EXPERIMENTS ON BUILDING HIGH LEVEL ABSTRACTIONS WITH C

PART 1: SMART POINTERS

With a tasteful hint of GNU extensions

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EPITA – GCONFS

SMART POINTERS FOR GNU C99

Memory management is an unsolved problem.

Known techniques rely on RAII, Reference counting, Garbage collection

There is no silver bullet, each has its drawbacks

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File I/O and RAII:

```
{
  std::fstream file("foo.txt");
  file << "Hello world";
} // file is closed when exiting the scope
```

C++ solves the problem with RAII and smart pointers:

File I/O and RAII:

```
{
  std::fstream file("foo.txt");
  file << "Hello world";
} // file is closed when exiting the scope
```

Memory allocation:

```
{
  auto ptr = std::make_unique<int>(42);
  std::cout << *ptr;
} // the memory is freed when exiting the scope
```

RAII WITH C

There are no RAII facilities in standard C – cleanup is mainly done with goto

```
FILE *f = fopen("foo.txt", "w");
if (!f)
  goto cleanup;

// do things

if (error_case)
  goto cleanup;

// do more things

cleanup:
  if (f) fclose(f);
```

EXTENSIONS TO THE RESCUE

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MSVC: Structured exception handling and try/finally

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FILE *f = NULL;
__try {
    f = fopen("foo.txt", "w");
} __finally {
    if (f) fclose(f);
}
```

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    if (f) fclose(f);
}
```

GCC, Clang/LLVM, ICC: cleanup attribute

```
void fclose_stack(FILE **f) { if (*f) fclose(*f); }

__attribute__((cleanup(fclose_stack)))
FILE *f = fopen("foo.txt", "w");
```

BUILDING AN AUTOMATIC POINTER

The cleanup attribute provides the basic building block for an automatic pointer:

```
void free_stack(void **f) {
    free(*f);
}

#define auto_ptr __attribute__((cleanup(free_stack)))

auto_ptr int *val = malloc(sizeof (int));
*val = 31>174;
```

But it's not good enough.

A FEW ISSUES

```
auto_ptr int *val = malloc(sizeof (int));
*val = 24;
```

VS.

```
auto ptr = std::make_unique<int>(24);
```

- Not convenient to use
- No support for structure cleanup
- Resource not shareable

In other words, it's useless garbage.

IMPLEMENTING DESTRUCTORS

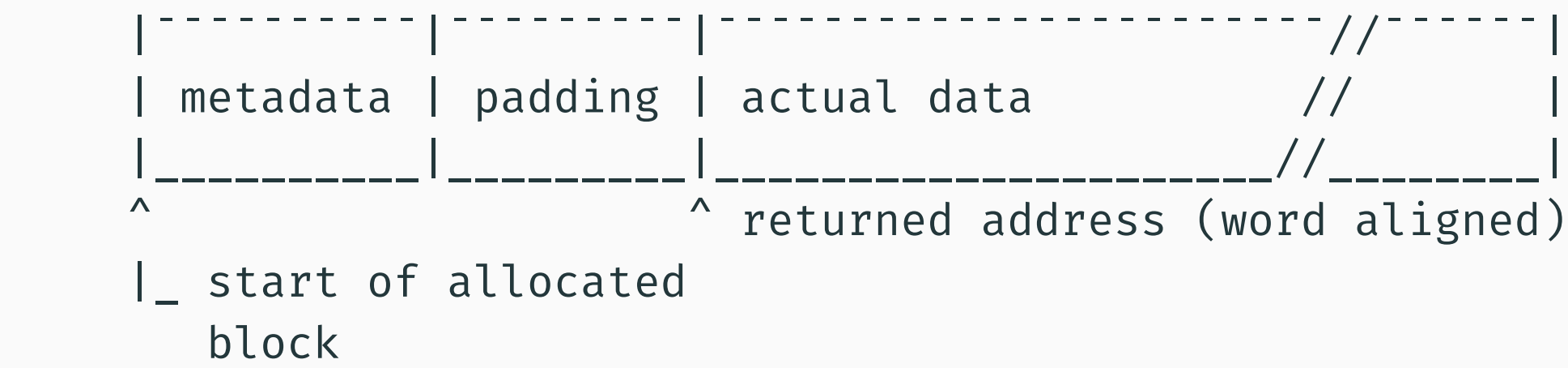
We need to store a destructor function.

We need to store metadata.

We need a custom allocator.

