Exercise 13 –Dynamically Allocated Memory, Expression Trees

Informatik I für Mathematiker und Physiker (HS 2015)

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Agenda

- Catching up
- Dynamic data structures
- Old exams

Dynamic Storage Exercise

Dynamic Storage Exercise

```
int i;
while (std::cin >> i) ...
```

reads inputs as long as there are more available.

Write a code snippet which reads inputs as described above, and which then stores these inputs in an array. For this exercise you are not allowed to use the Standard Library (i.e. **no** `std::vector`).

To achieve this you will have to use `new[]` and `delete[]`.

(From: Script Exercise 158.a)

Dynamic Storage Solution

- Idea:

(From: Script Exercise 158.a)

Dynamic Storage Solution

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  1. Allocate some range (using `new[]`)

(From: Script Exercise 158.a)

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  1. Allocate some range (using `new[]`)
  2. As soon as range full, allocate larger range (using `new[]`)

(From: Script Exercise 158.a)

Dynamic Storage Solution

- Idea:
  1. Allocate some range (using `new[]`)
  2. As soon as range full, allocate larger range (using `new[]`)
  3. Copy over initial range

(From: Script Exercise 158.a)

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(From: Script Exercise 158.a)

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  1. Allocate some range (using `new[]`)
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  4. Delete initial range (using `delete[]`)
  5. Go back to 2. with newly generated memory

(From: Script Exercise 158.a)

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(From: Script Exercise 158.a)

Dynamic Storage Solution

```
int n = 1; // current array size
int k = 0; // number of elements read so far

// dynamically allocate array
int* a = new int[n]; // this time, n is NOT a constant

// read into the array
while (std::cin >> a[k]) {
  if (++k == n) {
    // next element wouldn't fit; replace the array a by
    // a new one of twice the size
    int* b = new int[n*=2];  // get pointer to new array
    for (int i=0; i<k; ++i)  // copy old array to new one
        b[i] = a[i];
    delete[] a;              // delete old array
    a = b;                   // let a point to new array
  }
}

...

delete[] a; // don't forget to delete after use
```


(From: Script Exercise 158.a)

New Range - How Much Larger?

Dynamic Storage Solution

- "Much" larger?
  - Pro: ranges less often full → copy less often
  - Con: larger memory consumption

- Important: Larger by a factor, not by a constant…
  - ```
    length_n = length_o * 2
    length_n = length_o + 2
    ```


(From: Script Exercise 158.a)
    ```

Dynamic Storage Solution

- Larger by: a) factor 2 b) constant 2

elements	Case a)	Case b)

(From: Script Exercise 158.a)

Dynamic Storage Solution

- Larger by: a) factor 2 b) constant 2

elements	Case a)	Case b)
	2	2
	4	4
	4	4
	8	6
	8	6
	8	8
	8	8
	16	10
	16	10
	16	12
	16	12
	16	14
	16	14
	16	16
	16	16
	32	18

(From: Script Exercise 158.a)

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arbitr. chosen

Case a):

Significantly fewer resizings.

(From: Script Exercise 158.a)

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Each resizing means:

Copy WHOLE array.

Case a):

Significantly fewer resizings.

(From: Script Exercise 158.a)

Dynamic Storage Solution

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		8
		8
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hosen

Each resizing means:

Copy WHOLE array

Factor 2 is an arbitrary, but good choice.

ficantly fewer resizings.

(From: Script Exercise 158.a)

Vectors

Vectors

- Vectors can grow!

