Applied Databases

Lecture 3
DTDs (regular expressions) & DOM

Sebastian Maneth

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Outline

1. DTD Regular Expression → Glushkov Automaton
2. DOM **D**ocument **O**bject **M**odel

1. Regular Expressions

```
<!DOCTYPE addressbook [
    <!ELEMENT addressbook (person*) >
    <!ELEMENT person (name,greet*,address*,(fax|tel)*,email*)>
    <!ELEMENT name (#PCDATA)>
    <!ELEMENT greet (#PCDATA)>
    <!ELEMENT address (#PCDATA)>
    <!ELEMENT fax (#PCDATA)>
    <!ELEMENT tel (#PCDATA)>
    <!ELEMENT email (#PCDATA)>
]>
```

1. Regular Expressions

- choice: (. . | . . | . .)
- sequence: (. . , . . , . .)
- optional: . . . ?
- zero or more: . . . *
- one or more: . . . +
- element names

Note

→ #PCDATA may **not** appear in these regular expressions!

→ use *mixed content* instead

Regular Expressions are a very useful concept

→ used in EBNF, for defining the syntax of PLs

→ used in various unix tools (e.g., `grep`)

→ supported in most PLs (esp. `Perl`), text editors

→ classical concept in CS (Stephen Kleene, 1950's)

How can you **implement** a regular expression?

Input: RegEx e, string w
Question: Does w *match* e?

→ use Finite Automata (FA)

Example
e = (ab | b)* a* a

w = a b b a a b a

match?

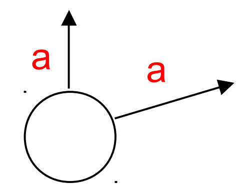
Finite-State Automata (FA)

→ *constant memory* computation

→ as Turing Machines, but *read-only* and *one-way* (left-to-right)

for every ReEx there is a FA (and vice versa)

Deterministic FA (DFA) = **no** two outgoing edges with same label



not
allowed

DFA Matching: time O(|DFA| + |w|)
“one finger needed”

FA Matching: time O(|FA| + m * |w|)
“at most $\underbrace{\text{\#states}}_{m}$ many fingers needed”

→ every FA can be effectively transformed into an equivalent DFA.

→ can take exponential time! ("*subset construction*")

How can you **implement** a regular expression?

```
FA = BuildFA(e);
FA.run;
→ or
DFA = BuildDFA(FA);
DFA.run
```

Input: RegEx e, string w
Question: Does w *match* e?

$m = |e|$
$n = |w|$

Running time O(m + mn)
or O(m + 2^m + n)

builds Glushkov automaton

Regular expressions e for which `BuildFA(e)`

is deterministic are called **deterministic regular expressions**.

→ max number of transitions (edges) for m states and k symbols?

To avoid these expensive running times

W3C requires that `BuildFA(e)` must be deterministic!

Is small! ☺
size is only O(m^2)

Running time O(km + n)

W3C DTD-definition

builds Glushkov automaton

Regular expressions e for which `BuildFA(e)`

is deterministic are called deterministic regular expressions.

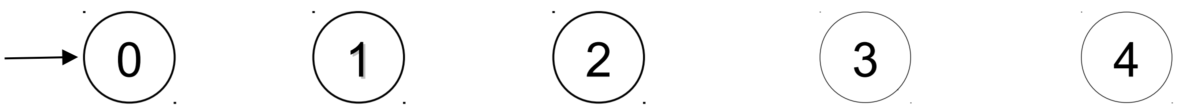
max number of transitions (edges) for m states and k symbols?

BuildFA(e) = "Glushkov Automaton" = "Position Automaton" [Glushkov1961]

BuildFA(e) = every letter in e becomes a *state*

(a | b)*aa*

0 1 2 3 4



plus extra *start-state* "0"

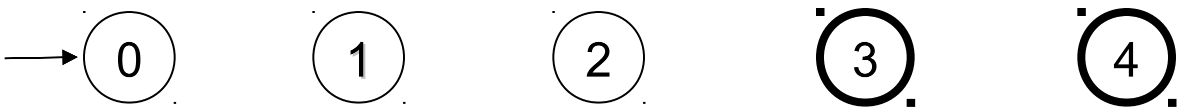
BuildFA(e) = "Glushkov Automaton" = "Position Automaton" [Glushkov1961]

→ identify **end-position(s)**

`BuildFA(e) = every letter in e becomes a state`

(a | b)*aa*

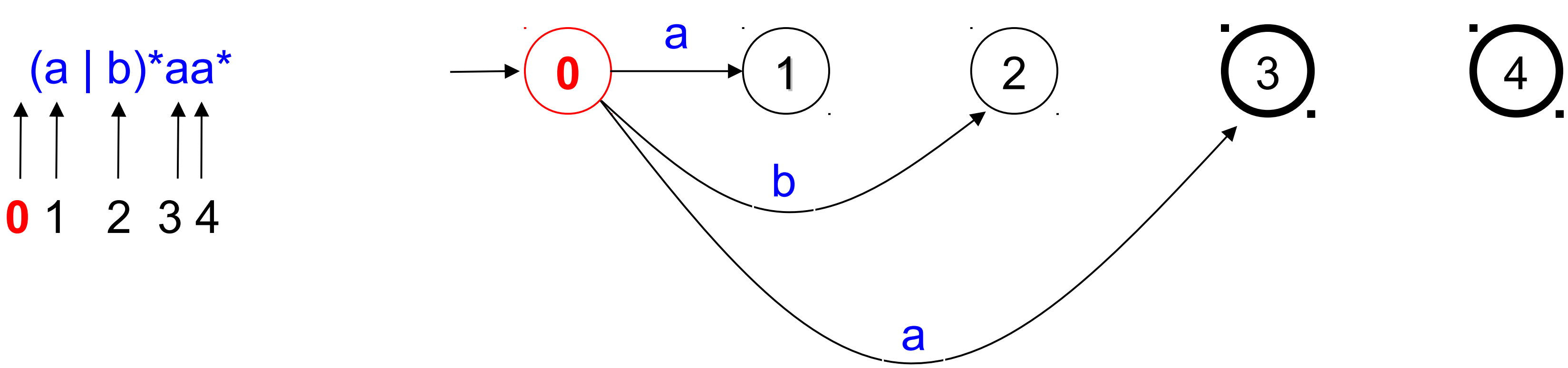
0 1 2 3 4



`BuildFA(e)` = "Glushkov Automaton" = "Position Automaton" [Glushkov1961]

→ which positions are reachable from "position 0"?

