Chapter 1

Introduction

Course “Compiler Construction”

Martin Steffen

Spring 2021

Chapter 1

Learning Targets of Chapter “Introduction”.

The chapter gives an overview over different phases of a compiler and their tasks. It also mentions *organizational* things related to the course.

Chapter 1

Outline of Chapter “Introduction”.

Introduction

Compiler architecture & phases

Bootstrapping and cross-compilation

Section

Introduction

Chapter 1 “Introduction”
Course “Compiler Construction”
Martin Steffen
Spring 2021

Course info

Course material from:

- Martin Steffen (msteffen@ifi.uio.no)
- Stein Krogdahl (stein@ifi.uio.no)
- Birger Møller-Pedersen (birger@ifi.uio.no)
- Eyvind Wærstad Axelsen (eyvinda@ifi.uio.no)

This semester, Gianluca Turin (gianlutu@ifi.uio.no) will assist, for instance, with the exercises.

Course's web-page

http://www.uio.no/studier/emner/matnat/ifi/INF5110

- overview over the course, pensum (watch for updates)
- various announcements, beskjeder, etc.

Course material and plan

- based roughly on [2] and [3], but also other sources will play a role. A classic is "the dragon book" [1], we might use part of code generation from there
- see also *errata* list at
  `http://www.cs.sjsu.edu/~louden/cmptext/`
- approx. 3 hours teaching per week (+ exercises)
- mandatory assignments (= "obligs")
  - O_1 published mid-February, deadline mid-March
  - O_2 published beginning of April, deadline beginning of May
- group work up-to 3 people recommended. Please inform us about such planned group collaboration
- slides: see updates on the net

Exam

The status is unclear right now (at the beginning of the semester). The announcement on the net (home exam) is not final. It may be changed to oral.

Motivation: What is CC good for?

- not everyone is actually building a full-blown compiler, but
  - fundamental concepts and techniques in CC
  - most, if not basically all, software reads, processes/transforms and outputs "data"

  $\Rightarrow$ often involves techniques central to CC
  - understanding compilers $\Rightarrow$ deeper understanding of programming language(s)
  - new languages (domain specific, graphical, new language paradigms and constructs...)

  $\Rightarrow$ CC & their principles will *never* be "out-of-fashion".

Section

Compiler architecture & phases

Chapter 1 “Introduction”
Course “Compiler Construction”
Martin Steffen
Spring 2021

