Syntax Analysis

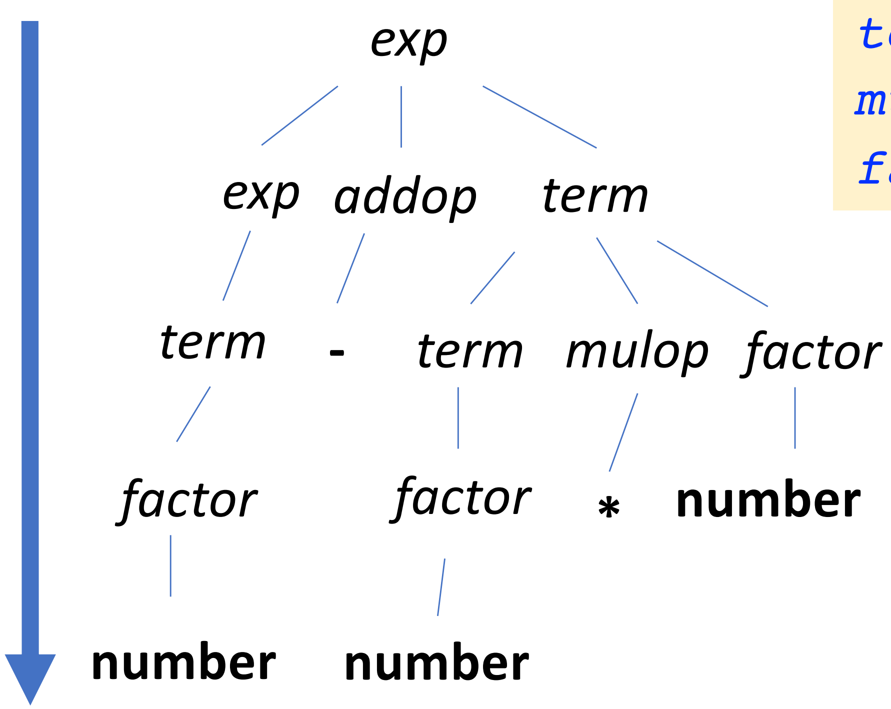
(Chapters 4 & 5)

Top-Down Parsing (Chapter 4)

- Builds a parse tree top down, from the start nonterminal
- and creating tree nodes in **preorder** (a leftmost derivation)

```
34 – 3 * 42
```

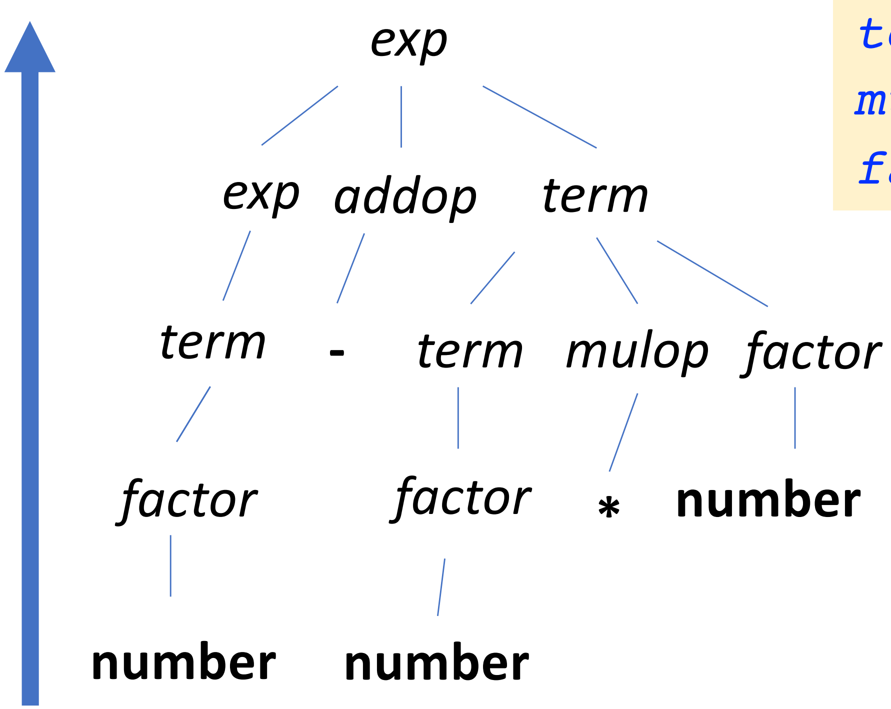
```
exp → exp addop term | term
addop → + | -
term → term mulop factor | factor
mulop → *
factor → ( exp ) | number
```



