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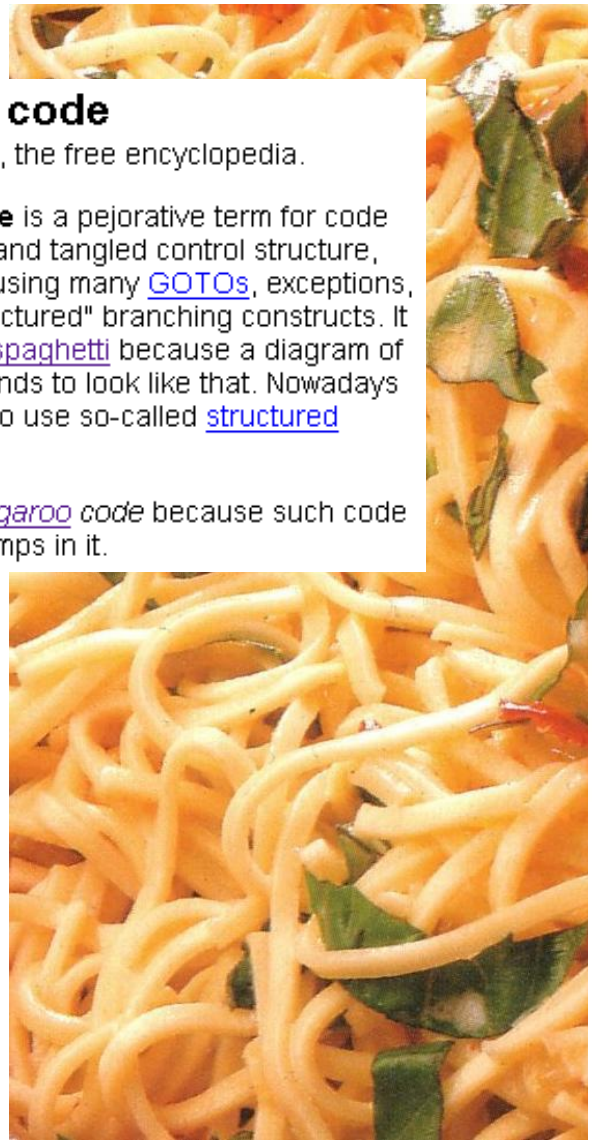
Structured Programming – Control Structures

