Building an elaborator using extensible constraints

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June 12th, 2023

🐥🐍

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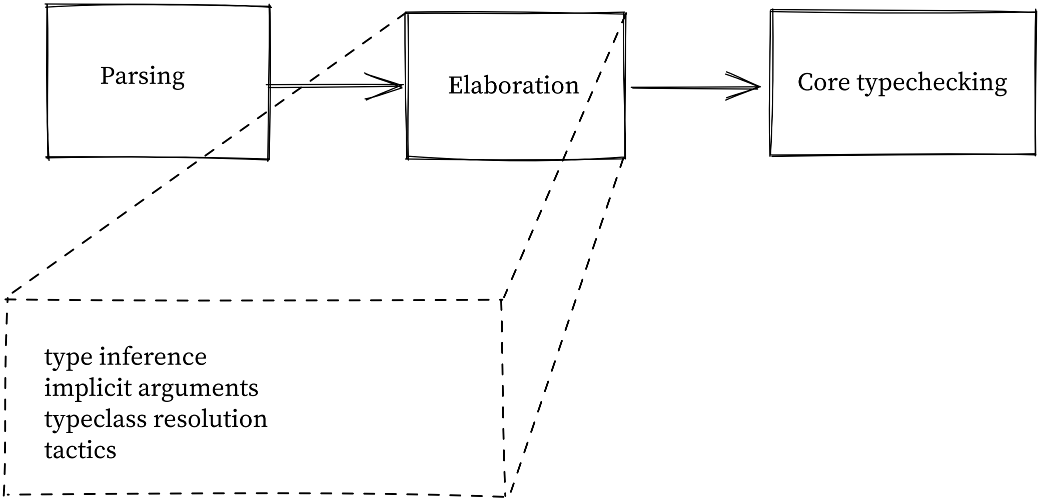
Then we'll fix the core language but make the elaborator modular!

Elaborator under attack



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- unifier
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- Which parts can we make more modular?
- Can we mediate the interactions?

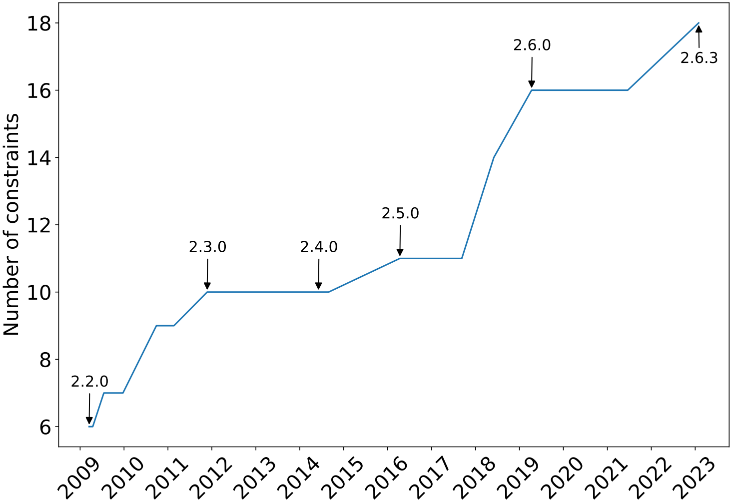
Constraints in Haskell

```
W = empty
  | W1, W2 # conjunction
  | C t1 .. tn # type class constraint
  | t1 ~ t2 # equality constraint
  | ∀a1..an. W1 => W2 # implication constraint
```

