Introduction to the C programming language

Pointers

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Outline

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Pointers

- A pointer is a special type of variable that can hold *memory addresses*
- Syntax

```
char c;       // a char variable
char *pc;     // pointer to char variable
int i;        // an integer variable
int *pi;      // pointer to an int variable
double d;     // double variable
double *pd;   // pointer to a double variable
```

- In the declaration phase, the `*` symbol denotes that the variable contains the address of a variable of the corresponding type

Syntax - cont.

- A pointer variable may contain the address of another variable

```
int i;
int *pi;

pi = &i;
```

- The `&` operator is used to obtain the address of a variable.
- It is called the *reference* operator
  - Warning: in C++ a reference is a different thing! Right now, pay attention to the meaning of this operator in C.

Indirection

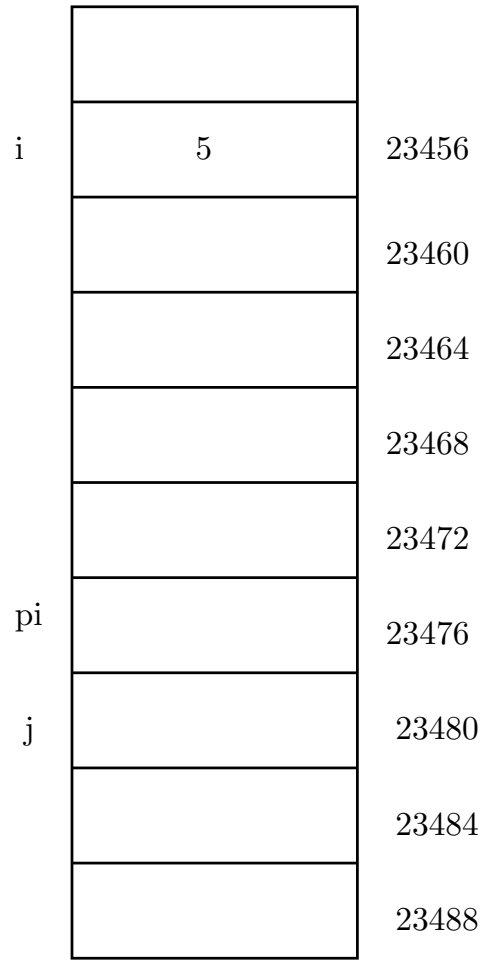
- The reverse is called *indirection* operator and it is denoted by `*`

```
int j;
j = *pi;  // get the value pointed by pi

*pi = 7;  // store a value in the address stored in pi
```

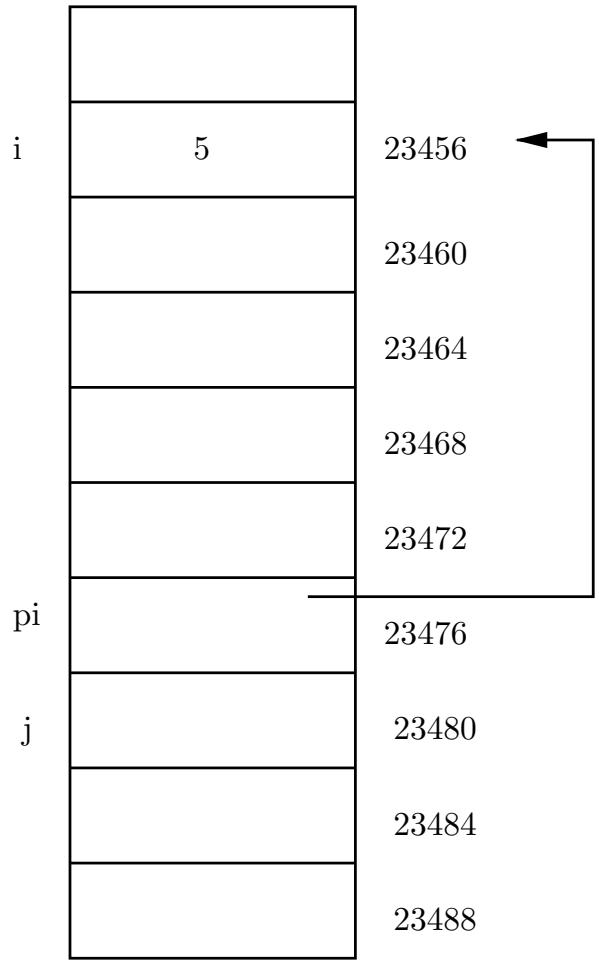
- In the first assignment, `j` is assigned the value present at the address pointed by `pi`.
- In the second assignment, the constant `7` is stored in the location contained in `pi`
- `*pi` is an *indirection*, in the sense that is the same as the variable whose address is in `pi`

