Chapter 4. Pointers

Programming Concepts in Scientific Computing

EPFL, Master class

September 25, 2024

Pointers and the Computer Memory

Addresses

```
int x = 1;
int y = 2;
std::cout << &x << "\n";
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Pointers and the Computer Memory

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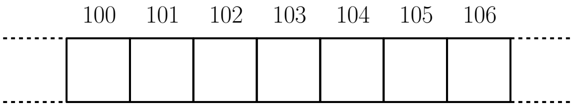

Pointers and the Computer Memory

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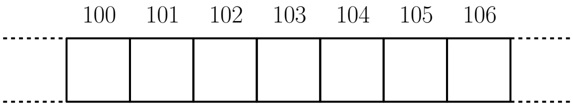

Debug this program (breakpoint)

(gdb) x/2wx &x
(gdb) x/2wx &y

Want to know more ? ⇒ (gdb) help x

Pointers and the Computer Memory

Addresses

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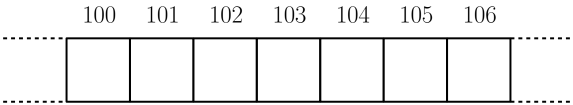

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Pointers and the Computer Memory

Addresses

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int total_sum = 10;
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Pointers and the Computer Memory

Addresses

```c
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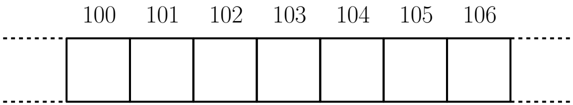

Pointers and the Computer Memory

Addresses

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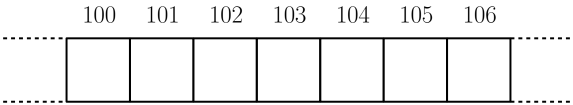

Getting an adress: &

```
std::cout << &total_sum << "\n";
```

Pointers and the Computer Memory

Pointer Variables

Using the *star* in types:

```
int *p_x;
```

Pointers and the Computer Memory
Pointer Variables

Using the *star* in types:

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int *p_x;
```

Example of use

```
// x stores an int precision number
int x = 3;
// p_x stores the address of an int
int *p_x = &x;
```

Try it with CLion !

```
int x = 3;
int *p_x = &x;

std::cout << p_x << std::endl;
```

Try it with CLion !

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int x = 3;
int *p_x = &x;

std::cout << p_x << std::endl;
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Debug this program (breakpoint)

Try it with CLion !

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int x = 3;
int *p_x = &x;

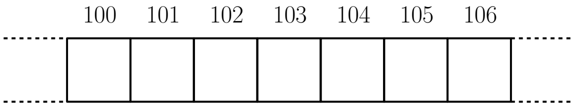
std::cout << p_x << std::endl;
```

Debug this program (breakpoint)

Hit this command in gdb:
(gdb) x/3wx &x

Try it with CLion !

What is the memory structure ?



String of characters

Declare an array of characters:

```
char name[250] = "yopla";
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Declare an array of characters:

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char name[250] = "yopla";
```

However, I can write:

```
char *ptr = name;
```

because an array of characters is actually a pointer!

Aliasing/de-reference

```
int y = 3;
int *p_x = &y;
```

Aliasing/de-reference

```c
int y = 3;
int *p_x = &y;



// This changes the value of y
*p_x = 1;
```

Pointers and the Computer Memory

Addresses

```
int x = 1;
int y = 2;
*(&y + 1) = 3;
```

What does this do ?

Main: argv structure

Considering this code:

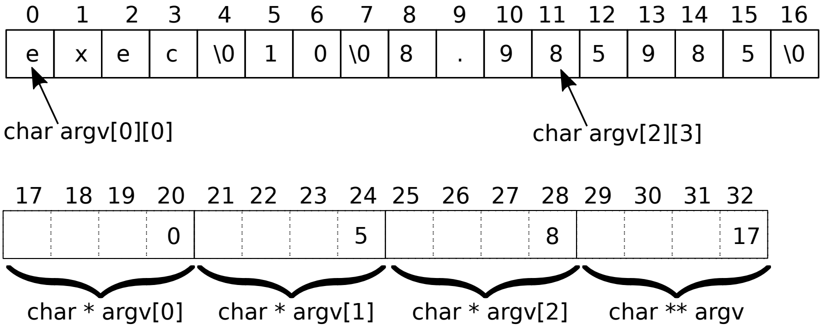
```
int main(int argc, char ** argv){
  int p = atoi(argv[1]);
  double z = atof(argv[2]);
}
```