Architecture of a typical compiler

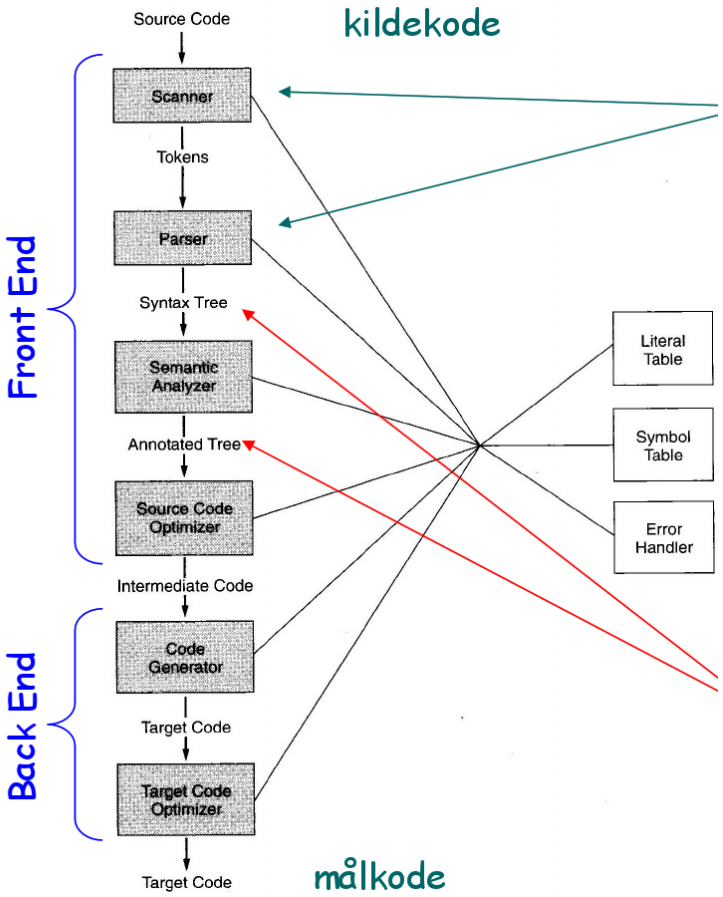
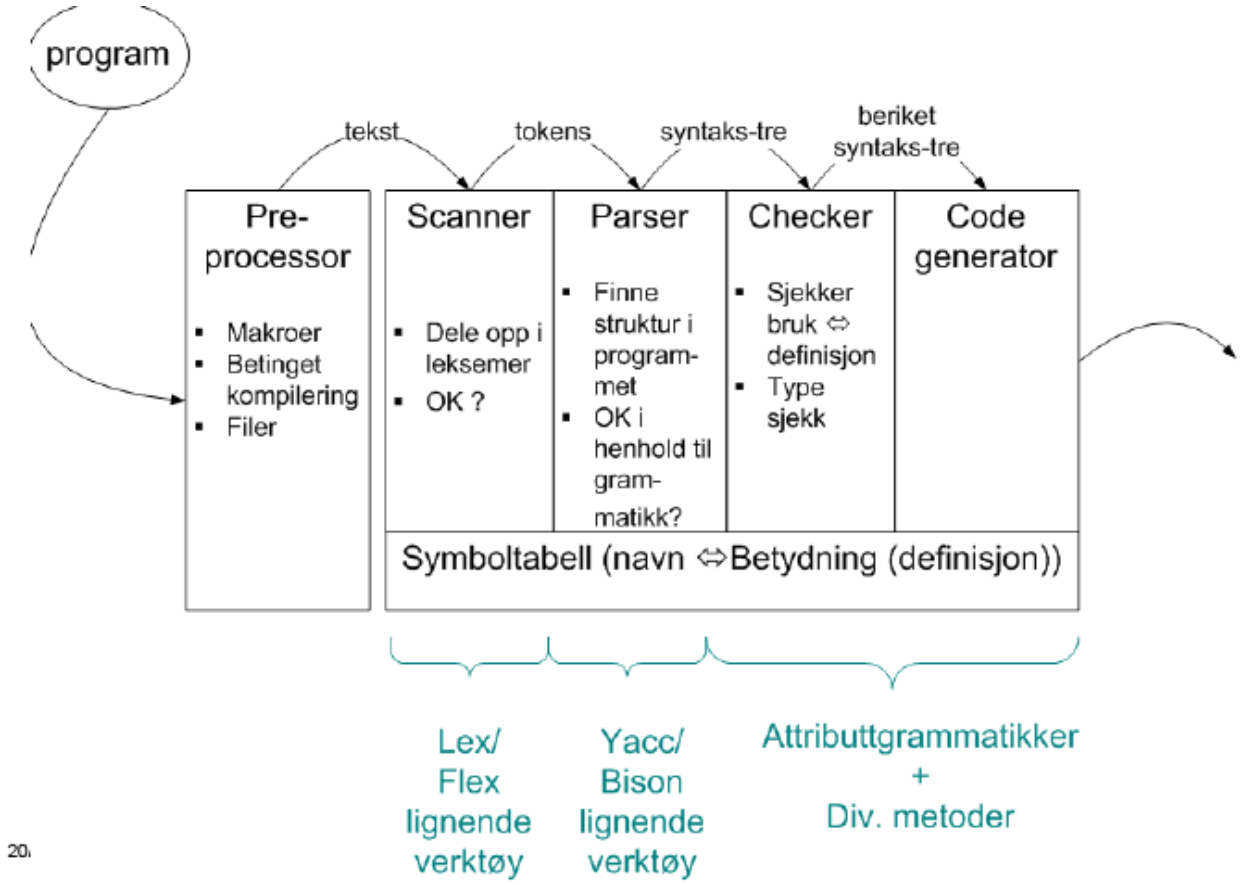


Figure: Structure of a typical compiler

Anatomy of a compiler



20.

Pre-processor

- either separate program or integrated into compiler
- nowadays: C-style preprocessing sometimes seen as "hack" grafted on top of a compiler.
- examples (see next slide):
  - file inclusion
  - macro definition and expansion
  - conditional code/compilation: Note: `#if` is *not* the same as the `if`-programming-language construct.
- problem: often messes up the line numbers (among other things)

C-style preprocessor examples

```
#include <filename>
```

Listing 1: file inclusion

```
#vardef #a = 5; #c = #a+1
 ...
#if (#a < #b)
      ..
#else
   ...
#endif
```

Listing 2: Conditional compilation

C-style preprocessor: macros

```
#macrodef hentdata(#1,#2)
    ---- #1-----
     #2---(#1)---
#enddef

...
#hentdata(kari,per)
```

Listing 3: Macros

```
 ---- kari -----
per----(kari)---
```

Scanner (lexer . . .)

