EASY Meta-Programming with Rascal

Leveraging the Extract-Analyze-SYnthesize Paradigm

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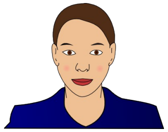
Cast of Our Heroes

- Alice, system administrator

- Bernd, forensic investigator

- Charlotte, financial engineer



- Daniel, multi-core specialist

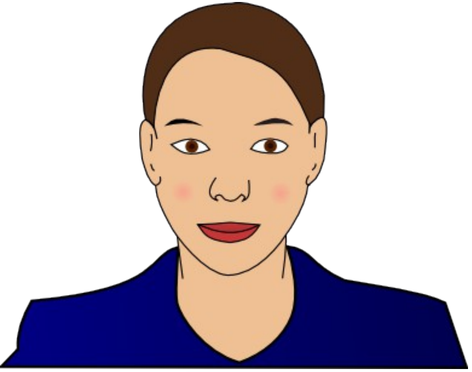
- Elisabeth, model-driven engineering specialist

Meet Alice

- Alice is security administrator at a large online marketplace
- Objective: look for security breaches
- Solution:
    - Extract relevant information from system log files, e.g. failed login attempts in Secure Shell
    - Extract IP address, login name, frequency, …
    - Synthesize a security report

Meet Bernd

- Bernd: investigator at German forensic lab
- Objective: finding common patterns in confiscated digital information in many different formats. This is very labor intensive.
- Solution:
  - Design DERRICK a domain-specific language for this type of investigation
  - Extract data, analyze the used data formats and synthesize Java code to do the actual investigation



Meet Charlotte

- Charlotte works at a large financial institution in Paris
- Objective: connect legacy software to the web
- Solution:
  - extract call information from the legacy code, analyze it, and synthesize an overview of the call structure
  - Use entry points in the legacy code as entry points for the web interface
  - Automate these transformations

Meet Daniel

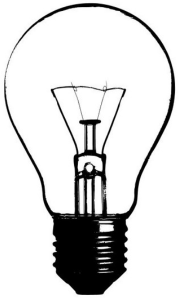
- Daniel is concurrency researcher at one of the largest hardware manufacturers worldwide
- Objective: leverage the potential of multi-core processors and find concurrency errors
- Solution:
  - extract concurrency-related facts from the code (e.g., thread creation, locking), analyze these facts and synthesize an abstract automaton
  - Analyze this automaton with third-party verification tools

Meet Elisabeth

- Elisabeth is software architect at an airplane manufacturer
- Objective: Model reliability of controller software
- Solution:
  - describe software architecture with UML and add reliability annotations
  - Extract reliability information and synthesize input for statistics tool
  - Generate executable code that takes reliability into account

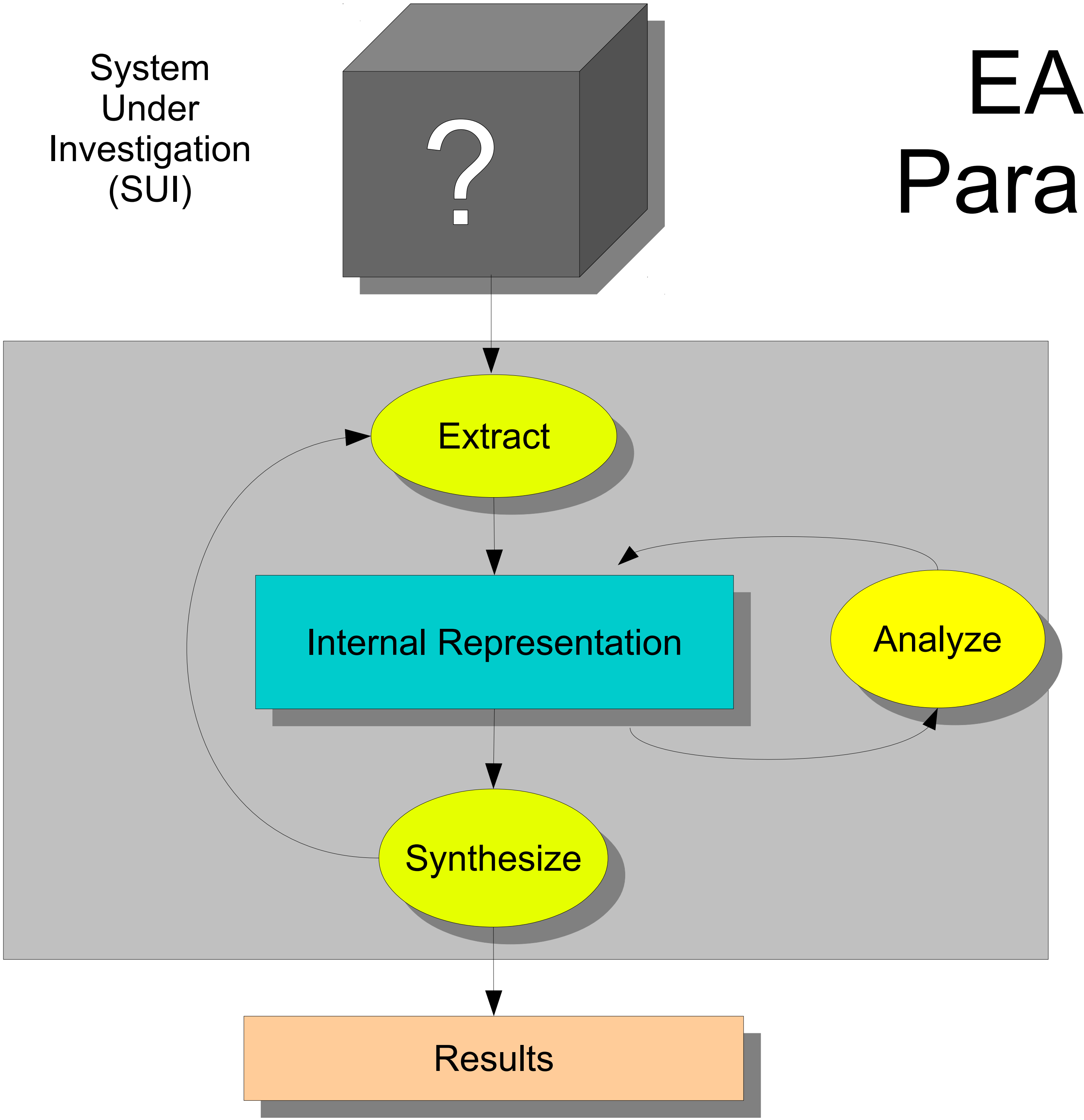
What are their *Technical Challenges*?

- How to parse source code/data files/models?
- How to extract facts from them?
- How to perform computations on these facts?
- How to generate new source code (trafo, refactor, compile)?
- How to synthesize other information?



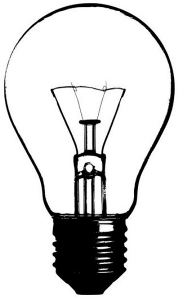
EASY: Extract-Analyze-SYnthesize Paradigm

EASY Paradigm



Why a new Language?

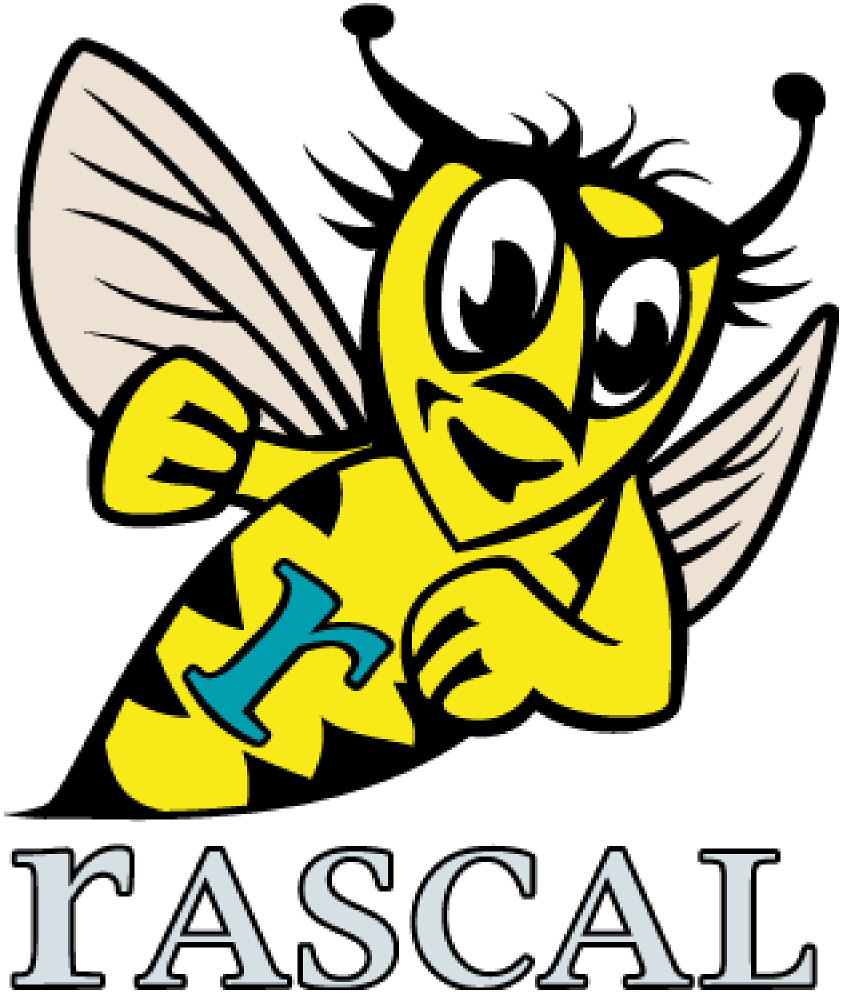
- No current technology spans the full range of EASY steps
- There are many fine technologies but they are
  - highly specialized with steep learning curves
  - hard to learn unintegrated technologies
  - not integrated with a standard IDE
  - hard to extend



