Data Structures in Coco/R

Hanspeter Mössenböck
Johannes Kepler University Linz
Institute of System Software
June 2004

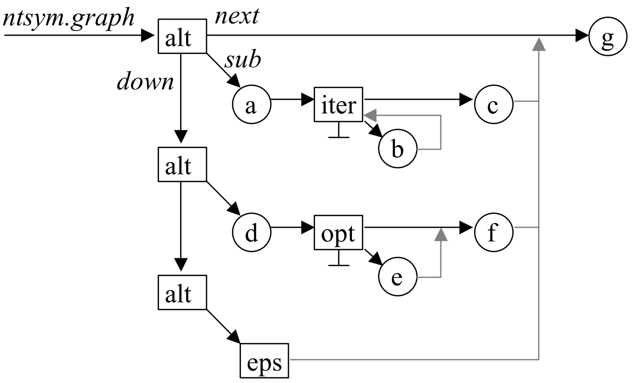
This technical note describes the data structures in the C# and Java implementations of the compiler generator Coco/R. The major data structures are:

- **The Symbol table** (Classes: `Symbol`). All terminals, pragmas and nonterminals in linear sequence. This data structure is trivial and therefore not further described.
- **The Syntax graph** (Classes: `Node`, `Graph`). The productions of the grammar as separate subgraphs. For every nonterminal sym there is a pointer sym.graph to the root of this symbol's syntax graph. A snapshot of this data structure is described in Section 1.
- **The Scanner automaton** (Classes: `State`, `Action`, `Target`, `Melted`). The DFA generated from token declarations. The token declarations are first translated to a syntax graph which is then transformed into a deterministic finite automaton. These steps are shown in Section 2.
- **The Character classes** (Class: `CharClass`). The character sets declared in the grammar stored as a linear list. This data structure is trivial and therefore not further explained.
- **The literals table** (Class: `Tab`). A mapping between token names and their literal representation.

1. Syntax Graph

Production: `A = (a {b} c | d [e] f | ) g.`

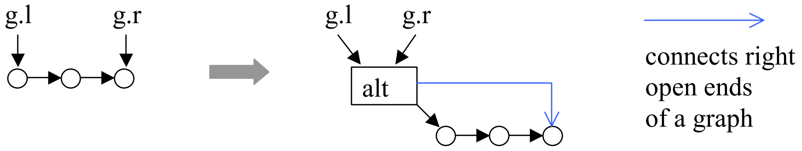
Graph:



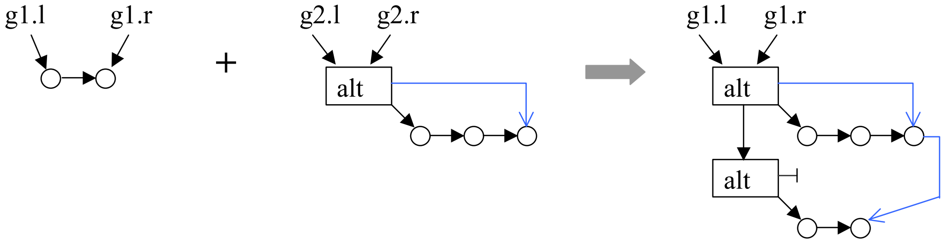
Gray lines denote `next` pointers that point upwards. For any node `n`, if `n.next` points upwards, then `n.up` is true.