- input: "the program text" (= string, char stream, or similar)
- task
  - *divide* and *classify* into *tokens*, and
  - remove blanks, newlines, comments . . .
- theory: finite state automata, regular languages

Scanner: illustration

```
a[index] = 4 + 2
```

lexeme	token class	value
a	*identifier*	"a"
[	*left bracket*	
index	*identifier*	"index"
]	*right bracket*	
=	*assignment*	
4	*number*	"4"
+	*plus sign*	
2	*number*	"2"

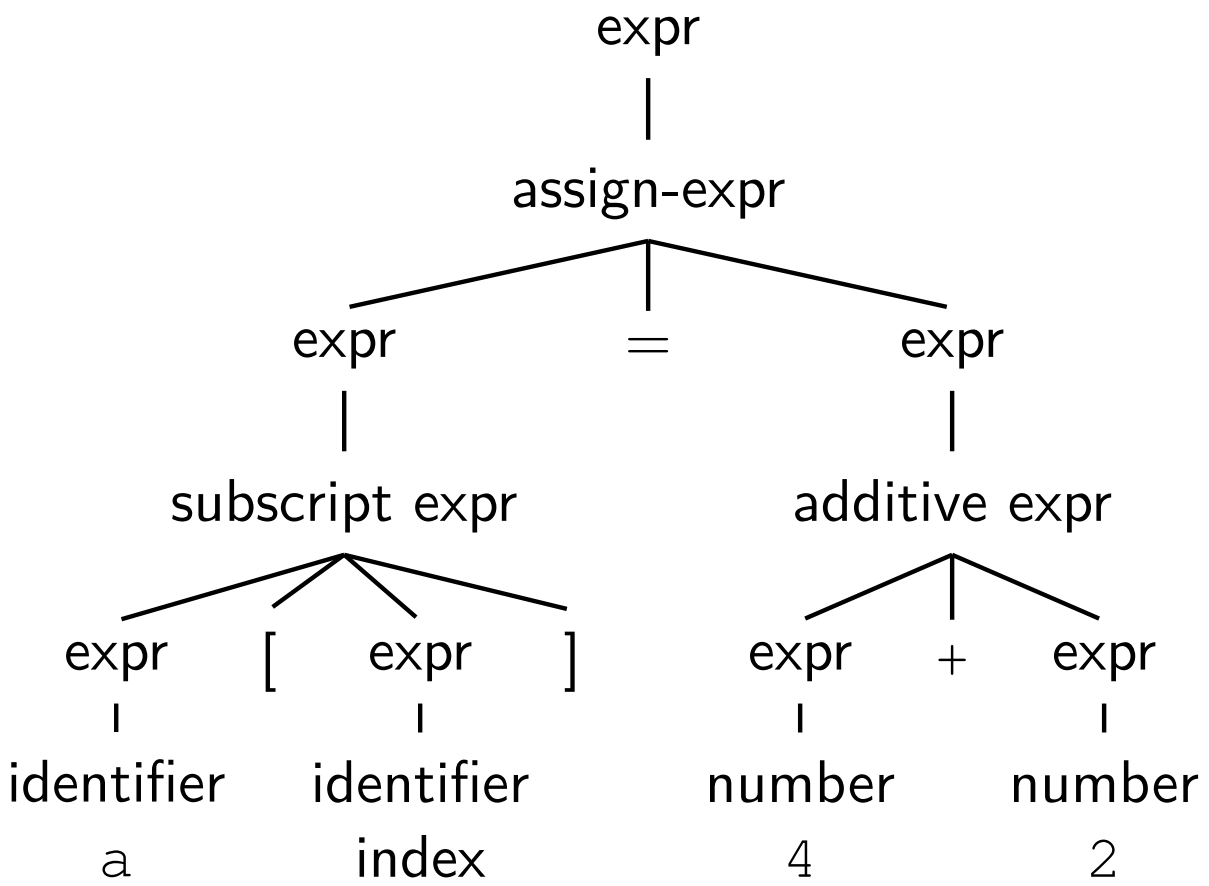
Scanner: illustration

```
a [ index ] = 4 + 2
```

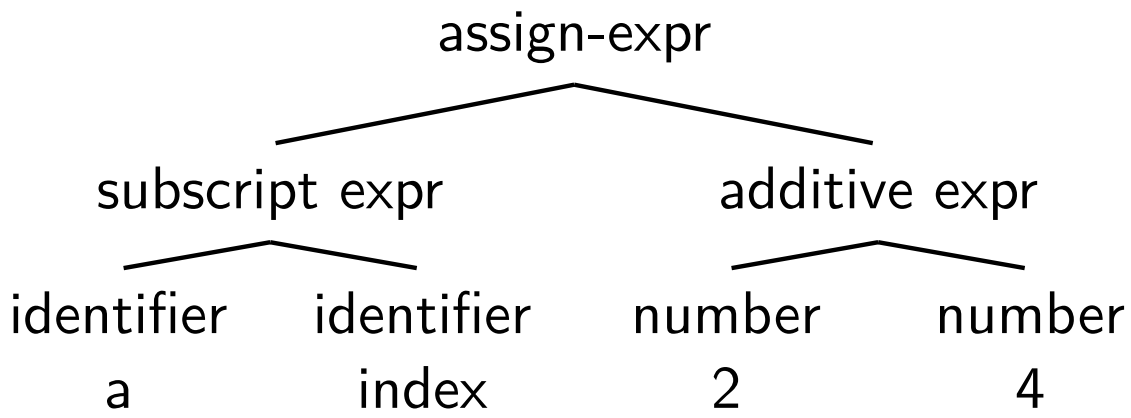
lexeme	token class	value
a	*identifier*	2
[	*left bracket*	
index	*identifier*	21
]	*right bracket*	
=	*assignment*	
4	*number*	4
+	*plus sign*	
2	*number*	2