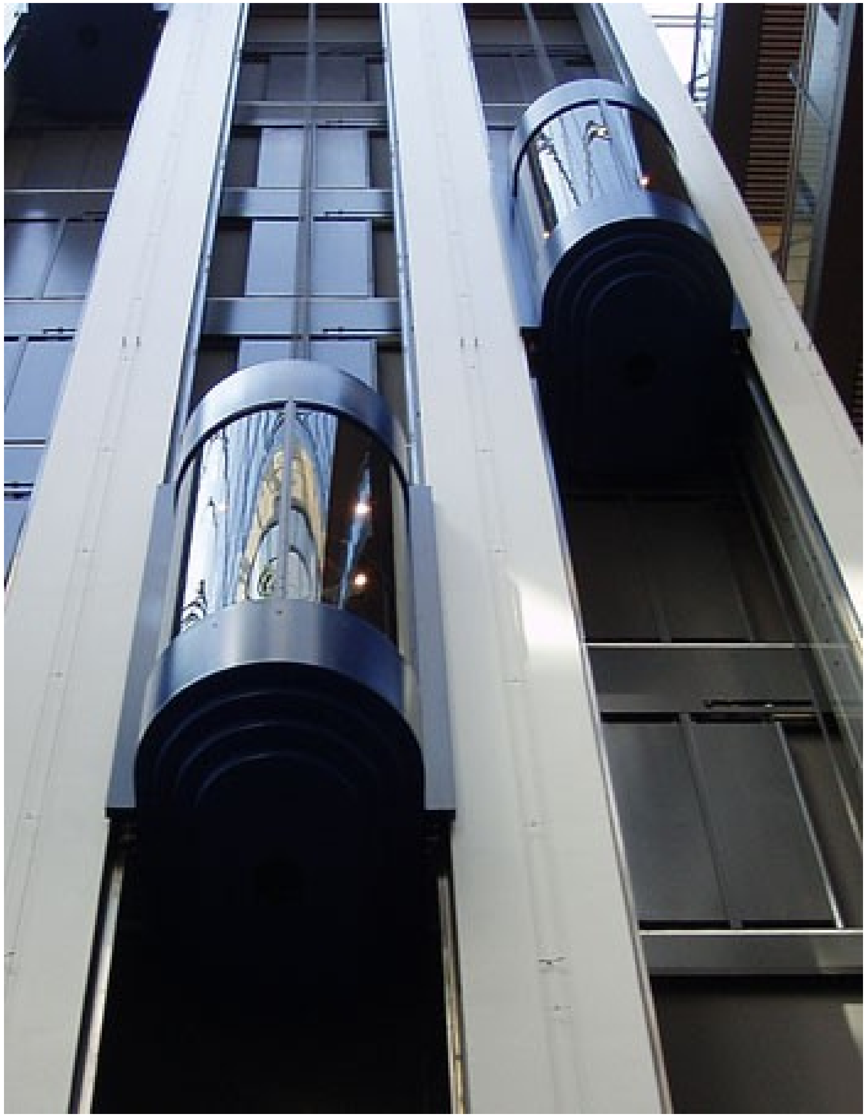
Goal

Keep all benefits of ASF+SDF and Rscript in a **new**, **unified**, **extensible**, **teachable** framework

Here comes Rascal to the Rescue



Rascal Elevator Pitch



Rascal Elevator Pitch

- Sophisticated built-in data types
- Immutable data
- Static safety
- Generic types
- Local type inference
- Pattern Matching
- Syntax definitions and parsing
- Concrete syntax
- Visiting/traversal
- Comprehensions
- Higher-order
- Familiar syntax
- Java and Eclipse integration
- Read-Eval-Print (REPL)


HOW EXCITING!! PLEASE TELL ME MORE!!

Rascal ...

- is a new language for meta-programming
- is based on *Syntax Analysis*, *Term Rewriting*, *Relational Calculus*
- extended super set (regarding features not syntax!) of ASF+SDF and Rscript
- relations used for sharing and merging of facts for different languages/modules
- embedded in the Eclipse IDE
- easily extensible with Java code

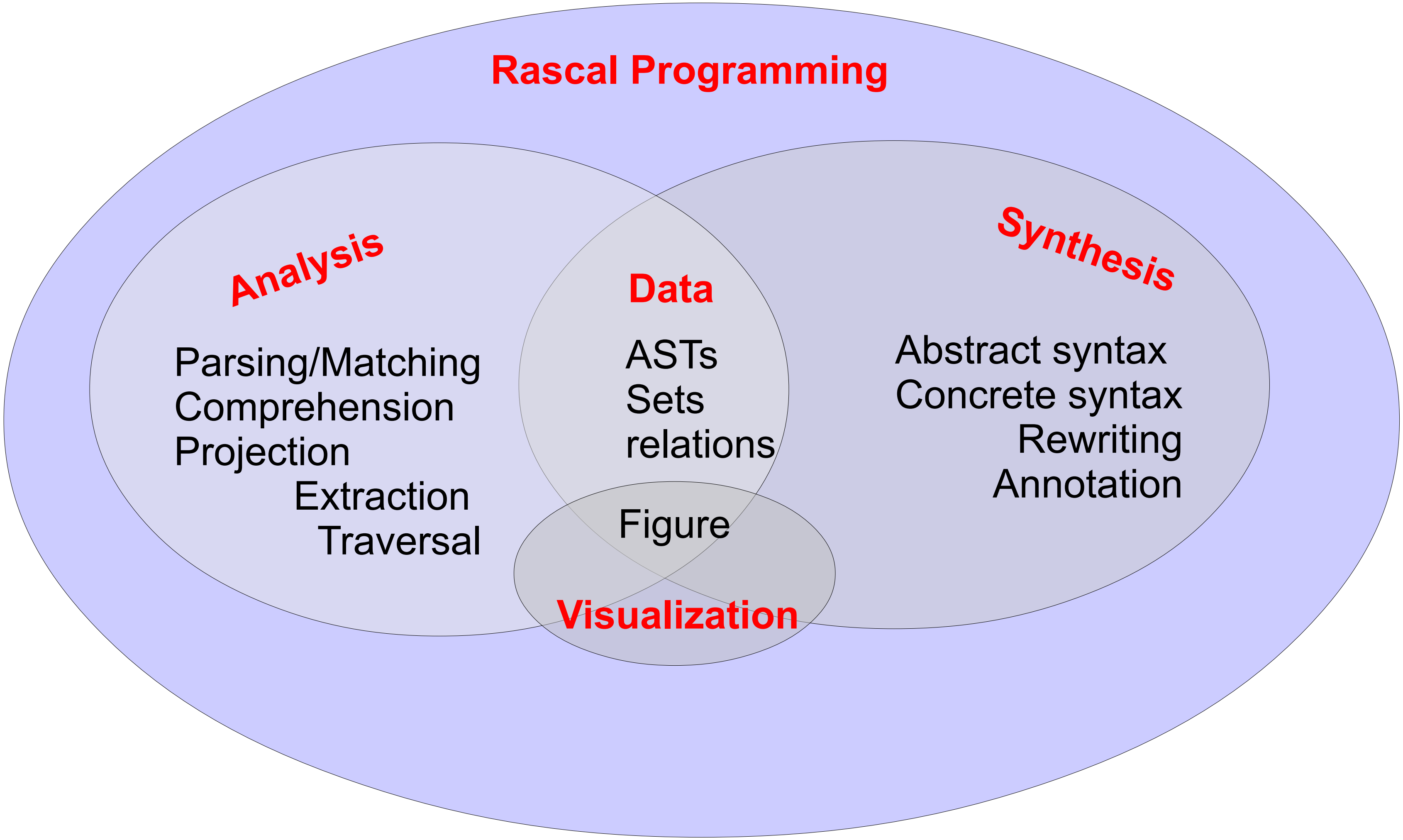
Rascal design based on ...

