Reflex Outside the Browser

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Queensland Functional Programming Lab

CSIRO's Data61

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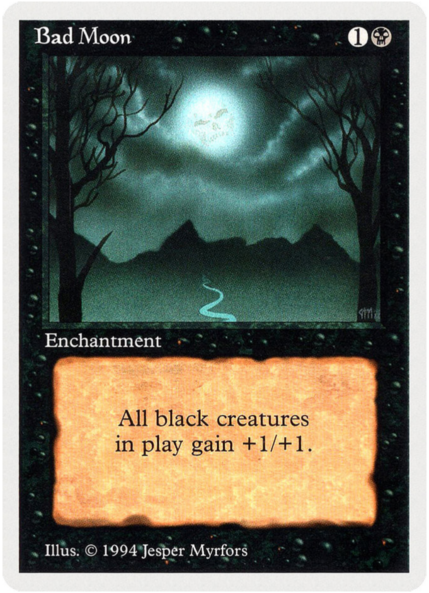
Thought Experiment: Implement a Card Game


Bad Moon
1
Enchantment
All black creatures in play gain +1/+1.
Illus. © 1994 Jesper Myrfors

What is Reflex?

- Functional Reactive Programming (FRP) is a solid theory for talking about time-varying values and instantaneous phenomena
- Reflex is an implementation of this theory*
- Primitives:
  - `Behavior a`: a time-varying a
  - `Event a`: instantaneous occurrences of a
  - `Dynamic a`: like `Behavior a`, but also signals its updates

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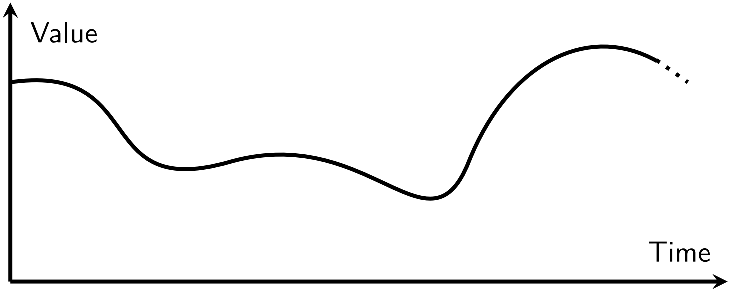

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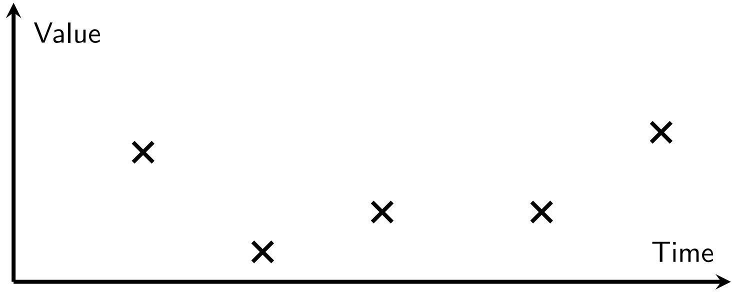

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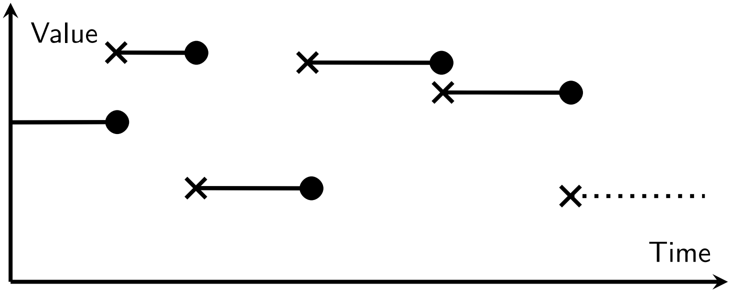

Typeclasses

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- `Event` has a `Functor` instance but isn't even `Applicative`!
    - but it is `Filterable` (from `witherable`)
    - and `Semialign` (from `these`/`semialign`)

```
class Functor f => Filterable f where
  mapMaybe :: (a -> Maybe b) -> f a -> f b
  catMaybes :: f (Maybe a) -> f a
  filter :: (a -> Bool) -> f a -> f a
```

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- `Event` has a `Functor` instance but isn't even `Applicative`!
    - but it is `Filterable` (from `witherable`)
    - and `Semialign` (from `these`/`semialign`)

```
data These a b = This a | That b | These a b

class Functor f => Semialign f where
  align :: f a -> f b -> f (These a b)
```

Laws!

