HTWK Hochschule für Technik, Wirtschaft und Kultur Leipzig

# `std::span`

presentation for the course “C133 - OS Modern C++”

2025-06-23

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# outline

1. motivation
2. implementation
3. usage
4. benefits and limitations
5. additions after C++20

moseschmiedel/std-span-talk

Which types exist in C++20 to describe a contiguous sequence of objects?

# contiguous sequence types

- `int[N]` (C-style array)
  - not much more then a raw pointer
- `std::array`
  - fixed-size at compile-time
- `std::vector`
  - dynamic-size
- iterators (`arr.begin(), arr.end()`)
- `std::ranges::range` and `std::ranges::view`
- ...and `std::span`!

[1], [2], [3], [4], [5], [6]

# motivation

- decoupling from container implementation
- bounds-safety
- type-safety
  - clearer semantic hints for analysis tools then

```
struct { size_t len; void* buf; };
```

[7, p. 6]

# std::span

- header 

```
template<
    class T,
    std::size_t Extent = std::dynamic_extent
> class span;
```

- Extent can be
  - std::dynamic_extent (default)
  - constexpr std::size_t for static sizes

[6]

# `std::span`

- unowned “view” over contiguous sequence of objects starting at position 0
- bounds-safety guarantees

[6]

# usage

```cpp
#include <span>

// simple (fixed) span usage
void foo(std::span<int, 10> s);
void bar(std::span<int, std::dynamic_extent> s);

// generic span usage
template <typename T, size_t E>
void f(std::span<T, E> s);
```

[6]

# construct from `std::vector`, `std::array` and C array

```cpp
std::vector<int> vector({1,2,3,4});
std::array<int, 4> array({2,3,4,1});
int c_array[4] = {3,4,1,2};
```

| Constructor | Extent | data |
|---|---|---|
| `std::span{vector}` | `std::dynamic_extent` | `[1,2,3,4]` |
| `std::span{array}` | `4` | `[2,3,4,1]` |
| `std::span{c_array}` | `4` | `[3,4,1,2]` |

[6], [8]

# construct from iterators

```
int* it = c_array;
```

| Constructor | Extent | data |
|---|---|---|
| `std::span{it, 4}` | `std::dynamic_extent` | `[3,4,1,2]` |
| `std::span{it, it+4}` | `std::dynamic_extent` | `[3,4,1,2]` |
| `std::span<int,4>{it,4}` | `4` | `[3,4,1,2]` |
| `std::span<int,4>{it,it+4}` | `4` | `[3,4,1,2]` |

[6], [8]

# data members

```
class span {
  public:
    constexpr std::size_t extent = Extent;
  private:
    T* data_; // pointer to underlying sequence

    // only present when extent == std::dynamic_extent
    std::size_t size_; // number of elements
}
```

[6]

# member functions

- `operator=`
- **iterators:** `begin`, `end`, `rbegin`, `rend`
- **access:** `front`, `back`, `data`, `operator[]`
  - *C++26:* `at` checks array bounds before access
- **length:** `size`, `size_bytes`, `empty`
- **subviews:** `first`, `last`, `subspan`

⇒ no methods which change array size!

[6]

# complex example

```
class MyContainer {
    public:
        std::size_t size;
    private:
        std::vector<int> vector_;
    public:
    MyContainer(std::size_t s, int arr[s]) {
        vector_ = std::vector<int>();
        for (int idx = 0; idx < s; idx++) {
            vector_.emplace(vector_.end(), arr[idx]);
        }
    }
...
```

# complex example

```
...
    using iterator = std::vector<int>::iterator;
    iterator begin() {
        return this->vector_.begin();
    }
    iterator end() {
        return this->vector_.end();
    }
};
```

# complex example

```
int main() {
    int arr[] = {1,2};
    auto m = MyContainer{2, arr};
    auto s = std::span{m};

    std::println("{}", s);

    return EXIT_SUCCESS;
}
```

## Output

```
[1, 2]
```

# std::mdspan

- header <mdspan>

```
template<
    class T,
    class Extents,
    class LayoutPolicy = std::layout_right,
    class AccessorPolicy = std::default_accessor<T>
> class mdspan;
```

- multidimensional array view
  - maps multidimensional index to array element
  - array does not need to be contiguous

[9]

# std::mdspan

```cpp
#include <print>
#include <vector>
#include <mdspan>

int main() {
  std::vector d{1,0,0,1};

  auto m2by2 = std::mdspan(d.data(), 2, 2);
  auto m2by1by2 = std::mdspan(d.data(), 2, 1, 2);

  std::println("{}", m2by2[1,1]);
  std::println("{}", m2by1by2[1,0,1]);
}
```

[9]

# benefits

- small, “zero-cost” abstraction
- builtin safety guarantees
- performance increase for frequently called code paths
- simple answer for the question “Which array type should I use?”

# limitations

- needs contiguous memory
- has fixed size, no resizing possible
- dangling `std::span` possible

# dangling `std::span`

```
void f() {
  int arr[] = {1, 2};
  s = arr;
}

int main() {
  f();
  std::println("{}, {}", s, s.size());

  return EXIT_SUCCESS;
}
```

# conclusion

`std::span` is a **“zero-cost” abstraction**, that **simplifies** the **passing** of **contiguous** data structures where **no ownership** of the underlying memory is required!

# bibliography

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