Build your own DSL with Rascal

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CWI

Rascal = Functional Metaprogramming language

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- Immutable values
- Higher order functions
- Static safety, with local type inference

Rascal = Functional Metaprogramming

???

Metaprogramming

From Wikipedia, the free encyclopedia

Metaprogramming is a programming technique in which computer programs have the ability to treat other programs as their data. It means that a program can be designed to read, generate, analyze or transform other programs […]

Rascal = Functional Metaprogramming

- “Code as data”
- Program that generates/analyzes other programs
- Syntax definitions and parsing
- Pattern matching and rewriting mechanisms
- Visiting / traversal of Tree structure

Rascal can be used for…

Forward Engineering
(Prototyping, DSL development)

Reverse Engineering
(Analysis, detectors, renovations)

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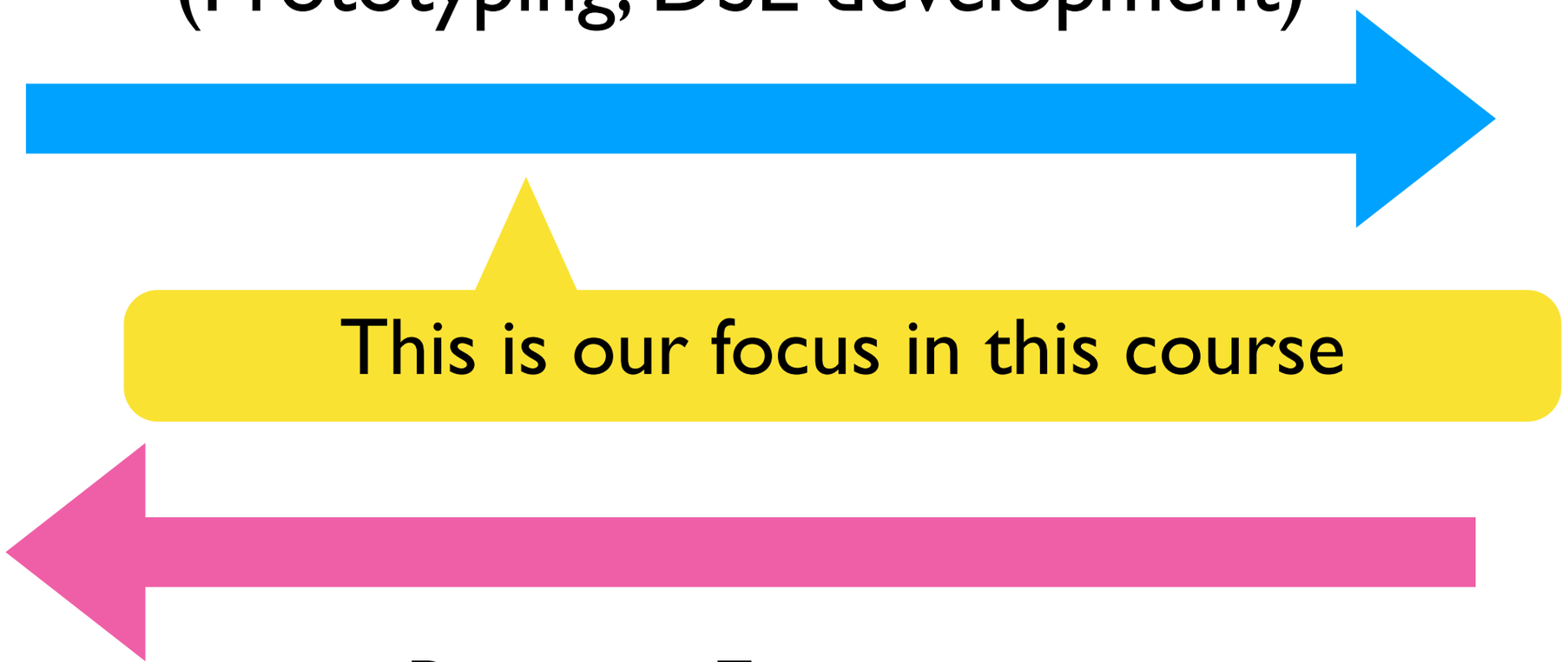
Forward Engineering
(Prototyping, DSL development)



Reverse Engineering
(Analysis, detectors, renovations)

Why learn *yet* another new language?


