Markedly: a cartographic approach for mapping eDSL implementation costs

Karl Cronburg
karl@cs.tufts.edu

Authors: Matthew P. Ahrens, Karl Cronburg, Jeanne-Marie Musca
Siriusly PL Lab @ Tufts University
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Background

Members of the PL lab at Tufts regularly implement eDSLs in Haskell:

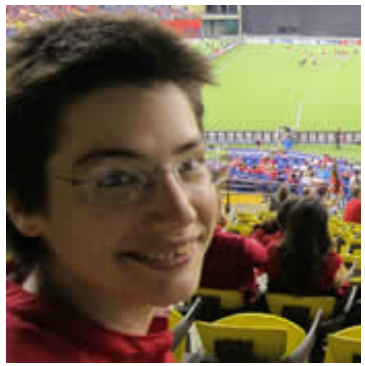
Karl Cronburg

ANTLR-like parsing eDSL

Matt Ahrens

Cyber-physical systems eDSL

Jeanne-Marie Musca



Multi-union data types (extensible records) eDSL

The problem

Embedded domain specific languages (eDSLs) are difficult to design, implement, and maintain to stand the test of time. EDSL creators want to:

- $\mathbb{P}$reserve . . . the correctness of $\boldsymbol{D}$ in $\boldsymbol{I}$
- $\mathbb{E}$xtend . . . $\boldsymbol{D}$ and $\boldsymbol{I}$ to support new features
- $\mathbb{A}$dhere . . . exclusively to $\boldsymbol{D}$ in $\boldsymbol{I}$
- $\mathbb{R}$ecognize . . . spans in $\boldsymbol{I}$ as features in $\boldsymbol{D}$

Design	$\boldsymbol{D}$	set of features, $f \in \boldsymbol{D}$
Implementation	$\boldsymbol{I}$	set of spans, $(s, e) \in \boldsymbol{I}$

Proposed solution

- Provide eDSL creators with a methodology to discuss where costs originate.
- Both the design ***D*** and implementation ***I*** of an eDSL contribute to implementation costs.

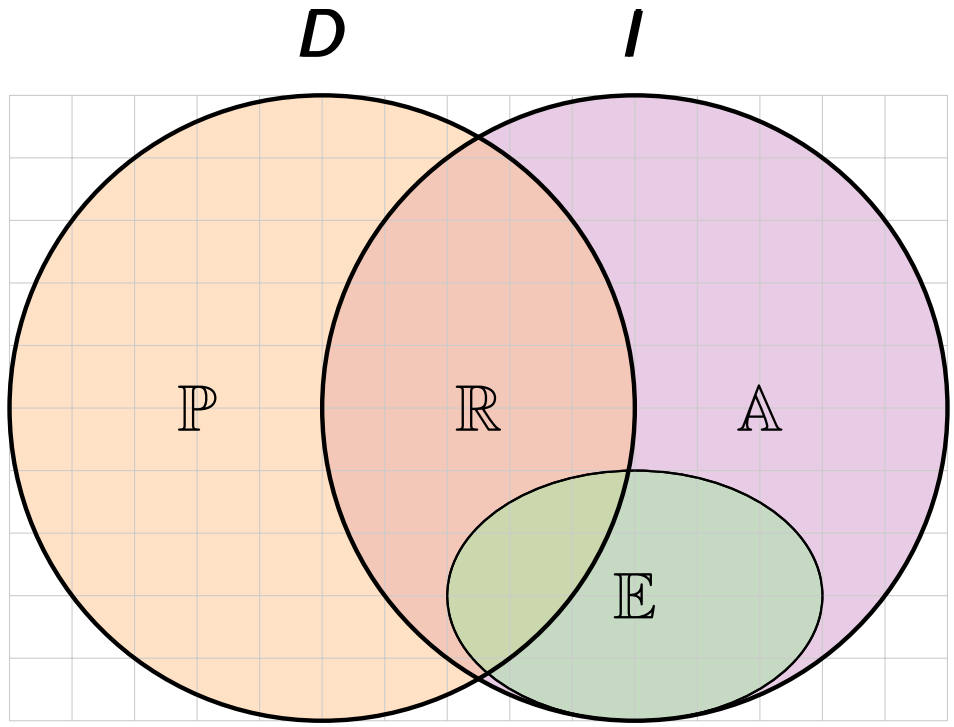


Figure: Sources of $\mathbb{PEAR}$ costs.

