HMIN103

Données du Web

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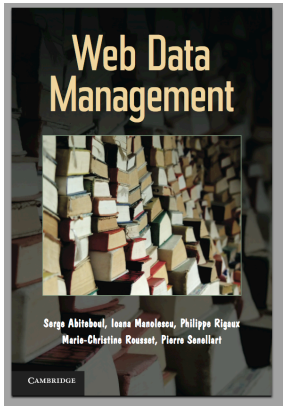
Slides collected from J. Cheney, S. Abiteboul, I. Manolescu, P. Senellart, P. Genevès, D. Florescu and the W3C

DTD and Regular Grammars

(fun with regular expressions)

Readings



- Web Data Management - Abiteboul & al.
- [WDM-XML] Chapter : Data-model
  - http://webdam.inria.fr//Jorge/files/wdm-datamodel.pdf
- [WDM-DTD] Chapter : Schemas (only section 3)
  - http://webdam.inria.fr//Jorge/files/wdm-typing.pdf

Schemas for XML Data

- Many schema languages/formalisms have been proposeed
  - DTD (XML 1.0)
  - XML Schema (W3C)
  - Relax/NG (OASIS), DSD, Schematron, ...
  - Regular expression types (XDuce, XQuery)

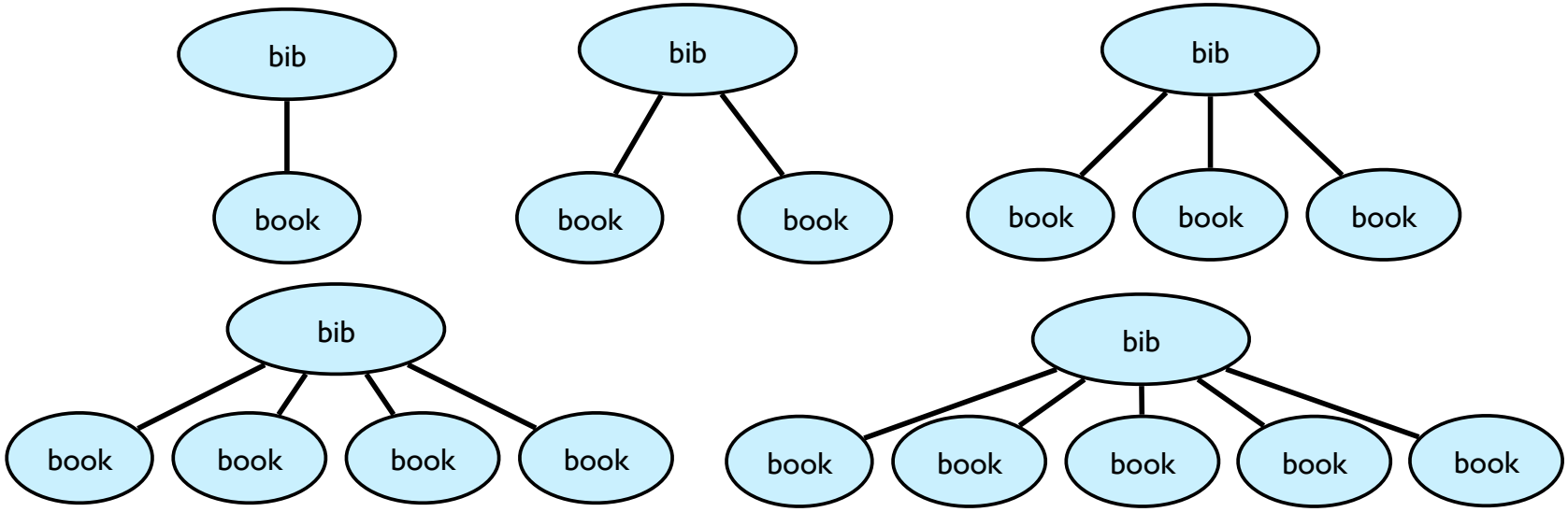
- Every XML schema language is based on regular expressions and grammars.
  - This illustrates an important use of theory in real applications.

Regular Tree Grammars

A DTD defines a (possibly infinite) **regular** set of XML trees.

```
<!ELEMENT bib book+>
```

```
<!ELEMENT book EMPTY>
```



Plan

- Grammars
- Validation
- Determinism

Word Grammars

Sets of rules used to specify a formal language of words.

```
S -> PQ          P -> aP|a          Q -> b
```

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```
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```

```
ab

aab

aaab

aaaab
```

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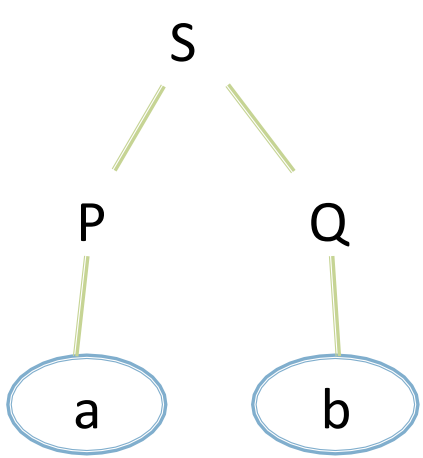
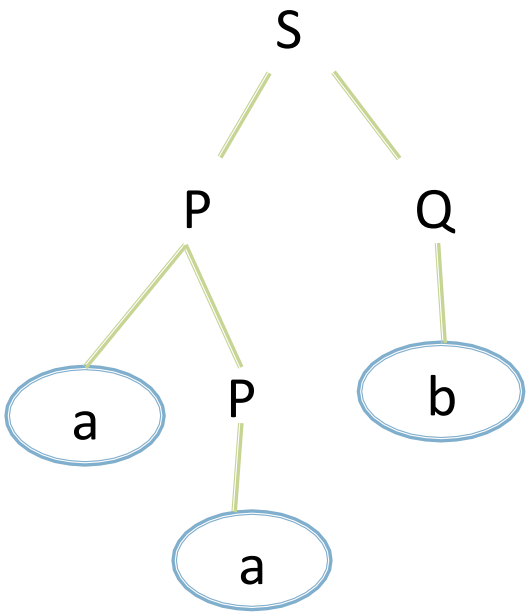


