interactive creation of well-typed expressions in Domain Specific Languages

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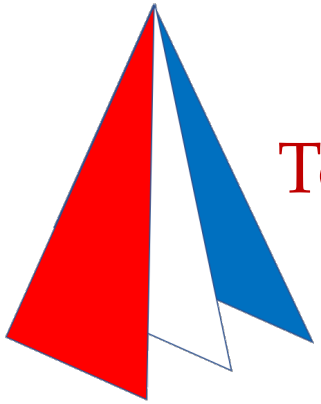

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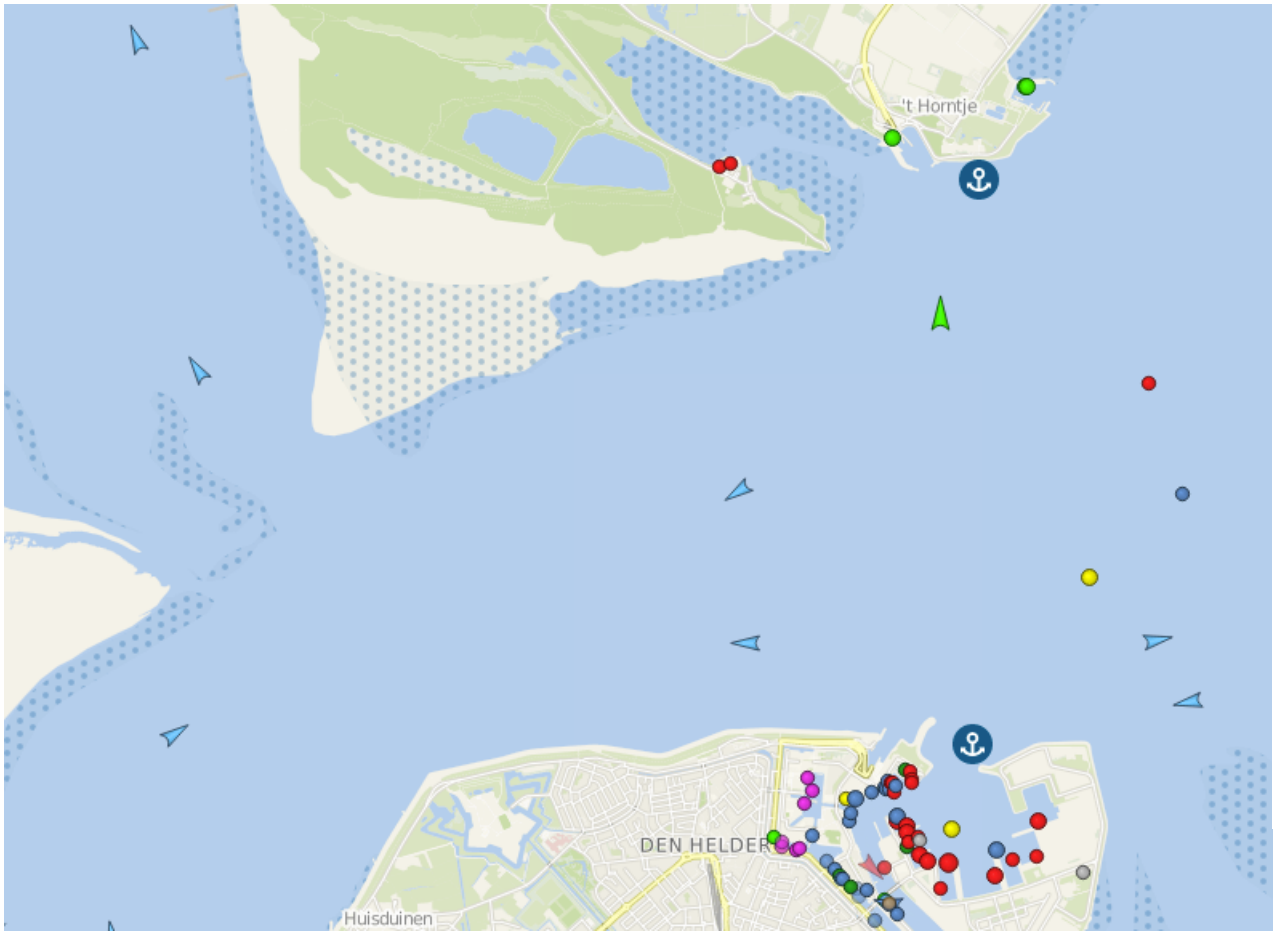
our use case: a DSL to query ships