- For `Filterable`:

```
mapMaybe (Just . f) = fmap f
mapMaybe f . mapMaybe g = mapMaybe (f <=< g)
```

- For `Semialign`:

```
-- (N.B.: join f = f x x):
join align = fmap (join These)
align (f <$> x) (g <$> y) = bimap f g <$> align x y
alignWith f a b = f <$> align a b align x (align y z)
  = fmap assoc (align (align x y) z)
```

- For `Foldable Semialigns`:

```
toList x
  = toListOf (folded . here) (align x y)
  = mapMaybe justHere (toList (align x y))
```

Challenges of Reflex

- Feels like a big jump:
  - Spectacular type signatures
  - Pigeonholed as frontend tech (GHCjs)
  - Reflex-platform (nix)

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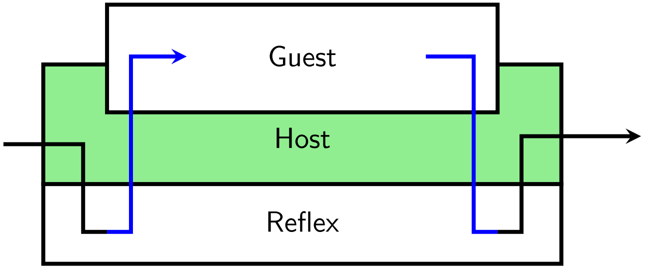
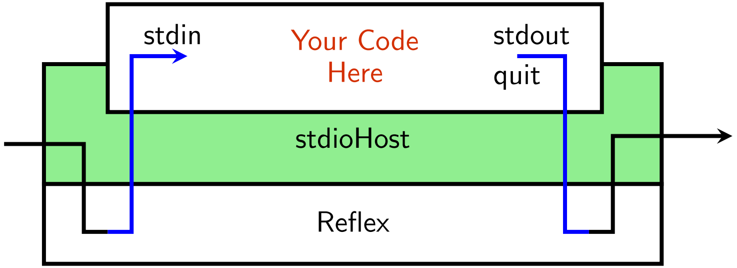
- Feels like a big jump:
  - Spectacular type signatures
  - Pigeonholed as frontend tech (GHCjs)
  - Reflex-platform (nix)
- For today:
  - Simplified type signatures:
    - Reflex: `Event t a`
    - These slides: `Event a`
  - Native binaries
  - Recent versions of Reflex are on Hackage

Hosts and Guests



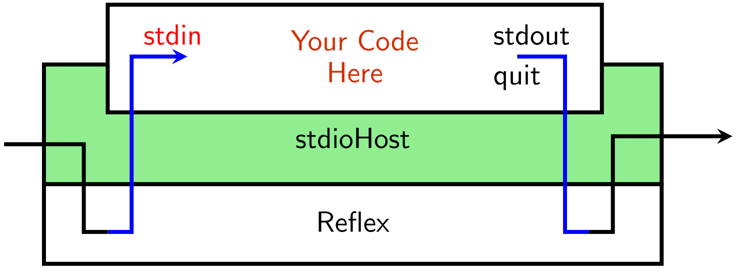
- Guests ask for features, classy MTL-style:
  - `(PostBuild m, TriggerEvent m) => ... -> m ()`
- This lets us switch out the FRP runtime
- Extend the runtime with `PostBuildT`, `TriggerEventT`, `PerformEventT`, ...

Example Host: String I/O



```
stdioHost
  :: (Event String -> m (Event String, Event ()))
  -> IO ()
```

