Course Summary

COMP 520: Compiler Design (4 credits)

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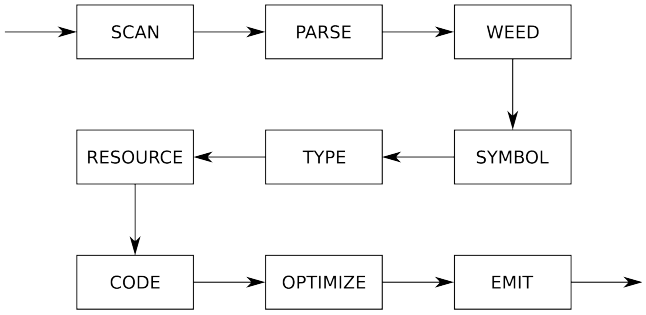
MWF 9:30-10:30, TR 1080

http://www.cs.mcgill.ca/~cs520/2018/



Bob, from Accounting

Announcements (Wednesday, April 11)

Milestones

- Peephole due: Friday, April 13th 11:59 PM
- Final report due: Sunday, April 15th 11:59 PM (Monday at the latest, but 24hrs before your meeting)
- Course evaluations! Please let us know what you think of the course!
- Project meeting signup in myCourses (under groups tab). 1 person per team signup

Review classes

- **Today:** Scanner – bytecode generation
- **Monday/(Friday?):** Optimization – native code generation + special topics

Why did we learn about Compilers?

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Language design

Look under-the-hood at how code is transformed for execution

Connect theory (automata/CFG) to practice

CS credits

How does learning about compilers change your view of Programming Language Design?

How does learning about compilers change your view of Programming Language Design?

Funky features are hard to support

Go is weird!

Be careful! Unintended consequences are easy!

Type and semantics rules are quirky, but essential to compilers

For your next compiler, what advice would you give yourself?

For your next compiler, what advice would you give yourself?

*The AST is **essential***

Decouple passes and phases as much as possible

Test, test, test! (automation is key)

Start early!

*Your work is **never** perfect*

Classes can be fun!

Final Exam (100 points)

1. Scanners and Parsers (20 points)
2. Typechecking (10 points)
3. Bytecode Generation (15 points)
4. Optimization (10 points)
5. Native Code Generation (12 points)
6. Garbage Collection (10 points)
7. Special Topics (8 points)
8. GoLite Project (15 points)

Other info

- Emphasis on application
- Virtual machines (JVM and VirtualRISC) and TinyLang cheatsheets included

Studying Tips

- Review Vincent's midterm review
- Review the midterm, if you got something wrong, go back to the notes and figure out the right answer
- Practice real questions like those on the board

Writing tips

- Organize your answers - make is easy for me to find your answers
- Write neatly, don't squish in your answers to make a lot fit on one page
- Start each question on a new page
- Be precise

Scanners+Parsers

Scanners

- Know how to implement a parser/scanner in `flex` or `SableCC`
- Know the limitations and languages that be recognized by regular expressions/DFAs/NFAs

Parsers

- Know what makes a grammar ambiguous, and how to write unambiguous context-free grammars in `bison` or `SableCC`
- Know the limitations and languages that be recognized by context-free grammars

Example

- Give the scanner+parser in either `flex`+`bison` or `SableCC` using no precedence directives

Scanners+Parsers

```
void main(string s) {
   int x, y;                  // comma-separated lists in declarations
   string s;

   x = y = 10;                // an integer constant (no leading zeros)
   s = "Hello" + "World";     // a string constant, concatenation
   write(x);                  // write built-in function, reserved keyword
   {                          // block statements
      y = cube(x);            // function calls
      write(foo(x, y));       // functions can have multiple parameters
   }
}

int cube(int x) {
   return x ** 3;             // exponentiation (right associative)
}

int foo(int x, int y) {
   if (y) {                   // if-else statements
      return y * -1;          // return statements
   } else {
      return x + (3 * y);
   }
}
```

Typechecking

- Know how to express type rules as pseudocode, inference rules, or plain English

Example

- Give the type inference rule for typechecking the + binary expression
- Give the pseudocode and prose for the following type inference rule for typechecking an assignment

$$\frac{\boldsymbol{V}(\boldsymbol{x}) = \boldsymbol{\tau} \quad \boldsymbol{V} \vdash \boldsymbol{E} : \boldsymbol{\sigma} \quad \boldsymbol{\tau} := \boldsymbol{\sigma}}{\boldsymbol{V} \vdash \boldsymbol{x} = \boldsymbol{E} : \boldsymbol{\tau}}$$

Bytecode Generation

- Know how to generate JVM bytecode (Jasmin syntax): directives, types, instructions, labels, etc.
- Know how to access fields, and invoke functions/constructors, etc.
- Know how the baby stack works to compute output (some internals of the JVM)

Example

```
public class Computer
{
   protected bool status;

   public bool SetStatus(String s)
   {
      if (wait() == 0)
      {
         return status = s.equals("on");
      }
      return false;
   }

   public int wait();
}
```

What if `status` was a `Boolean` (with appropriate constructor calls)?

Optimization

- Understand why and how generated code is inefficient
- Know how and when to optimize code, while maintaining the original semantics (soundness)
- Peephole optimization (not static analysis)

Example

```
 iload_0
 iload_1
 if_icmple _else0
 iconst_0
 goto _end0          ⟹        ?
_else0:
 iconst_1
_end0:
 ifne _end1
```

What conditions are necessary for this pattern?

Native Code Generation

- Know the 3 different register allocation schemes covered in this class (naïve, fixed, and basic block)
- Understand the register allocations for each scheme and the associated advantages/disadvantages

Example

Given the following code, write the equivalent VirtualRISC code using the naïve and fixed register allocation schemes ($m = n = k = 2$).

```
public static bool isPrime(int p) {
   int iter = p / 2;
   int current;

   while (iter > 1) {
      current = p / iter;
      current = current * iter;
      if (x == current) {
         return false;
      }
      iter = iter - 1;
   }
   return true;
}
```

Garbage Collection

- Understand workings of garbage collection techniques
- Know the rules for reference counting, mark-and-sweep, and stop-and-copy
- Know what makes record live and dead

Example

```
public void foo(Object a /* id=1 */) {
   int b = 1337;
   Object c = new Object(2);
   {
      c.SetField_1(a)
      c.SetField_2(new Object(3));

      Object d = new Object(4);
      d.SetField_1(c.GetField_2())
      // (a) GIVE THE REFERENCE COUNTS FOR ALL OBJECTS AT THIS POINT
   }

   // (b) SHOW THE PROGRESSION OF MARK-AND-SWEEP AND STOP-AND-COPY AT THIS POINT
   c = a
   // (c) GIVE THE REFERENCE COUNTS FOR ALL OBJECTS AT THIS POINT
}
```

Special Topics

GPUs

- Understand modern GPU architecture at a *high*-level (threads, concurrency, etc.)
- Know the benefits of coalescing memory accesses, and the impact on the number of memory transactions

WebAssembly

- Understand the underlying implementation (i.e. it is a stack machine) at a *high*-level
- Know how the ISA is validated before execution

Examples

- Look at the slides/notes!

My Thoughts

- Language design is a curious topic, where seemingly innocuous changes suddenly create this...

https://xkcd.com/292/

- Semantics are fun! (but hard)
- Compilers are fun! (but a lot of work)
- Hopefully this comes in handy one day!

Thanks...

- To David, who worked hard as your TA
- To you! This class is a ton of work and you worked hard all semester
- To Laurie, for help and support all semester