- **Principle of least surprise**
  - Familiar (Java-like) syntax
  - Imperative core
- **What you see is what you get**
  - No heuristics (or at least as few as possible)
  - *Explicit* preferred over *implicit*
- **Learnability**
  - Layered design
  - Low barrier to entry

Rascal provides

- Rich (immutable) data: lists, sets, maps, tuples, relations, ... with comprehensions and many operators
- Syntax definitions & parser generation
- Syntax trees, tree traversal
- Pattern matching (text, trees, lists, sets, ...) and pattern-directed invocation
- Code generation (string templates & trees)
- Java and Eclipse (IMP) integration

Bridging Gaps



Rascal Programming

Analysis

Parsing/Matching
Comprehension
Projection
Extraction
Traversal

Data

ASTs
Sets
relations

Synthesis

Abstract syntax
Concrete syntax
Rewriting
Annotation

Figure

Visualization

One-stop-shop

Cool parsers

Deal of the day:
Cheap type checkers

Fancy visualization

Just in: new modeling gadgets

Some Classical Examples

- Read-Eval-Print
- Hello
- Factorial
- ColoredTrees

Read-Eval-Print

```
rascal>1 + 1
int: 2

rascal>[1,2,3]
list[int]: [1,2,3]

rascal>[1,2,3] + [9,5,1]
list[int]:[1,2,3,9,5,1]
```

List concatenation

Read-Eval-Print

```
rascal>{1,2,3}
set[int]: {1,2,3}

rascal>{1,2,1}
set[int]: {1,2}

rascal>{1,2,3} + {9,5,1}
set[int]:{1,2,3,9,5}
```

Sets do not contain duplicates

Set union

Read-Eval-Print

Set comprehension

```
rascal>{i*i|i <- [1..10]}
set[int]: {1,4,9,16,25,36,...}

rascal>{i*i|i <- [1..10],t%2==0}
set[int]: {4,16,36,...}
```

Read-Eval-Print

String interpolation

```
rascal>import IO;
ok
rascal>for (i <- [1..10]) {
>>>>>>>  println("<i> * <i> = <i * i>");
>>>>>>>}
1 * 1 = 1
2 * 2 = 4
3 * 3 = 9
4 * 4 = 16
5 * 5 = 25
6 * 6 = 36
7 * 7 = 49
8 * 8 = 64
9 * 9 = 81
10 * 10 = 100
list[void]: []
```

Hello (on the command line)

```
rascal > import IO;
ok

rascal> println(“Hello, my first Rascal program”);
Hello, my first Rascal program
ok
```

Hello (as function in module)

```
module demo::basic::Hello
import IO;
public void hello() {
  println(“Hello, my first Rascal program”);
}
```

```
rascal > import demo::basic::Hello;
ok

rascal> hello();
Hello, my first Rascal program
ok
```

Factorial

```
module demo::Factorial
public int fac(int N){
  return N <= 0 ? 1 : N * fac(N - 1);
}
```

```
rascal> import demo::Factorial;
ok

rascal> fac(47);
int: 2586232415111681806429643551536119799
69197632389120000000000
```

Types and Values

- Atomic: bool, num, int, real, str, loc (source code location), datetime
- Structured: list, set, map, tuple, rel (n-ary relation), abstract data type, parse tree
- Type system:
  - Types can be parameterized (polymorphism)
  - All function signatures are explicitly typed
  - Inside function bodies types can be inferred (local type inference)

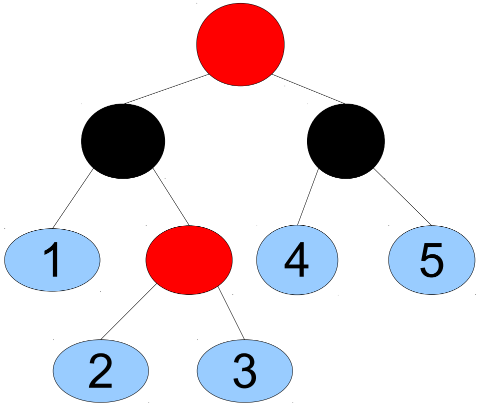
Type	Example
bool	true, false
int, real	1, 0, -1, 123, 1.023e20, -25.5
str	“abc”, “values is <x>”
loc	|file:///etc/passwd|
datetime	$2010-07-15T09:15:23.123+03:00
tuple[t_1, …, t_n]	<1,2>, <“john”, 43, true>
list[*t*]	[], [1], [1,2,3], [true, 2, “abc”]
set[*t*]	{}, {1,3,5,7}, {“john”, 4.0}
rel[t_1, …, t_n]	{<1,10,100>,<2,20,200>}
map[*t*, *u*]	(), (“a”:1, “b”:2,”c”:3)
node	f, add(x,y), *g*(“abc”,[2,3,4])

User-defined datastructures

- Named alternatives
  - name acts as constructor
  - can be used in patterns
- Named fields (access/update via . notation)
- All datastructures are a subtype of the standard type `node`
  - Permits very generic operations on data
- Parse trees resulting from parsing source code are represented by the datatype `ParseTree`

ColoredTrees: *CTree*

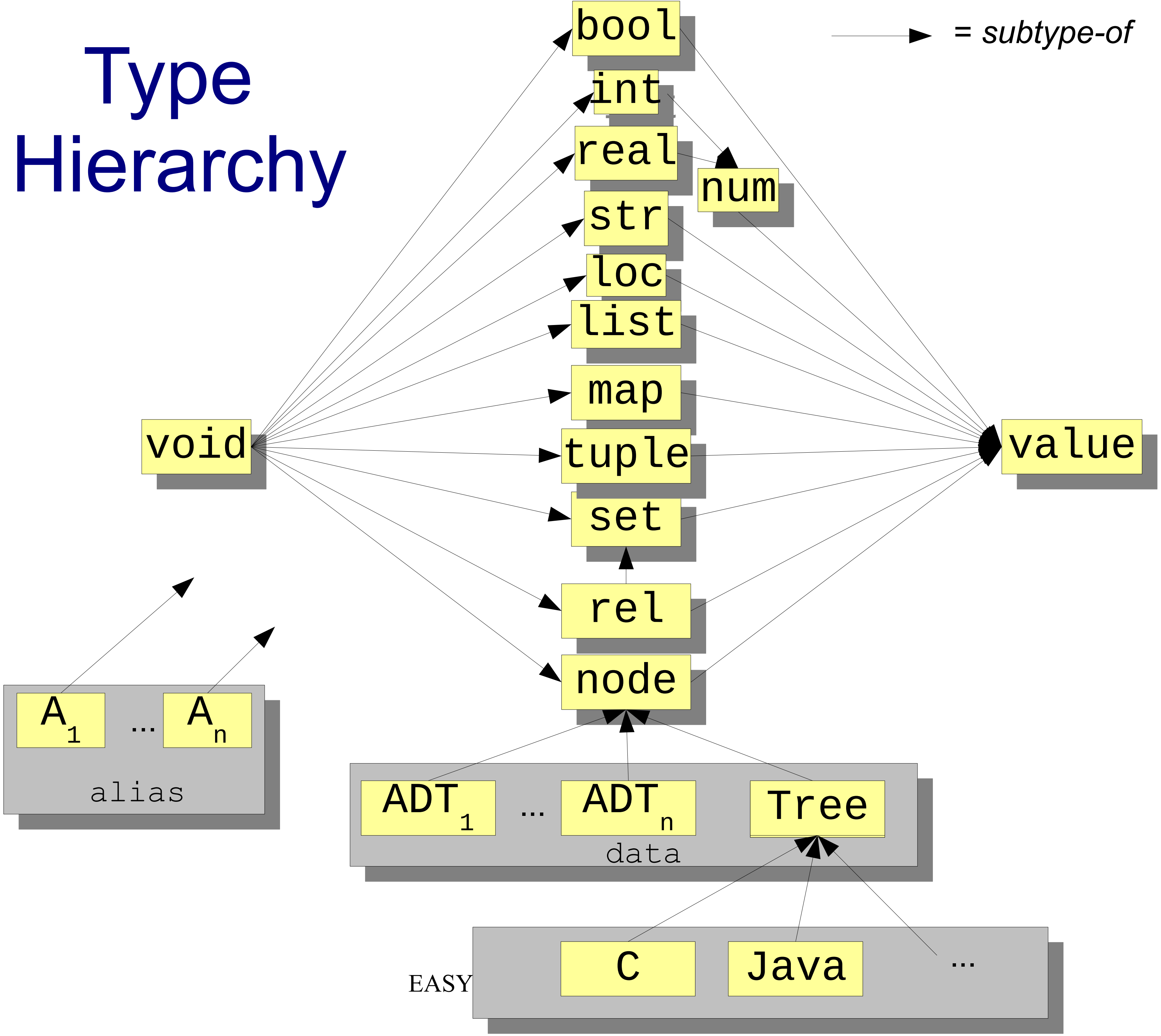
```
data CTree =  leaf(int N)
            | red(CTree left, CTree right)
            | black(Ctree left, Ctree right) ;

rb = red(black(leaf(1), red(leaf(2), leaf(3))),
         black(leaf(4), leaf(5)));
```