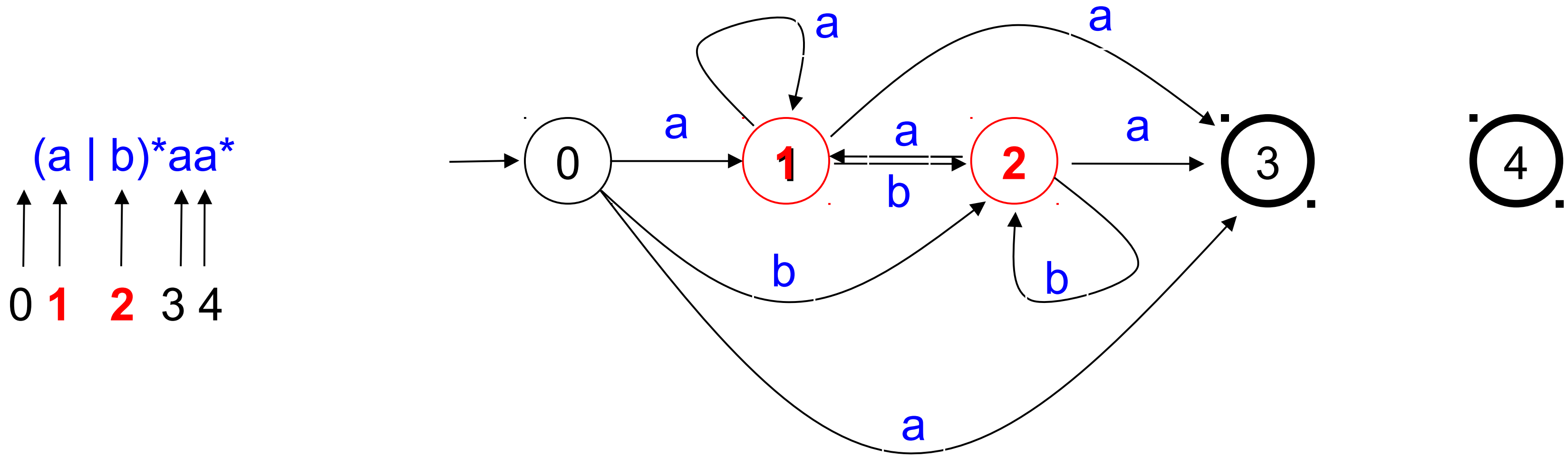
`BuildFA(e) = every letter in e becomes a state`



`BuildFA(e)` = "Glushkov Automaton" = "Position Automaton" [Glushkov1961]

→ which positions are reachable from positions 1 and 2?

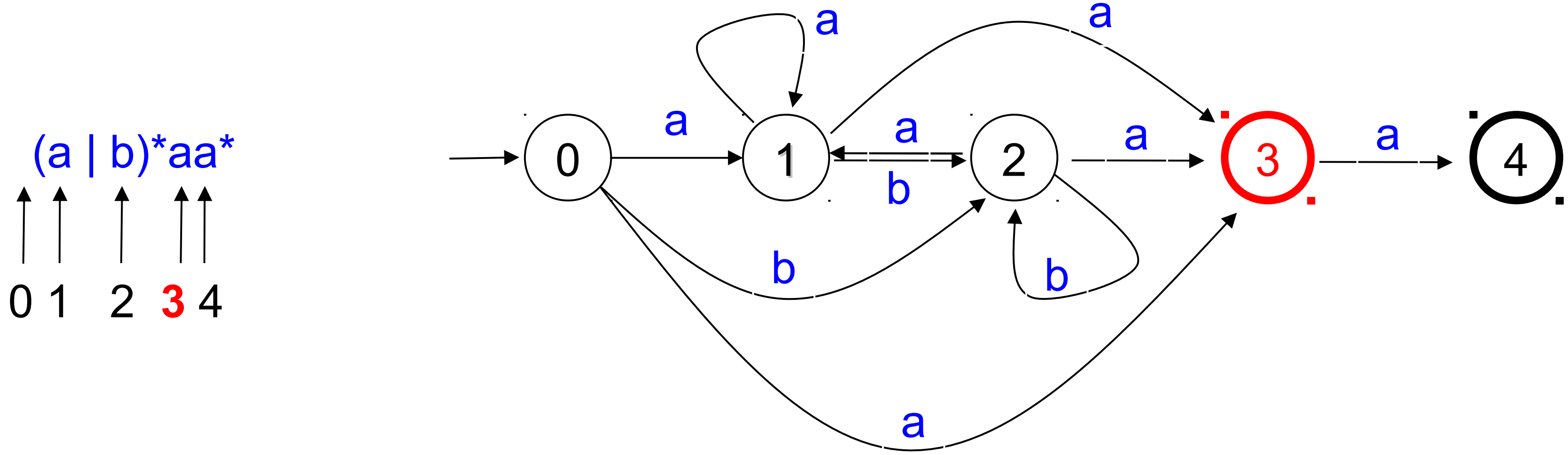
`BuildFA(e) = every letter in e becomes a state`



BuildFA(e) = “Glushkov Automaton” = “Position Automaton” [Glushkov1961]

→ which positions are reachable from position 3?

