Arrays

CS 115

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One, two, and multi-dimensional arrays

Motivation

- Print 1000 numbers in reverse order

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```
int value0;
int value1;
int value2;
// ...
int value999;

cin >> value0;
cin >> value1;
// ...
cin >> value999;

cout << value999 << endl;
cout << value998 << endl;
// ...
cout << value0 << endl;
```

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```
int a[120000];    // Array declaration

for (int i = 0; i < 120000; i++)
  cin >> a[i];    // Array access
for (int i = 119999; i >= 0; i--)
  cout << a[i] << endl;
```

Array Operations

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- Set the ith element: `array[i] = someValue;`

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const int N = 120000;
int a[N];    // Array declaration

for (int i = 0; i < N; i++)
  cin >> a[i];    // Array access
for (int i = N-1; i >= 0; i--)
  cout << a[i] << endl;
```

- Array size must be a constant expression

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```

- Array size must be a constant expression
- Easy to change size: just update N (the rest of the program remains intact)

Passing arrays as arguments

Passing arrays as arguments

```
int sumArray(int a[], unsigned int n) // Array argument
{
  int sum = 0;
  for (int i = 0; i < n; i++)
    sum += a[i];
  return sum;
}

int main()
{
  // Array initialization
  int a[] = { 3, 24, -88, 17, -1 };
  cout << sumArray(a, 5) << endl;
}
```

- Array size can be left unspecified in array initialization syntax

Passing arrays as arguments

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- Interface not safe: can modify the content of A

A Safer Interface

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- Use the following instead:

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- use sizeof function:

```
int a[] = {1,2,6,3,8};
int x = sumArray(a, sizeof(a) / sizeof(int));
```

Play time

- Check if integer array sorted

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```
bool arrayIsSorted(const int a[], unsigned int n){
  for (int i = 0; i < n-1; i++){
    if (a[i] > a[i+1])
      return false;
  }
  return true;
}
```

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- Reversing items in integer array

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```
void swap(int &a, int &b) {
  int tmp = a;
  a = b;
  b = tmp;
}
// below a[] is not a constant as want to produce side-effect
void reverseArray(int a[], unsigned int n) {
  for (int i = 0; i < n/2; i++)
    swap(a[i], a[n - i - 1]);
}
```

Processing subarrays

- Compute the sum of an array segment

Processing subarrays

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```
// pos   : index of the first component in the subarray
// count: total number of components in the subarray
int sumSubarray(const int a[],
                unsigned int pos,
                unsigned int count){
  int sum = 0;
  for (int i = pos; i < pos + count; i++)
    sum += a[i];

  return sum;
}
```

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- Another way to do the same thing

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```
// begin: index of first component in the subarray
// end   : index of the last component in the subarray
int sumSubarray(const int a[],
                unsigned int begin,
                unsigned int end){
  assert(begin <= end);
  int sum = 0;
  for (int i = begin; i <= end; i++)
    sum += a[i];

  return sum;
}
```

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- copy cell by cell:

```
a[6]=b[9] // works!
```

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```
if(a == b) // invalid
```

- compare each pair of cells at a time

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```

- compare each pair of cells at a time
- No need to return array as function output, uses call by reference anyway!

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- C++ will never change
  - Backwards compatibility
  - `std::array` is safe but isn't the default
- Languages like Rust make sure that these errors are *impossible*
  - Unless you explicitly disable safety

Example

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```
#include <iostream>
using namespace std;
int main(){
  char passwd[8] = "secret";
  char username[8] = "bob101";
  string toPrint = "";
  // Oops reading past end of array!
  for (int i = 0; i < 16; i++){
    toPrint += username[i];
  }
  cout << toPrint << endl;
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```

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```

```
bob101secret
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Two Dimensional Arrays

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- `sales[2][1]` are the total number of items sold for location 2 and product 1
- recall item n is the (n+1)-th item
  - index starts from 0!

Declaration and Access

Declaration and Access

```
const unsigned int NUM_OF_REGIONS = 4;
const unsigned int NUM_OF_PRODUCTS = 3;

unsigned int sales[NUM_OF_REGIONS][NUM_OF_PRODUCTS];
```

- To access sales figure for first product in second region, use:

Declaration and Access

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- e.g., want to set sales figure for first product in second region to 500

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sales[1][0] // recall, indices start from 0
```

- e.g., want to set sales figure for first product in second region to 500

```
sales[1][0] = 500;
```

Populating and Accessing

Populating and Accessing

```
// Read input stream
for (unsigned int region = 0; region < NUM_OF_REGIONS; region++)
  for (unsigned int product = 0; product < NUM_OF_PRODUCTS; product++)
    cin >> sales[region][product];

// total sales for a particular product (product 0)
unsigned int total_sales = 0;

for (unsigned int region = 0; region < NUM_OF_REGIONS; region++)
  // add up sales from all regions for product 0
  total_sales += sales[region][0];
```

- Can you compute total sales from region 1?