Abstract Syntax

```
data STAT = asgStat(Id name, EXP exp)
          | ifStat(EXP exp,list[STAT] thenpart,
                           list[STAT] elsepart)
          | whileStat(EXP exp, list[STAT] body)
          ;
```

Type Hierarchy



Pattern matching

Given a pattern and a value:

- Determine whether the pattern matches the value
- If so, bind any variables occurring in the pattern to corresponding subparts of the value

Pattern matching

Pattern matching is used in:

- Explicit match operator `Pattern := Value`
- Switch: matching controls case selection
- Visit: matching controls visit of tree nodes

Patterns

Regular: Grep/Perl like regular expressions

```
/^<before:\W*><word:\w+><after:.*$>/
```

Abstract: match data types

```
whileStat(Exp, Stats*)
```

Concrete: match parse trees

```
` while <Exp> do <Stats*> od `
```

Regular Patterns

```
rascal>/[a-z]+/ := "abc"
bool: true

rascal>/rac/ := "abracadabra";
bool: true

rascal>/^rac/ := "abracadabra";
bool: false

rascal>/rac$/ := "abracadabra";
bool: false
```

Regular Patterns

```
rascal>if(/\W<x:[a-z]+>/ := "12abc34")
          println("x = <x>");
ok
```

- Matches non-word characters (`\W`) followed by one or more letters.
- Binds text matched by `[a-z]+` to variable `x`. (Is only available in the body of the if statement)
- Prints: `abc`.
- Regular patterns are tricky (in any language)!

Patterns

Abstract/Concrete patterns support:

- List matching: [P1, ..., Pn]
- Set matching: {P1, ..., Pn}
- Named subpatterns: N:P
- Anti-patterns: !P
- Descendant: /N

Can be combined/nested in arbitrary ways

List Matching

```
rascal> L = [1, 2, 3, 1, 2];
list[int]: [1,2,3,1,2]

rascal> [X*, 3, X] := L;
bool: true

rascal> X;
Error: X is undefined

rascal> if([X*, 3, X] := L) println("X = <X>");
X = [1, 2]
ok
```

List pattern

X* is a list variable and abbreviates list[int] X

X is bound but has limited scope

List matching provides **associative** (A) matching

Set Matching

```
rascal> S = {1, 2, 3, 4, 5};
set[int]: {1,2,3,4,5}

rascal> {3, Y*} := S;
bool: true

rascal> if({3, Y*} := S) println(“Y = <Y>”);
Y = {5,4,2,1}
ok
```

Set pattern

Y* is a set variable and abbreviates `set[int] Y`

Set matching provides
associative, **commutative**, **identity** (ACI) matching

Note

- List and Set matching are non-unitary
- E.g., [L*, M*] := [1, 2] has three solutions:
  - L == [ ],   M == [1,2]
  - L == [1],   M == [2]
  - L == [1,2], M == [ ]
- In boolean expressions, matching, etc. solutions are generated when failure occurs later on (local backtracking)
- Side effects are undone (using recovery cache)

Descendant Matching

```
whileStat(_, /ifStat(_,_,_))
```

Match a while statement that contains an if statement at arbitrary depth

Enumerators and Tests

- Enumerate the elements in a value
- Tests determine properties of a value
- Enumerators and tests are used in comprehensions

Enumerators

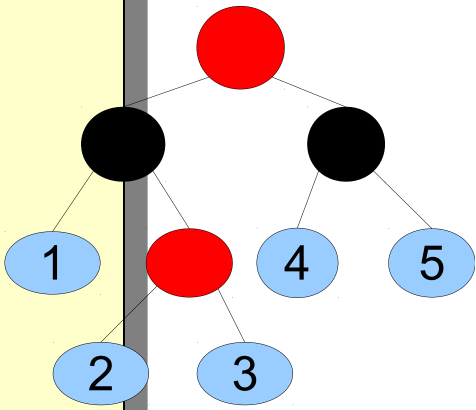
- Elements of a list or set
- The tuples in a relation
- The key/value pairs in a map
- The elements in a datastructure (in various orders!)

```
int x <- { 1, 3, 5, 7, 11 }
int x <- [ 1 .. 10 ]
asgStat(Id name, _) <- P
```

Comprehensions

- Comprehensions for lists, sets and maps
- Enumerators generate values; tests filter them

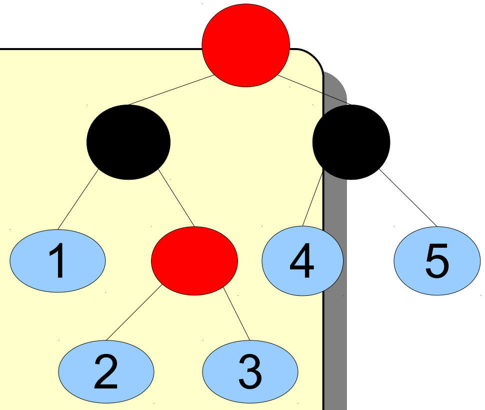
```
rascal> {n * n | int n ← [1 .. 10], n % 3 == 0};
set[int]: {9, 36, 81}

rascal> [ n | /leaf(int n) ← rb ];
list[int]: [1,2,3,4,5]

rascal> {name | /asgStat(id name, _) ← P};
{ ... }
```



Control structures

- Combinations of enumerators and tests drive the control structures
- for, while, all, one

```
rascal> for(/int n ← rb, n > 3){ println(n);}
4
5
ok
rascal> for(/asgStat(Id name, _) ← P, size(name)>10){
    println(name);
}
...
```



Switching

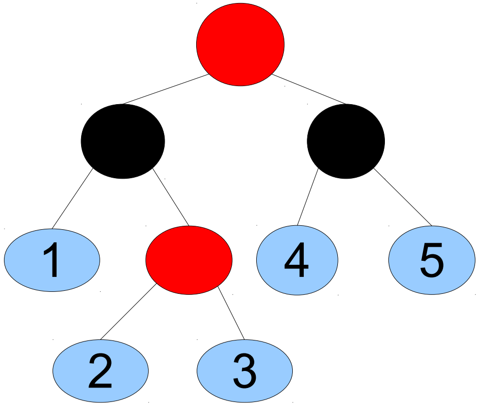
- A *switch* does a top-level case distinction

```
switch (P){
case whileStat(EXP Exp, Stats*):
     println("A while statement");
case ifStat(Exp, Stats1*, Stat2*):
     println("An if statement");
}
```

Visiting

- Recall the visitor design pattern:
  - Decouples traversal, and
  - Action per visited node
- A `visit` does a complete traversal

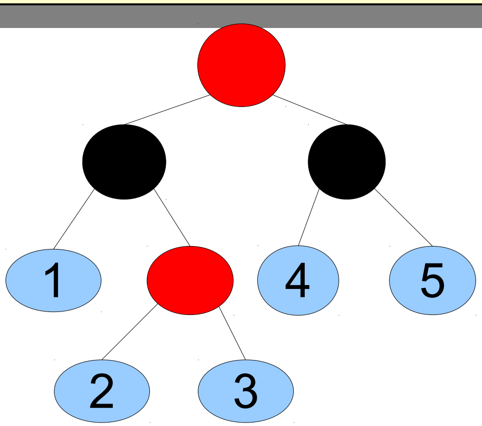
Recall the coloured trees (`CTree`):



