jInfer Architecture

Michal Klempa, Mário Mikula, Robert Smetana, Michal Švirec, Matej Vitásek
Advisors: RNDr. Irena Mlýnková, Ph.D., Martin Nečaský, Ph.D.

Praha, 2011

Target audience: developers willing to extend jInfer.

Note: we use the term ***inference*** *for the act of creation of schema throughout this and other jInfer documents.*

The description of jInfer architecture will commence by describing the data structures, namely representations of regular expressions and XML elements, attributes and simple data.

Afterwards the interfaces of basic inference modules - Initial Grammar Gen- erator, Simplifier and Schema Generator - will be explained.

Finally, the process of inference will be described.

1 Package naming conventions

All packages start with `cz.cuni.mff.ksi.jinfer`. Afterwards is the short, normalized name of the module (e.g. `base`) and finally the package structure in this module (e.g. `objects.utils`). All in all, a package in the Base module could look like `cz.cuni.mff.ksi.jinfer.base.objects.utils`

2 Data structures

2.1 Regular expressions

For general information on regular expressions, please refer to [wik], [HMU01]. All classes pertaining to regular expressions can be found in the package `cz.cuni.mff.ksi.jinfer.base.regexp`. In jInfer, we use extended regular expressions as they give us nicer syntax (and easier programming).

Regular expression is implemented as class `Regexp` with supplementing classes `RegexpInterval` and `RegexpType`. Each `Regexp` instance has one of the enum `RegexpType` type:

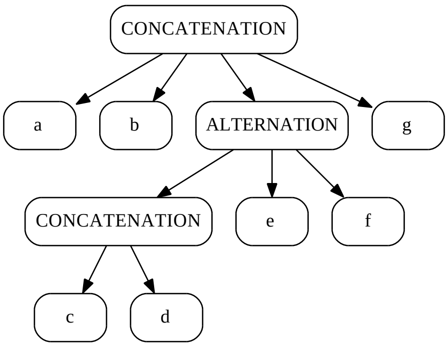
- Lambda - empty string (also called ϵ in literature),
- Token - a letter of the alphabet,
- Concatenation - one or more regular expression in an ordered sequence. Eg. (a, b, c, d),
- Alternation - a choice between one or more regular expressions. Eg. $(a|b|c|d)$,
- Permutation - shortcut for all possible permutations of regular expressions. Our syntax to write down permutation is $(a\&b\&c\&d)$.

Type of regexp is held in `type` member in class `Regexp` and can be tested by calling methods `isLambda()`, `isToken()` etc.

Each `Regexp` instance has one instance of `RegexpInterval` as member. Class `RegexpInterval` represents POSIX-like intervals for expression:

- $a\{m, n\}$ means a at least m-times, at most n-times,
- $a\{m, \}$ means at least m-times (unbounded).

Figure 1: Example tree for regular expression $(a, b, ((c|d), e), f)$



Interval is either bounded (you have to set both lower and upper bound integers), or unbounded (you have to set only lower bound). Testing interval commonly follows routine:

```
RegexpInterval i = r.getInterval();
if (i.isUnbounded()) {
  print(i.getMin());
} else {
  print(i.getMin(), i.getMax());
}
```

That is, first check interval for being unbounded, only if it is bounded, you can ask for maximum.

Class `Regexp` can represent regular expression over any alphabet. This is done by using java generics, `Regexp` evinceis implemented as `Regexp<T>`. Only token regexps hold instance of type `T` in member `content`.

Regular expression is in fact n-ary tree, for example expression $(a, b, ((c|d), e), f)$ can be viewed as in fig. 1. We implement this tree by member of `Regexp` class called `children`, which is of type `List<Regexp<T>>`. List contains children of regexp in means of regexp tree.

Regexp has to obey constraits:

- type, children and interval have to be non-null references,
- when type is lamba, content and interval has to be null,
- when type is token, content has to be non-null,
- when type concatenation, alternation or permutation, content has to be null.

These constraits are checked by constructors, so the best way to construct new regexps is by using methods `getToken()`, `getConcatenation()` etc.

Regexp instance is by default created as immutable, that is, once instantiated, you cannot add more children to list of children, cannot change type, content etc. It is to prevent missuse. In special circumstances, one does not know future children of regexp in time of creation. This occurs mainly in input modules, where by parsing XML data sequentially, one does not know contents of element in time of handling start element event. For these cases, special `getMutable()` method is implemented to obtain regexp with none of members set. One has to fill in all properties carefully and call `setImmutable()` aftewards. Proper usage should be one of following:

```
Regexp<T> r = Regexp.<T>getMutable();
r.setInterval(...);
r.setType(RegexpType.LAMBDA);
r.setImmutable();

Regexp<T> r = Regexp.<T>getMutable();
r.setInterval(...);
r.setType(RegexpType.TOKEN);
r.setContent(...)
r.setImmutable();
```

