transition counters by the counter of the incoming state: this gives a transition probability

Complexity linear in the size of the automaton and the corpus.

Example Run

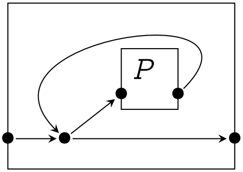


directory

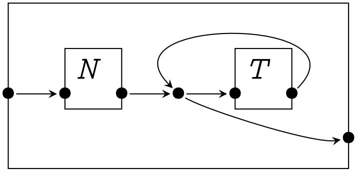
person person person

name name phone phone name phone

D: directory



P: person



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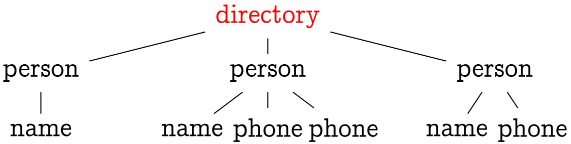
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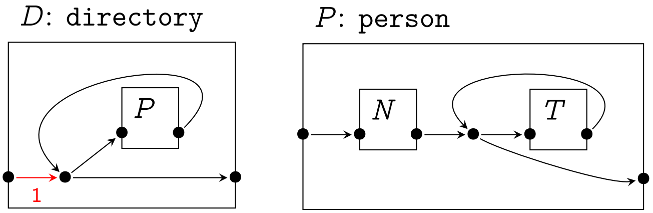
D: directory
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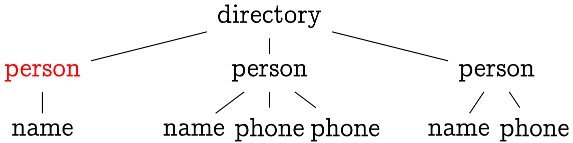
Example Run



directory

person

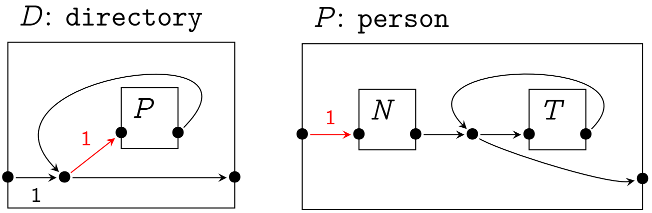
person

person

name

name phone phone

name phone



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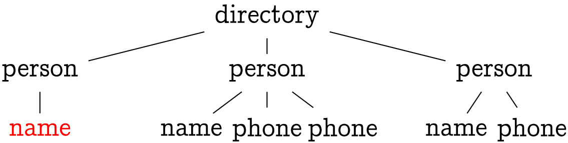
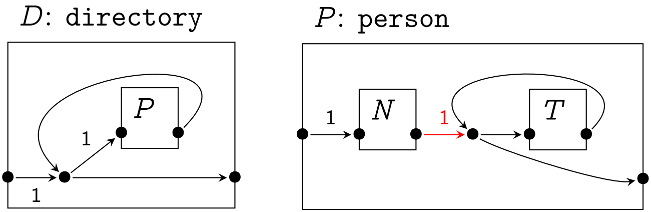


directory

person person person

name name phone phone name phone



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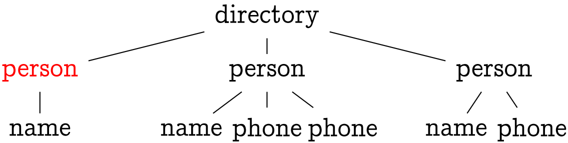

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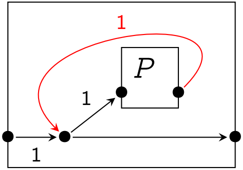

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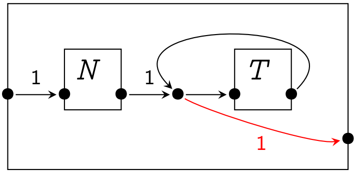

