Trees That Grow

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Chalmers University, December 2016

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Peyton Jones

Summer of Haskell 2016

Simon
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Summer of Haskell 2016

Jacques Carette

Richard Eisenberg

Alan Zimmerman

Niklas Broberg

Summer of Haskell 2016

Haskell Community

Edward Kmett

Ryan Trinkle

GHC

GHC

- Haskell
  Abstract Syntax Tree

GHC

- AST

GHC

- AST
- Parser

GHC

- AST
- Parser
- Printer

GHC

- AST
- Parser
- Printer
- ...

Haskell Suite
(Haskell-Src-Exts)

GHC

- AST
- Parser
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- ...

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(Haskell-Src-Exts)

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GHC

- AST
- Parser
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- ...

Template Haskell

Haskell Suite (Haskell-Src-Exts)

- AST
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- ...

GHC

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- ...

Template Haskell

- AST

Haskell Suite (Haskell-Src-Exts)

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Template Haskell

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GHC

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Template Haskell

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Haskell Suite (Haskell-Src-Exts)

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- Printer
- ...

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Template Haskell

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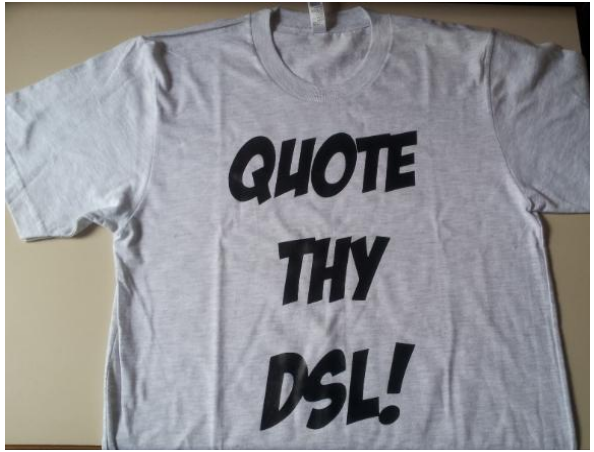
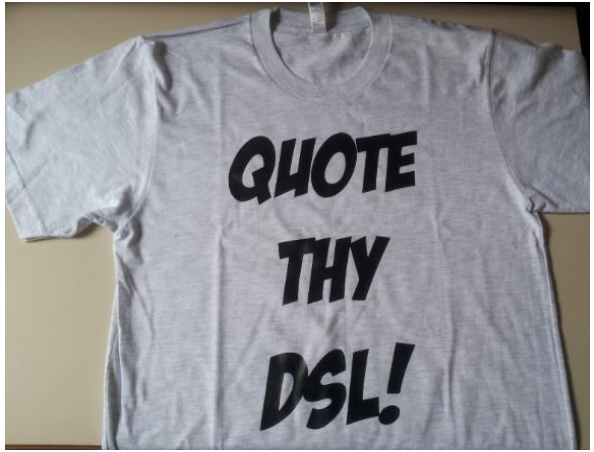
Quoted Domain-Specific Languages (QDSLs)

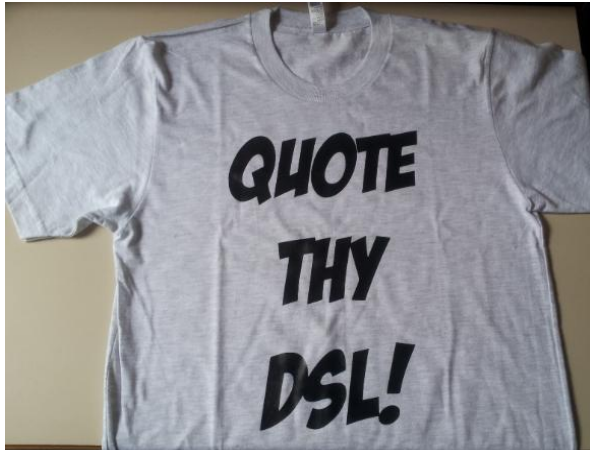


Quoted Domain-Specific Languages (QDSLs)