Example Host: String I/O



```
stdioHost
  :: (Event String -> m (Event String, Event ()))
  --   ~~~~~~~~~~~~~ stdin
  -> IO ()
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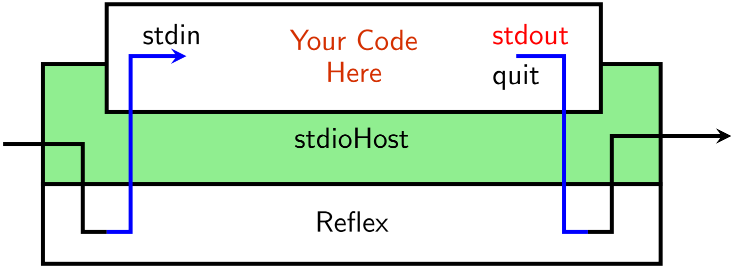
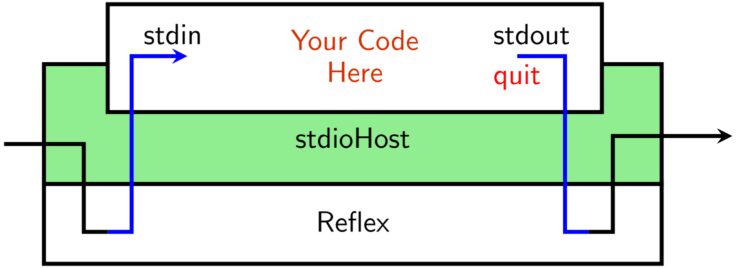


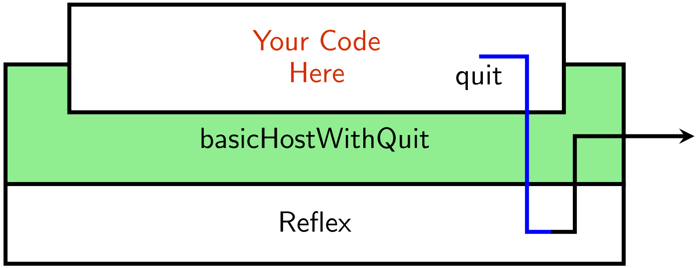
```
stdioHost
 :: (Event String -> m (Event String, Event ()))
 --                     ~~~~~~~~~~~~ stdout
 -> IO ()
```

Example Host: String I/O



```
stdioHost
  :: (Event String -> m (Event String, Event ()))
  --                                   ~~~~~~~~~ quit
  -> IO ()
```

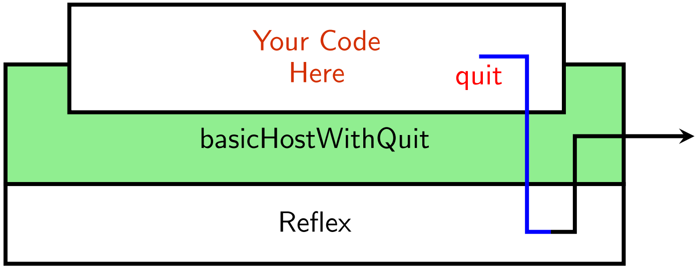
Basic Host



```
basicHostWithQuit :: m (Event ()) -> IO ()
```

- Provided by `reflex-basic-host`
- Run until the returned event fires
- You connect your guest to the outside world

Basic Host



```
basicHostWithQuit :: m (Event ()) -> IO ()
                  --    ~~~~~~~~~ quit
```

- Provided by `reflex-basic-host`
- Run until the returned event fires
- You connect your guest to the outside world

class PostBuild (Reflex.PostBuild.Class)

```
class PostBuild m where
  getPostBuild :: m (Event ())
```

- Morally: “Here’s an event that fires when the network is built”

class TriggerEvent (Reflex.TriggerEvent.Class)

```
class TriggerEvent m where
  -- And a couple of others
  newTriggerEvent :: m (Event a, a -> IO ())
```

- Morally: “`m` can create new events”
- Usually pass the trigger to another thread

class TriggerEvent (Reflex.TriggerEvent.Class)

```
class TriggerEvent m where
  -- And a couple of others
  newTriggerEvent :: m (Event a, a -> IO ())
                  --    ~~~~~~~ The event
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```
class TriggerEvent m where
  -- And a couple of others
  newTriggerEvent :: m (Event a, a -> IO ())
                  --             ~~~~~~~~~~~~ Its trigger
```

- Morally: “`m` can create new events”
- Usually pass the trigger to another thread

class PerformEvent (Reflex.PerformEvent.Class)

```
class PerformEvent m where
  type Performable m :: Type -> Type

  -- And a couple of others
  performEvent
    :: Event (Performable m a)
    -> m (Event a)
```

- Morally: “Perform each action as it happens, and fire off the results”
- `Performable m` is often `MonadIO`

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--~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Associated type

  -- And a couple of others
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```haskell
class PerformEvent m where
  type Performable m :: Type -> Type

  -- And a couple of others
  performEvent
    :: Event (Performable m a)
    --        ~~~~~~~~~~~~~~~~ Actions to perform
    -> m (Event a)
```

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- `Performable m` is often `MonadIO`