ab

aab

aaab

aaaab

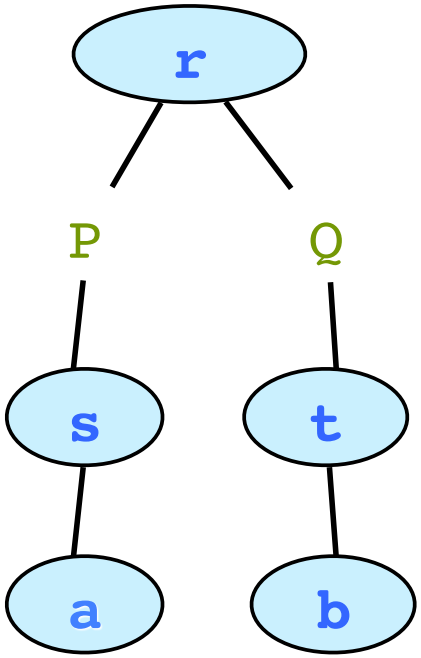


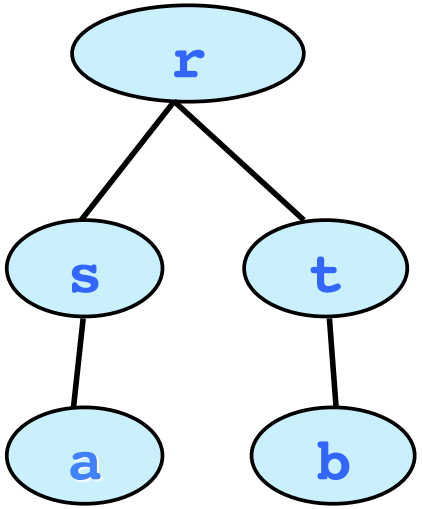
Concatenation of leaves = recognized word

Tree Grammars

Sets of rules used to specify a formal language of trees.

```
S -> r[PQ]        P -> s[a]        Q -> t[b]
```





Tree Grammars

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```
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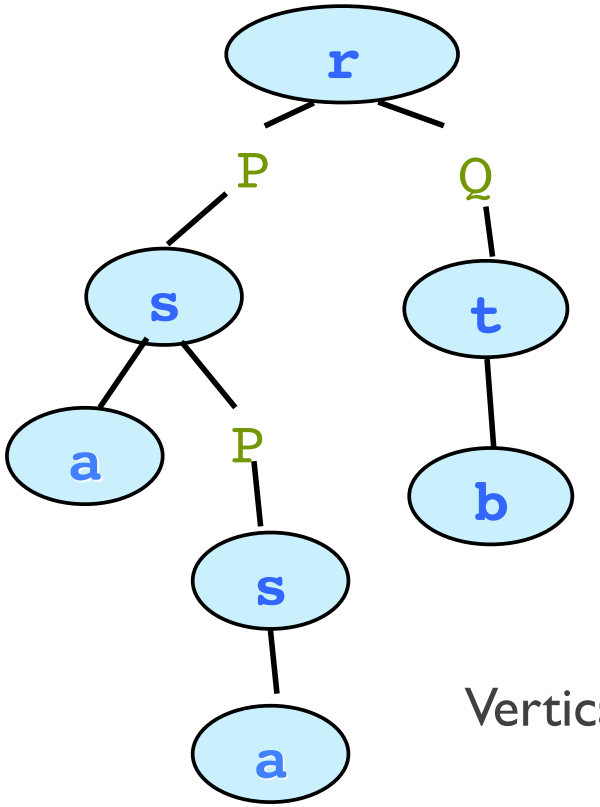
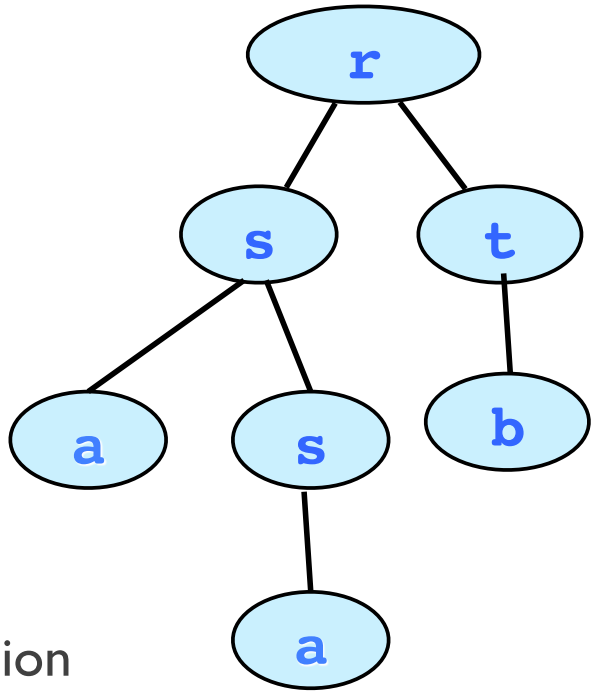