0	
1	
2	"a"
	⋮
21	"index"
22	
	⋮

a[index] = 4 + 2: parse tree/syntax tree

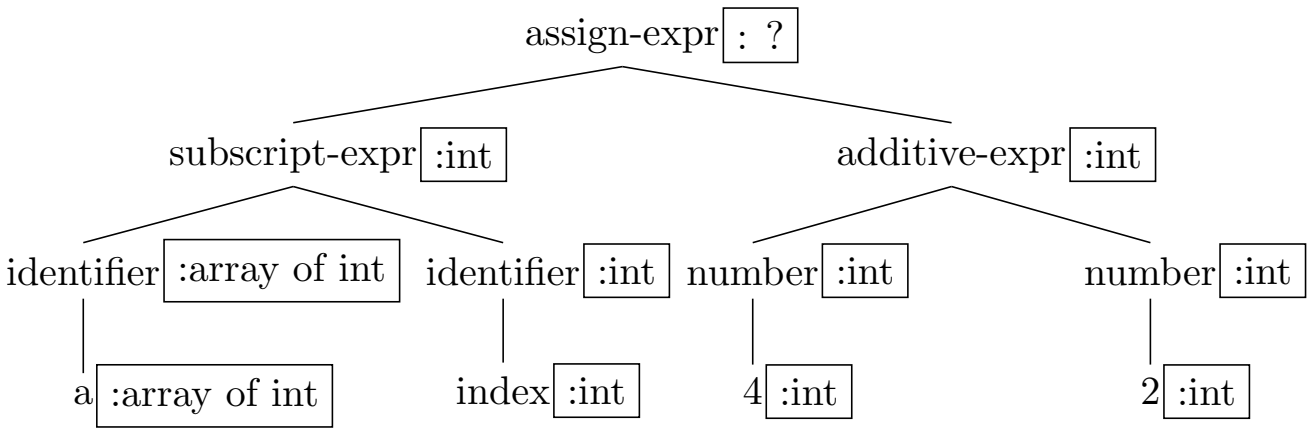


`a[index] = 4 + 2`: abstract syntax tree



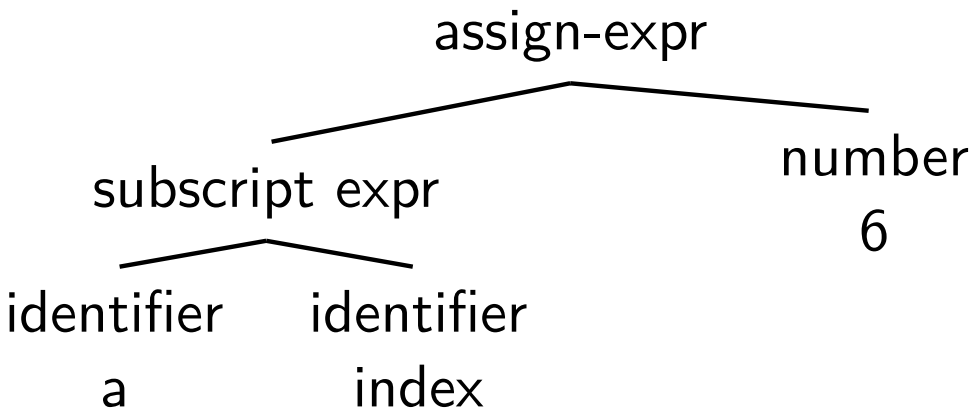
(One typical) Result of semantic analysis

- one standard, general outcome of semantic analysis: "annotated" or "decorated" AST
- additional info (non context-free):
  - *bindings* for declarations
  - (static) *type* information



- here: *identifiers* looked up wrt. declaration
- 4, 2: due to their form, basic types.