Count all Red Nodes (switch + recursion)

```
public int cntRed(CTree t) {
  switch(t){
    case leaf(_): return 0;
    case red(l,r): return 1 + cntRed(l) + cntRed(r);
    case black(l,r): return cntRed(l) + cntRed(r);
  };
}
```

cntRed(



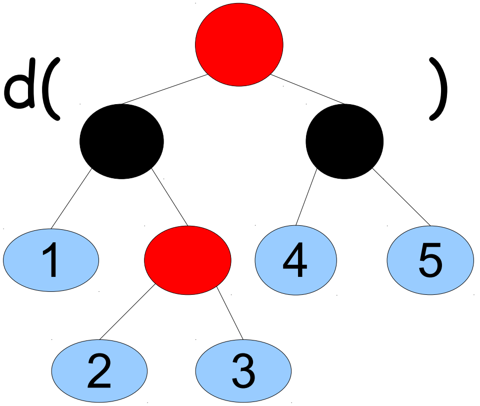
=> 2

Count all Red Nodes (using visit)

```
public int cntRed(CTree t) {
  int c = 0;
  visit(t){
    case red(_,_): c += 1;
  };
  return c;
}
```

Visit traverses the complete tree and modifies c

cntRed(



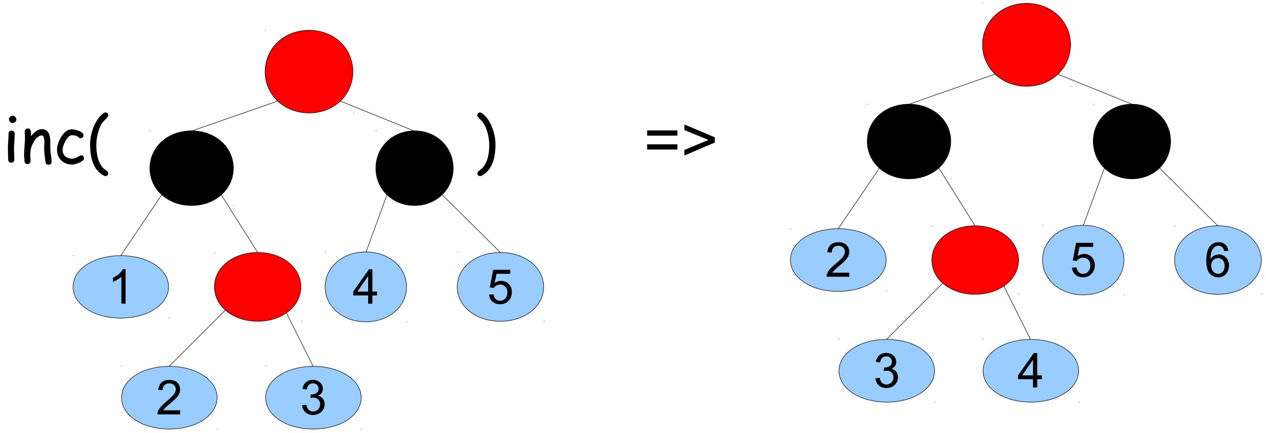
) => 2

Increment all leaves in a CTree

```
public CTree inc(CTree T) {
   return visit(T) {
     case int N => N + 1;
   };
}
```

Visit traverses the complete tree and returns modified tree

Matching by cases and local subtree replacement



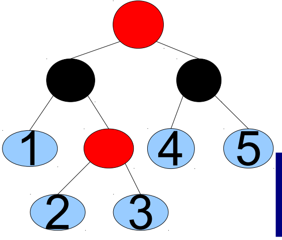
Note

- This code is insensitive to the number of constructors
  - Here 3: `leaf`, `black` and `red`
  - In Java or Cobol: hundreds
- Lexical/abstract/concrete matching
- List/set matching
- Visits can be parameterized with a strategy

Let's add green nodes

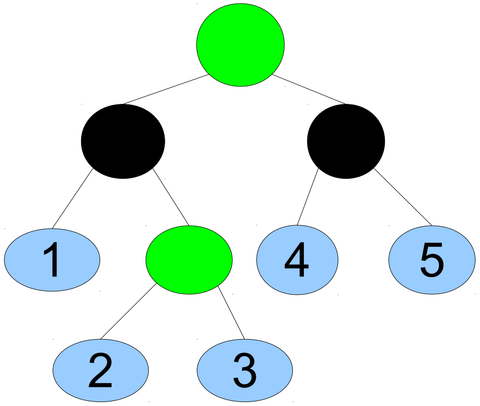
```
data CTree green(CTree left, CTree right);
```

Problem: convert **red** nodes into **green** nodes

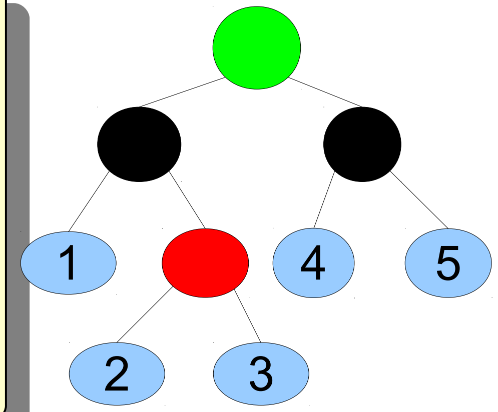


Full/shallow/deep replacement

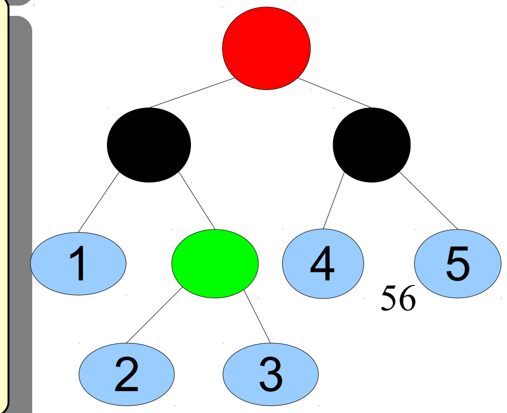
```
public CTree frepl(CTree T) {
    return visit (T) {
       case red(CTree T1, Ctree T2) =>  green(T1, T2)
    };
}
```



```
public Ctree srepl(CTree T) {
    return top-down-break visit (T) {
       case red(CTree T1, Ctree T2) =>  green(T1, T2)
    };
}
```



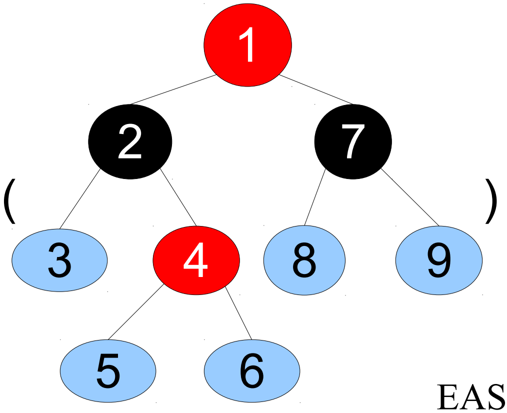
```
public Ctree drepl(Ctree T) {
    return bottom-up-break visit (T) {
       case red(Ctree T1, Ctree T2) =>  green(T1, T2)
    };
}
```



Different ways to Traverse a Tree,1

```
data CTree = leaf(int N)
           | red(int N, CTree left, CTree right)
           | black(int N, CTree left, CTree right);

public list[int] getLeaves1(CTree t){
   switch(t) {
     case leaf(n):      return [n];
     case black(n,l,r): return [n] + getLeaves1(l) + getLeaves1(r);
     case red(n,l,r):   return [n] + getLeaves1(l) + getLeaves1(r);
   };
}
```

getLeaves1(

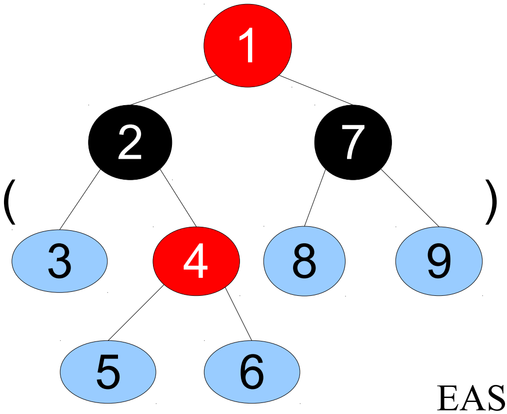


) = `[1,2,3,4,5,6,7,8,9]`

Different ways to Traverse a Tree,2

```
data CTree = leaf(int N)
           | red(int N, CTree left, CTree right)
           | black(int N, CTree left, CTree right);
```

```
public list[int] getLeaves2(CTree t){
   switch(t) {
     case leaf(n):        return [n];
     case black(n,l,r): return getLeaves2(l) + getLeaves2(r) + [n];
     case red(n,l,r):    return getLeaves2(l) + getLeaves2(r) + [n];
   };
}
```