Example


i
5
23456
23460
23464
23468
23472
pi
23476
j
23480
23484
23488

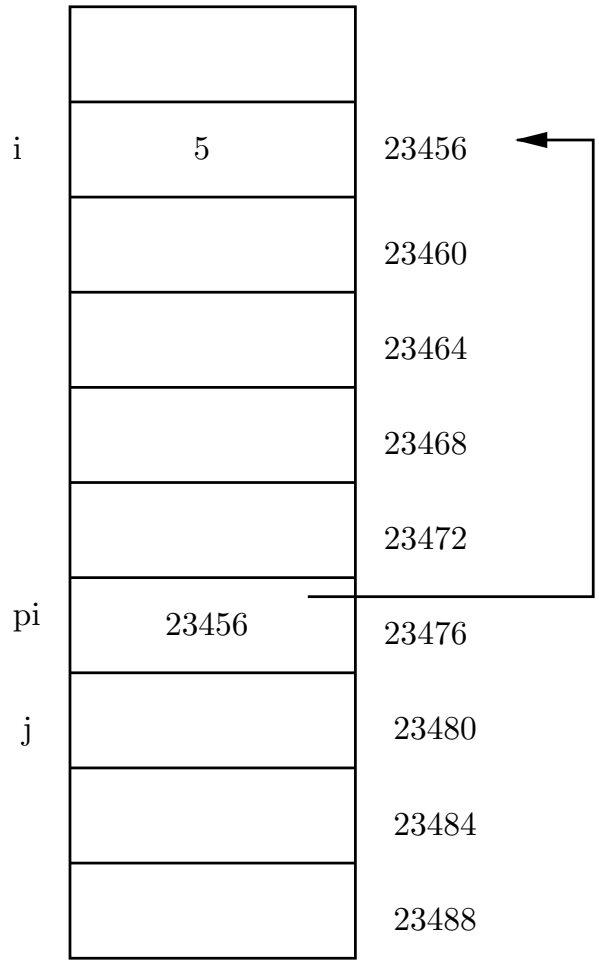
Example

- `pi` is assigned the address of `j`



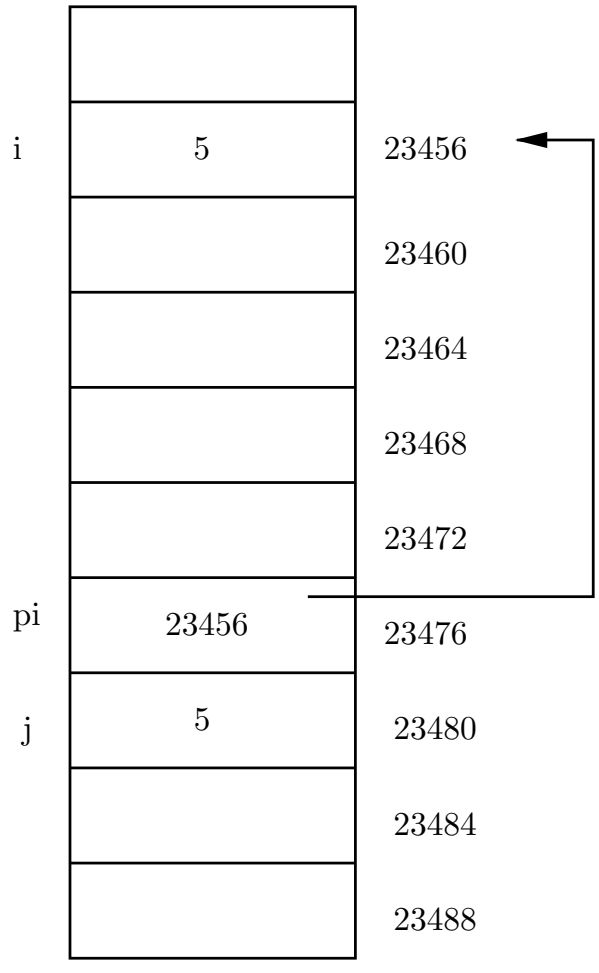
Example

- `pi` is assigned the address of `j`



Example

- `pi` is assigned the address of `j`
- `j` is assigned the value of the variable pointed by `pi`



Examples

pointers/point1.cpp

```
int main()
{
    int d = 5;
    int x = 7;
    int *pi;

    pi = &x;
    cout << "&x = " << &x << endl;
    cout << "&d = " << &d << endl;
    cout << "pi = " << pi << endl;

    cout << "*pi = " << *pi << endl;

    //pi = d;  // compilation error

    d = *pi;

    cout << "pi = " << pi << endl;
    cout << "x = " << x << endl;
    cout << "d = " << d << endl;
}
```