```
std::vector<int> vec (2,0); // 0 0
vec.push_back(7);           // 0 0 7
vec.push_back(2);           // 0 0 7 2
vec.push_back(6);           // 0 0 7 2 6
```

- This works as discussed before!

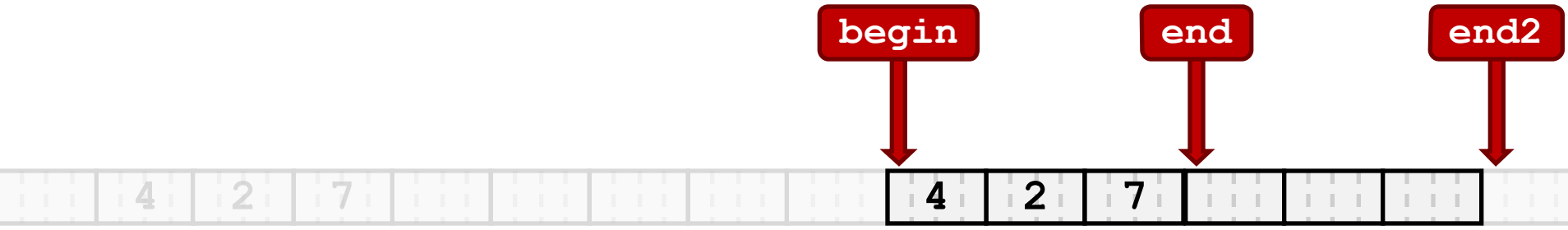
Dynamic Storage in Vectors

- Vectors store 3 pointers:

  `begin`: begin of memory

  `end`: end of *user-accessible* part

  `end2`: end of allocated part



Dynamic Storage in Vectors

- Example:

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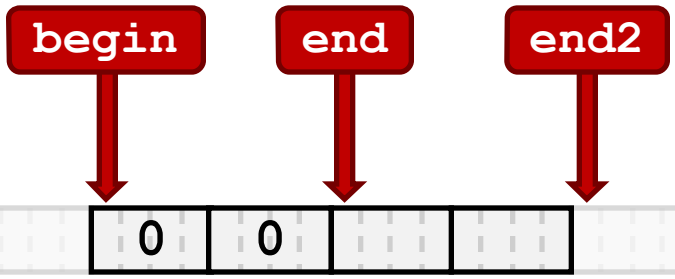

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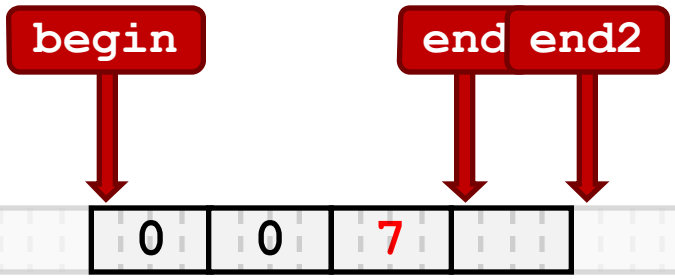

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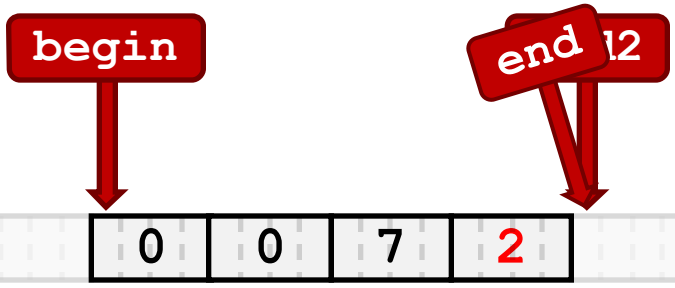

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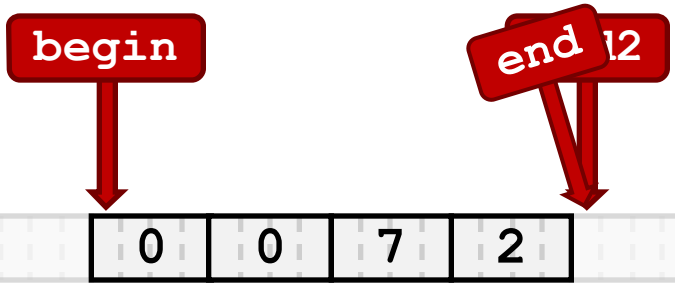


Dynamic Storage in Vectors

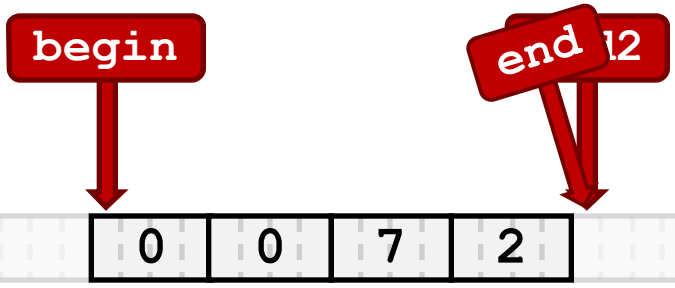
- Example:

```
ifmp::vector<
vec.push_ba
vec.push_b
vec.push_b
```

```
// 0 0
   0 0 7
   0 7 2
   0 7 2 6
```

Space full

Now:
copy range



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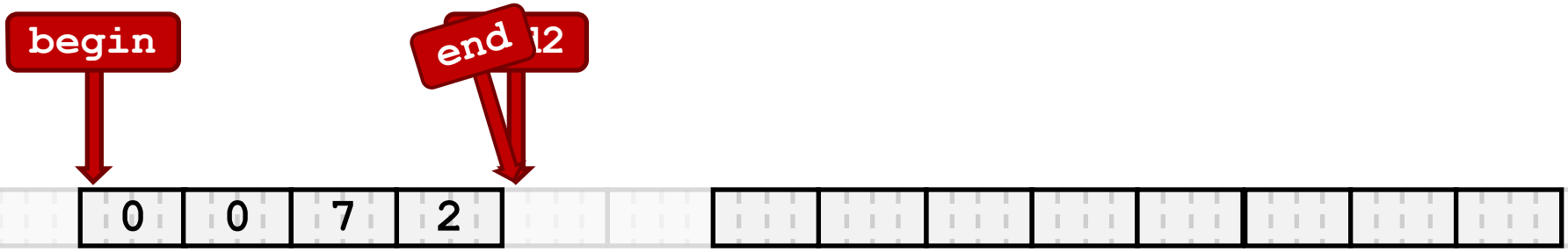

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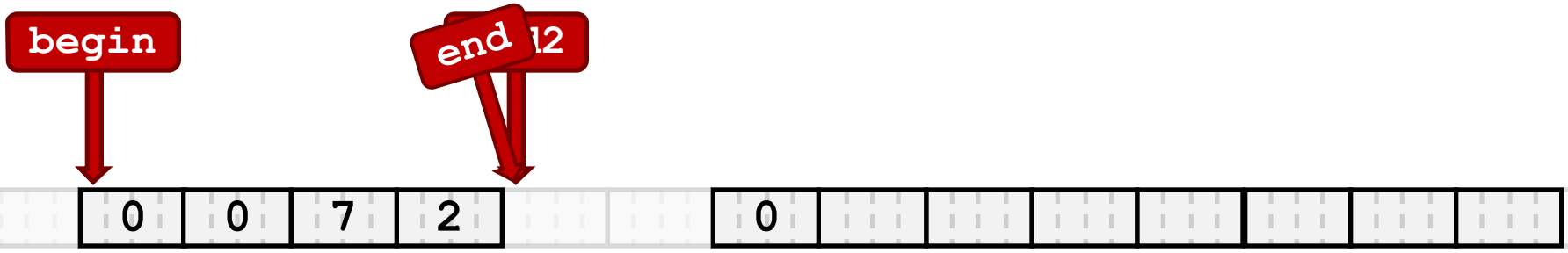

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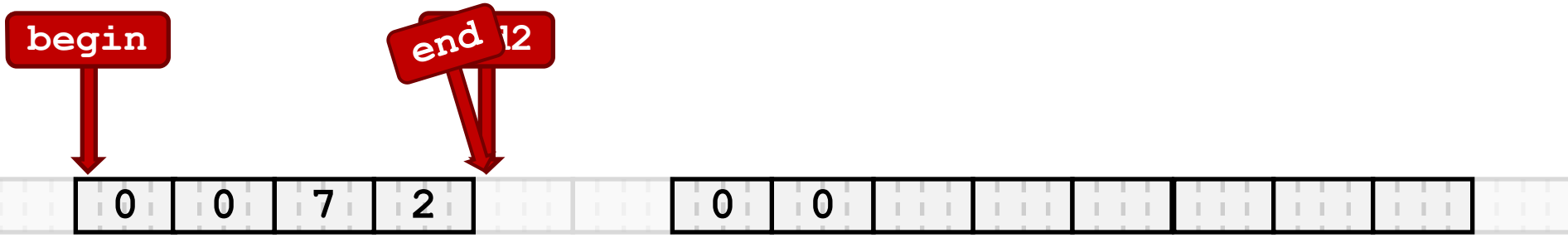