Introducing smalloc/sfree:

```
void *smalloc(size_t size, void (*dtor)(void*));
void sfree(void *);
#define smart __attribute__((cleanup(sfree_stack)))
```



SIMPLE IMPLEMENTATION

```
typedef void (f_dtor)(void*);
typedef struct {
    f_dtor *dtor;
} s_meta;

void *smalloc(size_t size, f_dtor *dtor) {
    size_t prefix_sz = align(sizeof (s_meta));
    s_meta *ptr = malloc(size + prefix_sz);
    ptr->dtor = dtor;
    return (char *) ptr + prefix_sz;
}

void sfree(void *ptr) {
    s_meta *meta = get_meta(ptr);
    if (meta->dtor) meta->dtor(ptr);
    free(ptr);
}
```

ENHANCING SMALLOC

```
void *smalloc(size_t size, void (*dtor)(void*));
```

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```
void *smalloc(size_t size,
              void (*dtor)(void*, void*),
              void *meta,
              size_t metasize);
```

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```

:’(

ENHANCING SMALLOC

```
struct smalloc_args {
  size_t size;
  void (*dtor)(void*, void*);
  struct {
      void *data;
      size_t metasize;
  } meta;
};

void *smalloc(struct smalloc_args *);

#define smalloc(...)                          \
  smalloc(&(struct smalloc_args) {            \
      __VA_ARGS__                             \
  })
```

ENHANCING SMALLOC

```
smart int *ptr = smalloc(sizeof (int));

smart int *ptr = smalloc(sizeof (int), my_int_dtor);

smart int *ptr = smalloc(
        sizeof (int),
        my_int_dtor,
        { my_meta, sizeof (my_meta) }
    );

smart int *ptr = smalloc(
        .size = sizeof (int),
        .dtor = my_int_dtor,
        .meta = { my_meta, sizeof (my_meta) }
    );
```

Awesome!

A LOOK BACK ON WHAT WE DID

`sfree` is the universal deallocator, just like `delete` in C++

ISO C99:

```
whatever *ptr = smalloc(
        .size = sizeof (whatever),
        .dtor = dtor_whatever
    );
// manipulate ptr
sfree(ptr);
```

C99 with GNU extensions:

```
smart whatever *ptr = smalloc(
        .size = sizeof (whatever),
        .dtor = dtor_whatever
    );
// manipulate ptr
```

We could leave it at that, but...

But it's still not enough.

SHARED POINTERS

Unique pointers (no shared ownership)

```
smart int *ptr = smalloc(UNIQUE, sizeof (int));
```

Shared pointers (shared ownership)

```
void *sref(void *); // increments reference counter

smart int *ptr = smalloc(SHARED, sizeof (int));
smart int *ref = sref(ptr);
```

SHARED POINTERS: A SIMPLE EXAMPLE

```
smart int *ptr = smalloc(SHARED, sizeof (int));
if (!ptr)
    abort();

*ptr = 42;

list_add(some_list, sref(ptr));
list_add(some_list, sref(ptr));
list_add(some_list, sref(ptr));
```

SYNTAX SUCKS AGAIN

The boilerplate code strikes back.

```
smart foo *ptr = smalloc(UNIQUE,
        sizeof (foo),
        foo_dtor);
if (!ptr)
    abort();
*ptr = (foo) {...};
```

SYNTAX SUCKS AGAIN

The boilerplate code strikes back.

```
smart foo *ptr = smalloc(UNIQUE,
        sizeof (foo),
        foo_dtor);
if (!ptr)
    abort();
*ptr = (foo) {...};
```

- Obligatory NULL check.
- We almost always define a value right away.

Nobody wants to do that hundred of times.

ADDING MORE SYNTACTIC SUGAR TO THE CAKE

Let's introduce two macros: `unique_ptr` and `shared_ptr`.

```
smart int *yes = unique_ptr(int, 1);
smart int *yes = unique_ptr(int, .value = 1);

typedef struct { float x; float y; } point;

smart point *zero = unique_ptr(point);
smart point *p = shared_ptr(point, { 1.3, 4.2 });
```

HANDLING ARRAYS

smalloc/sfree is the equivalent of new/delete in C++.

There is no equivalent for new[] and delete[].

We need to change the implementation of smalloc to handle arrays and change `unique_ptr` and `shared_ptr`.

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```
smart int *arr = unique_ptr(int[5], {1, 2, 3, 4, 5});
```

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We need to change the implementation of smalloc to handle arrays and change `unique_ptr` and `shared_ptr`.

```
smart int *arr = unique_ptr(int[5], {1, 2, 3, 4, 5});

for (size_t i = 0; i < array_length(arr); ++i)
    printf("%d\n", arr[i]);
```

What's next?

what's next?

- weak pointers
- move semantics for ownership transfer

Any sensible contribution is welcome.

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 `franklinmathieu+libcsptr@gmail.com`

`Snaipe` on `#criterion-dev` @ `irc.freenode.net`

Questions?

ADDENDUM

EXTRACTING THE SIZE OF AN ARRAY

Let `T` be a type and `dummy` be a variable of type `T[1]`.

Then:

- `sizeof (dummy[0])` is the size in bytes of the compound type of T.
- `sizeof (dummy) / sizeof (dummy[0])` is the length of the array if T is an array type, 1 otherwise.

Example:

```
T[1] v;
size_t size = sizeof (v[0]);
size_t lenght = sizeof (v) / sizeof (v[0]);
printf("%lu, %lu\n", size, length);
```

If T is an int, this prints `4, 1`.

If T is an int[20], this prints `4, 20`.

Note: If T is a multidimensional array type, the yielded length is the length of the flattened array.