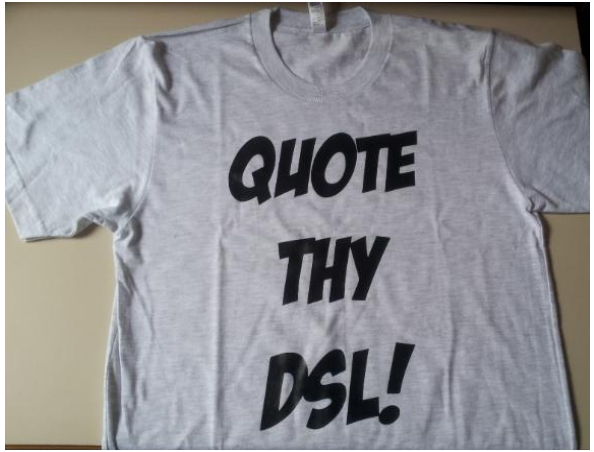
- AST

Quoted Domain-Specific Languages (QDSLs)



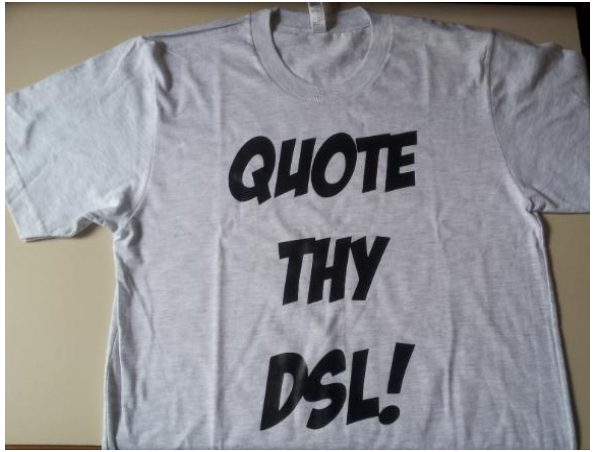
- AST
- Parser

Quoted Domain-Specific Languages (QDSLs)



- AST
- Parser
- Printer

Quoted Domain-Specific Languages (QDSLs)



- AST
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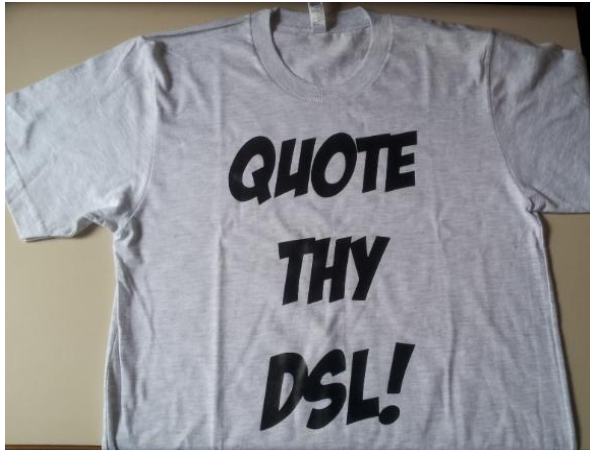
- Printer
- ...

Quoted Domain-Specific Languages (QDSLs)



- AST
- Parser
- Printer
- Type Inference Engine
- Desugaring Machinery
- ...


ENOUGH!

GHC

- AST

GHC

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GHC

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GHC

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- ...

GHC

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- Type Inference Engine
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Oskars
SURSTRÖMMING
KYLKONSERV SKALL FÖRVARAS KALLT
(+4° till +6°)

