Script generated by TTT

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Virtual Machines

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0 Introduction

Principle of Interpretation:

Program + Input ⇒ **Interpreter** ⇒ Output

Advantage: No precomputation on the program text $\Longrightarrow$ no/short startup-time

Disadvantages: Program parts are repeatedly analyzed during execution + less efficient access to program variables

$\Longrightarrow$ slower execution speed

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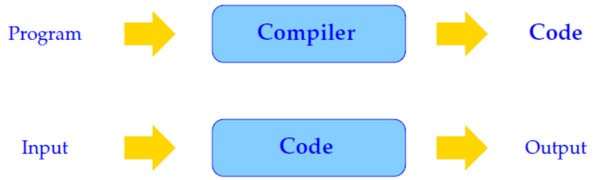
Principle of Compilation:



Two Phases (at two different Times):

- Translation of the source program into a machine program (at compile time);
- Execution of the machine program on input data (at run time).

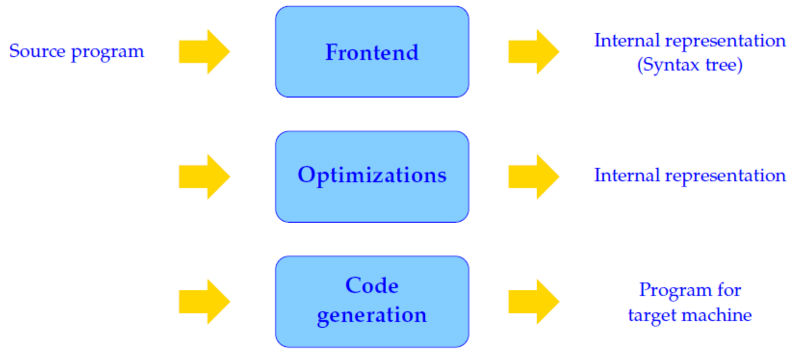
Preprocessing of the source program provides for

- efficient access to the values of program variables at run time
- global program transformations to increase execution speed.

Disadvantage: Compilation takes time

Advantage: Program execution is sped up $\Longrightarrow$ compilation pays off in long running or often run programs

Structure of a compiler:



Subtasks in code generation:

Goal is a good exploitation of the hardware resources:

1. Instruction Selection: Selection of efficient, semantically equivalent instruction sequences;
2. Register-allocation: Best use of the available processor registers
3. Instruction Scheduling: Reordering of the instruction stream to exploit intra-processor parallelism

For several reasons, e.g. modularization of code generation and portability, code generation may be split into two phases:

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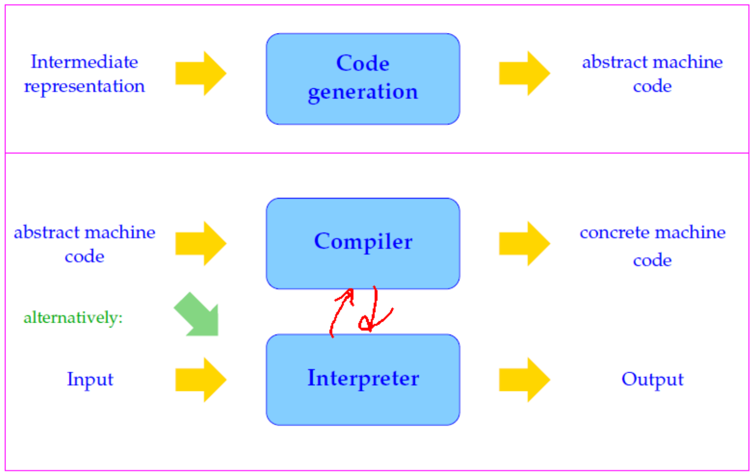


Virtual machine

- idealized architecture,
- simple code generation,
- easily implemented on real hardware.

Advantages:

- Porting the compiler to a new target architecture is simpler,
- Modularization makes the compiler easier to modify,
- Translation of program constructs is separated from the exploitation of architectural features.

Virtual (or: abstract) machines for some programming languages:

Pascal	→	P-machine	
Smalltalk	→	Bytecode	
Prolog	→	WAM	("Warren Abstract Machine")
SML, Haskell	→	STGM	
Java	→	JVM	

We will consider the following languages and virtual machines:

C	→	CMa	//	*imperative*
PuF	→	MaMa	//	*functional*
Proll	→	WiM	//	*logic based*
C±	→	OMa	//	*object oriented*
multi-threaded C	→	threaded CMa	//	*concurrent*

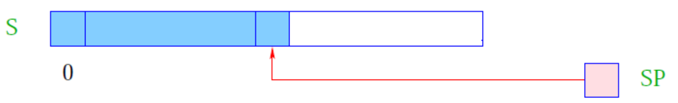
The Translation of C

1 The Architecture of the CMa

- Each virtual machine provides a set of instructions
- Instructions are executed on the virtual hardware
- This virtual hardware can be viewed as a set of data structures, which the instructions access
- ... and which are managed by the run-time system

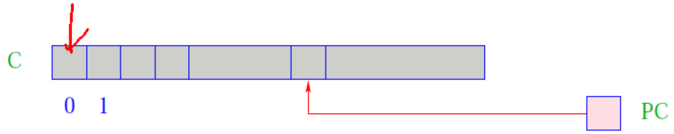
For the CMa we need:

The Data Store:



- S is the (data) store, onto which new cells are allocated in a LIFO discipline
  $\Longrightarrow$ Stack.
- SP (≙ Stack Pointer) is a register, which contains the address of the topmost allocated cell,
  Simplification: All types of data fit into one cell of S.

The Code/Instruction Store:



- C is the Code store, which contains the program.
  Each cell of field C can store exactly one virtual instruction.
- PC (≙ Program Counter) is a register, which contains the address of the instruction to be executed next.
- Initially, PC contains the address 0.
  $\Longrightarrow$ C[0] contains the instruction to be executed first.

Execution of Programs:

- The machine loads the instruction in C[PC] into a Instruction-Register IR and executes it
- PC is incremented by 1 before the execution of the instruction

```
while (true) {
    IR = C[PC]; PC++;
    execute (IR);
}
```

- The execution of the instruction may overwrite the PC (jumps).
- The Main Cycle of the machine will be halted by executing the instruction halt , which returns control to the environment, e.g. the operating system
- More instructions will be introduced by demand

2 Simple expressions and assignments

Problem: evaluate the expression $(1+7)*3$!

This means: generate an instruction sequence, which

- determines the value of the expression and
- pushes it on top of the stack...

Idea:

- first compute the values of the subexpressions,
- save these values on top of the stack,
- then apply the operator.

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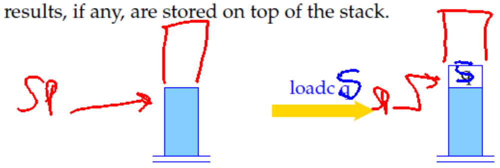
The general principle:

- instructions expect their arguments on top of the stack,
- execution of an instruction consumes its operands,
- results, if any, are stored on top of the stack.




```
SP++;
S[SP] = q;
```

Instruction loadc q needs no operand on top of the stack, pushes the constant q onto the stack.

Note: the content of register SP is only implicitly represented, namely through the height of the stack.

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