CENG 444

LANGUAGE PROCESSORS

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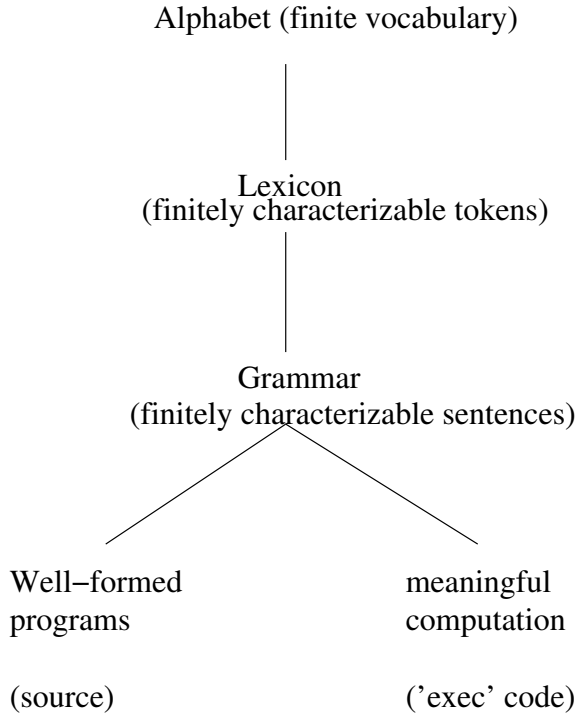
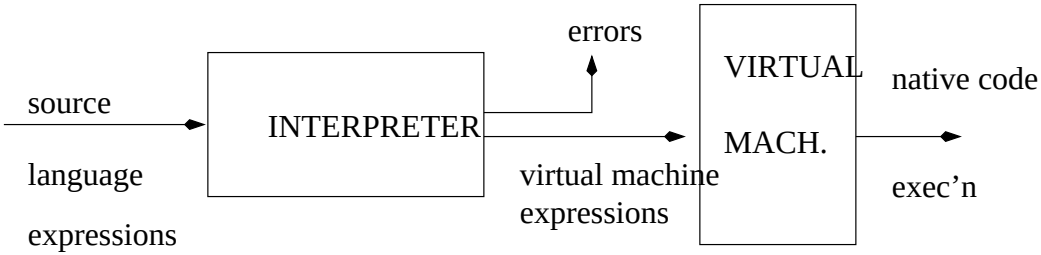


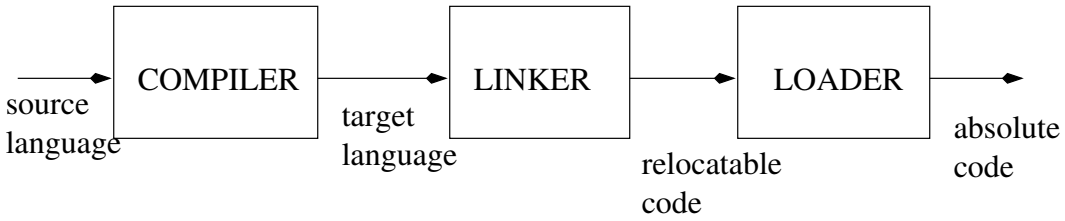
GENERAL ARCHITECTURE OF LANGUAGE
INTERPRETATION

- Language processing (compiling/interpretation/translation) brings together Computer Architecture, OS, Formal Languages, Software Engineering and Programming Languages.

