High-Level Server Side Web Scripting in Curry

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HTML/CGI PROGRAMMING

Early days of the World Wide Web: web pages with static contents

Common Gateway Interface (CGI): web pages with dynamic contents

Retrieval of a dynamic page:

- ➜ server executes a program
- ➜ program computes an HTML string, writes it to stdout
- ➜ server sends result back to client

HTML with input elements (forms):

- ➜ client fills out input elements
- ➜ input values are sent to server
- ➜ server program decodes input values for computing its answer

TRADITIONAL CGI PROGRAMMING

CGI programs on the server can be written in any programming language

- ➜ access to environment variables (for input values)
- ➜ writes a string to stdout

Scripting languages: (Perl, Tcl,. . .)

- ➜ simple programming of single pages
- ➜ error-prone: correctness of HTML result not ensured
- ➜ difficult programming of interaction sequences

Specialized languages: (MAWL, DynDoc,. . .)

- ➜ HTML support (structure checking)
- ➜ interaction support (partially)
- ➜ restricted or connection to existing languages

CGI PROGRAMMING IN A MULTI-PARADIGM LANGUAGE

Library in multi-paradigm language

Exploit functional and logic features for

- ➜ HTML support (data type for HTML structures)
- ➜ simple access to input values (free variables and environments)
- ➜ simple programming of interactions (event handlers)
- ➜ wrapper for hiding details

Exploit imperative features for

- ➜ environment access (files, data bases,. . .)

Domain-specific language for HTML/CGI programming

CURRY

[Dagstuhl'96, POPL'97]

- multi-paradigm language
  (higher-order concurrent functional logic language,
  features for high-level distributed programming)
- extension of Haskell (non-strict functional language)
- developed by an international initiative
- provide a standard for functional logic languages
  (research, teaching, application)
- several implementations available

VALUES

Values in imperative languages: basic types + pointer structures

Declarative languages: **algebraic data types** (Haskell-like syntax)

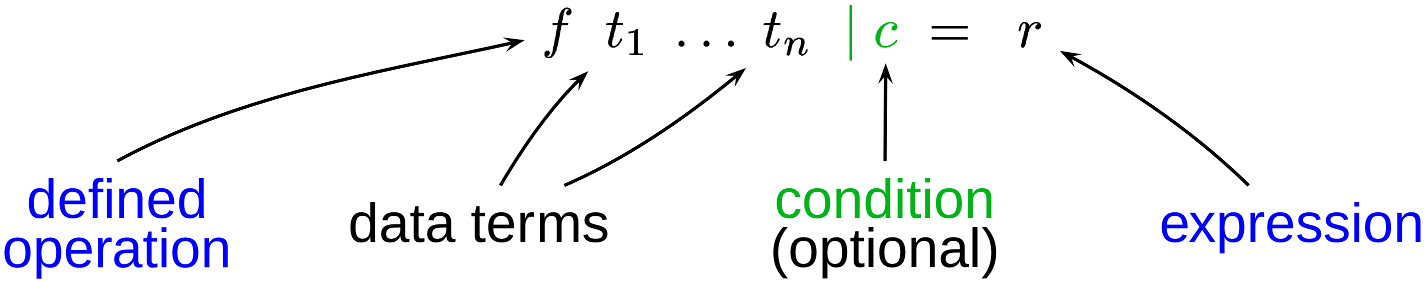
```
data Bool   = True   | False
data Nat    = Z      | S Nat
data List a = []     | a : List a        -- [a]
data Tree a = Leaf a | Node [Tree a]

data Int = 0 | 1 | -1 | 2 | -2 | ...
```

Value ≈ **data term**, **constructor term**:
well-formed expression containing variables and data type constructors

`(S Z)`   `1:(2:[])`   `[1,2]`   `Node [Leaf 3,Node [Leaf 4,Leaf 5]]`

CURRY PROGRAMS

Functions: operations on values defined by equations (or rules)



$$f \ t_1 \ \ldots \ t_n \ \mid c \ = \ r$$

defined operation

data terms

condition (optional)

expression

```
conc []     ys = ys
conc (x:xs) ys = x : conc xs ys

last xs | conc ys [x] =:= xs
        = x                       where x,ys free
```

