

# Data Structures in Coco/R

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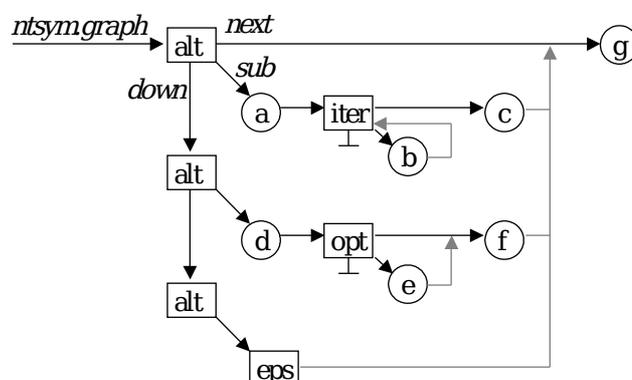
This technical note describes the data structures in the C# and Java implementations of the compiler generator Coco/R. The major data structures are:

- **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:**  $A = (a \{b\} c \mid d [e] f \mid ) g$ .

**Graph:**

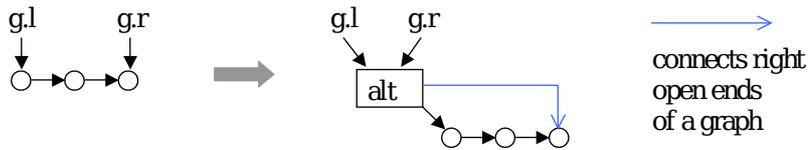


Gray lines denote `next` pointers that point upwards. For any node  $n$ , if  $n.next$  points upwards, then  $n.up$  is true.

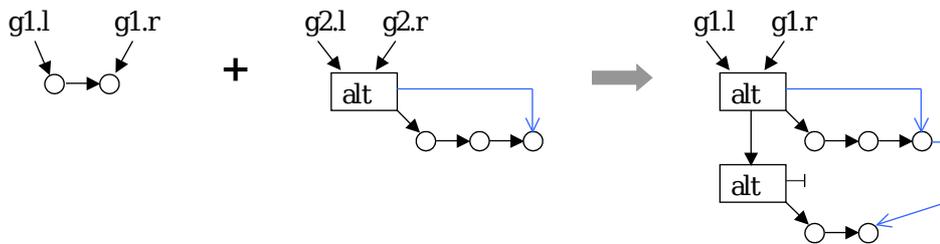


## Operations to build the syntax graph

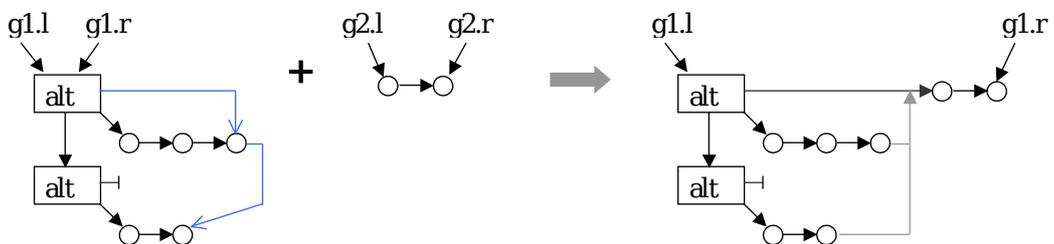
### Tab.MakeFirstAlt(g)



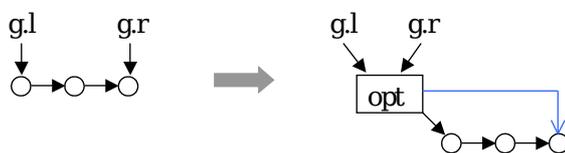
### Tab.MakeAlternative(g1, g2)



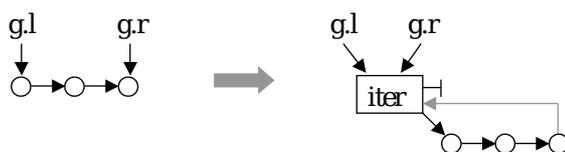
### Tab.MakeSequence(g1, g2)



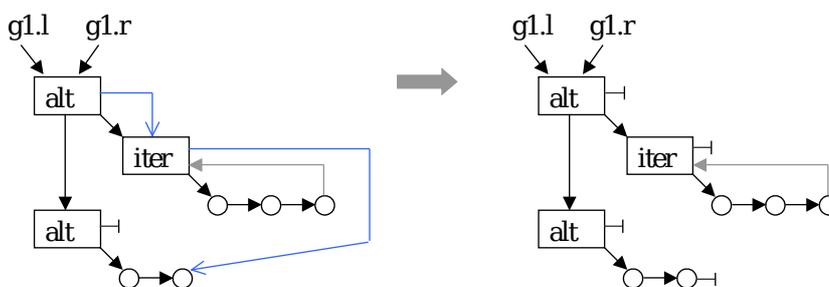
### Tab.MakeOption(g)