- AIS
  - Automatic Identification System
  - transceiver reports on ship position, name, speed, kind, ..
  - typically a few times per minute
- users need dynamic queries
  - about ships, ports, wind-parks
  - distance, names, flags
  - …
- example
  - which Dutch tankers are within 5 miles of a wind-park

screenshot from www.vesselfinder.com by OpenStreetMap

DSL design

• Grammar

Gen
::= **Ship** *Identifier Gen*
| **WindPark** *Identifier Gen*
| **Cond** *Cond Gen*
| **Return** *Expr*

:: *Cond*
::= **LE** *Expr Expr*
| **And** *Cond Cond*
| **HasFlag** *Expr Country-list*
| **HasName** *Expr Name-list*

:: *Expr*
::= *Identifier*
| *Number*
| **Distance** *Expr Expr*
| **Name** *Expr*

• typical example

Ship s
    Cond (**HasFlag** s [NL])
WindPark p
    Cond (**LE** (Distance s p) 5)
    Return (**Name** s)

- the names of all Dutch ships that are withing 5 miles of a windpark

• users need guidance to write queries
- nautical experts, no computer scientists

• **web-editor provides guidance**
• **strong typing prevents errors**

DSL implementation: basic approach

- Grammar

Gen
::= **Ship** *Identifier Gen*
| **WindPark** *Identifier Gen*
| **Cond** *Cond Gen*
| **Return** *Expr*

:: *Cond*
::= **LE** *Expr Expr*
| **And** *Cond Cond*
| **HasFlag** *Expr Country-list*
| **HasName** *Expr Name-list*

:: *Expr*
::= *Identifier*
| *Number*
| **Distance** *Expr Expr*
| **Name** *Expr*

- data types matching the grammar

```
:: Gen
   = Ship Name Gen
   | WindPark Name Gen
   | Cond Cond Gen
   | Ret Expr
:: Cond
   = LE Expr Expr
   | And Cond Cond
   | HasFlag Expr [Country]
   | HasName Expr [Name]
:: Expr
   = Var Name
   | Num Real
   | Distance Expr Expr
   | Name Expr
```

