Array versus container classes

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Goal

- Why should one prefer a container class over a plain array?
  - Why arrays?
  - Why use container classes?
  - What are the problems with arrays?
  - Benchmark of arrays versus std::vector [1]

[1] In C++11, one would use std::array

The history of arrays

Why use container classes?

- ...

Because the literature says so ...

- Bjarne Stroustrup. A tour of C++. 2014. ISBN: 978-0-321-958310. Chapter 11.7.11: 'Prefer array over built-in arrays'
- Bjarne Stroustrup. The C++ Programming Language (3rd edition). ISBN: 0-201-88954-4 Chapter 5.8.4 'Use vector and valarray rather than built-in (C-style) arrays'
- Bjarne Stroustrup. The C++ Programming Language (4th edition). 2013. ISBN: 978-0-321-56384-2. Chapter 7.8. Advice. page 199: '[6] Use containers (e.g., vector, array, and valarray) rather than built-in (C-style) arrays'
- Herb Sutter and Andrei Alexandrescu. C++ coding standards: 101 rules, guidelines, and best practices. ISBN: 0-32-111358-6. Chapter 77: 'Use vector and string instead of arrays'

Bjarne Stroustrup

Herb Sutter

Andrei Alexandrescu

Because the literature says so ...

- Marshall Cline, Greg Lomow and Mike Girou. C++ FAQs. ISBN: 0-201-3098301, FAQ 28.02: 'Are arrays good or evil?' (Answer: 'Arrays are evil'
- Joint Strike Fighter Air Vehicle C++ Coding Standards for the System Development and Demonstration Program. Document Number 2RDU00001 Rev C. December 2005. AV Rule 97: 'Arrays shall not be used in interfaces. Instead, the Array class should be used.'
- Scott Meyers. C++ And Beyond 2012 session: 'Initial thoughts on Effective C++11'. 2012. 'Prefer std::array to built-in Arrays'
- Scott Meyers. Effective Modern C++ (1st Edition). 2014. ISBN: 978-1-491-90399-5. Item 1, page 17: 'Of course, as a modern C++ developer, you'd naturally prefer a std::array to a built-in array'

Scott Meyers

F-35 Lightning II

Problems according to the literature

- An array does not know its size
- Cannot assign plain arrays
- Implicit conversion to pointer

Example, adapted from [1]

```
void iota(int a[], const int sz) {
  for (int i=0; i!=sz; ++i) {
    a[i] = i;
  }
}

int main() {
  int v[20];
  int w[10];
  iota(v,20);
  iota(w,20); //Oops
}
```

[1] https://isocpp.org/wiki/faq/containers

Example, adapted from [1]

```
int main()
{
  int v[] = {1,2};
  int w[] = {3,4};
  v = w; //Invalid array assignment

  //Cannot be fixed by std::memcpy
  //for non-PODs
}
```

[1] https://isocpp.org/wiki/faq/containers

Example, adapted from [1]

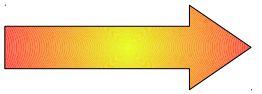
```
void f()
{
  Derived v[3];
  Base * const w = v; //Disaster waiting to happen
  std::cout << w[1];
}
```

[1] Stroustrup, 'A Tour of C++, 2014, page 123

Example, adapted from [1]

```
struct Base { int m_base; };
struct Derived : public Base { int m_derived; };
void f() {
  const int sz = 3;
  Derived v[sz];
  //Initialize
  for (int i=0; i!=sz; ++i) { v[i].m_base = i+1; v[i].m_derived = i+4; }
  //Display
  for (int i=0; i!=sz; ++i) {
    std::cout << v[i].m_base << " " << v[i].m_derived << '\n'; }
  Base * const w = v; //Disaster waiting to happen
  //Display
  for (int i=0; i!=sz; ++i) { std::cout << w[i].m_base << '\n'; }
}
```

```
1 4
2 5
3 6
```



```
1
4
2
```

Base has a different offset than Derived

[1] Stroustrup, 'A Tour of C++, 2014, page 123

My definition of the problem

- You abandon compile-time and run-time checking

- I do not like long nights of debugging

My example

```
void f(const int * const p, const int sz)
{
  //Cannot check if p indeed has size sz
}

void g()
{
  /* ... */
  //Cannot check if i is a valid index from v only
  v[i] = 42;
}
```

Alternative

```
void f(const std::vector<int>& v)
{
  //Can get the true size of v
}

void g()
{
  /* ... */
  //Checks if i is a valid index
  v.at(i) = 42;
}
```

Speed

- Common misconception: arrays are faster
- Many benchmarks compare array and C++ containers incorrectly using those containers

Experiment

- Google for 'std::vector slower than array'
- Compile the first benchmark
- Measure
- Improve the benchmark
- Measure again

Benchmark

- Found post on Stack Overflow
- Benchmark on Travis CI with this GitHub
- Measured these results:

```
UseArray completed in 6.191 seconds
UseVector completed in 44.706 seconds
```

Original code

```
std::vector<Pixel> pixels;
pixels.resize(dimension * dimension);
for(int i = 0; i!=dimension * dimension; ++i)
{
  pixels[i].r = 255;
  pixels[i].g = 0;
  pixels[i].b = 0;
}
```

Original code

Writes Pixels twice!

```
std::vector<Pixel> pixels;
pixels.resize(dimension * dimension);
for(int i = 0; < dimension * dimension; ++i)
{
  pixels[i].r = 255;
  pixels[i].g = 0;
  pixels[i].b = 0;
}
```

Indexed access

Equivalent code

```
std::vector<Pixel> pixels(
  dimension * dimension,
  Pixel(255,0,0)
);
```

Second benchmark

- In debug mode:

```
UseArray completed in 6.965 seconds
UseVector completed in 19.794 seconds
```

Third benchmark

- In release mode:

```
UseArray completed in 2.438 seconds
UseVector completed in 2.437 seconds
```

Conclusion

- The literature advises to use container classes
- Use of arrays can result in errors that cannot be discovered at compile-time nor run-time
- Speed benchmarks incorrectly suggest array is faster, due to naive author
  - Do not forget to benchmark in release mode