### Tab.MakeIteration(g)



### Tab.Finish(g)



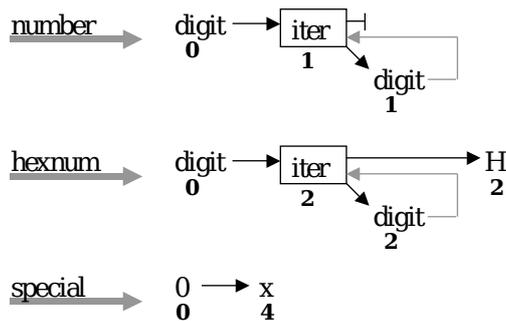
## 2. Scanner automaton

### Declarations

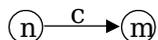
```

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

### Syntax graph for the tokens

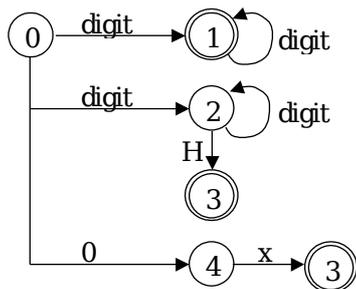


The bold numbers denote the states that were assigned to the nodes by the method `DFA.NumberNodes`. They are used to derive the automaton from the graph as follows: if a node for a character or a character class `c` has the number `n` and its `next` pointer points to a node with a number `m`, then this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



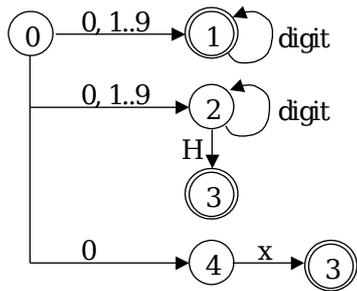
If there is no next node, the transition leads to a new state.

### Nondeterministic automaton



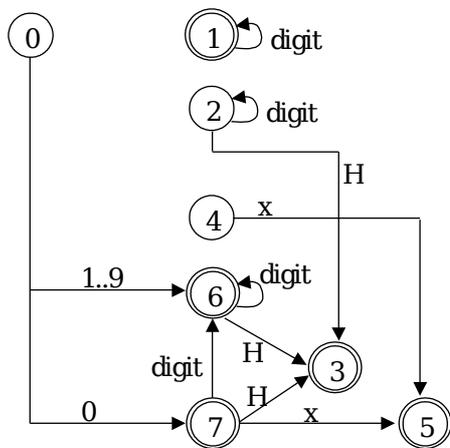
The automaton is nondeterministic since there are three transitions with '0' in state 0 and two with 'digit' in state 0. The first step in making the automaton deterministic is to split overlapping character ranges. This is done by `DFA.MakeUnique`.

