An Overview of Compilation

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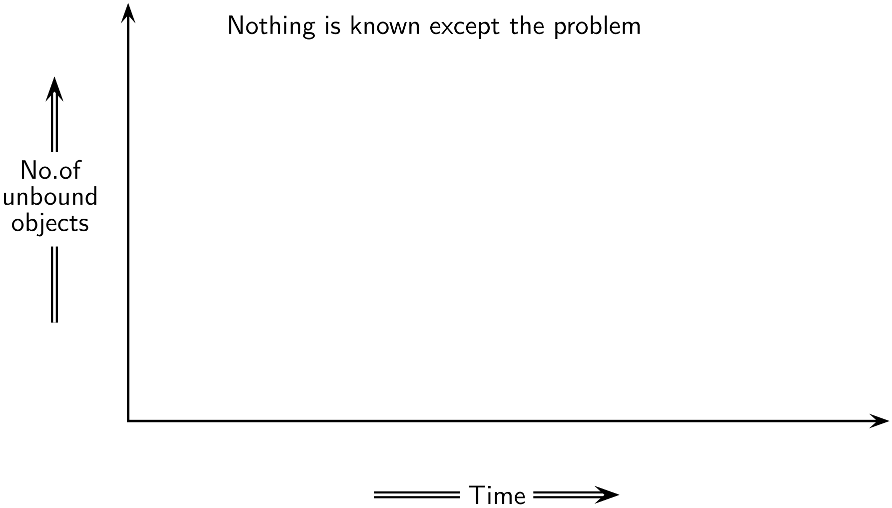
Outline

- Introduction
- compilation sequence
- compilation models

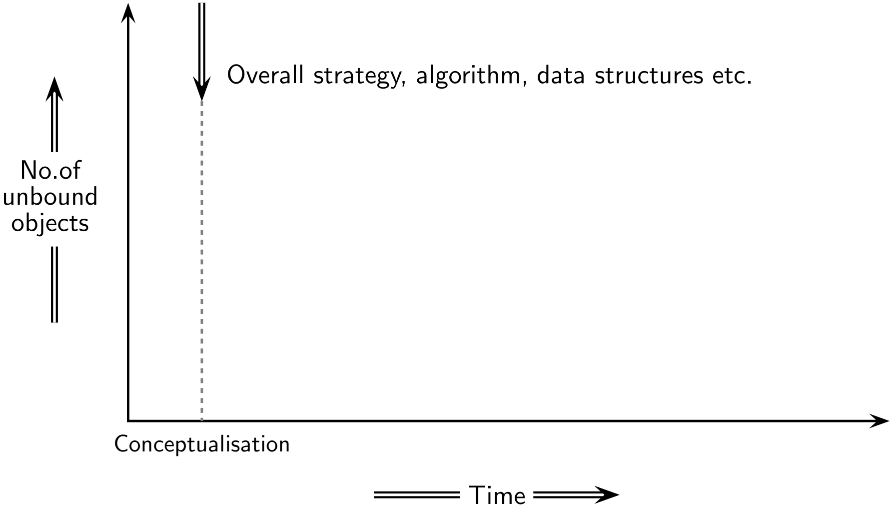
Part 1

Introduction to Compilation

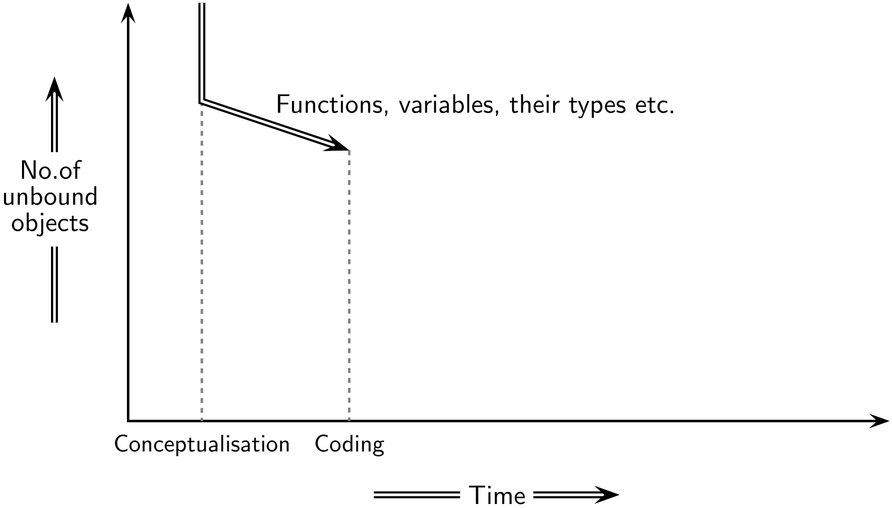
Binding


Nothing is known except the problem
No.of unbound objects
Time

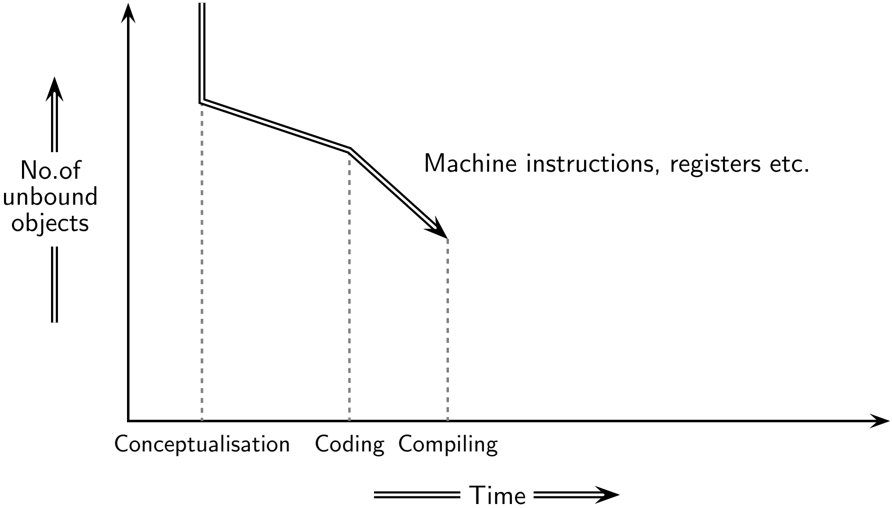
Binding


Overall strategy, algorithm, data structures etc.
No.of unbound objects
Conceptualisation
Time