Bottom-Up Parsing (Chapter 5)

- Builds a parse tree bottom up, from the leaf nodes

```
34 – 3 * 42
```




```
exp → exp addop term | term
addop → + | -
term → term mulop factor | factor
mulop → *
factor → ( exp ) | number
```

Top-Down Parsing
(Chapter 4)

Top-Down Parsing

- Backtracking parsers **More Powerful** **Exponential Time**
  - try different possibilities
  - back up arbitrary number of input symbols once a try fails
- Predictive parsers
  - use one or more lookahead symbols to narrow down the possibilities

```
34 – 3 * 42
```

```
exp → exp addop term | term
addop → + | -
term → term mulop factor | factor
mulop → *
factor → ( exp ) | number
```

Top-Down Parsing (Predictive)

- Recursive-descent parsing
  - versatile
  - better for a hand-written parser
- LL(1) parsing
  - scan from **left to right**, and perform **leftmost** derivation
  - look ahead at most **one** input symbol

```
34 – 3 * 42
```

```
exp → exp addop term | term
addop → + | -
term → term mulop factor | factor
mulop → *
factor → ( exp ) | number
```

Recursive Descent Parsing

Recursive-Descent Parsing

- <u>Basic Ideas</u>
  - for each nonterminal, define a function to recognize it

```
factor()
{
  switch(token)
    case (:
      match(()
      exp()
      match())
    case number:
      match(number)
    default:
      error()
}
```

Lookahead

Match and consume the symbol

exp → *exp addop term* | *term*
addop → + | -
term → *term mulop factor* | *factor*
mulop → *
factor → (*exp*) | **number**

Recursive-Descent Parsing

- Basic Ideas
  - for each nonterminal, define a function to recognize it

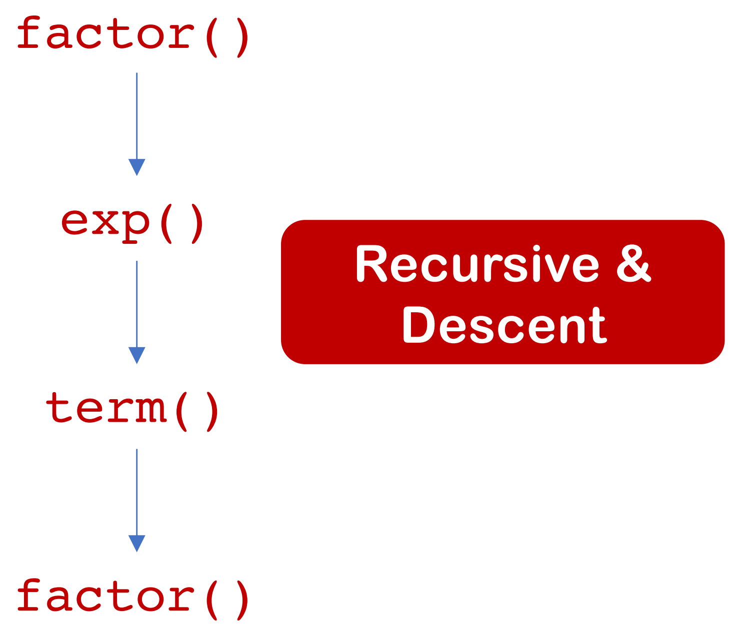
```
match(expectedToken)
{
  if (token == expectedToken)
     token = getToken()
  else
     error()
}
```

advance the input

Recursive-Descent Parsing

- <u>Basic Ideas</u>
  - for each nonterminal, define a function to recognize it

```
factor()
{
  switch(token)
    case (:
      match(()
      exp()
      match())
    case number:
      match(number)
    otherwise
      error()
}
```



