Software
Languages.Lab

Structuur van Computerprogramma's 2

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Chapter 4 - Built-in Type Constructors 2

Structuur van Computerprogramma's 2

Dynamically Allocating Data Members

Example: a Ztring Class

Ztring: Class

```
#ifndef ZTRING_H
#define ZTRING_H
#include <iostream>

class Ztring {
public:
   Ztring(const char* cstring = 0); // constructor
   Ztring(const Ztring&);           // copy constructor
   ~Ztring();                       // destructor
   Ztring& operator=(const Ztring&);// assignment operator
   const char* data() const;        // why return const char*?
   unsigned int size() const;
   void print(std::ostream&) const;
   void concat(const Ztring&);      // concatenates to *this
private:
   char* data_;                     // a C-style string
   char* init(const char* string);  // return a copy of string
};
//...
```

ztring.h

Ztring: Overloaded Operators

```
//...

// Auxiliary functions: overloaded operators
// E.g.
// Ztring x("abc");
// Ztring y("def");
// cout << x + y << endl;
Ztring
operator+(const Ztring& s1, const Ztring& s2);

std::ostream&
operator<<(std::ostream& os, const Ztring& s);

#endif
```

ztring.h

Ztring: Constructors and Destructor

```
#include "ztring.h"
#include <string.h> // for strlen

// constructor
Ztring::Ztring(const char* cstring) : data_(init(cstring)) { }

// copy constructor
Ztring::Ztring(const Ztring& s) : data_(init(s.data())) { }

// destructor
Ztring::~Ztring() {
   // very important: avoid memory leak (init uses new[])!
   delete[] data_;
}

// ...
```

ztring.cpp

Ztring: Assignment Operator

```
// ...

// assignment operator
Ztring&
Ztring::operator=(const Ztring& s) {
  if (this == &s)                          // why test this?
    return *this;
  delete[] data_;                          // avoid memory leak
  data_ = init(s.data());
  return *this;
}

// ...
```