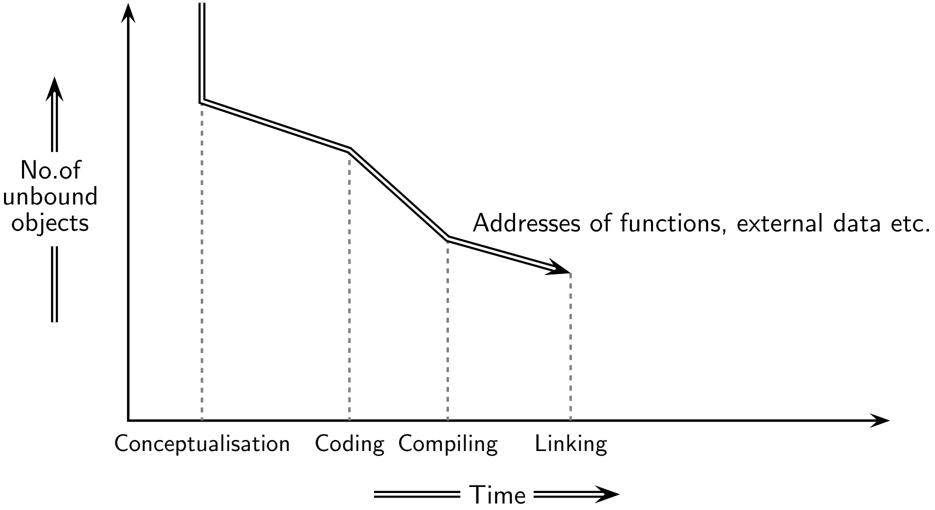
Binding


Functions, variables, their types etc.
No.of unbound objects
Conceptualisation
Coding
Time

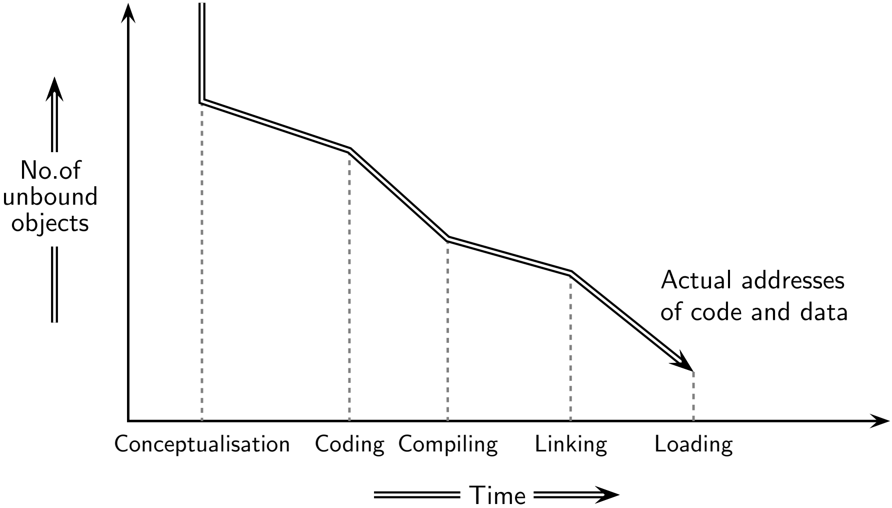
Binding


No.of
unbound
objects
Machine instructions, registers etc.
Conceptualisation
Coding
Compiling
Time

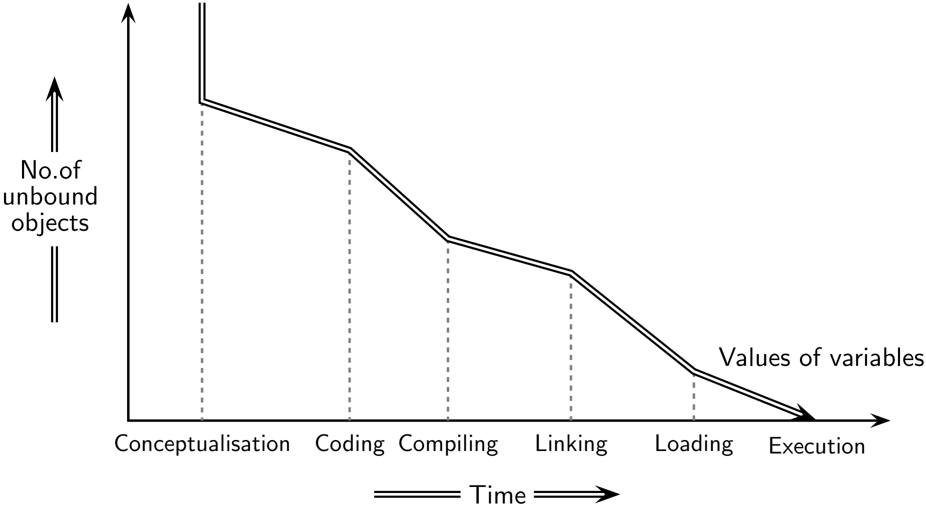
Binding


No.of unbound objects
Addresses of functions, external data etc.
Conceptualisation
Coding
Compiling
Linking
Time

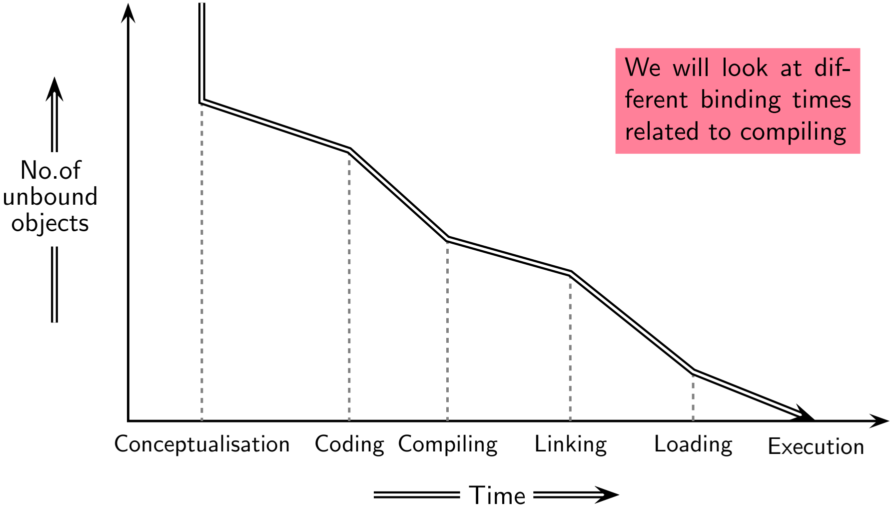
Binding


No.of
unbound
objects
Actual addresses
of code and data
Conceptualisation
Coding
Compiling
Linking
Loading
Time