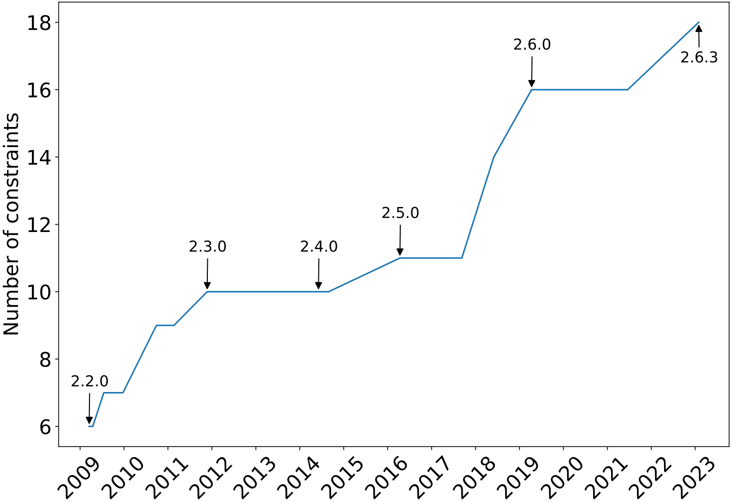
Constraints in Agda

```
W = ValueCmp t1 t2 # eq comparison
  | ElimCmp typ t1 e1 e2 # elim comparison
  | SortCmp s1 s2 # (type) sort comparisons
  | LevelCmp l1 l2 # (type) level comparisons
  | UnBlock m1 # Meta created for a term blocked
  | FindInstance m1 c # type class instances
  | CheckFunDef ... # couldn't check a function def because
  | UnquoteTactic ...
  ... # plenty more
```

Constraints in Agda



Constraints in Agda



[1]

[1]xkcd.com/605/

Our solution

Our design

- Typechecker traverses the syntax and generates constraints
- The constraint datatype open (as in Data types à la carte [Swi08])
- Solvers are provided by the plug-ins

Mantra: constraints are async function calls, metavariables are “promises”.

Our constraints

- aiming for something in-between in the core 🐍 + your 🐥 extensions

```
CoreW = EqualityComparison t1 t2 ty m
      | BlockedOnMeta m tc
      | FillInMeta m ty
      ...
```

- both we 🐍 and you 🐥 supply the solvers

Example: type classes

Type classes: what's in the base 🐍

```haskell
inferType (App t1 t2) = do
  (et1, Pi tyA tyB) <- inferType t1
  et2 <- checkType t2 tyA
  return (App et1 et2, subst tyB et2)

checkType (Implicit) ty = do
  m <- createMetaTerm
  raiseConstraint $ FillInTheMeta m ty
  return m
```

Type classes: what does the user write

```
plus : {A : Type} -> {{PlusOperation A}}
     -> (a : A) -> (b : A) -> A

instance PlusNat : PlusOperation Nat where
  plus = plusNat

two = plus 1 1
```

Type classes: desugaring user input

```
plus : (impA : Implicit Type)
    -> TypeClass PlusOperation (deImp impA)
    -> (a : deImp impA) -> (b :  deImp impA)
    ->  deImp impA

PlusNat = Instance {
    class = PlusOperation Nat,
    body = {plus = plusNat}}

two = plus _ _ 1 1
```

Type classes: elaborating the program

1. Create the metas:

   ```
   two = plus ?_1 ?_2 1 1
   ```

2. Raise the constraints:

   ```
   C1: FillInTheTerm ?_1 (Implicit Type)
   C2: FillInTheTerm ?_2 (TypeClass PlusOperation (deImp ?_1))
   C3: EqualityConstraint ?_1 Nat Type
   C4: EqualityConstraint ?_1 Nat Type
   ```

Type classes: writing the plugin 🐥

```
tcHandler :: Constraint c -> MonadElab Bool

tcSolver :: Constraint c -> MonadElab Bool

tcSymbol = "type class instance search"

tc = Plugin { handler = tcHandler
            , solver  = tcSolver
            , symbol  = tcSymbol
            , pre = []
            , suc = []
            }
```

Type classes: writing the plugin 🐥

```haskell
tcHandler :: Constraint c -> MonadElab Bool

tcHandler constr = do
  f <- match @FillInTheTerm constr
  case f of
    Just (FillInTheTerm _ (App (TCon "TypeClass") ...)) ->
      return True
    _ ->
      return False
```

