Source Code Manipulation

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UvA, MSc SE, 30 November 2015

Roadmap

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W50	Legacy and Renovation	TBA
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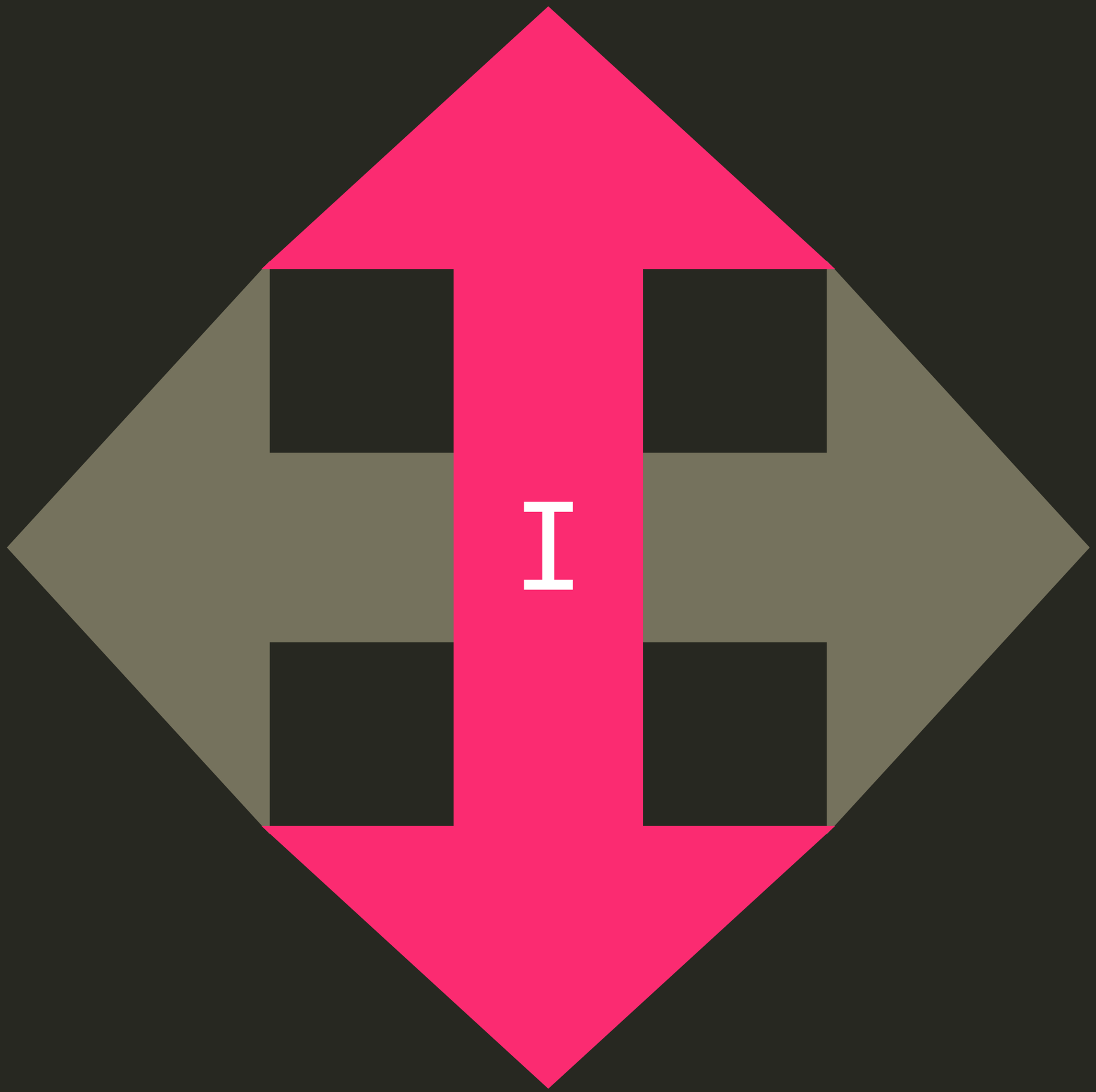
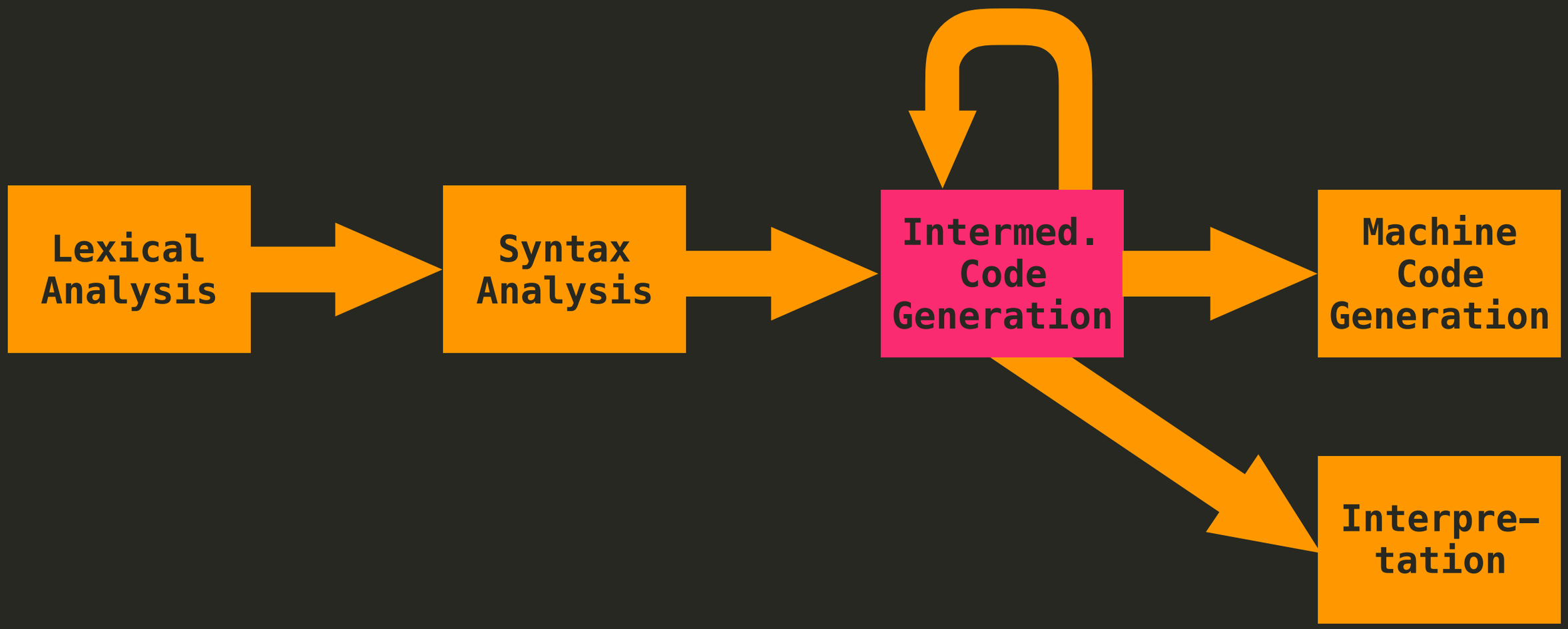