The Problem

Haskell Suite

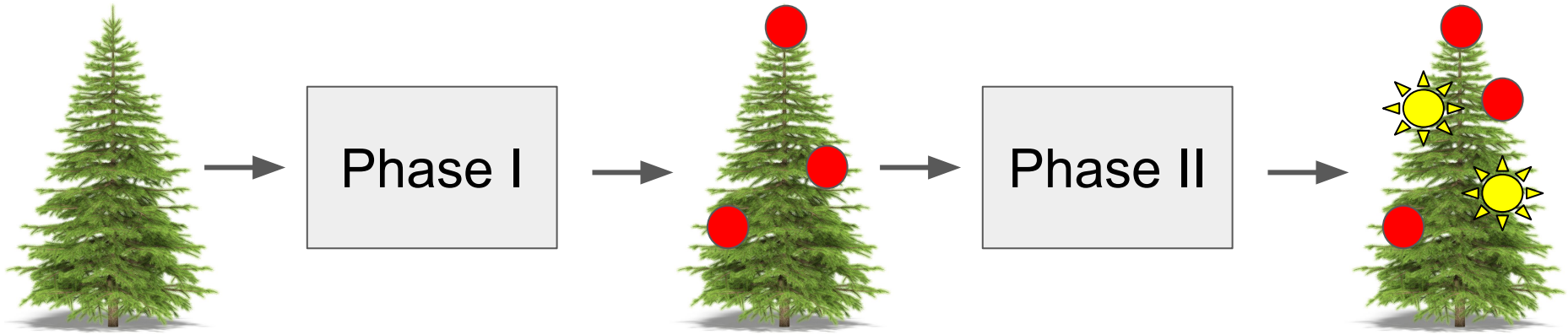
GHC

Template Haskell

Tree-Decoration Problem

V.S.

Compilers



Tree-Decoration Problem

```
data Exp id
  = Lit Integer
  | Var id
  | Ann (Exp id) Typ
  | Abs id       (Exp id)
  | App (Exp id) (Exp id)
```

Undecorated

```
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

Decorated

V.S.

Tree-Decoration Problem

```
data Exp id
  = Lit Integer
  | Var id
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  | Abs id       (Exp id)
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Undecorated

V.S.

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Decorated

Tree-Decoration Problem

```
data Exp id
  = Lit Integer
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```

Undecorated

+

```
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  = Lit     Integer
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  | App Typ (Exp id) (Exp id)
  | Val Val
```

Decorated

V.S.

Tree-Decoration Problem


```
data Exp id
  = Lit Integer
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Undecorated

V.S.

Decorated

Tree-Decoration Problem

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data Exp id
  = Lit Integer
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  | Abs id       (Exp id)
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```

Undecorated

+

+

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data Exp id
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  | Val Val
```

Decorated

V.S.

Common Practice

Fully Decorated

```
data Exp id
  = Lit    Integer
  | Var    id
  | Ann    (Exp id) Typ
  | Abs    id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

→ Phase I →

Fully Decorated

```
data Exp id
  = Lit    Integer
  | Var    id
  | Ann    (Exp id) Typ
  | Abs    id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

→ Phase II →

Fully Decorated

```
data Exp id
  = Lit    Integer
  | Var    id
  | Ann    (Exp id) Typ
  | Abs    id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

V.S.

Undecorated

```
data Exp id
  = Lit Integer
  | Var id
  | Ann (Exp id) Typ
  | Abs id       (Exp id)
  | App (Exp id) (Exp id)
```

→ Phase I →

Partly Decorated

```
data Exp id
  = Lit    Integer
  | Var    id
  | Ann    (Exp id) Typ
  | Abs    id       (Exp id)
  | App Typ (Exp id) (Exp id)
```

→ Phase II →

Fully Decorated

```
data Exp id
  = Lit    Integer
  | Var    id
  | Ann    (Exp id) Typ
  | Abs    id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

Common Practice

Fully Decorated

```
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

→ Phase I →

Fully Decorated

```
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

→ Phase II →

Fully Decorated

```
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

✗ Unnecessary Information & Dependencies

✓ No Duplication

Common Practice

✓ No Unnecessary Information & Dependencies

✗ Duplication

Undecorated

```
data Exp id
  = Lit Integer
  | Var id
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  | Abs id       (Exp id)
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```

→ Phase I →

Partly Decorated

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data Exp id
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→ Phase II →

Fully Decorated

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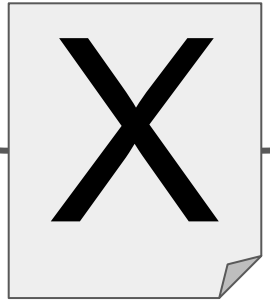
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

Our Approach:

(1) declare ASTs using ***extensible data types***
(2) define decorations as extensions