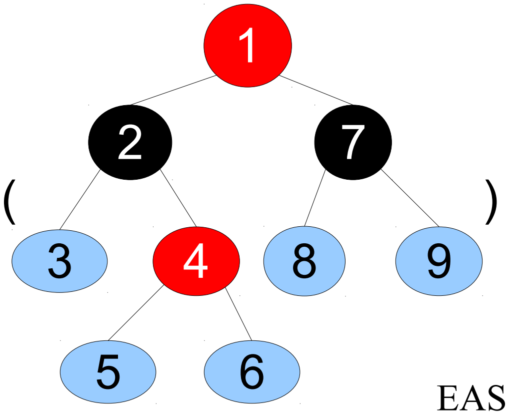
getLeaves2( ) = [3,5,6,4,2,8,9,7,1]

Different ways to Traverse a Tree,3

```
  data CTree = leaf(int N)
             | red(int N, CTree left, CTree right)
             | black(int N, CTree left, CTree right);
```

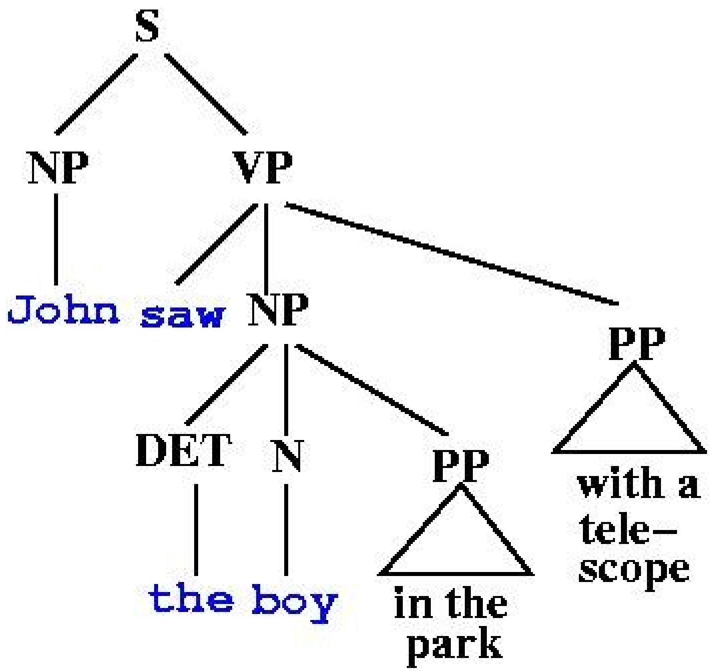
```
public list[int] getLeaves3(CTree t){
   switch(t) {
     case leaf(n):        return [n];
     case black(n,l,r): return getLeaves3(l) + [n] + getLeaves3(r);
     case red(n,l,r):   return getLeaves3(l) + [n] + getLeaves3(r);
   };
}
```

getLeaves3(



) = `[3,2,5,4,6,1,8,7,9]`

Syntax and Parsing



Given a grammar and a sentence find the structure of the sentence and discover its parse tree

Syntax and Parsing

- Uses a new formalism that is based on (and improves upon) the Syntax Definition Formalism (SDF)
- Modular grammar definitions
- Integrated lexical and context-free parsing
- A complete grammar can be imported and can be used for:
  - Parsing source code (parse functions)
  - Matching concrete code patterns
  - Synthesizing source code

Syntax for Exp

```
module demo::lang::Exp::Concrete::NoLayout::Syntax

lexical IntegerLiteral = [0-9]+;

start syntax Exp =
            IntegerLiteral
          | bracket "(" Exp ")"
          > left Exp "*" Exp
          > left Exp "+" Exp
          ;
```

Example

Even numbers:
In many flavours

See Tutor: Recipes/Basic/Even

Even0: initial version

```
public list[int] even0(int max) {
  list[int] result = [];
  for (int i <- [0..max])
    if (i % 2 == 0)
      result += i;
  return result;
}
```

```
rascal>even0(25);
list[int]: [0,2,4,6,8,10,12,14,16,18,20,22,24]
```

Even1: remove type declarations

```
public list[int] even0(int max) {
  list[int] result = [];
  for (int i <- [0..max])
    if (i % 2 == 0)
      result += i;
  return result;
}
```

Even1: remove type declarations

```
public list[int] even1(int max) {
  result = [];
  for (i <- [0..max])
    if (i % 2 == 0)
      result += i;
  return result;
}
```

```
rascal>even1(25);
list[int]: [0,2,4,6,8,10,12,14,16,18,20,22,24]
```

Even2: merge for and if

```
public list[int] even1(int max) {
  result = [];
  for (i <- [0..max])
    if (i % 2 == 0)
      result += i;
  return result;
}
```

Even2: merge for and if

```
public list[int] even2(int max) {
  result = [];
  for (i <- [0..max], i % 2 == 0)
      result += i;
  return result;
}
```

```
rascal>even2(25);
list[int]: [0,2,4,6,8,10,12,14,16,18,20,22,24]
```

Even3: for returns the list (using append)

```
public list[int] even2(int max) {
  result = [];
  for (i <- [0..max], i % 2 == 0)
      result += i;
  return result;
}
```

Even3: for returns the list (using append)

```
public list[int] even3(int max) {
  result =  for (i <- [0..max], i % 2 == 0)
                   append i;
  return result;
}
```

```
rascal>even3(25);
list[int]: [0,2,4,6,8,10,12,14,16,18,20,22,24]
```

Even4: eliminate result variable

```
public list[int] even3(int max) {
  result =  for (i <- [0..max], i % 2 == 0)
                 append i;
  return result;
}
```

Even4: eliminate result variable

```
public list[int] even4(int max) {
  return  for (i <- [0..max], i % 2 == 0)
                    append i;
}
```

```
rascal>even4(25);
list[int]: [0,2,4,6,8,10,12,14,16,18,20,22,24]
```

Even5: use comprehension

```
public list[int] even4(int max) {
  return  for (i <- [0..max], i % 2 == 0)
               append i;
}
```

Even5: use comprehension

```
public list[int] even5(int max) {
  return  [i | i <- [0..max], i % 2 == 0];
}
```

```
rascal>even5(25);
list[int]: [0,2,4,6,8,10,12,14,16,18,20,22,24]
```

Even6: use abbreviated function declaration

```
public list[int] even5(int max) {
  return  [i <- [0..max], i % 2 == 0];
}
```

Even6: use abbreviated function declaration

```
public list[int] even6(int max) =  [i | i <- [0..max], i % 2 == 0];
```

```
rascal>even5(25);
list[int]: [0,2,4,6,8,10,12,14,16,18,20,22,24]
```

Pattern-directed Invocation

- A conventional function has formal parameters:
  - `int factorial(int n) { … }`
- In Rascal, also patterns can be used as formal parameters.
- At the call site, pattern matching determines which funcion to call => pattern-directed invocation.

Pattern-directed Invocation: 99 bottles of beer

See Tutor: Recipes/Basic/BottlesOfBeer

99 Bottles of Beer

99 bottles of beer on the wall, 99 bottles of beer.
Take one down, pass it around, 98 bottles of beer on the wall.

98 bottles of beer on the wall, 98 bottles of beer.
Take one down, pass it around, 97 bottles of beer on the wall.

…
1 bottle of beer on the wall, 1 bottle of beer.
Take one down, pass it around, no more bottles of beer on the wall.

No more bottles of beer on the wall, no more bottles of beer.
Go to the store and buy some more, 99 bottles of beer on the wall.