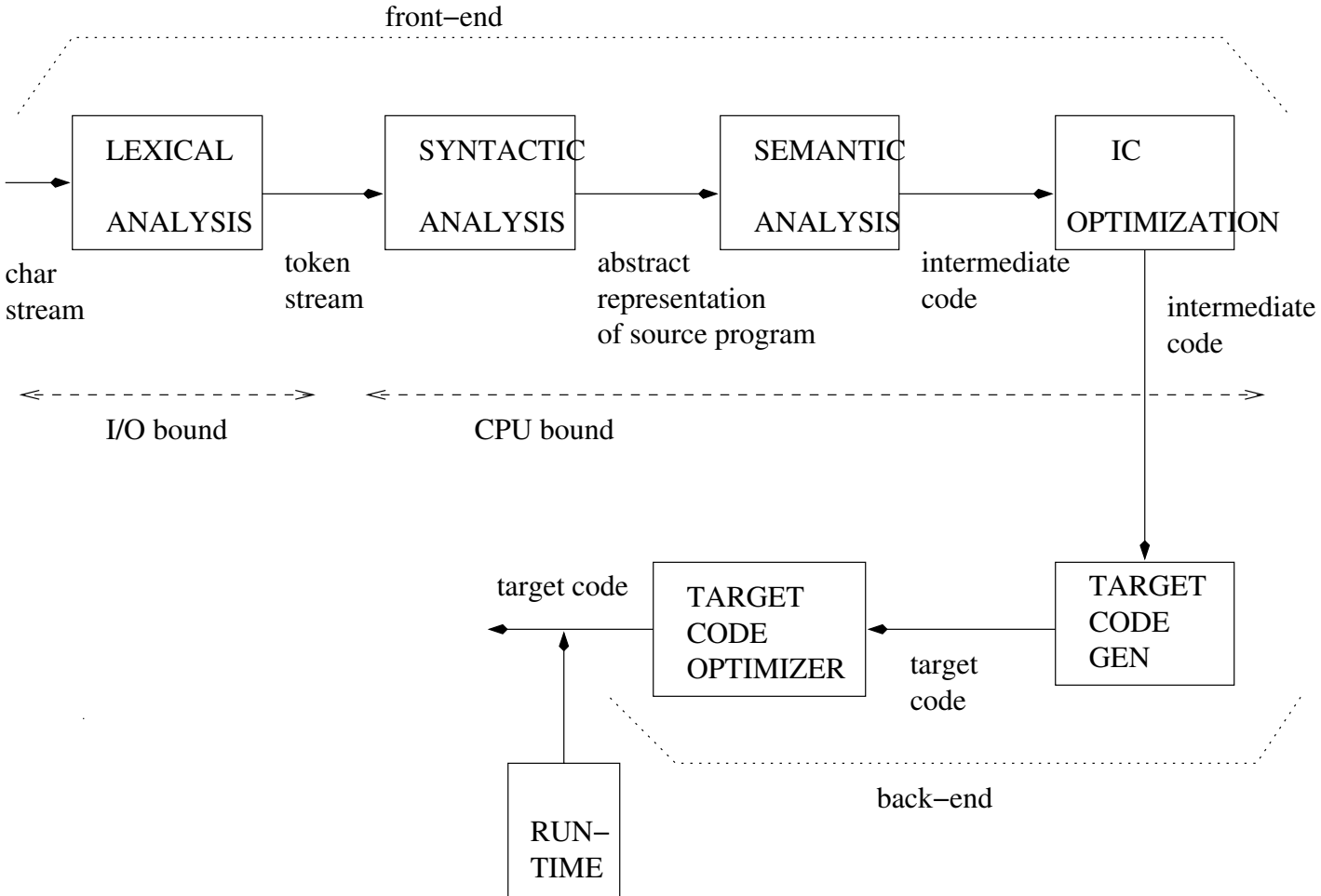
- Any computation can be visualized as the following process:



- Some virtual machines: Java Virtual Machine (JVM); FAM: Functional Abstract Machine; WAM: Warren’s Abstract Machine

