scal.cs.uni-salzburg.at
concurrent data structures

scalloc.cs.uni-salzburg.at
concurrent memory allocator

selfie.cs.uni-salzburg.at

Teaching Computer Science Through Self-Referentiality

Christoph Kirsch, University of Salzburg, Austria

Helmut Veith Memorial Workshop, Obergurgl, February 2017

Joint Work

- Martin Aigner, teaching assistant
- Sebastian Arming, teaching assistant
- Christian Barthel, bachelor thesis
  RISC-V port, presented @ Google PhD Summit
- Michael Lippautz, original emulator design
- Simone Oblasser, bachelor thesis
  RISC-V port, presented @ Google PhD Summit

Inspiration

- Niklaus Wirth: Compiler Construction
- Jochen Liedtke: Microkernels

Computer Science for Everyone

nsf.gov / csforall

code.org

computingatschool.org.uk

programbydesign.org

bootstrapworld.org

k12cs.org

csfieldguide.org.nz

Teaching the absolute basics!

What are the absolute basics?

What is Computer Science?

To Create Meaning with a Machine

Selfie: Teaching Computer Science [selfie.cs.uni-salzburg.at]

- *Selfie* is a self-referential 7k-line C implementation (in a single file) of:

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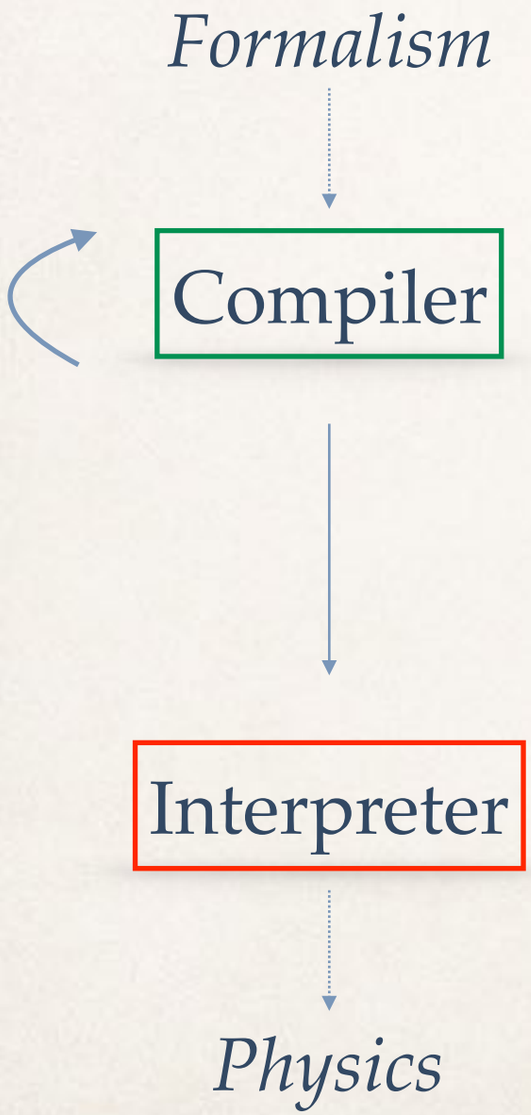
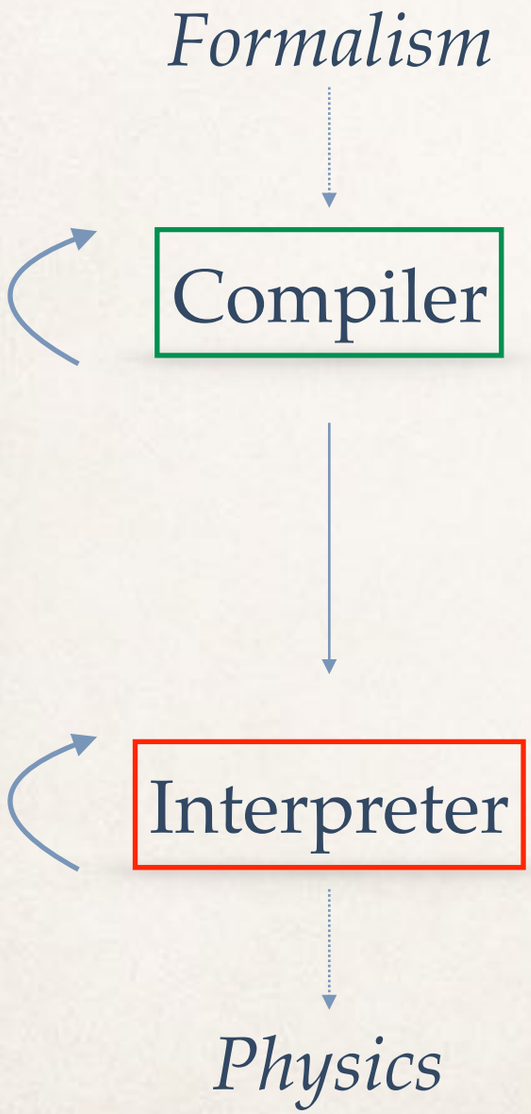
  4. a tiny C* library called *libcstar* utilized by all of selfie.