Compiler



D.Grune, K.v.Reeuwijk, H.E.Bal, C.J.H.Jacobs, K.Langendoen, Modern Compiler Design, 2ed, 2012, p. 300.

Generated code

* Preferably
  * avoid any evolution
  * regenerate on sync
* Possibly
  * bidirectional link
* Properties:
  * correctness, speed, size, energy…

F.Ferreira, B.Pientka, Bidirectional Elaboration of Dependently Typed Programs, PPDP 2014.

Supercompilation

* History
* partial evaluation (1964, L.A.Lombardi & B.Raphael?)
* supercompilation (1966, Valentin Turchin)
* local simplification (1975–)
* subgoal abstraction (1975)
* symbolic execution (1976, James C. King)
* mixed computation (1977, Andrei Ershov)
* Futamura projections (1983, Yoshihiko Futamura)
* abstract interpretation (1977, P. & R. Cousot)
* . . .

Supercompilation

* Given is F(X,Y); find G(X) = F(X,z)
  * partial application (currying)
  * partial evaluation (residual)
* Also covers:
  * lazy evaluation
  * theorem proving
  * problem solving

Supercompilation

```
* map f $ map g xs


* map (f . g) xs
```

Supercompilation

```
* let ones = 1:ones
  in map (\ x -> x + 1) ones
```

```
* let twos = 2:twos
  in twos
```

Supercompilation

```
* sum x = case x of
            [] -> 0
            x:xs -> x + sum xs
  range i n = case i>n of
                True -> []
                False -> i:range (i+1) n
  main n = sum (range 0 n)

* main2 i n = if i>n
              then 0
              else i + main2 (i+1) n
  main n = main2 1 n
```

Generative SE

* Program generator
  * a program that produces programs
  * in a high-level language

* Structured program generation
  * any generated program should type check
  * (it will be before running anyway)
  * (any error is a bug in a generator)

Everyone's Doing It!

```
* sqlProg = "SELECT name FROM" +
    tableName + "WHERE id = " + id;
```

```
* sqlProg = new SelectStmt(
        new Column("name"),
        table,
        new WhereClause(new Column("id"),
        id));
```

Everyone's Doing It!

* template<int X, int Y>
  struct Adder
    { enum { result = X + Y }; };

* aspect S
  {
    declare parents:
    Car implements Serializable;
  }

Everyone's Doing It!

```
* expr = `[7 + i];
```

```
* stmt = `[
    if (i > 0) return #[expr];
  ];
```

Staging

* Scala, MetaML, MetaOCaml, …
* Explicit delaying of computation
  * quote
  * unquote
  * run/eval

MetaOCaml

```
let even n = (n mod 2) = 0;;
let square x = x * x;;
let rec powerS n x =
  if n = 0 then .<1>.
  else if even n
       then .<square .~(powerS (n/2) x)>.
       else .<.~x *  .~(powerS (n-1) x)>.;;

let power5 = !. .<fun x -> .~(powerS 5 .<x>.)>.;;
```

Scala

```
def powerS (n : Rep[Int], x : Int) : Rep[Int] = {
  if (n == 0) 1
  else if (n % 2 == 0) {
    val result = powerS(n/2, x)
    result * result
  }
  else x * powerS(n-1, x)
}

def powerTest(n : Rep[Int]) : Rep[Int] = powerS(n, 5)
```

Java + MorphJ

```
class LogMe<class X> extends X {
  <R,A*>[m] for ( public R m(A) : X.methods )
  public R m (A a) {
    R result = super.m(a);
    System.out.println(result);
    return result;
  }
}
```

Java + MorphJ

```
class Listify<Subj> {
  Subj ref;
  Listify(Subj s) {ref = s;}

  <R,A>[m] for (public R m(A): Subj.methods)
  public R m (List<A> a) {
   // … call m for all elements
  }
}
```

Java + SafeGen

```
#defgen MakeDelegator ( input(Class c) => !Abstract(c) ) {
  #foreach( Class c : input(c) ) {
    public class Delegator extends #[c] {
      #foreach(Method m : MethodOf(m, c) & !Private(m)) {
        #[m.Modifiers] #[m.Type] #[m] ( #[m.Formals] ) {
          return super.#[m](#[m.ArgNames]);
        }
      }
    }
  }
}
```

Pigs from Sausages

* Interactive disassembly
  * IDA Pro
* Tool-independent
  * Dava, Boomerang, dcc
* Compiler-specific
  * javac: Mocha, Jad, Jasmin,
    Wingdis, SourceAgain

Decompilation uses

* recover lost source code
* adapt to another platform
* check security-critical code
* find malware
* inspect vulnerabilities
* learn algorithms & data formats

Mike Van Emmerik, http://www.program-transformation.org/Transform/WhyDecompilation

Decompilation

* Load binary code into virtual memory
* Parse / disassemble
* Recognise compilation patterns
* Build control flow graph
* Perform data flow analysis
* Perform control flow analysis
* Restructure intermediate result
* Generate high-level code