If I launch the executable like this:

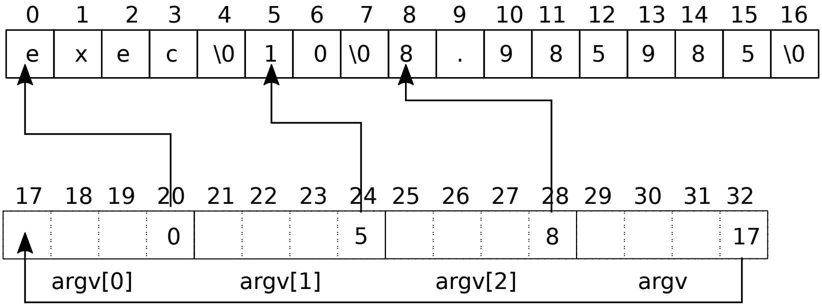
```
> ./exec 10 8.985985
```

What is the memory structure in that case ?

Main: argv structure



Main: argv structure



Warnings on the Use of Pointers

What is the problem with this code ?

```
int *p_x;

*p_x = 1;
```

Warnings on the Use of Pointers

```
// p_x stores the address of a int
// not yet specified
int *p_x;

// trying to assign 1.0 in an unspecified
// memory location
*p_x = 1;
```

Dynamic Allocation of Memory

```
int *x = new int;
```

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int *x = new int;

*x = 10;
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Dynamic Allocation of Memory

```
int *x = new int;

*x = 10;

delete x;
```

Dynamic Allocation of Memory

Vectors

```
double *x = new double[10];
double *y = new double[10];
```

Dynamic Allocation of Memory

Vectors

```
double *x = new double[10];
double *y = new double[10];

for (int i = 0; i < 10; i++) {
  x[i] = double(i);
  y[i] = 2.0 * x[i];
}
```

Dynamic Allocation of Memory

Vectors

```
double *x = new double[10];
double *y = new double[10];

for (int i = 0; i < 10; i++) {
  x[i] = double(i);
  y[i] = 2.0 * x[i];
}

delete[] x;
delete[] y;
```

Matrices

```
int rows = 5, cols = 3;
double **A = new double *[rows];
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// you can access the values of the array with
A[2][4] = 5;
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Matrices

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  A[i] = new double[cols];
}

// you can access the values of the array with
A[2][4] = 5;

// At the end: deallocate the memory
for (int i = 0; i < rows; i++) {
  delete[] A[i];
}
delete[] A;
```

ROW MAJOR format

```
double *p_a = new double[rows * cols];
```

ROW MAJOR format

```
double *p_a = new double[rows * cols];

double **A = new double *[rows];
for (int i = 0; i < rows; i++) {
  A[i] = &p_a[i * rows];
  A[i] = p_a + i * rows;
}
```

ROW MAJOR format

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double **A = new double *[rows];
for (int i = 0; i < rows; i++) {
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// you can access the values of the array with
A[2][4] = 5;
// or with
p_a[2 * rows + 4] = 5;
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for (int i = 0; i < rows; i++) {
  A[i] = &p_a[i * rows];
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}

// you can access the values of the array with
A[2][4] = 5;
// or with
p_a[2 * rows + 4] = 5;

// At the end: de-allocate the memory
delete[] A;
delete[] p_a;
```

ROW MAJOR format

- ROW MAJOR: C, C++
- COLUMN MAJOR: Matlab and Fortran

Tips

- Pointer Aliasing: e.g. coding
  - $C = A \cdot B$
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- Dynamic Allocation: check non-null pointer:

```
int *p_x = new int;
assert(p_x != NULL);
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Tips

- Pointer Aliasing: e.g. coding
  - $C = A \cdot B$
  - $A = A \cdot B$
- Dynamic Allocation: check non-null pointer:

```
int *p_x = new int;
assert(p_x != NULL);
```

- Every new Has a delete

Pointers

Take away message

- **pointer**: variable storing an address (of another variable)
- **Type *ptr**: pointers are typed (int*, double*, ...)
- **&var**: get the address of *var* (int* ptr = &a;)
- ***ptr**: access the pointed variable (*ptr = 1;)
- **C-array**: a pointer to the first item of the array (int vec[256]; ∼ int *vec;)
- **char **argv**: array of array of characters
- **Dynamic allocation**: *long life* variables should be **created** and **destructed** using **new&delete**

```cpp
double *var = new double;
// ...
delete var;
```

```cpp
double *vec = new double[1000];
// ...
delete[] vec;
```