COMP 10
EXPLORING COMPUTER SCIENCE

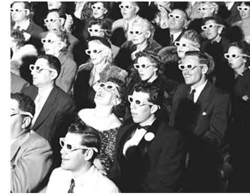
Lecture 6

Arrays

MOTIVATION

Did you see *Inception* this weekend?

```
float movieRating1 = 1.0;
float movieRating2 = 3.5;
float movieRating3 = 1.0;
float movieRating4 = 4.0;
float movieRating5 = 4.0;
float movieRating6 = 3.0;
. . .
float movieRating25 = 2.5;
```



What's the average rating?

```
float averageRating = (movieRating1 + movieRating2 + … + movieRating25) / 25.0;
```

What's the lowest rating?

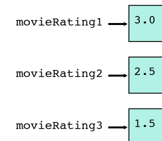
```
minRating = 4.0;
if(movieRating1 < minRating)
   minRating = movieRating1;
if(movieRating2 < minRating)
   minRating = movieRating2;

...

if(movieRating25 < minRating)
   minRating = movieRating25;
```

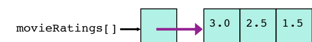
It is a common scenario in a program to have a collection of data that we need to do something to

Could store as separate variables



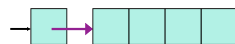
An *array* is a more practical way of storing similar data

movieRatings[]

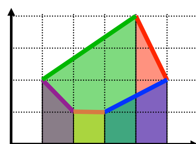


TODAY'S OUTLINE

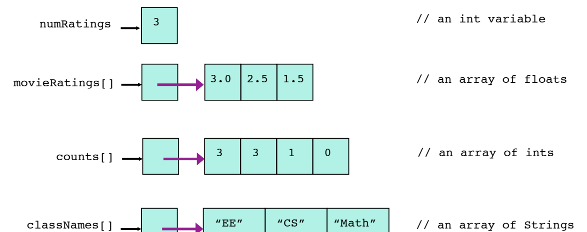
Arrays
- Declaration, access
- As function parameters
- Applications



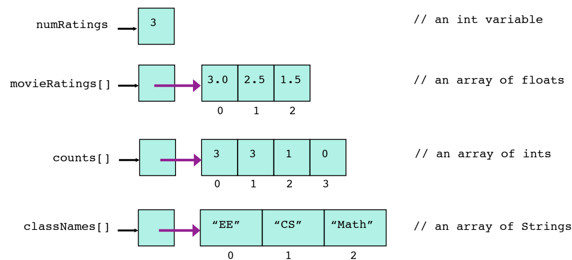
Lab 5 preview:
- Storing vertices
- Visualization: LEDA
- Makefile



Arrays let us store and access *data collections* of a certain type



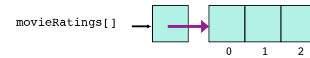
Each value is identified by an *index*



CREATING ARRAYS

```
float movieRatings[3];          //declares an array of 3 floats
```

```
const int numRatings = 3;
float movieRatings[numRatings];  //an equivalent declaration
```

movieRatings[] 

ARRAY DECLARATION SYNTAX

```
float movieRatings[3];          //declares an array of 3 floats
```

```
const int numRatings = 3;
float movieRatings[numRatings];  //an equivalent declaration
```

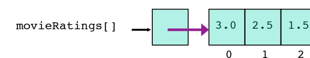
type — name — size (must be an integer constant)

- movieRatings is of type *array of float* with size 3
- movieRatings[0], movieRatings[1], movieRatings[2] are the *elements* of the array -- each is a variable of type float
- 0, 1, 2 are the *indices* of the array (a.k.a. *subscripts*)
- *bounds*: the lowest and highest values of the subscripts (here: 0 and 2)

ACCESSING ARRAY ELEMENTS

```
float movieRatings[3];          //declares an array of 3 floats

movieRatings[0] = 3.0;          //assign values to elements
movieRatings[1] = 2.5;
movieRatings[2] = 1.5;
```

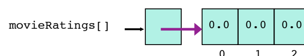
movieRatings[] 

INITIALIZING ARRAY ELEMENTS

Typically want to assign default values before doing anything:

```
float movieRatings[3];          //declares an array of 3 floats

movieRatings[0] = 0.0;          //initialize array elements
movieRatings[1] = 0.0;
movieRatings[2] = 0.0;
```

movieRatings[] 

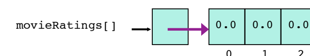
INITIALIZING ARRAY ELEMENTS

Typically want to assign default values before doing anything:

```
float movieRatings[3];          //declares an array of 3 floats

movieRatings[0] = 0.0;          //initialize array elements
movieRatings[1] = 0.0;
movieRatings[2] = 0.0;
```

```
float movieRatings[3] = {0.0, 0.0, 0.0};
```

movieRatings[] 

STORING AND RETRIEVING DATA

An array is a collection of variables

Each element can be used wherever a simple variable of that type is allowed: assignment, expressions, input/output, etc.

```
movieRatings[2] = 1.5;
cout << movieRatings[2] << endl;
```

```
float myRating = movieRatings[0];
cout << myRating << endl;
```

```
if (movieRatings[1] == movieRatings[2]) {
    cout << "rating 1 equals rating 2" << endl;
}
```

What's wrong with this code?

