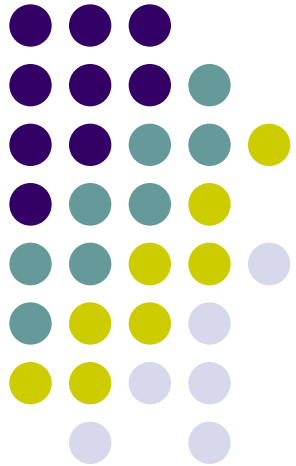
CS 460

Programming Languages

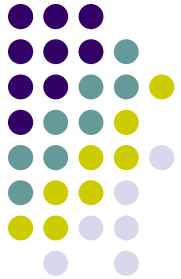
Fall 2023

Dr. Watts

(6 November 2023)



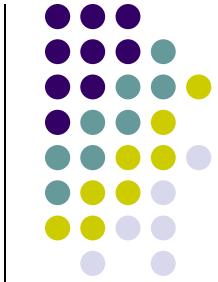
Assignments



- Exercise 2
  - Script running so that your groups can improve their testing techniques
- Exercise 3
  - Posted – let me know if you see typos
  - Part 2 – comment out last function call

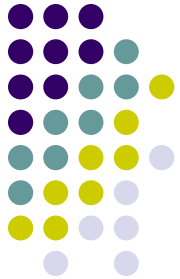
```
;; (main)
```

Project 2



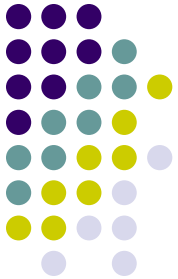
- Spec and Framework posted
- Extra Credit
  - PL460 program that uses all 93 grammar rules
  - Thursday, 16 November 2023, 6:59 am
  - Draw from Exercise 3
- Suggestions
  - Create First and Follow sets
  - Start with sets for the “Short Grammar”
  - Add in the remaining grammar rules
  - Testing

First and Follow Sets



- Firsts
  - A terminal symbol T_i is a member of the First Set of non-terminal symbol <nt_j> if T_i can become the first terminal symbol in a complete expansion of <nt_j>.
- Follows
  - A terminal symbol T_i is a member of the Follow Set of non-terminal symbol <nt_j> if T_i can become the first terminal symbol immediately following a complete expansion of <nt_j>.

Why do we need the First and Follow Sets?



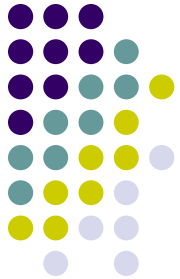
- Making decisions!

15. <non_terminal_10> → T21 …
16. <non_terminal_10> → T22 …
17. <non_terminal_10> → <non_terminal_11> …
18. <non_terminal_11> → T24 …

- Error Recovery

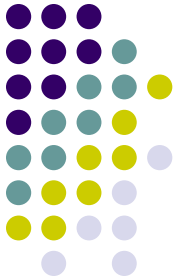
```
void non_terminal_10 ()
{
        if (current_token == T21)
        { // Use rule 15
        }
        else if (current_token == T22)
        { // Use rule 16
        }
        else if (current_token == T24)
        { // Use rule 17
        }
        else
        // No applicable rule
                call error_routine;
        return;
}
```

Parse Table



T	BEGIN	END	SEMI	EQUAL	A	B	C	PLUS	MULT
<nt>	-TOK	-TOK	-TOK	-TOK	-TOK	-TOK	-TOK	-TOK	-TOK
<program>	1	Error	Error	Error	Error	Error	Error	Error	Error
<stmt_list>					2	2	2		
<stmt_tail>		4	3						
<stmt>					5	5	5		
<var>					6	7	8		
<expr>					9	9	9		
<expr_tail>		12	12					10	11

First and Follow Sets



	First Set	Follow Set
<program>	BEGIN_TOK (1)	
<stmt_list>	A_TOK (2), B_TOK (2), C_TOK(2)	END_TOK
<stmt_tail>	SEMI_TOK (3), END_TOK (4)	END_TOK
<stmt>	A_TOK (5), B_TOK (5), C_TOK (5)	END_TOK, SEMI_TOK
<var>	A_TOK (6), B_TOK (7), C_TOK (8)	END_TOK, SEMI_TOK, EQUAL_TOK, PLUS_TOK, MULT_TOK
<expr>	A_TOK (9), B_TOK (9), C_TOK (9)	END_TOK, SEMI_TOK
<expr_tail>	PLUS_TOK (10), MULT_TOK (11), END_TOK (12), SEMI_TOK (12)	END_TOK, SEMI_TOK