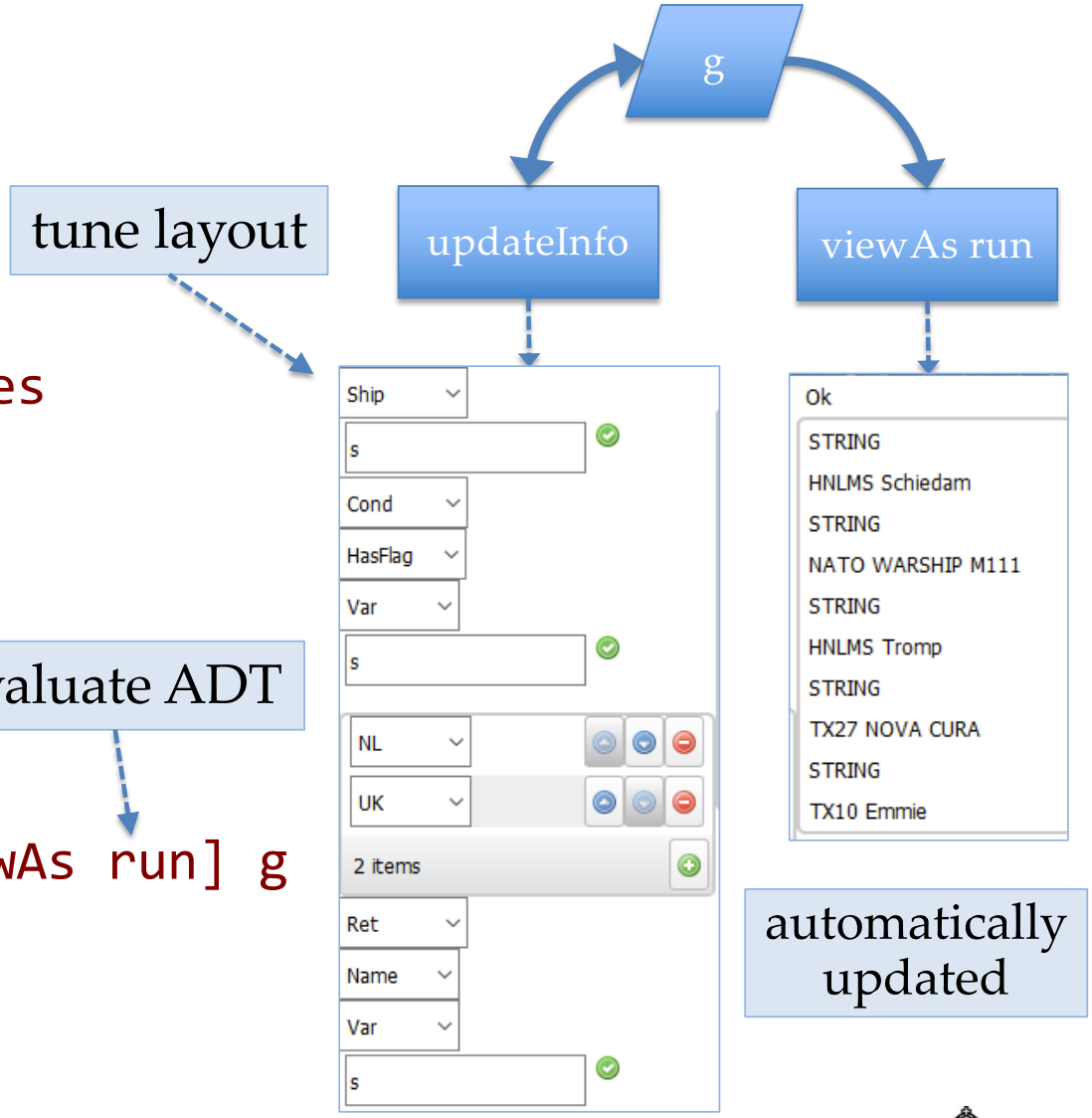
web-editor in iTasks

- Task Oriented Programming
- generate web-editors based on types

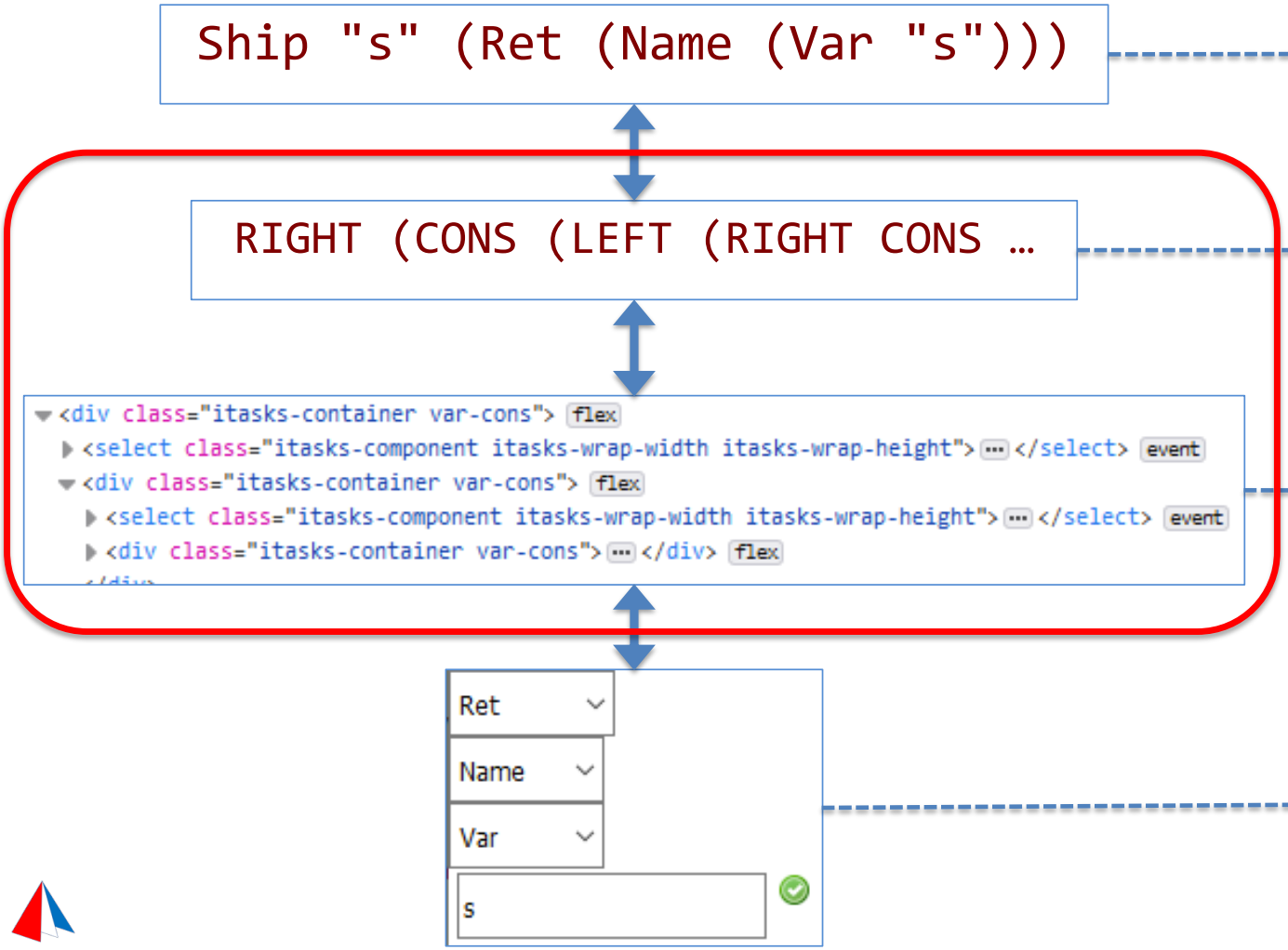
```
derive class iTasks Gen, Cond, Res

genTask :: Task Gen
genTask =
  withShared e0 \g.
  updateSharedInformation [] g
  -|| viewSharedInformation [ViewAs run] g

Start w = doTasks genTask  w
```