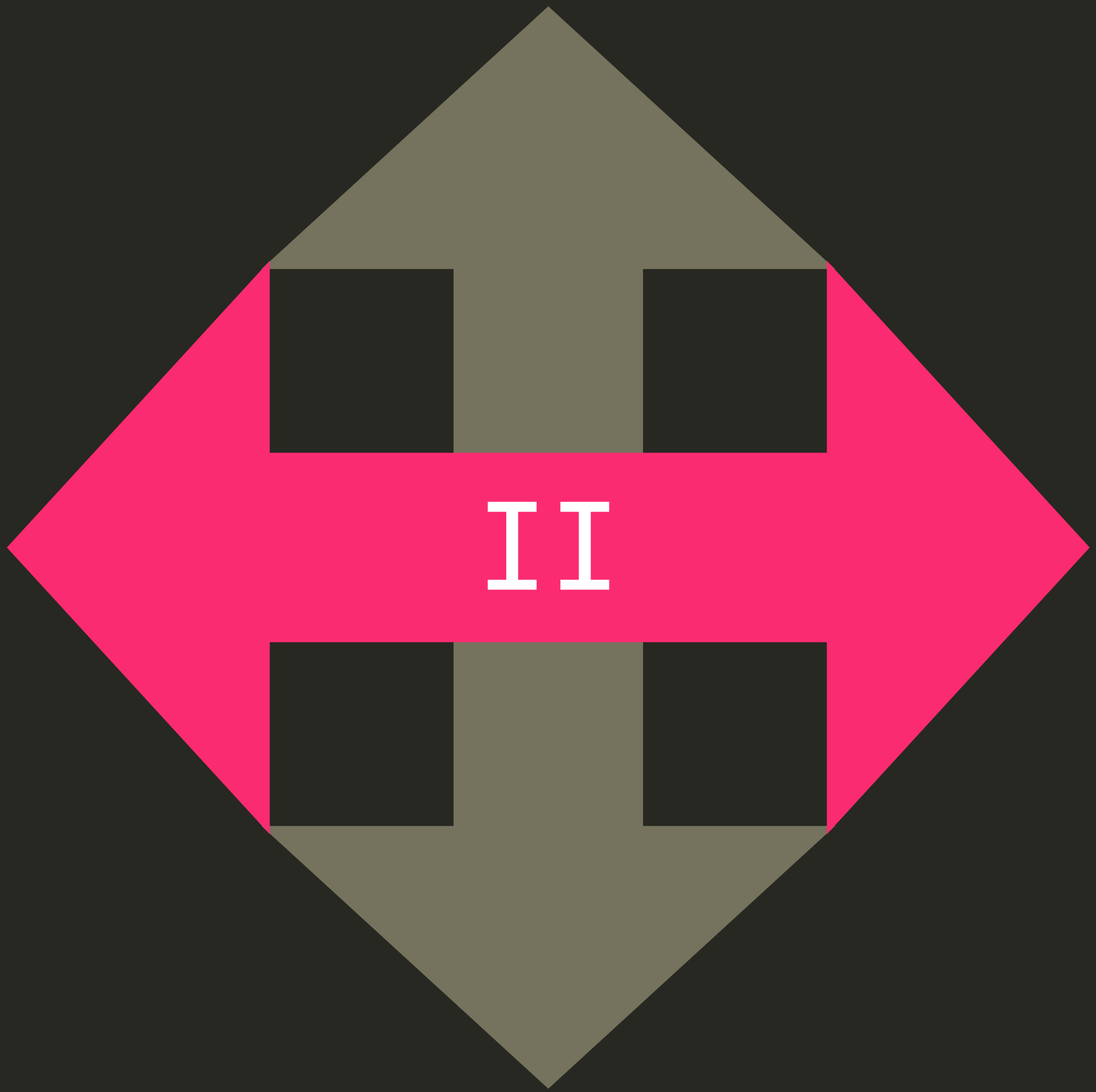
C.Cifuentes, K.J.Gough, Decompilation of Binary Programs, SPE 25(7), 1995