Recursive-Descent Parsing

- Exercise
  - Write down the pseudocode for recognizing `if-stmt`

if-stmt → **if** **(***exp***)** *stmt* **else** *stmt*

```
factor()
{
  switch(token)
    case (:
      match(()
      exp()
      match())
    case number:
      match(number)
    otherwise
      error()
}
```

exp → *exp addop term* | *term*
addop → **+** | **-**
term → *term mulop factor* | *factor*
mulop → *****
factor → **(** *exp* **)** | **number**

Recursive-Descent Parsing

- EBNF
  - extended BNF

```
ifStmt()
{
    match(if)
    match(()
    exp()
    match())
    stmt()
    if(token == else)
      match(else)
      stmt()
}
```

if-stmt → **if** **(***exp***)** *stmt*
| **if** **(***exp***)** *stmt* **else** *stmt*

rewrite

if-stmt → **if** **(***exp***)** *stmt* [**else** *stmt*]

means "optional"

Recursive-Descent Parsing

- EBNF
  - extended BNF

left recursion

exp → exp addop term
| term

rewrite ⇩

exp → term { addop term }

means "repetition"

```
exp()
{
  term()
  while(token == + or -)
  {
    match(token)
    term()
  }
}
```

no "addop" call

Recursive-Descent Parsing

- <u>EBNF</u>
  - extended BNF

```
term → term mulop factor
  | factor
```

rewrite

```
term → factor { mulop factor}
```

```
term()
{
  factor()
  while(token == *)
  {
    match(token)
    factor()
  }
}
```

Recursive-Descent Parsing

- Calculation can be embedded in parsing
- Preserve left associativity

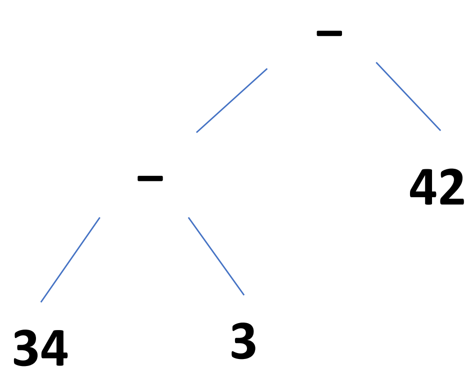
exp → *term* { *addop* *term* }

```
int exp()
{
  int temp = term()
  while(token == + or -) {
    switch(token)
      case + :
        match(+)
        temp += term()
      case - :
        match(-)
        temp -= term()
  }
  return temp
}
```

Recursive-Descent Parsing

- Tree construction can be embedded in parsing
- Example for generating a AST

exp → term { addop term }




```
34 - 3 - 42
```

```
treeNode exp()
{
  treeNode node = term()
  while(token == + or -)
  {
    treeNode newnode
    newnode = makeOpNode(token)
    match(token)
    newnode.leftChild = node
    newnode.rightChild = term()
    node = newnode
  }
  return node
}
```

LL(1) Parsing

LL(1) Parsing

- Use a **stack** rather than recursive calls to build a tree
- Similar to running some pushdown automaton (PDA)
  - Begin by pushing the start nonterminal to the stack
  - Perform some **actions** based on the stack and next input symbol
  - Accept if both stack and input become empty

E.g.

tokens	**grammar**
( )	$S \rightarrow (\; S \;) \; S \mid \varepsilon$

LL(1) Parsing

- Example

tokens

( )

grammar

$S \rightarrow (\; S \;) \; S \mid \varepsilon$

$: marks stack bottom

stack top: leftmost of RHS

	Parsing Stack	Input	Action
1	$ *S*	( ) $	$S \rightarrow (\; S \;) \; S$
2	$ *S*) *S* (	( ) $	match
3	$ *S*) *S*	) $	$S \rightarrow \varepsilon$
4	$ *S*)	) $	match
5	$ *S*	$	$S \rightarrow \varepsilon$
6	$	$	match