`last [1,2]` $\rightsquigarrow$ `2`

EXPRESSIONS

$e ::=$

c	(constants)
x	(variables x)
$(e_0\ \ e_1 \ldots e_n)$	(application)
$\texttt{\textbackslash}x\ \texttt{->}\ e$	(abstraction)
$\texttt{if}\ \ b\ \ \texttt{then}\ \ e_1\ \ \texttt{else}\ \ e_2$	(conditional)

EXPRESSIONS

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`\`x `->` e	(abstraction)
`if` b `then` e_1 `else` e_2	(conditional)
e_1`=:=`e_2	(equational constraint)
e_1 `&` e_2	(concurrent conjunction)
`let` $x_1, \ldots, x_n$ `free in` e	(existential quantification)

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$\texttt{\\}x\ \texttt{->}\ e$	(abstraction)
$\texttt{if}\ \ b\ \ \texttt{then}\ \ e_1\ \ \texttt{else}\ \ e_2$	(conditional)
$e_1\texttt{=:=}e_2$	(equational constraint)
$e_1\ \ \texttt{\&}\ \ e_2$	(concurrent conjunction)
$\texttt{let}\ \ x_1, \ldots, x_n\ \ \texttt{free in}\ \ e$	(existential quantification)

Equational constraints over functional expressions:

$\texttt{conc ys [x] =:= [1,2]} \quad \leadsto \quad \{\texttt{ys=[1],x=2}\}$

Further constraints: real arithmetic, finite domain, ports

FUNCTIONS

- lazy evaluation (evaluate only needed redexes)
- support infinite data structures, modularity
- optimal evaluation (also for *logic programming*)

Distinguish:

flexible (generator) and *rigid* (consumer) functions

Flexible functions $\rightsquigarrow$ logic programming

Rigid functions $\rightsquigarrow$ concurrent programming

FLEXIBLE VS. RIGID FUNCTIONS

```
f 0 = 2
f 1 = 3
```

rigid/flexible status not relevant for ground calls:

`f 1` $\leadsto$ `3`

`f` flexible:

`f x =:= y` $\leadsto$ `{x=0,y=2} | {x=1,y=3}`

`f` rigid:

`f x =:= y` $\leadsto$ *suspend*

`f x =:= y & x =:= 1` $\leadsto$ `{x=1} f 1 =:= y` (suspend `f x`)

$\leadsto$ `{x=1} 3 =:= y` (evaluate `f 1`)

$\leadsto$ `{x=1,y=3}`

Default in Curry: constraints are flexible, all others are rigid

MODELING HTML

Data type for representing HTML expressions:

```
data HtmlExp = HText String
             | HStruct String [(String,String)] [HtmlExp]
```

Some useful abbreviations:

```
htxt   s     = HText (htmlQuote s)       -- plain string
bold   hexps = HStruct "B"  [] hexps     -- bold font
italic hexps = HStruct "I"  [] hexps     -- italic font
h1     hexps = HStruct "H1" [] hexps     -- main header
...
```

Example: `[h1 [htxt "1. Hello World"],`
`italic [htxt "Hello"], bold [htxt "world!"]]`

⇝ **1. Hello World**

Hello **world!**

Advantages:

- ➜ static checking of HTML structure (well-balanced parentheses)
- ➜ flexible dynamic documents
- ➜ functions for computing HTML documents

Converting tree structure (leaves contain strings) into nested HTML lists:

```
data Tree a = Leaf a | Node [Tree a]

htmlTree :: Tree String -> [HtmlExp]

htmlTree (Leaf s)     = [htxt s]
htmlTree (Node trees) = [ulist (map htmlTree trees)]


ulist       :: [[HtmlExp]] -> HtmlExp
ulist items = HStruct "UL" [] (map litem items)

litem hexps = HStruct "LI" [] hexps
```