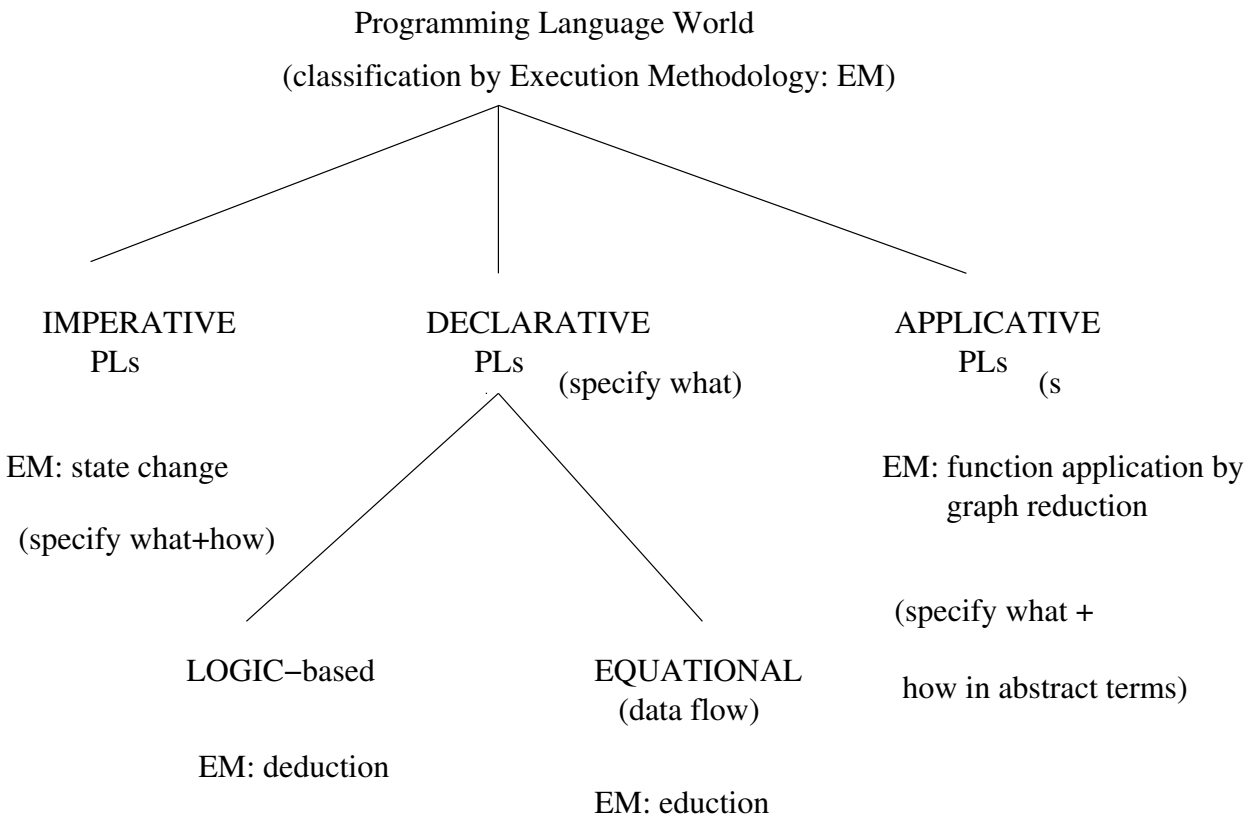


USE OF COMPILERS IN AN ENVIRONMENT



- Need for modularization: Portability, extendibility.

  In many cases the stages are combined (single vs. multi-pass compilers)



- We will study compilers for imperative languages

- Different paradigms call for different compiler design; choice of intermediate code, compiling vs. interpretation; VM-based interpretation.