Semantics and Performance

Semantics and Performance



Semantics and Performance



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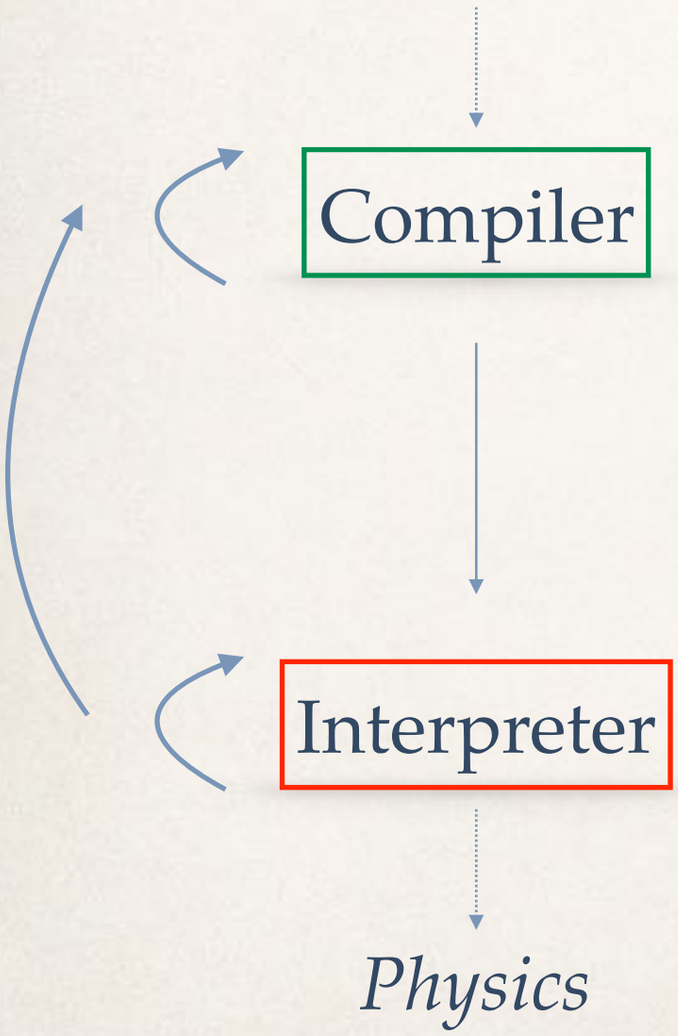

