CRICOS PROVIDER 00123M

School of Computer Science

COMP SCI 2000 Computer Systems
Lecture 18

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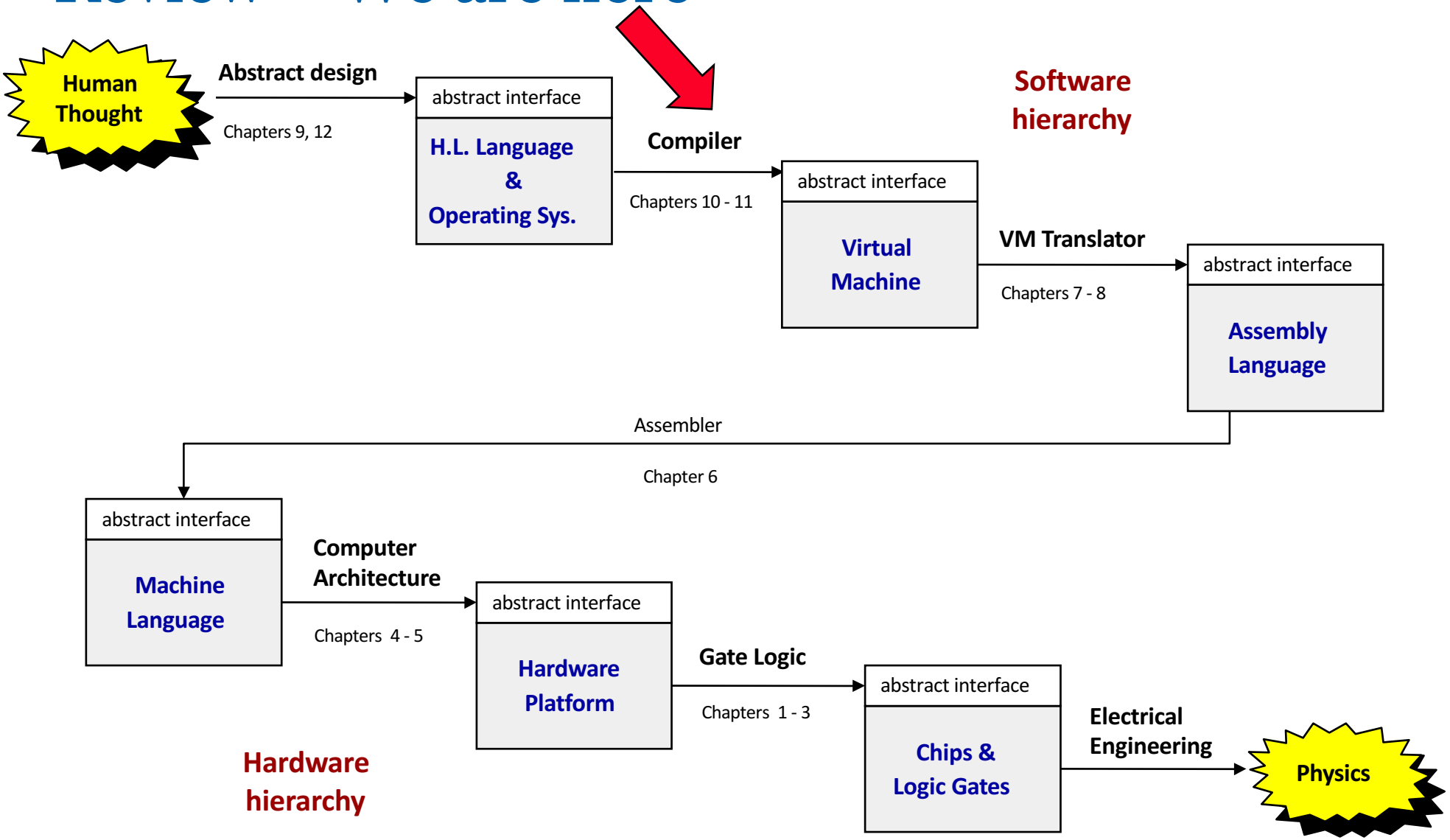
seekLIGHT

Review – We are here



Review – Last Lecture

- In the last lecture we showed
  - What syntax analysis is
  - What tokenising is
  - What parsing is
  - Potential problems of ambiguous statements
  - Introduction to Grammars

Preview

- In this lecture we will show
  - More detail on grammars
  - The Jack grammar
  - The Jack Tokeniser
  - The Jack Parser

Recursive descent parsing

grammar

```
program:        statement
statement:      whileStatement |
                ifStatement |
                'statement' ';' |
                '{' statements '}'
whileStatement: 'while' '(' 'expression' ')' statement
ifStatement:    'if' '(' 'expression' ')'
                statement ( 'else' statement )?
statements:     statement*
```

code sample

```
while (expression)
{
   statement;
   statement;
   while (expression)
   {
      while (expression)
         statement;
         statement;
   }
}
```

- LL(1) grammars: the first token determines the rule
- In other grammars you have to look ahead more tokens
- Jack is almost LL(1).

