Avoiding quadratic GHC core code size

Introducing the `large-records` library

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Work done on behalf of Juspay.

Well-Typed

The Haskell Consultants

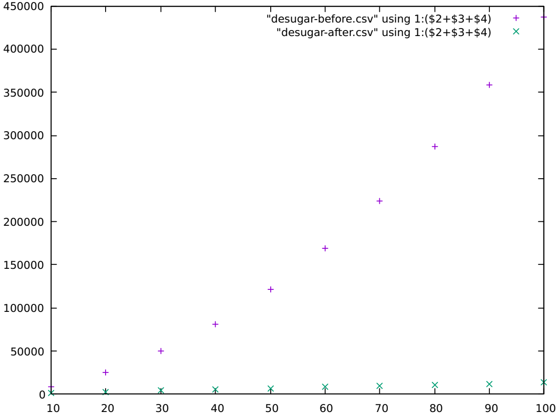
Motivation

```
{-# OPTIONS_GHC -fplugin=RecordDotPreprocessor #-}

module Before where

-- ..

data R = MkR {
      field1 :: T 1
    , field2 :: T 2
      -- ...
    , fieldN :: T N
    }
  deriving (Show, Eq)

deriveGeneric ''R -- SOP generics

instance ToJSON R where
  toJSON = gtoJSON defaultJsonOptions
```

Motivation

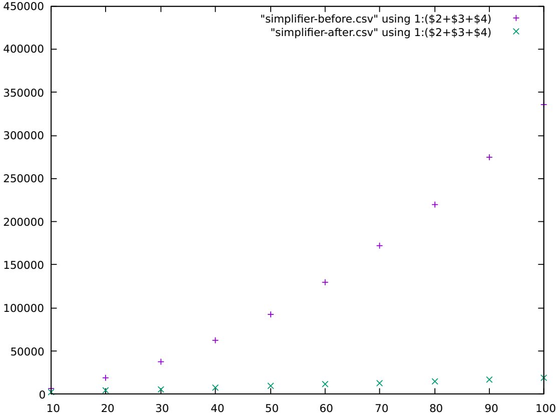
```
module After where

-- ..

largeRecord defaultLazyOptions [d|
  data R = MkR {
       field1 :: T 1
     , field2 :: T 2
       -- ...
     , fieldN :: T N
     }
   deriving (Show, Eq)
 |]

instance ToJSON R where
  toJSON = gtoJSON
```

Motivation



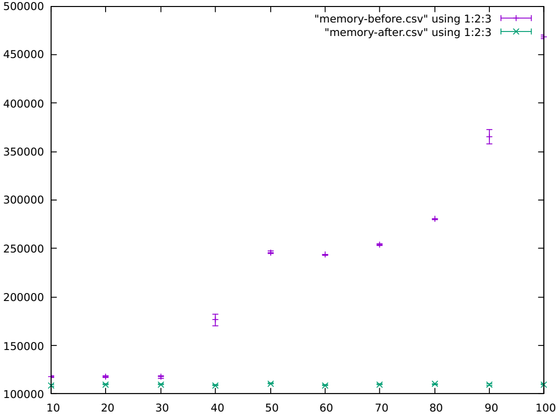
AST size (sum of terms/types/coercions) versus number of record fields, after desugaring.

Motivation



AST size (sum of terms/types/coercions) versus number of record fields, after the simplifier.

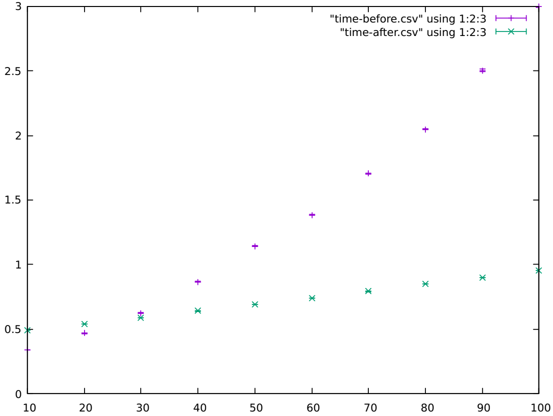
Motivation



OS reported maximum resident set size in KB versus number of record fields.
Mean and standard error over 100 compilations (no linking), normalized to a baseline of an empty module.