Figure 2: How should interfaces and classes for XML representation look like in theory

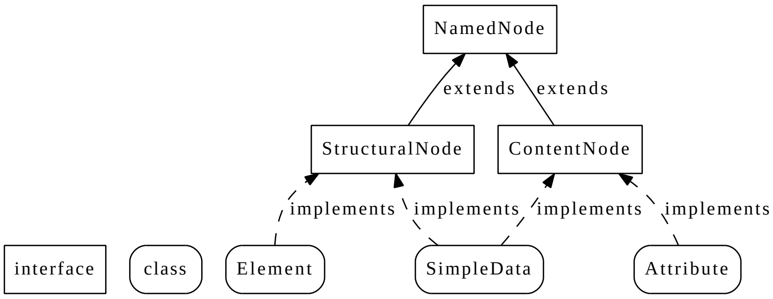
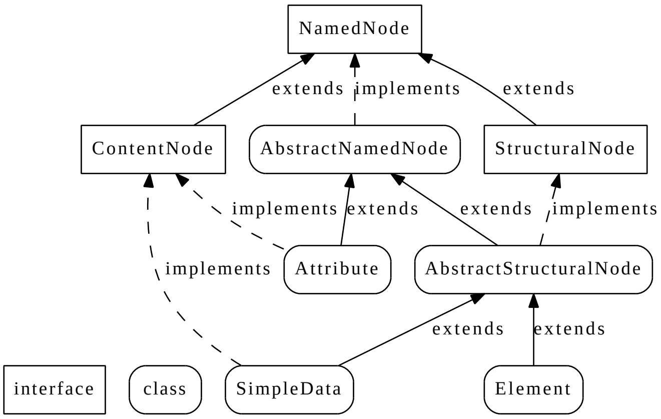


Figure 3: How are interfaces and classes for XML representation arranged in practice



```
Regexp<T> r = Regexp.<T>getMutable();
r.setInterval(...);
r.setType(RegexpType.CONCATENATION);
r.addChild(...);
r.addChild(...);
r.addChild(...);
r.setImmutable();
```

Finally, regexp contain one useful method for obtaining all leaves in the regexp tree, it is called `getTokens()` and it recursively traverses tree returning list of leaves (token type regexps).

2.2 XML representation

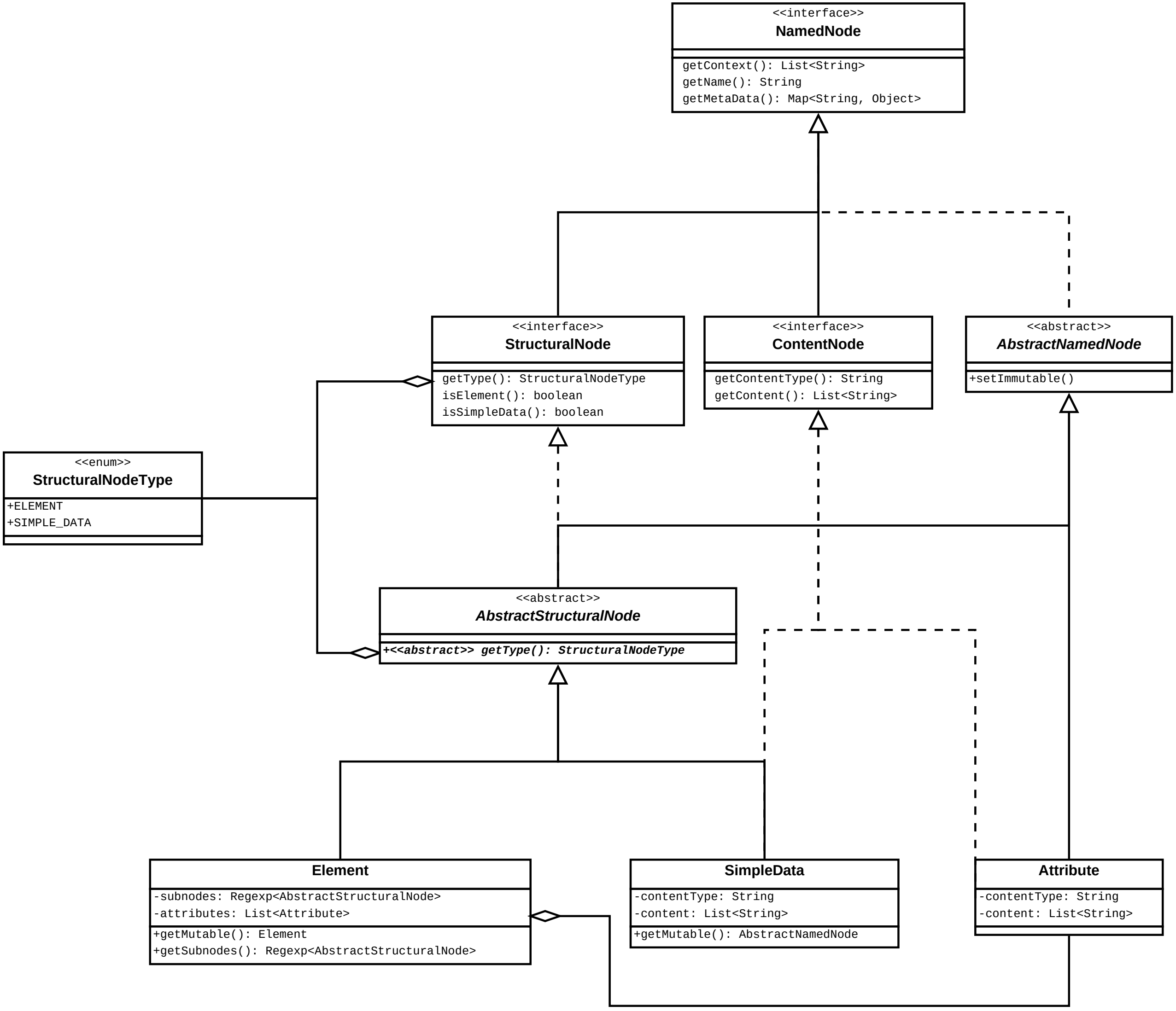
XML data basically contains elements, text nodes (characters inside elements) and attributes. For maximum generality, we decided to break apart theese objects. We define three basic interfaces: `NamedNode`, `StructuralNode` and `ContentNode` (see package `cz.cuni.mff.ksi.jinfer.base.interfaces.nodes`).