how this works



user defined types

Clean

datatype-generic version

itasks
task-oriented programming framework

HTML + WA

HTML

WA

GUI: web-editor

limitations of this approach

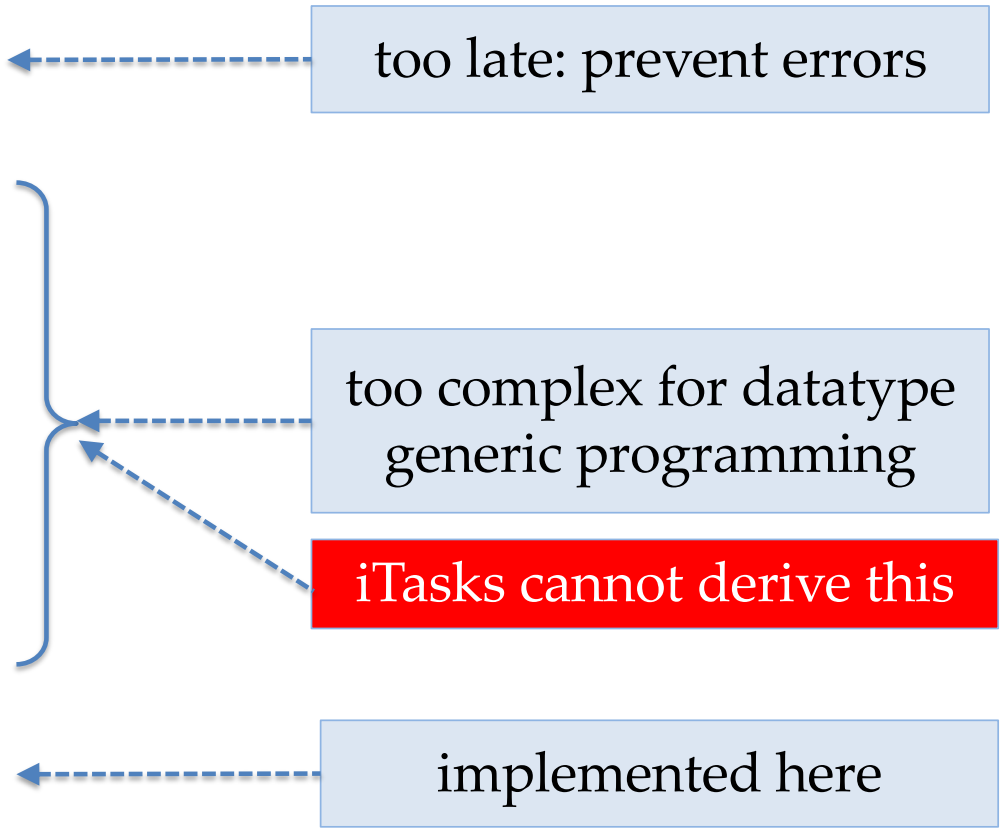
- datatype generic programming
  - one algorithm that work for 'any' datatype
  - datatype must be known completely
  - no functions, no quantifiers, no class restrictions
- datatypes allows ill-typed DSL expressions
  - correct as datatype in host language
  - no meaning in our DSL

cannot be prevented by design of datatypes if we need overloading

```
HasFlag (Num 42.0) [NL]
Distance (Num 7.0) (String "Hello World!")
LE (Var "a") (Num 137.0)
Var "undefined name"
```

making type-safe DSL-editors

1. type-checker for DSL
   - checks expression after user made it
2. DSL with phantom types
   - extra type parameter tells type of expression
3. DSL as GADT
   - Generalised Algebraic DataType
4. shallow embedded DSL
   - set of functions instead of datatype
5. let programmer define editor cases
   - this can assure correct types
   - phantom types, GADT, or functions



dynamic editors

- programmer specifies a list of edit clauses
- system selects the options applicable

```
dynamicEditor =
  [de "Add" \x y -> x + y  :: Int Int -> Int
  ,de "Eq"  \x y -> x == y :: Int Int -> Bool
  ,de "And" \x y -> x && y :: Bool Bool -> Bool
  ,ce "Int.Val"  intEditor
  ,ce "Bool.Val" boolEditor
  ]
```

rejected by the type system

list elements should have the same type

dynamic editors

- programmer specifies a list of edit clauses
- system selects the options applicable

transforms any type to `Dynamic`

```
dynamicEditor =
  [de "Add" (dynamic \x y -> x + y  :: Int Int -> Int)
  ,de "Eq"  (dynamic \x y -> x == y :: Int Int -> Bool)
  ,de "And" (dynamic \x y -> x && y :: Bool Bool -> Bool)
  ,ce "Int.Val"  intEditor
  ,ce "Bool.Val" boolEditor
  ]
```

use editor recursively for arguments

for a Bool result

```
intEditor :: Editor Int (?Int)
intEditor = gEditor{|*|} EditValue
```

dynamic editors

- programmer specifies a list of edit clauses
- system selects the options applicable

```
dynamicEditor =
  [de "Add" (dynamic \x y -> x + y  :: Int Int -> Int)
  ,de "Eq"  (dynamic \x y -> x == y :: Int Int -> Bool)
  ,de "And" (dynamic \x y -> x && y :: Bool Bool -> Bool)
  ,ce "Int.Val"  intEditor
  ,ce "Bool.Val" boolEditor
  ]

intEditor :: Editor Int (?Int)
intEditor = gEditor{|*|} EditValue
```