Binding


No.of unbound objects
Values of variables
Conceptualisation
Coding
Compiling
Linking
Loading
Execution
Time

Binding

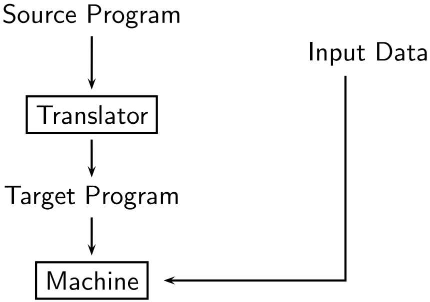


We will look at different binding times related to compiling

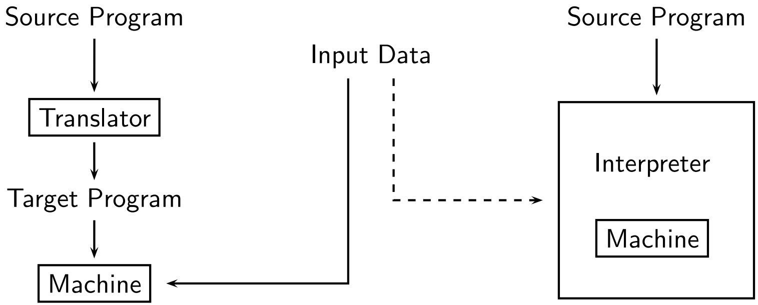
Implementation Mechanisms

$$
\begin{array}{c}
\text{Source Program} \\
\downarrow \\
\boxed{\text{Translator}} \\
\downarrow \\
\text{Target Program} \\
\downarrow \\
\boxed{\text{Machine}}
\end{array}
$$

Implementation Mechanisms

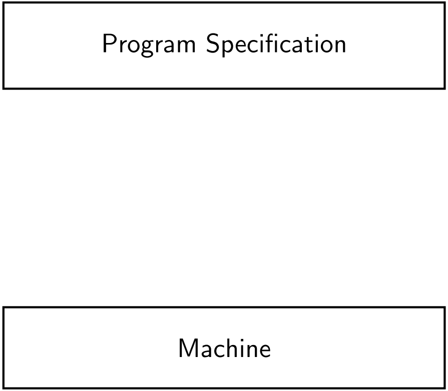


Implementation Mechanisms



Implementation Mechanisms as "Bridges"

- "Gap" between the "levels" of program specification and execution



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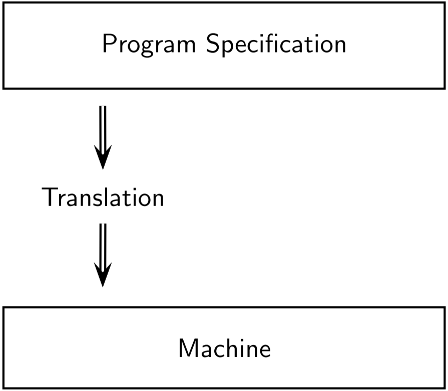

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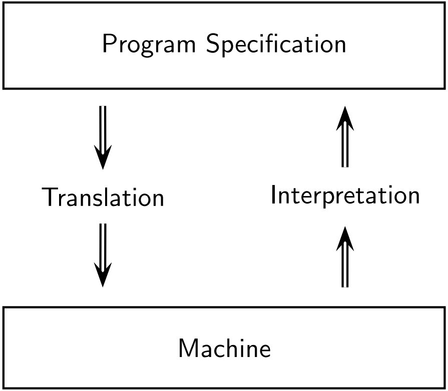

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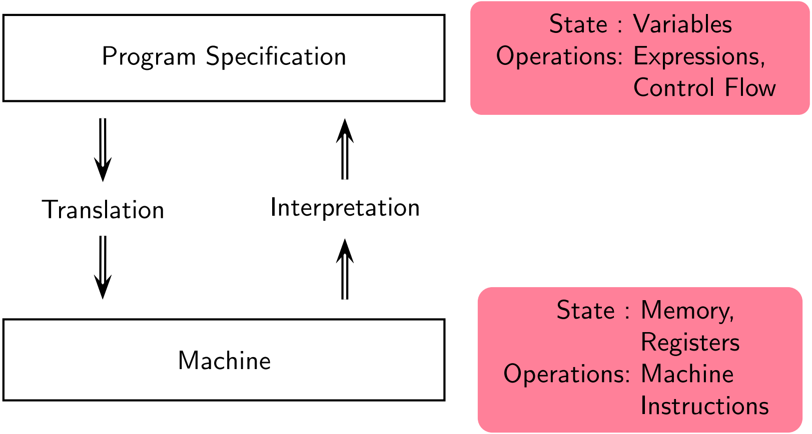


High and Low Level Abstractions

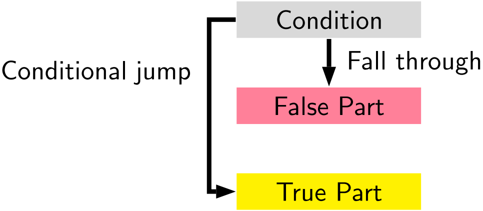
Input C statement

```
a = b<10?b:c;
```

Spim Assembly Equivalent

```
    lw   $t0, 4($fp)   ;     t0 <- b          # Is b smaller
    slti $t0, $t0, 10  ;     t0 <- t0 < 10    # than 10?
    not  $t0, $t0      ;     t0 <- !t0
    bgtz $t0, L0:      ;     if t0>0 goto L0
    lw   $t0, 4($fp)   ;     t0 <- b          # YES
    b    L1:           ;     goto L1
L0: lw   $t0, 8($fp)   ;L0: t0 <- c          # NO
L1: sw   0($fp), $t0   ;L1: a <- t0
```

High and Low Level Abstractions



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```

High and Low Level Abstractions

NOT Condition

True Part

False Part

Input C statement

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```
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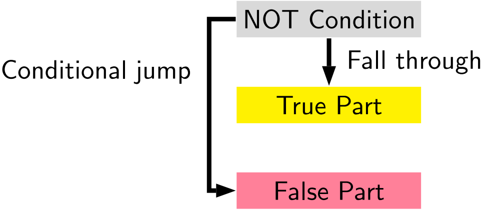
High and Low Level Abstractions