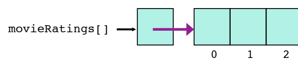
```
float movieRatings[3];          //declares an array of 3 floats

movieRatings[0] = 3.0;          //assign values to elements
movieRatings[1] = 2.5;
movieRatings[2] = 1.5;
movieRatings[3] = 3.0;
```

What's wrong with this code?

```
float movieRatings[3];          //declares an array of 3 floats

movieRatings[0] = 3.0;          //assign values to elements
movieRatings[1] = 2.5;
movieRatings[2] = 1.5;
movieRatings[3] = 3.0;
```



What's wrong with this code?

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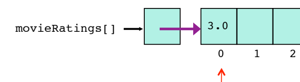
float movieRatings[3];          //declares an array of 3 floats

movieRatings[0] = 3.0;          //assign values to elements
movieRatings[1] = 2.5;
movieRatings[2] = 1.5;
movieRatings[3] = 3.0;
```



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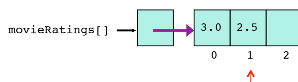
```
float movieRatings[3];          //declares an array of 3 floats

movieRatings[0] = 3.0;          //assign values to elements
movieRatings[1] = 2.5;
movieRatings[2] = 1.5;
movieRatings[3] = 3.0;
```



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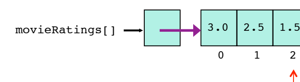
movieRatings[0] = 3.0;          //assign values to elements
movieRatings[1] = 2.5;
movieRatings[2] = 1.5;
movieRatings[3] = 3.0;
```



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movieRatings[1] = 2.5;
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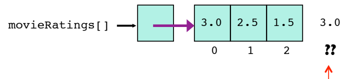
movieRatings[3] = 3.0;
```



Error: Array out of bounds!

INDEX RULE

If an array has n elements, then an array index must evaluate to an int between 0 and n-1

```
float movieRatings[3];          //declares an array of 3 floats
...
movieRatings[i+3+k] = 3.0;      //OK if 0 <= (i+3+k) <= 2
movieRatings[1] = 2.5;          //the index may be simple or complex
movieRatings[(int)(abs(sin(2.0*PI*sqrt(29.067))))] = 3.0;
```

No exceptions!

STORING AND RETRIEVING DATA

An array is a *collection* of variables

Each element can be used wherever a simple variable of that type is allowed: assignment, expressions, input/output, etc.

An entire array can't be treated as a single variable in C++

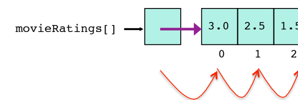
- Can't assign or compare entire arrays using =, ==, <, …
- Can't use cout or cin on an entire array

But, you can do these things *one element at a time*

TRAVERSING AN ARRAY

Loops are useful for *traversing* an array, or accessing each of its elements in sequence

```
float movieRatings[3];
for (int i = 0; i < 3; i++)
{
  cout << "Rating " << i << " = " << movieRatings[i] << endl;
}
```



RAINFALL DATA

General task: Read daily rainfall amounts and print some interesting information about them

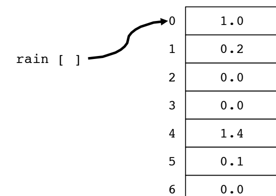
Input data: Zero or more measurements, followed by a *sentinel*

Example input data:
1.0 0.2 0.0 0.0 1.4 0.1 0.0 -1.0

Empty input sequence:
-1.0

A named, ordered collection of variables of identical type

- Rainfall for 1 week:
- Name the collection (rain); number the elements (0 to 6)



Example declaration:

float rain[7];

Example access:

rain[0] has value 1.0

rain[6] has value 0.0

2*rain[4] has value 2.8

rain [ ]

0	1.0
1	0.2
2	0.0
3	0.0
4	1.4
5	0.1
6	0.0

ELEMENTS IN USE

Since an array has to be declared a fixed size, you often declare it bigger than you think you will really need