Parser implementation: a set of parsing functions one for each rule:

- `parseStatement()`
- `parseWhileStatement()`
- `parseIfStatement()`
- `parseStatements()`

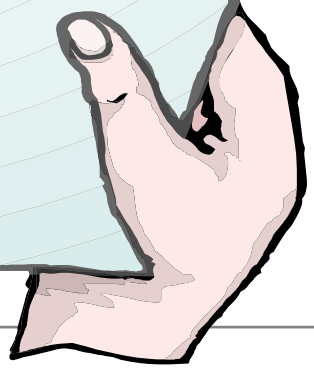
Do worksheet Question 1

A linguist view on parsing

Parsing:

One of the mental processes involved in sentence comprehension, in which the listener determines the syntactic categories of the words, joins them up in a tree, and identifies the subject, object, and predicate, a prerequisite to determining who did what to whom from the information in the sentence.

(Steven Pinker,
The Language Instinct)



The Jack grammar

Lexical elements:	The Jack language includes five types of terminal elements (tokens):
keyword:	**'class'** | **'constructor'** | **'function'** | **'method'** | **'field'** | **'static'** | **'var'** | **'int'** | **'char'** | **'boolean'** | **'void'** | **'true'** | **'false'** | **'null'** | **'this'** | **'let'** | **'do'** | **'if'** | **'else'** | **'while'** | **'return'**
symbol:	**'{'** | **'}'** | **'('** | **')'** | **'['** | **']'** | **'.'** | **','** | **';'** | **'+'** | **'-'** | **'*'** | **'/'** | **'&'** | **'|'** | **'<'** | **'>'** | **'='** | **'~'**
integerConstant:	A decimal number in the range 0 .. 32767.
StringConstant	'"' A sequence of Unicode characters not including double quote or newline '"'
identifier:	A sequence of letters, digits, and underscore ('_') not starting with a digit.
Program structure:	A Jack program is a collection of classes, each appearing in a separate file. The compilation unit is a class. A class is a sequence of tokens structured according to the following context free syntax:
class:	**'class'** className **'{'** classVarDec* subroutineDec* **'}'**
classVarDec:	(**'static'** | **'field'**) type varName (',' varName)* ';'
type:	**'int'** | **'char'** | **'boolean'** | className
subroutineDec:	(**'constructor'** | **'function'** | **'method'**) (**'void'** | type) subroutineName **'('** parameterList **')'** subroutineBody
parameterList:	((type varName) (',' type varName)*)?
subroutineBody:	**'{'** varDec* statements **'}'**
varDec:	**'var'** type varName (',' varName)* ';'
className:	identifier
subroutineName:	identifier
varName:	Identifier

'x': x appears verbatim

x: x is a language construct

x?: x appears 0 or 1 times

x*: x appears 0 or more times

x|y: either x or y appears

x y: x appears, then y.

The Jack grammar (cont.)

Statements:

statements:	statement*
statement:	letStatement | ifStatement | whileStatement | doStatement | returnStatement
letStatement:	'let' varName ('[' expression ']')? '=' expression ';'
ifStatement:	'if' '(' expression ')' '{' statements '}' ('else' '{' statements '}')?
whileStatement:	'while' '(' expression ')' '{' statements '}'
doStatement:	'do' subroutineCall ';'
ReturnStatement	'return' expression? ';'

Expressions:

expression:	term (op term)*
term:	integerConstant | stringConstant | keywordConstant | varName | varName '[' expression ']' | subroutineCall | '(' expression ')' | unaryOp term
subroutineCall:	subroutineName '(' expressionList ')' | (className | varName) '.' subroutineName '(' expressionList ')'
expressionList:	(expression (',' expression)*)?
op:	'+' | '-' | '*' | '/' | '&' | '|' | '<' | '>' | '='
unaryOp:	'-' | '~'
KeywordConstant:	'true' | 'false' | 'null' | 'this'

Do worksheet Question 2

'x':	x appears verbatim
x:	x is a language construct
x?:	x appears 0 or 1 times
x*:	x appears 0 or more times
x|y:	either x or y appears
x y:	x appears, then y.