Java
Grep
ANTLR
awk

Basic concepts

Functional immutability with an imperative syntax

- All data is immutable

- Can write code that looks like ‘mutating variables’

Functional immutability with an imperative syntax

- **All data is immutable**

- Can write code that looks like ‘mutating variables’

Common Data Types

- e.g. Sets, Lists, Maps, Tuples and Relations
  - `{1,2,3}`
  - `[1,2,3]`
  - `(1:2, 3:4)`
  - `{<“a”, “b”>, <“b”, “c”>}`
- Can all be used in comprehensions
  - `{ i*i | int i ← [1..10] } etc.`

Source Locations

- Provide a uniform way to represent files on local or remote storage

- Can have different schemes
  - `file:///`
  - `project://`
  - `http://`
  - etc …

- Can contain text location markers

- `|project://rascal-dsl-crashcourse/examples/errors.myql|(0,471,<1,0>,<21,1>)`

Pattern Matching

- Determines whether pattern matches a given value
- One of Rascal's most powerful features
- Can bind matches to local variables
- Can be used in many places
- May result in multiple matches so employs local backtracking

Different types of matching

type-based matching

```
int x := 3;
```

structural matching

```
event(x, y) := event("a", "b");
```

anti-matching

```
event("c", "d") !:= event("a", "b");
```

list matching

```
[*x, 1, *y] := [5, 6, 1, 1, 1, 3, 4];
```

set matching

```
{1, *x} := {4, 5, 6, 1, 2, 3};
```

deep matching

```
/transition(e, "idle") := ast;
/state(x, _, /transition(_, x)) := ast;
```

element matching

```
3 ← {1,2,3}
int x ← {1,2,3}
```

regular expressions

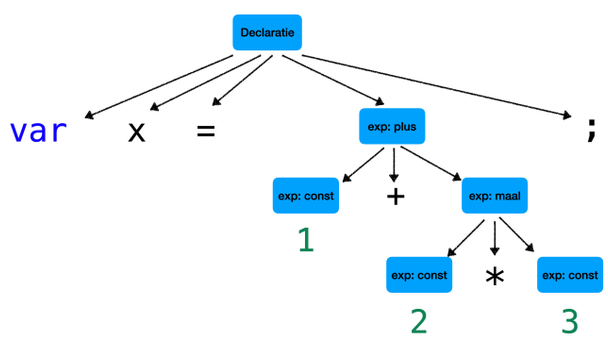
```
/[A-Za-z]*/ := “09090aap noot mies”
```

Tools for Language Engineering

Basic language pipe line

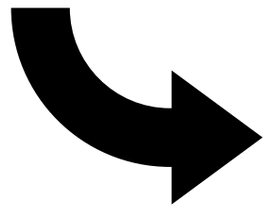
```
var x = 1 + 2 * 3;
```

Parse



Check

Execute



Result

Describes all possible strings which can be produced

```
start syntax Program = "begin" Stat* "end";

syntax Statement
  = "i                  " Stat* "else" Stat* "fi"
  | Id
  | "while" Expression "do" Stat* "od"
  ;

syntax Expression
  = Id
  | "(" Expression ")"
  | left Expression "*" Expression
                    on "+" Expression

lex                                  -9\-]*;

layout Whitespace = [\ \t\n\r]*;
```

Nonterminal

Terminal

Layout characters

Tips and Tricks

Common errors
Undeclared variable

- Forgetting to import a module, i.e.:

- Function is declared private

```
rascal>l = [1,2,3];
list[int]: [1,2,3]
rascal>size(l);
|prompt:///|(0,4,<1,0>,<1,4>): Undeclared variable: size
Advice: |http://tutor.rascal-mpl.org/Errors/Static/UndeclVariable.html|
```

- Solution for above example: `import List;`

Common errors
CallFailed

- Calling a function with the wrong arguments

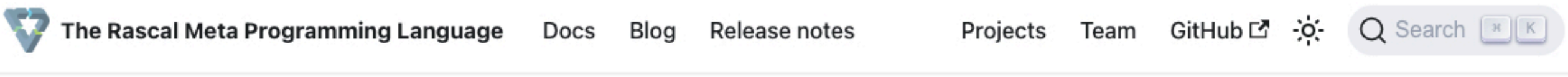
```
void someFunc(str a) {
  println(a);
}
```

```
rascal>someFunc("a");
a
ok
rascal>someFunc(2);
|prompt:///|(9,1,<1,9>,<1,10>): CallFailed(
  |prompt:///|(9,1,<1,9>,<1,10>),
  [2])
        at $root$(|prompt:///|(0,12,<1,0>,<1,12>))
```

Looking for how you can do stuff in Rascal?