HTML INPUT FORMS

Specific HTML elements for dealing with user input

```
<INPUT TYPE="TEXT" NAME="INPTEXT" VALUE="fill out!">
```

Form is submitted ⇝

clients sends the current value of this field (identified by `"INPTEXT"`)

Expressible as HTML term:

```
HStruct "INPUT" [("TYPE","TEXT"),("NAME","INPTEXT"),
                 ("VALUE","fill out!")] []
```

Problems:

- ➜ server program must decode input values
- ➜ server program must know right names of field identifiers (`"INPTEXT"`)
- ➜ error-prone

ABSTRACT INPUT FORMS

Solution:

- ➜ use free variables as references to input fields (CGI references)
- ➜ collect input values in CGI environments:
  mapping from CGI references to strings
- ➜ associate event handlers to submit buttons
- ➜ event handlers take a CGI environment and produce an HTML form

Implementation:

straightforward in a functional logic language!

ABSTRACT INPUT FORMS: IMPLEMENTATION

CGI references:

```
data CgiRef = CgiRef String  -- data constructor not exported
```

- ➜ no construction of wrong references
- ➜ only free variables of type `CgiRef`
- ➜ global wrapper function instantiates with the right strings

HTML elements with CGI references:

```
data HtmlExp = ... | HtmlCRef HtmlExp CgiRef
```

Example: Text fields with a CGI reference and initial contents

```
textfield :: CgiRef -> String -> HtmlExp
textfield (CgiRef ref) contents =
 HtmlCRef (HStruct "INPUT" [("TYPE","TEXT"),
                            ("NAME",ref),("VALUE",contents)])
          (CgiRef ref)
```

HTML form: title + list of HTML expressions

```
data HtmlForm = Form String [HtmlExp]
```

Example: simple form with a single input element (a text field)

```
Form "Form" [h1 [htxt "A Simple Form"],
             htxt "Enter a string:", textfield sref ""]
```

CGI environments: map CGI references to strings

```
type CgiEnv = CgiRef -> String
```

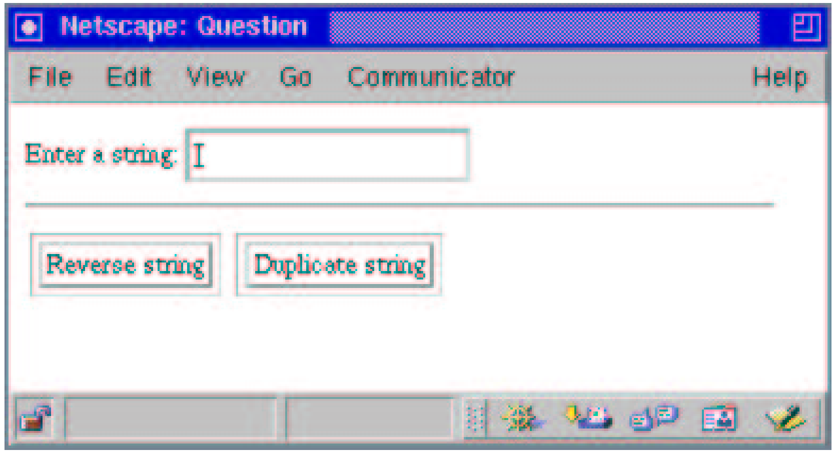
Event handlers have type `CgiEnv -> IO Form`

Event handlers are associated to submit buttons:

user presses a submit button

⇝ execute associated event handler with current environment

EXAMPLE: FORM TO REVERSE/DUPLICATE A STRING



```
Form "Question" [htxt "Enter a string: ", textfield tref "", hr,
                 button "Reverse string"   revhandler,
                 button "Duplicate string" duphandler]

where tref free

 revhandler env = return $ Form "Answer"
       [h1 [htxt ("Reversed input: " ++ rev (env tref))]]

 duphandler env = return $ Form "Answer"
       [h1 [htxt ("Duplicated input: " ++ env tref ++ env tref)]]
```