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```haskell
class PerformEvent m where
  type Performable m :: Type -> Type

  -- And a couple of others
  performEvent
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    --    ~~~~~~~ Results of actions
```

- Morally: “Perform each action as it happens, and fire off the results”
- `Performable m` is often `MonadIO`

Recreating stdio: Standard Output

```
performEvent_
  :: PerformEvent m
  => Event (Performable m ())
  -> m ()

stdout :: PerformEvent m => Event String -> m ()
stdout eStrings = performEvent_
  (liftIO . putStrLn <$> eStrings)
```

Recreating stdio: Standard Output

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  :: PerformEvent m
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stdout eStrings = performEvent_
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-- ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Event-of-actions
```

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--                       ~~~~~~~~ Event String
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  (liftIO . putStrLn <$> eStrings)
-- ~~~~~~~~~~~~~~~~~~~ MonadIO io => String -> io ()
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- After the network is built, create an event, and. . .
- . . .kick off a thread, which. . .
- . . .loops forever, feeding lines into the trigger

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```
performEventAsync
  :: (TriggerEvent m, PerformEvent m)
  => Event ((a -> IO ()) -> Performable m ())
  -> m (Event a)
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stdin :: (...) => m (Event String)
stdin = do
  ePostBuild <- getPostBuild
  let loop fire = void $ liftIO $ forkIO
        (forever $ getLine >>= fire)
  performEventAsync (loop <$ ePostBuild)
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--~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Perform on PostBuild
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--                   ~~~~~~~ Perform the loop function
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  let loop fire = void $ liftIO $ forkIO
                                   -- ~~~~~~ Fork worker thread
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     --                      ~~~~ Trigger: String -> IO ()
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Recompiling OpenGL Shaders: `fsnotify`

- Callback-oriented libraries work well with `TriggerEvent`
- `fsnotify` watches a directory for file changes and calls your callback when that happens
- We want an `Event (FSNotify.Event)`

```
watchDir
  :: WatchManager
  -> FilePath
  -> ActionPredicate
  -> Action
  -> IO StopListening
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```
newEventWithLazyTriggerWithOnComplete
  :: TriggerEvent m
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newEventWithLazyTriggerWithOnComplete
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  --        ~~~~~ On-complete callback
  -> m (Event a)
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newEventWithLazyTriggerWithOnComplete
  :: TriggerEvent m
  => ((a -> IO () -> IO ()) -> IO (IO ()))
  --                               ~~~~~ Teardown action
  -> m (Event a)
```

Recompiling OpenGL Shaders: `fsnotify`

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  :: TriggerEvent m
  => WatchManager
  -> FilePath
  -> m (Event FSNotify.Event)
watchDir manager dir
  = newEventWithLazyTriggerWithOnComplete $
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        manager
        dir
        (\_ -> True)
        (\fsEvent -> fire fsEvent (pure ()))
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      -- ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Action
```

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        dir
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        (\fsEvent -> fire fsEvent (pure ()))
      --             ~~~~ Reflex trigger:
      --                  FSNotify.Event -> IO () -> IO ()
```