Well-Typed

Motivation



OS reported elapsed real time (wall clock) in seconds versus number of record fields.
Mean and standard error over 100 compilations (no linking), normalized to a baseline of an empty module.

Sources of quadratic core size

- No way to access/update a record without mentioning every field of the record
- No way to introduce and control sharing at the type level

Sources of quadratic core size: Records

```
data R = MkR {
    f00 :: T 00
  , f01 :: T 01
  , f02 :: T 02
  -- .. lots more ..
  , f98 :: T 98
  , f99 :: T 99
  }
```

Sources of quadratic core size: Records

```
data R = MkR {
    f00 :: T 00
  , f01 :: T 01
  , f02 :: T 02
  -- .. lots more ..
  , f98 :: T 98
  , f99 :: T 99
  }

f00 :: R -> T 0
f00 = \(r :: R) ->
    case r of
      MkR x00 x01 x02 x03 x04 x05 x06 x07 x08 x09
          x10 x11 x12 x13 x14 x15 x16 x17 x18 x19
          -- .. lots more ..
          x90 x91 x92 x93 x94 x95 x96 x97 x98 x99 ->
        x00
```

Sources of quadratic core size: Records

```
instance HasField ”f00” R (T 00) where
  hasField r = (\x -> r { f00 = x }, f00 r)
```

Sources of quadratic core size: Records

```
instance HasField ”f00” R (T 00) where
  hasField r = (\x -> r { f00 = x }, f00 r)
```

```
hasField_f00 :: R -> (T 0 -> R, T 0)
hasField_f00 r = (
      \new -> case r of
        MkR x00 x01 x02 x03 x04 x05 x06 x07 x08 x09
            x10 x11 x12 x13 x14 x15 x16 x17 x18 x19
            -- .. lots more ..
            x90 x91 x92 x93 x94 x95 x96 x97 x98 x99 ->
          MkR new x01 x02 x03 x04 x05 x06 x07 x08 x09
              x10 x11 x12 x13 x14 x15 x16 x17 x18 x19
              -- .. lots more ..
              x90 x91 x92 x93 x94 x95 x96 x97 x98 x99
    , case r of
        MkR x00 x01 x02 x03 x04 x05 x06 x07 x08 x09
            x10 x11 x12 x13 x14 x15 x16 x17 x18 x19
            -- .. lots more ..
            x90 x91 x92 x93 x94 x95 x96 x97 x98 x99 ->
          x00
```

Sources of quadratic core size: Records

```
class (
    c (T 00)
  , c (T 01)
  , c (T 02)
  -- .. lots more ..
  , c (T 98)
  , c (T 99)
  ) => Constraints_R c
```

Sources of quadratic core size: Records

```
class (
    c (T 00)
  , c (T 01)
  , c (T 02)
  -- .. lots more ..
  , c (T 98)
  , c (T 99)
  ) => Constraints_R c
```

```
$p1Constraints_R :: Constraints_R c => c (T 0)
$p1Constraints_R = \dict ->
    case dict of
      Constraints_R d00 d01 d02 d03 d04 d05 d06 d07 d08 d09
                    d10 d11 d12 d13 d14 d15 d16 d17 d18 d19
                    -- .. lots more ..
                    d90 d91 d92 d93 d94 d95 d96 d97 d98 d99 ->
        d00
```

Sources of quadratic core size: Type arguments

```
zipMyRecordWith ::
     Applicative f
  => (forall n. T n -> T n -> f (T n))
  -> R -> R -> f R
zipMyRecordWith f r r' =
        pure MkR
    <*> f (f00 r) (f00 r')
    <*> f (f01 r) (f01 r')
    <*> f (f02 r) (f02 r')
    -- .. lots more ..
    <*> f (f98 r) (f98 r')
    <*> f (f99 r) (f99 r')
```

Sources of quadratic core size: Type arguments

```
zipMyRecordWith ::
     Applicative f
  => (forall n. T n -> T n -> f (T n))
  -> R -> R -> f R
zipMyRecordWith f r r' =
        pure MkR
    <*> @(T 00) @(T 01 -> T 02 -> T 03 -> .. -> T 99 -> R) f (f00 r) (f00 r')
    <*> @(T 01) @(        T 02 -> T 03 -> .. -> T 99 -> R) f (f01 r) (f01 r')
    <*> @(T 02) @(                T 03 -> .. -> T 99 -> R) f (f02 r) (f02 r')
    -- .. lots more ..
    <*> @(T 98) @(                              T 99 -> R) f (f98 r) (f98 r')
    <*> @(T 99) @(                                      R) f (f99 r) (f99 r')
```