Computer Engineering 1

Motivation

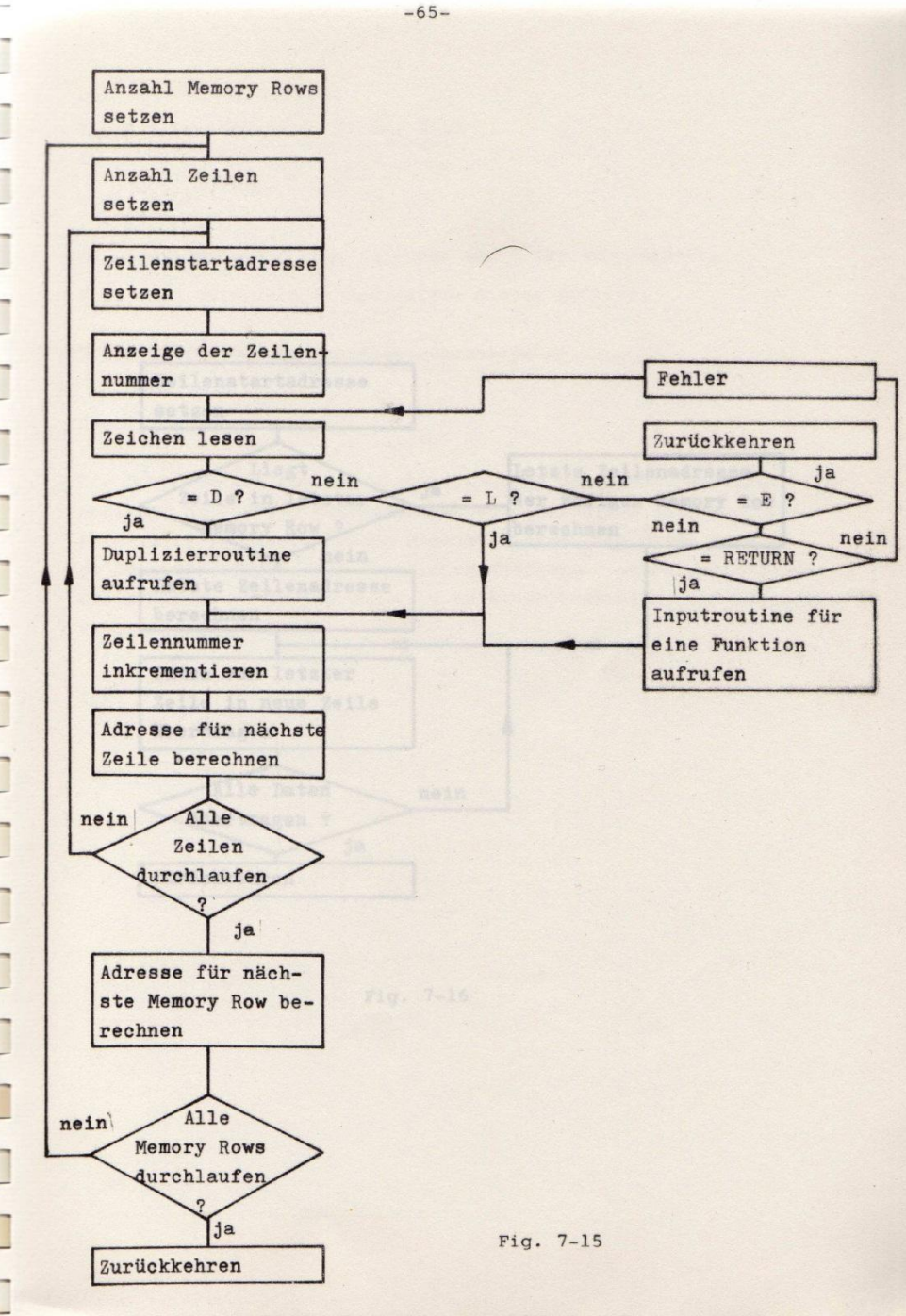


Spaghetti code

From Wikipedia, the free encyclopedia.

Spaghetti code is a pejorative term for code with a complex and tangled control structure, especially one using many GOTOs, exceptions, or other "unstructured" branching constructs. It is named after spaghetti because a diagram of program flow tends to look like that. Nowadays it is preferable to use so-called structured programming.

Also called *kangaroo code* because such code has so many jumps in it.



Agenda

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- **Structured Programming**
- **Selection**
  - if – then - else
- **Loops**
  - Do – While
  - While
  - For
- **Switch Statements**

Learning Objectives

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At the end of this lesson you will be able

- to explain the basic concepts of structured programming
- to enumerate and explain the basic elements of a structogram
- to comprehend how a C-compiler implements control structures in assembly language
  - if-then-else
  - do-while loops
  - while loops
  - for loops
  - switch statements
- to program basic structograms in assembly language

Why Structured Programming ?

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- **Rules for the structure of a program**
  - Patterns for control structures
    - Sequence
    - Selection if - then - else
    - Iteration / Loop for, while, do - while
  - Compilers generate code-blocks based on these patterns

- **Supports program development**
  - Clarity
  - Documentation
  - Maintenance
  - Allows to program on a higher level of abstraction

Structured Programming

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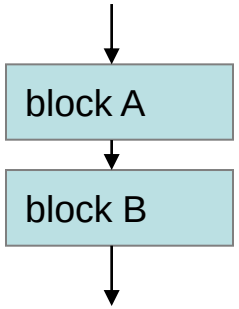
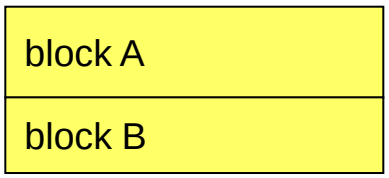
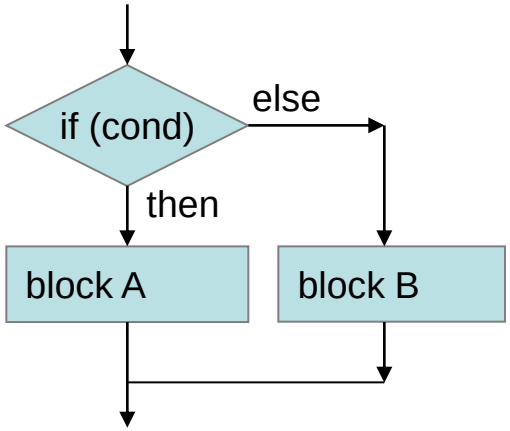
- **Program flow can be represented with three elements**