BuildFA(e) = every letter in e becomes a state



BuildFA(e) = “Glushkov Automaton” = “Position Automaton” [Glushkov1961]

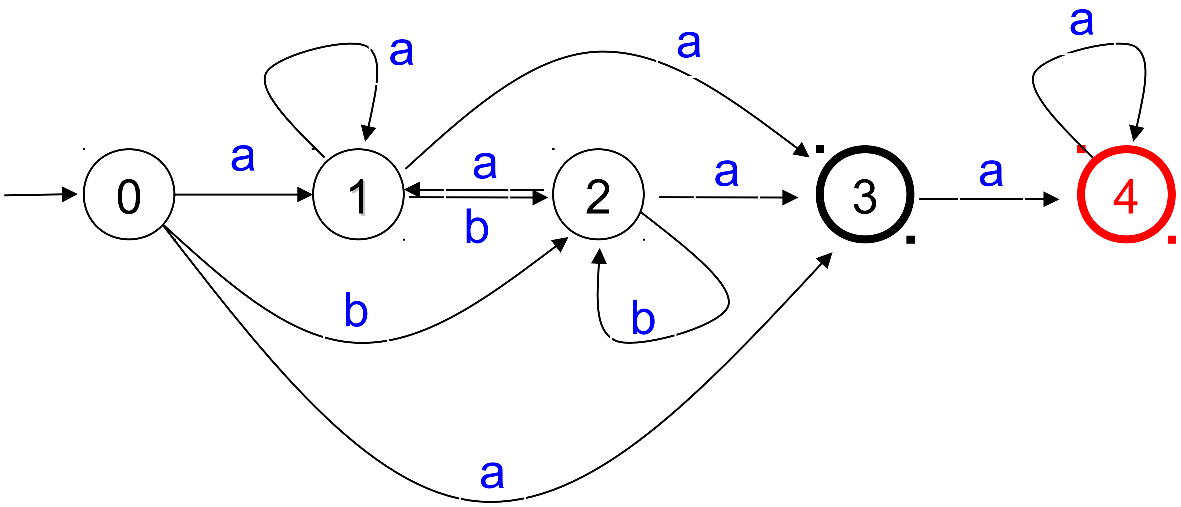
→ which positions are reachable from position 4?

→ Done!

BuildFA(e) = every letter in e becomes a state

(a | b)*aa*

0 1 2 3 4



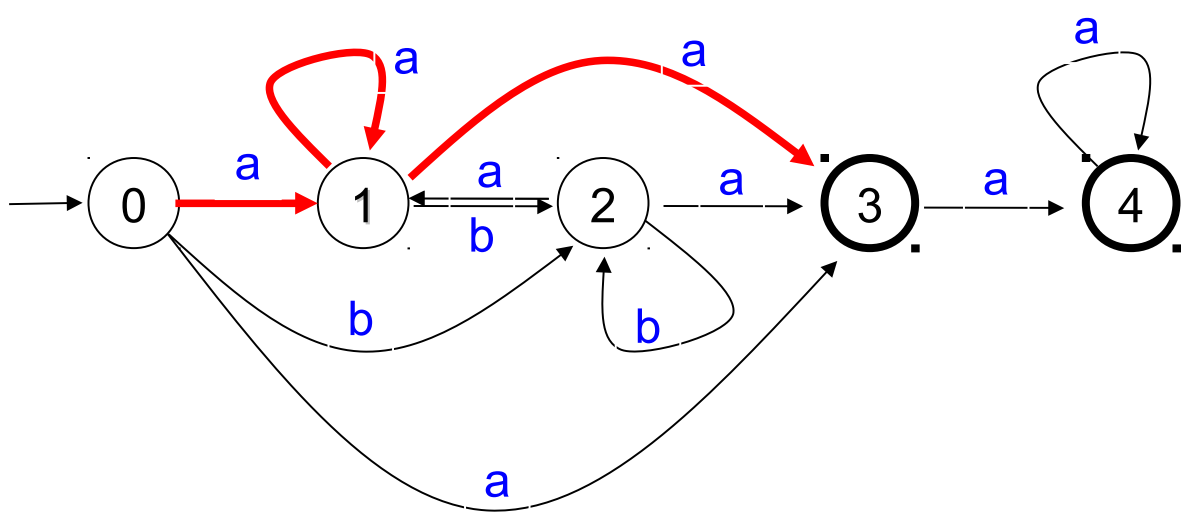
BuildFA(e) = “Glushkov Automaton” = “Position Automaton” [Glushkov1961]

→ a “**successful run**” for the input word “aaa”