Disasm advice

* Do not underestimate debuggers
  * ptrace, gdb, windbg
  * winice, softice, linice
  * vmware, dosbox, bochs, xen, parallels
* Obfuscation & deobfuscation
  * elfcrypt, upx, burneye, shiva
* Learn system software
* Beware of anti-hacking hacks

Part I: Conclusion

* Compilation and code generation
* Supercompilation
* Generative programming
  * morphing as improved generics
  * staging as guided evaluation
* You want meta-type safety

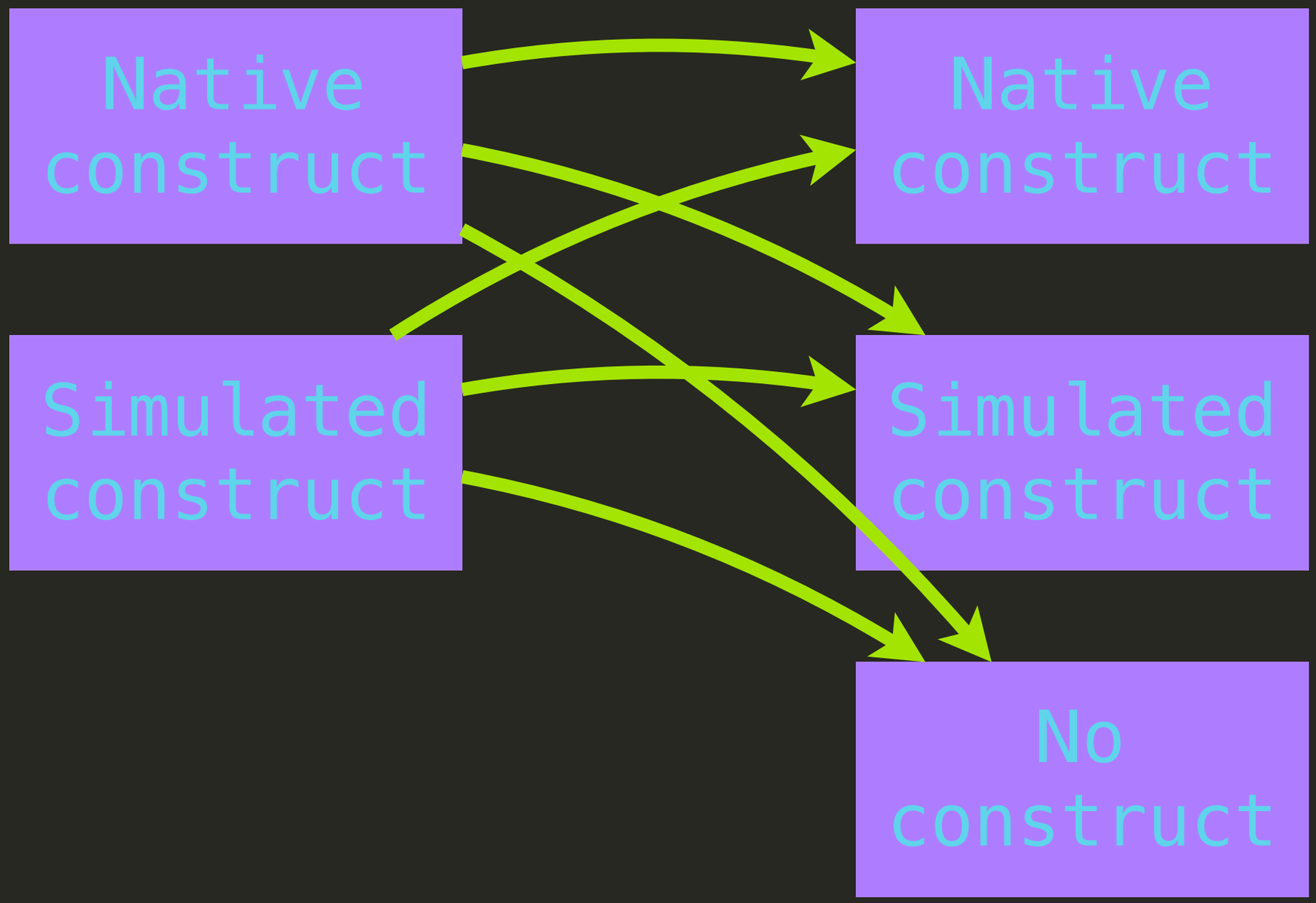


Language Conversion

* Everybody lies.
* Syntax swap is NEVER a solution.
  * not even OS/VS COBOL to VS COBOL II
* Wrapping is NOT a solution!
* Component wrapping COULD be a solution for a while.
* *Two wrongs make a right, almost.*