LL(1) Parsing

- Two Actions:
  - If stack top is a nonterminal A and A → α, replace A with α (**generate**)
  - If stack top is a terminal (token), **match** it with input token
    - If matched, pop stack and advance input
    - Otherwise, throw an error

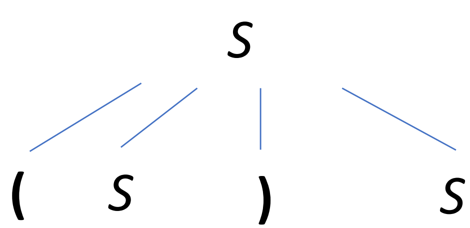
Error Input:
)

	Parsing Stack	Input	Action
1	$ *S*	) $	*S* → (*S*) *S*
2	$ *S*) *S* (	) $	mismatch

	Parsing Stack	Input	Action
1	$ *S*	) $	*S* → ε
2	$	) $	mismatch

LL(1) Parsing

- <u>Parse Tree Construction</u>
  - root node is constructed at the beginning of the parse
  - construct and attach tree nodes in each **generate** action



	Parsing Stack	Input	Action
1	$ *S*	( ) $	*S* → (*S*) *S*
2	$ *S*) *S* (	( ) $	match

First and Follow Sets

Why First ?

$ …… A   b…………

Stack   Tokens

A → a B | X C | c D

X → Y y | Z z

Z → b b | z z

First Set: Definition

- Suppose **α** is a string of terminals and nonterminals, **First(α)** consists of the first terminals that can be derived from **α**.

if $\alpha \Rightarrow^* a\beta$, then $a \in \text{First}(\alpha)$

if $\alpha \Rightarrow^* \varepsilon$ (nullable), then $\varepsilon \in \text{First}(\alpha)$

E.g.

```
First(ABc) = {a, c, d}

First(BC) =  {b, c, ε}
```

Another grammar

$A \rightarrow aB \mid CD$

$B \rightarrow Bb \mid \varepsilon$

$C \rightarrow c \mid \varepsilon$

$D \rightarrow d$

First Set: Properties

1. If **X** is a terminal or **ε**, then **First(X) = {X}**
2. Suppose **X** is a nonterminal and **X → $Y_1Y_2...Y_k$**
   - if for some **i**, **$Y_1...Y_{i-1} \Rightarrow^* \varepsilon$** , then **First(X) ⊇ First(Y_i) – {ε}**
   - if **$Y_1...Y_k \Rightarrow^* \varepsilon$**, then **ε ∈ First(X)**

Why exclude it ?

E.g.

```
First(A) = {a, c, d}
```

Another grammar

$A \rightarrow aB \mid CD$
$B \rightarrow Bb \mid \varepsilon$
$C \rightarrow c \mid \varepsilon$
$D \rightarrow d$

First Set: Algorithm

- Compute the First set for each nonterminal iteratively

```
for each nonterminal A
  First(A) = {}
while some First set changed
  for each A → X1X2...Xn
    k = 1
    continue = true
    while continue == true and k<=n
      add First(Xk) – {ε} to First(A)
      if ε ∉ First(Xk)
        continue = false
      k++
    if continue == true
      add ε to First(A)
```

Why iterative ?

First Set: Algorithm

	A	B	C	D
init	{}	{}	{}	{}
round-1	{a}	{b}	{ε}	{d, ε}
round-2	{a, ε, d}	{b}	{ε}	{d, ε}
round-3	{a, ε, d}	{b}	{ε}	{d, ε}

The same results, so iteration stops

$A \rightarrow aB \mid CD$
$B \rightarrow bC$
$C \rightarrow \varepsilon$
$D \rightarrow d \mid \varepsilon$

Why Follow ?

$ ……b A

Stack

b…………

Tokens

$$A \rightarrow a\,B \mid \epsilon \mid c\,D$$

✓

if b can Follow A

Follow Set: Definition

- For a nonterminal **A**, if there exists a derivation from the start nonterminal **$S \Rightarrow^* \alpha A a \beta$**, then **a ∈ Follow(A)**
- If **$S \Rightarrow^* \alpha A$**, then **\$ ∈ Follow(A)**

E.g.