Short Project Grammar

Character Sets

```
α = upper or lower alphabetic characters
η = digits 0 to 9
Θ = all typeable characters
```

Lexeme Regular Expression

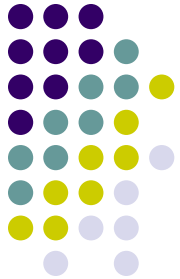
define | (|) | α(α|η|_)* | (+|-|λ)(η⁺ | η*.η⁺ | η⁺.η* | η⁺/η⁺) | "Θ*"
| **#f** | **#t** | **display** | **newline**

T = {DEFINE_T, LPAREN_T, RPAREN_T, IDENT_T, NUMLIT_T, STRLIT_T, FALSE_T, TRUE_T, DISPLAY_T, NEWLINE_T, EOF_T};

NT = {<program>, <more_defines>, <define>, <stmt_list>, <stmt>, <literal>, <logical_lit>, <param_list>, <action >}

S = <program>

Short Project Grammar

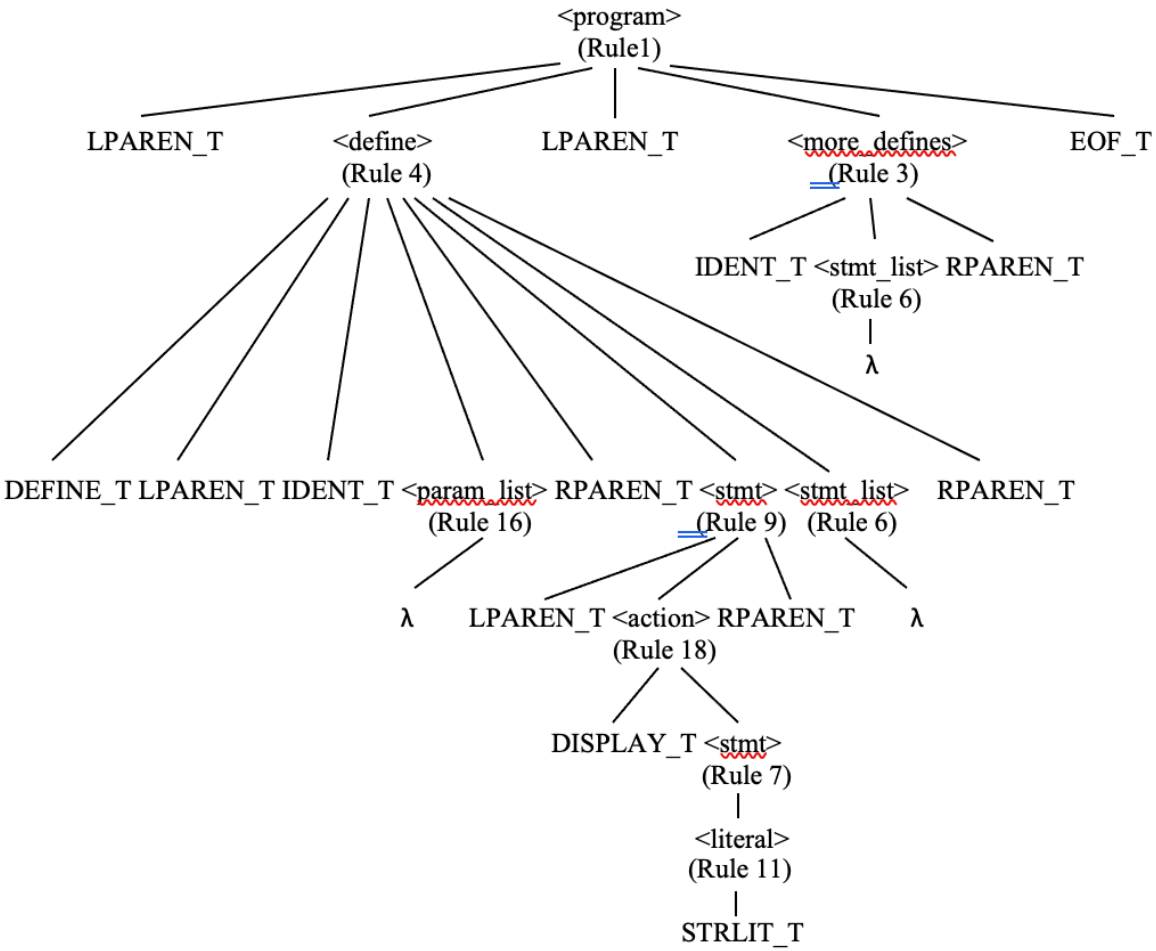


P = {

1. <program> -> LPAREN_T <define> LPAREN_T <more_defines> EOF_T
2. <more_defines> -> <define> LPAREN_T <more_defines>
3. <more_defines> -> IDENT_T <stmt_list> RPAREN_T
4. <define> -> DEFINE_T LPAREN_T IDENT_T <param_list> RPAREN_T <stmt> <stmt_list> RPAREN_T
5. <stmt_list> -> <stmt> <stmt_list>
6. <stmt_list> -> λ
7. <stmt> -> <literal>
8. <stmt> -> IDENT_T
9. <stmt> -> LPAREN_T <action> RPAREN_T
10. <literal> -> NUMLIT_T
11. <literal> -> STRLIT_T
12. <literal> -> <logical_lit>
13. <logical_lit> -> TRUE_T
14. <logical_lit> -> FALSE_T
15. <param_list> -> IDENT_T <param_list>
16. <param_list> -> λ
17. <action> -> IDENT_T <stmt_list>
18. <action> -> DISPLAY_T <stmt>
19. <action> -> NEWLINE_T