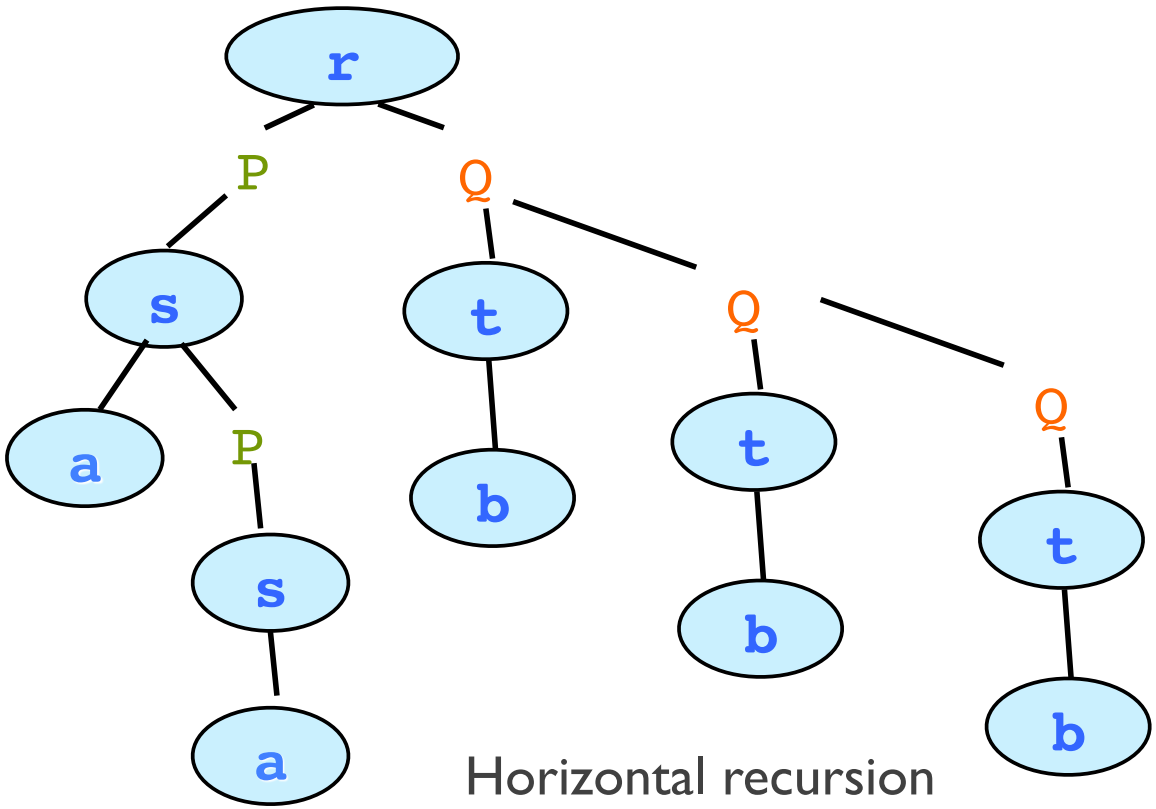
Vertical recursion



Tree Grammars

Sets of rules used to specify a formal language of trees.

```
S -> r[PQ]        P -> s[a]        Q -> t[b],Q
```

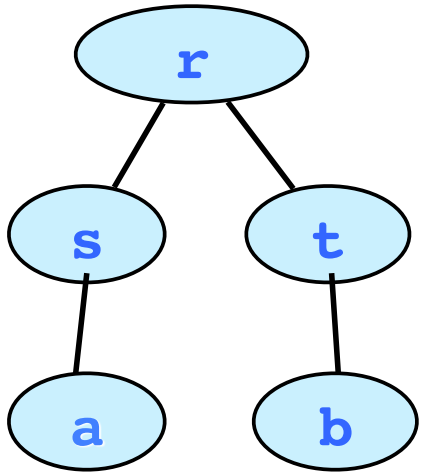


Horizontal recursion

Regular Tree Grammars

Sets of rules used to specify a formal regular language of trees.

```
S -> r[P,Q]        P -> s[aP|a]        Q -> t[b],Q
```



Forbid certains uses of horizontal recursion

```
Q -> t[b],Q          OK

Q -> t[b],Q,t[b]     NO
```

(analogous to the definition of regular word grammars)

Regular Tree Grammars

Sets of rules used to specify a formal regular language of trees.

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S -> r[P,Q]        P -> s[aP|a]        Q -> t[b]
```
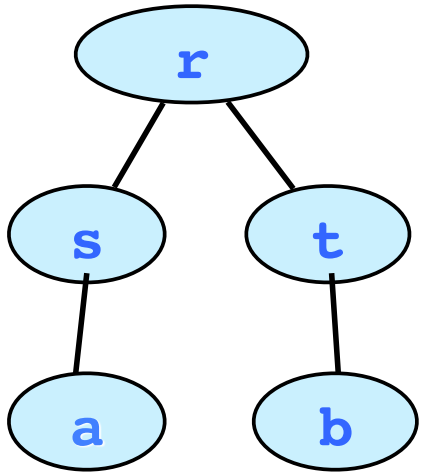



Equivalently : allow Regular Expressions

```
Q -> t[ _reg_expr_ ]
```

DTD

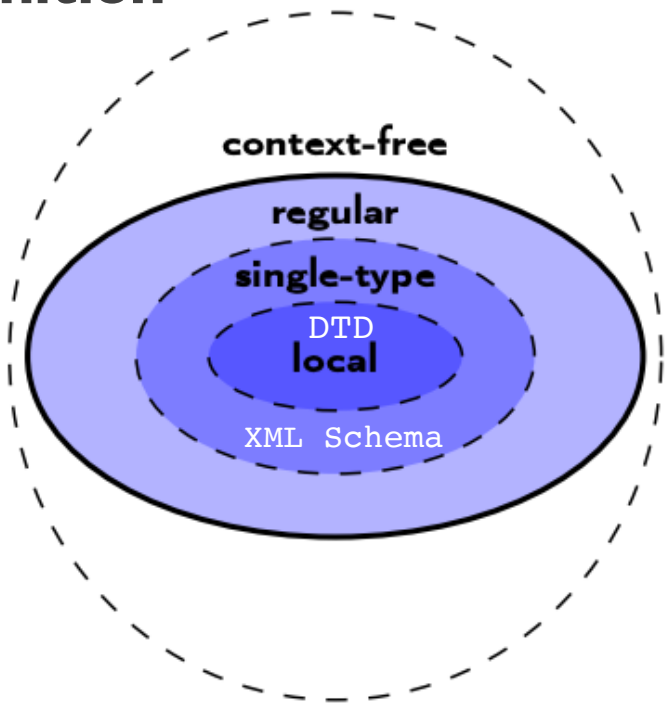
```
<!ELEMENT   t ( _reg_expr_ )>
```

Regular Tree Grammars

DTD are a subclass of regular tree-grammars called "**local**" :

any element has at most one definition