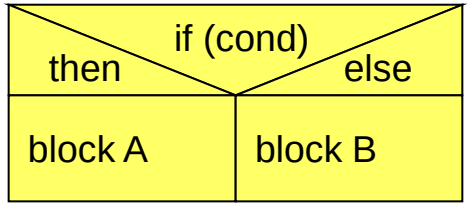
Sequence



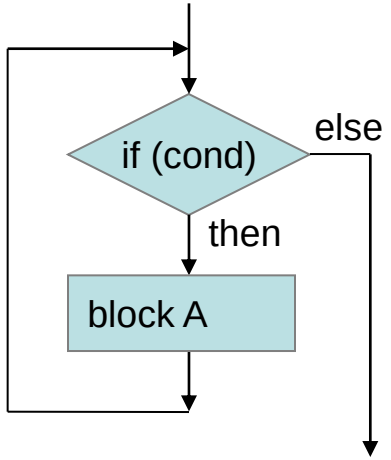


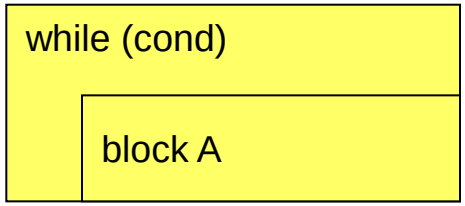
Selection





Iteration / loop

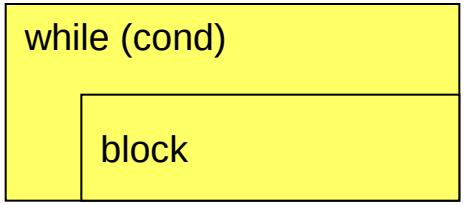




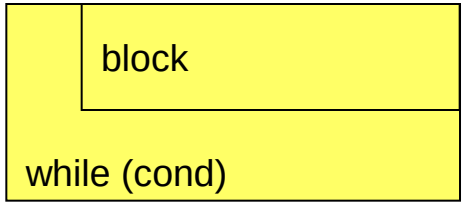
Further Structograms

- **Iteration**

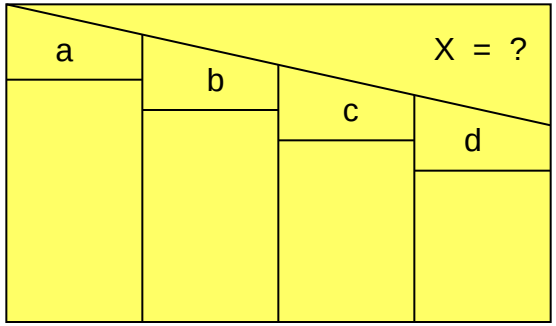
pre-test loop



post-test loop



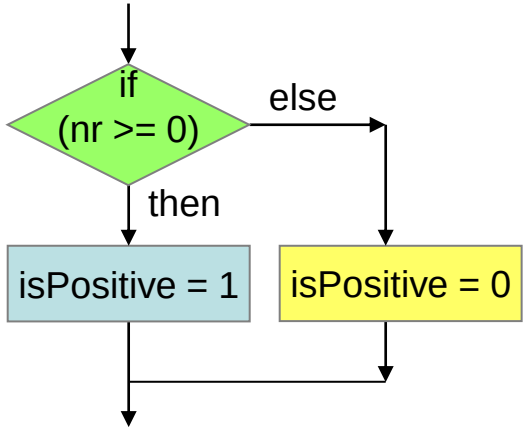
- **Switch statement (case)**

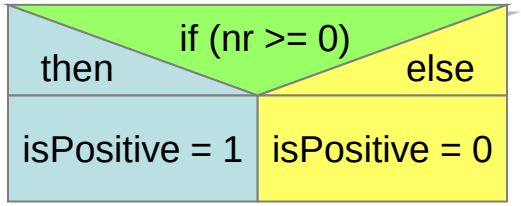


Selection

- **if(...) – then - else**

```
int32_t nr, isPositive;
...
if (nr >= 0) {
    isPositive = 1;
}
else {
    isPositive = 0;
}
```