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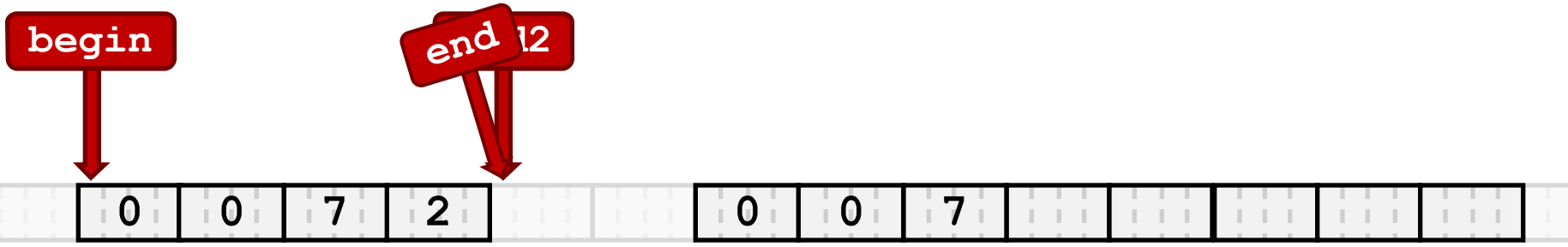

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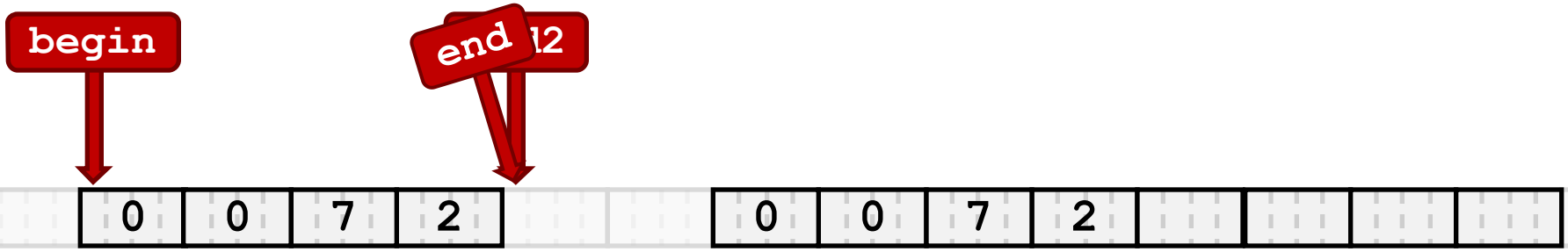

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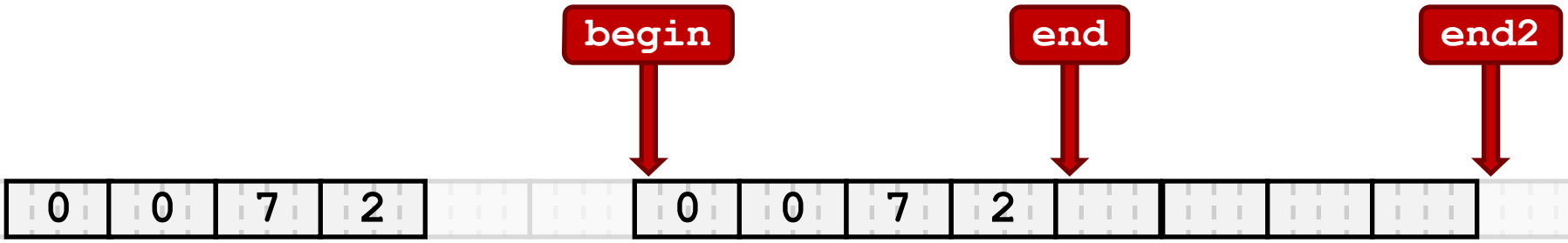

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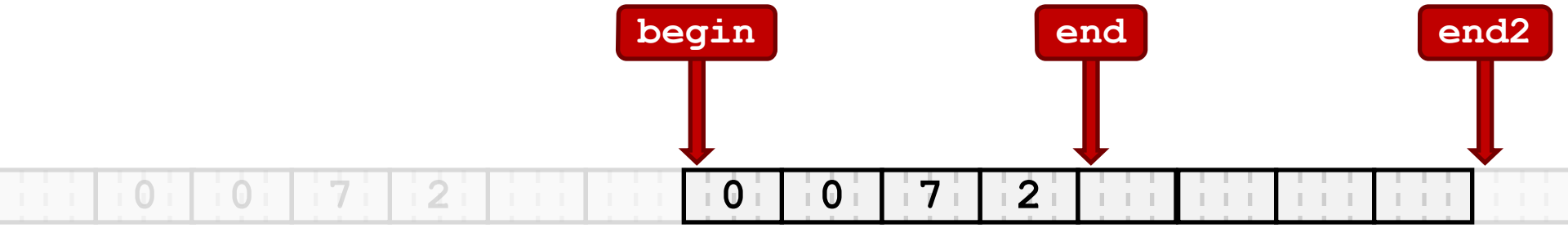

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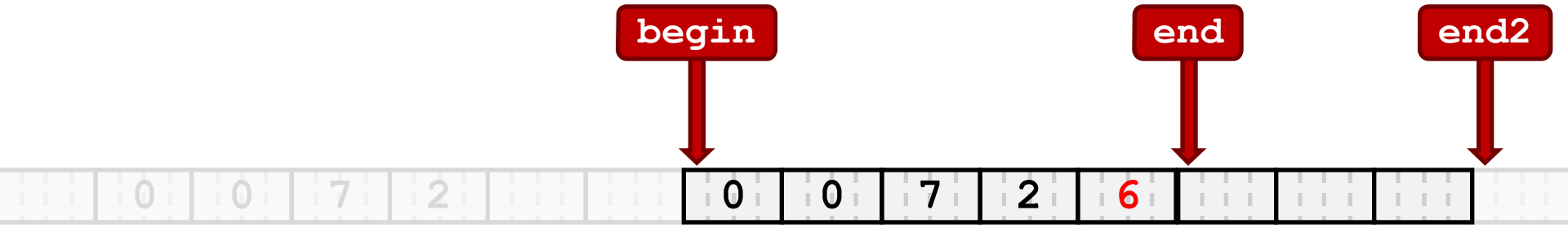