A Walk Through The Stages of Compilation

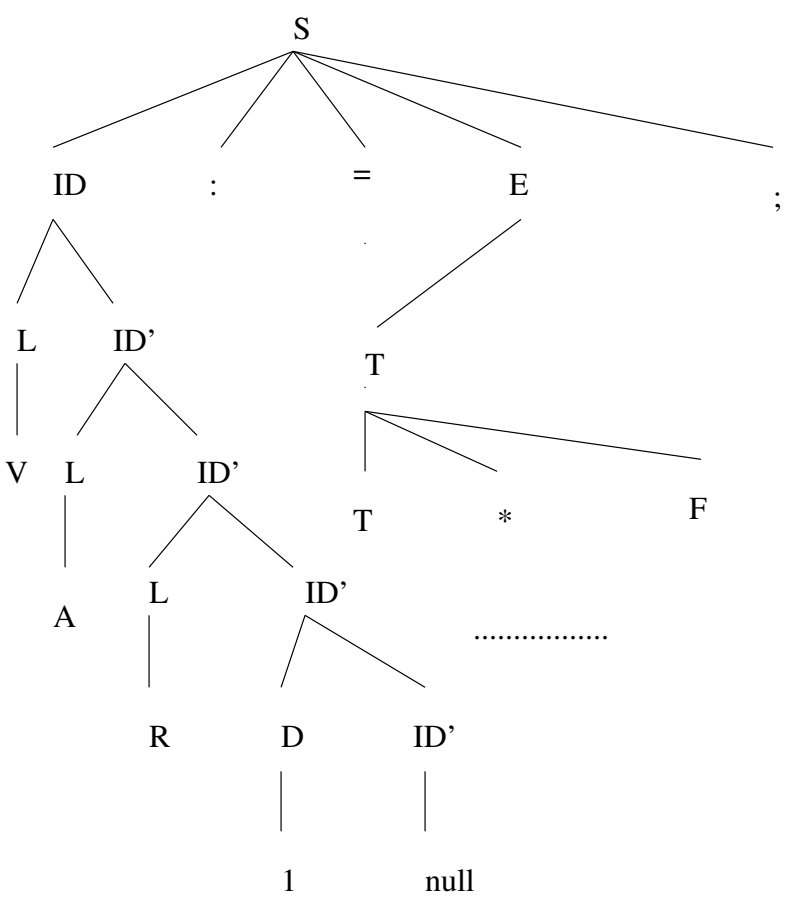
- XP: A language for arithmetic expressions

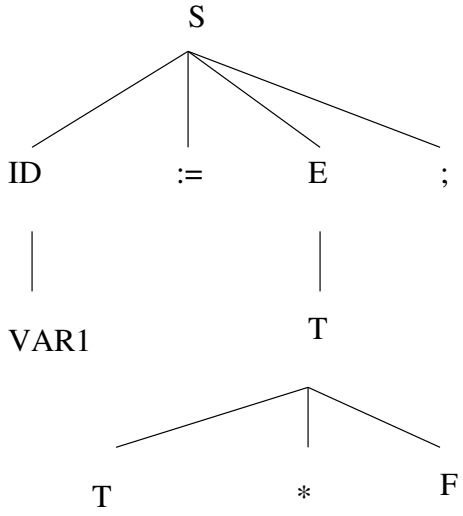
S $\rightarrow$	ID := E;
E $\rightarrow$	E - T | E + T | T
T $\rightarrow$	T * F | T / F | F
F $\rightarrow$	ID | NUM | (E)
ID $\rightarrow$	L ID′
ID′ $\rightarrow$	(L| D) ID′ | ϵ
NUM$\rightarrow$	D NUM | D

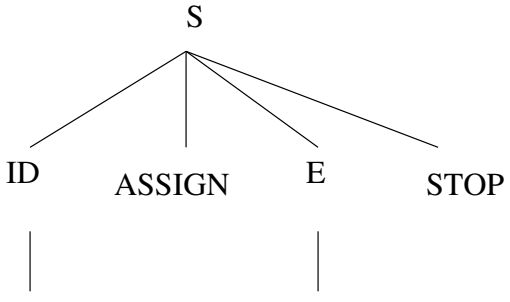
STAGE I: LEXICAL ANALYSIS. Tokenize the incoming stream of text.

Why separate lexical and syntactic analysis?

VAR1 := (B+C)*VAR2/(256−VAR3);







- Separation makes both stages simpler; The parser need not worry about internal structure of tokens, whitespace, comments etc.

- Usually, the grammar of a language is context-free, but the grammar of its tokens is regular. Use more efficient techniques.

- Machine-dependent I/O and alphabetical conventions can be localized.

token types	patterns	lexemes
ID	$L(L\|D)^*$	var1, b, abc5rd
NUM	D^+	256
OP	$(+\mid-\mid*\mid/)$	+
ASSIGN	:=	:=

- VAR1 := (B+C)*VAR2 /(256-VAR3);

  ID ASSIGN DEL ID OP ID DEL .....