Optimization at source-code level




```
t = 4+2;          t = 6;
a[index] = t;     a[index] = t;     a[index] = 6;
```

Code generation & optimization

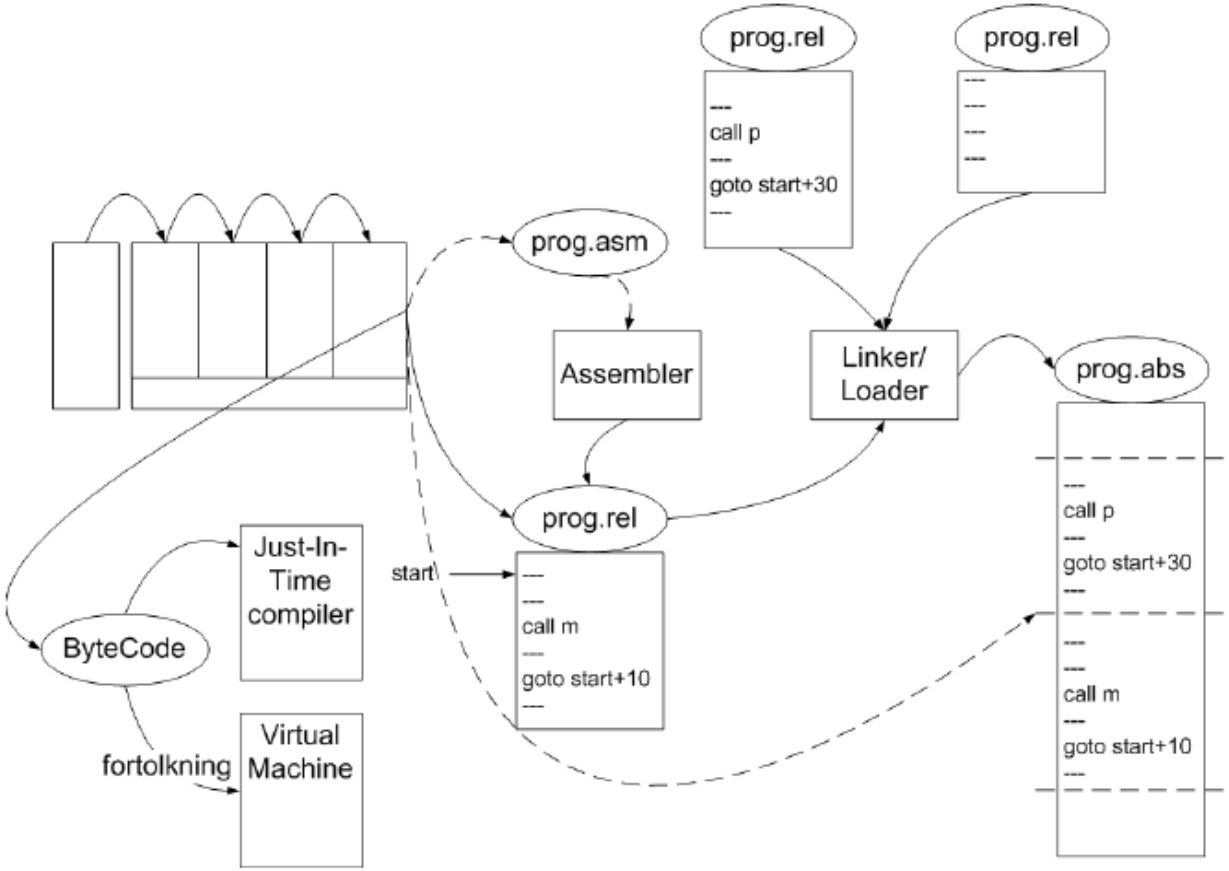
```
MOV  R0, index  ;;  value of index -> R0
MUL  R0, 2      ;;  double value of R0
MOV  R1, &a     ;;  address of a -> R1
ADD  R1, R0     ;;  add R0 to R1
MOV *R1, 6      ;;  const 6 -> address in R1
```

```
MOV R0, index       ;; value of index -> R0
SHL R0              ;; double value in R0
MOV &a[R0], 6       ;; const 6 -> address a+R0
```

- *many* optimizations possible
- potentially difficult to automatize[1], based on a formal description of language and machine
- platform dependent

[1] Not that one has much of a choice. Difficult or not, *no one* wants to optimize generated machine code by hand ....

Anatomy of a compiler (2)



Misc. notions

- front-end vs. back-end, analysis vs. synthesis
- separate compilation
- how to handle *errors*?
- "data" handling and management at run-time (static, stack, heap), garbage collection?
- language can be compiled in *one pass*?
  - E.g. C and Pascal: declarations must *precede* use
  - no longer too crucial, enough memory available
- compiler assisting tools and infrastructure, e.g.
  - debuggers
  - profiling
  - project management, editors
  - build support
  - ...