```haskell
data Exp id
  = Lit Integer
  | Var id
  | Ann (Exp id) Typ
  | Abs id       (Exp id)
  | App (Exp id) (Exp id)
```

```haskell
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```



Common Practice

✓ No Unnecessary Information & Dependencies

✗ Duplication

Undecorated

```
data Exp id
  = Lit Integer
  | Var id
  | Ann (Exp id) Typ
  | Abs id       (Exp id)
  | App (Exp id) (Exp id)
```

→ Phase I →

Partly Decorated

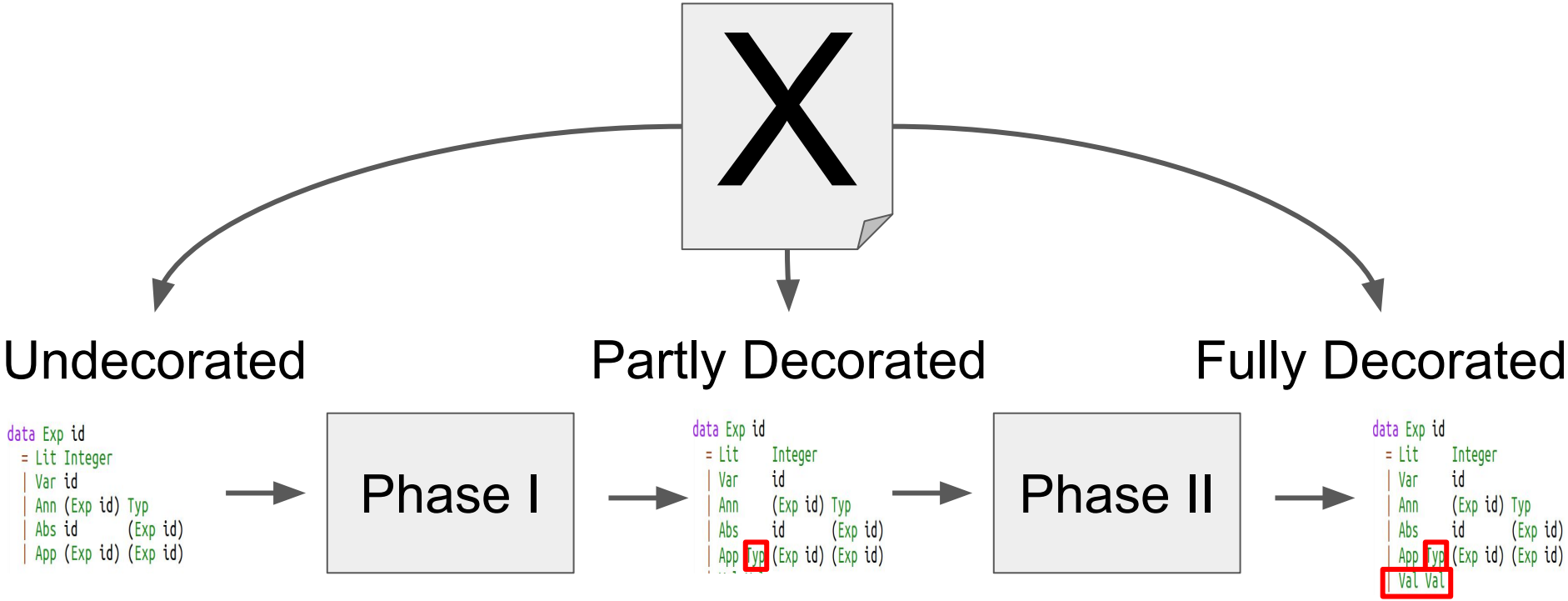
```
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
```