A.A.Terekhov, C.Verhoef, The Realities of Language Conversions, IEEE Software 2000.

Language Conversion



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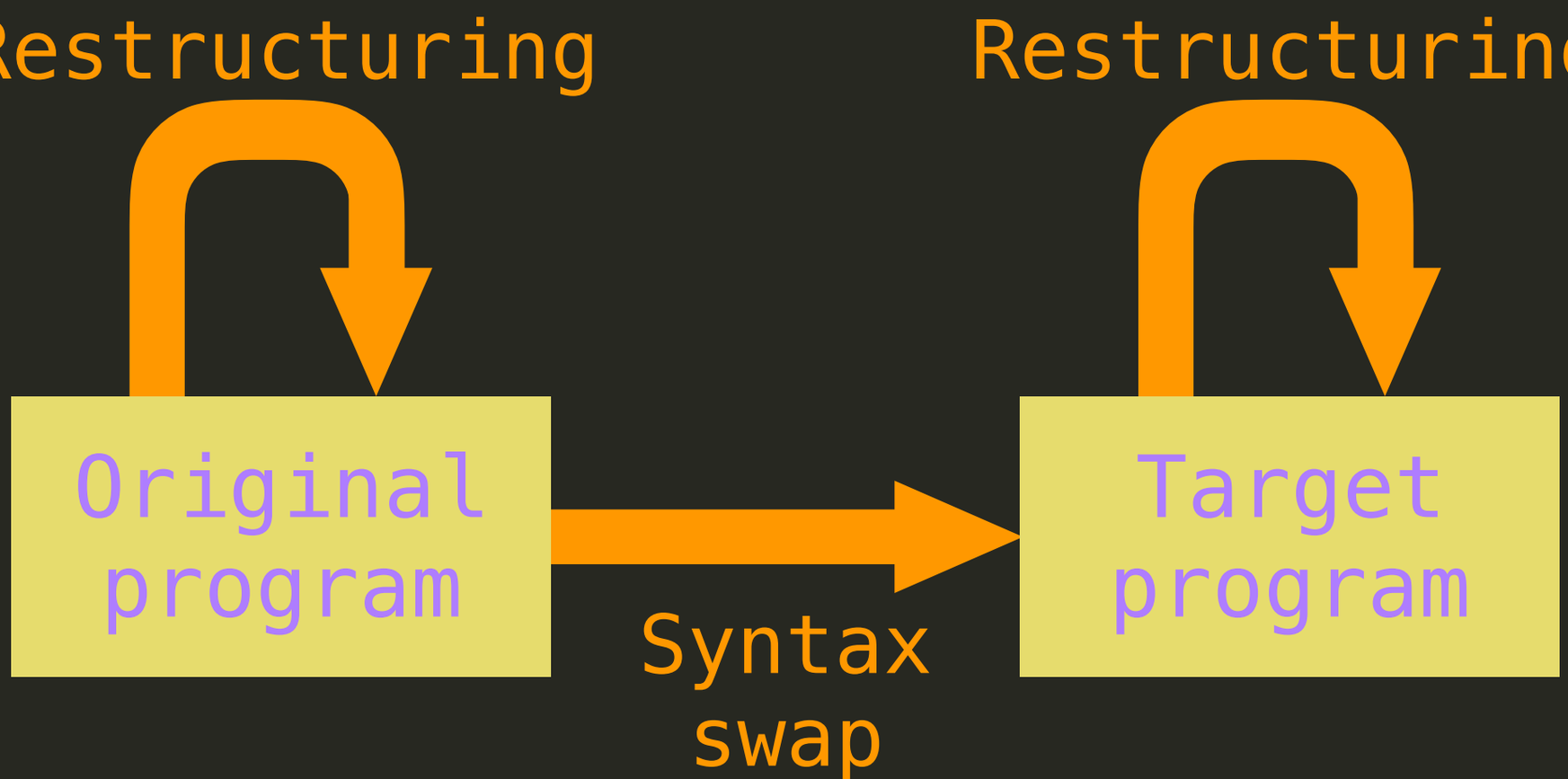


A.A.Terekhov, C.Verhoef, The Realities of Language Conversions, IEEE Software 2000.