Passing 2D Arrays

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```
unsigned int sumProductSales(
        unsigned int sales[NUM_OF_REGIONS][NUM_OF_PRODUCTS],
        unsigned int product)
{
  unsigned int total_sales = 0;
  for (unsigned int region = 0; region < NUM_OF_REGIONS; region++)
    total_sales += sales[region][product];

  return total_sales;
}
```

- Can you implement a safer interface?

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- As usual, can leave size of first dimension unspecified, e.g. `int F(int arr[ ][SIZE])`
- but not the second one (why?)

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```
// Implement a function that returns
// the value of one element from the sales array
unsigned int getSales(
        const unsigned int sales[NUM_OF_REGIONS][NUM_OF_PRODUCTS],
        unsigned int r, unsigned int p){
  return sales[r][p];
}
// Implement a function that sets the value
// of one element from the sales array
void setSales(unsigned int sales[NUM_OF_REGIONS][NUM_OF_PRODUCTS],
              unsigned int r, unsigned int p, unsigned int v){
  sales[r][p] = v;
}
```

Using typedef

Using typedef

```
// too lazy to write long types? Use typedef instead!

typedef unsigned int Sales[NUM_OF_REGIONS][NUM_OF_PRODUCTS];

unsigned int sumSales(const Sales sales){
  ...
    }
```

Simulating Two-dimensional Arrays by One-dimensional Ones

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- Now you know why the size of the 2nd dimension can't be left unspecified!
  - Can you write the formula for column-major order?

Using Row-Major Order

Using Row-Major Order

```
unsigned int totalSales = 0;

for (unsigned int region = 0; region < NUM_OF_REGIONS; region++)
  for (unsigned int product = 0;
       product < NUM_OF_PRODUCTS;
       product++){
    totalSales += _sales[region * NUM_OF_PRODUCTS + product];
  }
```

- This is why we need to know the size of the second dimension

Using Row-Major Order

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for (unsigned int region = 0; region < NUM_OF_REGIONS; region++)
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  }
```

- This is why we need to know the size of the second dimension
  - To calculate offset

Multi-dimensional Arrays

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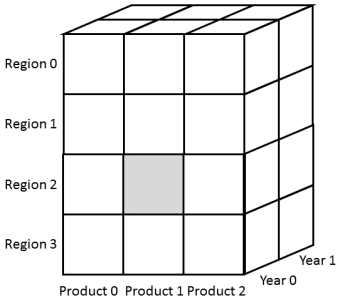
```
const unsigned int NUM_YEARS = 2;
const unsigned int NUM_REGIONS = 4;
const unsigned int NUM_PRODUCTS = 3;

typedef unsigned int Sales[NUM_YEARS][NUM_REGIONS][NUM_PRODUCTS];

unsigned int total_sales = 0;
for (unsigned int year = 0; year < NUM_YEARS; year++)
  for (unsigned int region = 0; region < NUM_REGIONS; region++)
    for (unsigned int product = 0; product < NUM_PRODUCTS; product++)
      total_sales += sales[year][region][product];
```

Simulating 3d with 1d

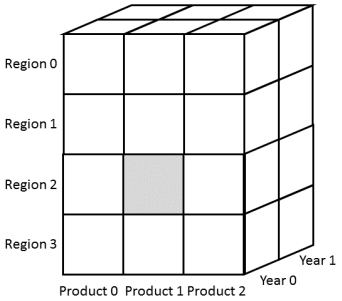
- `Sales[year][region][product]`



Mem-Pos	
0	Y0R0P0
1	Y0R0P1
2	Y0R0P2
3	Y0R1P0
4	Y0R1P1
5	Y0R1P2
6	Y0R2P0
7	Y0R2P1
8	Y0R2P2
9	Y0R3P0
10	Y0R3P1
11	Y0R3P2
12	Y1R0P0
13	Y1R0P1
14	Y1R0P2
15	Y1R1P0
16	Y1R1P1
17	Y1R1P2
18	Y1R2P0
19	Y1R2P1
20	Y1R2P2
21	Y1R3P0
22	Y1R3P1
23	Y1R3P2

Simulating 3d with 1d

- `Sales[year][region][product]`
- vs `_Sales[(year * NUM_REGS * NUM_PRODS) + (region * NUM_OF_PRODS) + product]`



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Simulating Multi-dimensional Arrays

- In general for a d-dimensional array with dimensions S_1, S_2, …, S_d, the element at `Item[n_1][n_2]...[n_d]` can be represented as a single dimensional array with the following index

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```
_Item[n_d + S_d * (n_{d-1} + S_{d-1}
   * (n_{d-2} + S_{d-2} * (...+S_2*n_1) ... ))]
```