$ always in Follow set of start symbol

grammar

A	→	a*BD*	|	*CC*
B	→	a		
C	→	b*D*e		
D	→	d		

`Follow(A) = {$}`

`Follow(B) = {d}`

`Follow(C) = {b, $}`

`Follow(D) = {e, $}`

Follow Set: Definition

- For a nonterminal **A**, if there exists a derivation from the start nonterminal **$S \Rightarrow^* \alpha A a \beta$ ($a \neq \varepsilon$)**, then **$a \in$ Follow(A)**
- If **$S \Rightarrow^* \alpha A$**, then **$\$ \in$ Follow(A)**

Exercise:

Follow(A) =	{$}
Follow(B) =	{d, $}
Follow(C) =	{d, e, $}
Follow(D) =	{e, $}

Another grammar

$A \rightarrow \mathtt{a}BD \mid CC$

$B \rightarrow \mathtt{a}$

$C \rightarrow D\mathtt{e}$

$D \rightarrow \mathtt{d} \mid \varepsilon$

Follow Set: Properties

1. If **A** is the start symbol, **$\$ \in$ Follow(A)**
2. For any nonterminal **A**, **$\varepsilon \notin$ Follow(A)**
3. If **A –> αBγ** then **First(γ) – {ε} $\subseteq$ Follow(B)**
4. If **A –> αBγ** and **$\gamma \Rightarrow^* \varepsilon$** then **Follow(A) $\subseteq$ Follow(B)**

Follow Set: Algorithm

- Compute the Follow set for each nonterminal iteratively

```
for each nonterminal A
  if A is start-symbol
    Follow(A)={$}
  else
    Follow(A)={}
while some Follow set changed
  for each A → X1X2...Xn
    for each Xi that is a nontermianl
      add First(Xi+1Xi+2...Xn) – {ε} to Follow(Xi)
      if ε ∈ First(Xi+1Xi+2...Xn)
        add Follow(A) to Follow(Xi)
```

3rd property

4th property

Follow Set: Algorithm

First	S	A	B	C
	{e}	{e}	{b}	{e}

Follow	S	A	B	C
init	{$}	{}	{}	{}
round-1	{$}	{b, a}	{$}	{b, a}
round-2	{$}	{b, a}	{$}	{b, a}

The same results, so iteration stops

$S \rightarrow AB$
$A \rightarrow eC$
$B \rightarrow bAa$
$C \rightarrow e$

Example: Compute First/Follow Set

```
E → T E'
E' → addop T E' | ε
addop → + | -
T → F T'
T' → mulop F T' | ε
mulop → *
F → ( E ) | id
```

First(E) = { **(**, **id** }

First(E') = { **+**, **-**, **ε** }

First(addop) = { **+**, **-** }

First(T) = { **(**, **id** }

First(T') = { *****, **ε** }

First(mulop) = { ***** }

First(F) = { **(**, **id** }

Follow(E) = { **$**, **)** }

Follow(E') = { **$**, **)** }

Follow(addop) = { **(**, **id** }

Follow(T) = { **$**, **)**, **+**, **-** }

Follow(T') = { **$**, **)**, **+**, **-** }

Follow(mulop) = { **(**, **id** }

Follow(F) = { **$**, **)**, **+**, **-**, ***** }

Example:

E → T E'
E' → + T E' | ε
T → F T'
T' → * F T' | ε
F → (E) | id

	FIRST
E	{ (, id }
E'	{ +, ε }
T	{ (, id }
T'	{ *, ε }
F	{ (, id }

F → (E) | id

FIRST(F) = { (, id }

T' → * F T' | ε

FIRST(T') = { *, ε }

E' → + T E' | ε

FIRST(E') = { +, ε }

T → F T'

FIRST(T) = FIRST(F) = { (, id }

E → T E'

FIRST(E) = FIRST(T) = { (, id }

Example:

E → T E'
E' → + T E' | ε
T → F T'
T' → * F T' | ε
F → (E) | id

FOLLOW(E)

E is the start symbol

$ ε FOLLOW(E)

F → (E)

) ε FOLLOW(E)

FOLLOW(E) = { $,) }

FOLLOW(E')

E → T E' & E' → + T E'

.........E■....... → ....TE'■........