Compiler vs. interpeter

compilation

- classical: source ⇒ machine code for given machine
- different "forms" of machine code (for 1 machine):
  - executable ⇔ relocatable ⇔ textual assembler code

full interpretation

- directly executed from program code/syntax tree
- often for command languages, interacting with the OS, etc.
- speed typically 10–100 slower than compilation

compilation to intermediate code which is interpreted

- used in e.g. Java, Smalltalk, ...
- intermediate code: designed for efficient execution (byte code in Java)

More recent compiler technologies

- *Memory* has become cheap (thus comparatively large)
  - keep whole program in main memory, while compiling
- OO has become rather popular
  - special challenges & optimizations
- Java
  - "compiler" generates byte code
  - part of the program can be *dynamically* loaded during run-time
- concurrency, multi-core
- virtualization
- graphical languages (UML, etc), "meta-models" besides grammars

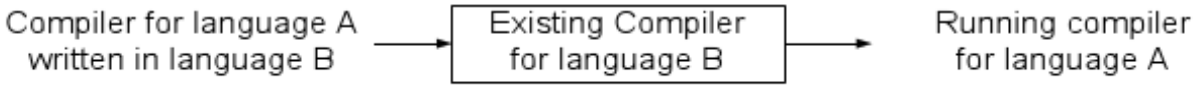
Section

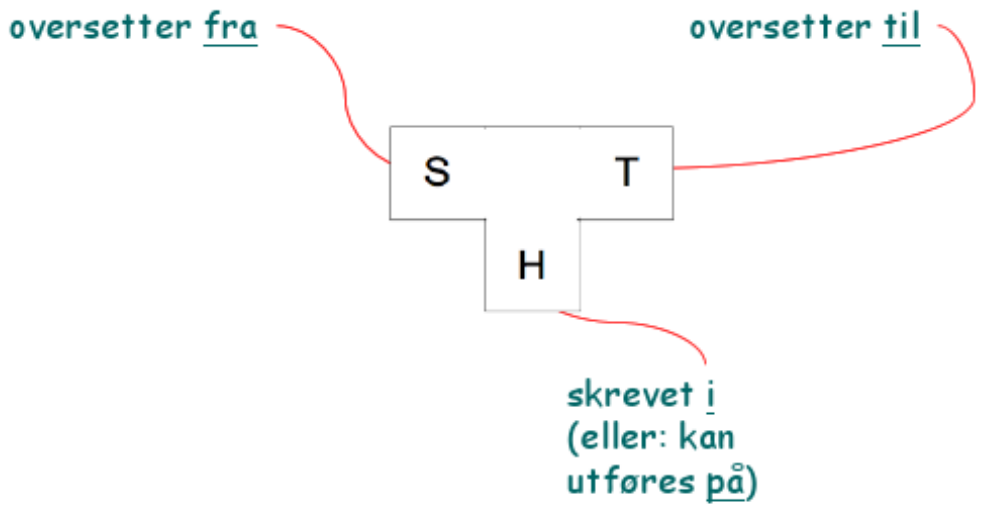
Bootstrapping and cross-compilation

Chapter 1 “Introduction”
Course “Compiler Construction”
Martin Steffen
Spring 2021

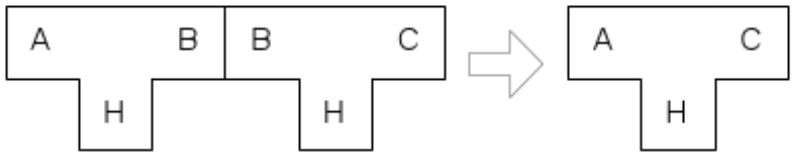
Compiling from source to target on host

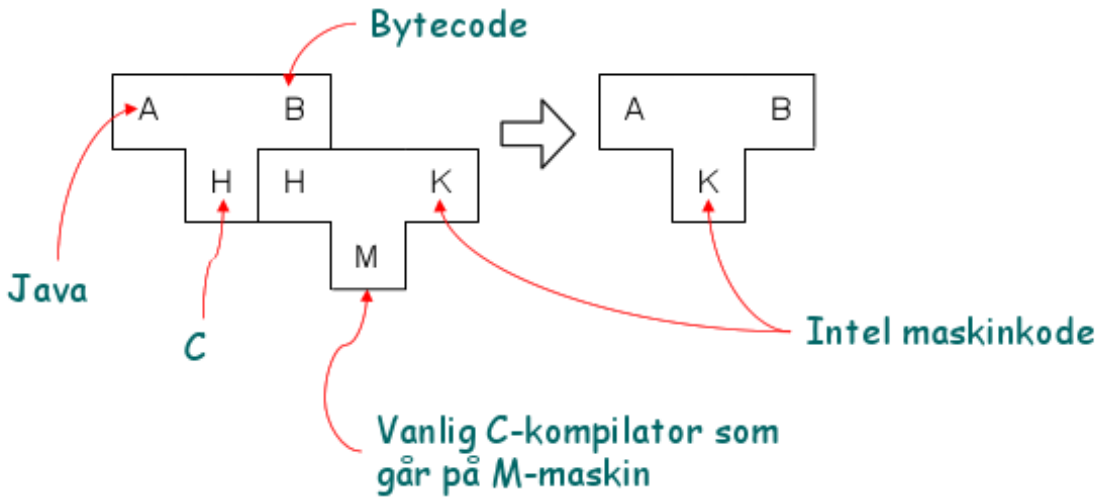
"tombstone diagrams" (or T-diagrams)....