Well-Typed

Sources of quadratic core size: Type arguments

```
data NP :: (k -> Type) -> [k] -> Type where
  Nil  :: forall f.                        NP f '[]
  (:*) :: forall f x xs. f x -> NP f xs -> NP f (x ': xs)
```

Sources of quadratic core size: Type arguments

```
data NP :: (k -> Type) -> [k] -> Type where
  Nil  :: forall f.                        NP f '[]
  (:*) :: forall f x xs. f x -> NP f xs -> NP f (x ': xs)
```

```
npFromR :: R -> NP T IndicesR
npFromR MkR{..} = (
       f00 :* f01 :* f02 :* f03 :* f04 :* f05 :* f06 :* f07 :* f08 :* f09
    :* f10 :* f11 :* f12 :* f13 :* f14 :* f15 :* f16 :* f17 :* f18 :* f19
    -- .. lots more ..
    :* f90 :* f91 :* f92 :* f93 :* f94 :* f95 :* f96 :* f97 :* f98 :* f99
    :* Nil
    )
```

Sources of quadratic core size: Type arguments

```
npFromR MkR{..} =
    (:*) @00 @'[1, 2, .., 98, 99] f00 (
    (:*) @01 @'[   2, .., 98, 99] f01 (
    (:*) @02 @'[      .., 98, 99] f02 (
    -- .. lots more ..
    (:*) @98 @'[              99] f98 (
    (:*) @99 @'[                ] f99 (
    Nil )))))
```

Sources of quadratic core size: Type arguments

```
data SList :: [k] -> Type where
  SNil  :: SList '[]
  SCons :: SList xs -> SList (x ': xs)

class SListI (xs :: [k]) where
  sList :: SList xs

instance SListI '[] where
  sList = SNil

instance SListI xs => SListI (x ': xs) where
  sList = SCons sList
```

Sources of quadratic core size: Type arguments

```
$dSListI_99 :: SList '[99]
$dSListI_98 :: SList '[98, 99]
$dSListI_97 :: SList '[97, 98, 99]
...

$dSListI_99 = SCons @99 @'[] ..
$dSListI_98 = SCons @98 @'[99] ..
$dSListI_97 = SCons @97 @'[98, 99] ..
...
```

Sources of quadratic core size: Type arguments

```
type family InterpretTo d xs ys :: Constraint where
  InterpretTo _ '[]             '[]             = ()
  InterpretTo d ('(f, x) ': xs) ('(f, y) ': ys) = (
      Coercible x (Interpreted d y)
    , InterpretTo d xs ys
    )
```

Sources of quadratic core size: Type arguments

```
type family InterpretTo d xs ys :: Constraint where
  InterpretTo _ '[]             '[]             = ()
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      Coercible x (Interpreted d y)
    , InterpretTo d xs ys
    )

evidence1 = (,) @X @() ...
evidence2 = (,) @X @(X, ()) ...
evidence3 = (,) @X @(X, (X, ())) ...
```

large-records

```
largeRecord defaultLazyOptions [d|
    data R = MkR {
          field1 :: T 1
        , field2 :: T 2
          -- ...
        , fieldN :: T N
        }
      deriving (Show, Eq)
  |]
```

large-records

```
largeRecord defaultLazyOptions [d|
    data R = MkR {
          field1 :: T 1
        , field2 :: T 2
          -- ...
        , fieldN :: T N
        }
      deriving (Show, Eq)
  |]

newtype R = RFromVector {vectorFromR :: Vector Any}
```

large-records: Records

```
unsafeGetIndexR :: Int -> R -> x
unsafeGetIndexR n (RFromVector r) =
    unsafeCoerce $ unsafeIndex r n

unsafeSetIndexR :: Int -> R -> x -> R
unsafeSetIndexR n r x = RFromVector $
    unsafeUpd (vectorFromR r) [(n, unsafeCoerce x)]
```

