Arrays in Classes

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1. Can you make a class around a vector?

You may want a class of objects that contain a vector. For instance, you may want to name your vectors.

```
1 class named_field {
2 private:
3   string name;
4   vector<double> values;
```

to be instantiated as:

```
1 name_field stresses("stress",50000);
```

The problem here is when and how that stored vector is going to be created.

2. Create the contained vector

Use initializers for creating the contained vector:

```
1  class named_field {
2  private:
3    string name;
4    vector<double> values;
5  public:
6    named_field( string name,int n )
7      : name(name),
8        values(vector<double>(n)) {
9    };
10 };
```

Even shorter:

```
1    named_field( string name,int n )
2      : name(name),values(n) {
3    };
```

Multi-dimensional arrays

3. Multi-dimensional vectors

Multi-dimensional is harder with vectors:

```
1 vector<float> row(20);
2 vector<vector<float>> rows(10,row);
```

Create a row vector, then store 10 copies of that: vector of vectors.

4. Naive matrix class

```
matrix mymatrix(10,50);
```

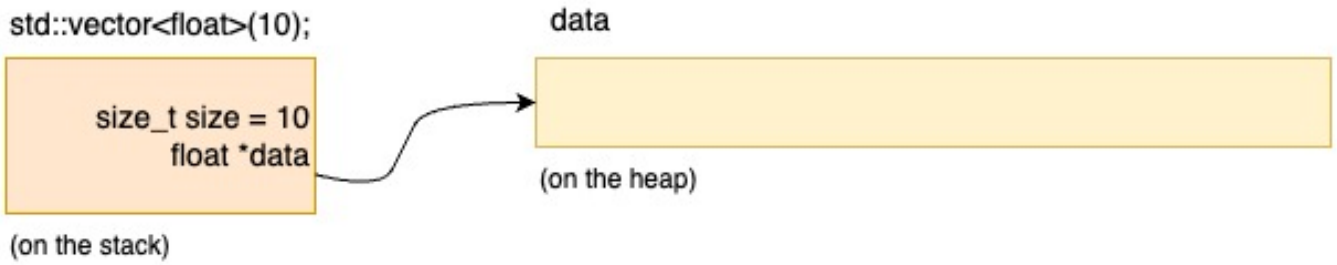
Naive constructor

```
// array/matrixclass.cpp
class matrix {
private:
  vector<vector<double>>
     matrix_data;
  int m,n;
public:
  matrix(int m,int n)
    : m(m),n(n) {
    matrix_data = vector<
      vector<double>(n)
      >(m);
  };
};
```