BuildFA(e) = every letter in e becomes a state

(a | b)*aa*

0 1 2 3 4

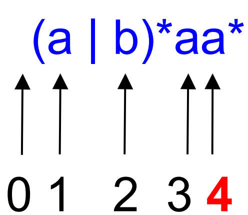


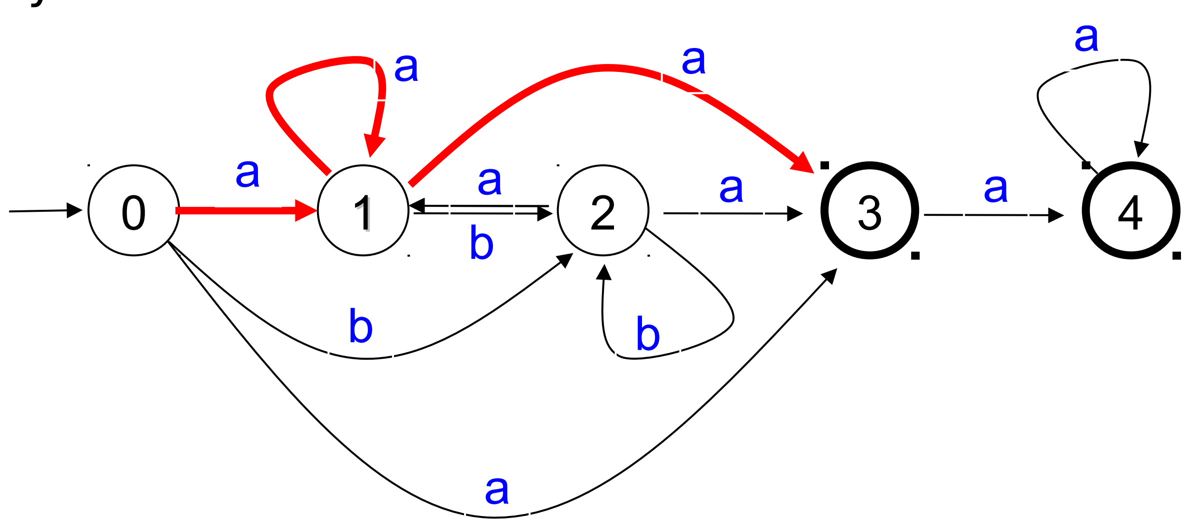
`BuildFA(e)` = "Glushkov Automaton" = "Position Automaton" [Glushkov1961]

→ a "**successful run**" for the input word "aaa"

→ how many other successful runs are there for "aaa"?

`BuildFA(e) = every letter in e becomes a state`





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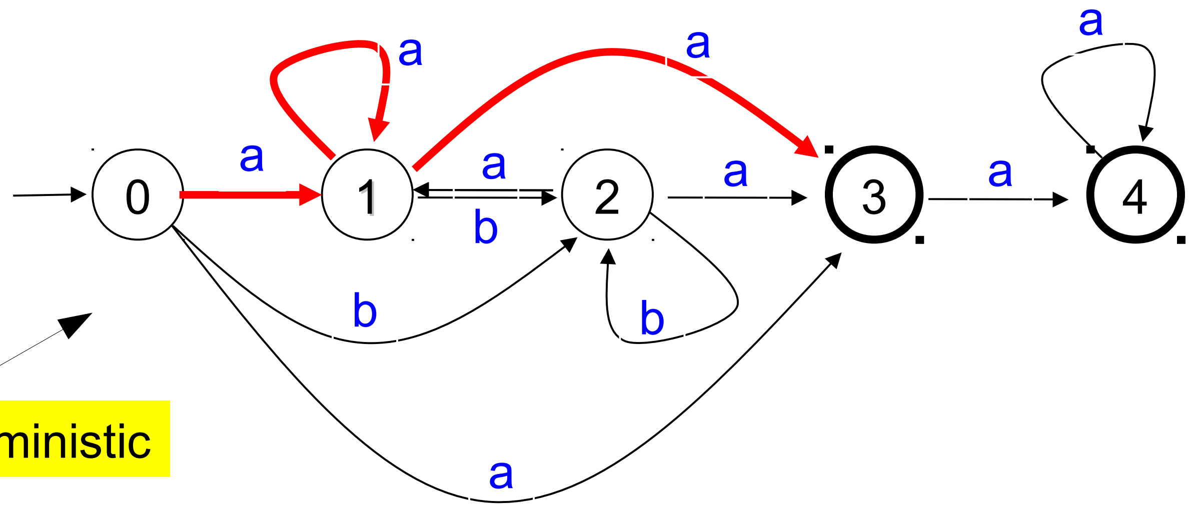
(a | b)*aa*

0 1 2 3 **4**



not deterministic

Document Type Definitions (DTDs)

- The XML specification restricts regular expressions in DTDs to be deterministic (***1-unambiguous***).

- Unambiguous regular expression: "*each word is witnessed by at most one sequence of positions of symbols in the expression that matches the word*" .[Brüggemann-Klein, Wood 1998]

  - ✓ Ambiguous expression $(a \mid b)^*aa^* \xrightarrow[\text{subscripts}]{\text{mark with}} (a_1 \mid b_1)^*a_2a_3^*$
  - ✓ For aaa $\longrightarrow$ three witnesses: $a_1a_1a_2$ $a_1a_2a_3$ $a_2a_3a_3$
  - ✓ Unambiguous equivalent expression : $(a \mid b)^*a$

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  ✓ For aaa $\longrightarrow$ three witnesses: $a_1a_1a_2$ $a_1a_2a_3$ $a_2a_3a_3$

  ✓ Unambiguous equivalent expression : $(a \mid b)^*a$ ***not*** 1-unambiguous!

→ 1-unambiguous: decide position by looking **only at current symbol**

consider baa: b_1a**?**

Questions for each expression, deterministic or not?

→ a?b?

→ a?b?a

→ a(aba)*b

→ (a?b?c?d?e?)*

Questions for each expression, deterministic or not?

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How many edges in the Glushkov automaton?
(a1?a2? …. ak?) for distinct a1,a2,...

Questions for each expression, deterministic or not?

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→ (a | b)*a is not deterministic.

Can you find an *equivalent expression* that **is** deterministic?

Questions for each expression, deterministic or not?

→ a?b?

→ a?b?a

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→ (a | b)*a(a | b) is not deterministic.

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Questions for each expression, deterministic or not?

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→ a?b?a

→ a(aba)*b

→ (a?b?c?d?e?)*

How many edges in the Glushkov automaton?
(a1?a2? …. ak?) for distinct a1,a2,...