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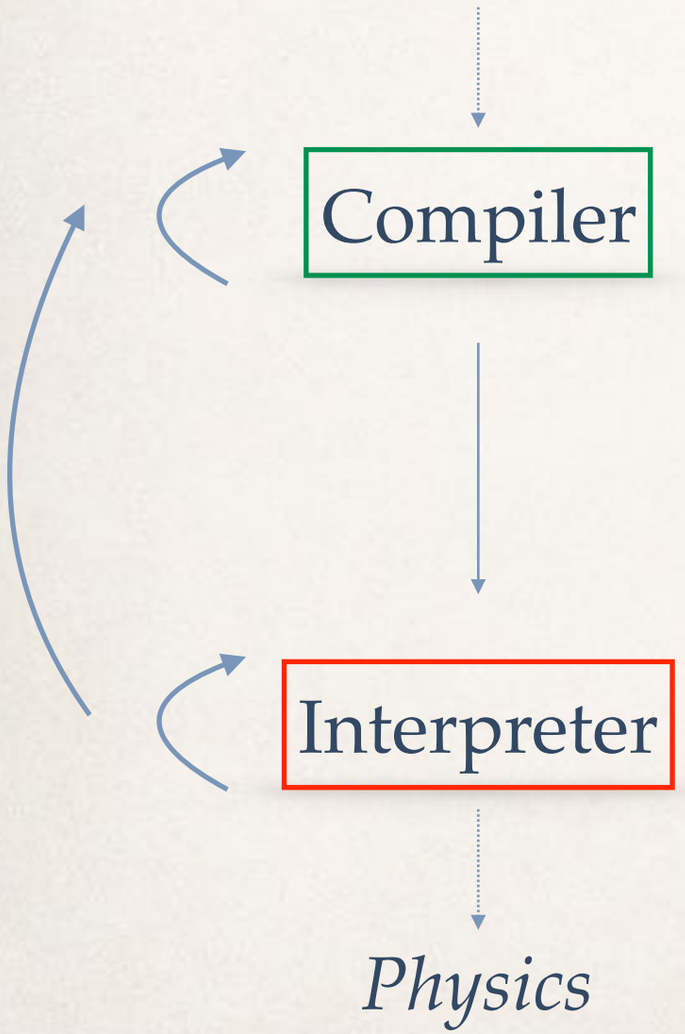