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a = b<10?b:c;
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Spim Assembly Equivalent

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Implementation Mechanisms

- Translation $=$ Analysis $+$ Synthesis

  Interpretation $=$ Analysis $+$ Execution

Implementation Mechanisms

- $$\begin{aligned}\text{Translation} &= \text{Analysis} + \text{Synthesis}\\ \text{Interpretation} &= \text{Analysis} + \text{Execution}\end{aligned}$$

- Translation Instructions $\Longrightarrow$ Equivalent Instructions

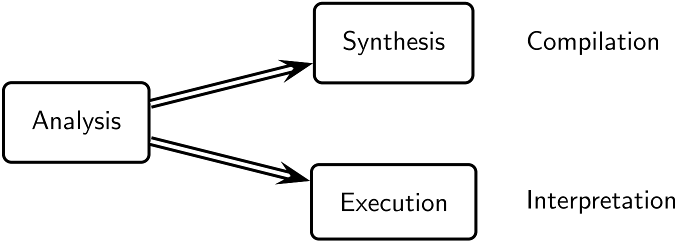
Implementation Mechanisms

- Translation $=$ Analysis $+$ Synthesis
  Interpretation $=$ Analysis $+$ Execution

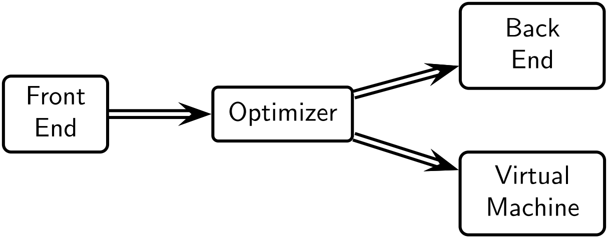
- Translation Instructions $\Longrightarrow$ Equivalent Instructions

  Interpretation Instructions $\Longrightarrow$ Actions Implied by Instructions

Language Implementation Models



Language Processor Models



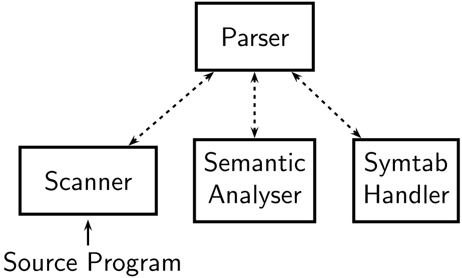
C,C++

Java, C#

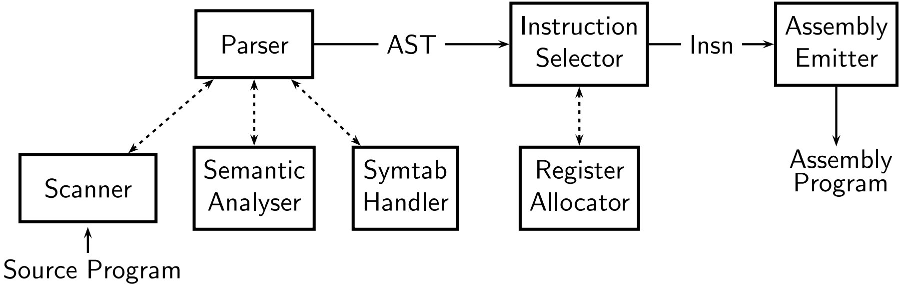
Part 2

An Overview of Compilation Phases

The Structure of a Simple Compiler



The Structure of a Simple Compiler



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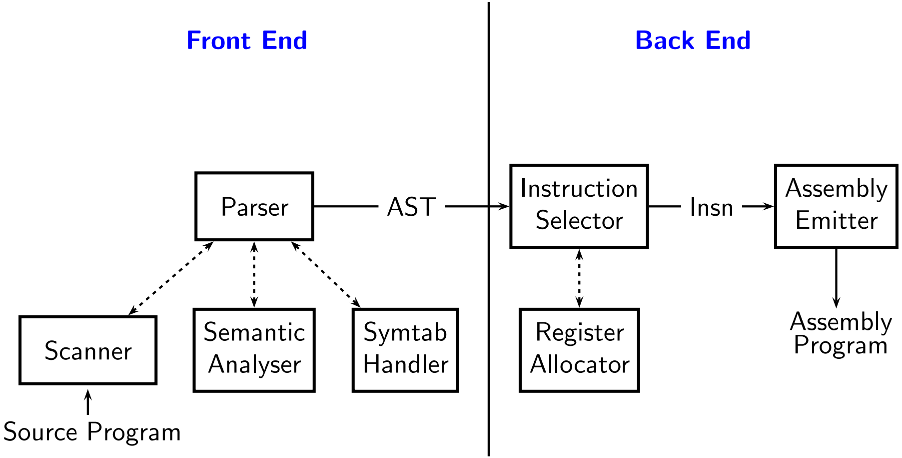
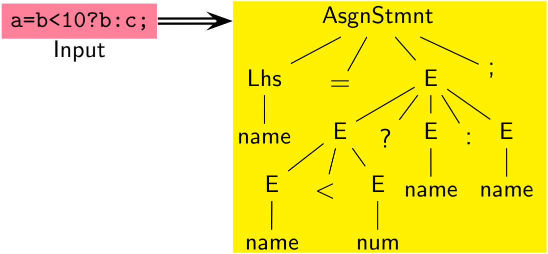


Translation Sequence in Our Compiler: Parsing

`a=b<10?b:c;`

Input

Translation Sequence in Our Compiler: Parsing

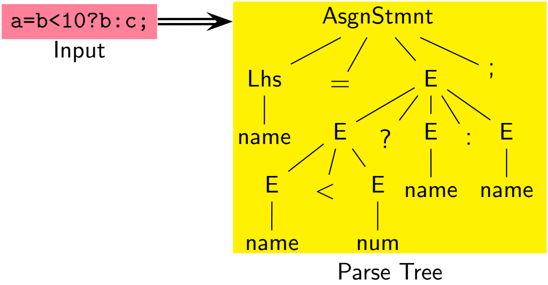


Parse Tree

Issues:

- Grammar rules, terminals, non-terminals
- Order of application of grammar rules
  eg. is it `(a = b<10?)` followed by `(b:c)`?
- Values of terminal symbols
  eg. string "10" vs. integer number 10.