Type Level Natural Numbers (TLN)

0 Language creator Mark wants to create an eDSL in Haskell with the ability to annotate Haskell types with natural numbers.

1

Mark first writes down the desired features:

- human-readable natural number weights,
- to attach weights to arbitrary expressions,
- and to sum weights across function application.

The TLN implementation

2 Mark implements a prototype of TLN using GHC's† `DataKinds` and `TypeFamilies` metaprogramming facilities.

```
data Nat = Z | S Nat
type Weighted (w :: Nat) a = a
```

```
type family
  (w1 :: Nat) :+: (w2 :: Nat) :: Nat
```

```
type instance Z :+: m = m
type instance (S n) :+: m = S (n :+: m)
```

```
($$) :: Weighted w1 (a -> b)
     -> Weighted w2 a
     -> Weighted (w1 :+: w2) b
($$) f a = f a
```

† Glasgow Haskell Compiler

The TLN map

3 With Haskell code in hand (previous slide), Mark hand-draws a Markedly map depicting how meta-information† flows through the code.

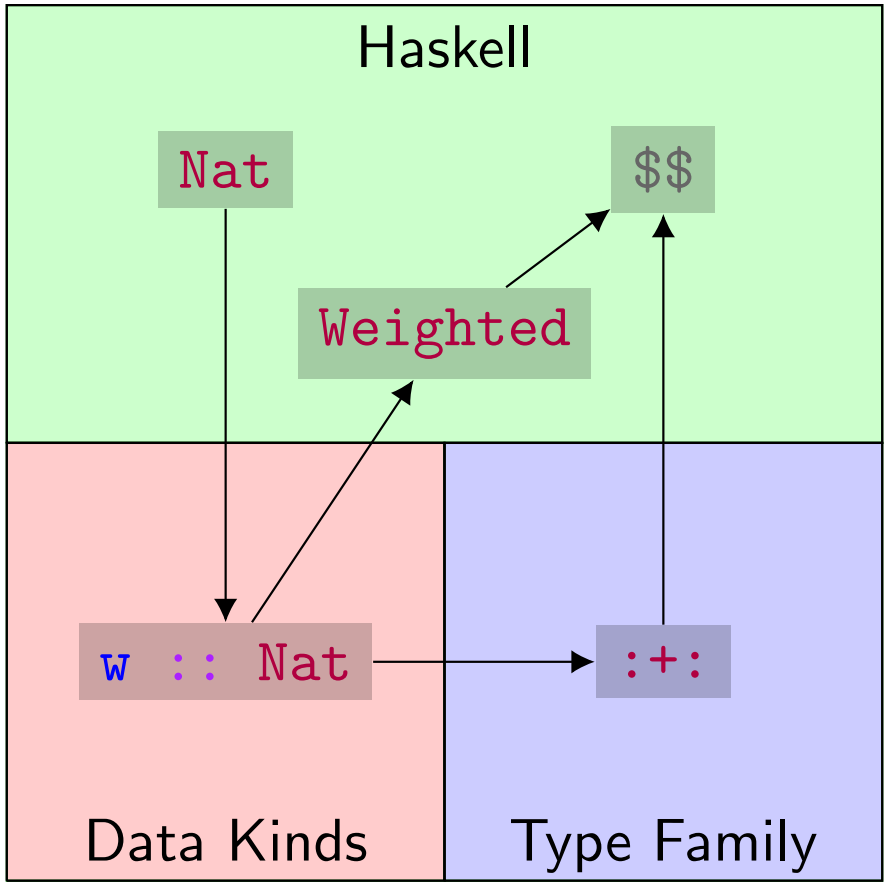


Figure: Haskell map for TLN.