Codegen properties

* Correctness
* Speed
* Size
* Memory use
* Network demands
* Energy
* . . .

F.Ferreira, B.Pientka, Bidirectional Elaboration of Dependently Typed Programs, PPDP 2014.

Correct codegen

* semantic preservation
  * …under special conditions
* protect from logical errors
  * verification
  * testing

Bit flip

* Software-Implemented Hardware Fault Tolerance (SIHFT)
* Measurement unit:
  * FIT (Failure in 1000000000 hours ≈114155 years)
* Reasons for SEU (Single Event Upsets)
  * natural radiation
  * chip temperature instability
  * malicious intervention
  * experimental technology
* Known victims
  * Sun, Toyota

M.Heing-Becker, T.Kamph, S.Schupp, Bit-error injection for software developers, CSMR-WCRE 2014

Fast code

* Optimisation
  * traditional semantic-preserving
* Supercompilation
  * partial evaluation
* Folding/unfolding
  * inlining functions

Code optimisation

* By basic blocks
* Construct data dependency graphs
* Convert to SSA
  * (Static Single Assignment)
* Eliminate common subexpressions
* Form a ladder sequence
* Allocate registers, pseudo-, memory…

D.Grune, K.v.Reeuwijk, H.E.Bal, C.J.H.Jacobs, K.Langendoen, Modern Compiler Design, 2ed, 2012, §9.1.2.

Code optimisation

* By rewriting
* Prepare instruction patterns
  * “load constant”, “multiply registers”, “add from memory”, etc
* Traverse the tree bottom-up thrice
  * Instruction collection
  * Instruction selecting
  * Code generation

D.Grune, K.v.Reeuwijk, H.E.Bal, C.J.H.Jacobs, K.Langendoen, Modern Compiler Design, 2ed, 2012, §9.1.4.

Folding/unfolding

* If code occurs several times
  * fold into a function and call it
* If a function is scarcely called
  * unfold its body
* Balancing
  * statically: with thresholds
  * dynamically: search-based

Folding/unfolding

* Function inlining
  * void f
    { ...

```
     print_square( i++ );
    ...
  }
void print_square(int n)
 { printf ("square = %d\n", n*n); }
```

D.Grune, K.v.Reeuwijk, H.E.Bal, C.J.H.Jacobs, K.Langendoen, Modern Compiler Design, 2ed, 2012, §7.3.3.

Folding/unfolding

* Function inlining
  * void f
    { ...

```
      printf ("square = %d\n", (i++)*(i++));
    ...
  }
void print_square(int n)
 { printf ("square = %d\n", n*n); }
```

D.Grune, K.v.Reeuwijk, H.E.Bal, C.J.H.Jacobs, K.Langendoen, Modern Compiler Design, 2ed, 2012, §7.3.3.

Folding/unfolding

* Function inlining
  * void f
    { ...
    {int n=i++;
     printf ("square = %d\n", n*n); }
    ...
  }

```
void print_square(int n)
 { printf ("square = %d\n", n*n); }
```

D.Grune, K.v.Reeuwijk, H.E.Bal, C.J.H.Jacobs, K.Langendoen, Modern Compiler Design, 2ed, 2012, §7.3.3.

Folding/unfolding

* Function inlining + supercompilation
  * void f
    { ...
    {int n=3;
     printf ("square = %d\n", n*n); }
    ...
  }

```
void print_square(int n)
 { printf ("square = %d\n", n*n); }
```

D.Grune, K.v.Reeuwijk, H.E.Bal, C.J.H.Jacobs, K.Langendoen, Modern Compiler Design, 2ed, 2012, §7.3.3.