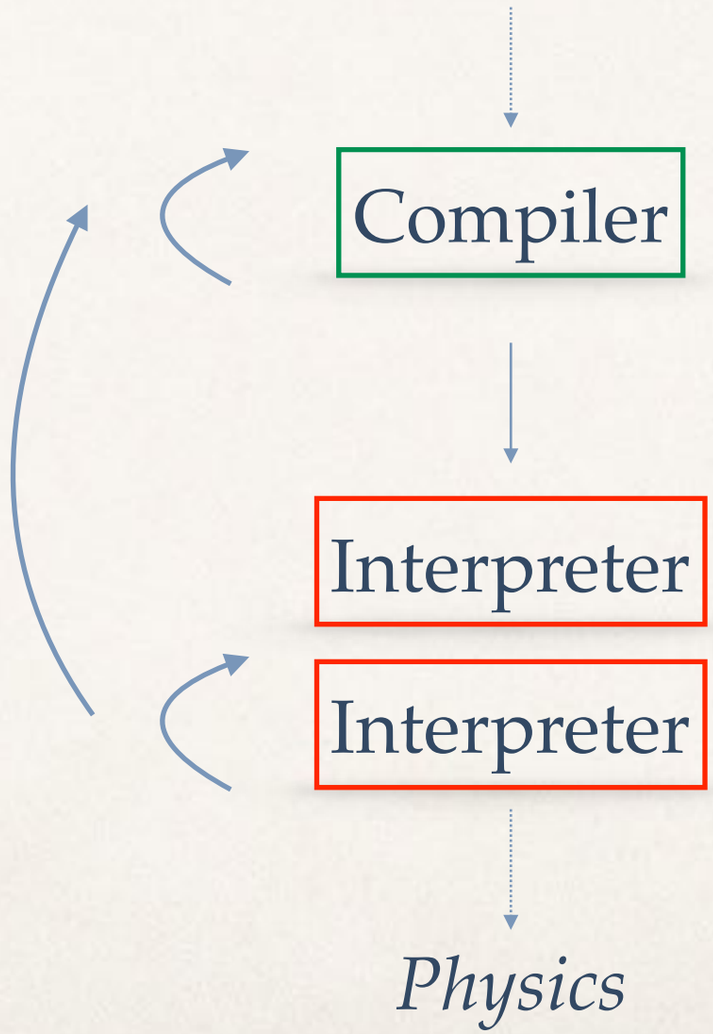

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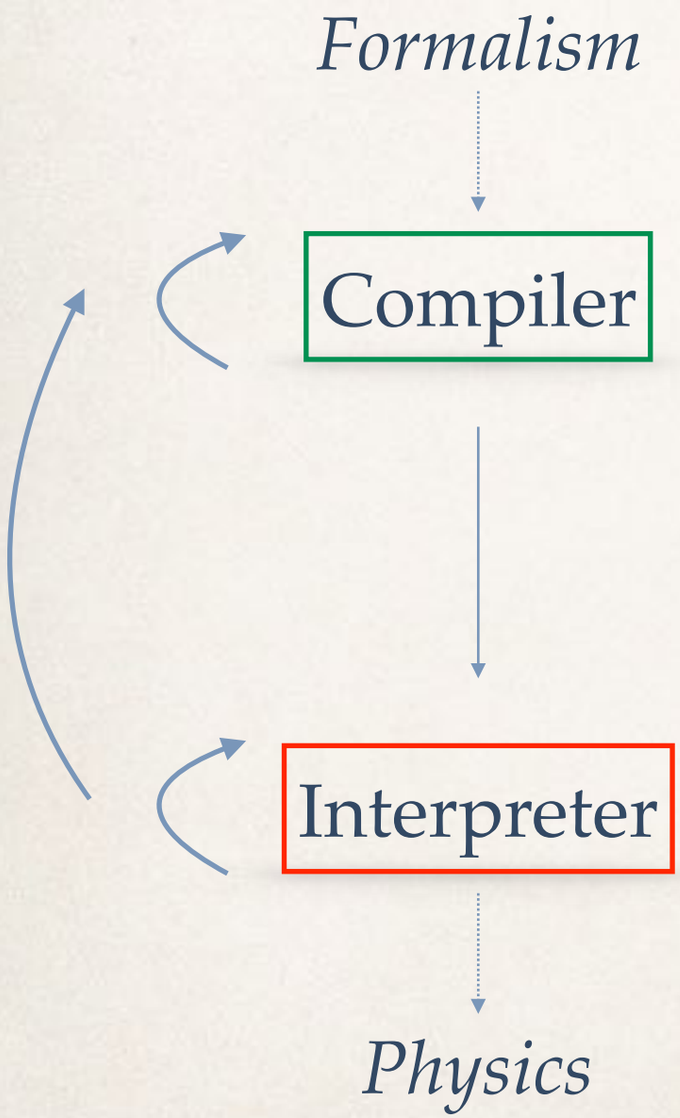