```
<!ELEMENT root child*>

<!ELEMENT child (#PCDATA)>

<!ELEMENT child EMPTY>
```



Why Regular Tree Grammars ?

- Regular Tree Grammars are expressive enough, and computationally more easy to handle than context-free
  - To illustrate, the following problems for context-free **tree** grammars cannot be algorithmically solved :
    - determine wether a context-free grammar is actually a regular grammar
    - determine wether a context-free grammar G1 is more general than (or, "includes") a context-free grammar G2
      - This is solvable for regular grammars

XML VALIDATION

Document Validation

- Problem : is an XML document valid with respect to a given DTD ?

Validation Algorithm

- Traverse XML tree in pre-order (document order) & check:

1. that each node is valid
2. that each attribute (of a node) is valid
3. the id-unicity and idref-references

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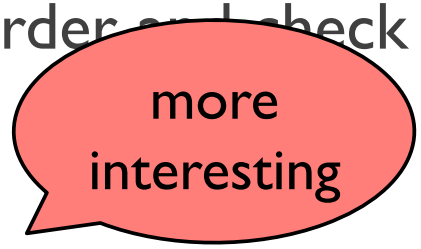
Validation Algorithm

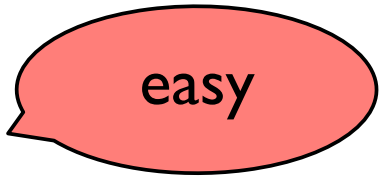
- Traverse XML tree in pre-order and check

1. that each node is valid

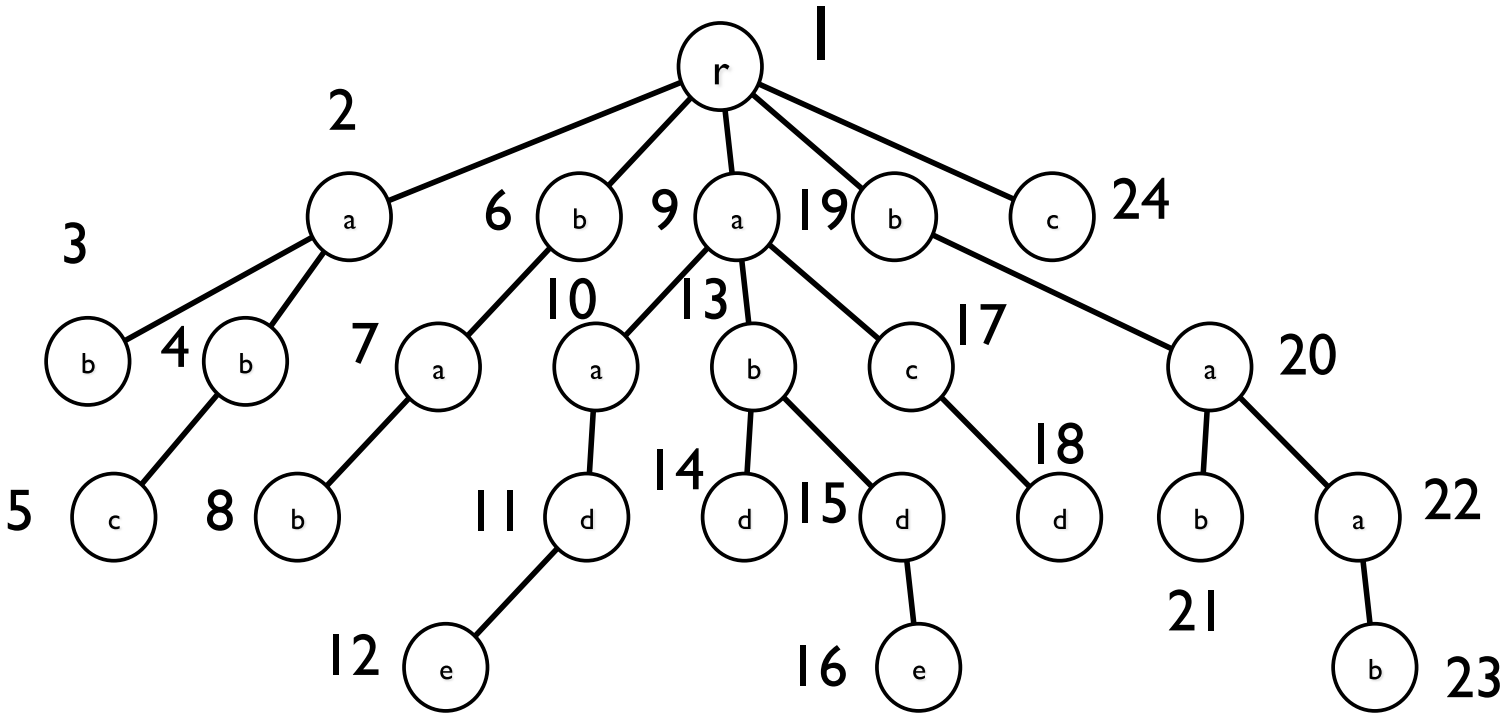


2. that each attribute (of a node) is valid

3. the id-unicity and idref-references

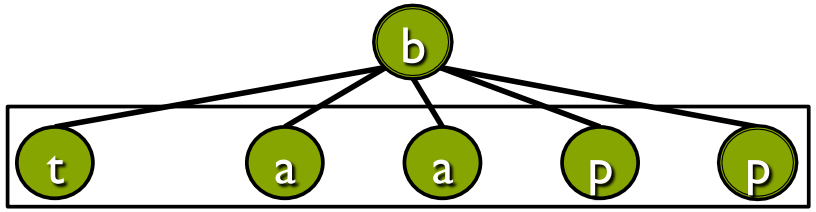


Pre-order Traversal



(Single Node) Validation

- Problem : does the sequence of children of the node match the regular expression specified by the DTD ?



Regular expressions

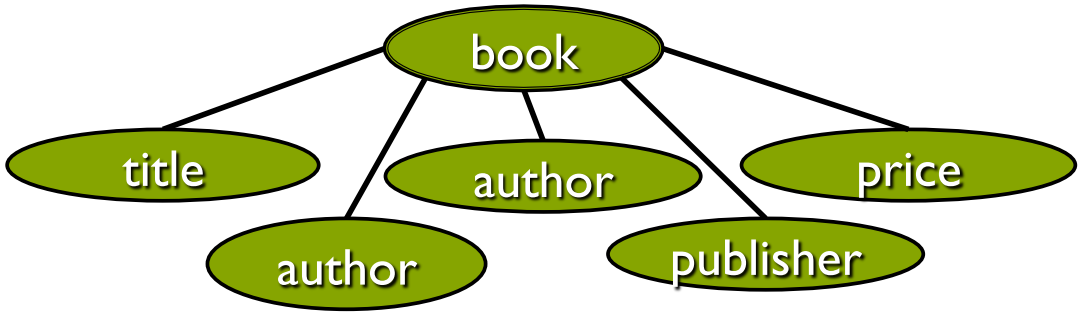
`r ::=`	`ϵ`	empty sequence
`|`	`a`	atomic symbol (in DTD, an element name)
`|`	`(r,s)`	sequential composition
`|`	`(r|s)`	union (alternation)
`|`	`(r+)`	repetition

`r* = r+|ϵ` `r? = r|ϵ`

Example

The regular expression for a book node is

