Generating VScode extensions for **DSLs** using **Rascal**

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Strumenta Online Community
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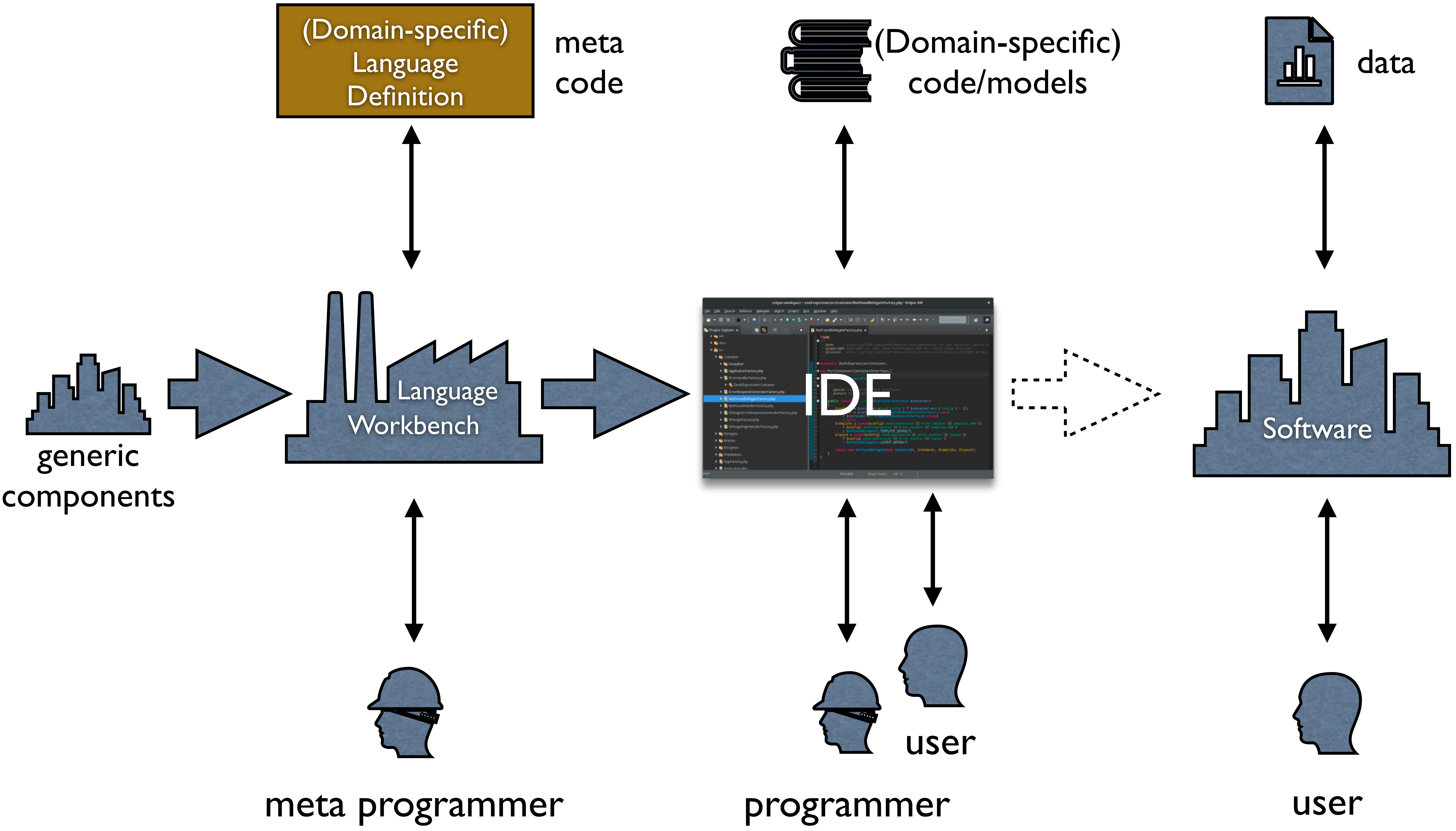
Teamwork

In no particular order, many people have contributed in one way or another to the software that I'm about to demonstrate:

Paul Klint, **Tijs van der Storm**, Mark van den Brand, Mark Hills, Frank Tip, Arie van Deursen, Michael Steindorfer, Davy Landman, Hayco de Jong, Pieter Olivier, Merijn de Jonge, Jeroen Scheerder, Eelco Visser, Joost Visser, Ali Afroozeh, Anastasia Izmaylova, Bastiaan Heeren, Alexander Serebrenik, Rodin Aarssen, Riemer van Rozen, Aiko Yamashita, Anya Helene Bagge, Arnold Lankamp, Ashim Shahi, Bas Basten, Bert Lisser, Vadim Zaystev, Jasper Timmer, Jouke Stoel, Jeroen van den Bos, Lina Maria Ochoa Venegas, Mauricio Verano Merino, Pablo Inostroza Valdera, Thomas Degueule, Ralf Lämmel, Dinesh, Jan Rekers, Emma van der Meulen, Wilco Koorn, Susan Uskudarli, Tobias Kuipers, Leon Moonen, Jasper Kamperman, Magiel Bruntink, Thomas van Binsbergen, Chris Verhoef, Alex Sellink, Tim Soethout, ... (...apologies if you should have been on this list)

"Generating IDEs"



Agenda

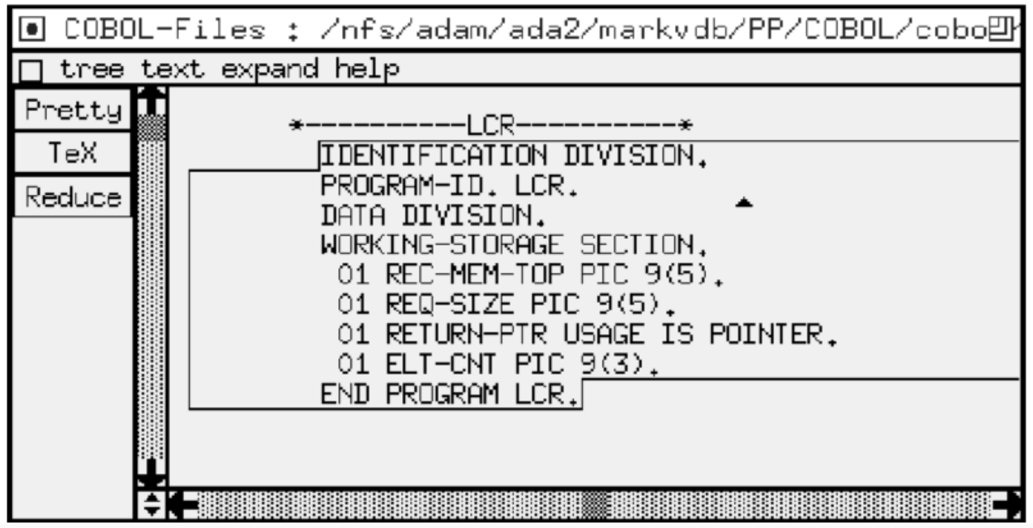
- History
- Design
- Tutorial
- Live Demo
- Pointers
- Questions

History of Rascal

● ASF+SDF + LeLISP	1983 - 1998
● ASF+SDF Meta-Environment	1999 - 2008
● ASF+SDF Meta + IMP + Eclipse	2007 - 2008
● Rascal + IMP + Eclipse	2009 - ...
● Rascal + LSP + VScode	2021 - ...

ASF+SDF+LeLISP (1984-1998)

