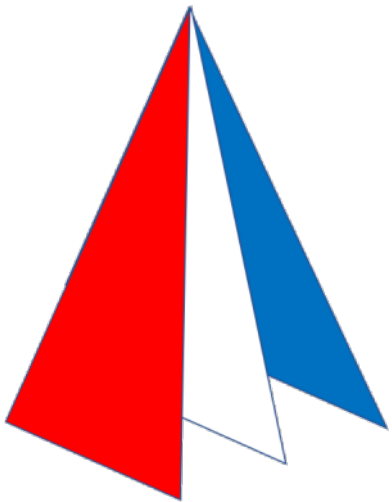


interactive creation of well-typed expressions in Domain Specific Languages

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Top Software Technology

interactive creation of well-typed DSL expressions

- a Domain Specific Language, DSL, is programming language specialized to a particular domain
 - e.g. queries over ships and their risks for the coast guard
 - Task Oriented Programming, TOP, for workflows
 - co-operative devices for the Internet of Things, IoT
 - tax forms and associated calculations
 - ...
- our DSLs are embedded inside another language: eDSL
 - inherit all operations of the host language
 - we are particularly focused on **strong typing**
- focus of today: interactive creation of DSL expressions
 - e.g. dynamic creation of a query over ships
 - can we avoid parsing, type-checking and dynamic linking?



editor for deep embedded DSL

like the context
free grammar

- running example with integers and Booleans

```
:: Expr = Int Int          | Bool Bool          | Add Expr Expr  
        | And Expr Expr    | Eq   Expr Expr    | If   Expr Expr Expr
```

- making a browser-based editor for this type:

derive class iTask Expr

Start world = doTasks (updateInformation [] (Int 0)) world

a web-editor for Expr!
What is our problem ?

correct strong typing !



iTask editor magic: generic programming

type driven generic functions:

- 1 algorithm for all datatypes
- uniform encoding of types
- define operation (here edit) for PAIR, EITHER, Int etc.
- implicit transformation to and from generic type

```
:: PAIR a b = PAIR a b
:: EITHER a b = LEFT a | RIGHT b
:: CONS a = CONS a
:: UNIT = UNIT
```

```
:: Expr = Int Int          | Bool Bool          | Add Expr Expr
        | And Expr Expr | Eq   Expr Expr | If   Expr Expr Expr
:: GExpr = EITHER (CONS INT)                // for Int Int
            (EITHER (CONS BOOL)              // for Bool Bool
             (EITHER (CONS (PAIR Expr Expr)) // for Add Expr Expr
              ...
```

- Clean derives editor for Expr based on generic editors



limitations of this approach

```
:: Expr = Int Int          | Bool Bool          | Add Expr Expr  
        | And Expr Expr    | Eq    Expr Expr    | If   Expr Expr Expr
```

- allows expression that are well-type in Clean, but incorrectly typed in the Expr-DSL
- some ill-typed DSL expressions

Add (Int 42) (Bool True) // Add :: Int Int -> Int

And (Int 42) (Bool True) // And :: Bool Bool -> Bool

If (Int 42) (Bool True) (Int 7) // If :: Bool a a -> a

Eq (Int 42) (Bool True) // Eq :: a a -> Bool

required type

we need
overloading

- we want a static type system spotting these errors
- **we do not want to write our own type-checker !**



dynamics to the rescue

- any type can be packed into a `Dynamic`

```
list :: [Dynamic]
```

```
list = [dynamic 7, dynamic (fib,4) :: (Int->Int,Int)  
       ,dynamic (s2i,"30"), dynamic "1"]
```

we can add a
type if we want

- dynamic type match to unpack dynamics type-safely

```
dSum :: [Dynamic] -> Int
```

```
dSum [x::Int:      rest] = x + dSum rest
```

```
dSum [t::(a->Int, a):rest] = (fst t) (snd t) + dSum rest
```

```
dSum [x:          rest] = dSum rest
```

```
dSum [] = 0
```

we can add
cases by need

- application `Start = dSum list`

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- these dynamics can implement our runtime type-checker!



dynamic editors

- plan:

1. programmer specifies list of labelled dynamic functions
 - each dynamic specifies a typed DSL construct
 - additional details for grouping, layout etc.
2. system selects items that produce required result type
3. user selects option in GUI based on label
4. dynamic editor used recursively for function arguments

- options to avoid DSL type-errors

1. better type information in editor
2. better typed DSL

- this is more work than generic deriving an editor,
but ensures that we obtain correctly typed DSL expressions



1: better type information in editor

```
:: Expr = Int Int          | Bool Bool          | Add Expr Expr
        | And Expr Expr   | Eq Expr Expr       | If Expr Expr Expr
:: Typed a b = Typed a    // b holds additional type information
```