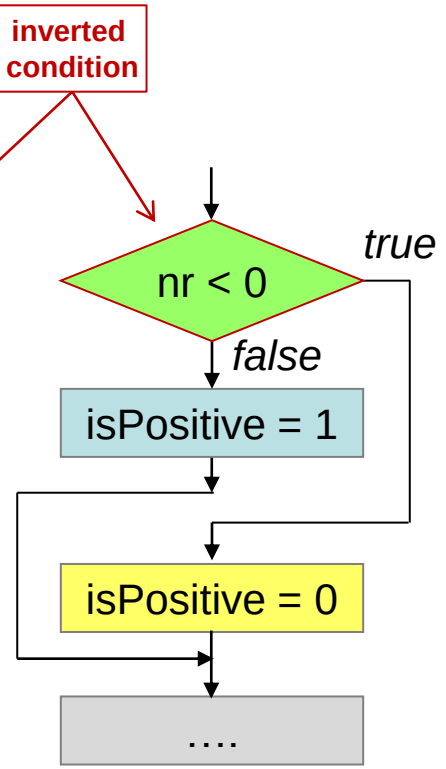
Selection: if – then – else

- Compiler translates *selection* into assembly code
  - uses conditional and unconditional jumps

```
int32_t nr;
int32_t isPositive;
...
if (nr >= 0) {
    isPositive = 1;
}
else {
    isPositive = 0;
}
```

Assume: nr in R1
isPositive in R2

```
        CMP     R1,#0x00
        BLT     else
        MOVS    R2,#1
        B       end_if
else
        MOVS    R2,#0
end_if
        ....
```



Loops: Do-While Loops

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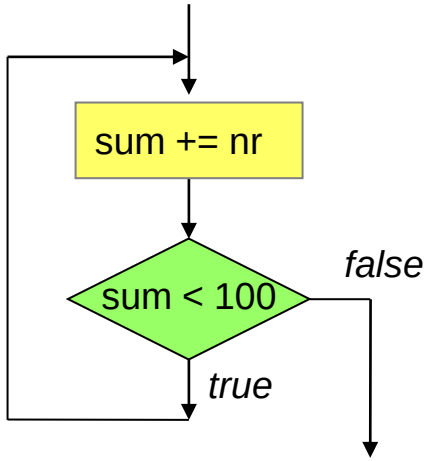
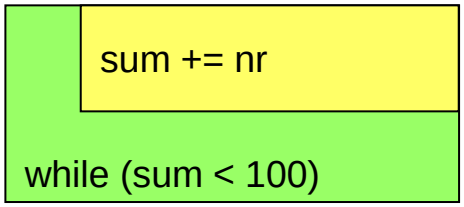
```
int32_t nr;
int32_t sum;
...
sum = 0;
do {
    sum += nr;
} while (sum < 100);
```



post-test loop



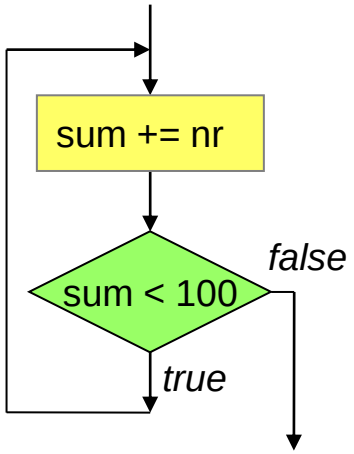
Loops: Do-While Loops

- Compiler translates *post-test loop* to assembly code

```
int32_t nr;
int32_t sum;
...
sum = 0;
do {
    sum += nr;
} while (sum < 100);
```

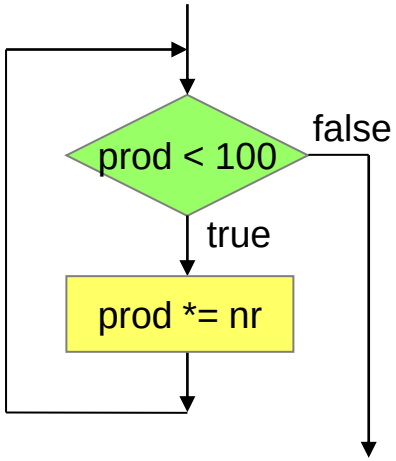
Assume: nr in R1
sum in R2

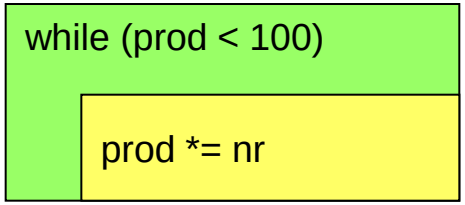
```
        MOVS   R2,#0
loop    ADDS   R2,R2,R1
        CMP    R2,#100
        BLT    loop
        ....
```



Loops: While Loops

```
int32_t nr;
int32_t prod;
...
prod = 1;
while (prod < 100) {
    prod *= nr;
}
```