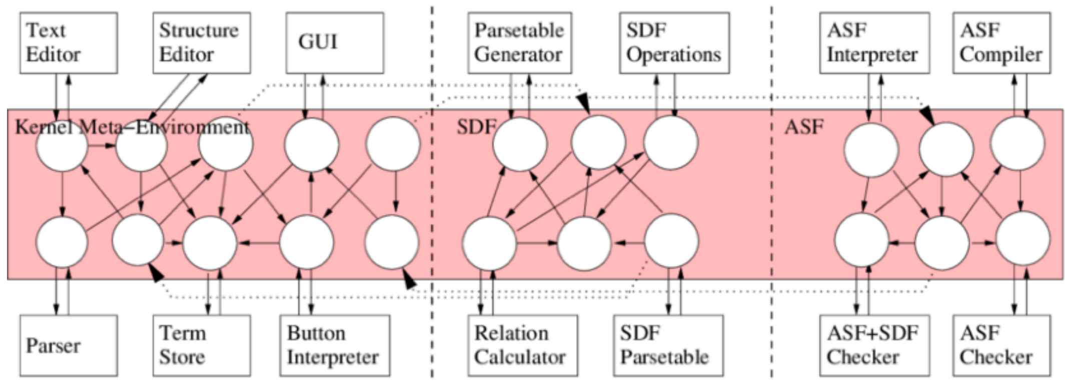
- **EEC programs for research and development in information technologies: FP1:ESPRIT *1984-1988*, FP2:ESPRIT 2 *1987-1992***
- GIPE: “Generating Interactive Programming Environments”
- Le**LISP**: LISP + homemade GUI on SUN Sparc/Solaris
- LISP macros, LISP libraries, everything LISP
- SDF: Syntax Definition Formalism
- ASF: Algebraic Specification Formalism
- **ASF+SDF Concrete Syntax: tree patterns and expressions in object language syntax (!!!)**
- BOX: declarative pretty printing formalism
- **SEAL: declaratively linking (generated) language processors to the IDE (buttons, etc.)**
- ±15 related Ph.D. theses (Paul Klint et al.), much (inter)national collaboration
- COBOL software renovation applications (Chris Verhoef et al.)
- In 1994 —I was 17 years old— Paul Klint visited my high school and demonstrated this system

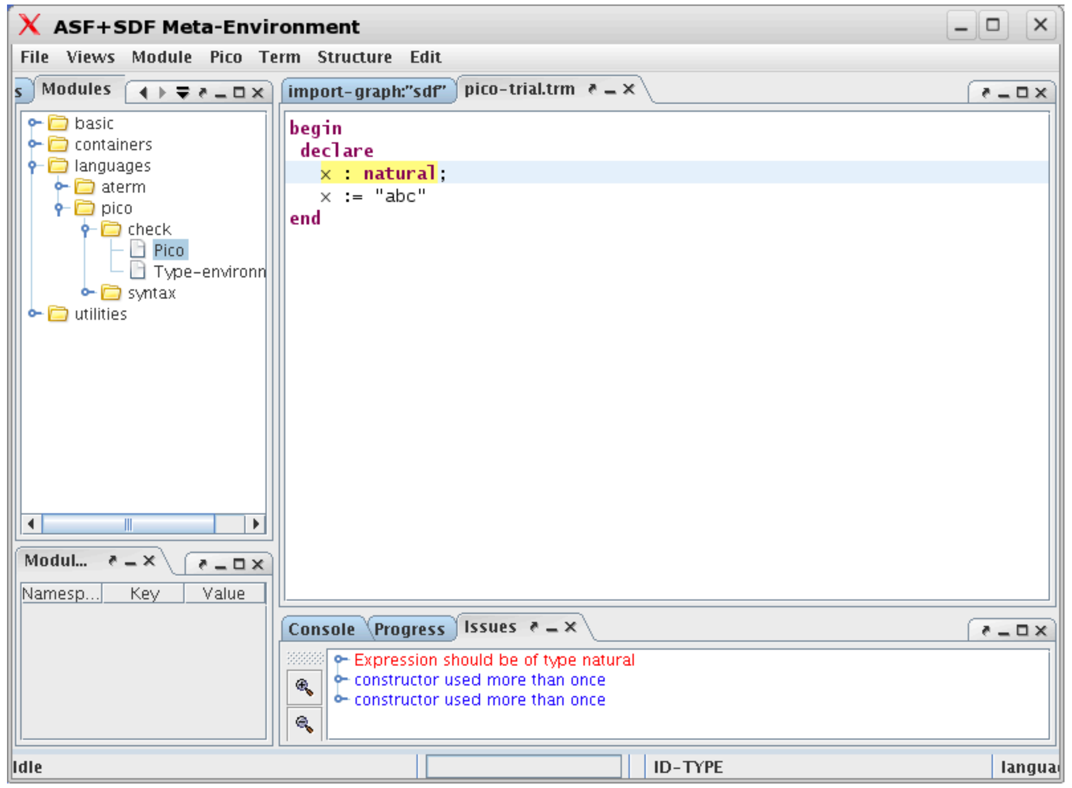


```
*----------LCR----------*
IDENTIFICATION DIVISION.
PROGRAM-ID. LCR.
DATA DIVISION.
WORKING-STORAGE SECTION.
 01 REC-MEM-TOP PIC 9(5).
 01 REQ-SIZE PIC 9(5).
 01 RETURN-PTR USAGE IS POINTER.
 01 ELT-CNT PIC 9(3).
END PROGRAM LCR.
```