Translation Sequence in Our Compiler: Semantic Analysis



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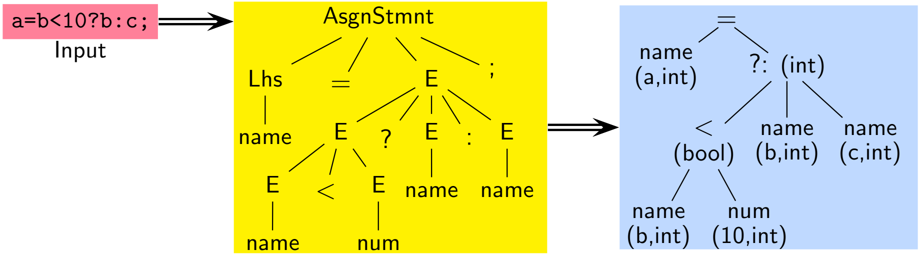


Parse Tree

Abstract Syntax Tree
(with attributes)

Issues:

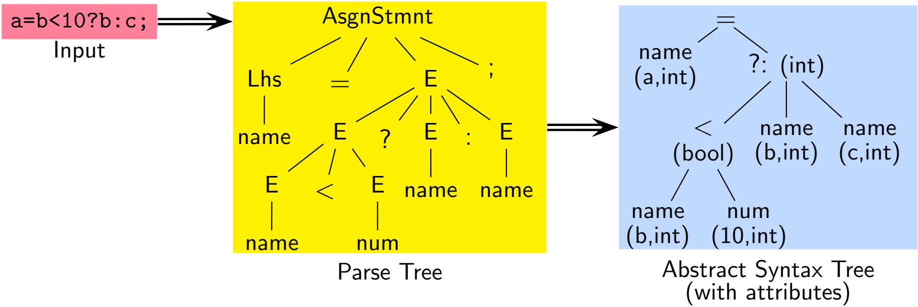
- Symbol tables

  Have variables been declared? What are their types? What is their scope?

- Type consistency of operators and operands

  The result of computing `b<10?` is bool and not int

Translation Sequence in Our Compiler: IR Generation



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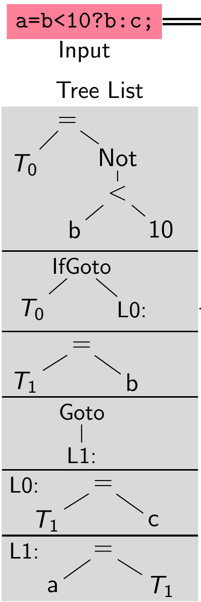
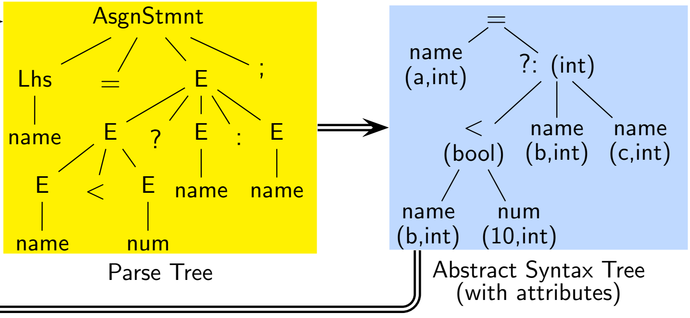




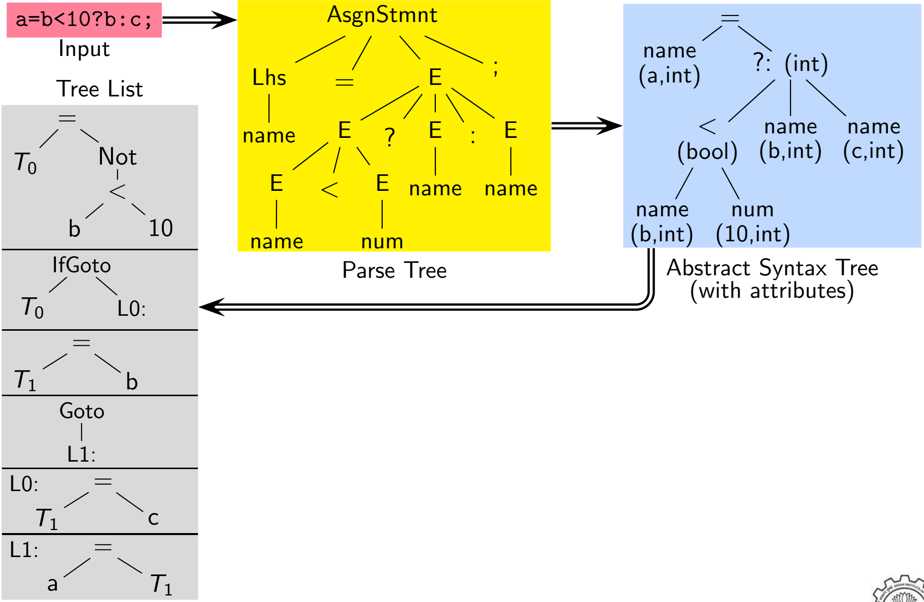
Issues:

- Convert to maximal trees which can be implemented without altering control flow

  Simplifies instruction selection and scheduling, register allocation etc.

- Linearise control flow by flattening nested control constructs

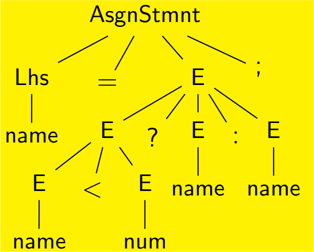
Translation Sequence in Our Compiler: Instruction Selection



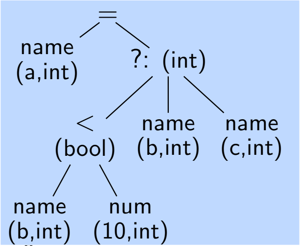
Translation Sequence in Our Compiler: Instruction Selection

`a=b<10?b:c;`

Input

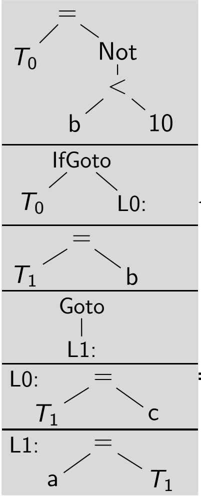


Parse Tree



Abstract Syntax Tree
(with attributes)

Tree List



Instruction List

$T_0 \leftarrow$ b
$T_0 \leftarrow T_0 < 10$
$T_0 \leftarrow\, !\, T_0$
if $T_0 > 0$ goto L0:
$T_1 \leftarrow$ b
goto L1:
L0: $T_1 \leftarrow$ c
L1: a $\leftarrow T_1$