Jack syntax analyser in action

```
class Bar
{
    method Fraction foo(int y)
    {
        var int temp; // a variable
        let temp = (xxx+12)*-63;
         ...
    ...
```

Syntax analyzer

```
<vardec>
  <keyword> var </keyword>
  <keyword> int </keyword>
  <identifier> temp </identifier>
  <symbol> ; </symbol>
</vardec>
<statements>
 <statement>
  <letstatement>
   <keyword> let </keyword>
   <identifier> temp </identifier>
   <symbol> = </symbol>
   <expression>
     <term>
       <symbol> ( </symbol>
       <expression>
         <term>
           <varName>
            <identifier> xxx </identifier>
           </varName>
         </term>
         <symbol> + </symbol>
         <term>
          <integerConstant> 12 </integerConstant>
         </term>
         ...
```

Syntax analyzer

- Using the language grammar, a programmer can write a syntax analyser program (parser)
- The syntax analyser takes a source text file and attempts to match it on the language grammar
- If successful, it can generate a parse tree in some structured format, e.g. XML.

The syntax analyser's algorithm shown in this slide:

- If xxx is non-terminal, output:

  <xxx>
  Recursive code for the body of **xxx**
  </xxx>

- If **xxx** is terminal (keyword, symbol, constant, or identifier), output:

  <xxx>
  xxx value
  </xxx>

Do worksheet question 3

JackTokeniser: a tokeniser for the Jack language (proposed)

JackTokenizer: Removes all comments and white space from the input stream and breaks it into Jack-language tokens, as specified by the Jack grammar.			
Routine	**Arguments**	**Returns**	**Function**
Constructor	input file / stream	--	Opens the input file/stream and gets ready to tokenize it.
`hasMoreTokens`	--	Boolean	Do we have more tokens in the input?
`advance`	--	--	Gets the next token from the input and makes it the current token. This method should only be called if *hasMoreTokens()* is true. Initially there is no current token.
`tokenType`	--	`KEYWORD`, `SYMBOL`, `IDENTIFIER`, `INT_CONST`, `STRING_CONST`	Returns the type of the current token.
`keyWord`	--	`CLASS`, `METHOD`, `FUNCTION`, `CONSTRUCTOR`, `INT`, `BOOLEAN`, `CHAR`, `VOID`, `VAR`, `STATIC`, `FIELD`, `LET`, `DO`, `IF`, `ELSE`, `WHILE`, `RETURN`, `TRUE`, `FALSE`, `NULL`, `THIS`	Returns the keyword which is the current token. Should be called only when `tokenType()` is `KEYWORD`.

JackTokenizer (cont.)

`symbol`	--	Char	Returns the character which is the current token. Should be called only when `tokenType()` is `SYMBOL`.
`identifier`	--	String	Returns the identifier which is the current token. Should be called only when `tokenType()` is `IDENTIFIER`
`intVal`		Int	Returns the integer value of the current token. Should be called only when `tokenType()` is `INT_CONST`
`stringVal`		String	Returns the string value of the current token, without the double quotes. Should be called only when `tokenType()` is `STRING_CONST`.

CompilationEngine: a recursive top-down parser for Jack

The CompilationEngine effects the actual compilation output.

- It gets its input from a JackTokeniser and emits its parsed structure into an output file/stream.
- The output is generated by a series of compilexxx() routines, one for every syntactic element xxx of the Jack grammar.
- The contract between these routines is that each compilexxx() routine should read the syntactic construct xxx from the input, advance() the tokeniser exactly beyond xxx, and output the parsing of xxx.
  Thus, compilexxx()may only be called if indeed xxx is the next syntactic element of the input.
- In the first version of the compiler, which we now build, this module emits a structured printout of the code, wrapped in XML tags (defined in the specs of project 10). In the final version of the compiler, this module generates executable VM code (defined in the specs of project 11).
- In both cases, the parsing logic and module API are exactly the same.

CompilationEngine (cont.)

Routine	Arguments	Returns	Function
Constructor	Input stream/file Output stream/file	--	Creates a new compilation engine with the given input and output. The next routine called must be `compileClass()`.
`CompileClass`	--	--	Compiles a complete class.
`CompileClassVarDec`	--	--	Compiles a static declaration or a field declaration.
`CompileSubroutine`	--	--	Compiles a complete method, function, or constructor.
`compileParameterList`	--	--	Compiles a (possibly empty) parameter list, not including the enclosing "`()`".
`compileVarDec`	--	--	Compiles a `var` declaration.

CompilationEngine (cont.)