TLN $\mathbb{PEAR}$ costs

4 Finally Mark computes $\mathbb{PEAR}$ costs according to the metrics listed above.

Element	$\mathbb{P}$	$\mathbb{E}$	$\mathbb{A}$	$\mathbb{R}$
`Nat`	1	·	·	·
`Weighted`	·	·	1	·
`w :: Nat`	·	·	·	1
`$$`	·	·	1	·
`Nat` ⟶ `w :: Nat`	·	·	·	1
`w :: Nat` ⟶ `Weighted`	·	·	·	1
`w :: Nat` ⟶ `:+:`	·	·	·	1
$\text{cost}(\boldsymbol{D}, \boldsymbol{I}) = \Sigma \langle \mathbb{P}, \mathbb{E}, \mathbb{A}, \mathbb{R} \rangle =$	1	·	2	4

Figure: Non-zero $\mathbb{PEAR}$ costs of TLN.

PEAR metrics

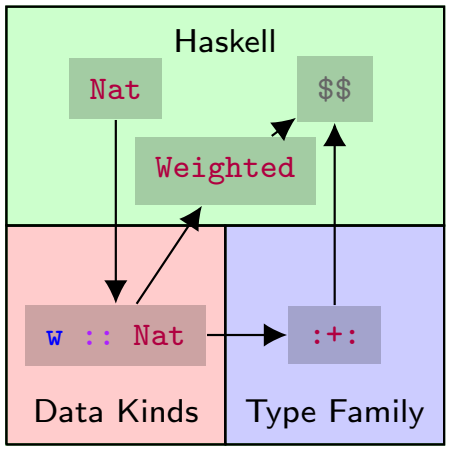
$\mathbb{P}$	How many features in ***D*** are compromised in ***I*** ?
$\mathbb{E}$	How many spans in ***I*** have inaccessible intermediate representations?
$\mathbb{A}$	How many spans in ***I*** are merely supporting annotations for a feature in ***D*** ?
$\mathbb{R}$	Is this source span in ***I*** present in ***D*** ?

PEAR metrics

$$
\begin{array}{c|l}
\mathbb{P} & \exists f \in \boldsymbol{D} \mid \forall (s,e) \in \boldsymbol{I}, \neg \mathrm{impl}\,(f,(s,e)) \\
\mathbb{E} & \exists (s,e) \in \boldsymbol{I} \mid \mathrm{hidden}(s,e) \\
\mathbb{A} & \exists (s,e) \in \boldsymbol{I}, f \in \boldsymbol{D} \mid \mathrm{impl}\,(f,(s,e)) \;\&\&\; \mathrm{annot}(s,e) \\
\mathbb{R} & \exists (s,e) \in \boldsymbol{I} \mid \forall f \in \boldsymbol{D}, \neg \mathrm{impl}(f,(s,e))
\end{array}
$$

Design	$\boldsymbol{D}$	set of features, $f \in \boldsymbol{D}$
Implementation	$\boldsymbol{I}$	set of spans, $(s,e) \in \boldsymbol{I}$
Source code span	(s,e)	start to end (characters)
$\mathrm{impl}(f,(s,e))$		Span (s,e) implements f
$\mathrm{annot}(s,e)$		Span (s,e) is an annotation
$\mathrm{hidden}(s,e)$		(s,e) representation is hidden

Walkthrough of computing $\mathbb{P}$



Element	$\mathbb{P}$	$\mathbb{E}$	$\mathbb{A}$	$\mathbb{R}$
Nat	1	·	·	·
Weighted	·	·	1	·
w :: Nat	·	·	·	1
$$	·	·	1	·
Nat ➤ w :: Nat	·	·	·	1
w :: Nat ➤ Weighted	·	·	·	1
w :: Nat ➤ :+:	·	·	·	1
$\Sigma \langle \mathbb{P}, \mathbb{E}, \mathbb{A}, \mathbb{R} \rangle$	=1	·	2	4

```haskell
data Nat = Z | S Nat
type Weighted (w :: Nat) a = a
```

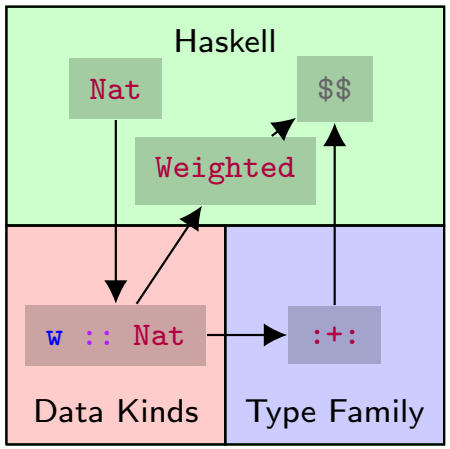
```haskell
type family
  (w1 :: Nat) :+: (w2 :: Nat) :: Nat
```

```haskell
type instance Z :+: m = m
type instance (S n) :+: m = S (n :+: m)
```

```haskell
($$) :: Weighted w1 (a -> b)
     -> Weighted w2 a
     -> Weighted (w1 :+: w2) b
($$) f a = f a
```

$\mathbb{P}$ = How many features in ***D*** are compromised in ***I*** ?