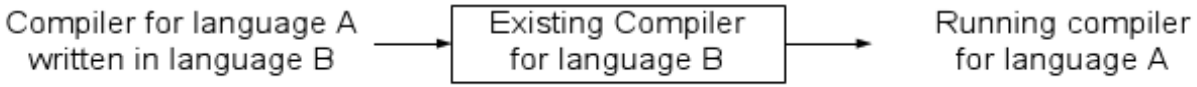


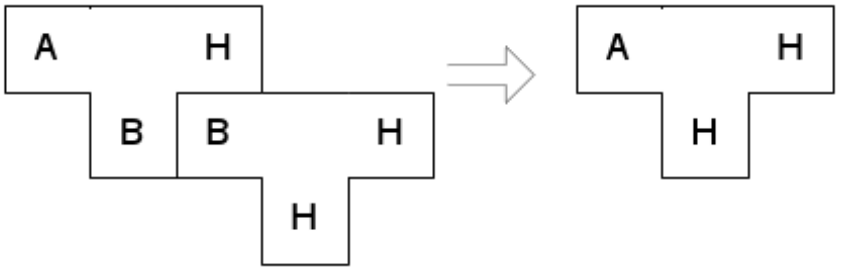
Two ways to compose “T-diagrams”





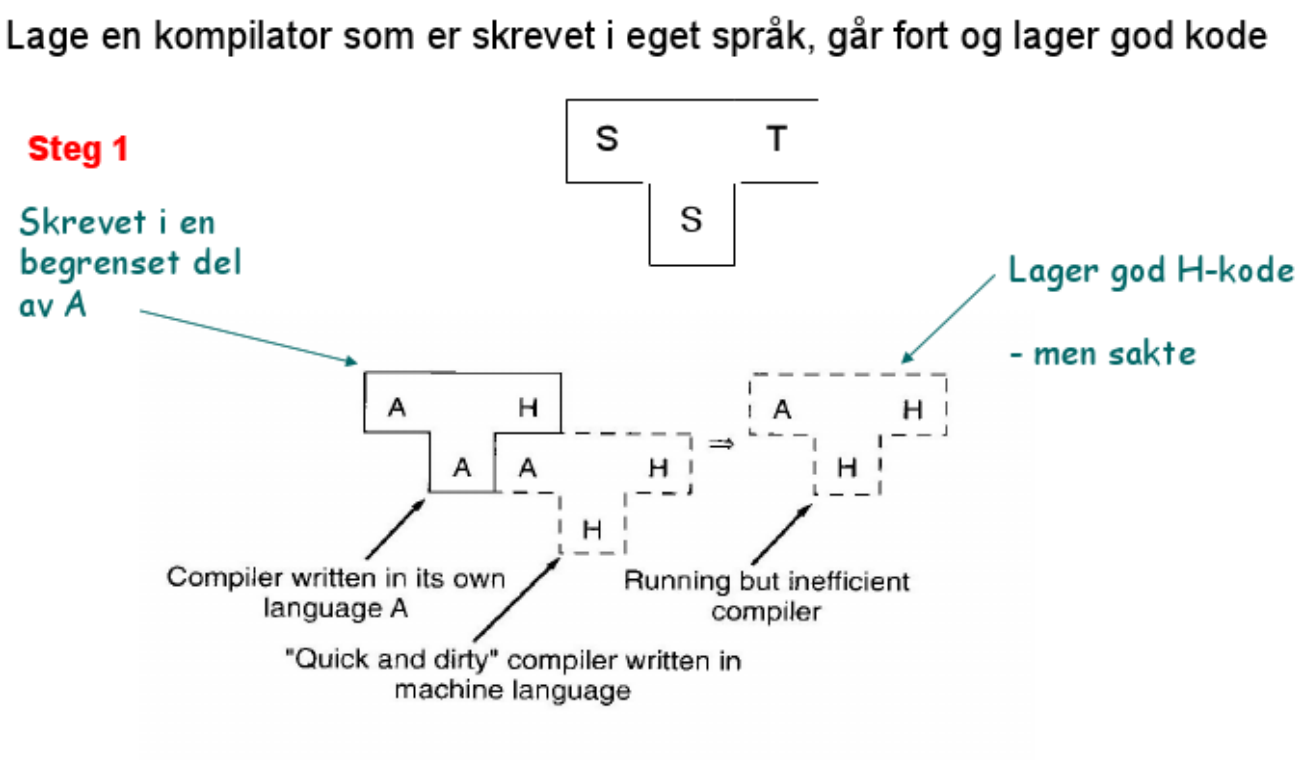
Using an “old” language and its compiler for write a compiler for a “new” one