Better constructor

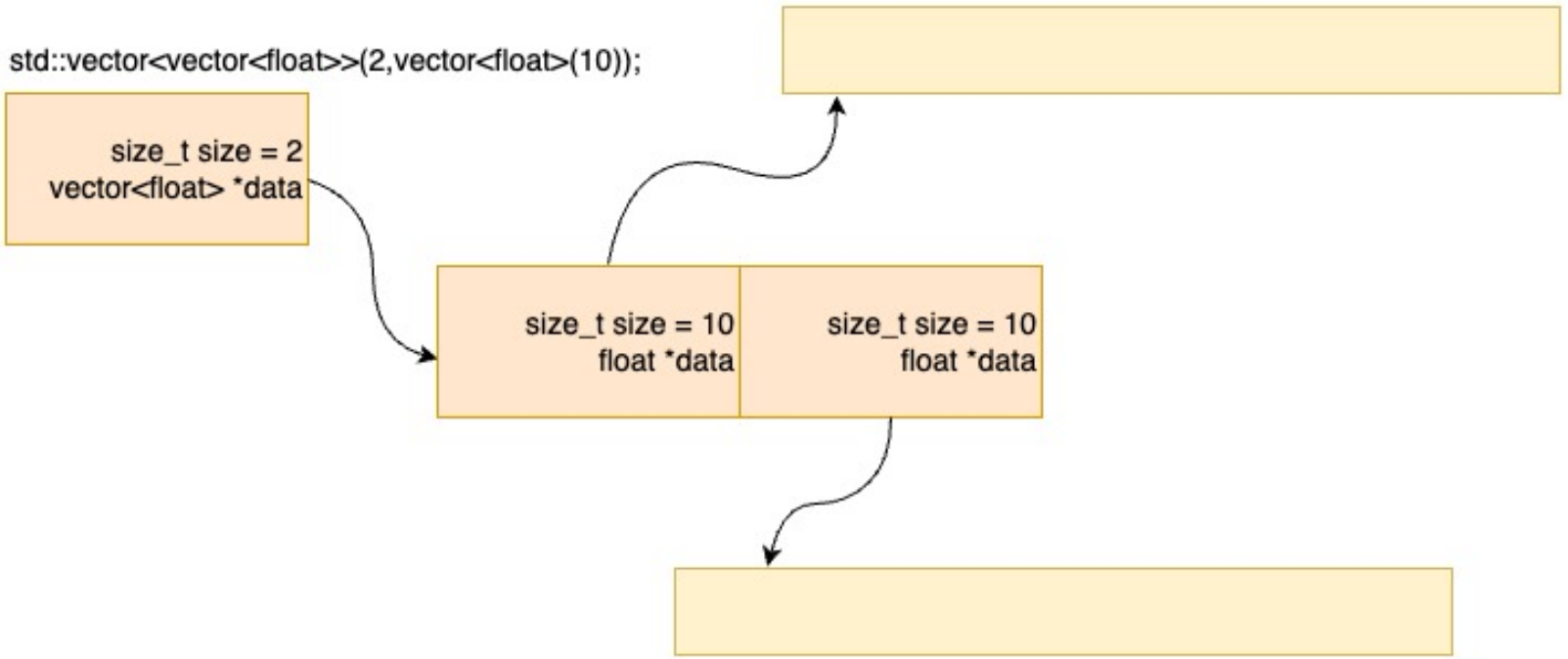
```
// array/matrixclass.cpp
matrix(int m,int n)
  : m(m),n(n),
    matrix_data(
       vector<vector<double>(n)>(m)
                 ) {};
};
```

5. Implementation of a vector



(Don't worry about stack/heap)

6. Vector of vectors



7. Better matrix class

```
1 // array/matrixclass.cpp
2 class matrix {
3 private:
4   vector<double> matrix_data;
5   int m,n;
6 public:
7   matrix(int m,int n)
8     : m(m),n(n),matrix_data(m*n) {};
```

Later we will write methods for getting/setting elements.

Exercise 1

Write `rows()` and `cols()` methods for this class that return the number of rows and columns respectively.

Exercise 2

In the matrix class of the previous slide, why are `m,n` stored explicitly while that would not be needed in the scheme of 6.

Exercise 3

Write a method `void set(double)` that sets all matrix elements to the same value.

Write a method `double totalsum()` that returns the sum of all elements.

Code:

```
1 // array/matrix.cpp
2 A.set(3.);
3 cout << "Sum of elements: "
4      << A.totalsum() << '\n';
```

Output:

```
1 Sum of elements: 30
```

8. Matrix class; naive indexing

Linearized indexing:

Class:

```
1 // array/matrixclass.cpp
2 class matrix {
3 private:
4   vector<double> matrix_data;
5   int m,n;
6 public:
7   matrix(int m,int n)
8     : m(m),n(n),matrix_data(m*n)
      {};
```

Methods:

```
1 void setij(int i,int j,double v) {
2   matrix_data.at( i*n +j ) = v;
3 };
4 double getij(int i,int j) {
5   return matrix_data.at( i*n +j );
6 };
```

Exercise 4

Can you set/get elements by overloading the index operator?

Exercise 5

Add methods such as *transpose*, *scale* to your matrix class.

Implement matrix-matrix multiplication.