- FOLLOW(E) is contained in FOLLOW(E')
- { $,) } is contained in FOLLOW(E')

FOLLOW(E') = { $,) }

Example:

E → T E'
E' → + T E' | ε
T → F T'
T' → * F T' | ε
F → (E) | id

	FIRST
E	{ (, id }
E'	{ +, ε }
T	{ (, id }
T'	{ *, ε }
F	{ (, id }

FOLLOW(T)

E → T **E'** & E' → + T **E'**

FIRST(E') – { ε } is contained in FOLLOW(T)

→ { + } is contained in FOLLOW(T)

ε belongs to FIRST(E')

→ FOLLOW(E) is contained in FOLLOW(T)

→ { $,) } is contained in FOLLOW(T)

FOLLOW(T) = { +, $,) }

Example:

E → T E'
E' → + T E' | ε
T → F T'
T' → * F T' | ε
F → (E) | id

	FIRST
E	{ (, id }
E'	{ +, ε }
T	{ (, id }
T'	{ *, ε }
F	{ (, id }

FOLLOW(T')

T → F T' & T' → * F T'

FOLLOW(T) is contained in FOLLOW(T')

→ { +, $,) } is contained in FOLLOW(T')

FOLLOW(T') = { +, $,) }

Example:

E → T E'
E' → + T E' | ε
T → F T'
T' → * F T' | ε
F → (E) | id

	FIRST
E	{ (, id }
E'	{ +, ε }
T	{ (, id }
T'	{ *, ε }
F	{ (, id }

FOLLOW(F)

T → F **T'** & T' → * F **T'**

FIRST(T') – { ε } is contained in FOLLOW(F)

→ { * } is contained in FOLLOW(F)

ε belongs to FIRST(T')

→ FOLLOW(T) is contained in FOLLOW(F)

→ { +, $,) } is contained in FOLLOW(F)

FOLLOW(F) = { *, +, $,) }

Example:

E → T E'
E' → + T E' | ε
T → F T'
T' → * F T' | ε
F → (E) | id

	FIRST
E	{ (, id }
E'	{ +, ε }
T	{ (, id }
T'	{ *, ε }
F	{ (, id }

	FOLLOW
E	{ $,) }
E'	{ $,) }
T	{ +, $,) }
T'	{ +, $,) }
F	{ *, +, $,) }

Back to LL(1) Parsing

LL(1) Parsing

- Parsing Table
  - if the stack top is **N**, and the lookahead token is **T**, then entry **[N, T]** in the table is the production rule to use

	Parsing Stack	Input	Action
1	…	…	…
2	…	…	…
3	**$** … *S*	**(…$**	*S* → (*S*) *S*
4	…	…	…
5	…	…	…

next token *(terminal)*

	(	)	$
S	S → (S) S	…	…

stack top
(nonterminal)

LL(1) Parsing

- <u>Parsing Table Construction</u>

  Given $A \rightarrow \alpha$

  - for each token a in First(α), add $A \rightarrow \alpha$ to the entry [A, a]
  - if $\varepsilon \in$ First(α), for each a in Follow(A), add $A \rightarrow \alpha$ to entry [A, a]

$S \rightarrow (\; S \;) \; S$
$S \rightarrow \varepsilon$

First(**(** S **)** S) = { **(** }

First(ε) = { ε } Follow(S) = { **)**, **$** }

	(	**)**	**$**
S	S → (S) S	S → ε	S → ε

LL(1) Parsing

- <u>Parsing Table Construction</u>

Given $A \rightarrow \alpha$

- for each token a in First(α), add $A \rightarrow \alpha$ to the entry [A, a]
- if $\varepsilon \in$ First(α), for each a in Follow(A), add $A \rightarrow \alpha$ to entry [A, a]