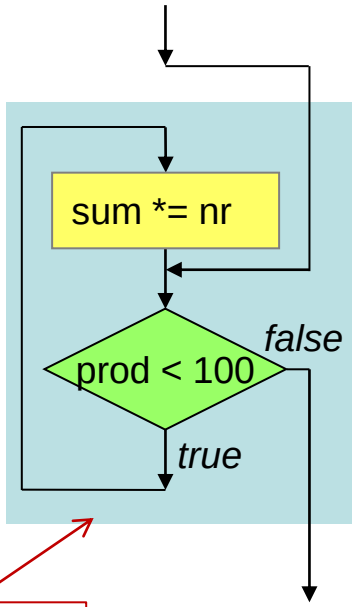
Loops: While Loops

- Compiler translates *pre-test loop* to assembly code
  - Re-using structure of do-while (pre-test loop)

```
int32_t nr;
int32_t prod;
...
prod = 1;
while (prod < 100) {
    prod *= nr;
}
```

Assume: nr in R1
prod in R2

```
        MOVS    R2,#1
        B       test
loop
        MULS    R2,R1,R2
test
        CMP     R2,#100
        BLT     loop
        ...
```



re-use do-while

Loops: For Loops

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- For Loops are converted into While Loops
  - break/continue statements require special treatment

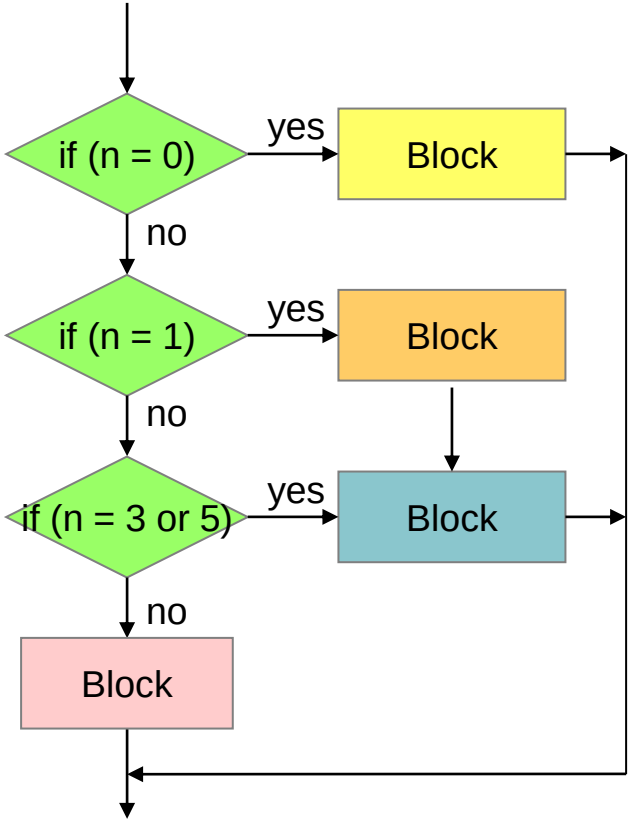
```
for (init-expr; test-expr; update-expr)
    body-block
```

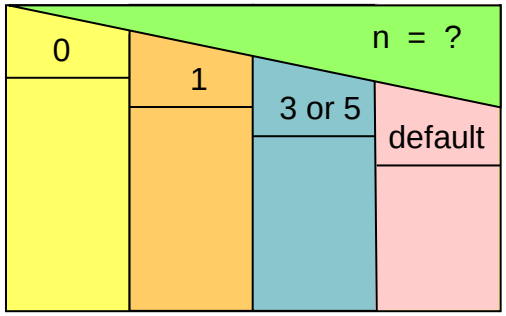
```
init-expr;
while (test-expr) {
    body-block
    update-expr;
}
```

Switch Statements

```
uint32_t result, n;

switch (n) {
case 0:
    result += 17;
    break;
case 1:
    result += 13;
    //fall through
case 3: case 5:
    result += 37;
    break;
default:
    result = 0;
}
```