```
(title, (author+ | editor+ ), publisher, price )
```



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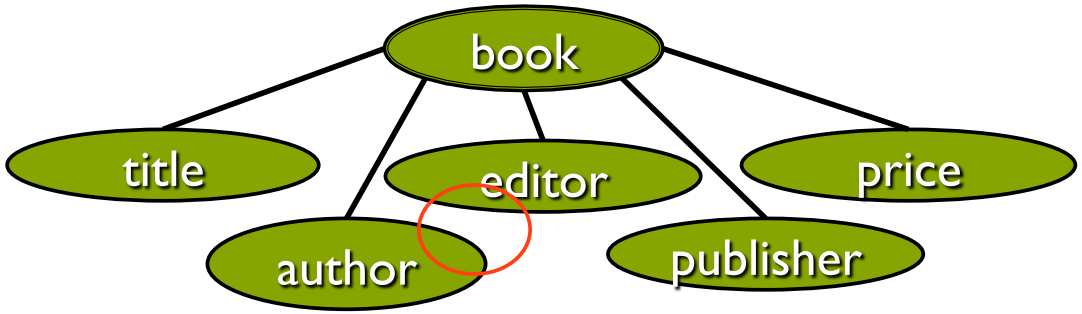


DETERMINISM

W3C Restriction

- Can we write any regular expression in a DTD ?
- NO.
- Regular expressions in DTDs must be deterministic:
  - *"there must be only one way to match any sequence of tags, no backtrack or look-ahead is required"*
- This is equivalent to say that the automata corresponding to the regular expression is deterministic.
- This eases the validation process

Example of Ambiguity

`( title, author* ) | ( title , editor* )` **NO**

can't decide if `<title/>` matches first or second "`title`"

Better to write `title , ( author* | editor* )`

How to test Determinism?

- Simplified algorithm

- Ingredients : three auxiliary functions

FirstTag() LastTag() FollowsTag()

(1/3) FirstTag

*What can be the **first** tag of a sequence matching r ?*

r_1 = `(title, (author+ | editor+ ), publisher, price )`

FirstTag(r_1) ? `title`

r_2 = `(author+ | editor+ )`

FirstTag(r_2) ? `author, editor`

(2/3) LastTag

*What can be the **last** tag of a sequence matching r ?*

r_1 = `(title, (author+ | editor+ ), publisher, price )`

LastTag(r_1) ? `price`

r_2 = `(author+ | editor+ )`

LastTag(r_2) ? `author, editor`

(3/3) FollowsTag

What tag can follow x in r ?

r_1 = `(title, (author+ | editor+ ), publisher, price )`

FollowsTag(r_1 , `title`) ? `author, editor`

r_4 = `(author | editor )*`

FollowsTag(r_4 , `author`) ? `author, editor`

Disambiguation

r_5 = `(author, title)? , author`

We resolve ambiguity by enumerating the tag occurrences

$r_5^{\#}$ = `(author`$_1$`, title)? , author`$_2$

FirstTag($r_5^{\#}$) = `author`$_1$`, author`$_2$

LastTag($r_5^{\#}$) = `author`$_2$

FollowsTag($r_5^{\#}$, `title`) = `author`$_2$

Determinism Algorithm

1) Enumerate all the occurrences of a tag in r

2) Build a graph were

 - there is a node x for each tag in ($r^{\#}$), plus a source-node x_0

 - there is a directed edge (x_0,y) if y belongs to FirstTag($r^{\#}$)

 - there is a directed edge (x,y) if y belongs to FollowsTag($r^{\#}$,x)

3) return **false** if there exists edges (x,y_i) and (x,y_j) with $i \neq j$

4) return **true** otherwise

Testing Determinism

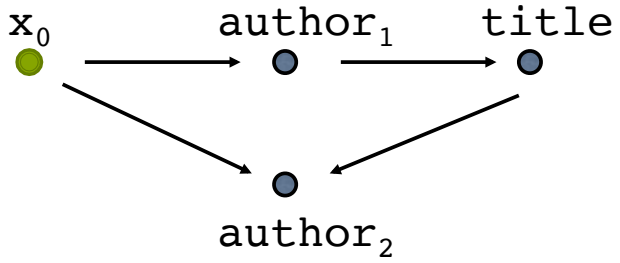
r_5 = `(author, title)? , author`

$r_5^{\#}$ = `(author`$_1$`, title)? , author`$_2$

FirstTag($r_5^{\#}$) = `author`$_1$`, author`$_2$

FollowsTag($r_5^{\#}$, `author`$_1$) = `title`

FollowsTag($r_5^{\#}$, `title`) = `author`$_2$

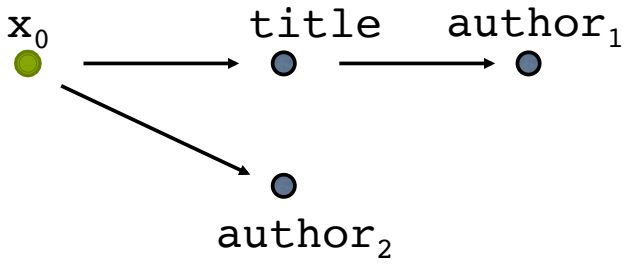


r_5 not deterministic

Testing Determinism

r_6 = `(title, author) | author`

$r_6^{\#}$ = `(title, author`$_1$`) | author`$_2$



FirstTag($r_6^{\#}$) = `title, author`$_2$

