Printing Trees That Grow

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June 2022

1 Introduction

Trees That Grow?? is a programming idiom to define extensible data types, which particularly addresses the need for decorating abstract syntax trees with different additional information accross compiler stages. With this newfound extensibility, we are able to share one AST data type accross compiler stages and other AST clients — both of which need to define their own extensions to the datatype. This extensibility comes from using type-level functions in defining the data types, and having the user instance them with the needed extension.

As an example, here is the extensible definition of an abstract syntax tree (AST).

```
type Var = String
data Typ = Int
         | Fun Typ Typ

data Expr p = Lit (XLit p) Integer
            | Var (XVar p) Var
            | Ann (XAnn p) (Expr p) Typ
            | Abs (XAbs p) Var (Expr p)
            | App (XApp p) (Expr p) (Expr p)
            | XExpr !(XXExpr p) -- Constructor extension point

type family XLit p
type family XVar p
type family XAnn p
type family XAbs p
type family XApp p
type family XXExpr p
```

And an AST with no additional decorations could be extended from the above definition as

```
data UD
```

```
type instance XLit    UD = ()
type instance XVar    UD = ()
type instance XAnn    UD = ()
type instance XAbs    UD = ()
type instance XApp    UD = ()
type instance XXExpr UD = Void
```

A drawback of this extensible definition of a datatype is that few can be done without knowing the particular instance of the datatype's extension. This means the defined AST is, by itself, unusable.

One of the promises of extensible data types is the reduction of duplicated code, therefore, we might be tempted to define generic functions or type-class instances for it. In the original paper some solutions are provided

- ignore the extension points, although we no longer give the user the flexibility of an function or instance that takes into consideration the extension points they defined.
- or make use of higher order functions in the implementation, allowing for some custom usage of the extension points, but still restricted within the context of the generic implementation.

The second option, while more flexible, still isn't sufficient when faced with the need to define a radically different implementation for a particular constructor of the datatype, in which we might want to additionally make use of the defined extensions. We might also note that to define functions generic over the field extension points, a lot of higher order functions or dictionaries must be passed to the functions, and the type-class instance of an extension point is the same regardless of the constructor its found in.

We are then faced with the unattractive choice of either reducing duplicated code at the cost of flexibility, or of requiring a complete implementation of the function from any user needing that extra bit of flexibility.

This paper describes an idiom to define generic functions over the extensible abstract syntax tree which allow drop-in definitions from the user that take their extension instance into account.

2 Watering Trees That Grow

We would like to construct a clever way of having generic definitions of functions over an extensible data type, definitions which allow the extensible data type user to override particular parts of the implementation and delegate to the generic implementation of the function the non-overriden cases — allowing for a possible complete reimplementation of the instance if desired.

At first sight, a function that can default to some other implementation can simply be a function that takes as parameter a higher-order function which is the default implementation itself.

With a small tweak, the default implementation itself always calls the so called *override* function and pass it the actual default implementation as an argument.

For example, if we were to write a pretty printer for the above defined AST, which by default works regardless of the extension points, but that can be overriden on some or all constructors, we could have

```
override :: (Expr p -> String) -> Expr p -> String

pprDefault :: Expr p -> String
pprDefault = override $ \case
    Lit _ i -> show i
    Var _ s -> s
    Ann _ e t -> "(" <> printE e <> ") :: (" <> printT t <> ")"
    Abs _ v e -> "" <> v <> "." <> printE e
    App _ f v -> "(" <> printE f <> ") (" <> printE v <> ")"
    XExpr _ -> ""
```