→ Phase II →

Fully Decorated

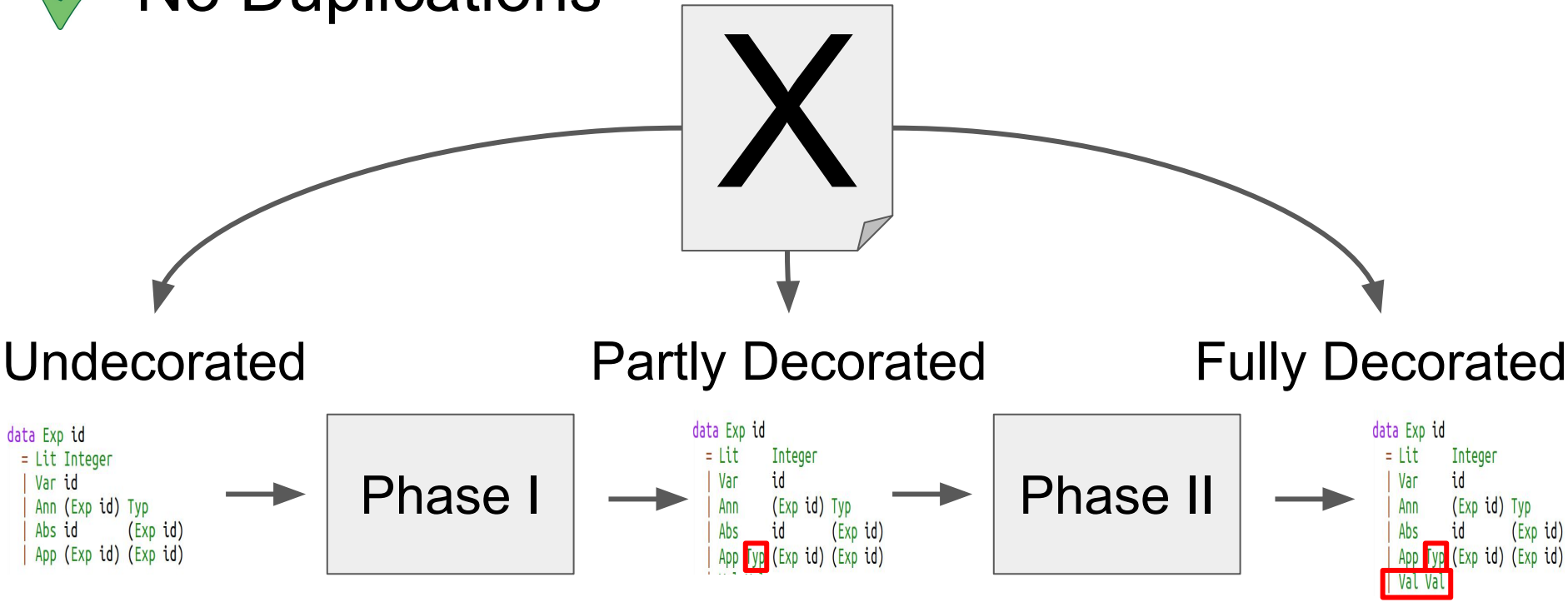
```
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

Our Approach



Our Approach

- ✓ No Unnecessary Information & Dependencies
- ✓ No Duplications



Key Challenge:

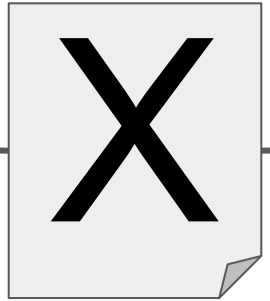
How do we declare eXtensible data types, where GHC does not support them off-the-shelf?

Key Idea:

Use same old parameterisation for extensibility!

```haskell
data Exp id
  = Lit Integer
  | Var id
  | Ann (Exp id) Typ
  | Abs id       (Exp id)
  | App (Exp id) (Exp id)
```

```haskell
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```



```
data Exp id
  = Lit Integer
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  | Abs id       (Exp id)
  | App (Exp id) (Exp id)
```

```
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

```
data ExpX   id
  = LitX                Integer
  | VarX                id
  | AnnX                (ExpX   id) Typ
  | AbsX                id          (ExpX   id)
  | AppX                (ExpX   id) (ExpX   id)
  | NewX
```

```
data Exp id
  = Lit Integer
  | Var id
  | Ann (Exp id) Typ
  | Abs id       (Exp id)
  | App (Exp id) (Exp id)
```

```
data ExpX   id
  = LitX  ∅   Integer
  | VarX  ∅   id
  | AnnX  ∅   (ExpX   id) Typ
  | AbsX  ∅   id          (ExpX   id)
  | AppX  ∅   (ExpX   id) (ExpX   id)
  | NewX  ∅*
```