Recompiling OpenGL Shaders: `fsnotify`

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  :: TriggerEvent m
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watchDir manager dir
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      \fire -> FSNotify.watchDir
        manager
        dir
        (\_ -> True)
        (\fsEvent -> fire fsEvent (pure ()))
      --   On complete: do nothing ~~~~~~~
```
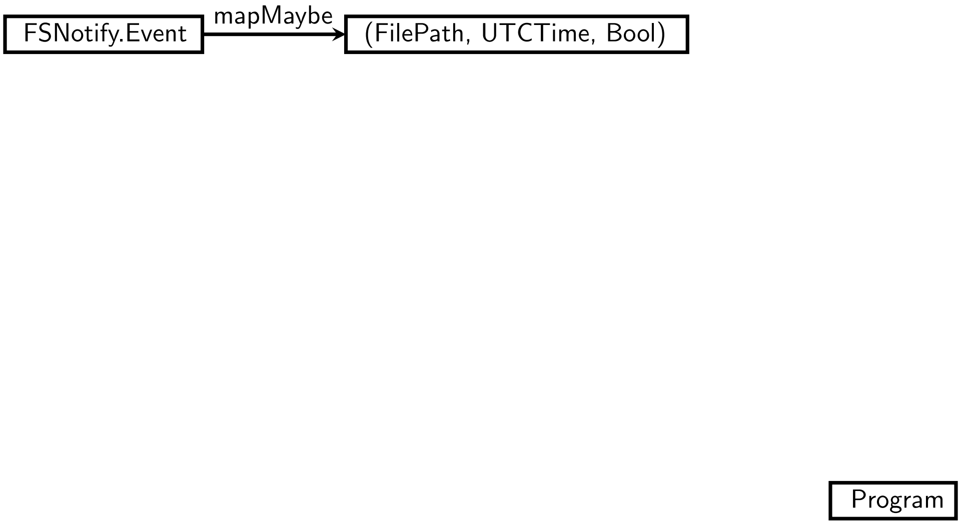

Recompiling OpenGL Shaders: Shader Wiring Diagram

FSNotify.Event
Program

- See `watchShaderProgram` in `Shader.hs`

Recompiling OpenGL Shaders: Shader Wiring Diagram



- See `watchShaderProgram` in `Shader.hs`