ASF+SDF Meta-Environment (1999-2008)

- Re-imagining of ASF+SDF (Mark van den Brand et al.) in C, Java, ASF+SDF, ToolBus
- **ToolBus** (1998, Paul Klint, Jan Bergstra)
  - Strict separation of coordination from computation
  - Connecting tools with sockets and protocols: **“LSP” avant-la-lettre (!)**
  - Process Algebra (ACP): DSL for coordinating (generated) tools
  - **Drop-in replacement of editors (Java, (g)vim, (x)emacs, Eclipse)**
- SDF2 - scannerless generalized LR parsing (Eelco Visser et al.)
- ASF compiler to C - *very* fast term rewriting (Mark van den Brand et al.)
- TIDE - generic/language parametric debugging (Pieter Olivier)
- RScript - Relational Calculus DSL for analysis (Paul Klint)
- APIgen - algebraic data-types for C and Java (De Jong, Olivier, Vinju)
- ATerms - *very* fast (serialized) terms + GC (Pieter Olivier, Hayco de Jong)
- Traversal Functions - structure-shy recursive functions (Vinju et al.)
- Many applications: COBOL, C, Java, Action Semantics (Peter Mosses)



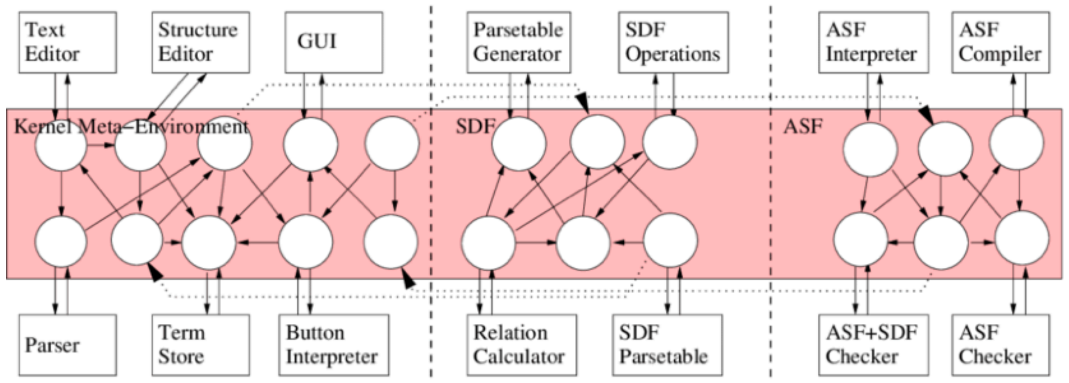


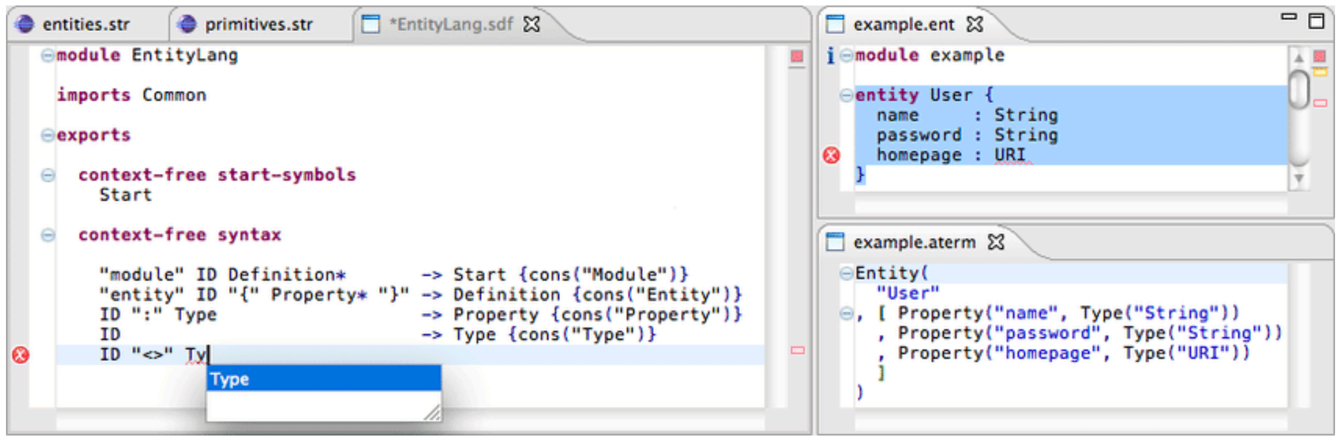
```
begin
 declare
  x : natural;
  x := "abc"
end
```

```
Expression should be of type natural
constructor used more than once
constructor used more than once
```

ASF+SDF Meta + IMP + Eclipse (2007 - 2008)

- Eclipse IMP "IDE Meta-tooling Platform" (Robert Fuhrer et al.) - Java, Eclipse Extension points: parametric interface for programming languages [OOPSLA 2008]
- IMP to ToolBus: every callback is a tool
- "ASF+SDF in Eclipse"
- Immediate Language Workbench; no "second level"
- More varied standard interactions with language semantics:
  - highlighters, outlines, search, jump-to-def, find references, completion





```
module EntityLang

imports Common

exports

  context-free start-symbols
    Start

  context-free syntax

    "module" ID Definition*      -> Start {cons("Module")}
    "entity" ID "{" Property* "}" -> Definition {cons("Entity")}
    ID ":" Type                  -> Property {cons("Property")}
    ID                           -> Type {cons("Type")}
    ID "<>" Ty
```

```
module example

entity User {
  name     : String
  password : String
  homepage : URI
}
```

```
Entity(
  "User"
, [ Property("name", Type("String"))
  , Property("password", Type("String"))
  , Property("homepage", Type("URI"))
  ]
)
```