Walkthrough of computing $\mathbb{E}$



Element	$\mathbb{P}$	$\mathbb{E}$	$\mathbb{A}$	$\mathbb{R}$
`Nat`	1	·	·	·
`Weighted`	·	·	1	·
`w :: Nat`	·	·	·	1
`$$`	·	·	1	·
`Nat` → `w :: Nat`	·	·	·	1
`w :: Nat` → `Weighted`	·	·	·	1
`w :: Nat` → `:+:`	·	·	·	1
$\Sigma \langle \mathbb{P}, \mathbb{E}, \mathbb{A}, \mathbb{R} \rangle$	=1	·	2	4

```haskell
data Nat = Z | S Nat
type Weighted (w :: Nat) a = a
```

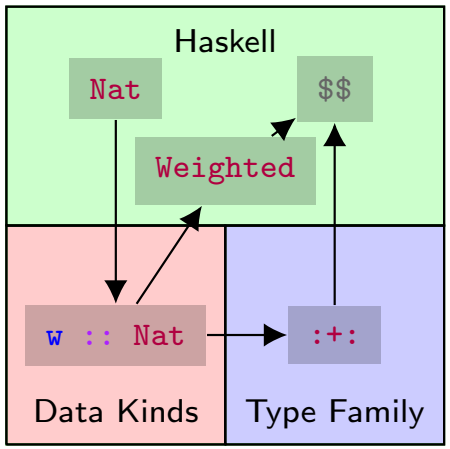
```haskell
type family
  (w1 :: Nat) :+: (w2 :: Nat) :: Nat
```

```haskell
type instance Z :+: m = m
type instance (S n) :+: m = S (n :+: m)
```

```haskell
($$) :: Weighted w1 (a -> b)
     -> Weighted w2 a
     -> Weighted (w1 :+: w2) b
($$) f a = f a
```

$\mathbb{E}$ = How many spans in ***I*** have inaccessible intermediate representations?

Walkthrough of computing $\mathbb{A}$



Element	$\mathbb{P}$	$\mathbb{E}$	$\mathbb{A}$	$\mathbb{R}$
`Nat`	1	·	·	·
`Weighted`	·	·	1	·
`w :: Nat`	·	·	·	1
`$$`	·	·	1	·
`Nat` ▶ `w :: Nat`	·	·	·	1
`w :: Nat` ▶ `Weighted`	·	·	·	1
`w :: Nat` ▶ `:+:`	·	·	·	1
$\Sigma \langle \mathbb{P}, \mathbb{E}, \mathbb{A}, \mathbb{R} \rangle$	=1	·	2	4

```
data Nat = Z | S Nat
type Weighted (w :: Nat) a = a
```

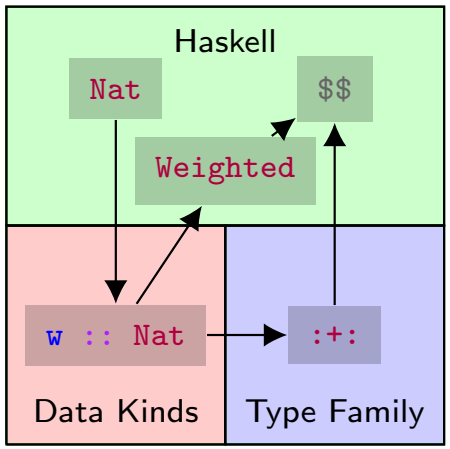
```
type family
  (w1 :: Nat) :+: (w2 :: Nat) :: Nat
```

```
type instance Z :+: m = m
type instance (S n) :+: m = S (n :+: m)
```

```
($$) :: Weighted w1 (a -> b)
     -> Weighted w2 a
     -> Weighted (w1 :+: w2) b
($$) f a = f a
```

$\mathbb{A}$ = How many spans in ***I*** are merely supporting annotations for a feature in ***D*** ?