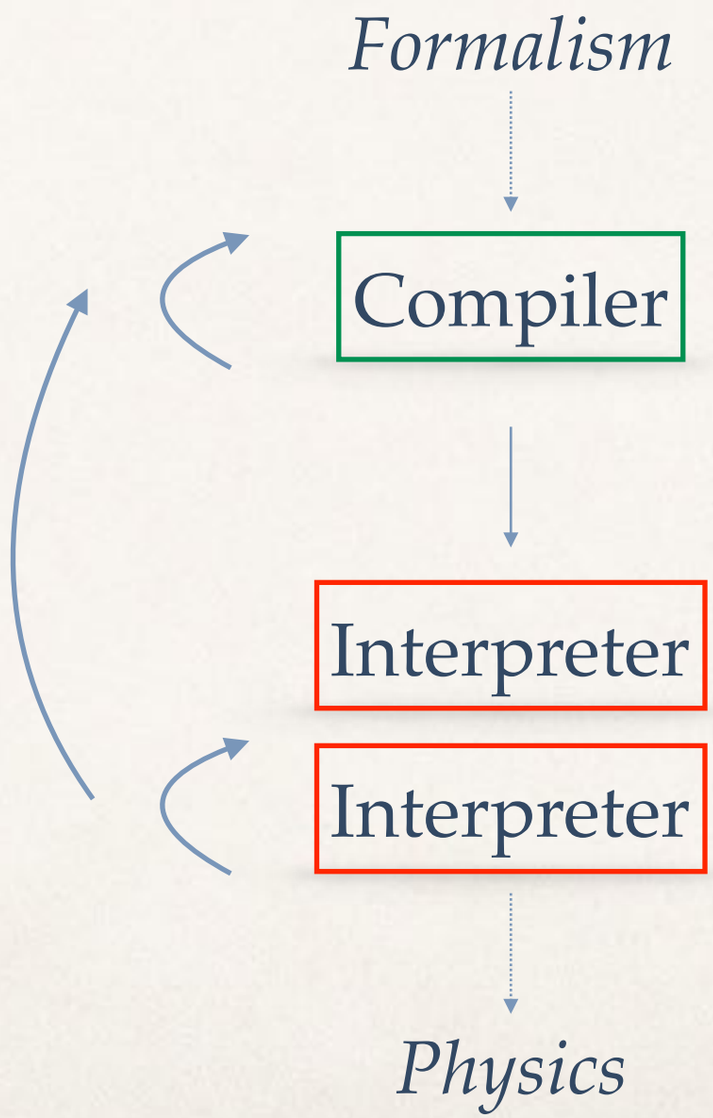

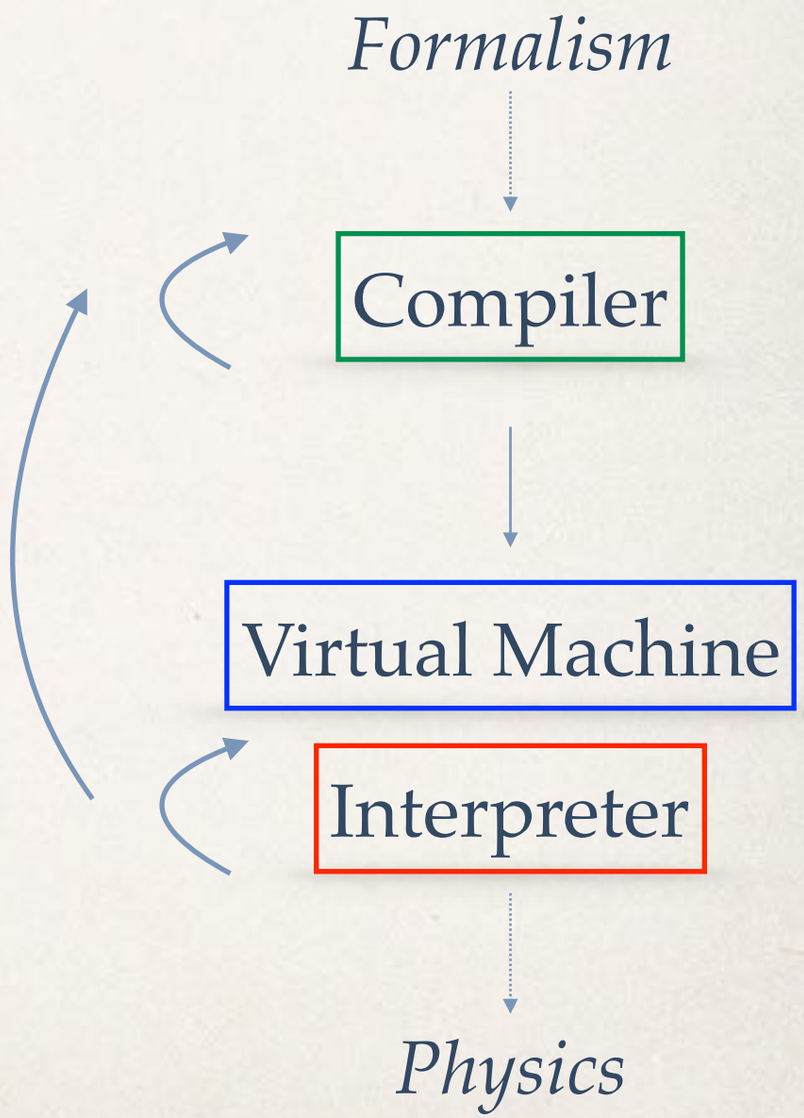

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    int i;
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    int c;