- dynamic editor cases needed

```
[de "int value" (dynamic \i.Typed (Int i) :: Int ->Typed Expr Int)
,de "Bool val" (dynamic \b.Typed (Bool b) :: Bool->Typed Expr Bool)
,de "add" (dynamic \((Typed x) (Typed y) -> Typed (Add x y) ::
  (Typed Expr Int) (Typed Expr Int) -> Typed Expr Int)
,de "equality" (dynamic \((Typed x) (Typed y).Typed (Eq x y) ::
  A.a: (Typed Expr a) (Typed Expr a) -> Typed Expr Bool)
,de "if" (dynamic \((Typed c) (Typed t) (Typed e).Typed (If c t e)::
  A.a:(Typed Expr Bool) (Typed Expr a) (Typed Expr a)->Typed Expr a)
..
```

no errors

this approach prevents all type problems



1: better type information in editor 2

The image compares two editor interfaces. The left interface shows a 'Select...' dropdown menu with a list of options categorized by type: **Integer** (integer value, add), **Boolean** (Boolean value, and, equality), and **Conditional** (conditional). A blue callout box labeled 'all options' points to this menu. The right interface shows a similar 'Select...' dropdown menu, but it is filtered to show only **Integer** options (integer value, add) and **Conditional** options (conditional). A blue callout box labeled 'just Int options' points to this menu. In the background, a code editor is visible with a variable 'integer value' set to '7'.

- DSL is unchanged
- user can make only DSL-type-correct instances: **success !**

overloading in the DSL

- in our DSL Eq and If should be overloaded:

```
,de "equality" (dynamic \(Typed x) (Typed y).Typed (Eq x y) ::  
  A.a: (Typed Expr a) (Typed Expr a) -> Typed Expr Bool)  
,de "if" (dynamic \(Typed c) (Typed t) (Typed e).Typed (If c t e)::  
  A.a:(Typed Expr Bool) (Typed Expr a) (Typed Expr a)->Typed Expr a)
```

- based on type Typed Expr a any Expr is allowed

- the dynamic editor does allow any Expr
- it uses dynamics to unify the arguments
- indicates an error as soon as unification fails

Could not unify
Typed Expr Int
with
Typed Expr Bool

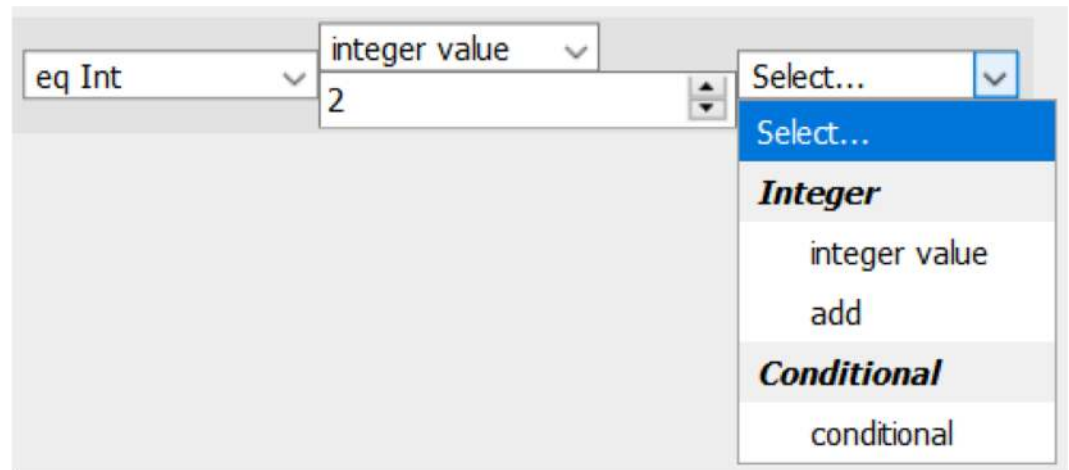
The screenshot shows a graphical user interface for a dynamic editor. It features three main components: a dropdown menu on the left labeled 'equality', a central input area with a dropdown labeled 'integer value' and a text field containing '137', and a right section with a dropdown labeled 'Boolean value' and an unchecked checkbox. A red circular icon with an exclamation mark is visible in the top right corner of the interface, indicating an error. A yellow callout box points to this icon, containing the text: 'Could not unify Typed Expr Int with Typed Expr Bool'.

preventing unification errors

- we can prevent unification by specialisation of type

```
,de "eq int" (dynamic \(Typed x) (Typed y).Typed (Eq x y) ::  
  (Typed Expr Int) (Typed Expr Int) -> Typed Expr Bool)  
,de "eq Bool" (dynamic \(Typed x) (Typed y).Typed (Eq x y) ::  
  (Typed Expr Bool) (Typed Expr Bool) -> Typed Expr Bool)
```

- now the dynamic editor knows the type of arguments:
no dynamic unification



- number of cases explodes if we have many types



2: better typed DSL – GADT based

```
:: Expr = Int Int          | Bool Bool          | Add Expr Expr
        | And Expr Expr   | Eq Expr Expr       | If Expr Expr Expr
```

- replace this by:

```
:: Expr a
  = Lit a
  | Add (BM a Int) (Expr Int) (Expr Int)
  | And (BM a Bool) (Expr Bool) (Expr Bool)
  | E.b: Eq (BM a Bool) (Expr b) (Expr b) & == b
  | If (Expr Bool) (Expr a) (Expr a)
```