Recompiling OpenGL Shaders: Shader Wiring Diagram

$$\begin{tikzcd} \boxed{\text{FSNotify.Event}} \arrow[r, "\text{mapMaybe}"] & \boxed{\text{(FilePath, UTCTime, Bool)}} \arrow[r, "\text{fmap}"] & \boxed{\text{FilePath}} \end{tikzcd}$$

$$\boxed{\text{Program}}$$

- See `watchShaderProgram` in `Shader.hs`

Recompiling OpenGL Shaders: Shader Wiring Diagram

$$\begin{tikzcd}
\boxed{\text{FSNotify.Event}} \arrow[r, "\text{mapMaybe}"] & \boxed{\text{(FilePath, UTCTime, Bool)}} \arrow[r, "\text{fmap}"] & \boxed{\text{FilePath}} \arrow[d, "\text{filter (== "frag.glsl")}"'] & \\
 & & \boxed{\text{FilePath}} & \\
 & & & \boxed{\text{Program}}
\end{tikzcd}$$

- See `watchShaderProgram` in `Shader.hs`

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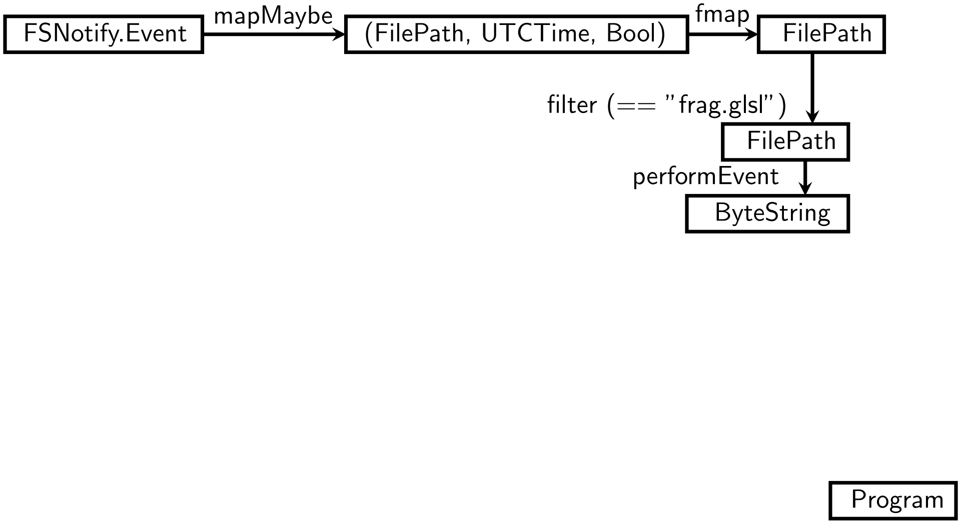

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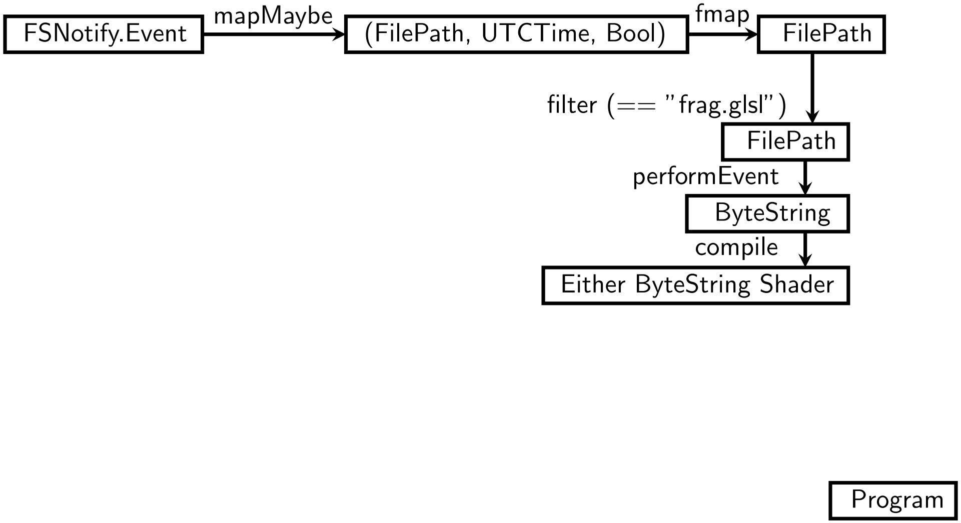

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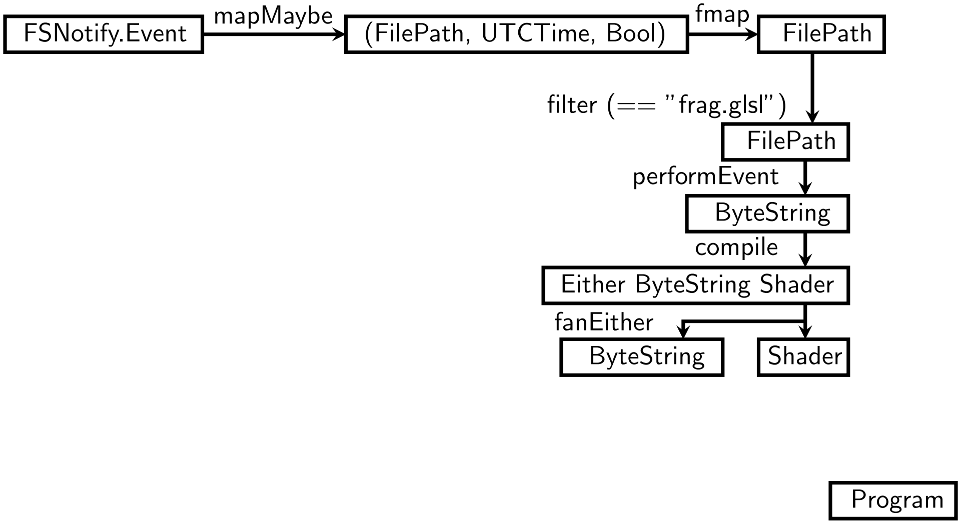

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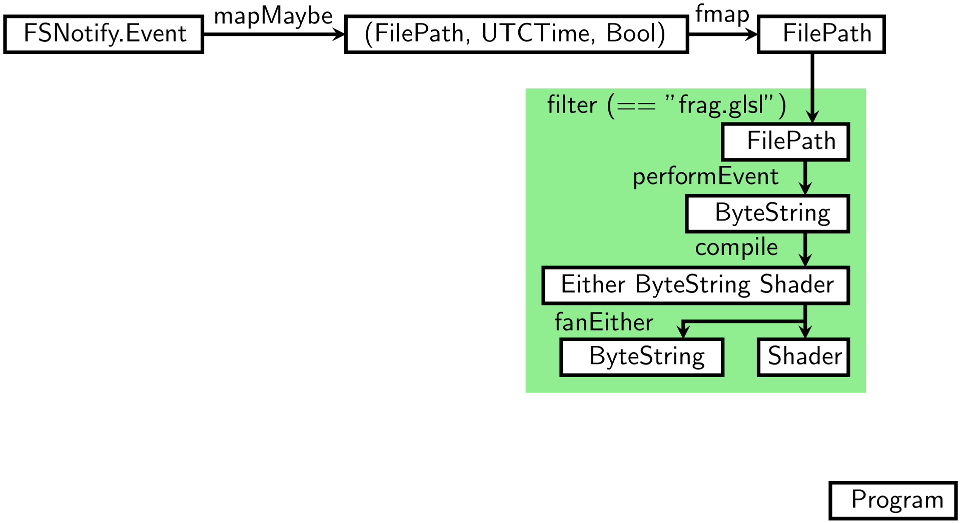

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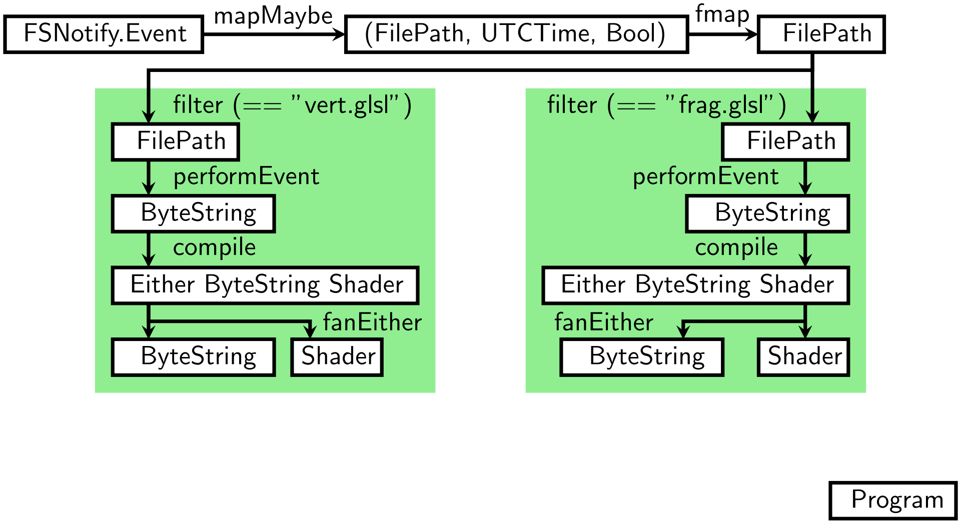

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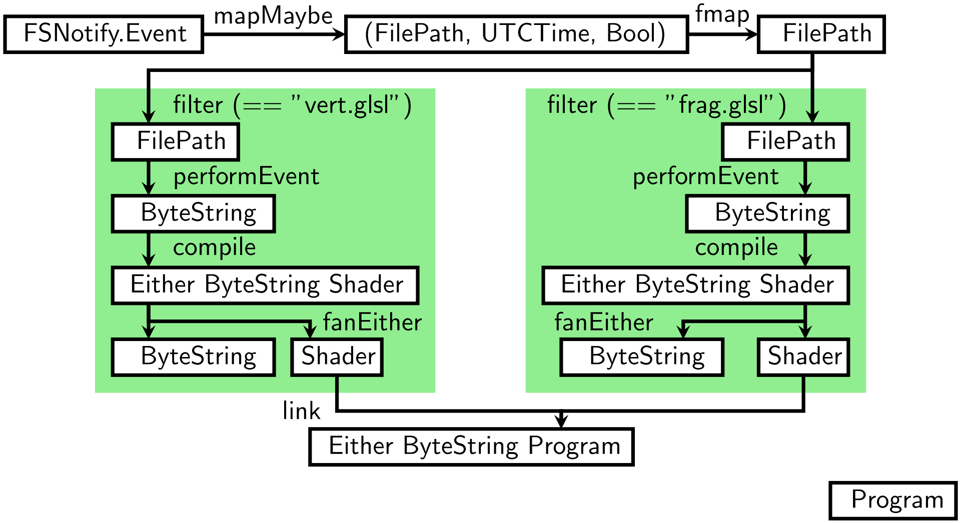

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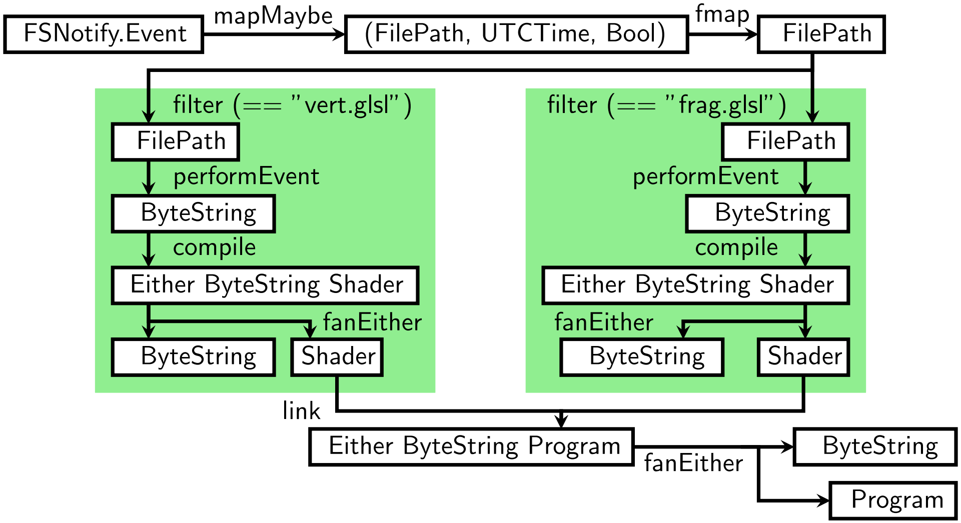