Notes

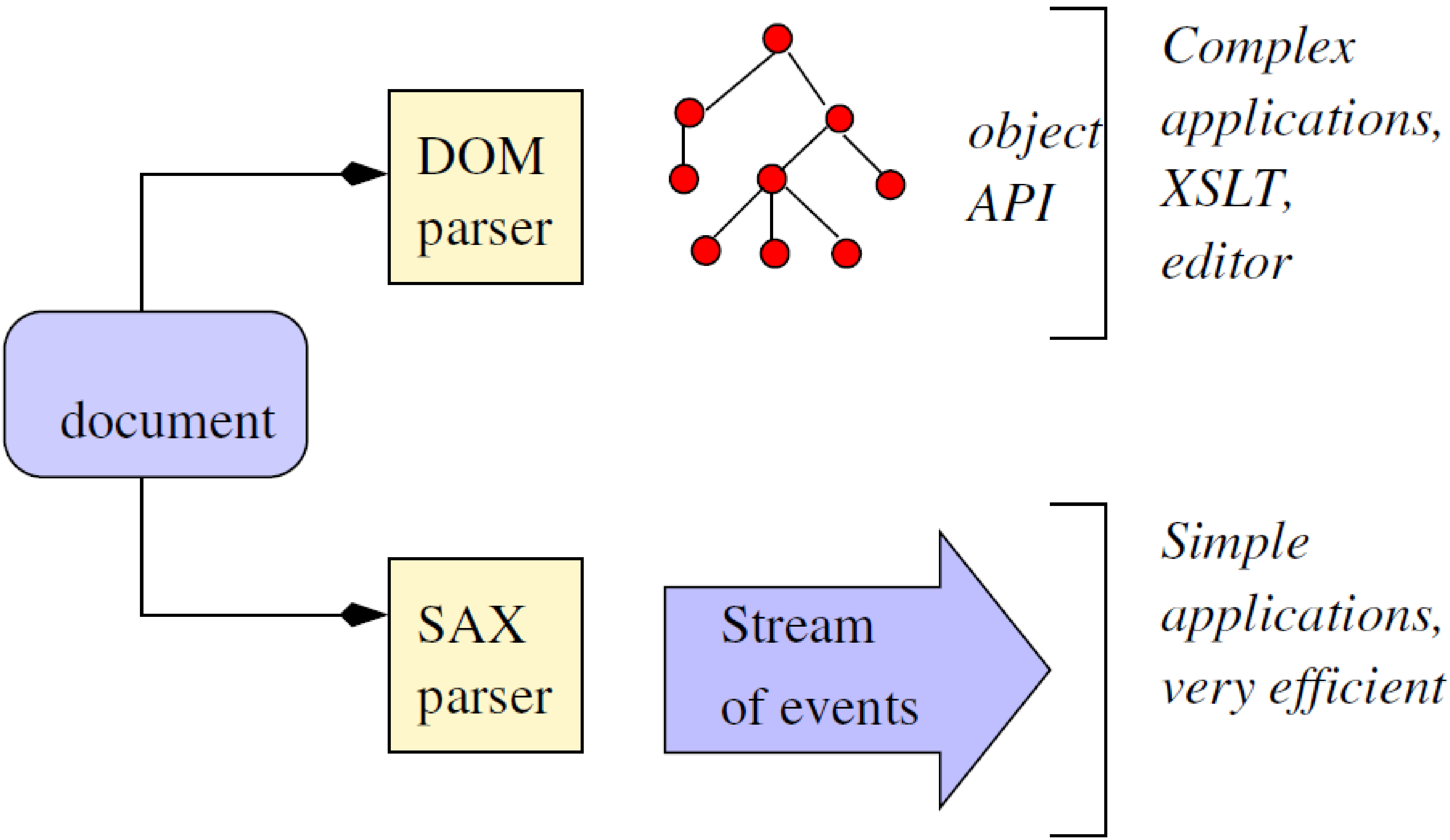
→ there exist regular expressions for which **no** equivalent deterministic expression exists

→ this can be decided, and an equivalent deterministic reg expr constructed if it exists [Brüggemann-Klein, Wood 1998]

XML Parsers

- → Document Object Model - DOM
- → Simple API for XML - SAX

XML Parsers


DOM
parser
object
API
Complex
applications,
XSLT,
editor
document
SAX
parser
Stream
of events
Simple
applications,
very efficient

XML Parsers

→ DOM - loads *full document* into memory

→ SAX - generates streaming events
- by default: *nothing* stored in memory

2. DOM – Document Object Model

→ Language and platform-independent view of XML

→ DOM APIs exist for many PLs (Java, C++, C, Python, JavaScript …)

DOM relies on two main concepts

(1) The XML processor constructs the
complete XML document tree (in-memory)

(2) The XML application issues DOM library calls to **explore** and **manipulate** the XML tree, or to **generate** new XML trees.

Advantages

- easy to use
- once in memory, no tricky issues with XML syntax anymore
- all DOM trees serialize to well-formed XML (even after arbitrary updates)!