Exercise:

$$S \rightarrow A$$
$$A \rightarrow (\ A\ )\ A$$
$$A \rightarrow \varepsilon$$

	(	)	$
S	**S → A**		**S → A**
A	**A → (A) A**	**A → ε**	**A → ε**

LL(1) Parsing

- Parsing Table Construction: Example

r1	*E* → *T E′*
r2	*E′* → *addop T E′*
r3	*E′* → *ε*
r4	*addop* → **+**
r5	*addop* → **-**
r6	*T* → *F T′*
r7	*T′* → *mulop F T′*
r8	*T′* → *ε*
r9	*mulop* → *****
r10	*F* → **(** *E* **)**
r11	*F* → **id**

	(	**id**	**)**	**+**	**-**	*****	**$**
E	r1	r1					
E'			r3	r2	r2		r3
addop				r4	r5		
T	r6	r6					
T'			r8	r8	r8	r7	r8
mulop						r9	
F	r10	r11					

LL(1) Parsing

- LL(1) Grammar
  - A grammar is an **LL(1) grammar** if the associated LL(1) parsing table has at most one production in each table entry
  - Cannot be ambiguous
  - A subset of CFG

$$S \rightarrow A$$
$$A \rightarrow (A) A$$
$$A \rightarrow \varepsilon$$

	(	)	$
S	**S → A**		**S → A**
A	**A → (A) A**	**A → ε**	**A → ε**

LL(1) Parsing: Algorithm

```
push start symbol S onto stack
while stack top ≠ $ and next token ≠ $
  if stack top is a and a == next token
    pop stack
    advance input
  else if stack top is A and next token is a
          and [A,a] has rule A → X1X2...Xn
    pop stack
    for i from n to 1
      push Xi onto stack
  else
    error
if stack top == next token == $
  accept
else
  error
```

Issues Related to LL(1)

A Grammar is LL(1) iff

$A \rightarrow \alpha \mid \beta$ ⇨ $First(\alpha) \cap First(\beta) = \Phi$

$A \rightarrow \alpha \mid \beta$
St $\beta \Rightarrow^* \varepsilon$ ⇨ $First(\alpha) \cap Follow(A) = \Phi$

Left Recursion

- Left recursion often makes the grammar non-LL(1)

```
exp → exp addop term | term
addop → + | -
term → term mulop factor | factor
mulop → * | /
factor → ( exp ) | number
```

First(exp addop term) = { **(**, **number** }

First(term) = { **(**, **number** }

	(	**number**	**...**
exp	*exp → exp addop term* *exp → term*	*exp → exp addop term* *exp → term*	

Left Recursion

- **Rewriting**: break it into two rules: (i) generate base case first and (ii) generate the repetition using right recursion

$$A \rightarrow A\ \alpha\ |\ \beta$$

$$\Downarrow$$

$$A \rightarrow \beta\ A'$$
$$A' \rightarrow \alpha\ A'\ |\ \varepsilon$$

right recursion

$$A \rightarrow A\alpha_1 | A\alpha_2 | \ldots | A\alpha_n | \beta_1 | \beta_2 | \ldots | \beta_m$$

$$\Downarrow$$

$$A \rightarrow \beta_1 A' | \beta_2 A' | \ldots | \beta_m A'$$
$$A' \rightarrow \alpha_1 A' | \alpha_2 A' | \ldots | \alpha_n A' | \varepsilon$$

General Form

α and β are strings of terminals and nonterminals and β does not begin with A

Left Recursion

- **Exercise**

```
A → A α | β
```

⇩

```
A  → β A'
A' → α A' | ε
```

```
exp → exp addop term | term
```

⇩

```
exp  → term exp'
exp' → addop term exp' | ε
```

Left Recursion

- Example

```
exp → exp addop term | term
addop → + | -
term → term mulop factor | factor
mulop → *
factor → ( exp ) | number
```

```
exp → term exp′
exp′ → addop term exp′ | ε
addop → + | -
term → factor term′
term′ → mulop factor term′ | ε
mulop → *
factor → ( exp ) | number
```

Left Factoring

- **Issue**: when grammar rule choices share a common prefix, look ahead one symbol may not be sufficient to determine the rule
- **Rewriting**: take the common part out and add a new nonterminal