9. Pascal's triangle

Pascal's triangle contains binomial coefficients:

```
Row    1:                      1
Row    2:                    1   1
Row    3:                  1   2   1
Row    4:                1   3   3   1
Row    5:              1   4   6   4   1
Row    6:            1   5  10  10   5   1
Row    7:          1   6  15  20  15   6   1
Row    8:        1   7  21  35  35  21   7   1
Row    9:      1   8  28  56  70  56  28   8   1
Row   10:    1   9  36  84 126 126  84  36   9   1
```

where

$$p_{rc} = \binom{r}{c} = \frac{r!}{c!(r-c)!}.$$

The coefficients can be computed from the recurrence

$$p_{rc} = \begin{cases} 1 & c \equiv 1 \vee c \equiv r \\ p_{r-1,c-1} + p_{r-1,c} & \end{cases}$$

(There are other formulas. Why are they less preferable?)

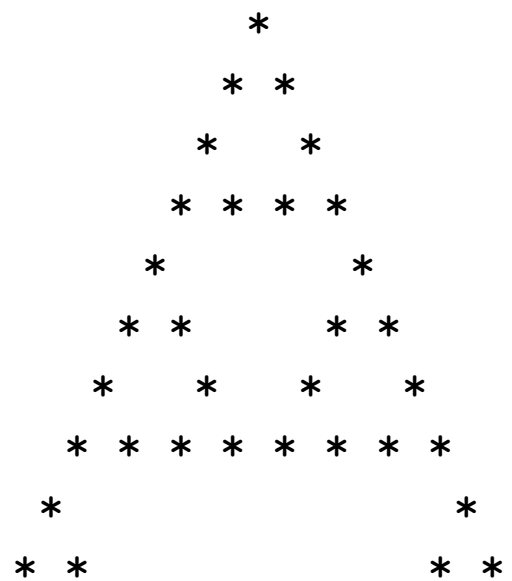
Exercise 6

- Write a class `pascal` so that `pascal(n)` is the object containing n rows of the above coefficients. Write a method `getvalue(i,j)` that returns the (i, j) coefficient.
- Write a method `print` that prints the above display.

The object needs to have an array internally. The easiest solution is to make an array of size $n \times n$. Optionally you can optimize your code to use precisely enough space for the coefficients.

Exercise 7

Write a method `print(int m)` that prints a star if the coefficient modulo *m* is nonzero, and a space otherwise.



Exercise 8

Extend the Pascal exercise:
Optimize your code to use precisely enough space for the coefficients.

Exercise 9

Write a class *storage* that provides `get`/`set` methods that only read from and write to the data structure. The *pascal* class can then inherit from it, and do the coefficient calculation. Do you use public or private inheritance?

Exercise 10

Extend the *storage* class:

- If a coefficient outside the initial triangle is asked, the triangle should dynamically be extended to the row of that coefficient.
- This requires the *storage* class to extend the space for the coefficients.
- It also requires the *pascal* class to track how many rows have been filled in, and possibly compute some missing coefficients.

Other array stuff

10. Array class

Arrays:

```
1 #include <array>
2 std::array<int,5> fiveints;
```

- Size known at compile time.
- Vector methods that do not affect storage
- Zero overhead.

11. Random walk exercise

```
// walk/walk_lib_vec.cpp
class Mosquito {
private:
  vector<float> pos;
public:
  Mosquito( int d )
    : pos( vector<float>(d,0.f) ) { };

// walk/walk_lib_vec.cpp
void step() {
  int d = pos.size();
  auto incr = random_step(d);
  for (int id=0; id<d; ++id)
    pos.at(id) += incr.at(id);
};
```

Finish the implementation. Do you get improvement from using the array class?

12. Span

Create a `span` from a `vector`, starting at its second element and ending before its last:

```
1 #include <span>
2 vector<double> v;
3 std::span<double> v_span( v.data()+1,v.size()-2 );
```

Array creation

C-style arrays still exist,

```
// array/staticinit.cpp
{
  int numbers[] = {5,4,3,2,1};
  println("{}",numbers[3]);
}
{
  int numbers[5]{5,4,3,2,1};
  numbers[3] = 21;
  println("{}",numbers[3]);
}
```

but you shouldn't use them.

Prefer to use `array` class (not in this course)

or `span` (C++20; very advanced)