Operations to build the syntax graph

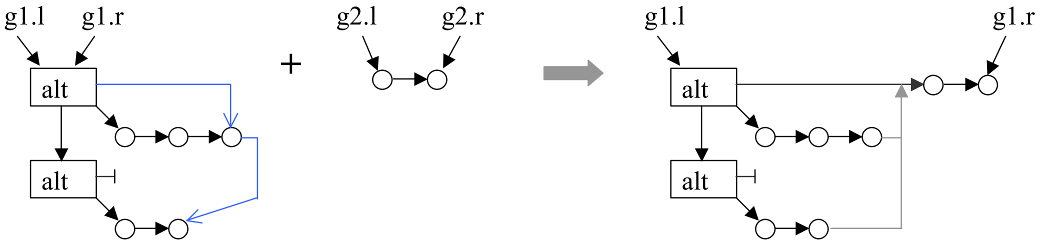
Graph.MakeFirstAlt(g)



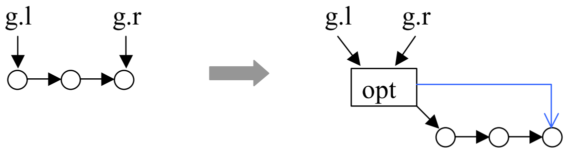
Graph.MakeAlternative(g1, g2)



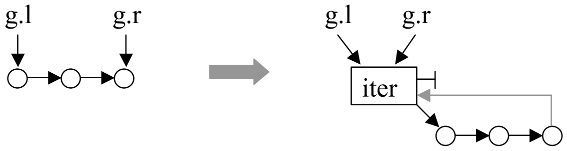
Graph.MakeSequence(g1, g2)



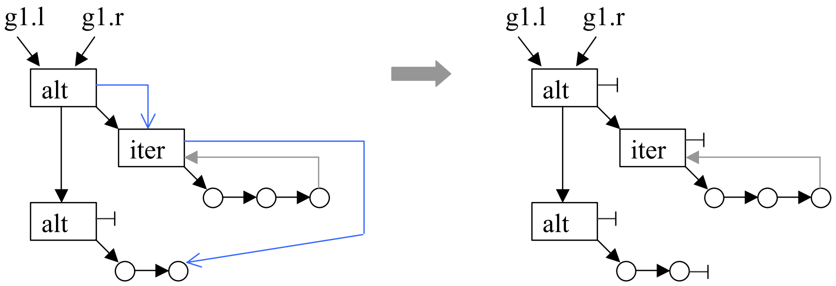
Graph.MakeOption(g)



Graph.MakeIteration(g)



Graph.Finish(g)

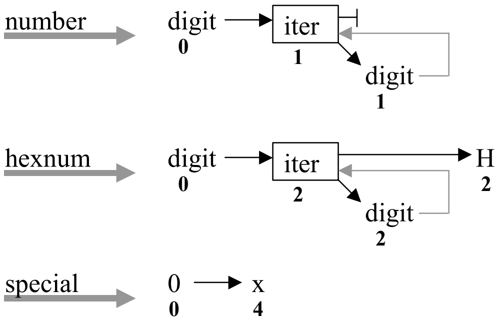


2. Scanner automaton

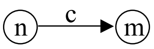
Declarations

```
CHARACTERS
   digit= '0'..'9'.
   hex   = digit + 'a'..'f'.
TOKENS
   number  = digit {digit}.
   hexnum  = digit {digit} 'H'.
   special = "0x".
```

Syntax graph for the tokens

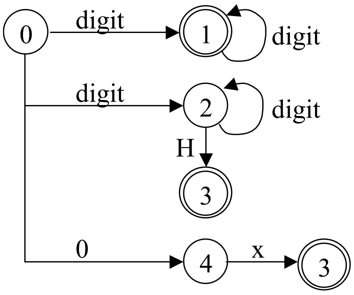


The bold numbers denote the states that were assigned to the nodes by the method `DFA.NumberNodes`. They are used to derive the automaton from the graph as follows: if a node for a character or a character class `c` has the number `n` and its `next` pointer points to a node with a number `m`, then this leads to a transition



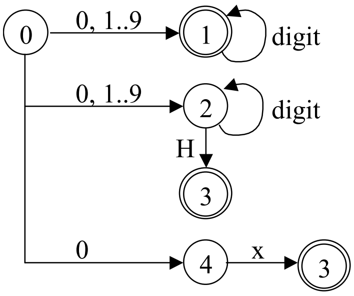
If there is no `next` node, the transition leads to a new state.