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Advantages
- easy to use
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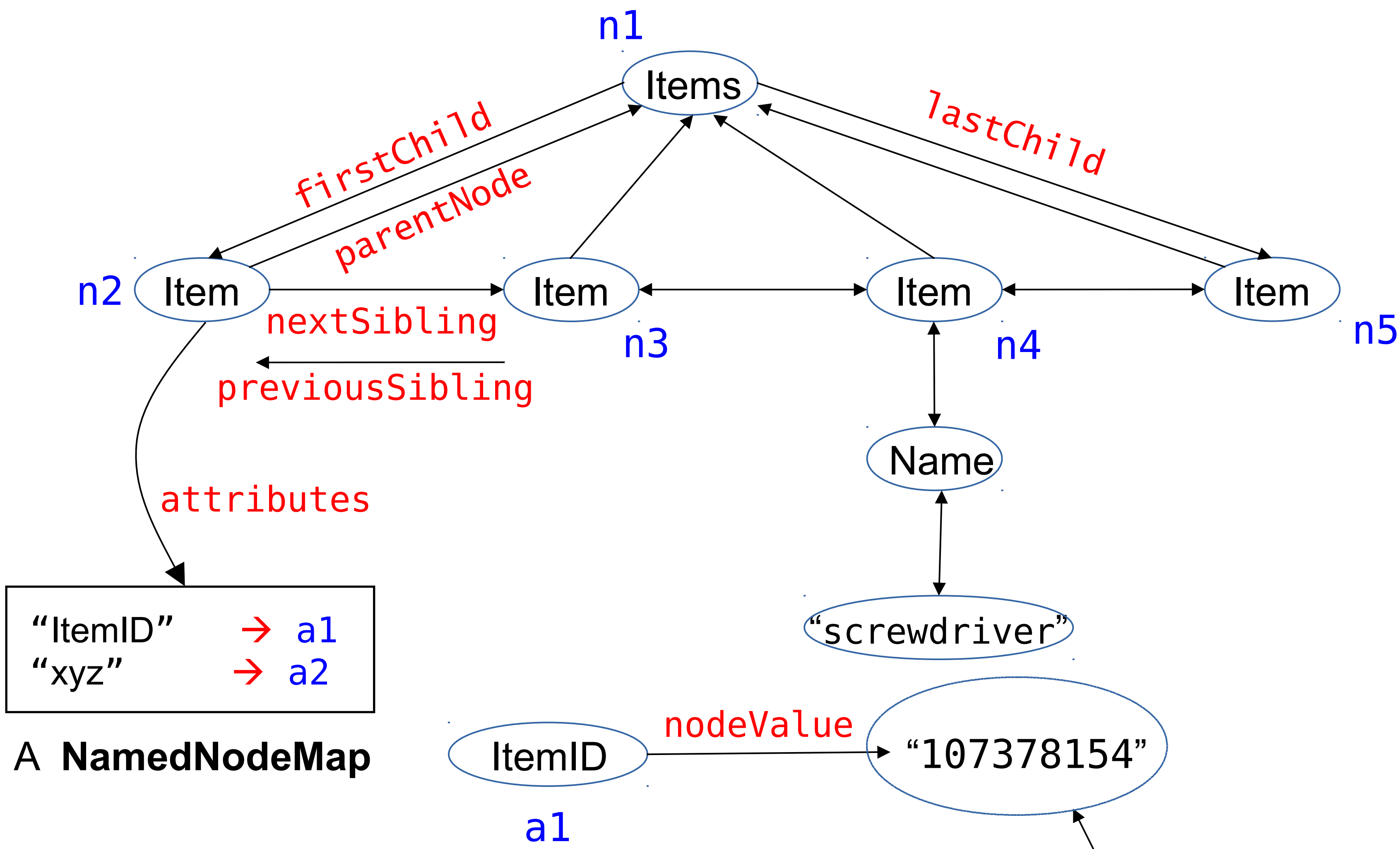
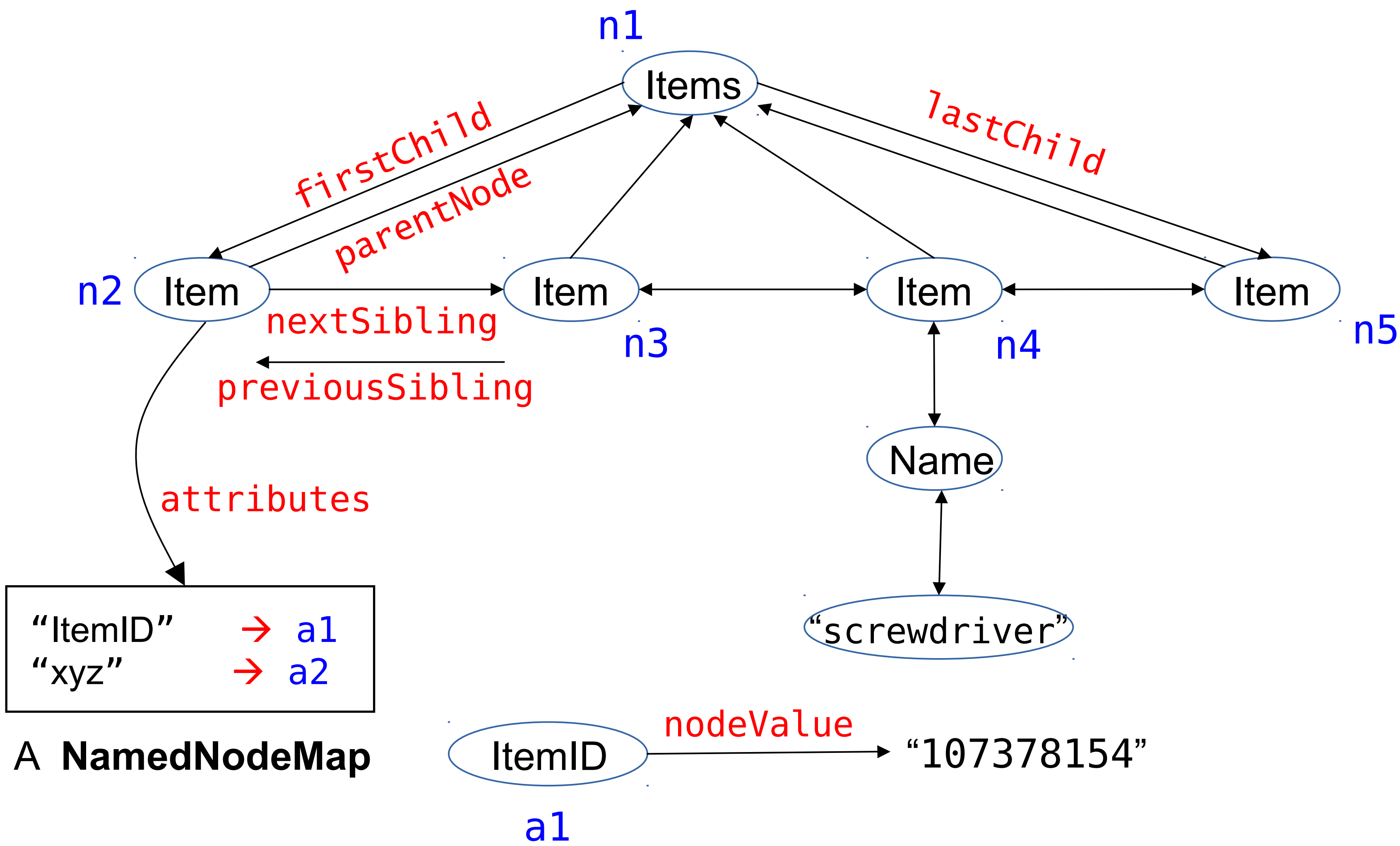
Disadvantage Uses LOTS of memory!!