}

Short Grammar Program

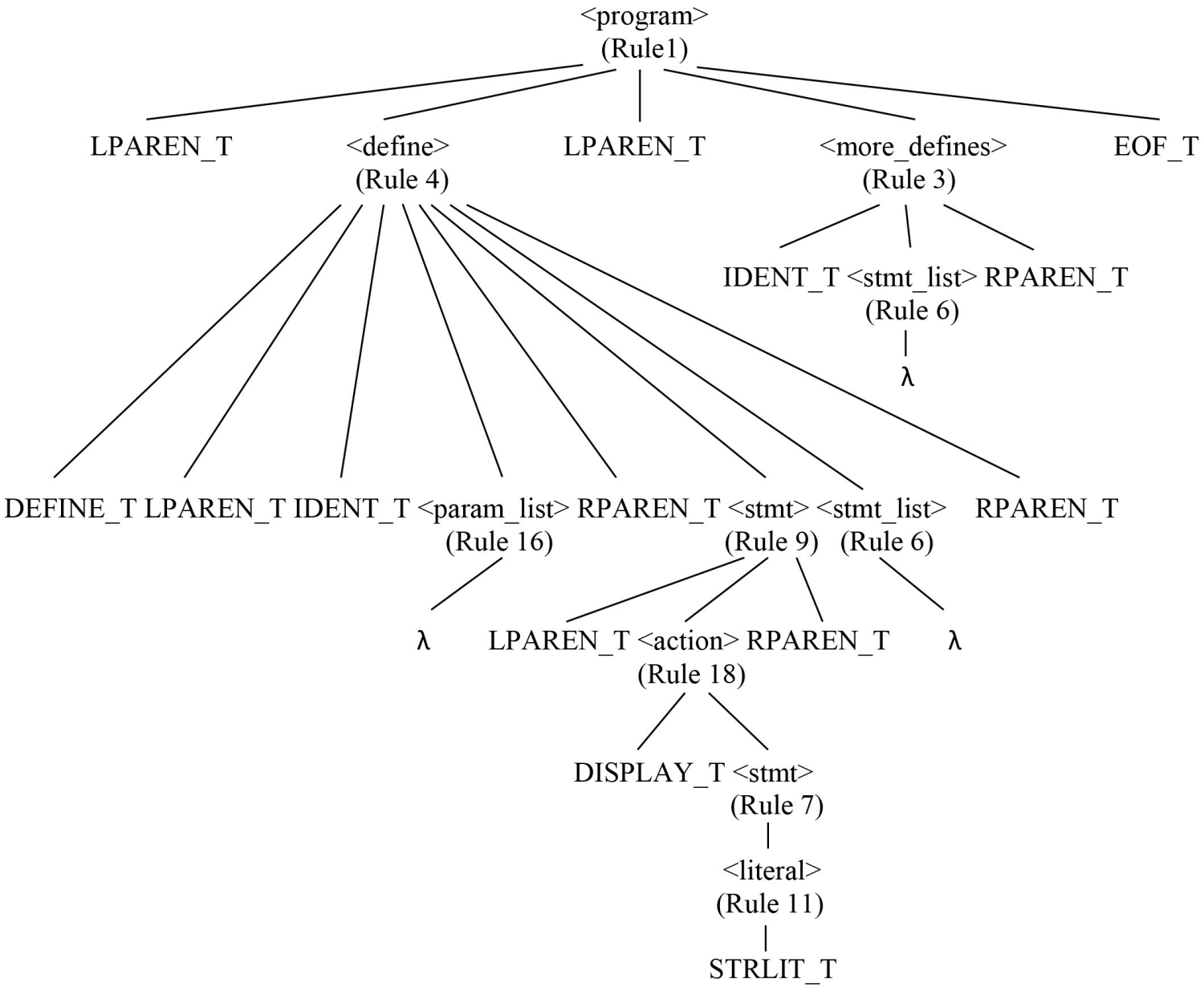


Tokens

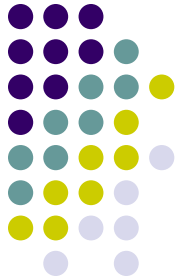
LPAREN_T DEFINE_T LPAREN_T IDENT_T RPAREN_T LPAREN_T DISPLAY_T STRLIT_T
RPAREN_T RPAREN_T LPAREN_T IDENT_T RPAREN_T EOF_T

Lexemes

```
(define (Team0) (display "Hello World")) (Team0)
```


<program>
(Rule1)
LPAREN_T
<define>
(Rule 4)
LPAREN_T
<more_defines>
(Rule 3)
EOF_T
IDENT_T <stmt_list> RPAREN_T
(Rule 6)
λ
DEFINE_T LPAREN_T IDENT_T <param_list> RPAREN_T <stmt> <stmt_list> RPAREN_T
(Rule 16)
(Rule 9)
(Rule 6)
λ
LPAREN_T <action> RPAREN_T
λ
(Rule 18)
DISPLAY_T <stmt>
(Rule 7)
<literal>
(Rule 11)
STRLIT_T

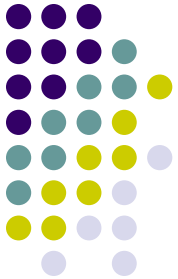
Calculating First and Follow Sets – Procedure A



- For each rule of the form
  a. $<nt_i> \rightarrow T_k \ldots$
  b. T_k is included in the first set of $<nt_i>$

- Which rules in the short grammar include the pattern needed for Procedure A?

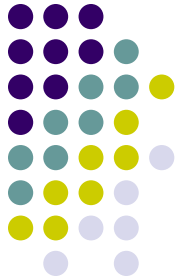
Calculating First and Follow Sets – Procedure B



- For each rule of the form
  a. $<nt_i>$ → $<nt_j>$ …
  b. if T_k is a member of the first set of $<nt_j>$ then T_k is included in the first set of $<nt_i>$

- Which rules in the short grammar include the pattern needed for Procedure B?

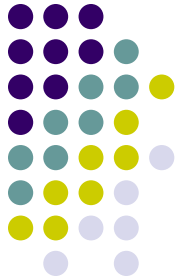
Calculating First and Follow Sets – Procedure C



- For each rule of the form
  a. $<nt_i> \rightarrow \lambda$
  b. if T_k is a member of the follow set of $<nt_i>$ then T_k is included in the first set of $<nt_i>$

- Which rules in the short grammar include the pattern needed for Procedure C?