```
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

```
data ExpX   id
  = LitX  ∅   Integer
  | VarX  ∅   id
  | AnnX  ∅   (ExpX   id) Typ
  | AbsX  ∅   id          (ExpX   id)
  | AppX  Typ (ExpX   id) (ExpX   id)
  | NewX  Val
```

Our Encoding

```
data Exp id
  = Lit Integer
  | Var id
  | Ann (Exp id) Typ
  | Abs id       (Exp id)
  | App (Exp id) (Exp id)
```

```
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

```
data ExpX   id
  = LitX                Integer
  | VarX                id
  | AnnX                (ExpX   id) Typ
  | AbsX                id          (ExpX   id)
  | AppX                (ExpX   id) (ExpX   id)
  | NewX
```

```
data Exp id
  = Lit Integer
  | Var id
  | Ann (Exp id) Typ
  | Abs id       (Exp id)
  | App (Exp id) (Exp id)
```

```
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

```
data ExpX x id
  = LitX (XLit x id) Integer
  | VarX (XVar x id) id
  | AnnX (XAnn x id) (ExpX x id) Typ
  | AbsX (XAbs x id) id          (ExpX x id)
  | AppX (XApp x id) (ExpX x id) (ExpX x id)
  | NewX (XNew x id)
```

```haskell
data Exp id
  = Lit Integer
  | Var id
  | Ann (Exp id) Typ
  | Abs id       (Exp id)
  | App (Exp id) (Exp id)
```

```haskell
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

```haskell
data ExpX x id
  = LitX (XLit x id) Integer
  | VarX (XVar x id) id
  | AnnX (XAnn x id) (ExpX x id) Typ
  | AbsX (XAbs x id) id          (ExpX x id)
  | AppX (XApp x id) (ExpX x id) (ExpX x id)
  | NewX (XNew x id)
```

```
data Exp id
  = Lit Integer
  | Var id
  | Ann (Exp id) Typ
  | Abs id       (Exp id)
  | App (Exp id) (Exp id)
```

```
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

```
data ExpX x id
  = LitX (XLit x id) Integer
  | VarX (XVar x id) id
  | AnnX (XAnn x id) (ExpX x id) Typ
  | AbsX (XAbs x id) id          (ExpX x id)
  | AppX (XApp x id) (ExpX x id) (ExpX x id)
  | NewX (XNew x id)
```

```haskell
data Exp id
  = Lit Integer
  | Var id
  | Ann (Exp id) Typ
  | Abs id       (Exp id)
  | App (Exp id) (Exp id)
```

```haskell
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

```haskell
data ExpX x id
  = LitX (XLit x id) Integer
  | VarX (XVar x id) id
  | AnnX (XAnn x id) (ExpX x id) Typ
  | AbsX (XAbs x id) id          (ExpX x id)
  | AppX (XApp x id) (ExpX x id) (ExpX x id)
  | NewX (XNew x id)
```

```haskell
data Exp id
  = Lit Integer
  | Var id
  | Ann (Exp id) Typ
  | Abs id       (Exp id)
  | App (Exp id) (Exp id)
```

```haskell
data Exp id
  = Lit     Integer
  | Var     id
  | Ann     (Exp id) Typ
  | Abs     id       (Exp id)
  | App Typ (Exp id) (Exp id)
  | Val Val
```

```haskell
data ExpX x id
  = LitX (XLit x id) Integer
  | VarX (XVar x id) id
  | AnnX (XAnn x id) (ExpX x id) Typ
  | AbsX (XAbs x id) id          (ExpX x id)
  | AppX (XApp x id) (ExpX x id) (ExpX x id)
  | NewX (XNew x id)
```

Demo

Extensions? I’ve heard that before!

- Nominal vs Structural
- Syntactic Completeness:
  rows **and** columns (and …)
- Within Haskell **now**
- Generic programming is a plus,
  not a must

Current Status

- Extensible HsSyn AST
- Liberated Parser from GHC
- Automation Using Template Haskell
- Syntax

Next Steps

- Performance Tests
- Splitting GHC into packages
- Replacing TH AST
- Direct Reflection in TH
- Extensible data types as language features