2. DOM – Document Object Model



This is also a `text node t1`
which is the `firstChild` of `a1`

2. DOM – Document Object Model



→ how much memory is needed for a typical XML document of 1GB?

2. DOM – Document Object Model

Example

XML size		DOM process size	
81M	$\xrightarrow{x2}$	164M	Text only, with one embracing element
52M	$\xrightarrow{x13}$	680M	Treebank, deep tree structure, short tagnames

→ how much memory is needed for a typical XML document of 1GB?

DOM Level 1 (Core)

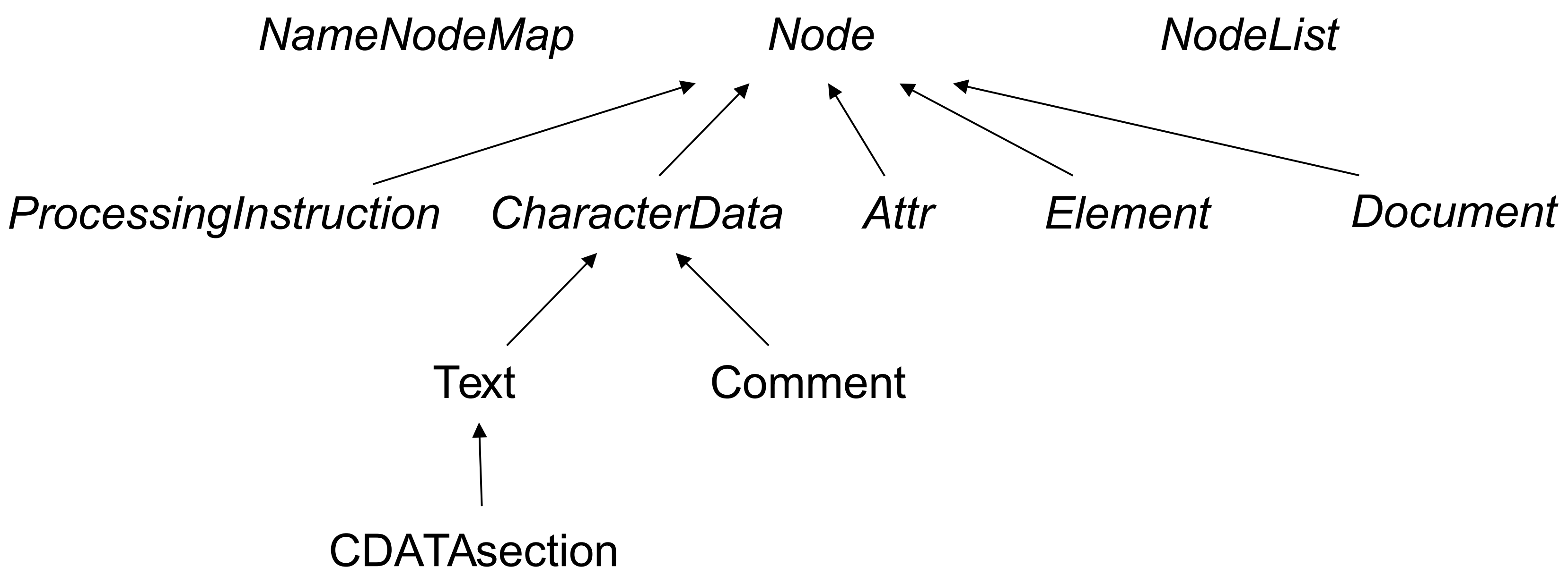
Some methods

```
DOM type       Method                            Comment

Node           nodeName     } : DOMString       redefined in subclasses
               nodeValue    }
               parentNode     : Node
               firstChild     : Node             leftmost child
               lastChild      : Node             rightmost child
               nextSibling    : Node             returns NULL for root elem
                                                 or last child or attributes
               previousSibling : Node
               childNodes     : NodeList
               attributes     : NamedNodeMap
               ownerDocument: Document
               replaceChild : Node


Document       createElement : Element           creates element with
                                                       given tag name
               createComment : Comment
               getElementsByTagName: NodeList    list of all Elem nodes
                                                          in document order
```

DOM Level 1 (Core)



Character strings (DOM type *DOMString*) are defined to be encoded using UTF-16 (e.g., Java DOM reresents type *DOMString* using its `String` type).

DOM Level 1 (Core)

Name,Value, and attributes depend on the **type** of the current node.