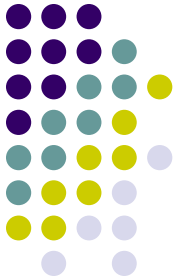
Calculating First and Follow Sets – Procedure D



- For each rule of the form
  a. < > → … <nt_i> T_k ...
  b. T_k is included in the follow set of <nt_i>

- Which rules in the short grammar include the pattern needed for Procedure D?

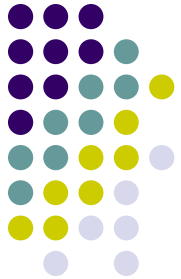
Calculating First and Follow Sets – Procedure E



- For each rule of the form
  a. < > → … <nt_i> <nt_j> …
  b. if T_k is a member of the first set of <nt_j> then T_k is included in the follow set of <nt_i>

- Which rules in the short grammar include the pattern needed for Procedure E?

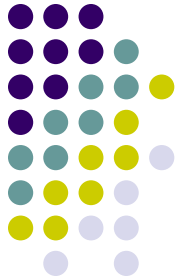
Calculating First and Follow Sets – Procedure F



- For each rule of the form
  a. $<nt_i> \rightarrow \ldots <nt_j>$
  b. if T_k is a member of the follow set of $<nt_i>$ then T_k is included in the follow set of $<nt_j>$

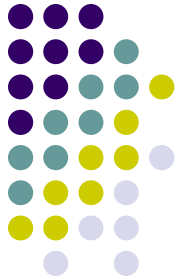
- Which rules in the short grammar include the pattern needed for Procedure F?

Subprogram Terminology



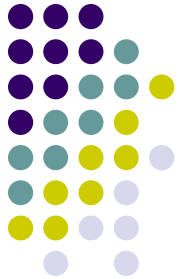
- A **subprogram definition** describes the interface to and the actions of the subprogram abstraction.
- A **subprogram call** is the explicit request that a specific subprogram be executed.
- A subprogram is said to be **active** if, after having been called, it has begun execution but has not yet completed that execution.
- Two fundamental kinds of subprograms: **procedures and functions**.
- A **subprogram header**, which is the first part of the definition,
  - specifies that the following syntactic unit is a subprogram definition of some particular kind.
  - provides a name for the subprogram.
  - may specify a list of parameters.
- The **parameter profile** of a subprogram contains the number, order, and types of its formal parameters.
- The **protocol** of a subprogram is its parameter profile plus, if it is a function, its return type.
- **Formal parameters** are defined in the subprogram header.
- **Actual parameters** are provided in the subprogram call.

Procedures vs Functions



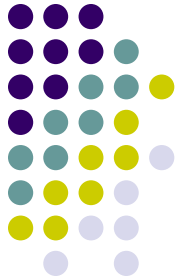
- Procedures do not have return values
- Procedures change the calling environment via call by reference and modification of shared variables (side effects)
- Functions have return values
- Functions should not create side effects
- Many languages use a hybrid approach

Local Referencing Environments

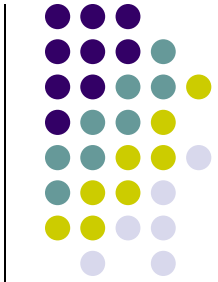


- Stack Frames
- Local variables
- Parameter passing methods
  - Pass by value
  - Pass by reference
  - Constant pass by reference
  - Pass by name
  - Implementing passing methods

Examples



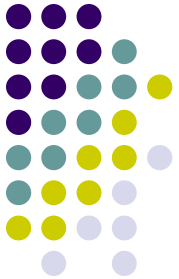
Recursion in PL460



- Rules of Recursion - Determine
  - the unit of work
  - the base case (how to make it stop)
  - the external call (how to make it start)
  - the internal call(s) (how to keep it going)

- PL460 Examples

Recursive display example



```
(define (tailRec value)
        (display value) (display " ")
        (if (> value 1)
                (tailRec (/ value 2))
        )
)

(define (headRec value)
        (if (> value 1)
                (headRec (/ value 2))
        )
        (display value) (display " ")
)

(define (main)
        (display "(tailRec 32) --> ")
        (tailRec 32)
        (newline)
        (display "(headRec 32) --> ")
        (headRec 32)
        (newline)
)

(main)
```