Pulling oneself up on one's own bootstraps

bootstrap (verb, trans.): to promote or develop . . . with little or no assistance
— Merriam-Webster

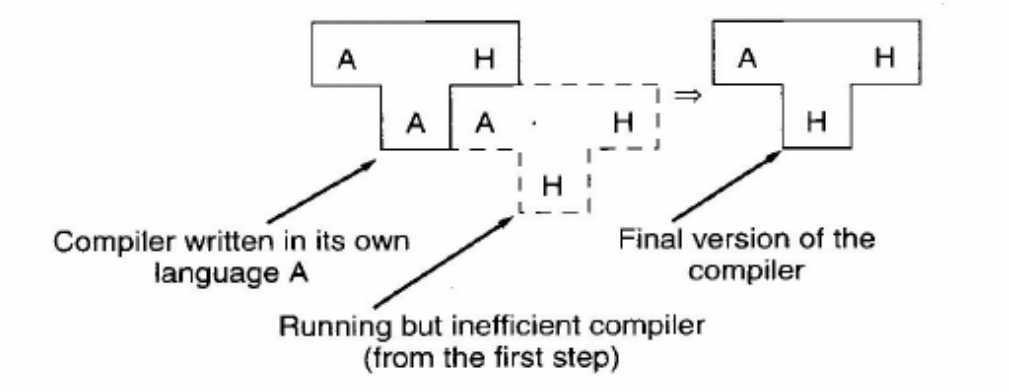


Bootstrapping 2

Steg 2

Lager god H-kode

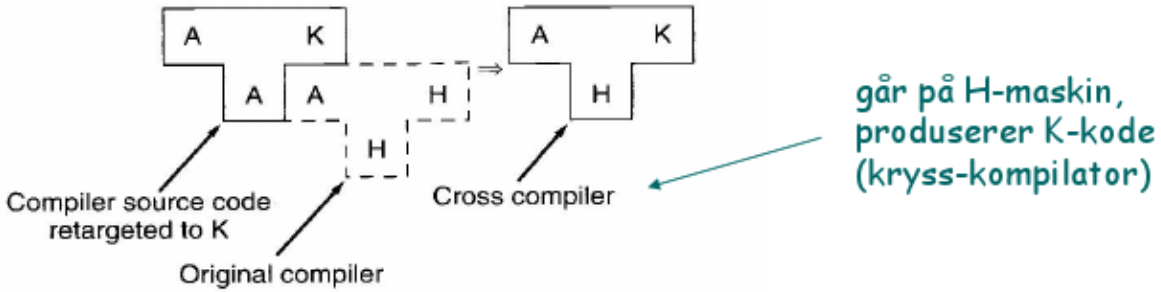
- og fort



Porting & cross compilation

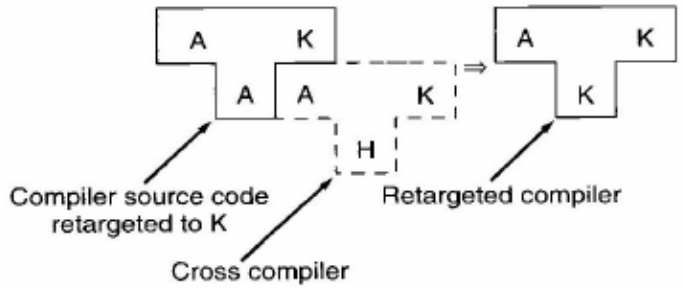
- Har: A kompilator som oversetter til H-maskinkode
- Ønsker: A-kompilator som oversetter til K-maskin kode

Steg 1: Skriv kompilator slik at den produserer K-kode (f.eks. vha ny back-end)



går på H-maskin, produserer K-kode (kryss-kompilator)

Steg 2: Oversetter den nye kompilatoren til K-kode. Gjøres på en H-maskin vha krysskompilatoren



20/01/15

References I

Bibliography

[1] Aho, A. V., Sethi, R., and Ullman, J. D. (1986). *Compilers: Principles, Techniques, and Tools*. Addison-Wesley.

[2] Cooper, K. D. and Torczon, L. (2004). *Engineering a Compiler*. Elsevier.

[3] Louden, K. (1997). *Compiler Construction, Principles and Practice*. PWS Publishing.