```
const int MAX_RAIN_DAYS=365;
float rain[MAX_RAIN_DAYS];
```

How do you know which elements in the array actually hold data, and which are unused extras?

KEEP VALID ENTRIES TOGETHER

rain[]

0	1.0
1	0.2
2	0.0
3	0.0
4	1.4
5	0.1
6	0.1
7	
...	
MAX_RAIN_DAYS – 1	

RECORD THE NUMBER OF VALID ENTRIES

rain[]

0	1.0
1	0.2
2	0.0
3	0.0
4	1.4
5	0.1
6	0.1
7	
...	
MAX_RAIN_DAYS – 1	

numRainDays

7

```
int k;
for(k=0; k<numRainDays; k++){
  cout << rain[k] << endl;
}
```

Problem:

Calculate and print number of days for which rainfall is above average

Sample output:

```
Please enter rainfall data for this week:
1.0  0.2  0.0  0.0  1.4  0.1  0.0  -1.0

Average: 0.386

There were 2 days with above average rain fall.
```

Algorithm?

ARRAYS AS PARAMETERS

```
const int ARRAY_SIZE=10

double average ( int a[ ], int num)  {
   int i, total = 0 ;
   for ( i = 0 ;  i < num ;  i++ ) {
       total = total + a[i]  ;
   }
   return ((double) total /  (double) num) ;
}


int main (){

   int rain[ARRAY_SIZE] ;

   ...

   float rain_avg = average ( rain, numRainDays ) ;
   ...
}
```

ARRAYS AS PARAMETERS

Array parameters (entire arrays) do not work like simple variables:

- An array is never copied
- The array name is always treated as a pointer

In C++, arrays do not contain information about their size, so the size often needs to be passed as an additional parameter

DATA STRUCTURES

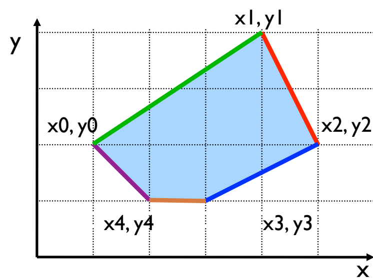
An array is an important data structure

Functions give us a way to organize programs

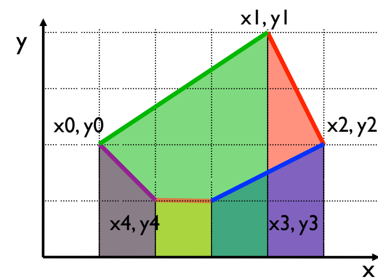
Data structures are used to organize data, especially:

- Large amounts of data
- Variable amounts of data
- Sets of data where the individual pieces are related to one another

LAB 5 PREVIEW: N-SIDED POLYGONS



LAB 5 PREVIEW: N-SIDED POLYGONS



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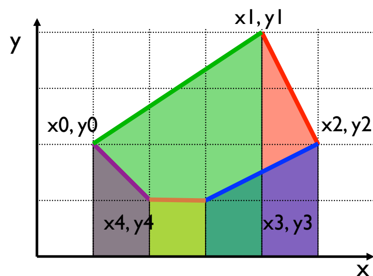

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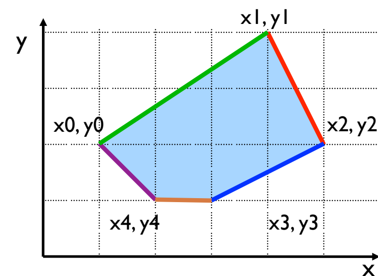


Use arrays to store vertices

ARRAYS OF VERTICES

Two arrays of size MAX_NUM_VERTICES

```
const int MAX_NUM_VERTICES=24;
int x[MAX_NUM_VERTICES];
int y[MAX_NUM_VERTICES];
```

For each garden: iterate over number of vertices

- Read x and y coordinate
- Store in the x[ ] and y[ ] arrays

VISUALIZATION: LEDA

LEDA: a platform for combinatorial and geometric computing

We will use only the graphics functionalities

Need to tell the shell how/where to find LEDA

Type at the command line:

```
use leda
```

VISUALIZATION: LEDA

Functions provided in visualize.cpp:

```
window_open();
window_close();
window_clear();
wait (int seconds);
draw_trapezoid (int xi, int xf, int yi, int yf)
```

MAKEFILE

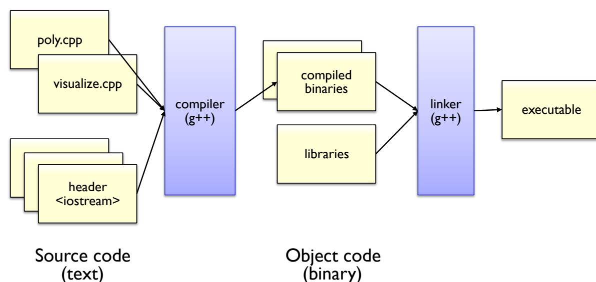
Compilation and linking getting more complicated

- Multiple source files: poly.cpp and visualize.cpp
- External libraries

Use a Makefile:

- Describes how to compile all the code files, what to link together and where to find external dependencies

MAKEFILE DESCRIBES DEPENDENCIES



COMPILING AND LINKING

To compile and link, type at the command line:

```
make
```

(Note: `g++ poly.cpp` will not work!)

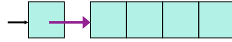
What happens:

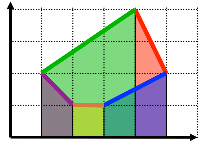
```
g++ -o poly -I/usr/cots/leda-6.1/incl poly.cpp
visualize.cpp
-L/usr/cots/leda-6.1 -lleda -L/usr/X11  -lX11 -lm
```

SUMMARY

Array data structure

- Groups data of same type
- Individual elements behave like simple variables
- Can be a function parameter
- Use loops





Lab 5

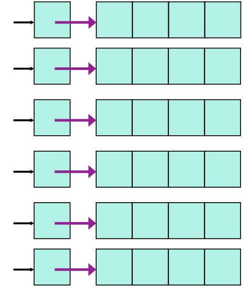
- LEDA
- make and Makefile

MULTIDIMENSIONAL ARRAYS

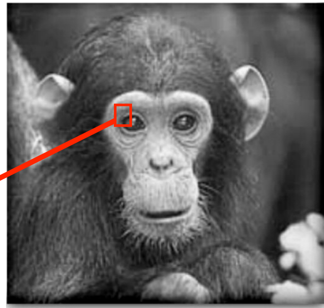
Use more than one index to access array elements

2D: an "array of arrays"

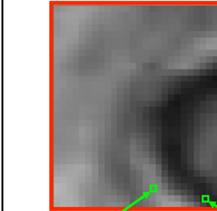
Loop through rows and columns



Digital images can be stored as 2D arrays



Pixels are array entries, and pixel values denote brightness ("intensity")



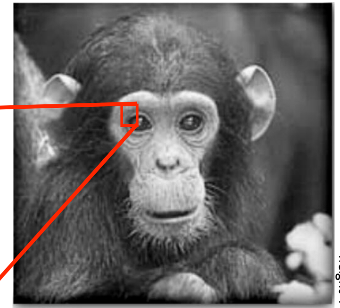


IMAGE PROCESSING

What happens if we look at the difference between two images?

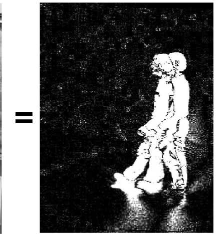
-

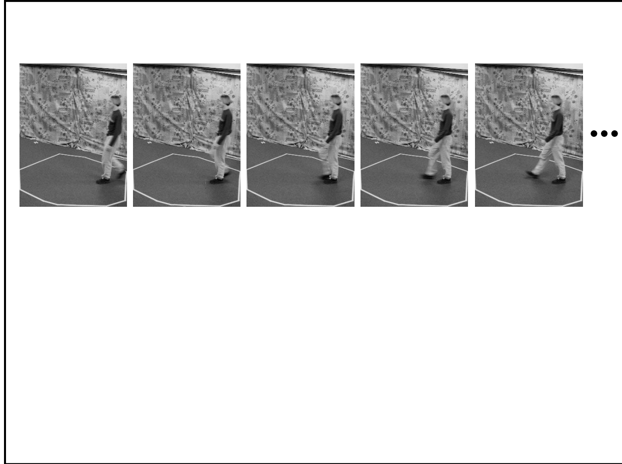
= ?

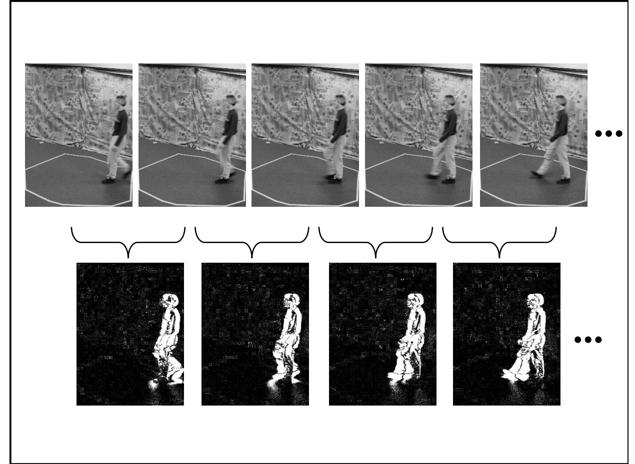
IMAGE PROCESSING

-

=







Frames

Motion

squared absolute differences between sequential frames

Foreground

differences from a background frame (smoothed)