Browse and search the documentation

- https://www.rascal-mpl.org/docs/GettingStarted/



The Rascal cheatsheet

Rascal Cheat Sheet

http://www.rascal-mpl.org
https://github.com/usethesource/rascal

Modules

```
module Example

import ParseTree;         // import
extend lang::std::Layout; // "inherit"
```

Declarations

```
// Algebraic data types (ADT)
data Exp
  = var(str x)         // unary constructor
  | add(Exp l, Exp r); // binary constructor

data Person        // keyword parameter
  = person(int id, bool married=false);

alias Age = int; // type alias

anno loc Exp@location; // annotation

private real PI = 3.14; // variables

// Functions:  signatures are lists of patterns
// May have keyword parameters.
void f(int x) { println(x); }      // block style
int inc(int x) = x+1;              // rewrite style
int inc0(int x) = x+1 when x == 0; // side condition
default int inc0(int x) = x;       // otherwise

// Test functions (invoke from console with :test)
test bool add() = 1+2 == 3;

// randomized test function
test bool comm(int x, int y) = x+y == y+x;

// Foreign function interface to Java
@javaClass{name.of.javaClass.with.Method}
java int method();
```

```
// Context-free grammars
start syntax Prog       // start symbol
  = prog:  Exp* exps    // production
  | stats:  {Stat ";"}* // separated list
  | stats:  {Stat ";"}+ // one-or-more sep.  list
  | "private"?  Func;   // optional

syntax Exp
  = var:  Id
  | left mul:  Exp l "*" Exp r     // or right, assoc
  | left div:  Exp!div "/" Exp!div // reject
  > left add:  Exp l "+" Exp r     // ">" = priority
  | bracket "(" Exp ")";

lexical Comment
  = ^"#" ![\n]* $; // begin/end markers

lexical Id
  = ([a-zA-Z] !<<         // look behind restriction
    [a-zA-Z][a-zA-Z0-9_]* // character classes
    !>> [a-zA-Z0-9_])     // lookahead restriction
    \ Reserved;           // subtract keywords

layout Layout // for whitespace/comments
  = [\ \t\n\r]*;

keyword Reserved   // keyword class
  = "if" | "else"; // finite langs
```

Statements

```
// Standard control-flow
if (E) S;
if (E) S; else S;
while (E) S;
do S; while(E);
continue; break;
return; return E;

// Loop over all bindings produce by patterns
for (i <- [0..10]) S; // Loop 10 times

fail;     // control backtracking
append E; // add to loop result list
```

```
// Pattern-based switch-case
switch (E) {
  case P: S;   // do something
  case P => E  // rewrite it
  default:  S; // otherwise
}

// Traversal with visit; like switch, but matches
// at arbitrary depth of value
visit (E) {
  case P: S;  // do something
  case P => E // rewrite something
  case P => E when E
}
insert E; // rewrite subject as statement

// Strategies:  bottom-up, innermost, outermost,
// top-down-break, bottom-up-break
top-down visit (E) {}

try S;      // pattern-based try-catch
catch P: S; // match to catch
finally S;

throw E; // throw values

// Fix-point equation solving;
// iterates until all params are stable
solve (out,ins) {
  out[b] = ( {} | it + ins[s] | s <- succ[b] );
  ins[b] = (out[b] - kill[b]) + gen[b];
};

x = 1;               // assignment
nums[0] = 1;         // subscript assignment
nums[1,3..10] = 2;   // sliced (see below)
p.age = 31;          // field assignment
ast@location = l;    // annotation update
<p, a> = <"ed", 30>; // destructuring

// A op=E  == A = A op E
A += E; A -= E; A *= E;
A /= E; A &= E;
```

https://github.com/cwi-swat/rascal-cheat-sheet/raw/master/sheet.pdf

Questionnaire Language

```
form taxOfficeExample {
  "Did you buy a house in 2010?"
    hasBoughtHouse: boolean

  "Did you enter a loan?"
    hasMaintLoan: boolean

  "Did you sell a house in 2010?"
    hasSoldHouse: boolean

  if (hasSoldHouse) {
    "What was the selling price?"
      sellingPrice: integer
    "Private debts for the sold house:"
      privateDebt: integer
    "Value residue:"
      valueResidue: integer =
        sellingPrice - privateDebt

  }
}
```