Nondeterministic automaton



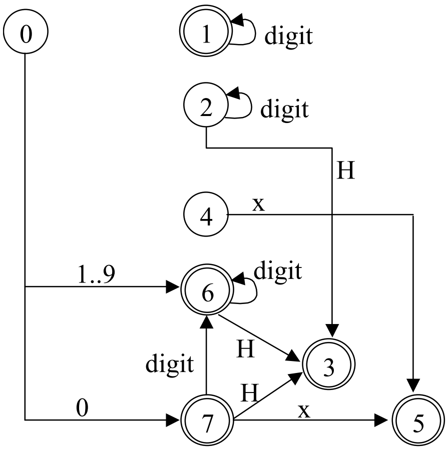
The automaton is nondeterministic since there are three transitions with `'0'` in state 0 and two with `digit` in state 0. The first step in making the automaton deterministic is to split overlapping character ranges. This is done by `DFA.MakeUnique`.

After MakeUnique



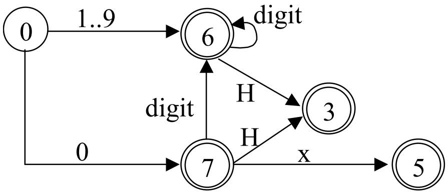
The next step is to melt those states that can be reached by a transition with the same symbol from the same state. This is done in `DFA.MeltStates`.

After MeltStates



The only remaining task now is to delete the redundant states (here 1, 2 and 4).