Issues:

- Cover trees with as few machine instructions as possible
- Use temporaries and local registers

Translation Sequence in Our Compiler: Instruction Selection

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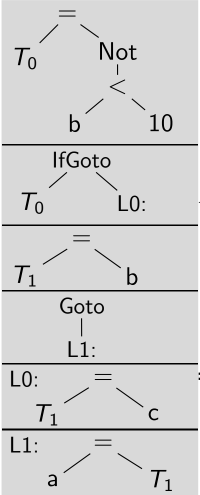
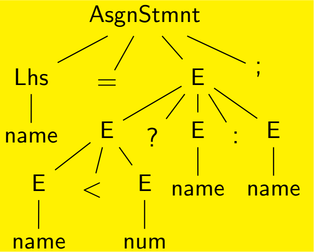
Tree List





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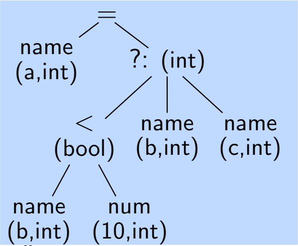

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Translation Sequence in Our Compiler: Emitting Instructions

`a=b<10?b:c;`

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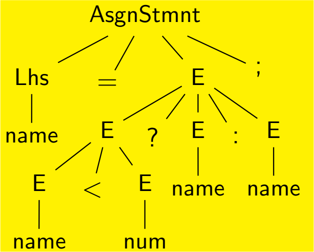
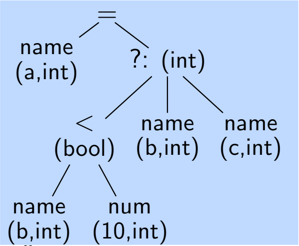


Parse Tree



Abstract Syntax Tree
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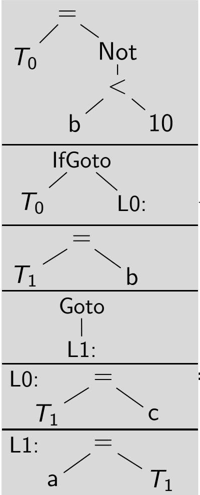
Tree List



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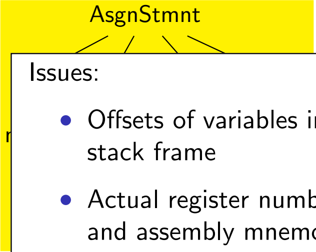
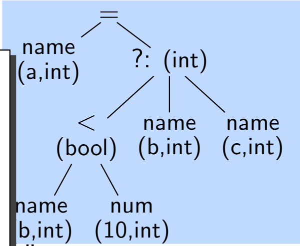
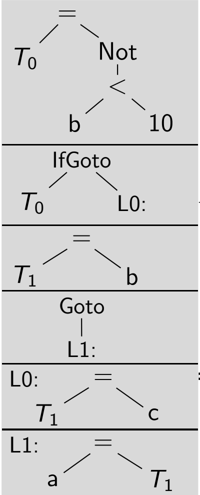




Abstract Syntax Tree (with attributes)

Tree List



Issues:

- Offsets of variables in the stack frame
- Actual register numbers and assembly mnemonics
- Code to construct and discard activation records

Instruction List

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Assembly Code

```
     lw   $t0, 4($fp)
     slti $t0, $t0, 10
     not  $t0, $t0
     bgtz $t0, L0:
     lw   $t0, 4($fp)
     b    L1:
L0:  lw   $t0, 8($fp)
L1:  sw   0($fp), $t0
```

Part 3

Compilation Models

Compilation Models

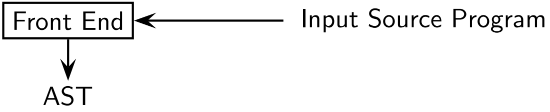
Aho Ullman Model

Davidson Fraser Model

Compilation Models

Aho Ullman Model

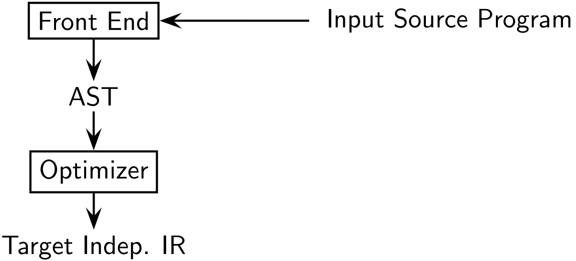
Davidson Fraser Model



Compilation Models

Aho Ullman Model

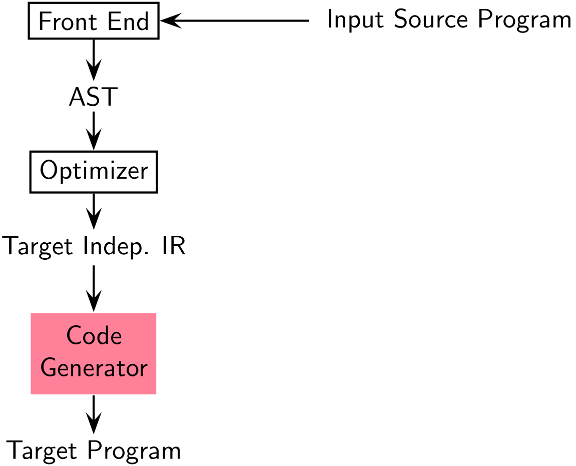
Davidson Fraser Model



Compilation Models

Aho Ullman Model

Davidson Fraser Model



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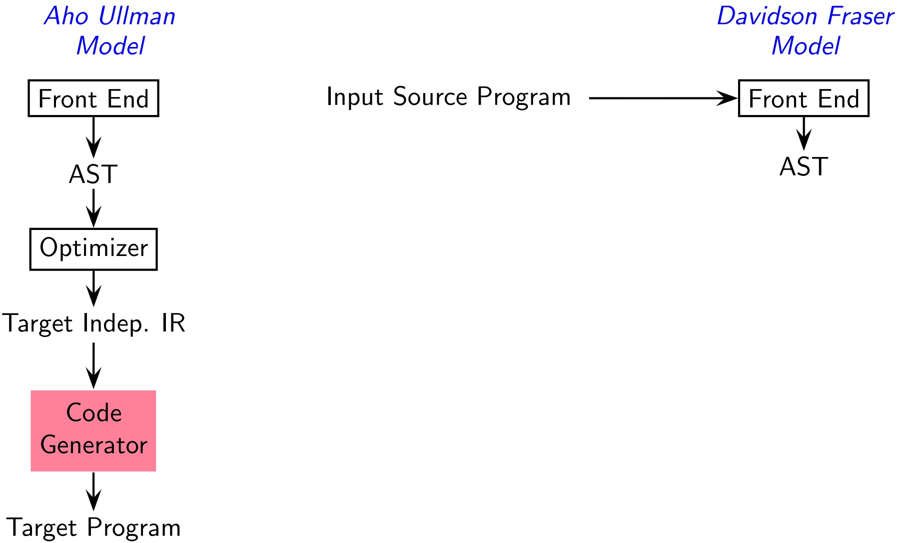