    i = 0;
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    c = *(s+i);

    while (c != 0) {
        n = n * 10 + c - '0';
        if (n < 0)
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while
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integer arithmetics
pointer arithmetics

no bitwise operators
no Boolean operators

library: `exit`, `malloc`, `open`, `read`, `write`

Selfie and Twelve Basic Principles

Library

Compiler

Emulator
Hypervisor

`selfie.c`

1. Semantics
2. Encoding
3. State
4. Regularity
5. Stack
6. Name
7. Time
8. Memory
9. Type
10. Bootstrapping
11. Interpretation
12. Virtualization

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6. Symbol Table and the Heap

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6. Symbol Table and the Heap
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```
> make
cc -w -m32 -D'main(a,b)=main(a,char**argv)' selfie.c -o selfie
```

bootstrapping `selfie.c` *into x86* `selfie` *executable*
using standard C compiler

(now also available for RISC-V machines)

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> ./selfie
./selfie: usage: selfie { -c { source } | -o binary | -s assembly
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selfie usage

compiling `selfie.c` *with x86* `selfie` *executable*

(takes seconds)

```
> ./selfie -c selfie.c

./selfie: this is selfie's starc compiling selfie.c

./selfie: 176408 characters read in 7083 lines and 969 comments
./selfie: with 97779(55.55%) characters in 28914 actual symbols
./selfie: 261 global variables, 289 procedures, 450 string literals
./selfie: 1958 calls, 723 assignments, 57 while, 572 if, 243 return
./selfie: 121660 bytes generated with 28779 instructions and 6544
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compiling `selfie.c` *with x86* `selfie` *executable into a MIPSter executable*

and

then running that MIPSter executable to compile `selfie.c` *again*

(takes ~6 minutes)

```
> ./selfie -c selfie.c -m 2 -c selfie.c

./selfie: this is selfie's starc compiling selfie.c

./selfie: this is selfie's mipster executing selfie.c with 2MB of
physical memory

selfie.c: this is selfie's starc compiling selfie.c

selfie.c: exiting with exit code 0 and 1.05MB of mallocated memory

./selfie: this is selfie's mipster terminating selfie.c with exit code
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0 and 1.16MB of mapped memory
```

compiling `selfie.c` *with x86* `selfie` *executable into a MIPSter executable*

and

then running that MIPSter executable to compile `selfie.c` *again*

(takes ~6 minutes)

compiling `selfie.c` *into a MIPSter executable* `selfie1.m`

and

then running `selfie1.m` *to compile* `selfie.c`

into another MIPSter executable `selfie2.m`

(takes ~6 minutes)

```
> ./selfie -c selfie.c -o selfie1.m -m 2 -c selfie.c -o selfie2.m

./selfie: this is selfie's starc compiling selfie.c
./selfie: 121660 bytes with 28779 instructions and 6544 bytes of data
written into selfie1.m

./selfie: this is selfie's mipster executing selfie1.m with 2MB of
physical memory

selfie1.m: this is selfie's starc compiling selfie.c
selfie1.m: 121660 bytes with 28779 instructions and 6544 bytes of data
written into selfie2.m

selfie1.m: exiting with exit code 0 and 1.05MB of mallocated memory

./selfie: this is selfie's mipster terminating selfie1.m with exit
code 0 and 1.16MB of mapped memory
```

compiling `selfie.c` *into a MIPSter executable* `selfie1.m`

and

then running `selfie1.m` *to compile* `selfie.c`

into another MIPSter executable `selfie2.m`

(takes ~6 minutes)

```
> ./selfie -c selfie.c -o selfie1.m -m 2 -c selfie.c -o selfie2.m

./selfie: this is selfie's starc compiling selfie.c
./selfie: 121660 bytes with 28779 instructions and 6544 bytes of data
written into selfie1.m

./selfie: this is selfie's mipster executing selfie1.m with 2MB of
physical memory

selfie1.m: this is selfie's starc compiling selfie.c
selfie1.m: 121660 bytes with 28779 instructions and 6544 bytes of data
written into selfie2.m

selfie1.m: exiting with exit code 0 and 1.05MB of mallocated memory

./selfie: this is selfie's mipster terminating selfie1.m with exit
code 0 and 1.16MB of mapped memory
```