The values of `nodeName`, `nodeValue`, and `attributes` vary according to the node type as follows:

	nodeName	**nodeValue**	**attributes**
Element	tagName	null	NamedNodeMap
Attr	name of attribute	value of attribute	null
Text	#text	content of the text node	null
CDATASection	#cdata-section	content of the CDATA Section	null
EntityReference	name of entity referenced	null	null
Entity	entity name	null	null
ProcessingInstruction	target	entire content excluding the target	null
Comment	#comment	content of the comment	null
Document	#document	null	null
DocumentType	document type name	null	null
DocumentFragment	#document-fragment	null	null
Notation	notation name	null	null

DOM Level 1 (Core)

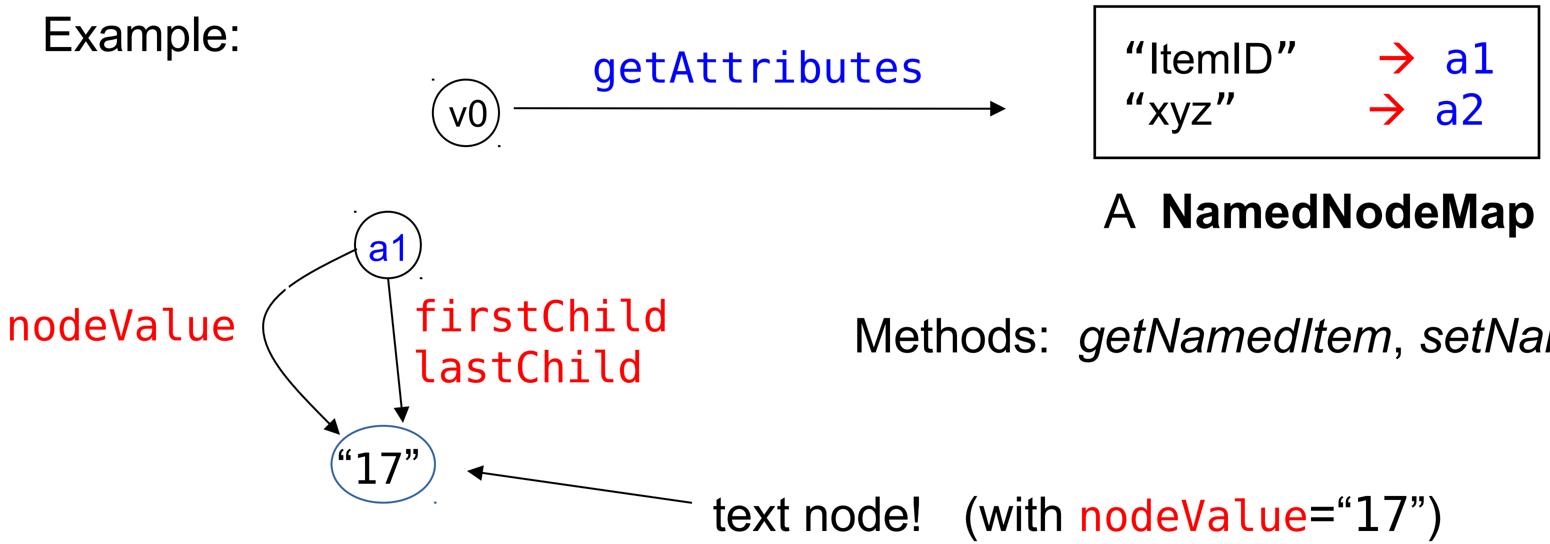
Some details

Creating an *element/attribute* using *createElement/createAttribute* does not wire the new node with the XML tree structure yet.
→Call *insertBefore, replaceChild*, …, to wire a node at an explicity position

DOM type *NodeList* makes up fo the lack of collection data types in many programming languages

DOM type *NamedNodeMap* represents an *association table* (nodes may be accessed by name)

Example:



Methods: *getNamedItem*, *setNamedItem*,…

```
public static void recursiveDescent(Node n, int level) {

    // adjust indentation according to level
    for(int i=0; i<4*level; i++) System.out.print(" ");

    // dump out node name, type, and value
    String ntype = typeName[n.getNodeType()];
    String nname = n.getNodeName();
    String nvalue = n.getNodeValue();
    System.out.println("Type = " + ntype + ", Name = " + nname + ",
                    Value = " + nvalue);

    // dump out attributes if any
    org.w3c.dom.NamedNodeMap nattrib = n.getAttributes();
    if(nattrib != null && nattrib.getLength() > 0)
        for(int i=0; i<nattrib.getLength(); i++)
            recursiveDescent(nattrib.item(i), level+1);

    // now walk through children list
    org.w3c.dom.NodeList nlist = n.getChildNodes();
    for(int i=0; i<nlist.getLength(); i++)
        recursiveDescent(nlist.item(i), level+1);
}
```

```
<?xml version="1.0"?>
<!DOCTYPE greeting [
  <!ENTITY hi "Hello">
  <!ENTITY hi1 "&hi;&hi;">
  <!ENTITY hi2 "&hi1;&hi1;">
  <!ENTITY hi3 "&hi2;&hi2;">
  <!ENTITY s "<d></d>">
]>
<a a1='17' a2='29'><b>xy &hi3; world &s; zz</b></a>
```

file.xml

element node!

```
$ java MyDOM file.xml
Successfully parsed - file.xml
Type = Document, Name = #document, Value = null
    Type = DocType, Name = greeting, Value = null
    Type = Element, Name = a, Value = null
        Type = Attr, Name = a1, Value = 17
            Type = Text, Name = #text, Value = 17
        Type = Attr, Name = a2, Value = 29
            Type = Text, Name = #text, Value = 29
        Type = Element, Name = b, Value = null
            Type = Text, Name = #text, Value = xy HelloHelloHelloH
elloHelloHelloHelloHello world
            Type = Element, Name = d, Value = null
            Type = Text, Name = #text, Value =  zz
```

END
Lecture 3