large-records: Records

```
unsafeGetIndexR :: Int -> R -> x
unsafeGetIndexR n (RFromVector r) =
    unsafeCoerce $ unsafeIndex r n

unsafeSetIndexR :: Int -> R -> x -> R
unsafeSetIndexR n r x = RFromVector $
    unsafeUpd (vectorFromR r) [(n, unsafeCoerce x)]

f00 :: R -> T 0
f00 = unsafeGetIndexR 0

instance HasField ”f00” R (T 0) where
  hasField r = ( unsafeSetIndexR 0 r
               , unsafeGetIndexR 0 r
               )
```

large-records: Records

```
unsafeGetIndexR :: Int -> R -> x
unsafeGetIndexR n (RFromVector r) =
    unsafeCoerce $ unsafeIndex r n

unsafeSetIndexR :: Int -> R -> x -> R
unsafeSetIndexR n r x = RFromVector $
    unsafeUpd (vectorFromR r) [(n, unsafeCoerce x)]

f00 :: R -> T 0
f00 = unsafeGetIndexR 0

instance HasField "f00" R (T 0) where
  hasField r = ( unsafeSetIndexR 0 r
               , unsafeGetIndexR 0 r
               )
```

(Pattern synonym awaiting NoFieldSelectors, currently using quasi-quoter.)

large-records: Dictionaries

```
newtype Rep f a = Rep (Vector (f Any))

class Constraints_R c where
  dictConstraints_R :: Proxy c -> Rep (Dict c) R

instance (c (T 0), c (T 1), c (T 2) {- .. -})
         ) => Constraints_R c where
  dictConstraints_R p = Rep $ fromList [
        unsafeCoerce (dictFor p) (Proxy @(T 0))
      , unsafeCoerce (dictFor p) (Proxy @(T 1))
      -- .. lots more ..
      , unsafeCoerce (dictFor p) (Proxy @(T 99))
      ]
```

large-records: Dictionaries

```
newtype Rep f a = Rep (Vector (f Any))

class Constraints_R c where
  dictConstraints_R :: Proxy c -> Rep (Dict c) R

instance (c (T 0), c (T 1), c (T 2) {- .. -})
         ) => Constraints_R c where
  dictConstraints_R p = Rep $ fromList [
        unsafeCoerce (dictFor p) (Proxy @(T 0))
      , unsafeCoerce (dictFor p) (Proxy @(T 1))
      -- .. lots more ..
      , unsafeCoerce (dictFor p) (Proxy @(T 99))
      ]
```

Note: the *a* in `Rep f a` is phantom; we are avoiding type-level lists nearly everywhere.

large-records: Transforms

```
normalize1 :: forall d f x.
     HasNormalForm (d f) (x f) (x Uninterpreted)
  => Proxy d
  -> Rep I                  (x f)
  -> Rep (Interpret (d f)) (x Uninterpreted)
normalize1 _ = unsafeCoerce
```

large-records: Transforms

```
normalize1 :: forall d f x.
     HasNormalForm (d f) (x f) (x Uninterpreted)
  => Proxy d
  -> Rep I                  (x f)
  -> Rep (Interpret (d f)) (x Uninterpreted)
normalize1 _ = unsafeCoerce

type HasNormalForm d x y =
  InterpretTo d (MetadataOf x) (MetadataOf y)

type family InterpretTo d xs ys :: Constraint where
  InterpretTo _ '[]             '[]             = ()
  InterpretTo d ('(f, x) ': xs) ('(f, y) ': ys) = (
      Coercible x (Interpreted d y)
    , InterpretTo d xs ys
    )
```

large-records: Transforms

```
type family InterpretTo d xs ys :: Constraint where
  InterpretTo _ ’[]             ’[]             = ()
  InterpretTo d (’(f, x) ’: xs) (’(f, y) ’: ys) =
    IfEqual x (Interpreted d y)
      (InterpretTo d xs ys)

type family IfEqual x y (r :: k) :: k where
  IfEqual actual actual k = k
```

Conclusions

- Avoiding quadratic core code size surprisingly difficult
- `large-records` provides support for records with accessors, lenses and generics that is guaranteed to be linear, but at the cost of (internal) type safety.
- No support for unboxed fields.
- Ideally would solve this in ghc itself
  - Need a way to access and update records/dictionaries
  - Need a way to introduce (and control) sharing at the type level.
- `large-records` generics is based on *True Sums of Products*, Edsko de Vries and Andres Löh, WGP 2014.
- Related work: *Scrap Your Type Applications*, Barry Jay and Simon Peyton Jones, MPC 2008