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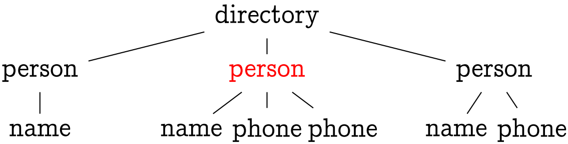

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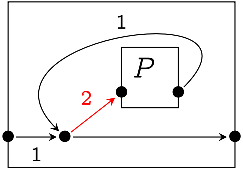

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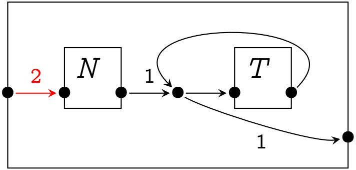

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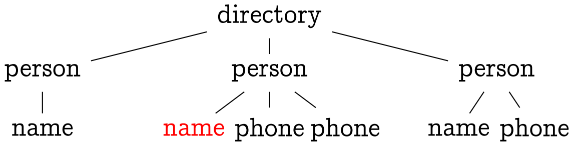
directory
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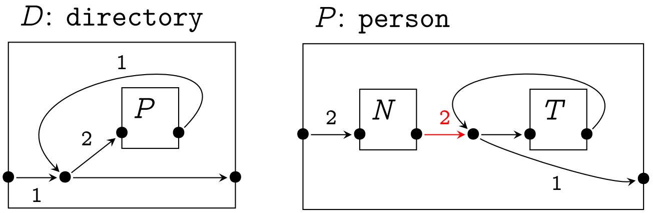
name phone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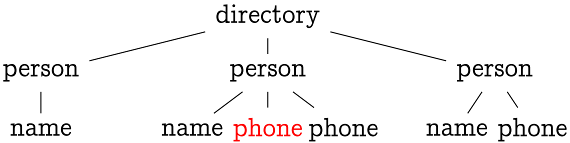
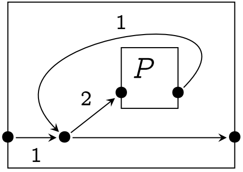


directory

person person person

name name phone phone name phone



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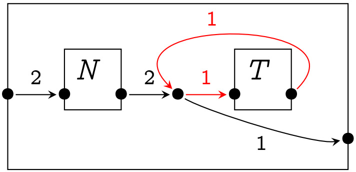

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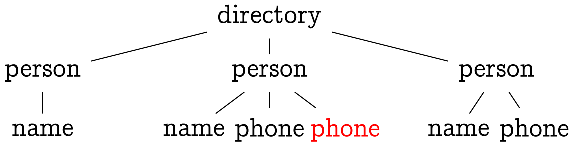

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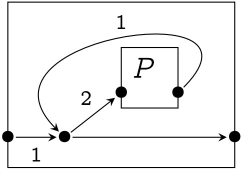

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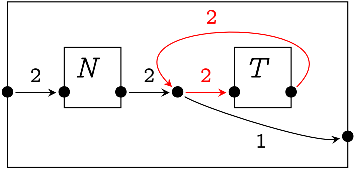

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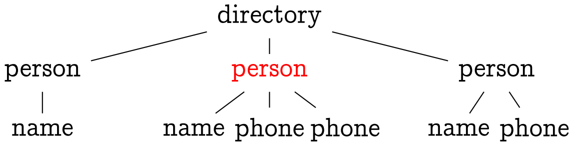

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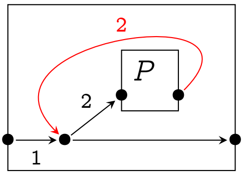

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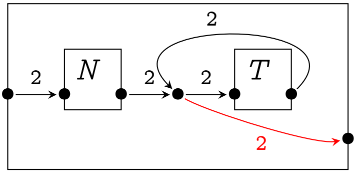

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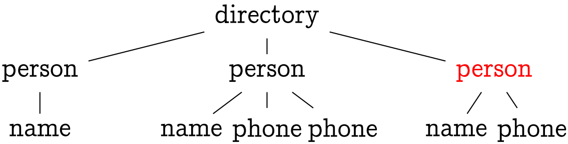

