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Guillaume Combette, Guillaume Munch-Maccagnoni

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# A resource modality for RAI

Guillaume Combette (CNRS, ENS Lyon)  
[Guillaume.Combette@ens-lyon.fr](mailto:Guillaume.Combette@ens-lyon.fr)

Guillaume Munch-Maccagnoni (Inria, LS2N CNRS)  
[Guillaume.Munch-Maccagnoni@inria.fr](mailto:Guillaume.Munch-Maccagnoni@inria.fr)

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## 1 RAI and move semantics

Stroustrup’s “*Resource acquisition is initialisation*” idiom (RAI, [Stroustrup 1994](#)) attaches *destructors* to types in C++, called whenever the lifetime of a variable ends, either by the end of its scope being reached, by an exception being raised, or by a control operator (*return*, *break*) being called. It is used in C++ to ensure the *basic exception-safety guarantee* ([Stroustrup, 2001](#)). Unlike finalizers called by a tracing garbage collector, destructors are called at fixed and predictable times.

RAI allows a form of resource management, for ensuring for instance that dynamically-allocated memory is always freed by the end of a scope. It is also used to ensure that locks are always freed, connections are always closed, etc. Doing so amounts to treat locks and connections as resources. Thus, a main point of RAI is that destructors may perform effects.

The extension of C++ with *move semantics* ([Hinnant, Dimov, and Abrahams, 2002](#)) allowed to express the moving of non-copiable resources. Moving a resource alters its lifetime: it can change the order in which destructors are called, or transfer the duty of calling the destructor to a different scope. Notably it allowed the definition of a non-copiable *smart pointer* for automatic resource management (*unique\_ptr*) expressing ownership.

[Baker \(1994a,b, 1995\)](#) has proposed a synthesis of the notion of resource from systems programming with that of resources from linear logic ([Girard, 1987](#)). Arguably, it contained an early description of move semantics (it mentioned in particular the compatibility of moving with C++-style destructors). Although these articles described many of the ideas behind the resource management model of the C++11 ([Stroustrup, Sutter, and Dos Reis, 2015](#)) and Rust ([Anderson, Bergstrom, Goregaokar, Matthews, McAllister, Moffitt, and Sapin, 2016](#)) languages, they appear in advance of their time and rarely mentioned. In this presentation, we substantiate a link between C++-style destructors and linear logic.

## 2 A resource modality for RAI

We consider  $\mathcal{L}$  any distributive symmetric monoidal closed category (such as in particular any standard model of linear logic). For any  $E \in \mathcal{L}$ , there is a monad  $-\oplus E$ . It has been noticed in [Hasegawa](#)

(2004) that this monad lacks in general a strength, and therefore cannot be used to model exceptions like in a cartesian setting (Moggi, 1991). Intuitively, the operations *bind* and *raise* (or *throw*) need to dispose of variables in their context.

The main idea to model exceptions in  $\mathcal{L}$  is to consider the slice category  $\mathcal{L}/I$  where  $I$  is the monoidal unit. We recall that the *slice category*  $\mathcal{C}/X$  of a category  $\mathcal{C}$  for  $X \in \mathcal{C}$  has objects  $(A, \delta)$  for  $A \in \mathcal{C}$  and  $\delta \in \mathcal{C}(A, X)$ , and morphisms those in  $\mathcal{C}$  that preserve the second component. In particular,  $(X, \text{id}_X)$  is terminal, and so  $\mathcal{L}/I$  is affine. When an object  $A \in \mathcal{L}$  interprets a type and  $\delta \in \mathcal{L}(A, I)$  interprets a derivation, we think of  $(A, \delta)$  as another type obtained by attaching the destructor  $\delta$  to the type  $A$ .

We are more generally interested in the case where we are given a strong monad  $(T, \eta, \mu, \sigma)$  on  $\mathcal{L}$ . We consider the slice category  $\mathcal{L}/TI$  and think of objects  $(A, \delta : A \rightarrow TI)$  as destructors that may perform an effect. We recall the following result attributed to Street<sup>1</sup>:

**Proposition 1.** *For any monoid  $M$  in  $\mathcal{L}$  with multiplication  $m \in \mathcal{L}(M \otimes M, M)$  and unit  $e \in \mathcal{L}(I, M)$ , the slice category  $\mathcal{L}/M$  has a monoidal structure with unit  $I_M = (I, e)$  and tensor  $(A, \delta) \otimes (B, \delta') = (A \otimes B, m \circ \delta \otimes \delta')$ . The forgetful functor  $U : \mathcal{L}/M \rightarrow \mathcal{L}$  is strict monoidal.*

Now, the object  $TI$  has a monoid structure given by  $\mu_I \circ \sigma_{TI, I} : TI \otimes TI \rightarrow TI$  and  $\eta_I : I \rightarrow TI$ . Thus,  $\mathcal{L}/TI$  has a monoidal structure and strict monoidal forgetful functor  $U : \mathcal{L}/TI \rightarrow \mathcal{L}$ .  $\mathcal{L}/TI$  has a terminal object  $(TI, \text{id}_{TI})$ . Notice that if  $\mathcal{L}$  is symmetric, the symmetry does not necessarily lift to a symmetry on  $\mathcal{L}/TI$ . This is the case though whenever  $T$  is commutative. Otherwise, there is a definite order in the application of destructors: the destructor of  $P \otimes Q$  first calls the destructor of  $Q$  and then the destructor of  $P$ .

We notice that the functor  $U$  has a right adjoint if and only if  $\mathcal{L}$  has the products  $- \times TI$  (as is the case in any model of multiplicative-additive intuitionistic linear logic). One therefore has a monoidal adjunction  $\mathcal{L}/TI \xrightleftharpoons[U_R]{U_L} \mathcal{L}$ , giving rise to a resource modality  $S = UR$  on  $\mathcal{L}$  in the sense of Mellies (2009). When  $\mathcal{L}$  has finite products, this adjunction has the structure of a (non-commutative) linear call-by-push-value model (Curien, Fiore, and Munch-Maccagnoni, 2016). In particular, its deductive system given by the oblique morphisms of the adjunction (Munch-Maccagnoni, 2014), still expresses multiplicative-additive intuitionistic linear logic, though with fewer identities between derivations, reflecting the presence of an evaluation order. The deductive system includes a symmetry  $A \otimes B \vdash B \otimes A$  found in

$$\mathcal{L}(UA \otimes UB, UB \otimes UA) \cong \mathcal{L}/TI(A \otimes B, RU(B \otimes A)),$$

in words, moving resources is available as an effectful operation.

In this setting, we study the monad  $T\mathcal{E} = T(- \oplus E)$  on  $\mathcal{L}$  and strength-like maps  $\theta_{P,A} : UP \otimes T\mathcal{E}A \rightarrow T\mathcal{E}(UP \otimes A)$  defined for  $P \in \mathcal{L}/TI$  and  $A \in \mathcal{L}$ .

### 3 Resource management modes as polarities

We will conclude with considerations of programming language design following from the analogy:

$$\text{smart pointer} \sim \text{resource modality}$$

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<sup>1</sup><https://mathoverflow.net/a/229371>

which is suggested by Chirimar, Gunter, and Riecke, 1996 (a resource modality for a reference-counted garbage collection) and the previous section (a resource modality for *unique\_ptr*).

We propose to extend it into an analogy:

resource management mode  $\sim$  polarity

where the notion of polarities (Girard, 1991, 1993) suggests a way of mixing different resource management modes as kinds in a functional programming language, presented recently in a companion article (Munch-Maccagnoni, 2018).

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