99 Bottles of Beer

```
module demo::basic::Bottles
import IO;

str bottles(0)     = "no more bottles";
str bottles(1)     = "1 bottle";
default str bottles(int n) = "<n> bottles";

public void sing(){
  for(n <- [99 .. 1]){
       println("<bottles(n)> of beer on the wall, <bottles(n)> of beer.");
       println("Take one down, pass it around, <bottles(n-1)> of beer on the wall.\n");
  }
  println("No more bottles of beer on the wall, no more bottles of beer.");
  println("Go to the store and buy some more, 99 bottles of beer on the wall.");
}
```

Examples

Pattern-directed Invocation: derivatives

See Tutor: Recipes/Common/Derivative

Recall from Calculus:
The Derivative of a Function

- dN / dX = 0, for constant N
- dX / dX = 1
- dX / dY = 0, when X != Y
- d(E1 + E2) / dx = d E1 / dX + d E2 / dX
- d(E1 * E2) / dX = (d E1 / dX * E2) + (E1 * d E2 / dX)

Representing Expressions

```
data Exp = con(int n)
         | var(str name)
         | mul(Exp e1, Exp e2)
         | add(Exp e1, Exp e2)
         ;

public Exp E = add(mul(con(3), var("y")), mul(con(5), var("x")));
```

3 * y + 5 * x

Derivative in Rascal

- dN / dX = 0, for constant N
- dX / dX = 1
- dX / dY = 0, when X != Y
- d(E1 + E2) / dx = d E1 / dX + d E2 / dX
- d(E1 * E2) / dX = (d E1 / dX * E2) + (E1 * d E2 / dX)

```
Exp dd(con(n), var(V))   = con(0);

Exp dd(var(V1), var(V2)) = con((V1 == V2) ? 1 : 0);

Exp dd(add(Exp e1, Exp e2), var(V)) = add(dd(e1, var(V)), dd(e2, var(V)));

Exp dd(mul(Exp e1, Exp e2), var(V)) =
                  add(mul(dd(e1, var(V)), e2), mul(e1, dd(e2, var(V))));
```

But ...

```
rascal> dd(E, var("x"));
Exp: add(
  add(
    mul(
      con(0),
      var("y")),
    mul(
      con(3),
      con(0))),
  add(
    mul(
      con(0),
      var("x")),
    mul(
      con(5),
      con(1))))
```

We expect

d (3 * y + 5 * x) /dx

=

5

We need simplification!

Simplifying Expressions

```
Exp simp(add(con(n), con(m))) = con(n + m);
Exp simp(mul(con(n), con(m))) = con(n * m);
Exp simp(mul(con(1), Exp e))  = e;
Exp simp(mul(Exp e, con(1)))  = e;
Exp simp(mul(con(0), Exp e))  = con(0);
Exp simp(mul(Exp e, con(0)))  = con(0);

Exp simp(add(con(0), Exp e))  = e;
Exp simp(add(Exp e, con(0)))  = e;

default Exp simp(Exp e)       = e;

Exp simplify(Exp e){
 return bottom-up visit(e){
          case Exp e1 => simp(e1)
        }
}
```

Victory!

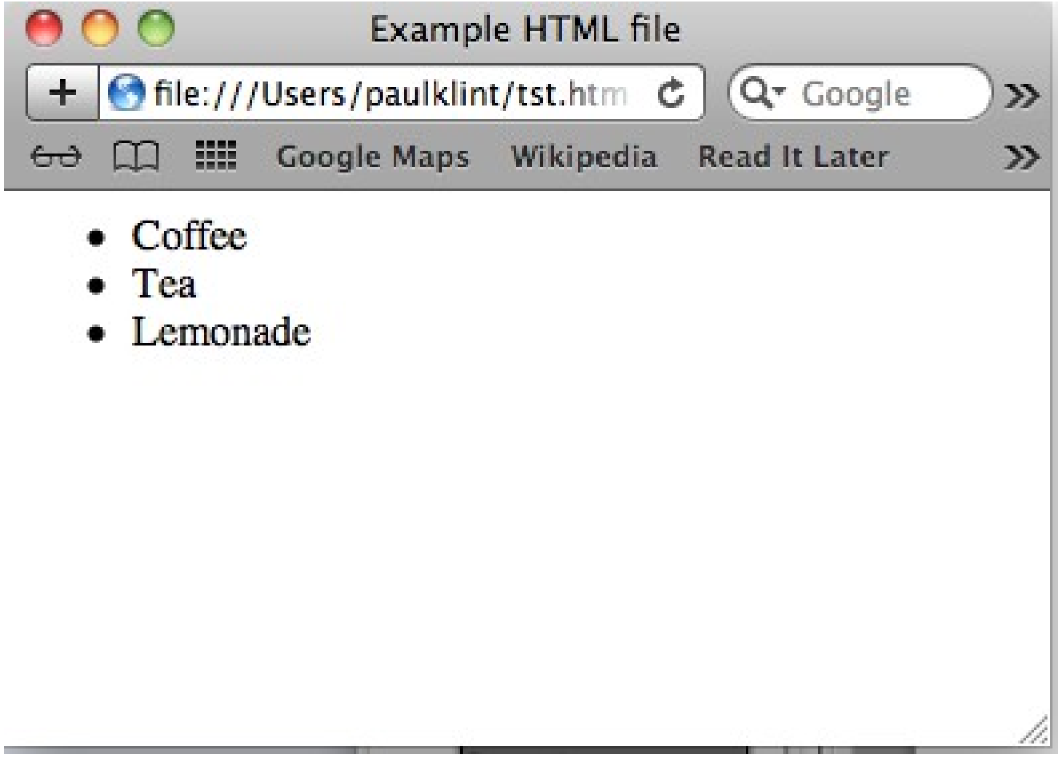
```
rascal>simplify(dd(E, var("x")));
Exp: con(5)
```

Example

Generating HTML

Generating HTML

```
<html>
<title>Example HTML file</title>
<body>
<ul>
<li>Coffee</li>
<li>Thee</li>
<li>Lemonade</li>
</ul>
</body>
</html>
```



- Coffee
- Tea
- Lemonade

Generating Drinks Example

```
module HTML
import IO;

public str item(str op, str content) = "\<<op>\><content>\</<op>\>\n";

public str html(str title, str content) =
      item("html", item("title", title) + item("body", content));
public str ul(str content) = item("ul", content);
public str li(str content) = item("li", content);
```

```
rascal>item("li", "Coffee")
str: "\<li\>Coffee\</li\>\n"

rascal>println(item("li", "Coffee"))
<li>Coffee</li>
ok
```

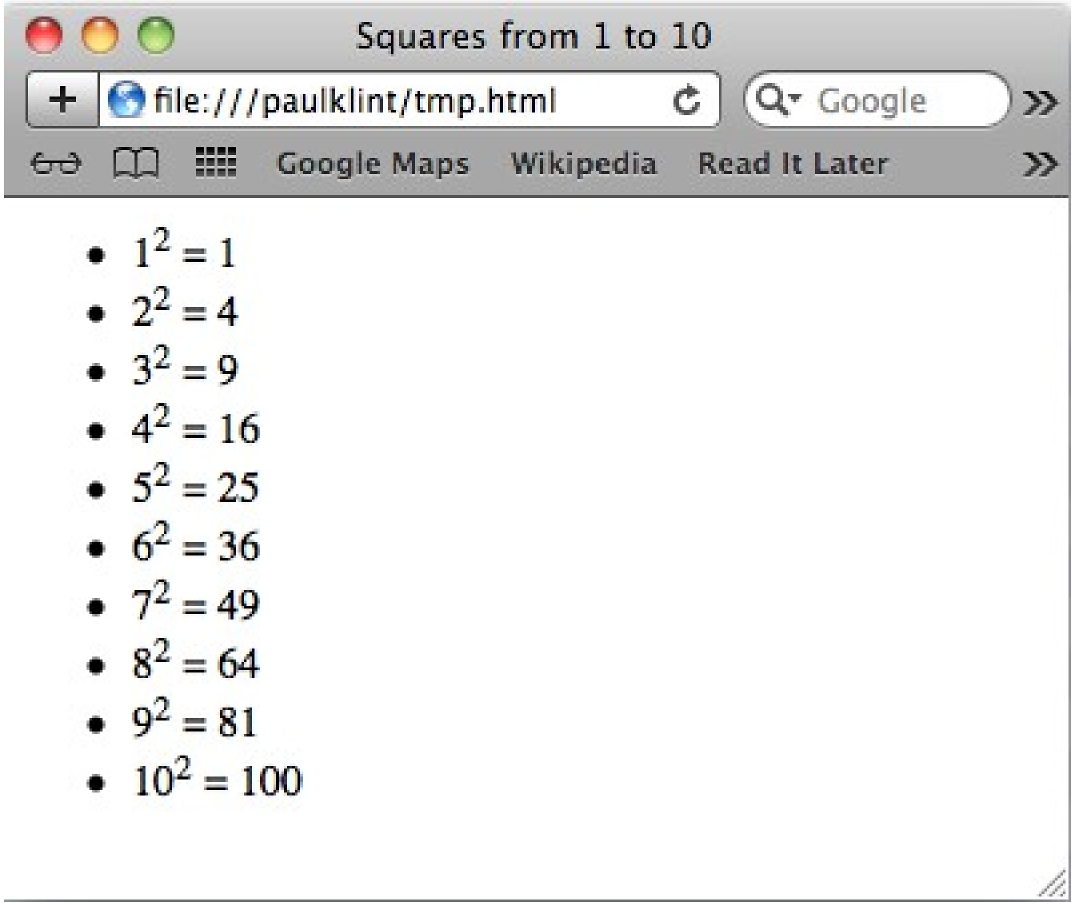
```
rascal>println(html("ex1", ul(li("coffee") + li("tea"))))
<html><title>ex1</title>
<body><ul><li>coffee</li>
<li>tea</li>
</ul>
</body>
</html>
ok
```

Saving to a file

```
rascal>writeFile(|file:///paulklint/tst.html|,
                     html("ex1", ul(li("coffee") + li("tea"))))
ok
```

And load in your browser to see the effect ...

