Class 10: Shift-reduce Parsing and CFSMs

SI 413 - Programming Languages and Implementation

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Fall 2011

Bottom-up Parsing

A bottom-up (LR) parser reads tokens from left to right and maintains a stack of terminal *and* non-terminal symbols.

At each step it does one of two things:

- **Shift**: Read in the next token and push it onto the stack
- **Reduce**: Recognize that the top of the stack is the r.h.s. of a production rule, and replace that r.h.s. by the l.h.s., which will be a non-terminal symbol.

The question is how to *build* an LR parser that applies these rules *systematically*, *deterministically*, and of course *quickly*.

Simple grammar for LR parsing

Consider the following example grammar:

$S \to E$
$E \to E$ + T
$E \to T$
$T \to$ `n`

Examine a bottom-up parse for the string `n + n`.

How can we model the "state" of the parser?

Parser states

At any point during parsing, we are trying to expand one or more production rules.

The state of a given (potential) expansion is represented by an "LR item".

For our example grammar we have the following LR items:

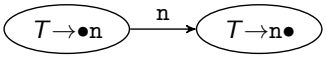
$S \rightarrow \bullet\ E$	$E \rightarrow E + T\ \bullet$
$S \rightarrow E\ \bullet$	$E \rightarrow \bullet\ T$
$E \rightarrow \bullet\ E + T$	$E \rightarrow T\ \bullet$
$E \rightarrow E\ \bullet + T$	$T \rightarrow \bullet\ \mathtt{n}$
$E \rightarrow E + \bullet\ T$	$T \rightarrow \mathtt{n}\ \bullet$

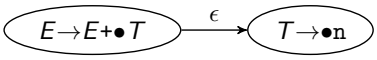
The $\bullet$ represents "where we are" in expanding that production.

Pieces of the CFSM

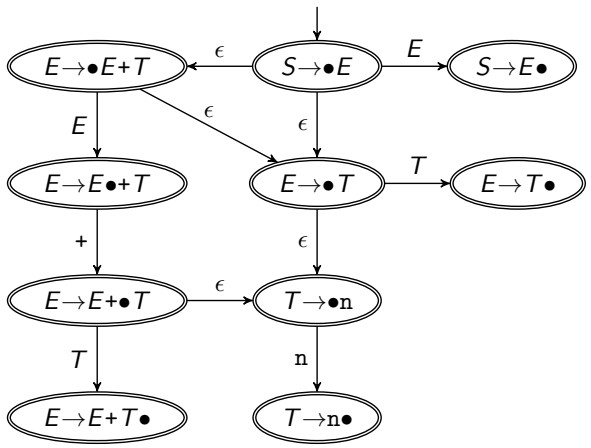
The CSFM (Characteristic Finite State Machine) is a FA representing the *transitions* between the LR item "states".

There are two types of transitions:

- **Shift**: consume a terminal *or non-terminal* symbol and move the $\bullet$ to the right by one.
  Example: 

- **Closure**: If the $\bullet$ is to the left of a non-terminal, we have an ϵ-transition to any production of that non-terminal with the $\bullet$ all the way to the left.
  Example: 

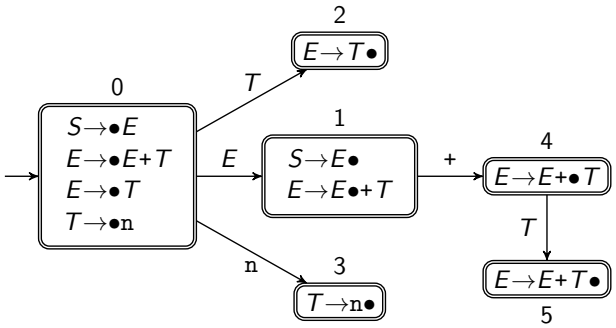
Nondeterministic CFSM for example grammar



CFSM Properties

- Observe that every state is accepting.
- This is an NDFA that accepts *valid stack contents*.
- The "trap states" correspond to a *reduce* operation:
  Replace r.h.s. on stack with the l.h.s. non-terminal.
- We can simulate an LR parse by following the CFSM on the current stack symbols AND un-parsed tokens, then starting over after every reduce operation changes the stack.
- We can turn this into a DFA just by combining states.

Deterministic CFSM for example grammar



- Every state is labelled with a number.
- Labels are pushed on the stack along with symbols.
- After a reduce, go back to the state label left at the top of the stack.