- for type conversions (a poor man's GADT)

```
:: BM a b = {ab :: a -> b, ba :: b -> a}
```

- the only instance used

```
bm :: BM a a
```

```
bm = {ab = id, ba = id}
```

- example

```
Add bm (Lit 6) (Lit 36)
```

use a dynamic editor

generics cannot handle:

1. functions in record BM
2. quantified variables E.b: ..
3. class constraints & == b



2: better typed DSL – GADT based 2

```
:: Expr a  
= Lit a
```

argument a indicates the type, we do not need :: Typed a b = Typed a

```
| Add (BM a Int) (Expr Int) (Expr Int)  
| E.b: Eq (BM a Bool) (Expr b) (Expr b) & == b
```

```
[ de "integer value"  
  (dynamic \i -> Lit i :: Int -> Expr Int)  
, de "add"      (dynamic \x y -> Add bm x y ::  
                  (Expr Int) (Expr Int) -> Expr Int)  
, de "eq Int"   (dynamic \x y -> Eq bm x y ::  
                  (Expr Int) (Expr Int) -> Expr Bool)  
, de "eq Bool" (dynamic \x y->Eq bm x y ::  
                  (Expr Bool) (Expr Bool) -> Expr Bool)  
...
```

the GADT approach makes the editor simpler



2: better typed DSL 2

Select... ▼

Select...

Integer

integer value

add

Conditional

conditional

Correct DSL types are enforced by host language compiler

Not only during edit

conditional ▼

Cond: eq Int ▼

Select... ▼

Select... ▼

Then: integer value ▼

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Else: add ▼

integer value ▼

137

Select... ▼

Select...

Integer

integer value

add

Conditional

conditional



DSL-variables

challenges:

- type of the variable
- existence of appropriate variable definition before use
 - even a GADT cannot guarantee this

```
:: Expr a
  = Lit a
  | Var String
  | Add (BM a Int) (Expr Int) (Expr Int) | ...
```

our solution:

- define a shared pool of typed variables in the editor
- dynamic editor selects well-typed items from this pool
 - in iTasks we can edit the pool and the expression concurrently

better editors can make
this pool on the fly



DSL-variables 2

Variables			Construct an expression
Idnt	Share	Val	Push the 'Run' button to evaluate this expression.
x	False	1	Select... ▼
y	False	2	
a	False	False	
b	False	True	
p	False	Alonzo Church	
q	False	Moses Schonfinkel	
sds1	True		

Add new variable

Idnt*:



Share:

☐

Val*:

Select... ▼

return ▼

add ▼

a value ▼

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Select... ▼

Select... ▼

Int expression

add

subtract

Conditional

a conditional

Constants and variables

a value

x

y

only the
variables with
the correct type

more serious example: interactive workflow editor

Variables

Idnt	Share	Val
a	False	False
b	False	True
p	False	Alonzo Church
q	False	Moses Schonfinkel
r	False	nobody
sds1	True	1
x	False	1
y	False	2

Add new variable

Idnt*:

 Share:
☐

Val*:

Select... ▾

Add

bind ▾
Person ▾
select one option ▾

button and task ▾
Mr Lambda
return ▾
p ▾

button and task ▾
Mr Combinators
return ▾
q ▾



r ▾
seq ▾
Person ▾
update ▾ change person r ▾
return ▾
a value ▾
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more serious example: executing the composed task

Make a choice

Mr Lambda Mr Combinators

press this

change person

Name*: Moses Schonfinkel

Birth*: 1889-09-04

Gender*: Male

Continue

press this

final result

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Back Finish

- this shows a restricted editor for iTask
- we can immediately execute the created task
- we do not want to make this a full programming language, but dynamic creation of limited tasks is very useful

ask a demo in the breaks



conclusion

- our goal: create well-typed DSL expressions dynamically
- iTask can derive editors for plain data-types, but this allows ill-typed DSL expressions
- the dynamic type-system can solve our type problems
- two approaches:
 1. add additional information to editor, but not to type
 2. improve the type holding the DSL, generics cannot handle it
- use a pool of typed variables to guarantee type and existence
- more tricks in the forthcoming paper

ask a demo in the breaks



better editors
can make this
pool on the fly



shallow embedded DSL

- shallow embedding is based on functions
- dynamic editors make datatypes,
but we can use the results immediately
- type for all results:

`:: Val a = Val a`

- relevant parts of the dynamic editor

```
[de "int val" (dynamic \i -> Val i :: Int -> Val Int)
,de "Boolean" (dynamic \b -> Val b :: Bool -> Val Bool)
,de "add"      (dynamic \(Val x) (Val y) -> Val (x + y) ::
                  (Val Int) (Val Int) -> Val Int)
,de "and"      (dynamic \(Val x) (Val y) -> Val (x && y) ::
                  (Val Bool) (Val Bool) -> Val Bool)
,de "eq int"   (dynamic \(Val x) (Val y) -> Val (x == y) ::
                  (Val Int) (Val Int) -> Val Bool)
,de "if"       (dynamic \(Val c) t e -> if c t e ::
                  A.a: (Val Bool) (Val a) (Val a) -> Val a)
```