for an integer result

type-safe editor for ship queries

types are Monadic but very similar

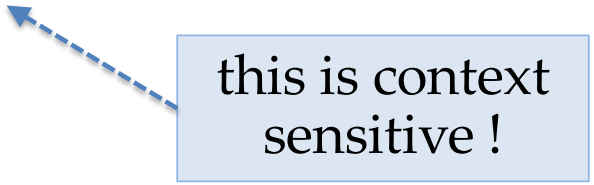
```
dynamicEditor =
[ de "Has flag"
    (dynamic \ship list = ship >>= \s->pure (isMember s.flag list)
       :: (Eval Ship) [Country] -> Eval Bool)
, de "Has name"
    (dynamic \x l = x >>= \s->pure (or (map (matchName s.name) l))
       :: (Eval Ship) [String] -> Eval Bool)
, de "And"
    (dynamic \x y = x >>= \a->y >>= \b->pure (a && b)
       :: (Eval Bool) (Eval Bool) -> Eval Bool)
...
```

type-safe variables

```
:: Expr = Var String | Not Expr | ..
```

- two problems

1. variables carry no type, they can cause type errors
2. variables can be undefined `Var "x"`, any string will do



type-safe variables

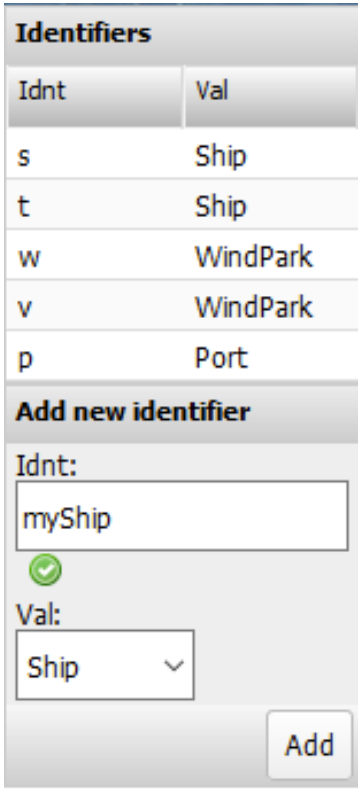
1. add a phantom type

```
:: VarName a = VarName String
```

2. select variables from a pool of defined variables

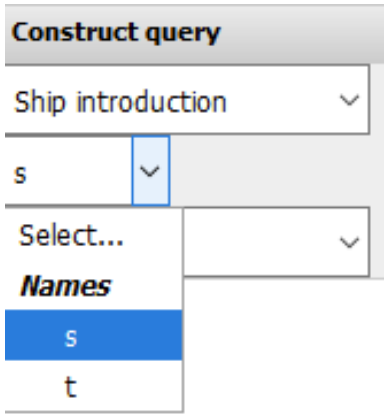
```
:: Bind = {idnt::String, val::Dynamic}

state0 :: [Bind]
state0 =[ {idnt = "s", val = dynamic ship0}
        , {idnt = "w", val = dynamic windpark0}
        ..
```



using these variables

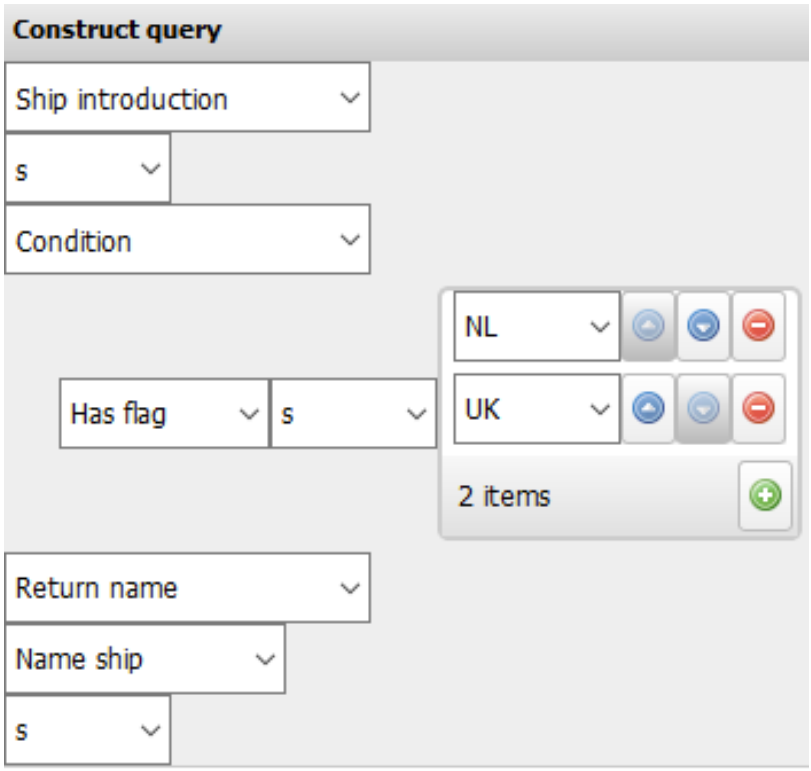
```
dynamicEditor =
[ de "Has flag"
    (dynamic \ship list = ship >>= \s. pure (isMember s.flag list)
        :: (Eval Ship) [Country] -> Eval Bool)
: map toFunctionConsDyn state
..
```