### After MakeUnique



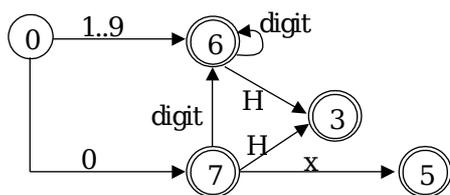
The next step is to melt those states that can be reached by a transition with the same symbol from the same state. This is done in `DFA.MeltStates`.

### After MeltStates



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

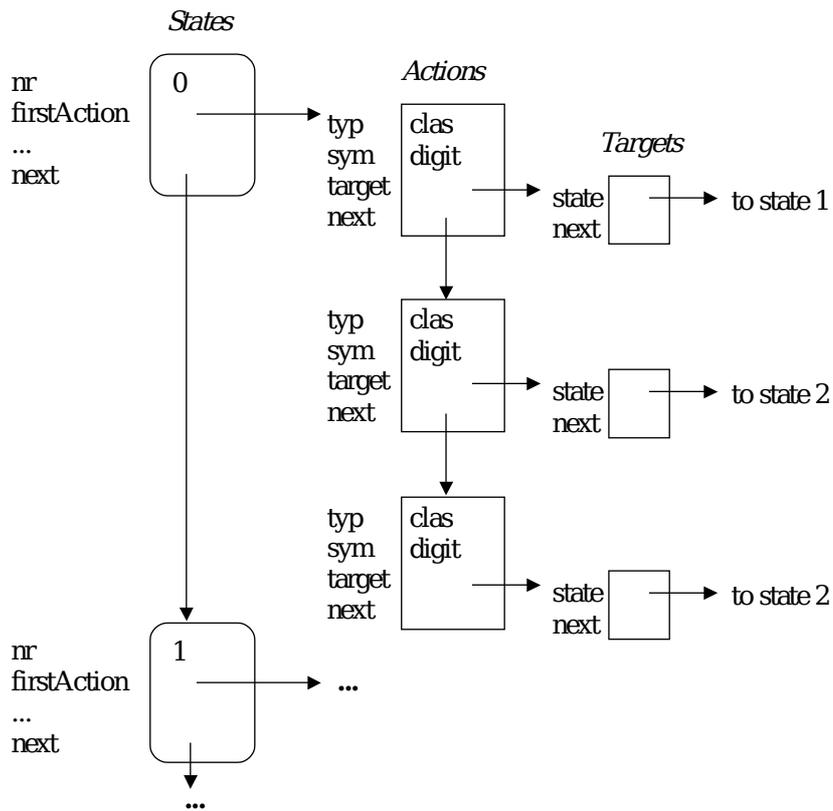
### After DeleteRedundantStates



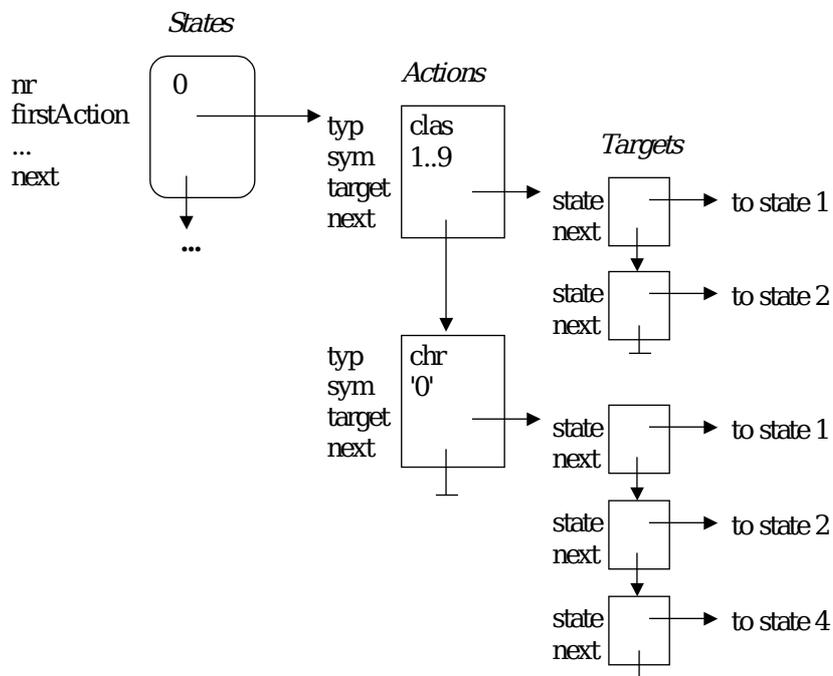
This is the resulting deterministic finite automaton from which the scanner is generated.

## Concrete data structures

### Nondeterministic automaton

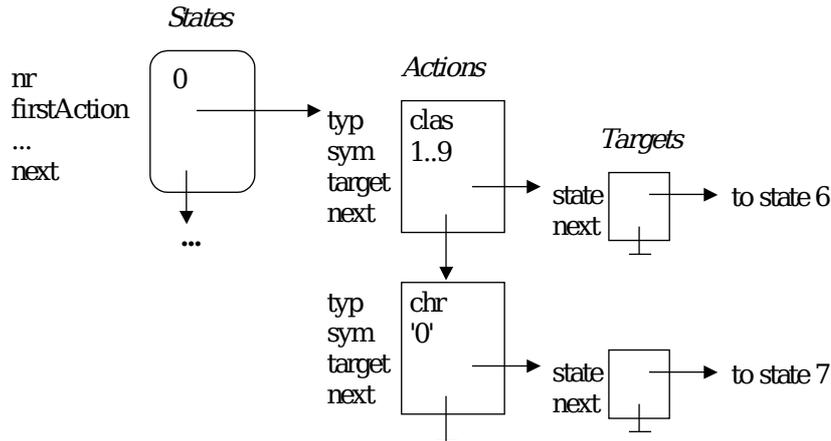


### After MakeUnique

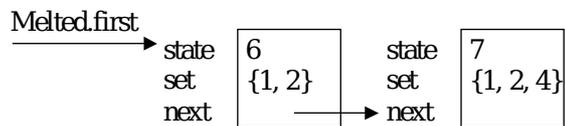


This means: from state 0 one can go with the characters 1..9 to state 1 and 2, and with the character 0 to state 1, 2 and 4.

## 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.