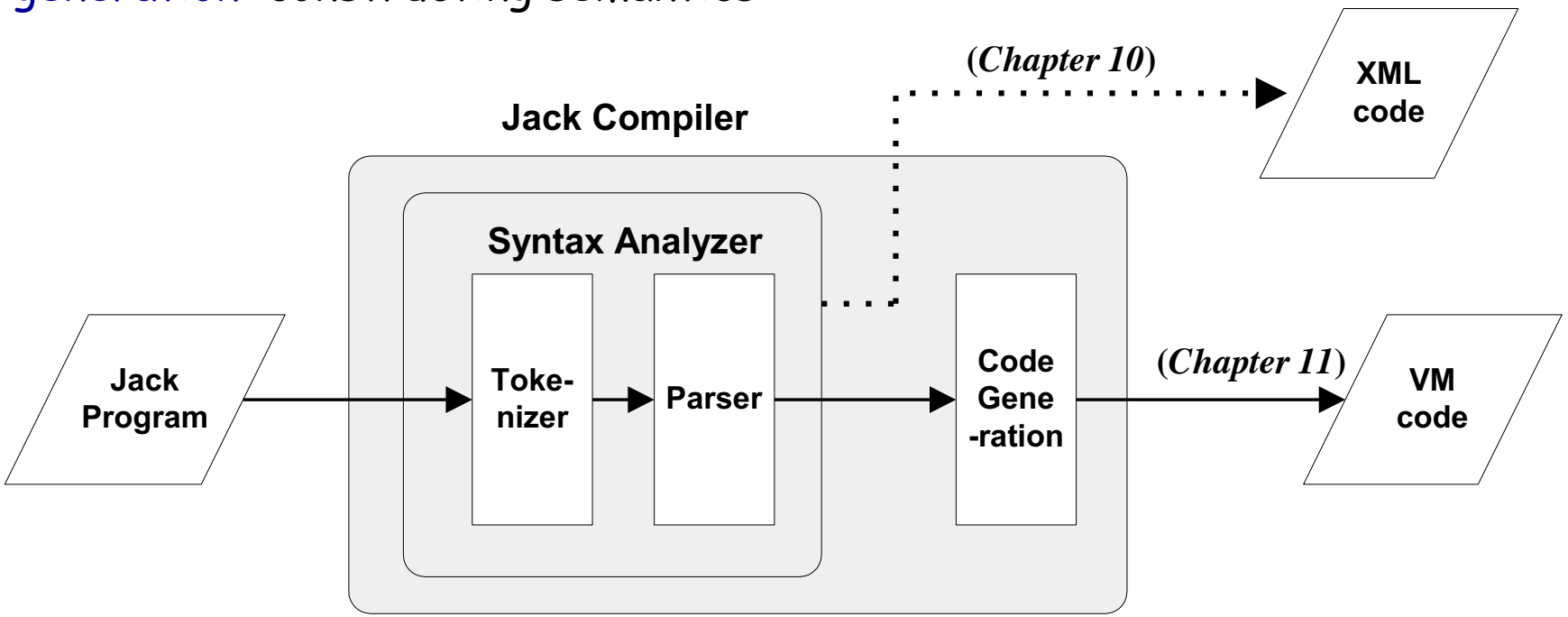
`compileStatements`	--	--	Compiles a sequence of statements, not including the enclosing "{}".
`compileDo`	--	--	Compiles a `do` statement.
`compileLet`	--	--	Compiles a `let` statement.
`compileWhile`	--	--	Compiles a `while` statement.
`compileReturn`	--	--	Compiles a `return` statement.
`compileIf`	--	--	Compiles an `if` statement, possibly with a trailing `else` clause.

CompilationEngine (cont.)

`CompileExpression`	--	--	Compiles an expression.
`CompileTerm`	--	--	Compiles a *term*. This routine is faced with a slight difficulty when trying to decide between some of the alternative parsing rules. Specifically, if the current token is an identifier, the routine must distinguish between a variable, an array entry, and a subroutine call. A single look-ahead token, which may be one of "[", "(", or "." suffices to distinguish between the three possibilities. Any other token is not part of this term and should not be advanced over.
`CompileExpressionList`	--	--	Compiles a (possibly empty) comma-separated list of expressions.

Summary and next step

- Syntax analysis: understanding syntax
- Code generation: constructing semantics



The code generation challenge:

- Extend the syntax analyser into a full-blown compiler that, instead of generating passive XML code, generates executable VM code
- Two challenges: (a) handling data, and (b) handling commands.

Perspective

- The parse tree can be constructed on the fly
- Syntax analyzers can be built using:
  - **`Lex`** tool for tokenizing
  - **`Yacc`** tool for parsing
  - Do everything from scratch (our approach …)
- The Jack language is intentionally simple:
  - Statement prefixes: **`let`**, **`do`**, …
  - No operator priority
  - No error checking
  - Basic data types, etc.
- Richer languages require more powerful compilers
- The Jack compiler: designed to illustrate the key ideas that underlie modern compilers, leaving advanced features to more advanced courses
- Industrial-strength compilers:
  - Have good error diagnostics
  - Generate tight and efficient code
  - Support parallel (multi-core) processors.