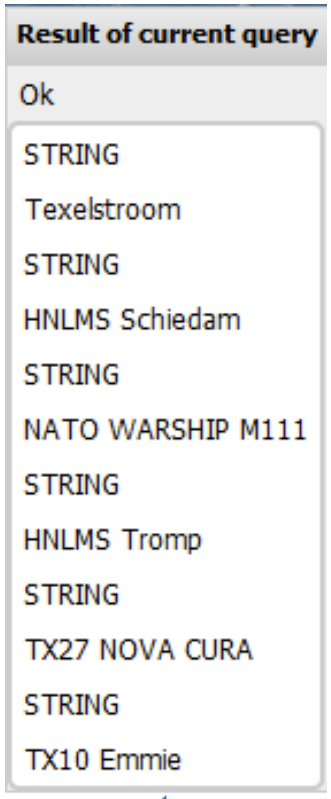


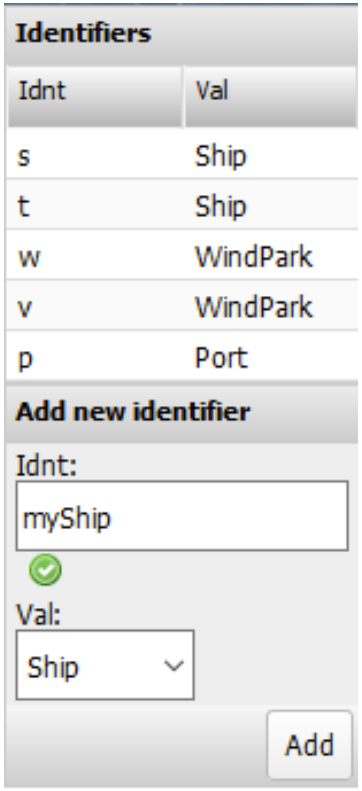

```
toName :: Bind -> DynamicCons
toName {idnt, val = x :: t}
    = de idnt (dynamic (VarName idnt) :: VarName t)
```