compiling `selfie.c` *into a MIPSter executable* `selfie1.m`

and

then running `selfie1.m` *to compile* `selfie.c`

into another MIPSter executable `selfie2.m`

(takes ~6 minutes)

```
> ./selfie -c selfie.c -o selfie1.m -m 2 -c selfie.c -o selfie2.m

./selfie: this is selfie's starc compiling selfie.c
./selfie: 121660 bytes with 28779 instructions and 6544 bytes of data
written into selfie1.m

./selfie: this is selfie's mipster executing selfie1.m with 2MB of
physical memory

selfie1.m: this is selfie's starc compiling selfie.c
selfie1.m: 121660 bytes with 28779 instructions and 6544 bytes of data
written into selfie2.m

selfie1.m: exiting with exit code 0 and 1.05MB of mallocated memory

./selfie: this is selfie's mipster terminating selfie1.m with exit
code 0 and 1.16MB of mapped memory
```

compiling `selfie.c` *into a MIPSter executable* `selfie1.m`

and

then running `selfie1.m` *to compile* `selfie.c`

into another MIPSter executable `selfie2.m`

(takes ~6 minutes)

compiling `selfie.c` *with x86* `selfie` executable

and

then running that executable to compile `selfie.c` *again*

and

then running that executable to compile `selfie.c` *again*

(takes ~24 hours)

```
> ./selfie -c selfie.c -m 2 -c selfie.c -m 2 -c selfie.c
```

compiling `selfie.c` *with x86* `selfie` executable

and

then running that executable to compile `selfie.c` *again*

and

then running that executable to compile `selfie.c` *again*

(takes ~24 hours)

```
> ./selfie -c selfie.c -m 2 -c selfie.c -m 2 -c selfie.c
```

compiling `selfie.c` *with x86* `selfie` executable

and

then running that executable to compile `selfie.c` *again*

and

then running that executable to compile `selfie.c` *again*

(takes ~24 hours)

```
> ./selfie -c selfie.c -m 2 -c selfie.c -m 2 -c selfie.c
```

compiling `selfie.c` *with x86* `selfie` executable

and

then running that executable to compile `selfie.c` *again*

and

then running that executable to compile `selfie.c` *again*

(takes ~24 hours)

```
> ./selfie -c selfie.c -m 2 -c selfie.c -m 2 -c selfie.c
```

compiling `selfie.c` *with x86* `selfie` executable

and

then running that executable to compile `selfie.c` *again*

and

then running that executable to compile `selfie.c` *again*

(takes ~24 hours)

"The OS is an interpreter until people wanted speed."

–selfie

compiling `selfie.c` *with x86* `selfie` *executable*

and

then running that executable to compile `selfie.c` *again*

and

then ***hosting*** *that executable in a virtual machine to compile* `selfie.c` *again*

(takes ~12 minutes)

```
> ./selfie -c selfie.c -m 2 -c selfie.c -y 2 -c selfie.c
```

compiling `selfie.c` *with x86* `selfie` *executable*

and

then running that executable to compile `selfie.c` *again*

and

then ***hosting*** *that executable in a virtual machine to compile* `selfie.c` *again*

(takes ~12 minutes)

```
> ./selfie -c selfie.c -m 2 -c selfie.c -y 2 -c selfie.c
```

compiling `selfie.c` *with x86* `selfie` *executable*

and

then running that executable to compile `selfie.c` *again*

and

then ***hosting*** *that executable in a virtual machine to compile* `selfie.c` *again*

(takes ~12 minutes)

Website

selfie.cs.uni-salzburg.at

Book (Draft)

leanpub.com/selfie

Code

github.com/cksystemsteaching/selfie

Thank you!