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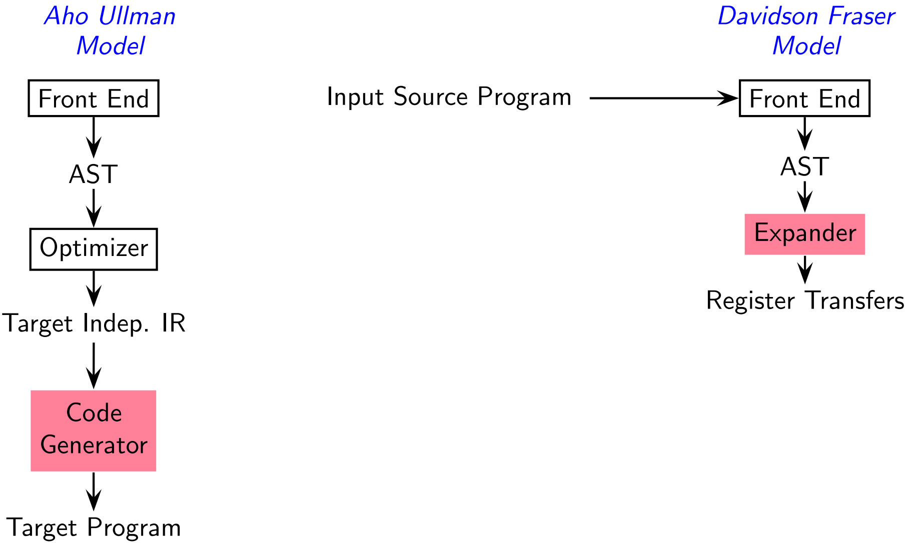
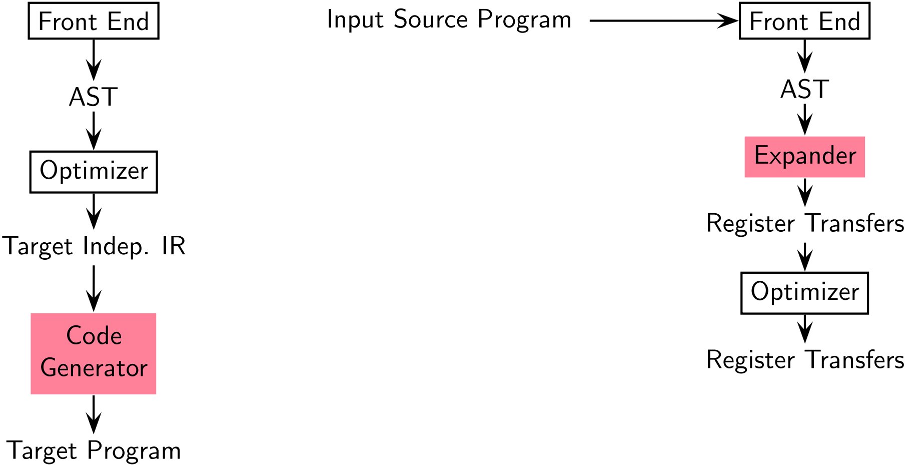


Compilation Models

Aho Ullman Model *Davidson Fraser Model*



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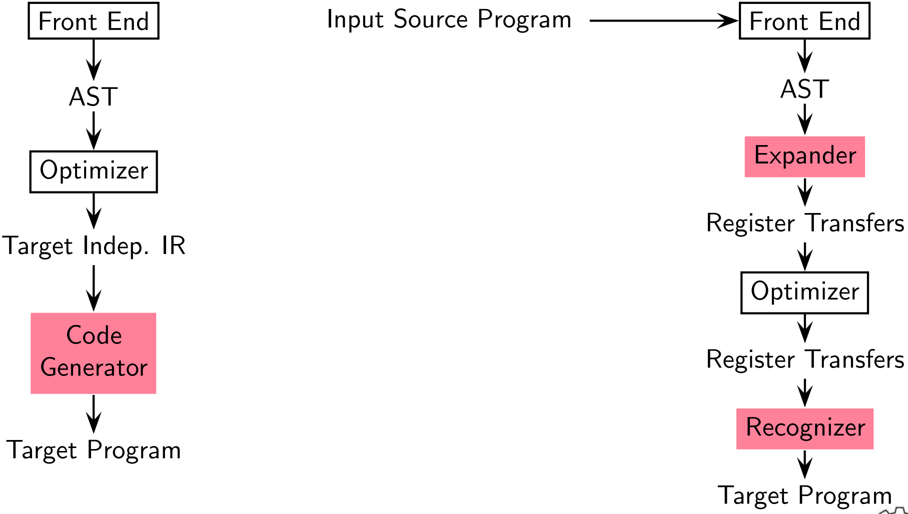
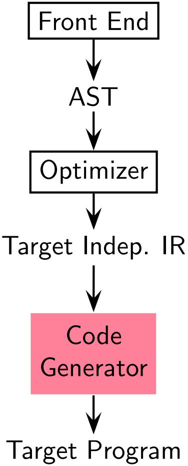


Compilation Models

Aho Ullman Model



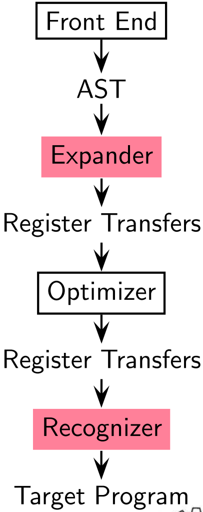
Aho Ullman: Instruction selection

- over optimized IR using
- cost based tree tiling matching

Davidson Fraser: Instruction selection

- over AST using
- simple full tree matching based algorithms that generate
- naive code which is
  - target dependent, and is
  - optimized subsequently