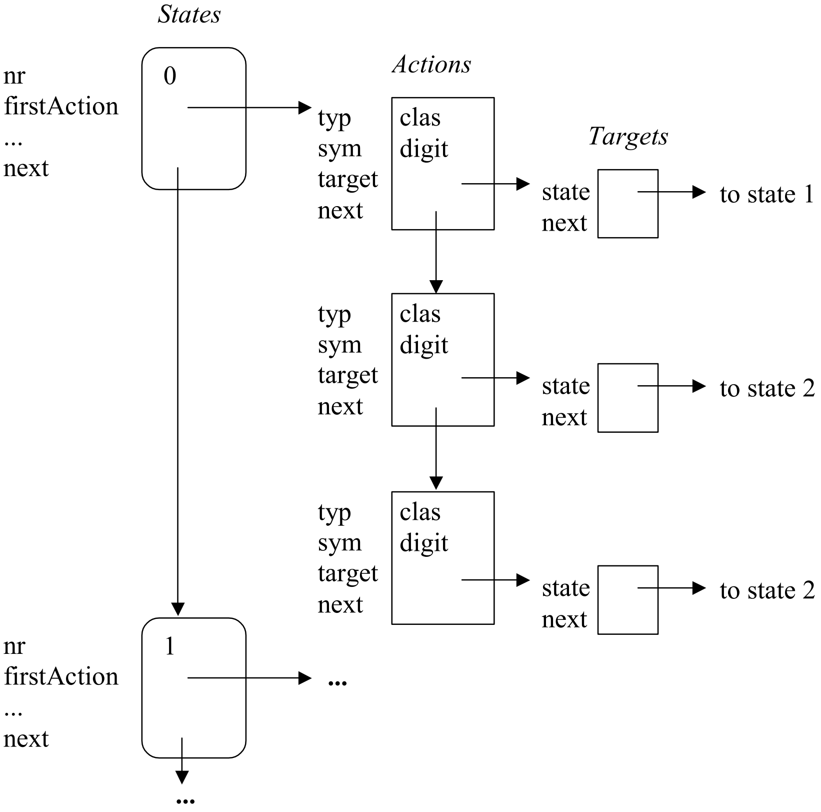
After DeleteRedundantStates



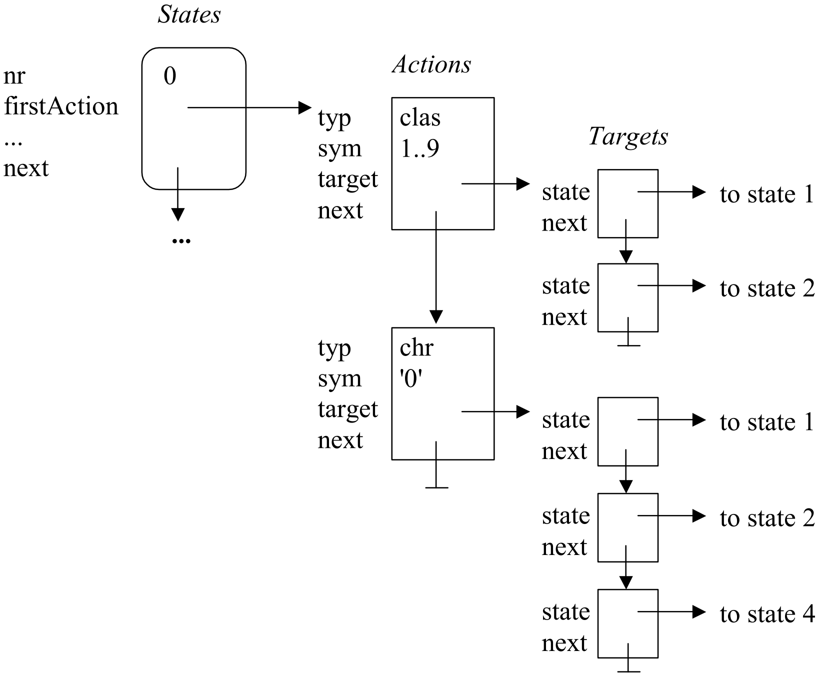
This is the resulting deterministic finite automaton from which the scanner is generated.

Concrete data structures

Nondeterministic automaton

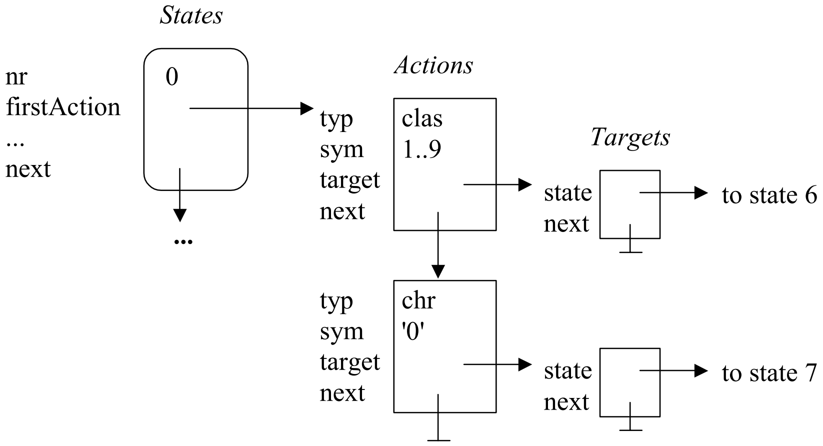


After MakeUnique

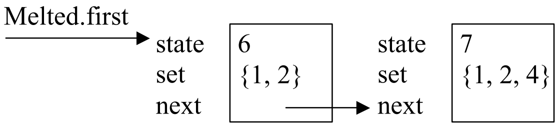


This means: from state 0 one can go with the characters 1..9 to state 1 and 2, and with the character 0 to state 1, 2 and 4.

After MeltStates



The states 1 and 2 have been "melted" into a new state 6, the states 1, 2 and 4 have been melted into a new state 7. This information is kept in class `Melted` using the following data structure:



The literals table

If a token is explicitly declared as a string, e.g.:

```
TOKENS
  while = "while".
  ...
```

it can be referenced in the productions both by its name (`while`) and by its literal representation (`"while"`). The symbol table just stores the names of such tokens. The hash table `Tab.literals` is used to map their literal representation to their node in the symbol table.