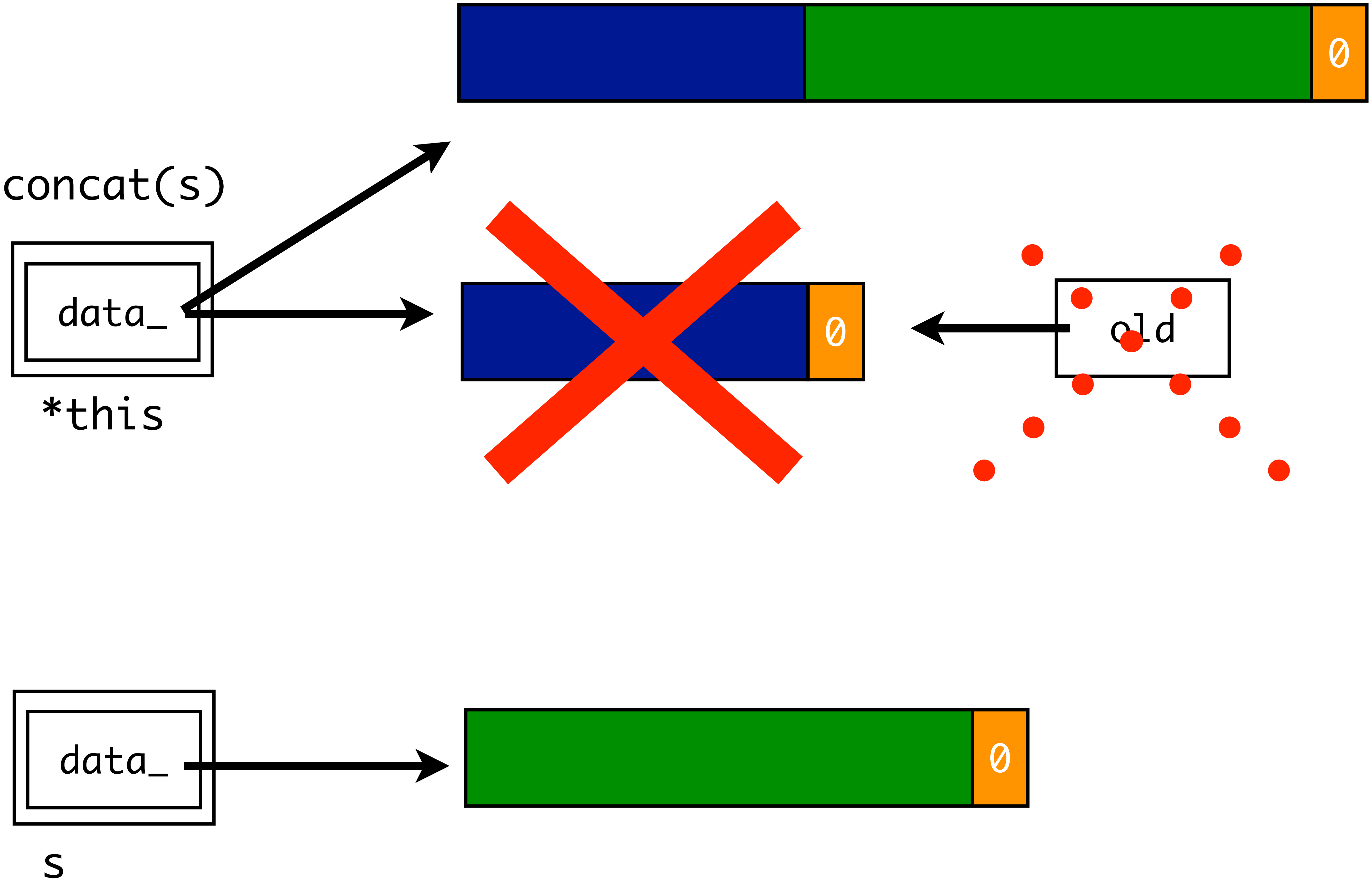
ztring.cpp

Ztring: Inspectors

```
// ...

// constant public member functions
const char*
Ztring::data() const {
   return data_;
}

unsigned int Ztring::size() const {
   if (data_ == 0)          // if no data_ was set (== NULL)
      return 0;
   return strlen(data_);    // compute the # of “non-/0” chars
}

void Ztring::print(std::ostream& os) const {
  // can be made shorter, illustrates low-level implementation
   for (unsigned int i = 0; (i < size()); ++i)
      os << data_[i];
}
```

ztring.cpp

Ztring: Concatenation



Ztring: Inspectors

```
void Ztring::concat(const Ztring& s) {
   // save old data of this ztring
   unsigned int old_size(size());
   char* old(data_);

   // allocate buffer large enough to hold both + trailing \0
   data_ = new char[old_size + s.size() + 1];
   unsigned int j(0);

   for (unsigned int i = 0; (i < old_size); ++i)
      data_[j++] = old[i]; // copy original string

   for (unsigned int i = 0; (i < s.size()); ++i)
      data_[j++] = s.data_[i]; // after that the argument s

   data_[j] = '\0'; // don’t forget trailing ’\0’ character
   delete[] old; // avoid memory leak
}
```

ztring.cpp

Notice how explicit memory management is **scattered** over several functions and how it **crosscuts** the implementation !

Ztring: Private Member Functions

```
char*
Ztring::init(const char* s) {
   if (s == 0)     // remember: as opposed to references,
      return 0;     // pointers can point to nil.  Always check!
   else {
      unsigned int len(strlen(s) + 1);
      char* p(new char[len]);
      for (unsigned int i = 0; (i < len); ++i)
         p[i] = s[i]; // s is an addres, copy its contents
      return p;
   }
}
```

ztring.cpp

Ztring: Auxiliary Functions

```
// auxiliary functions (overloaded operators)

Ztring operator+(const Ztring& s1, const Ztring& s2) {
   Ztring s(s1);
   s.concat(s2);
   return s;
}

std::ostream&
operator<<(std::ostream& os, const Ztring& s) {
   s.print(os);
   return os;
}
```

ztring.cpp

Notice how the implementation of these functions is simple and elegant because of **modularisation** and **abstraction**.
Often it is a good idea to **refactor** long function bodies (e.g. "extract method" refactoring)
Check out www.refactoring.com [M. Fowler]

Gang of three Rule: Avoiding Amnesia !

If a class `C` contains dynamically allocated data members then it should have:

- A **copy-constructor**
  `C:C(const C&)`
  to avoid unwanted sharing of data
- A tailored **assignment operator**
  `C& C::operator=(const C&)`
  to avoid unwanted sharing of data
- A **destructor**
  `C::~C()`
  to avoid memory leaks

Encapsulating Free Objects and Overloading `new`, `delete`

Example: Object Pool for Rationals

Overloading new, delete

```
class Rational {
   // ...
public:
   void* operator new(size_t) {
      return pool_.alloc();
   }

   void operator delete(void* p, size_t size) {
      assert(size == sizeof(Rational)); // sanity check
      if (p) // do not attempt to delete a null pointer
         pool_.dealloc(p);
   }
   // ...
private:
   static Pool pool_; // a Pool of reusable Rational Objects
   // ...
};
```

Rational.h

The `void*` type indicates a **'universal' pointer**.
Must be `static_cast` to a particular type before dereferencing

`size_t` is the unsigned integral type returned by the operator `sizeof()`

`alloc()` and `dealloc()` are member functions of our user-defined type `Pool`

```
// will allocate from Rational::pool_
Rational* p(new Rational(1, 3));
```