ACCESSING THE WEB SERVER ENVIRONMENT

Form to show the contents of an arbitrary file stored at the server:

```
Form "Get File" [htxt "Enter local file name:",
                 textfield fileref "",
                 button "Get file!" handler]

where fileref free

 handler env =
    do contents <- readFile (env fileref)
       return $ Form "Answer"
                 [h1 [htxt ("Contents of file " ++ env fileref)],
                  verbatim contents]
```

HANDLING INTERMEDIATE STATE

Sequence of forms to collect first and last name:

```
Form "First Name Form"
  [htxt "Enter your first name: ", textfield first "",
   button "Continue" fhandler]

 where first free

       fhandler _ =
          return $ Form "Last Name Form"
            [htxt "Enter your last name: ", textfield last "",
             button "Continue" lhandler]

        where last free

              lhandler env = return $ Form "Answer"
                [htxt ("Hi, " ++ env first ++ " " ++ env last)]
```

INTERACTION SEQUENCES

Programming arbitrary loops: a number guessing game:

```
guessform = return $ Form "Number Guessing" guessinput

guessinput =
  [htxt "Guess a number: ", textfield nref "",
   button "Check" (guesshandler nref)]    where nref free

guesshandler nref env =
 let nr = readInt (env nref)
 in return $ Form "Answer"
    (if nr==42
     then [htxt "Right!"]
     else [htxt (if nr<42 then "Too small!" else "Too large!"),
           hrule] ++ guessinput)
```

APPLICATION-ORIENTED ABSTRACTIONS

Abtraction: HTML element for looking up email addresses:

```
mail_epilog =
   [htxt "Enter a name: ", textfield nref "",
    button "search email" lookup, hrule]

 where nref free

      lookup env = ... send (GetEmail (env nref)) ...
```

Now, `mail_epilog` can be used as any other HTML element (without name conflicts with other form elements!):

```
[..., textfield nref "", hrule] ++ mail_epilog ++ ...
```

HTML/CGI PROGRAMMING

The main form is executed by a wrapper function

`runcgi :: String -> IO HtmlForm -> IO ()`

- ➜ takes a title string and a form and transforms it into HTML text
- ➜ replaces all CGI references by unique strings
- ➜ decodes input values and invokes associated event handler

Event handlers return forms rather than HTML expressions

- ➜ sequences of interactions
- ➜ use control abstractions (branching, recursion) of underlying language
- ➜ state between interactions handled by CGI environments

Note: no language extension necessary (CGI library)

multi-paradigm languages as scripting languages

IMPLEMENTATION

- ➜ completely implemented in Curry
- ➜ standard CGI programming features used
- ➜ no server extension, usable with any standard web server, no cookies
- ➜ available as library for

  PAKCS (Portland Aachen Kiel Curry System)

  `http://www.informatik.uni-kiel.de/~pakcs`
- ➜ based on a Curry→Prolog compiler [Antoy/Hanus FroCoS'00]

Applications:

- ➜ web pages for Curry
- ➜ access to distributed address server [PPDP'99]
- ➜ submission form for JFLP

  (Journal of Functional and Logic Programming)
- ➜ questionaires for students
- ➜ testing home assignments of students
- ➜ . . .

CONCLUSIONS

Domain-specific language for HTML/CGI programming (CGI library)

Exploit functional and logic features for

- ➜ correct HTML coding (data type for HTML structures)
- ➜ simple access to input values (free variables and environments)
- ➜ simple programming of interactions (event handlers)
- ➜ wrapper for hiding details

Curry supports appropriate abstractions for software development

Other examples:

- ➜ GUI programming [PADL'00]
- ➜ FL parser combinators [Caballero/Lopez-Fraguas FLOPS'99]

More infos on Curry:

`http://www.informatik.uni-kiel.de/~curry`