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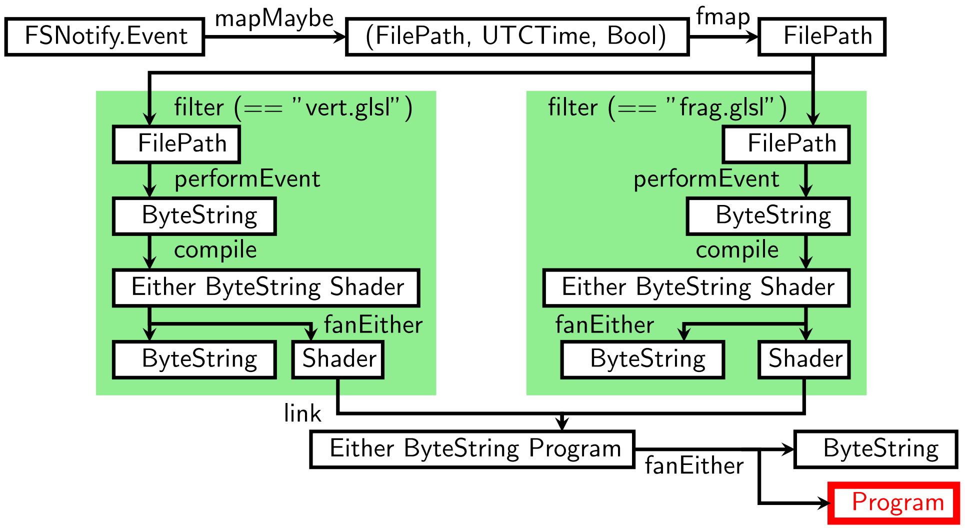

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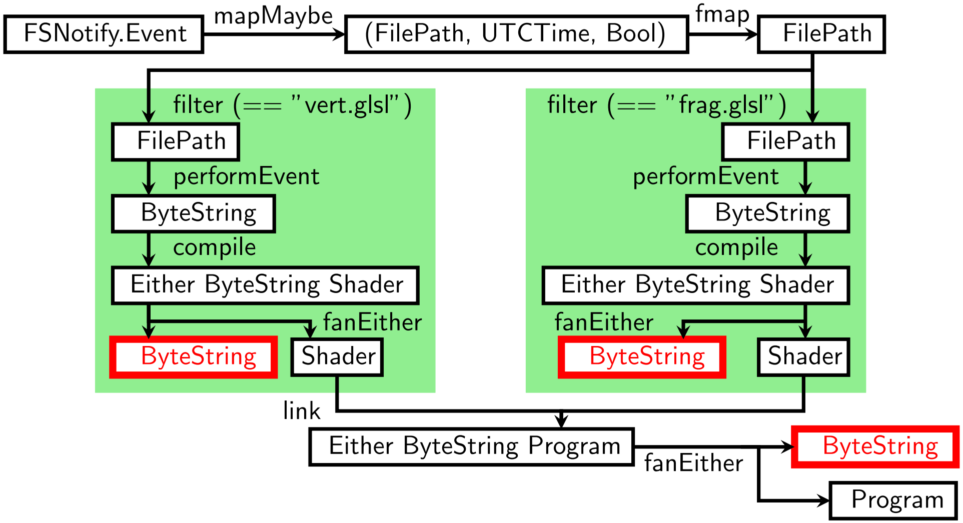

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Demo

- Demo Time!

Takeaways

- Learn by doing
- FRP first, web stuff later
- Start with `reflex-basic-host`
- Wiring diagrams!

Links

- Demo code: `https://github.com/qfpl/reflex-gl-demo`
- `reflex`: `https://hackage.haskell.org/package/reflex`
- `reflex-basic-host`: `https://github.com/qfpl/reflex-basic-host`
- `glow`: `https://github.com/ekmett/codex/tree/master/glow`