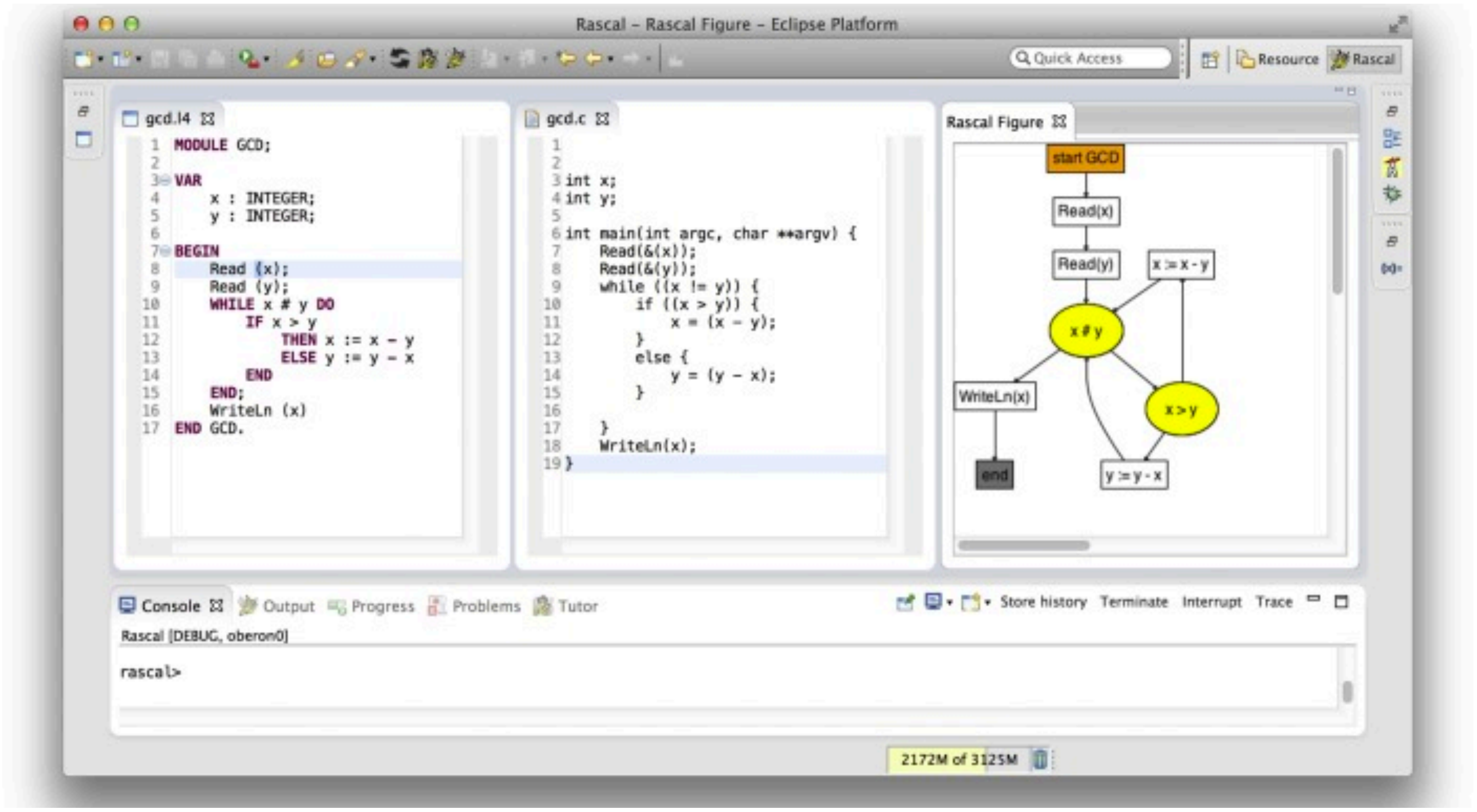
Rascal's origins (2008)

- **ASF, SDF, Box, Meta-Environment, RScript, APIgen, ATerms, ToolBus**:
  - separation-of-concerns: a "meta-DSL" for every aspect of a meta program
  - integration was a big challenge for us (and for the meta-programmers)
  - **meta-programmer context-switching between meta-languages for the same object language**
  - data marshalling overhead between different language processors
- **World was changing**:
  - **many new students without formal methods backgrounds**
  - **Eclipse** was becoming the de-facto standard for language development
  - Other transformation languages like TXL, StrategoXT, TOM, DMS started using external **database** technology
  - Other reverse engineering frameworks based on **relations** and their **visualizations** (Grok, Crokopat, Rigi)
- **Rascal design requirements**:
  - **Expressive**: Cover all the of power of ASF2, SDF2, Box, RScript, ApiGen and ATerms
  - **Learnable:** understandable **without formal methods background**
  - **Integrated**: no more context-switching and no more data marshalling
  - **Hi-Fi:** origin tracking to source locations, no a priori loss of comments and whitespace
  - **Interactive**: (Loosely) integrated with Eclipse

Rascal + IMP + Eclipse (2009)

- IMP provides an "LSP"
- Rascal generates implementations for IMP services (parser, outliner, checker, etc.)
- Rascal URI for Eclipse `|project://…/|`

- Immediate Language Workbench (no 2nd level)
- Powerful Read-Eval-Print loop
- Integrated web visualizations
- Integrated interactive



```
MODULE GCD;

VAR
    x : INTEGER;
    y : INTEGER;

BEGIN
    Read (x);
    Read (y);
    WHILE x # y DO
        IF x > y
            THEN x := x - y
            ELSE y := y - x
        END
    END;
    WriteLn (x)
END GCD.
```