Dynamic Storage in Vectors

- Exercise sheet 12: implement your own vector type.

- Important:
  - **In constructor** — Set initial range
  - **In copy-constructor** — Don't copy just pointers; i.e. copy the ranges behind them
  - **In `operator=`** — Like copy-constructor, in addition:
    i) prevent self-assignments
    ii) don't forget to delete old range

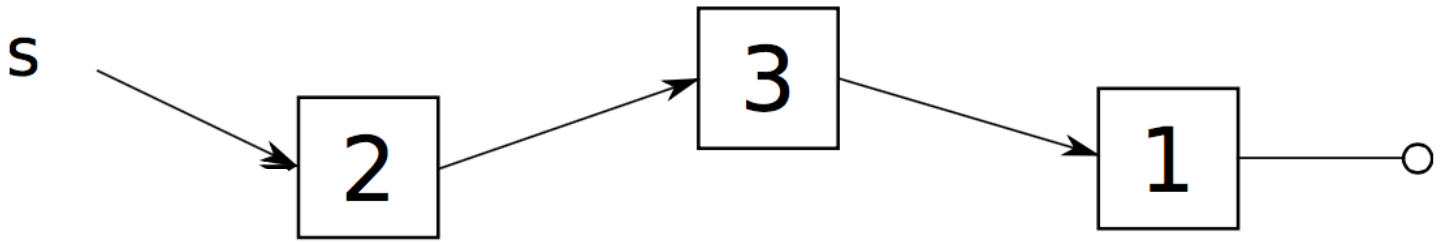
Stack

- Last element in is first element out