$A \rightarrow \alpha\ \beta \mid \alpha\ \gamma$

⇩

$A \rightarrow \alpha\ A'$
$A' \rightarrow \beta \mid \gamma$

if-stmt → **if** **(***exp***)** *stmt*
  | **if** **(***exp***)** *stmt* **else** *stmt*

⇩

if-stmt → **if** **(***exp***)** *stmt* *else-part*
else-part → **else** *stmt* | ε

Summary

Top-Down Parsing

- Backtracking Parsing ("brute force")
- Predictive Parsing (lookahead)
  - **Recursive Descent Parsing**
    - a func for a nonterminal
    - leverage call stack
  - **LL(1) Parsing**
    - use explicit stack
    - First and Follow sets
    - parsing table-driven

Common Issues:

- left recursion
- common prefix

SAMPLE PROBLEMS

Example

$S \rightarrow A \mid B\ C$
$A \rightarrow a\ A \mid \varepsilon$
$B \rightarrow b\ B \mid \varepsilon$
$C \rightarrow c\ C \mid d\ C \mid \varepsilon$

	FIRST	FOLLOW
S	a,b,c,d,ε	\$
A	a,ε	\$
B	b,ε	c,d,\$
C	c,d,ε	\$

	a	b	c	d	\$
S	$S \rightarrow A$	$S \rightarrow B\ C$	$S \rightarrow B\ C$	$S \rightarrow B\ C$	$S \rightarrow A$ $S \rightarrow B\ C$
A	$A \rightarrow a\ A$				$A \rightarrow \varepsilon$
B		$B \rightarrow b\ B$	$B \rightarrow \varepsilon$	$B \rightarrow \varepsilon$	$B \rightarrow \varepsilon$
C			$C \rightarrow c\ C$	$C \rightarrow d\ C$	$C \rightarrow \varepsilon$

Example

LEXP → ATOM | LIST
ATOM → num | id
LIST → (LSEQ)
LSEQ → LSEQ LEXP | LEXP

LEXP → ATOM | LIST
ATOM → num | id
LIST → (LSEQ)
LSEQ → LEXP LSEQ’
LSEQ’ → LEXP LSEQ’ | ε

	FIRST	FOLLOW
LEXP	num, id, (	$, num, id, (,)
ATOM	num, id	$, num, id, (,)
LIST	(	$, num, id, (,)
LSEQ	num, id, (	)
LSEQ’	num, id, (, ε	)

Example

LEXP → ATOM | LIST
ATOM → num | id
LIST → (LSEQ)
LSEQ → LEXP LSEQ'
LSEQ' → LEXP LSEQ' | ε

	FIRST	FOLLOW
LEXP	num, id, (	\$, num, id, (,)
ATOM	num, id	\$, num, id, (,)
LIST	(	\$, num, id, (,)
LSEQ	num, id, (	)
LSEQ'	num, id, (, ε	)

LEXP → ATOM | LIST FIRST(ATOM) ∩ FIRST(LIST) = ∅

ATOM → num | id FIRST(num) ∩ FIRST(id) = ∅

LSEQ' → LEXP LSEQ' | ε FIRST(LEXP) ∩ FOLLOW(LSEQ') = ∅

⇒ Grammar is LL(1)

Example

LEXP → ATOM | LIST
ATOM → num | id
LIST → (LSEQ)
LSEQ → LEXP LSEQ'
LSEQ' → LEXP LSEQ' | ε

	FIRST	FOLLOW
LEXP	num, id, (	$, num, id, (,)
ATOM	num, id	$, num, id, (,)
LIST	(	$, num, id, (,)
LSEQ	num, id, (	)
LSEQ'	num, id, (, ε	)

	num	id	(	)	$
LEXP	LEXP → ATOM	LEXP → ATOM	LEXP → LIST		
ATOM	ATOM → num	ATOM → id			
LIST			LIST → (LSEQ)		
LSEQ	LSEQ→LEXP LSEQ'	LSEQ→LEXP LSEQ'	LSEQ→LEXP LSEQ'		
LSEQ'	LSEQ'→LEXP LSEQ'	LSEQ'→LEXP LSEQ'	LSEQ'→LEXP LSEQ'	LSEQ'→ε	