Structogram without fall-through

Switch Statements

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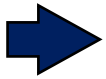
- **Jump Table**

```
uint32_t result, n;
switch (n) {
case 0:
    result += 17;
    break;
case 1:
    result += 13;
    //fall through
case 3: case 5:
    result += 37;
    break;
default:
    result = 0;
}
```



```
NR_CASES        EQU   6

case_switch     CMP   R1, #NR_CASES
                BHS   case_default
                LSLS  R1, #2    ; * 4
                LDR   R7, =jump_table
                LDR   R7, [R7, R1]
                BX    R7
case_0          ADDS  R2, R2, #17
                B     end_sw_case
case_1          ADDS  R2, R2, #13
case_3_5        ADDS  R2, R2, #37
                B     end_sw_case
case_default    MOVS  R2,#0
end_sw_case     ...
```

```
jump_table      DCD   case_0
                DCD   case_1
                DCD   case_default
                DCD   case_3_5
                DCD   case_default
                DCD   case_3_5
```

Assume: n in R1
result in R2

Limitations of Conditional Branches

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- **Limited range of -256..254 Bytes**
  - Example

```
IF      CMP   R1, R0
        BNE   ELSE

THEN    <some code>
        B     IF_END
ELSE    <some other code>

IF_END
```

Simple code for the case when <some code> is short

Unconditional branch has longer range than conditional branch

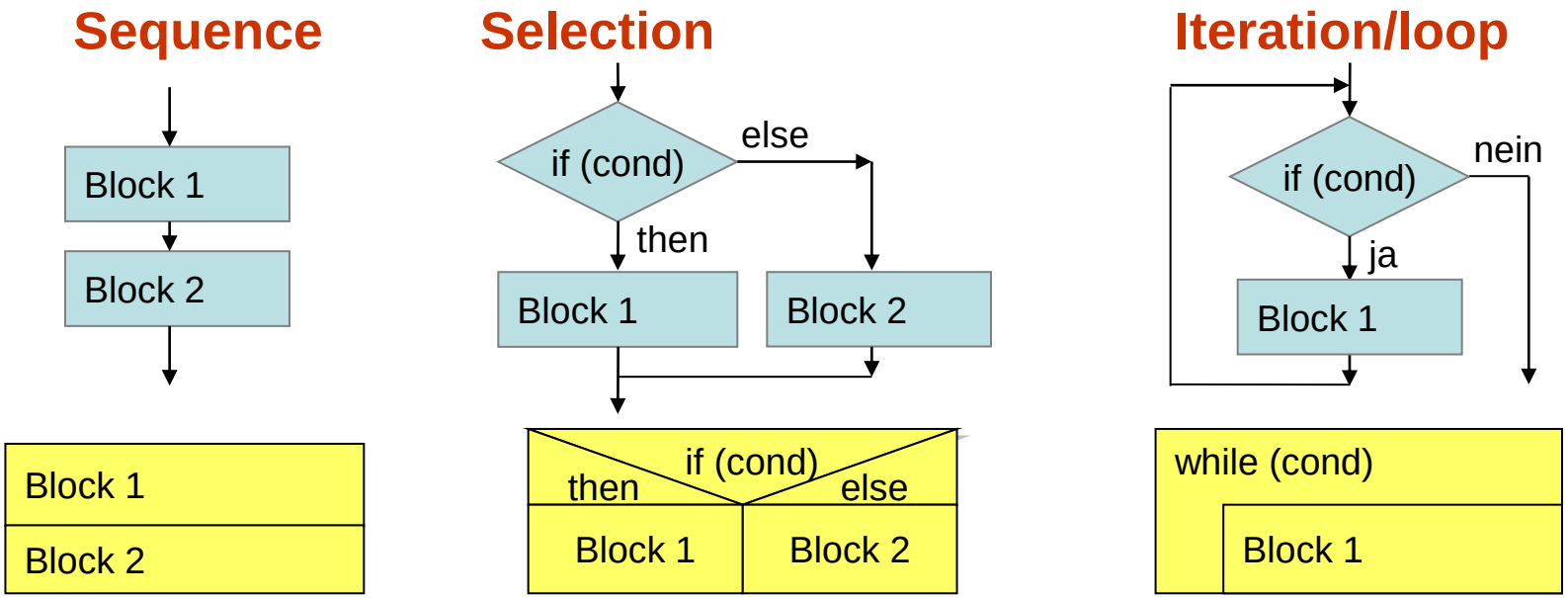
```
IF      CMP   R1, R0
        BEQ   THEN
        B     ELSE
THEN    <some code>
        B     IF_END
ELSE    <some other code>

IF_END
```

Code requires additional branch in case when <some code> is too long

Conclusion

- Program flow can be represented with three elements



- High level programming language provides these control structures
- Compiler translates control structures to assembly using conditional and unconditional jumps