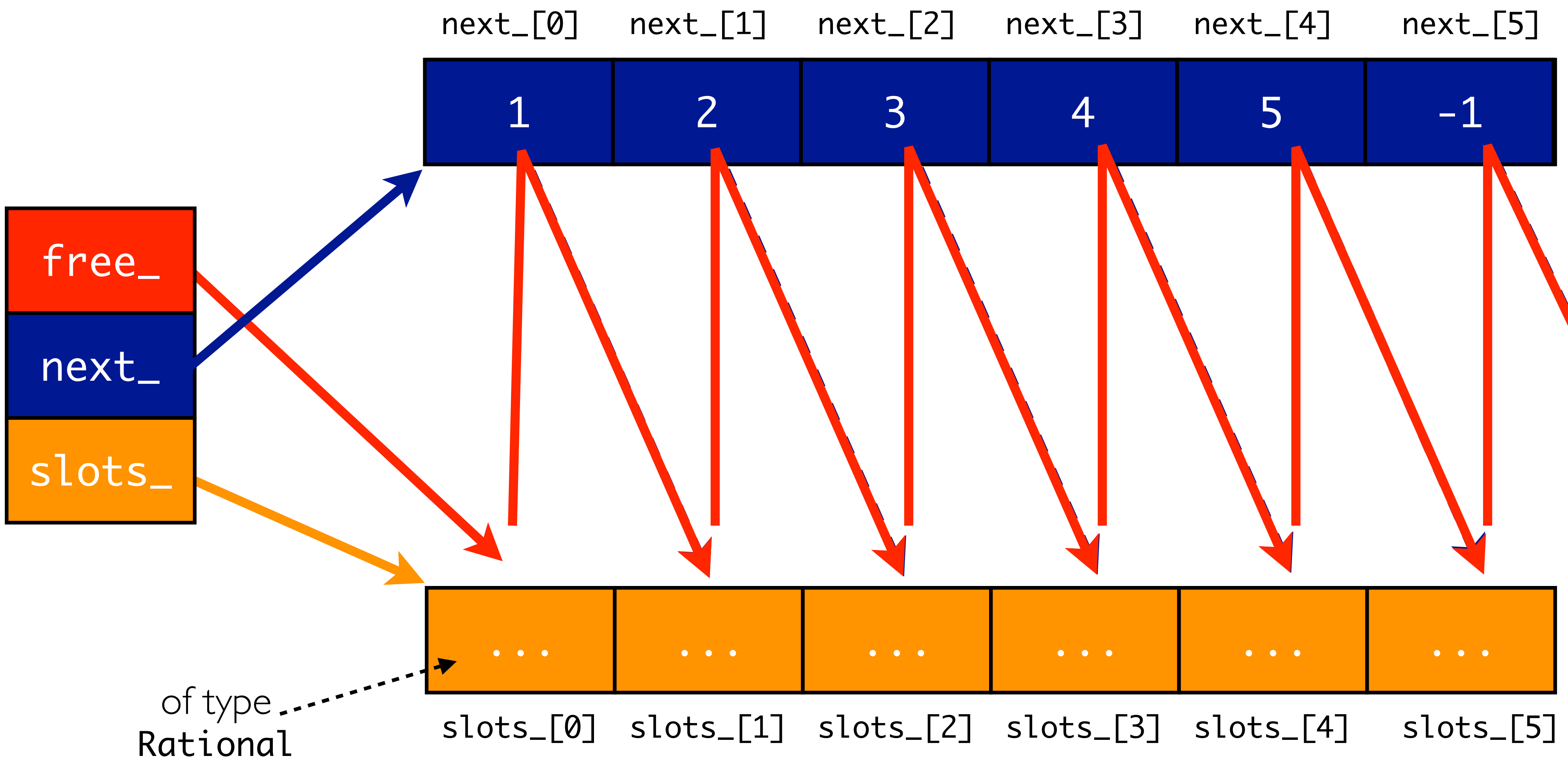
Can we achieve better performance than the default `new` and `delete` ?