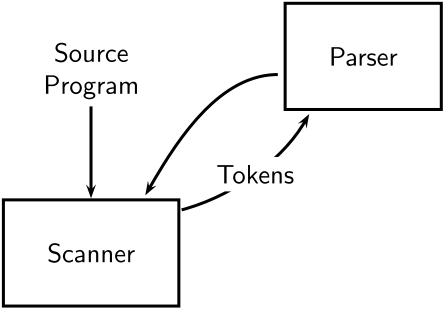
Davidson Fraser Model



Typical Front Ends

Parser

Typical Front Ends



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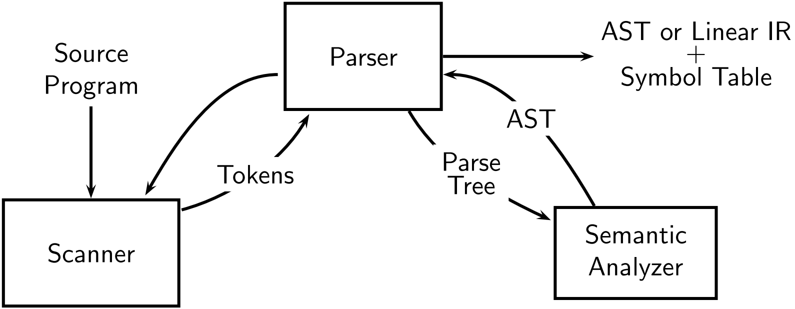

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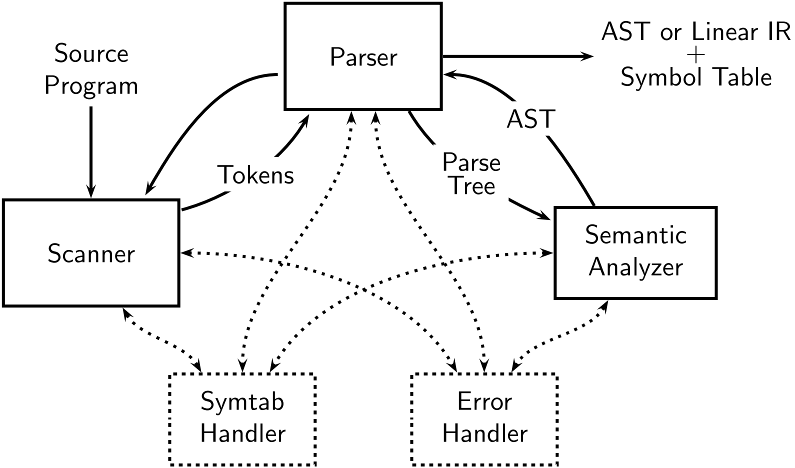
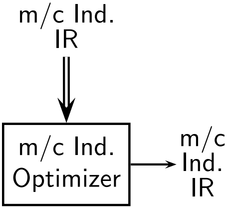
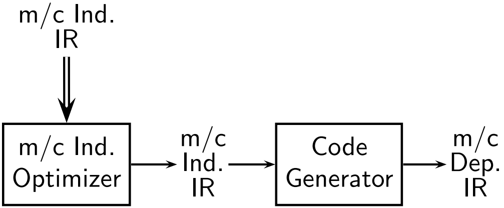


Typical Back Ends in Aho Ullman Model



- Compile time evaluations
- Eliminating redundant computations

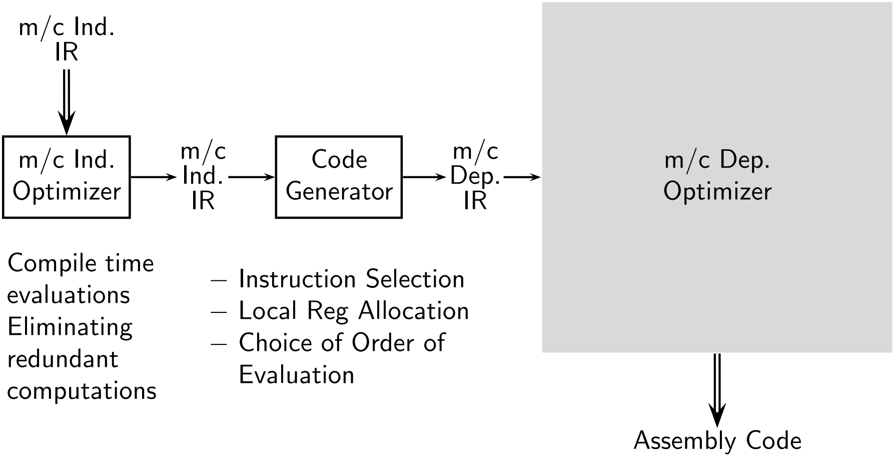
Typical Back Ends in Aho Ullman Model



– Compile time evaluations
– Eliminating redundant computations

– Instruction Selection
– Local Reg Allocation
– Choice of Order of Evaluation

Typical Back Ends in Aho Ullman Model



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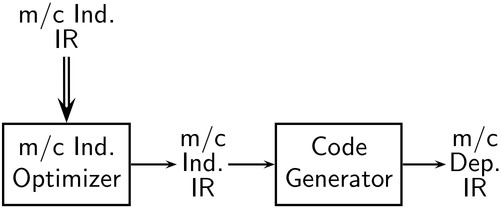

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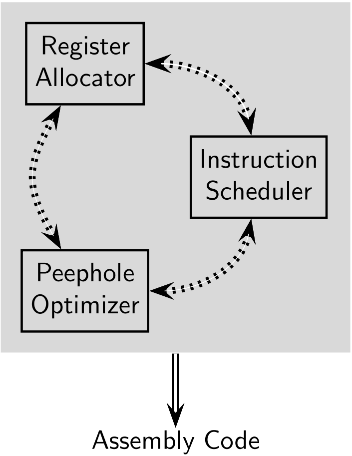

Retargetability in Aho Ullman and Davidson Fraser Models

	Aho Ullman Model	Davidson Fraser Model
Instruction Selection	• Machine independent IR is expressed in the form of trees • Machine instructions are described in the form of trees • Trees in the IR are “covered” using the instruction trees	
Optimization		

Retargetability in Aho Ullman and Davidson Fraser Models

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Retargetability in Aho Ullman and Davidson Fraser Models

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Optimization		

Retargetability in Aho Ullman and Davidson Fraser Models

	Aho Ullman Model	Davidson Fraser Model
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	Cost based tree pattern matching	Structural tree pattern matching
Optimization	Machine independent	

Retargetability in Aho Ullman and Davidson Fraser Models

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