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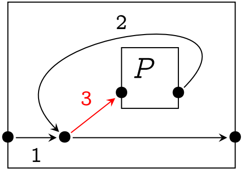

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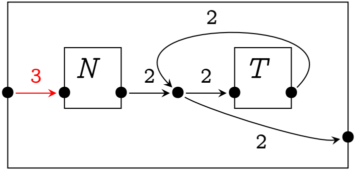

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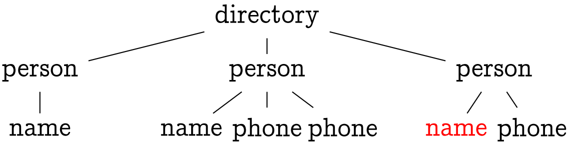

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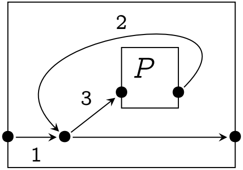

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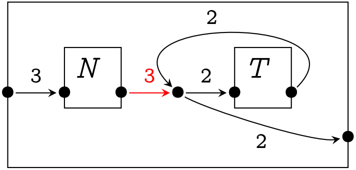

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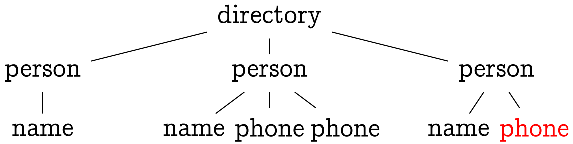
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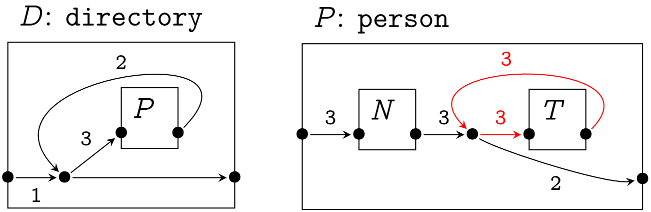
D: directory
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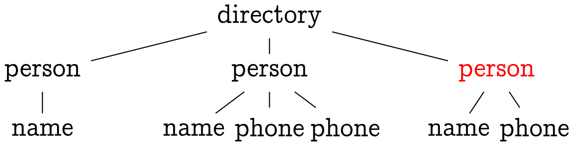
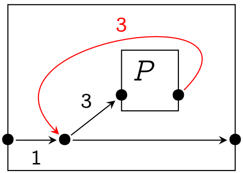
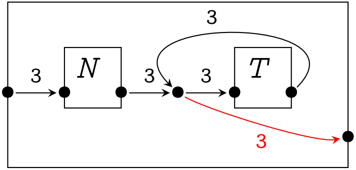
Example Run



D: directory



P: person



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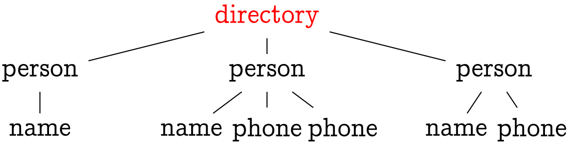
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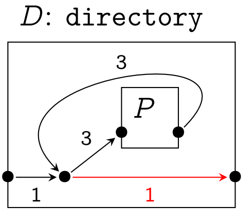
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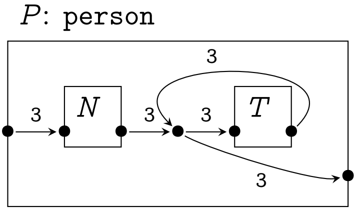
P: person
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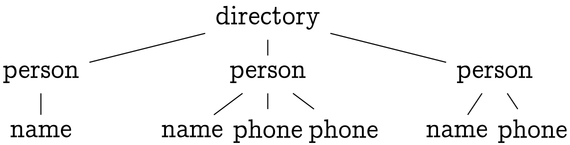
Example Run