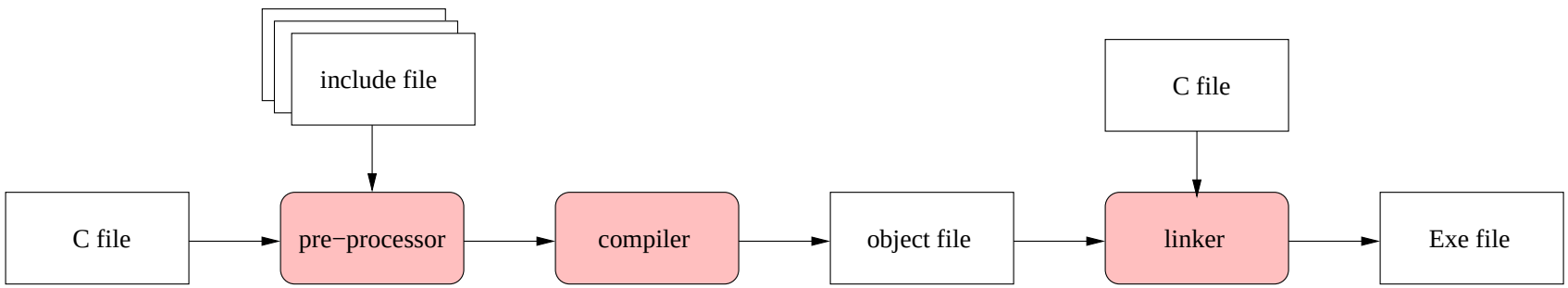
The commented line is a syntax error

- We are assigning a variable to a pointer
- The programmer probably forgot a `&` or a `*`

Outline

The pre-processor

- It is time to look in more details at the *compilation* process
  - That is, translating from high level C code to low-level machine code
- The step are described below



Pre-processor

- In this step, the input file is analyzed to process *preprocessor directives*
- A preprocessor directive starts with symbol `#`
  - Example are: **`#include`** and **`#define`**
- After this step, a (temporary) file is created that is then processed by the compiler

Directives

- With the **include** directive, a file is included in the current text file
  - In other words, it is copied and pasted in the place where the include directive is stated
- With the **define** directive, a symbol is defined
  - Whenever the preprocessor reads the symbol, it substitutes it with its definition
  - It is also possible to create macros
- To see the output of the pre-processor, run g++ with -E option (it will output on the screen)

```
g++ -E myfile.cpp
```

An example

preprocessor/main.cpp

```
#include "myfile.hpp"
#include "yourfile.hpp"

int d;
int a=5;
int b=6;

int main()
{
    double c = PI;    // pi grego
    d = MYCONST;      // a constant
    a = SUM(b,d);     // a macro
    return int(a);
}
```

preprocessor/myfile.hpp

```
#define MYCONST 76

extern int a, b;

#define SUM(x,y) x+y
```

preprocessor/yourfile.hpp

```
#define PI 3.14

extern int d;
```

An example

preprocessor/main.cpp

```
#include "myfile.hpp"
#include "yourfile.hpp"

int d;
int a=5;
int b=6;

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{
    double c = PI;     // pi grego
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```

preprocessor/myfile.hpp

```
#define MYCONST 76

extern int a, b;

#define SUM(x,y) x+y
```

preprocessor/yourfile.hpp

```
#define PI 3.14

extern int d;
```

preprocessor/main.cpp.post

```
# 1 "main.cpp"
# 1 "<built-in>"
# 1 "<command-line>"
# 1 "main.cpp"
# 1 "myfile.hpp" 1


extern int a, b;
# 2 "main.cpp" 2
# 1 "yourfile.hpp" 1


extern int d;
# 3 "main.cpp" 2

int d;
int a=5;
int b=6;

int main()
{
    double c = 3.14;
    d = 76;
    a = b+d;
    return int(a);
}
```

Macros effects

- Pay attention to macros, they can have bad effects

```
#define SUM(x,y) x+y

int main()
{
  int a = 5, b = 6, c;

  c = 5 * SUM(a,b);
}
```

- What is the value of variable c?

Some helpful “tricks”

- It is possible to define a macro for obtaining the literal name of a variable:

```
#define LIT_VAR(x) #x
```

A complete example: pointers/point2.cpp

```
#include <iostream>
using namespace std;

#define LIT_VAR(a) #a
#define PVAR(y) cout << LIT_VAR(y) " = " << y << endl

int main()
{
    int d = 5;
    int x = 7;
    int *pi;

    pi = &x;

    PVAR(d);  PVAR(&d);
    PVAR(x);  PVAR(&x);
    PVAR(pi); PVAR(*pi);

    d = *pi;