Type classes: writing the plugin 🐥

```
tcHandler :: (FillInTheTerm :<: c)
          => Constraint c -> MonadElab Bool

tcHandler constr = do
  f <- match @FillInTheTerm constr
  case f of
    Just (FillInTheTerm _ (App (TCon "TypeClass") ...)) ->
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```

Implementation

What is this language: base 🐍

- DT language with Pi, Sigma types
- inductive types with indeces
- case-constructs for elimination

What is this language: additions 🐥

- implicit arguments with placeholder terms
- type classes
- tactic arguments?
- subtyping by coercion?
- row types?

Conclusions and questions

Conclusions and questions

github.com/liesnikov/extensible-elaborator

- there's a simple unifier implemented
- working on implicit arguments

Backup slides

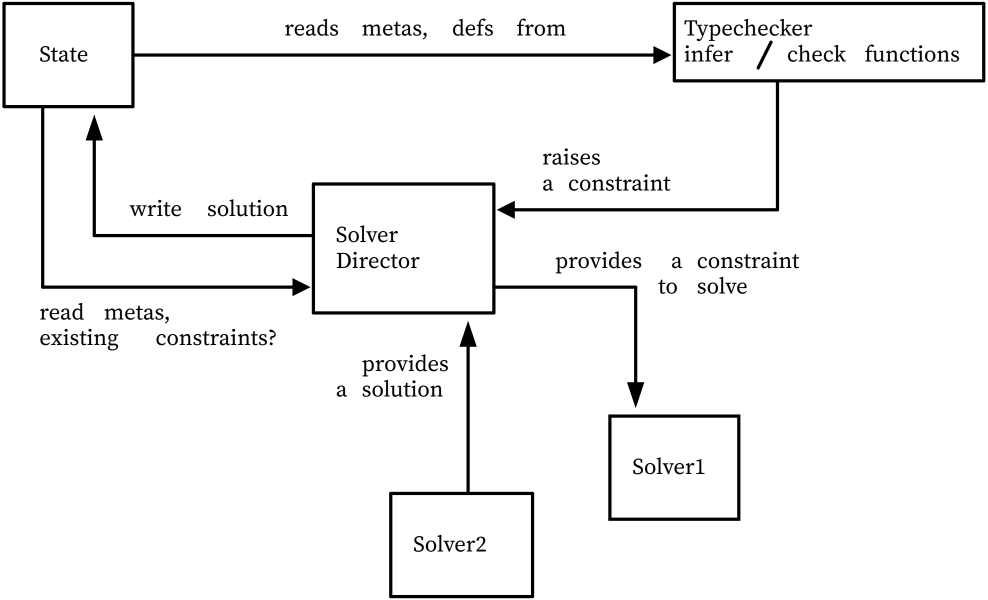
Open questions

- How far can you push these kinds of extensions? i.e. can you model erasure inference?
- What if we allow plugins to have a custom store in the monad?
- Can we make the solver parallel?

Prior work

- Haskell
  - plugins
  - hooks
  - was supposed to get dependent types
- Coq
  - plugins don't really have an interface
  - not restricted in any way, if you go into ml space
  - very confusing
- Lean
  - uses macros to redefine symbols
  - uses reflection and typechecking monads to define custom elaboration procedures
- TypOS
  - you have to buy into a whole new discipline
  - we hope to keep things a bit more conventional engineering-wise

Old architecture diagram



How do you make sure the solvers run in the right order?

specify a (pre-) order in which the solvers should run i.e. type classes run after name disambiguation

What does a plugin look like?

```
type PluginId = ...

type Solver cs = forall m. (MonadSolver cs m) =>
                 (Constraint cs) ->
                 m Bool

data Plugin cs = Plugin {
  handler :: Handler cs,
  solver :: Solver cs,
  symbol :: PluginId,
  pre :: [PluginId],
  suc :: [PluginId]
}
```

Why (bother with splitting)

- at the moment the biggest “usual” solver is a conversion checker
- it typically ranges around 1.7kloc in Idris, Lean, Coq
- in Agda also results in a lot of intricacies in the codebase
- chains of nested calls with logic spread around `compareAs`/`compareTerm`/`compareAtom`
- the need to manually catch and handle constraints at times `catchConstraint`/`patternViolation`

Why (open it up)

- get a relatively compact core of the elaborator
- build features around it as “extensions” or “plugins”
- allow cheaper experiments with the language
- main inspirations: Haskell [Jon+07; GHC], Matita [Tas+12]

Bottom line: this is a design study

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