

# Programming Languages: Control Flow

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# Control Flow

- Usual control flow: a command followed by the other.  
Executed in sequence. [single entrance - single exit](#)
- Commands to change control flow and transfer execution to another point: [sequencers](#)
  - Jumps
  - Escapes
  - Exceptions

# Jumps

- Jumps transfer control to a point in the code. The destination is marked with **labels**
- When jumps to arbitrary positions are possible:

```
L1:  x++;  
    if (x>10) goto L2;  
    j++;  
    for (i=0; i<j; j++) {  
        x=x*2;  
L2:    if (x>1000) goto L3;  
        else goto L1;  
    }  
L3:  printf("out\n");
```

The diagram illustrates the execution flow of the code. A green arrow starts at the beginning of the code and points to the first 'goto L2' statement. A red arrow starts at the 'goto L3' statement and points to the 'printf' statement. A purple arrow starts at the 'goto L1' statement and points to the beginning of the code. A blue arrow starts at the 'goto L1' statement and points to the 'goto L2' statement. A yellow arrow starts at the 'goto L2' statement and points to the 'goto L1' statement. A blue arrow starts at the 'goto L3' statement and points to the 'goto L1' statement.

- Called **spaghetti coding**

- Unrestricted jumps  $\Rightarrow$  spaghetti coding.
- Dream of a PL where labels are first order values. 😊
- Further problems. Which jumps have problems?:

```

L1:  ....
      goto L2;           ①
      ....
      for (i=0; i<10; i++) {
L2:  ....
          goto L1;       ②
          ...
          goto L2:       ③
      }

```

- Lifetime and values of local variables? Values of index variables?
- C: Labels are local to enclosing block. No jumps allowed into the block. Newer languages avoid jumps.
- Single entrance multiple exit is still desirable.  $\rightarrow$  escapes

# Escapes

- Restricted jumps to out of textually enclosing block(s)
- Depending on which enclosing block to jump out of:
  - loop: `break` sequencer.
  - loops: `exit` sequencer.
  - function: `return` sequencer.
  - program: `halt` sequencer.

- **break sequencer** in C, C++, Java terminates the innermost enclosing loop block.
- **continue** in C, C++ stays in the same block but ends current iteration.
- **exit sequencer** in Ada or labeled **break** in Java can terminate multiple levels of blocks by specifying labels. Java code:

```
L1:  for (i=0; i<10; i++) {  
        for (j=i; j<i; j++) {  
            if (...) break;  
            else if (...) continue;  
            else if (...) break L1;  
            else if (...) continue L1;  
            s+=i*j;  
        }  
    }
```

- **return sequencer** exist in most languages for terminating the innermost function block.
- **halt sequencer** either provided by operating system or PL terminates the program.
- Consider jump inside of a block or jump out of a block for the function case:

```
int f(int n) {  
    int a;  
  
L1: if (n<0) goto L2;    ①  
    else if (n=1) return 1;  
    else return f(n-1)*n;  
}  
int main() {  
    ...  
    f(12);  
L2: ....  
    goto L1:            ②  
}
```



- Jump out of a function block, jump inside of a function block
- Activation record, run-time stack? Possible only for one direction if stack position can be recovered.
- Non-local jumps
- unexpected error occurring inside of many levels of recursion. Jump to the outer-most related caller function. [Exceptions](#)

# Exceptions

- Controlled jumps out of multiple levels of function calls to an outer control point (handler or catch)
- C does not have exceptions but non-local jumps possible via `setjmp()`, `longjmp()` library calls.
- C++ and Java: `try {...} catch(...) {...}`
- Each try-catch block introduces a non-local jump point. try block is executed and whenever a `throw expr` command is called in any functions called (even indirectly) inside try block execution jumps to the `catch()` part.
- try-catch blocks can be nested. Execution jumps to closes catch block with a matching type in the parameters with the thrown expression.

- Conventional error handling. Propagate errors with return values.

```
...
int searchopen(char *f) { ...
    /* if search fails error occurs here */
    return -5;
...}
int openparse(char *f) { ...
    if ((r = searchopen(f)) < 0)
        return r;
    else ...
}
int main() { ...
    if ((rv = openparse("file.txt")) < 0) {
        /*handle error here */
    }
    ...
}
```

## ■ Error handling with try-catch. (based on run-time stack)

```
...
enum Exception { NOTFOUND, ..., PERMS};
void searchopen(char *f) { ...
    /* if open fails error occurs here */
    throw PERMS;
...}
void openparse(char *f) { ...
    searchopen(f);
    ...
}
int main() { ...
    try {...
        openparse("file.txt");
        ...
    } catch(Exception e) {
        /*handle error here */
    }
    ...
}
```

Nested exceptions are handled based on types. C++:

```

int main() {... try { C1; f() ; C2 } catch (double a) {...}}
void f() {...; try {...; g() ; ... } catch (int a) { ... } }
void g() {...; throw 4; ... ; throw 1.5; ...}

```

The diagram illustrates the flow of an exception through nested try-catch blocks. Blue arrows labeled "call" show the normal execution path: from `main()` to `f()`, and then to `g()`. Red arrows labeled "exception" show the path of an exception thrown from `g()`. The exception is first caught by the inner `catch (int a)` block in `f()`, and then it is re-thrown to be caught by the outer `catch (double a)` block in `main()`. This demonstrates how nested exceptions are handled based on their types.

In case no handlers found a run time error generated. Program halts.