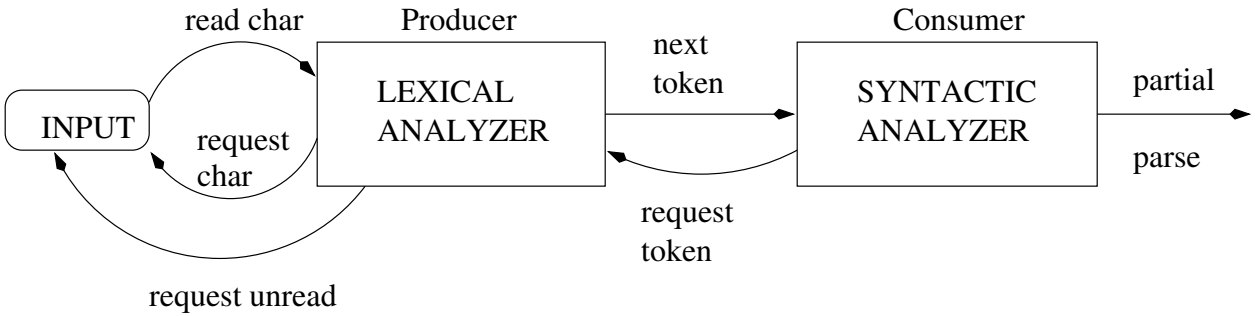
- A by-product of this stage is to start forming a table of meaning-bearing entities, called *the symbol table*.

- Lex analyzer doesn’t know anything about the *syntax* of the language; it can fill ST with limited amount of information.

- Symbol table is the most frequently accessed data structure in a compiler (lexical analyzer, parser, type checker, run-time system, optimizer etc.)

  Need efficient insertion and search techniques for ST.

STAGING OF LEXICAL−SYNTACTIC ANALYSES



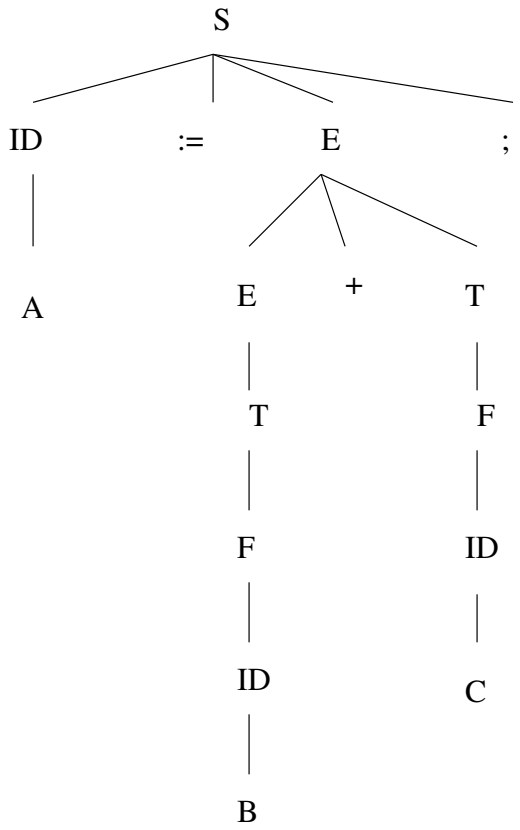
ex: Fortran IF stmt IF(I,J)=3

STAGE II: SYNTACTIC ANALYSIS

Assign roles to tokens in parsing; set up symbol table; assign meanings to the use of tokens (syntax-directed translation).

- The meaning (semantics) of a program is what it does (computes).

A:= B+C;



PARSE TREE for A:=B+C

rule	action
S –> ID := E;	output lvalue ID.name move
ID –> ...	put ID in symbol table
T –> F	T.val <– F.val
E –> E + T	output add
F –> ID	output rvalue ID.name
F –> NUM	output value NUM

- How to get semantic representation from the parse tree: associate semantic actions with rules.

- How do the attributes get instantiated?

  Depends on the parsing strategy.

  in Bottom-up parsing, the attributes are *synthesized* from value of child nodes.

  in top-down parsing, they are *inherited* by children.

- Choice of strategy also affects grammar. XP is left-recursive hence not very suitable for top-down parsing (re-write or use bottom-up).