FollowsTag($r_6^{\#}$,title) = `author`$_1$

r_6 deterministic

Determinism - Quiz

Are the following regular expressions deterministic ?

- `((e|cb),b)*((cc|b)e,d)*`
- `(a,(ab|c))|(b,(a|c))`

Why did we define **LastTag**(r) afterall ?

- It is hidden behind the definition of FollowsTag(r,x)

FirstTag()

Definition on the structure of the regular expression

- FirstTag(ϵ) = {}
- FirstTag(a) = { a }
- FirstTag(r|s) = ?
- FirstTag(r*) = ?
- FirstTag(r,s) = ?

FirstTag()

Definition on the structure of the regular expression

- FirstTag(ϵ) = {}
- FirstTag(a) = { a }
- FirstTag(r|s) = firstTag(r) U firstTag(s)
- FirstTag(r*) = firstTag(r)
- FirstTag(r,s) = firstTag(r) [U firstTag(s) IF r matches ϵ]

LastTag()

Definition on the structure of the regular expression

- LastTag(ϵ) = ?
- LastTag(a) = ?
- LastTag(r | s) = ?
- LastTag(r*) = ?
- LastTag(r,s) = ?

LastTag()

Definition on the structure of the regular expression

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FollowsTag()

Definition on the structure of the regular expression

- FollowsTag(ϵ) = ?
- FollowsTag(`a`) = ?
- FollowsTag(`r | s`) = ?
- FollowsTag(`r*`) = ?
- FollowsTag(`r ,s`) = ?

FollowsTag()

Definition on the structure of the regular expression

- FollowsTag(ϵ) = {}
- FollowsTag(a) = { }
- FollowsTag(r | s) = FollowsTag (r) U FollowsTag (s)
- FollowsTag(r*) = FollowsTag (r, r)
- FollowsTag(r ,s) = FollowsTag (r) U FollowsTag (s)

  U LastTag(r) x FirstTag(s)

... now back to Node Validation

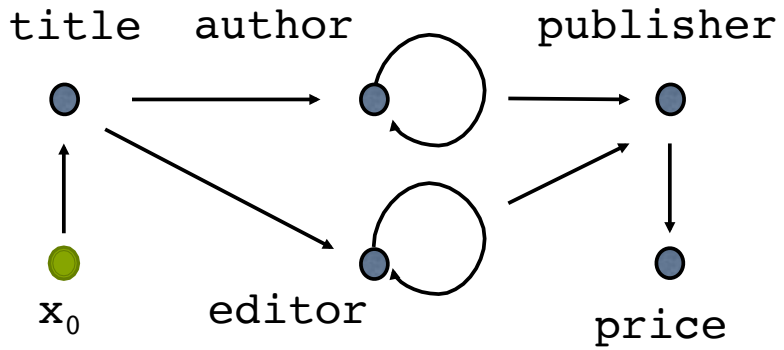
good news : this comes for free now!

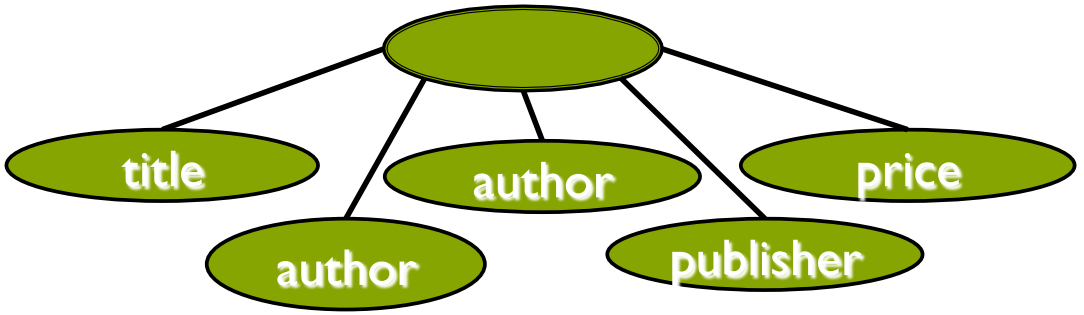
- check if the sequence defines a path

  in the graph which ends on a LastTag($r^{\#}$)

Sequence Validation

r = (title, (author+ | editor+), publisher, price)

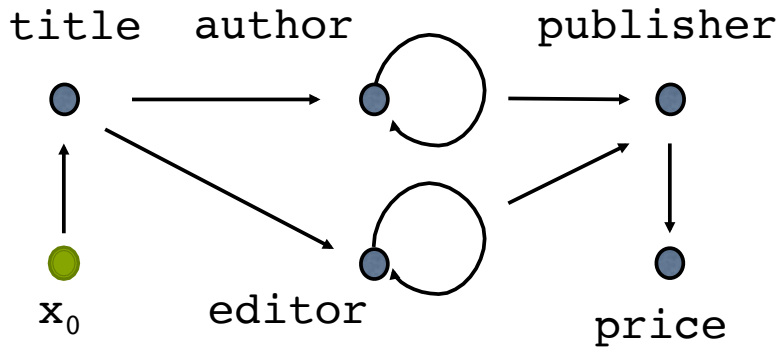


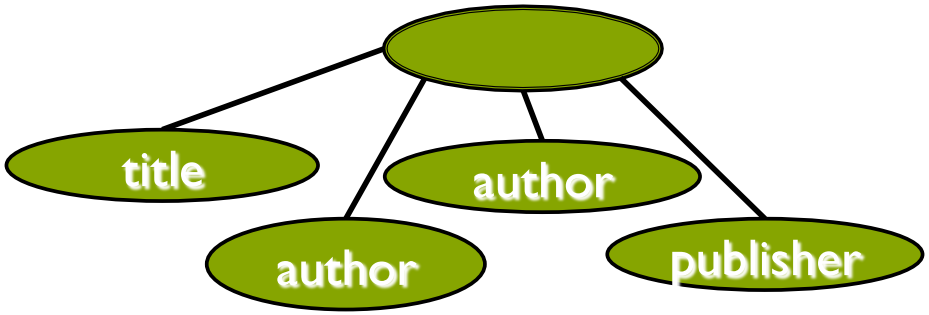


OK

Sequence Validation

r = `(title, (author+ | editor+ ), publisher, price )`

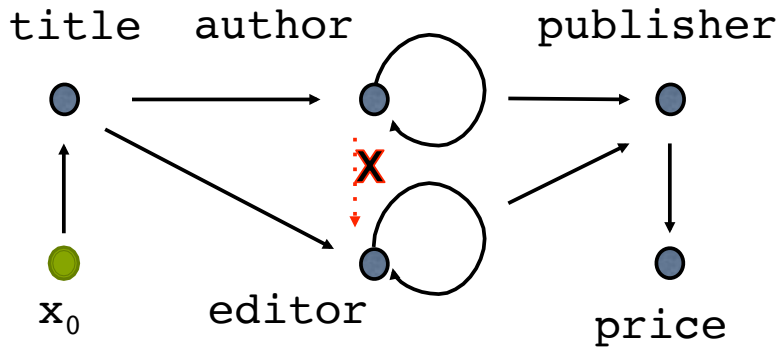


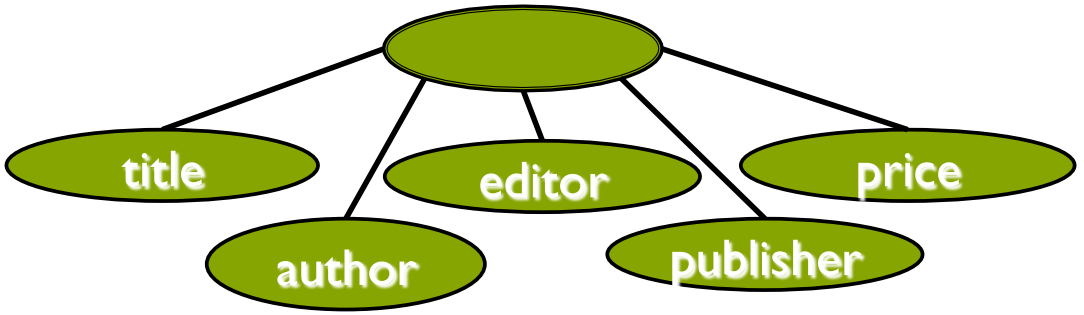


NO

Sequence Validation

r = `(title, (author+ | editor+ ), publisher, price )`



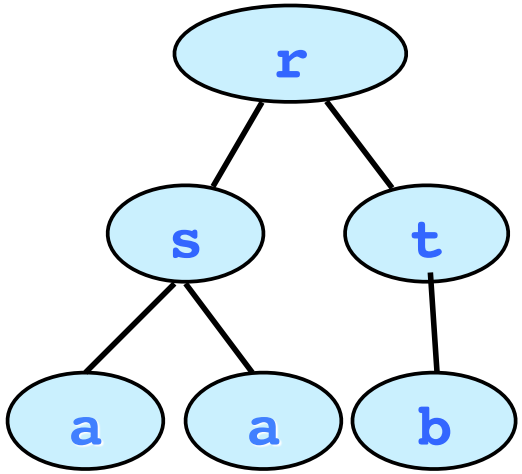


NO

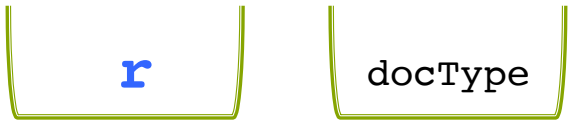
Document Validation Algorithm

- set **last** := root ; stackDTD.push(docType)
- for every node **n (!= root)** taken in a pre-order visit of the tree
- if **last** is the parent of **n** //moving down parent -> child
  - create new list **L** ; add n to **L**
  - stackXML.push(**L**) ; stackDTD.push(typeDTD(**last**))
- if n is the last of its siblings` //next move up child -> parent
  - stackXML.top.add(**n**)
  - stackXML.top.isValid(stackDTD.top())
  - stackXML.pop() ; stackDTD.pop() //empty buffers
- else //move left child -> sibling
  - stackXML.top.add(**n**)

Validation Example