Folding/unfolding

* Function inlining + supercompilation
  * void f
    { ...

```
      printf ("square = %d\n", 9);
    ...
  }
void print_square(int n)
 { printf ("square = %d\n", n*n); }
```

D.Grune, K.v.Reeuwijk, H.E.Bal, C.J.H.Jacobs, K.Langendoen, Modern Compiler Design, 2ed, 2012, §7.3.3.

Size matters

* Aggressive suppression of unused code
* Virtual machines + intermediate code
* Honest compression (e.g., LZ)
* Reliance on hardware
* Traditional optimisations

D.Grune, K.v.Reeuwijk, H.E.Bal, C.J.H.Jacobs, K.Langendoen, Modern Compiler Design, 2ed, 2012, §9.2

Superoptimisation

```
signum (x)
int x;
{
   if (x>0)       return  1;
   else if (x<0) return -1;
   else           return  0;
}
```

H.Massalin. Superoptimizer: A look at the smallest program, ASPLOS 1987.

Superoptimisation

```
(x in d0)
add.1  d0, d0
subx.1 d1, d1
negx.1 d0
addx.1 d1, d1
(result in d1)
```

H.Massalin. Superoptimizer: A look at the smallest program, ASPLOS 1987.

Superoptimisation

* State of the art:
  * brute force is viable
  * optimisation database caches solutions
    * enumerate everything possible
    * harvest beforehand
    * canonicalisation up to equivalence
    * stochastic search for large code segments
    * adapting memory subsystems
    * used in GCC (prooflink: PLDI-1992-GranlundK)

J.G.Wingbermuehle, R.K.Cytron, R.D.Chamberlain, Superoptimization of Memory Subsystems, LCTES 2014. http://bibtex.github.io/LCTES-2014-WingbermuehleCC.html

Power consumption

* More computation occurs on gadgets
* Save energy to increase optime
  * Reduce costs
  * Limit peak heat dissipation
  * Conceptually (weakly) linked to
    * sustainability

D.Grune, K.v.Reeuwijk, H.E.Bal, C.J.H.Jacobs, K.Langendoen, Modern Compiler Design, 2ed, 2012, §9.3

Power consumption

* Fast code uses less energy
  * `gcc -O1` saves 20%
* P = V × A
  * reduce CPU voltage
* Replace the scheduler
  * minimise changed bits

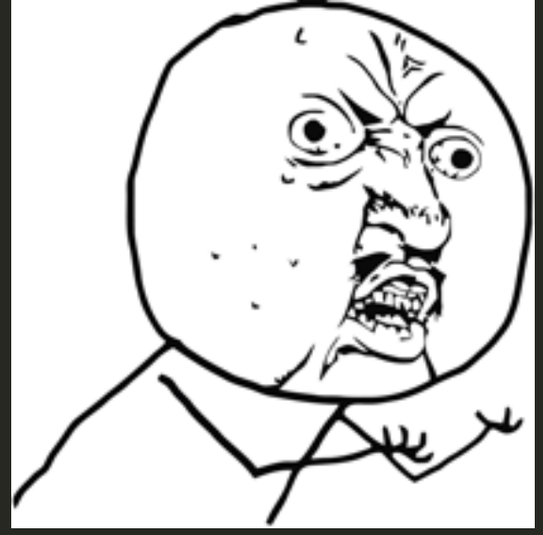
D.Grune, K.v.Reeuwijk, H.E.Bal, C.J.H.Jacobs, K.Langendoen, Modern Compiler Design, 2ed, 2012, §9.3

Part II Conclusion

* Language conversion does not exist
* Code should be correct
  * even with bit flips
* Code can be made small
  * Nothing beats superoptimisation
* Try to conserve energy
  * just make it fast and optimal

Conclusion

* General technology is easy
* Topics touched
  * Compilation: up, down, generative
  * Optimisation: speed, size, power
* Topics untouched
  * test suite optimisation
  * software transplantation



Y U NO SUBMIT REVIEW?!

Questions?