Überblick Zwischencode

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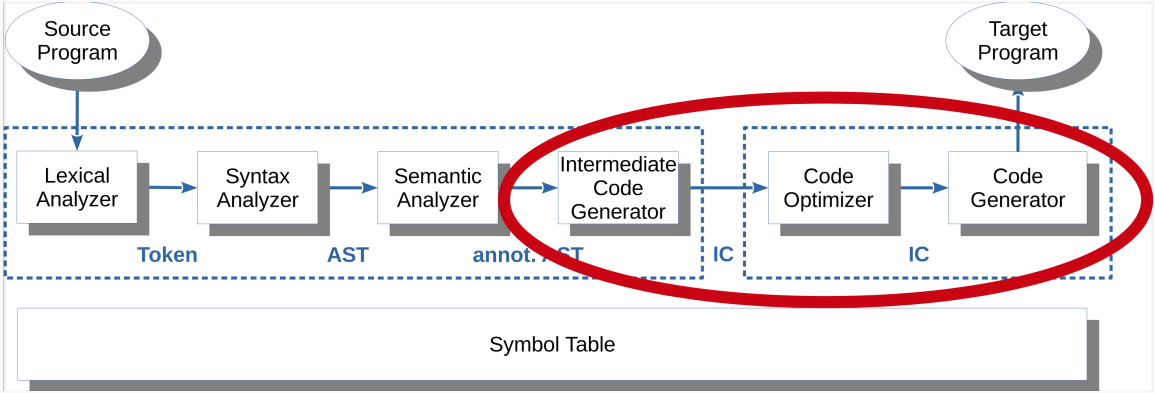
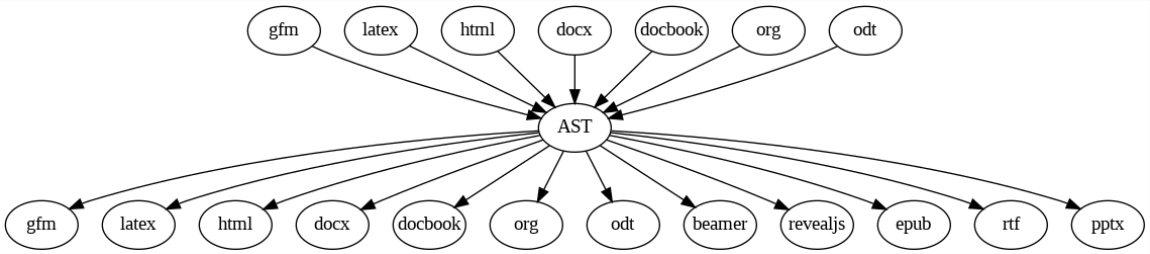
Einordnung


Source Program
Target Program
Lexical Analyzer
Syntax Analyzer
Semantic Analyzer
Intermediate Code Generator
Code Optimizer
Code Generator
Token
AST
IC
IC
Symbol Table

AST als Zwischencode (Beispiel Pandoc)



Konsole: pandoc hello.md -s -t native

Zwischenformat: Drei-Adressen-Code

```
i = i+1;
if (a[i] >= v) {
    i = 0;
}
```

```
    t1 = i + 1
    i  = t1
    t2 = i * 8
    t3 = a + t2
    if t3 >= v goto L1
    goto L2
L1: i  = 0
L2: ...
```

LLVM IR

Low **L**evel **V**irtual **M**achine

```c
int main() {
    int x = 7;
    int y = x + 35;

    return 0;
}
```

```
define i32 @main() #0 {
  %1 = alloca i32, align 4
  %2 = alloca i32, align 4
  %3 = alloca i32, align 4
  store i32 0, i32* %1, align 4
  store i32 7, i32* %2, align 4
  %4 = load i32, i32* %2, align 4
  %5 = add nsw i32 %4, 35
  store i32 %5, i32* %3, align 4
  ret i32 0
}
```

Beispiel: clang -emit-llvm -S -o - hello.c

Bytecode (Beispiel Python)

```
x = 7
y = x + 35
```

```
  1   0 LOAD_CONST    0 (7)
      3 STORE_NAME    0 (x)

  2   6 LOAD_NAME     0 (x)
      9 LOAD_CONST    1 (35)
     12 BINARY_ADD
     13 STORE_NAME    1 (y)
     16 LOAD_CONST    2 (None)
     19 RETURN_VALUE
```

Beispiel: python -m dis hello.py

Bytecode (Beispiel Java)

```java
public class Hello {

    void wuppie() {
        int x = 7;
        int y = x + 35;
    }

}
```

```
Compiled from "Hello.java"
public class Hello {
  public Hello();
    Code:
       0: aload_0
       1: invokespecial #1 // Method java/lang/Object."<init>":()V
       4: return

  void wuppie();
    Code:
       0: bipush        7
       2: istore_1
       3: iload_1
       4: bipush        35
       6: iadd
       7: istore_2
       8: return
}
```

Beispiel: javac Hello.java && javap -c Hello.class

Assembler

```c
int main() {
    int x = 7;
    int y = x + 35;

    return 0;
}
```

```
    .file   "hello.c"
    .text
    .globl  main
    .type   main, @function
main:
.LFB0:
    .cfi_startproc
    pushq   %rbp
    .cfi_def_cfa_offset 16
    .cfi_offset 6, -16
    movq    %rsp, %rbp
    .cfi_def_cfa_register 6
    movl    $7, -8(%rbp)
    movl    -8(%rbp), %eax
    addl    $35, %eax
    movl    %eax, -4(%rbp)
    movl    $0, %eax
    popq    %rbp
    .cfi_def_cfa 7, 8
    ret
    .cfi_endproc
.LFE0:
    .size       main, .-main
    .ident      "GCC: (Ubuntu 7.3.0-27ubuntu1~18.04) 7.3.0"
    .section    .note.GNU-stack,"",@progbits
```

Wrap-Up

- Compiler generieren aus AST Zwischencode ("*IC*" oder "*IR*")
- Kein allgemein definiertes Format, große Bandbreite:
  - AST als IR
  - LLVM IR
  - Drei-Adressen-Code
  - Diverse Arten von Bytecode
  - Assemblercode

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