```
<!DOCTYPE r [
<!ELEMENT r (s,t)>
<!ELEMENT s (a*)>
<!ELEMENT t (b?)>
]>
```



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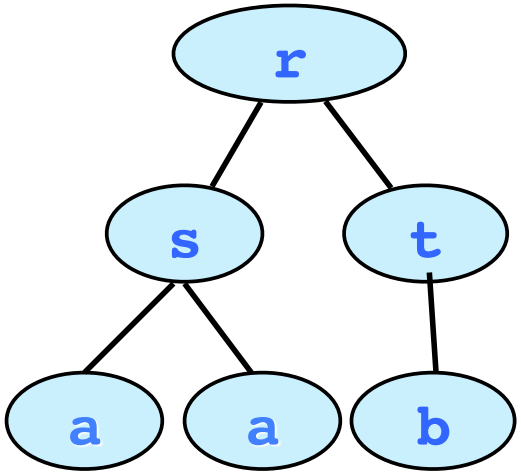

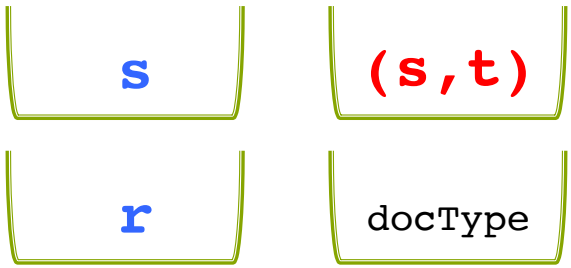


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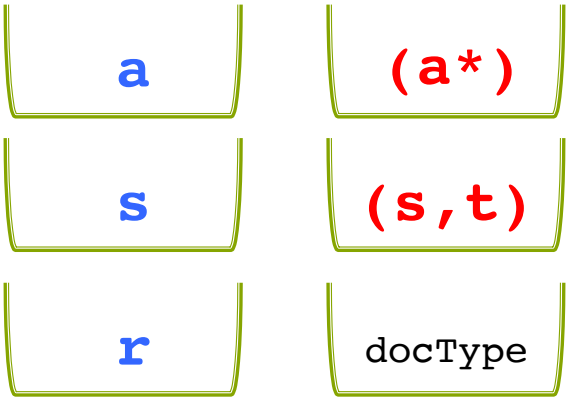

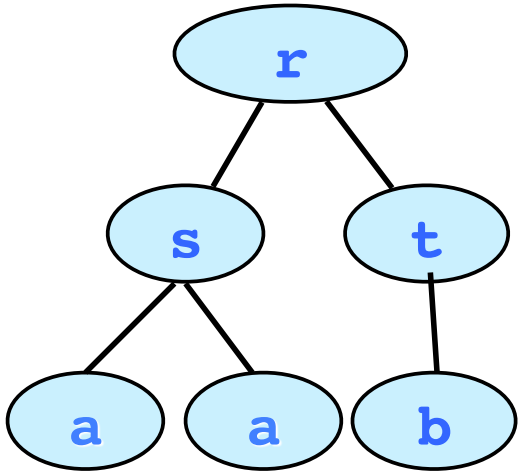


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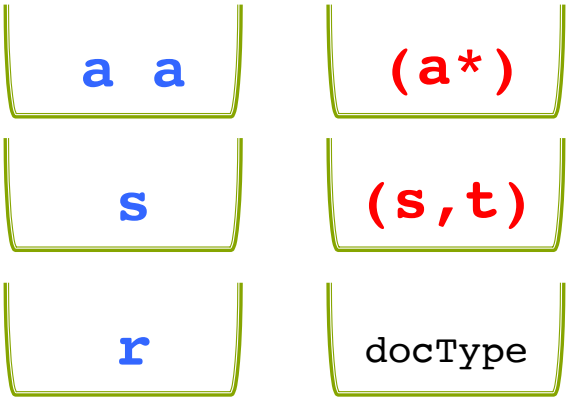

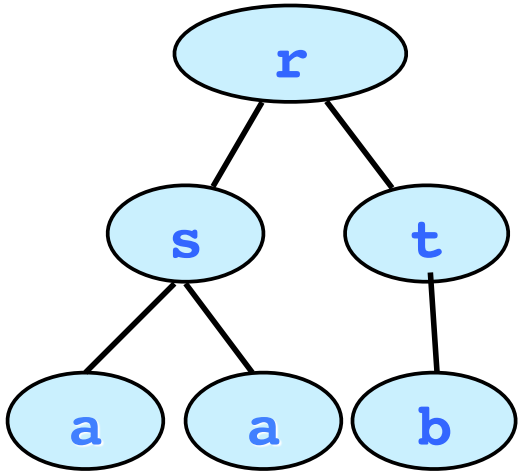


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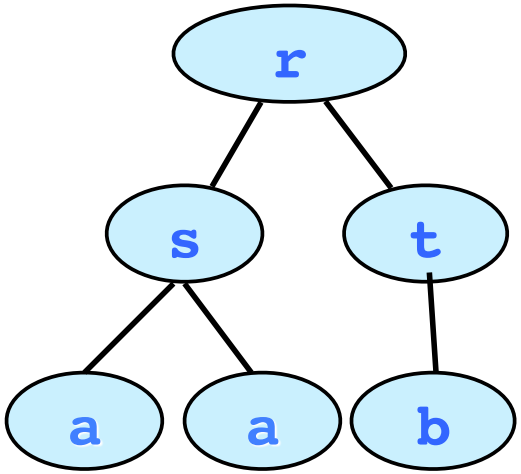
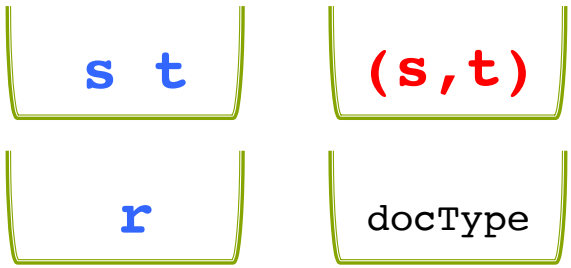
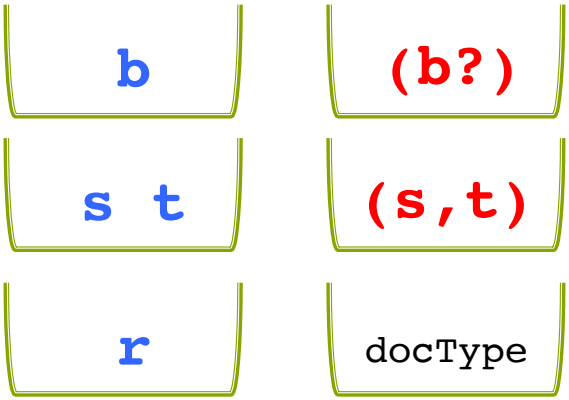
Validation Example

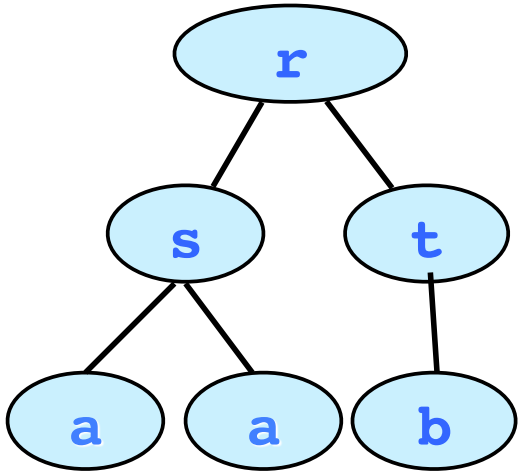