Pool for Allocating Free Rational Objects

```
#ifndef POOL_H
#define POOL_H
#include "rational.h"
// a pool of reusable areas, each of size sizeof(Rational)
class Pool {
public:
   Pool(unsigned int number_of_areas);  // constructor
   ~Pool();                             // destructor
   bool is_full() const { return free_ < 0; }
   Rational* alloc();                   // return pointer to free area
   void dealloc(void* p);               // free an area
private:
   Pool(const Pool&);                   // copying Pools is forbidden
   Pool& operator=(const Pool&);        // assigning Pools is forbidden

   Rational* slots_; // holds an array of reusable Rational areas.
   int* next_;       // if i equals the index of a free slot, then
                     // next_[i] is the index of another free
                     // slot or -1 if full.
   int free_;        // index of first free slot or <0 if pool is full.
};
#endif
```

pool.h

Pool After Construction



`slots_` holds an array of reusable `Rational` objects
`next_` holds and array where each slot holds the index of the next free slot after you use the selected slot
`free_` is the index of the next free slot in the pool (-1 if full)

Pool Constructor, Destructor

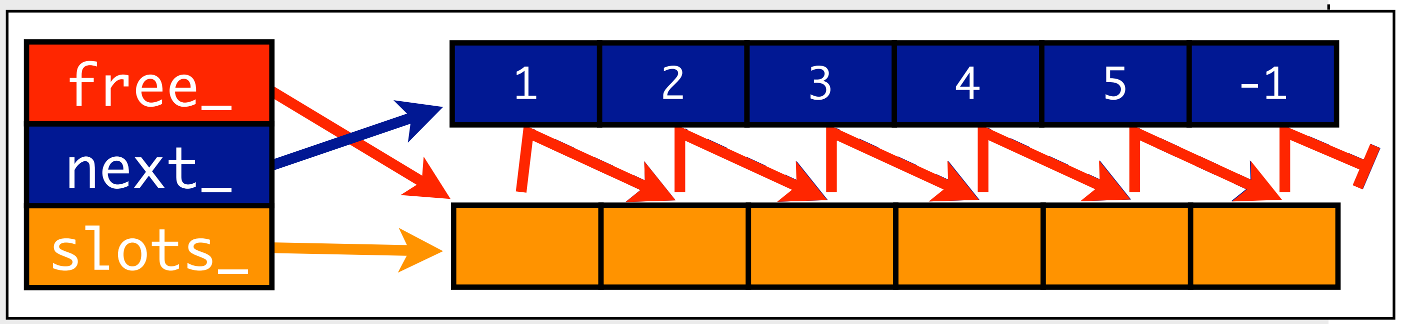
```
// note: this code assumes that Rational::operator new[]
// and Rational::operator delete[]
// are NOT overloaded (see earlier example) !

#include "pool"
#include <stdlib.h> // for abort()
// constructor
Pool::Pool(unsigned int size) :
  slots_(new Rational[size]), next_(new int[size]), free_(0) {
     // initially, the free list is 0, 1, 2, ..
     for (unsigned int i=0;(i<(size-1));++i)
        next_[i] = i+1;
     next_[size-1] = -1; // end of free list
}
// destructor
Pool::~Pool() {
  delete[] next_;
  delete[] slots_;
}
```

pool.cpp

(De)Allocation from a Pool

```
Rational*
Pool::alloc() {
   if (is_full())                // free < 0 ?
    abort();                     // not nice, use exceptions!
   Rational* r(&slots_[free_]);  // address of first free slot
  free_ = next_[free_];          // update start of free list
  return r;
}
```

The `static_cast` converts 'related' types e.g. converting a `void*` to a `Rational*`. There is no runtime check performed that asserts whether the data fits into the type.



```
void Pool::dealloc(void* p) {
  // compute index of pointer p in slots_ array
   int index(static_cast<Rational*> (p) - slots_);
  // add index of deallocated area to front of free list
   next_[index] = free_;
   free_ = index;
}
```

Why `void* p` instead of `Rational* p`?

pool.cpp

Smart Pointers

Mimicking Pointer behaviour with Smart Pointers (1)

A **smart pointer** gives a user-defined type
some of the functionality of a pointer
(e.g. dereferencing with `->` and `*`, pointer arithmetic)

The interpretation of `x->name` if `x` is of type `T` is
`(x.operator->())->name`
where `->` needs to be overloaded with `T::operator->()`

```
class Url; // defined elsewhere

class HtmlPage { // a page is uniquely identified by its URL
   friend class Proxy;
public:
   std::string title() const;
private:
   static HtmlPage* fetch(const Url&);  // retrieve page at URL
   HtmlPage(const HtmlPage&);           // forbidden to copy
   HtmlPage& operator=(const HtmlPage&);// forbidden to assign
};
```

Smart Pointers (2)

```
// Proxy acts as a logical pointer to a HtmlPage
// which is fetched on demand. The address is in this case a URL.
class Proxy {
public:
   Proxy(const std::string& url) : key_(url) { }

   // smart pointer
   HtmlPage* operator->() const {
      return HtmlPage::fetch(url());
   }

   const Url& url() const {
      return key_;
   }
private:
   Url key_;
};
```

```
Proxy proxy("http://www.vub.ac.be/index.html");
// call HtmlPage::fetch(http://www.vub.ac.be/index.html);
proxy->title();
```