CS 32: Data Structures + Algorithms

Objective

Data abstraction

C++ Classes

Pointers, Dynamic Arrays, Resource Management

Linked Lists

Stacks and Queues

Inheritance and Polymorphism

OOP

Recursion

Templates, Iterators, STL

Algorithmic Efficiency

Sorting

Trees

Tree-based tables, Hash tables

Priority Queues, Heaps

Graphs

CS 31 Review

Pointers

- → Another way to implement pass by reference
- → Traverse arrays
- → Manipulate dynamic storage
- → Represent relationships in data structures

double	is a number
double &	is a reference to a double (another name for a pre-existing object)
double*	is a pointer to a double.

&x	generate a pointer to x
*p	the object that p points to

Reference parameters

→ used to make a function return multiple values

```
void polarToCartesian (double rho, double theta,
                       double xx, double yy)

{
    xx = rho * cos(theta);
    yy = rho * sin(theta);
}

int main()
{
    double r;
    double angle;

    .. .. get r and angle ...

    double x;
    double y;

    polarToCartesian (r, angle, x, y)
```

while x and y obtain the correct value, they poof when the function poofs.

What I'd like to do: change variable values OUTSIDE the function.

```
void polarToCartesian(double rho, double theta,
                      double& xx, double& yy)
```

double rho and double theta create brand new doubles that the values are copied into.

But double& xx and double& yy are references — essentially, they point to the same double as x/y.

So if I change the value of x, even xx changes.

$\boxed{\text{i.e.}}$ the parameter is just another name for the original argument. NO COPY IS MADE.

x : 5

angle : 0

xx : ??? : xx

yy : ??? : yy

5 : rho

0 : theta

Upon ending the function, xx and yy go away - but they do their job, i.e. alter the values of x and y.

Pointers

r : 5   5 : rho

angle : 0   0 : theta

x : ??? $\longleftarrow$ xx

y : ??? $\longleftarrow$ yy

```
void polarToCartesian ( double rho,  double theta,
                        double* xx,  double* yy )
{
    *xx = rho * cos(theta);
    *yy = rho * sin(theta);
}

int main()
{
    double r;
    double angle;

    .. .. get r and angle ...
```

```
    double x;
    double y;

    polarToCartesian(r, angle, &x, &y)

}
```

The pointer xx points to the main routine's x
" " yy " " " y

Pointers are arrows pointing to something.
They don't actually hold a double, but tell you how to locate one.

To create an arrow/pointer to x, we append & before the variable name.

&x generates a pointer to x.

double * xx	→	data type for pointer
&x	→	pointer itself (address of x)
*p	→	the object that p points to (follow the pointer)

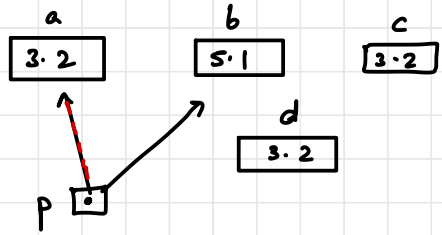
Mechanics of pointers

```
double a = 3.2;
double b = 5.1;

double* p = &a;

double c = a;

double d = *p;   // Now p points to b
```



$$p = b$$

`p = &b;`	`*p = b;`
make p point to b.	take b and store it where p points to.

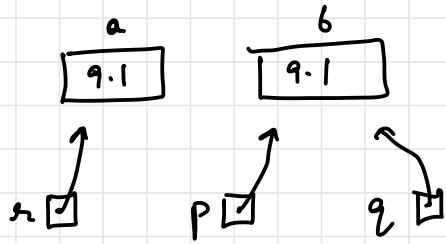
```
int k = 2;
p = &k;   // different type, cannot happen.
```

pointer types cannot be converted.

Cannot multiply a pointer with any data type, obviously. Cannot perform numerical operations.

Following an uninitialized pointer throws an error. Randomly replaces some bit pattern in/out your system might point anywhere and can be potentially very dangerous.

When we compare two pointers, we compare the address. While the value of the pointer might be the same, the address might not.



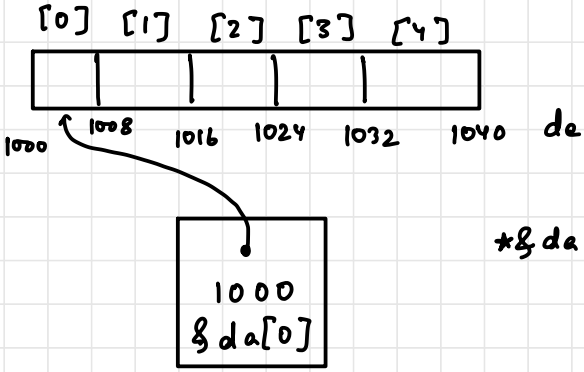

```
(p  ==  r)        // false
 ↓       ↳
 &b      &a

(p  ==  q)        // true

(*p  ==  *r)      // true
```

Pointers to traverse arrays

```
for (double *dp = &da[0]; dp < &da[5]; dp++)
    *dp = 3.6;
```



*&da[0] = da[0].

Algebra rules

→ &a[i] ± j = &a[i ± j]

Integer + pointer = pointer [sub + integer]

→ C++ standard allows position 1040 (just pass the end) but that pointer cannot be followed

→ &a[i] < &a[j] ⇒ i < j

>
<=
>=
==
!=

These compare positions in an array

→ In an expression, writing the name of an array without the sub is a pointer to element 0.

$$a \longleftrightarrow \&a[0]$$

$\&da[5]$
$\&da[0+5]$
$\&da[0] + 5$
$\boxed{a + 5}$

Template to traverse an array

```
for (double* dp = da; dp < da + MAXSIZE;
                      dp++)
```

→ double b[] is practically equivalent to double* b.

→ p[i] ↔ *(p + i) because p[] is a pointer to the begining of the array.

→ well-defined pointer that does not point to any object → nullptr. Used for error.

NULLPTR

1. `int * ip = nullptr;`
2. `ip = nullptr;`
3. `if (ip == / != nullptr)`

   `...`

Undefined : `*ip = 42` (if `ip = nullptr`)

An integer constant 0 in a context where a pointer is required is a nullptr.

Lecture 1 Part 1 — January 3

Undefined Behaviour

a[k] where k is out of bounds.

i/j where j = 0.

p→ [element undefined]

Uninitialized variable assumed to be 0.

Implementation-dependent behaviour

17/ -5	17% -5
-3 -4	2 -3

If there's no return statement in a function, (except void), it is undefined behaviour.

```
double f
{
    if ——
        return 0;
    if ——
        return 1;
}
```

probably will not give an error, although it will give a warning. Ensure return in the general function code.

int	-2 billion	to	2 billion
unsigned int (size_t)	0	to	4 billion

0 - 2 billion ⟶ treated the same way

```
for (int k = 0;  k < string.size() - 1;  k++)
```

unsigned [size_t] — signed

an expression containing a signed and an unsigned int always converts the signed to unsigned.

Therefore, if string.size = 0, the value returned is 4 billion.

```
for (int k = 0; k+1 < s.size(); k++)
```

↳ fixed version

Alternatively,

```
int ssize = string.size()
```

CONVERT BOTH POTENTIAL CASES TO INT AND ACT UPON THAT.

Lecture 1 Part 2 — January 3