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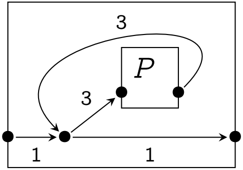
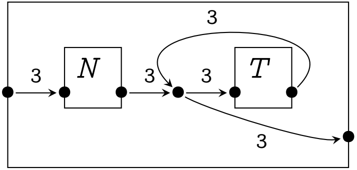


P: person



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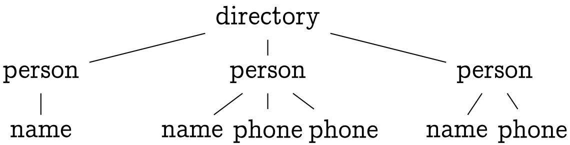
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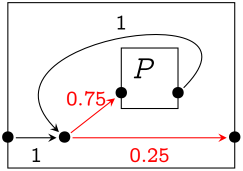
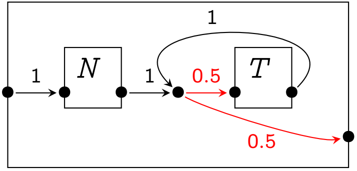
name phone

D: directory



P: person



Correctness of The Algorithm

Proposition

The probabilities assigned by the algorithm optimizes the likelihood of the corpus.

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The probabilistic generator constructed by the algorithms terminates with probability 1.

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Actually, results (kind of) known in the literature about probabilistic context-free grammars.

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Constraints

In XML Schema:

- xs:ID: global unary primary keys, only one kind per document
- xs:IDREF: global unary foreign keys, only one kind per document
- <xs:key>, <xs:unique>: primary keys, possibly local to a subtree, non-necessary unary
- <xs:keyref>: foreign keys, possibly local to a subtree, non-necessary unary

We consider for now:

- Global unary primary keys and foreign keys (extension to local should be possible)
- Domains of finite size: together with primary keys, act as a constraint!

Semilinear Sets

$$(A_1 \dots A_k) \in \bigcup_{i=1}^{p} \{v_{i0} + \alpha_1 v_{i1} + \cdots + \alpha_{n_1} v_{in_i} \mid \alpha_1 \dots \alpha_{n_1} \in \mathbb{N}\}$$

Interesting properties:

- The constraints on the number of times a tree automaton enters each particular state are given by a semilinear set (Parikh's theorem)
- Key constraints can be represented by semilinear sets
- Testing if the intersection of two semilinear sets is empty can be done in NP (integer programming)

How to Adapt the Algorithm

- For each transition, first check if the current document + the automaton + the constraints has a possible continuation (test the intersection of the semilinear sets)
- If only one transition from a given state, do not increment the counter of the
- Otherwise, proceed as usual
- Optimality results (for this class of probabilistic generator with continuation tests) still hold!

Remark

Only works for binary choices; but possible to transform n-ary choices into binary ones.

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In brief

- Work in progress
- Optimal probabilistic generator with respect to an XML schema and corpus
- Effective algorithm to compute it!
- Nondeterministic polynomial time: maybe not so bad, especially if we assume constraints are small

What Remains to Be Done

- Check everything really works ☺
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- Detailed complexity analysis
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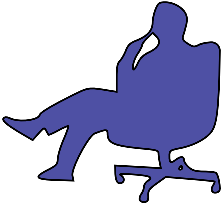

- More general constraint language? Things will become undecidable pretty fast.
- What about probabilistic constraints?
- What if the tree automaton is non-deterministic?
- What if we also want to discover the schema?
- Compelling application?

Merci.

Webdam

Serge Abiteboul, T-H. Hubert Chan, Evgeny Kharlamov, Werner Nutt, and Pierre Senellart. Aggregate queries for discrete and continuous probabilistic xml. In *Proc. ICDT*, Lausanne, Switzerland, March 2010.

Michael Benedikt, Evgeny Kharlamov, Dan Olteanu, and Pierre Senellart. Probabilistic XML via Markov chains. *Proceedings of the VLDB Endowment*, 3(1):770–781, September 2010. Presented at the VLDB 2010 conference, Singapore.