```
ifmp::stack s;

s.push(1);
s.push(3);
s.push(2);
```

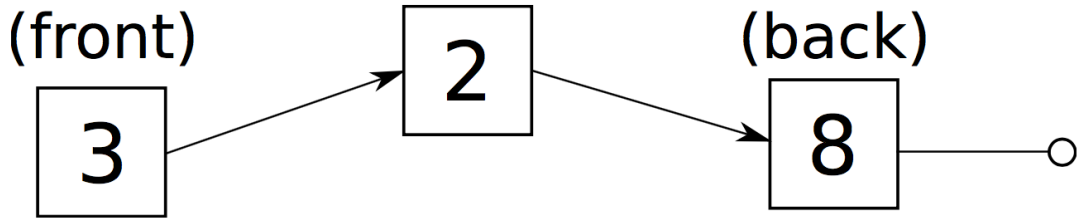
```
s.pop();      // 3 1
s.top();      // 3 1
s.pop();      // 1
s.empty();    // 1
```



Queues

- First element in is first element out (like waiting in line!)

```
ifmp::queue q; // empty queue
q.push_back(3); // q is 3
q.push_back(2); // q is 3 2
q.push_back(8); // q is 3 2 8
```



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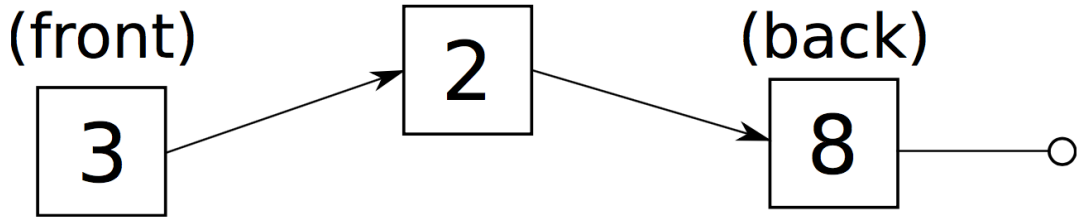


```
q.pop_front();  // q is 2 8
q.pop_front();  // q is 8
q.push_back(7); // q is 8 7
q.pop_front();  // q is 7
```

Expression Trees

- Represent mathematical calculations as trees
- Mathematical operation and values are the tree nodes.
  - Operation nodes store pointers to the each of the operands nodes
  - Numbers are stores as a node with value only (leaf)

$$-5 + 4 * 3$$