Exercise, generate squares



- $1^2 = 1$
- $2^2 = 4$
- $3^2 = 9$
- $4^2 = 16$
- $5^2 = 25$
- $6^2 = 36$
- $7^2 = 49$
- $8^2 = 64$
- $9^2 = 81$
- $10^2 = 100$

A Solution

```
module HTML

import IO;

public str item(str op, str content) = "\<<op>\><content>\</<op>\>\n";
public str html(str title, str content) =
           item("html", item("title", title) + item("body", content));
public str ul(str content) = item("ul", content);
public str li(str content) = item("li", content);

public str squared(int n) = li("<n><item("sup", "2")> = <n*n>");

public str squares(int max) =
   html("Squares from 1 to <max>",
         ul("<for(int i <- [1 .. max]){><squared(i)><}>")
       );

public void save(str name, str text){
  writeFile(|file:///paulklint/| + name, text);
}

public str ex1() = html("ex1", ul(li("coffee") + li("tea")));
```

Example

Job interview: FizzBuzz!

A test from job interviews

Write a program that prints the numbers from 1 to 100.

But for multiples of three print "Fizz" instead of the number and for the multiples of five print "Buzz".

For numbers which are multiples of both three and five print "FizzBuzz".

Surprisingly: a substantial amount of applicants fails!

Exercise: write your fizzbuzz

```
rascal>fizzbuzz();
1
2
Fizz
4
Buzz
Fizz
7
8
Fizz
Buzz
11
Fizz
13
14
FizzBuzz
...
```

FizzBuzz Solutions

```
public void fizzbuzz() {
   for(int n <- [1 .. 100]){
      fb = ((n % 3 == 0) ? "Fizz" : "") + ((n % 5 == 0) ? "Buzz" : "");
      println((fb == "") ?"<n>" : fb);
   }
}
```

```
public void fizzbuzz2() {
  for (n <- [1..100])
    switch(<n % 3 == 0, n % 5 == 0>) {
      case <true,true>  : println("FizzBuzz");
      case <true,false> : println("Fizz");
      case <false,true> : println("Buzz");
      default: println(n);
    }
}
```

```
public void fizzbuzz3() {
  for (n <- [1..100]) {
    if (n % 3 == 0) print("Fizz");
    if (n % 5 == 0) print("Buzz");
    else if (n % 3 != 0) print(n);
    println("");
  }
}
```

Example

Generating getters and setters

Generating Getters and Setters (1)

- Given:
  - A class name
  - A mapping from names to types

Required:

  - Generate the named class with getters and setters

Input

```
public map[str, str] fields = (
  "name" : "String",
  "age" : "Integer",
  "address" : "String"
);
```

Field name of type String

Field age of type Integerr

Field address of type String

```
genClass("Person", fields)
```

Generate class person
with these fields

Expect Output

```
public class Person {

    private Integer age;
    public void setAge(Integer age) {  this.age = age;   }
    public Integer getAge() { return age;   }


    private String name;
    public void setName(String name) { this.name = name;   }
    public String getName() {  return name;   }


    private String address;
    public void setAddress(String address) {  this.address = address;   }
    public String getAddress() {  return address;   }
  }
```

Generating Getters and Setters

```
public str genClass(str name, map[str,str] fields) {
 return "
   public class <name > {
    <for (x <- fields) {
      str t = fields[x];
      str n = capitalize(x);>
      private <t> <x>;
      public void set<n>(<t> <x>) { this.<x> = <x>;  }
      public <t> get<n>() { return <x>;  }
    <}>
   }
";
}
```

String with computed interpolations

Red is interpolated

Blue is literal

Generating Getters and Setters

```
public str genClass(str name, map[str,str] fields) {
 return "
   'public class <name > {
   '  <for (x <- fields) {
   '    str t = fields[x];
   '   str n = capitalize(x);>
   '  private <t> <x>;
   '  public void set<n>(<t> <x>) { this.<x> = <x>;  }
   '  public <t> get<n>() { return <x>;  }
   ' <}>
   '}
";
}
```

String with computed interpolations

Red is interpolated

Blue is literal

Text before ' is ignored

Other features

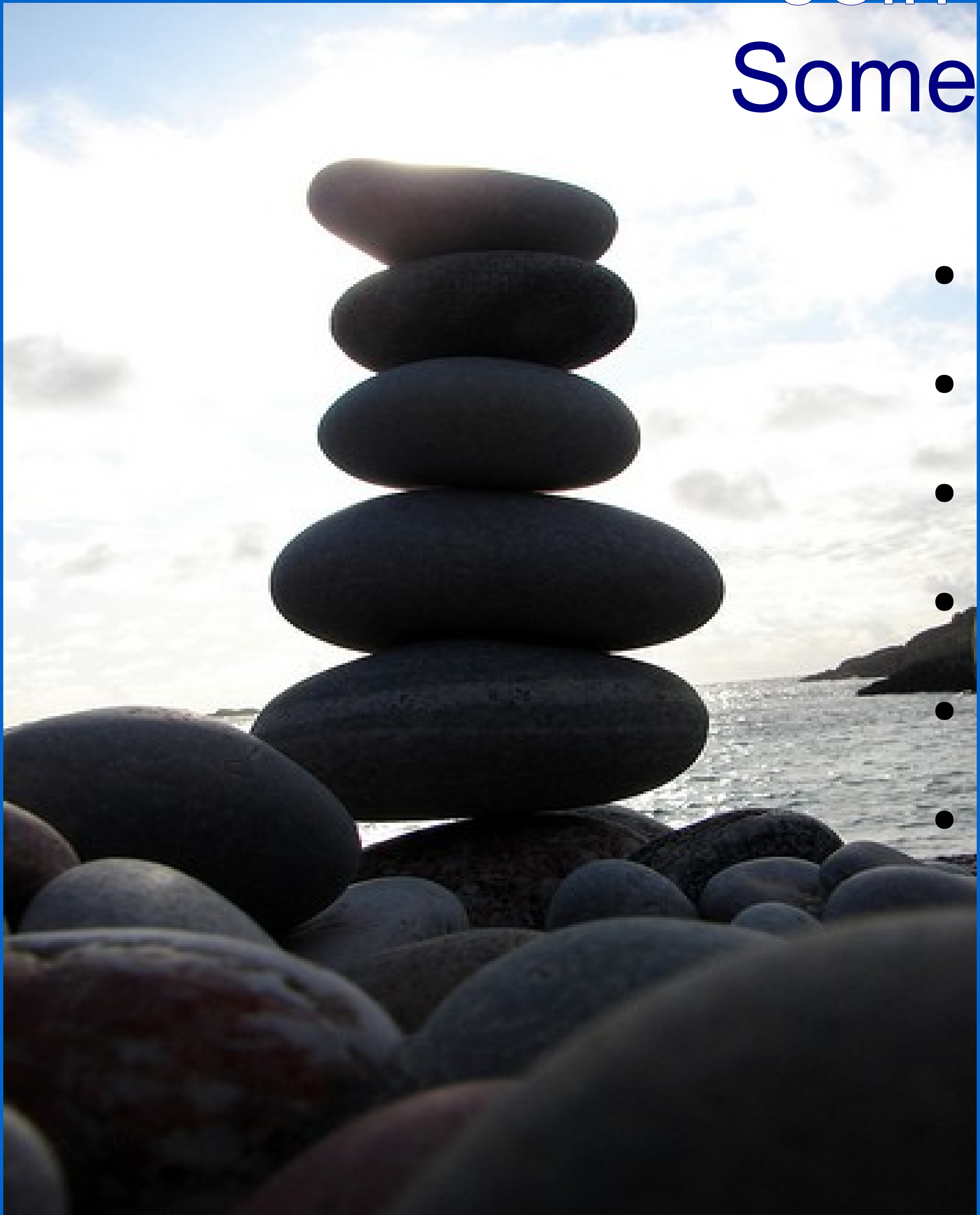
- Solve equations using fixed point iteration
- Get/set fields of ADTs
- Exception handling
- Annotations
- Parameterized types
- Higher order functions
- Many libraries ...

Information

See:

- http://www.rascal-mpl.org
- http://tutor.rascal-mpl.org
- http://ask.rascal-mpl.org

Join Us in Creating Something Beautiful



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