    PVAR(pi); PVAR(x);
    PVAR(d);
}
```

Outline

Arguments of function

- In C, arguments are passed by value
  - With the exception of arrays
- However, we can use pointers to pass arguments by *reference*

```
void swap(int *a, int *b)
{
  int tmp;

  tmp = *a;
  *a = *b;
  *b = tmp;
}

int main()
{
  int x = 1;
  int y = 2;

  swap(&x, &y);

  PVAR(x);
  PVAR(y);
}
```

Outline

Arrays

- An array denotes a set of consecutive locations in memory
- In C, the name of an array is seen as a *constant pointer* to the first location
- Therefore, it can be assigned to a pointer, and used as a pointer

```
int array[5] = {1, 2, 4, 6, 8};
int *p;
int d;

p = a;
d = *p;     // this expression has value 1
```

Pointer arithmetic

- It is possible to modify a pointer (i.e. the address) by incrementing/decrementing it

```
int a[5] = {1, 2, 3, 4, 5};
int *p;
p = a       // p now points to the first
            // element in the array

p++;        // p now points to the second
            // element (a[1])

p+=2;       // p now points to the fourth
            // element (a[3])
```

- Notice that in `p++`, `p` is incremented by 4 bytes, because `p` is a pointer to integers (and an integer is stored in 4 bytes)

Array and pointers

- Array are constant pointers, they cannot be modified

```
int a[10];
int d;
int *p;

p = &d;

a = p;  // compilation error, a cannot be modified
```

- Remember that the name of an array is not a *variable*, but rather an address!
- It can be used in the right side of an assignment expression, but not in the left side.

Equivalent syntax

- A pointer can be used to access the elements of an array in different ways:

```
int a[10];
int *p;

p = a;
*(p+1);   // equivalent to a[1]

int i;

*(p+i);   // equivalent to a[i]
p[i];     // this is a valid syntax
*(a+i);   // this is also valid
```

- In other words, `a` and `p` are equivalent also from a syntactic point o view

Pointer arithmetic - II

- The number of bytes involved in a pointer operator depend on the pointer type
- An operation like `p++` increments the pointer by
  - 1 byte if p is of type **`char`**
  - 2 bytes if p is of type **`float`**
  - 4 bytes if p is of type **`int`**
- To obtain the size of a type, you can use the macro **`sizeof`**`()`

```
int a, b;
char c;
double d;

a = sizeof(int);  // a is 4 after the assignment
a = sizeof(c);    // c is a char, so a is assigned 1
```

- **`sizeof`**`()` must be resolved at compilation time (usually during preprocessing)

Pointer arithmetic - III

- Pointer arithmetic is also applied to user-defined types;

pointers/struct.cpp

```
#include <iostream>

using namespace std;

struct mystruct {
    int a;
    double b[5];
    char n[10];
};

int main()
{
    struct mystruct array[10];

    cout << "size of mystruct: " << sizeof(mystruct) << endl;

    mystruct *p = array;

    cout << "p = " << p << endl;
    p++;
    cout << "p = " << p << endl;
}
```

void pointers

- In C/C++, the keyword **`void`** denotes something without a type
  - For example the return value of a functio can be specified as void, to mean that we are not returning any value
- When we want to define a pointer that can point to a variable of any type, we specify it as a void pointer

```
void *p;
int d;

p = &d;
p++;        // error, cannot do arithmetic
            // with a void pointer
```

Pointers and structures

- When using pointer with structures, it is possible to use a special syntax to access the fields

```
struct point2D {
  double x, y;
  int z;
};

point2D vertex;
point2D *pv;    // pointer to the structure

pv = &vertex;
(*pv).x;        // the following two expressions
p->x;           // are equivalent
```

- Therefore, to access a field of the structure through a pointer, we can use the arrow notation `p->x`

Outline

Copying a string (using arrays)

pointers/strcpy.cpp

```
#include <iostream>
using namespace std;

int strcpy(char *p, char *q)
{
    int c = 0;
    while (q[c] != 0) p[c] = q[c++];
    p[c] = 0;
    return c;
}

int main()
{
    char name[] = "Lipari";
    char copy[10];

    strcpy(copy, name);

    cout << "name = " << name << endl;
    cout << "copy = " << copy << endl;
}
```

Copying a string, (using pointers)

pointers/strcpy2.cpp

```
#include <iostream>
using namespace std;

int strcpy(char *p, char *q)
{
    int c = 0;
    while (*q != 0) {
        *(p++) = *(q++); c++;
    }
    *p = 0;
    return c;
}

int main()
{
    char name[] = "Lipari";
    char copy[10];

    strcpy(copy, name);

    cout << "name = " << name << endl;
    cout << "copy = " << copy << endl;
}
```