The first stands for bare node in XML document tree, it has its name and context withing the tree (path from root). The latter two extends `NamedNode` interface. `StructuralNode` is for nodes, which form structure of XML document tree: elements and text nodes. `ContentNode` is for nodes, that have content in XML documents: text nodes and attributes. We have three classes: `Element` for elements, `SimpleData` for text nodes, `Attribute` for attributes (see package `cz.cuni.mff.ksi.jinfer.base.objects.nodes`). In theory, the classes and interfaces would be layed out as on fig. 2

For even more generality in design, we decided to implement abstract classes in midlevel:

- `AbstractNamedNode`, which implements methods from `NamedNode` interface to handle context, name and metadata (will discuss later),
- `AbstractStructuralNode`, which implements only task of deciding if instance is `Element` or `SimpleData` actually.

Figure 4: XML representing interfaces and classes in detail



As practice showed, for methods handling and infering structural properties, it is important to recognize whether structural node on input is element or text node. However methods for content devising don't need to know, if they are working on infering model for content of attribute or text node.

Finally, our interface/class model for representing XML nodes is drafted on fig. 3. Those, who are brave enough, can look on fig. 4.

In result, `Element` and `SimpleData` have method `getType()` to devise type of `AbstractStructuralNode` variables. And `SimpleData` and `Attribute` have methods `getContentType()` and `getContent()` to work with content model.

Class `Element` has two important members of course:

- `Regexp<AbstractStructuralNode> subnodes` - for representing right side of grammar rule in resulting infered schema,
- `List<Attribute> attributes` - for representing all attributes in resulting infered schema.

Theese two are filled by import modules, processed further by infering (simplifying) modules and finally exported by exporter modules. We will look at proper interfaces later.

As in regular expressions, classes pertaining XML nodes are by default immutable. For elements, it means no adding of attributes and changing regexp reference (regexp instance itself is immutable). Same `getMutable()` principles and good usage practises hold for theese classes.

2.3 Something that will vektor declare priority

2.4 (Nondeterministic) Finite Automaton

References

[Aho96] H. Ahonen. *Generating grammars for structured documents using grammatical inference methods.* PhD thesis, Department of Computer Science, University of Helsinki, Series of Publications A, Report A-1996-4, 1996.

[HMU01] John E. Hopcroft, Rajeev Motwani, and Jeffrey D. Ullman. *Introduction to Automata Theory, Languages, and Computation (2nd Edition).* Addison-Wesley, 2001.

[HW07] Yo-Sub Han and Derick Wood. Obtaining shorter regular expressions from finite-state automata. *Theor. Comput. Sci.*, 370(1-3):110–120, 2007.

[VMP08] Ondřej Vošta, Irena Mlýnková, and Jaroslav Pokorný. Even an ant can create an xsd. In *DASFAA'08: Proceedings of the 13th international conference on Database systems for advanced applications*, pages 35–50, Berlin, Heidelberg, 2008. Springer-Verlag.

[wik] Regular expression. `http://en.wikipedia.org/wiki/Regular_expression`.