Walkthrough of computing $\mathbb{R}$



Element	$\mathbb{P}$	$\mathbb{E}$	$\mathbb{A}$	$\mathbb{R}$
Nat	1	·	·	·
Weighted	·	·	1	·
w :: Nat	·	·	·	1
$$	·	·	1	·
Nat ▶ w :: Nat	·	·	·	1
w :: Nat ▶ Weighted	·	·	·	1
w :: Nat ▶ :+:	·	·	·	1
$\Sigma\ \langle \mathbb{P}, \mathbb{E}, \mathbb{A}, \mathbb{R} \rangle$	=1	·	2	4

```
data Nat = Z | S Nat
type Weighted (w :: Nat) a = a
```

```
type family
  (w1 :: Nat) :+: (w2 :: Nat) :: Nat
```

```
type instance Z :+: m = m
type instance (S n) :+: m = S (n :+: m)
```

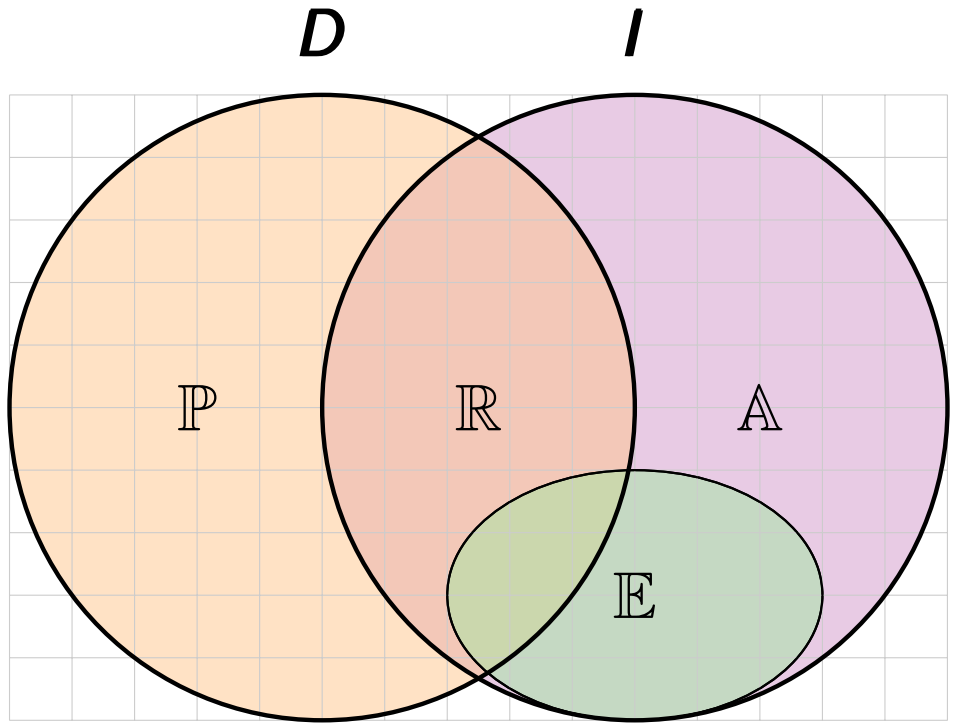
```
($$) :: Weighted w1 (a -> b)
     -> Weighted w2 a
     -> Weighted (w1 :+: w2) b
($$) f a = f a
```

$\mathbb{R}$ = Is this source span in ***I*** present in ***D*** ?

Future Work

- Markedly user study.
- Source span highlighting IDE support.
- Git integration.
- Extensible (multi-union) data types.

Conclusion



Web: `http://siriusly.cs.tufts.edu/`

Email: `karl@cs.tufts.edu`

Preprint: `cronburg.com/papers/markedly17.pdf`

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User Study

Programmers with functional programming experience will be tasked with implementing eDSLs over the course of a few months:

- Half of the programmers will be given a number of example Markedly maps.
- This half will be asked to recompute $\mathbb{PEAR}$ costs after substantial design and implementation progress.

Hypothesis: Markedly-enabled programmers will implement more design-preserving, extensible, adherent, and recognizable eDSLs.