match dynamic of type t

obtained query DSL for ships







updated if query changes

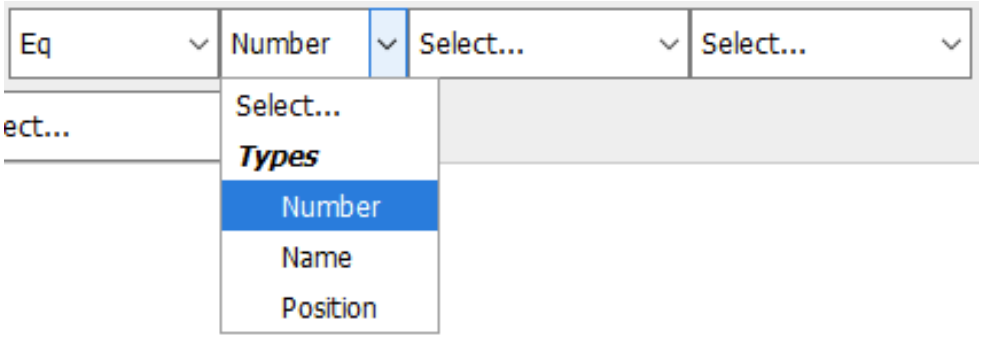
operator overloading

- we need to indicate the dictionaries for overloading
- e.g. add them in with the EQ editor

```
[ de "Eq"
    (dynamic \(EQ f) x y = f x >>= \a. y >>= \b.pure (a == b)
        :: A.a: (EQ a) (Eval a) (Eval a) -> Eval Bool)
, de "Number" (dynamic EQ id :: EQ Real) ..

:: EQ a = EQ ((Eval a)->Eval a) & == a
```

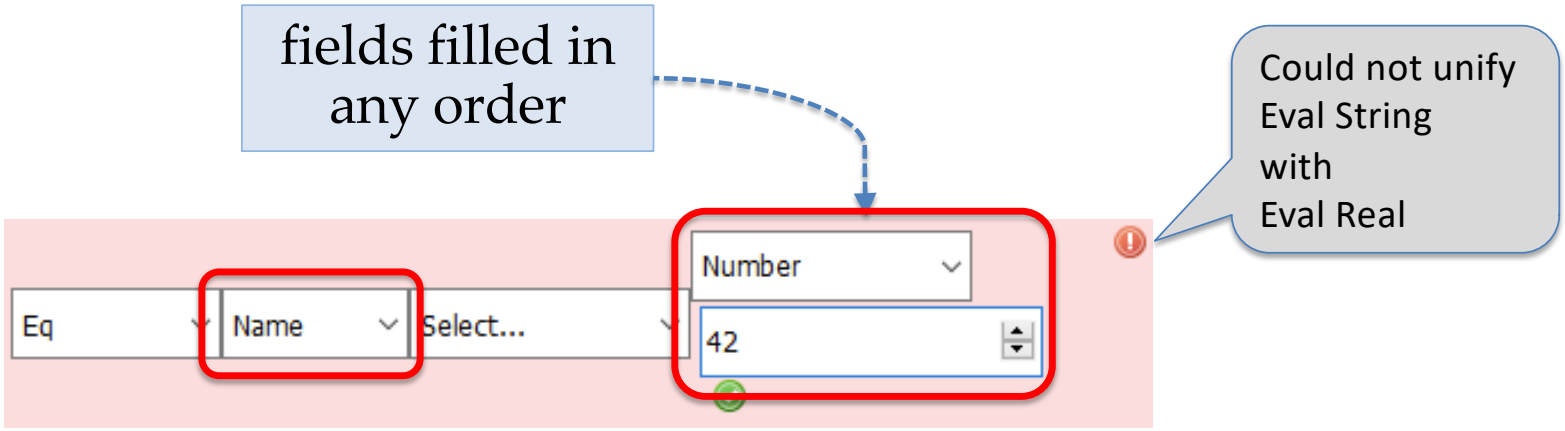
equal result types is context sensitive !



overloading errors

- cannot prevent overloading errors during editing
- dynamic editors signal them immediately

```
(dynamic \(EQ f) x y = f x >>= \a. y >>= \b.pure (a == b)
     :: A.a: (EQ a) (Eval a) (Eval a) -> Eval Bool)
```



conclusion

- we want type-safe editors for DSL expressions with guidance
- deriving editors for ADTs in iTask is wonderful
  - but often not good enough for a DSL (type errors, unsafe variables)
- dynamic-editors solve our problem
  - programmer specifies list of edit clauses
  - dynamic editor selects elements based on desired type
  - ✓ solves our problem: makes type-safe context sensitive editors
  - ✓ works for phantom types, GADTs and functions
  - ✓ can guarantee well-typed and defined variables
  - \- more work than just `derive class iTask MyDSL`

DEMO ??

future work

- define variables on-the-fly:
  the new changing state in the editors allows this
- more flexible editors:
  change an expression *x* in `Add` *x* `...`
- composable editors
  instead of one list of items for every editor
- …