Coercion Quantification

(Extended Abstract)

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Dependent Haskell [3, 4, 7] has been desired in the community of Haskell programmers for a long time. However, compatibility with existing GHC features makes adding full-fledged dependent types into GHC very difficult. Thus, our goal of this project [1] is to make the core language of Haskell, known as System F_C [2, 5, 6, 8], dependently typed, as steps are taken towards dependent Haskell.

To this end, the first step we take is to embrace *homogeneous equality*, which means equality is between types of a same kind. Homogeneous equality simplifies meta-theory. More importantly, it enables us to prove the important lemma, *congruence*, for the dependently typed core. Adopting homogeneous equality is not straightforward. It requires us to make the type of primitive equality, ~#, homogeneous, and requires patches to the constraint solver.

This is a working-in-progress project. We are at the very beginning of the stage. As a small step towards our final goal, the focus of this talk is on *coercion quantification*. To understand the motivation, consider if we had homogeneous ~#, and in the source Haskell, we still want to provide programmers the ability to use heterogeneous equalities, then we define the heterogeneous equality, ~~, based on the homogeneous equality[1]:

```
data (~~) :: forall k1 k2. k1 -> k2 -> Constraint where
  MkHEq :: forall k1 k2 (a :: k1) (b :: k2).
    (k1 ~# k2) -> (a ~# b) -> a ~~ b
```

However this is definitely wrong because a ~# b is ill-kinded, as ~# is homogeneous! To correct it, we need to give the coercion a name, and use it to fix the kind:

```
data (~~) :: forall k1 k2. k1 -> k2 -> Constraint where
  MkHEq :: forall k1 k2 (a :: k1) (b :: k2).
    forall (co :: k1 ~# k2).  -- a name here...
      (a |> co ~# b) ->       -- and a cast here
      a ~~ b
```

Coercion quantification is interesting as:

[1]Note here *data* means a *dictionary*, the representation of a *type class* in core.

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1) For people working in core, the patch to core formalization is worth attention. Adding coercion quantification means now polymorphic quantifications (over both types and coercions) could have a coercion in their bindings. Refactor of those basic types has a significant impact to files in the compilation pipeline and introduces several subtleties involving binders, substitutions, representations of datatypes, etc.

2) For Haskell users, coercion quantification opens up new questions to the design space in *source* Haskell. For example, is the type of `fun` well-formed in source Haskell?

```
SameKind :: k -> k -> Constraint
fun :: forall k1 k2 (a:k1) (b:k2).
             (k1 ~ k2) -> SameKind a b
```

In core, we now have the ability to name the coercion `k1 ~ k2` and use it to cast `a`. But accepting the code in the source level requires the solver to be smart enough to generate a name and insert the cast. This requires non-trivial extension of the solver and we would want Haskell users to answer if this feature is ever desired in their development.

To sum up, in this talk, we would like to share the high-level story-line of the dependently typed core, our low-level progress in implementing coercion quantification, as well as the involving design space, and seek feedbacks from the broader community.

References

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