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A resource modality for RAI

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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, δ) 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, 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, δ) as another type obtained by attaching the destructor δ to the type A .

We are more generally interested in the case where we are given a strong monad (T, η, μ, σ) 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 Street¹:

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, 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:

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

¹<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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