```
<!DOCTYPE r [
<!ELEMENT r (s,t)>
<!ELEMENT s (a*)>
<!ELEMENT t (b?)>
]>
```

Validation Example



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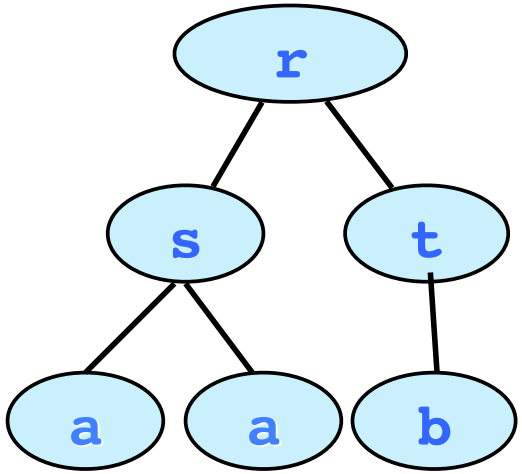


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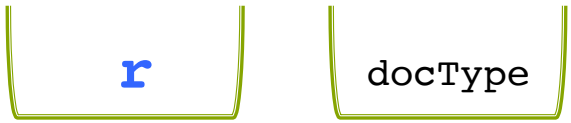

Research Highlights

Checking Determinism

- Quadratic algorithm [Brueggemann-Klein]
- (best) Linear algorithm [Groz, Staworko, Maneth '11]

Checking Validity

- (best) Sublinear space algorithm [Konrad, Magniez '11]