- RECURSIVE-DESCENT PARSING: a top-down approach

  Write a subprogram for each non-terminal in the grammar

  For terminals, call the lexical analyzer

  Flow of control shows the order of rule application

- ex: rewrite XP as a non-left-recursive grammar.

  ex: $S \rightarrow$ ID := E ;
  $E \rightarrow$ T E'
  $E' \rightarrow$ + TE' | - T E' | ϵ

```
match(T): returns true if next token is of type T

advance(): consumes the lookahead token

procedure S;
begin
   ID;
   if match(ASSIGN) then advance() else error();
   E;
   if match(STOP) then advance() else error();
end;

procedure ID;
begin
   if match(ID) then token:=advance();
   install_id(token);
end;

procedure E;
begin
   T;
```

```
   Eprime;
end;

procedure Eprime;
begin
   if match(OP) then {advance(); T; Eprime;}
   else /* no consumption */
end
```

- BOTTOM-UP PARSING: obtain rightmost derivations *in reverse order*.

  An algorithm to pick the right rule in derivations: LR parsing

  A:=B+C;
  ID:=B+C;
  ID:=ID+C;
  ID:=F+C;
  ID:=T+C;
  ID:=E+C;
  ID:=E+ID;
  ID:=E+F;
  ID:=E+T;
  ID:=E;
  S

- STAGE III: SEMANTIC ANALYSIS

ex: type checking

```
A:int;
B:real;

C:= A/B;
```

need to generate code like

```
T:=coerce(A,real);
C:=divide(T,B);
```

```
if (A+B) then ...
```

- STAGE IV: GENERATING INTERMEDIATE CODE (IC)

- choice of IC depend on source-target language and considerations.

  1. Easy to translate into IC (assembly-like for imperative; lambda-calculus like for applicative langs)

  2. Easy to obtain from source language (high-level assembler for imperative PLs; stack machines for arithmetic)

3. IC tends to be abstract three-address code (TAC) if RISC is the main target

IC tends to be two-address code if CISC is the main target

Architecture-independent virtual machines

- TAC: result := operand op operand

A:=(B+C-D)/2 translates to TAC

```
t1 := B+C;
```

```
t2 := t1-D;
t3 := t2/2;
A  := t3;
```

- SAM: A stack machine for XP

  fetch values of IDs from memory to stack (`rvalue x`)

  put values on stack (`push v`)

  put address of ID on stack (`lvalue x`)

store in memory (`move`)

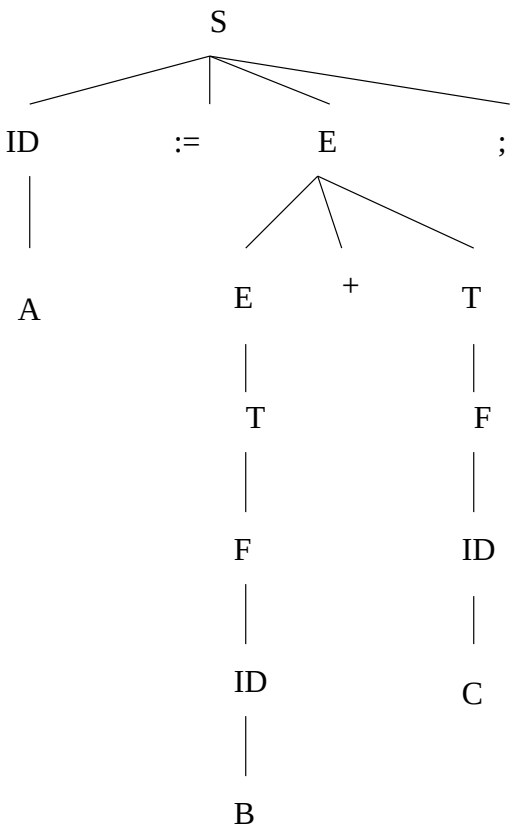
operators

- ex: SAM code for A:=B+C-D+10;

```
rvalue B
rvalue C
ADD
rvalue D
SUB
push 10
ADD
lvalue A
move
```

- obtaining the SAM instructions during parsing (as a syntax-directed semantic action)

A:= B+C;



- From IC to Target Code (TC)

  Optimizations on IC: combine common subexpresions; eliminate dead code; fix loops; replace some calls with local go to’s

  Optimizations on TC: reduce memory fetch; maximize register use