Aangifte inkomstenbelasting 2010 – Persoonlijke gegevens

- ✓ Persoonlijke gegevens: Bla
- ✓ Persoonlijke gegevens: Blasa
- ✓ Box 1: werk en woning
- Box 1: andere inkomsten
- Box 1: uitgaven lijfrenten e.d.
- Box 2: aanmerkelijk belang
- Box 3: sparen en beleggen
- Aftrekposten
- Vrijstellingen en verminderingen
- Bijzondere situaties
- Te verrekenen bedragen
- Heffingskortingen: Bla
- Overzicht: Bla
- Voorlopige aanslag 2011
- Naar ondertekenen met DigiD

IB 602E - 2Z01FOL2A

Persoonlijke gegevens

Naam: Bla

Telefoonnummer: 323

Burgerservicenummer/sofinummer: 1430.95.067

? Geboortedatum: 11-02-1979

? Nummer belastingconsulent:

? Hebt u van ons bericht ontvangen om aangifte te doen? ○ Ja ● Nee

Wilt u een rekeningnummer opgeven of wijzigen? ○ Ja ● Nee

? Uw persoonlijke situatie in 2010: Een deel van 2010 getrou...

? Periode dat u getrouwd was in 2010: 01-02 03-05

? Woonde u voor of na deze periode samen met uw echtgenoot? ○ Ja ● Nee

? Willen u en uw echtgenoot heel 2010 als fiscale partners worden beschouwd? ○ Ja ● Nee

? Woonde u buiten de periode dat u getrouwd was nog met iemand anders samen? Bijvoorbeeld met uw kind van 27 jaar of ouder? ○ Ja ● Nee

Akkoord

Stoppen | Instellingen | Rekenmachine | Help | Printen | Open bestand

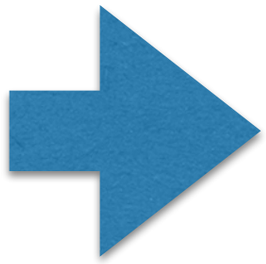
```
form taxOfficeExample {
  "Did you sell a house in 2010?"
    hasSoldHouse: boolean

  "Did you buy a house in 2010?"
    hasBoughtHouse: boolean

  "Did you enter a loan?"
    hasMaintLoan: boolean

  if (hasSoldHouse) {
    "What was the selling price?"
      sellingPrice: integer
    "Private debts for the sold house:"
      privateDebt: integer
    "Value residue:"
      valueResidue: integer =
        sellingPrice - privateDebt

  }
}
```



Did you sell a house in 2010?

Yes

Did you buy a house in 2010?

Choose an answer

Did you enter a loan?

Choose an answer

What was the selling price?

100

Private debts for the sold house:

200

Value residue:

-100.00

Submit taxOfficeExample

Tutorial (1 hour)

Open `tutorial/Series1.rsc`, click on `Run in new Rascal terminal` (top of editor). Fill in the blanks of the functions, and execute in the terminal. If you have time left, move on to `Series2.rsc`. Documentation can be found here. See also the cheat-sheet in the `slides` folder.

QL Exercises (3 hours total)

Each task corresponds to a Rascal module, see each module for an explanation:

- `Syntax.rsc`: syntax definition (grammars and parsing)
- `Check.rsc`: type checking
- `Eval.rsc`: semantics
- `App.rsc`: execution (run QL as a Salix web app)

Optional (if there's time left): extend the language with a `date` question type and revisit all the modules to adapt type checking, interpretation, and execution to support it.

https://github.com/cwi-swat/rascal-dsl-crashcourse

- 10:00-11:00 Intro lecture + tutorial (warm-up)
- 11:00-11:15 *break*
- 11:15-12:15 syntax
- 12:15-13:30 *lunch*
- 13:30-13:45 recap
- 13:45-14:45 type checking
- 14:45-15:00 *break*
- 15:00-16:00 evaluation and execution
- 16:00-16:30 wrap up