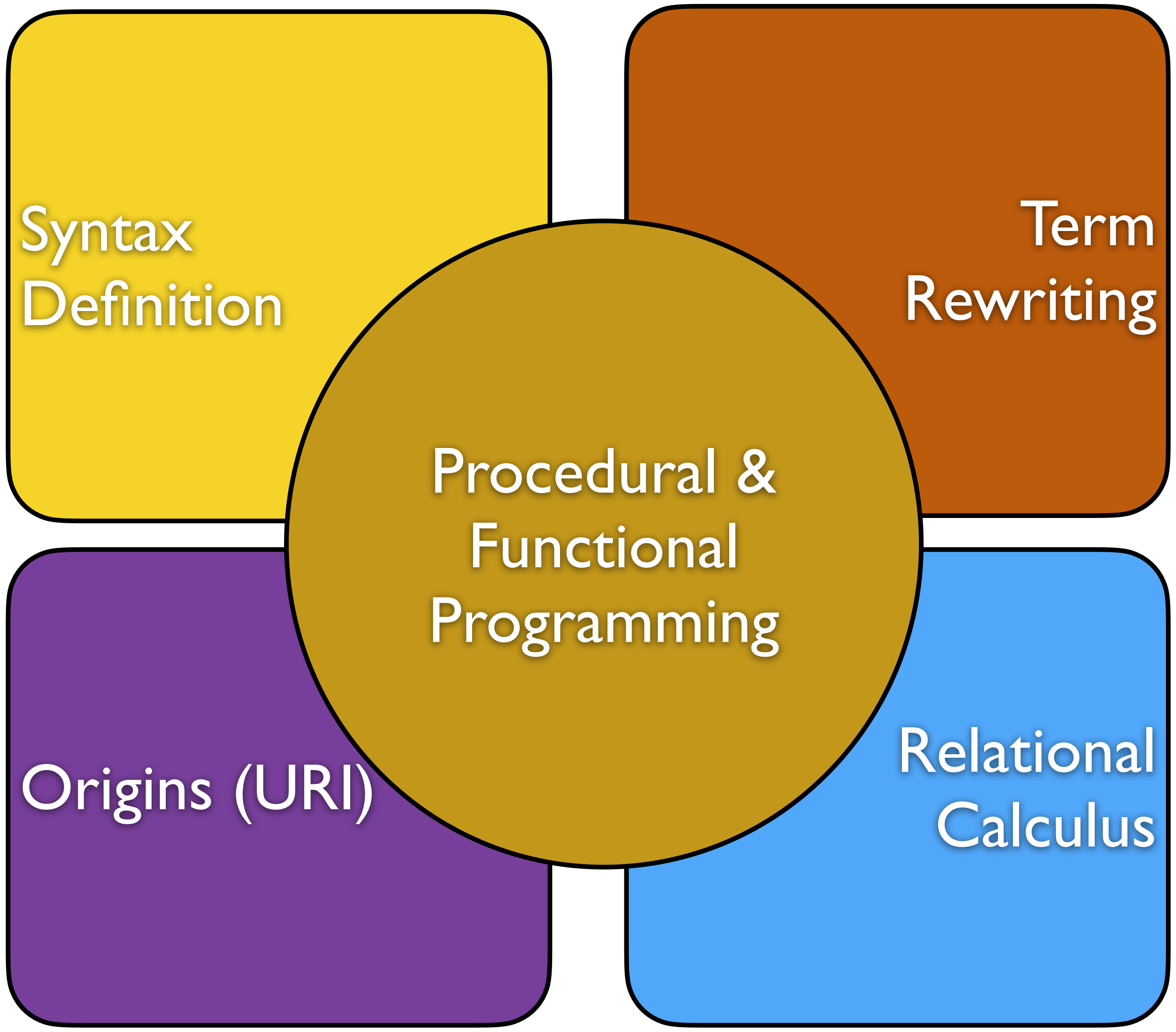
```


int x;
int y;

int main(int argc, char **argv) {
    Read(&(x));
    Read(&(y));
    while ((x != y)) {
        if ((x > y)) {
            x = (x - y);
        }
        else {
            y = (y - x);
        }

    }
    WriteLn(x);
}
```

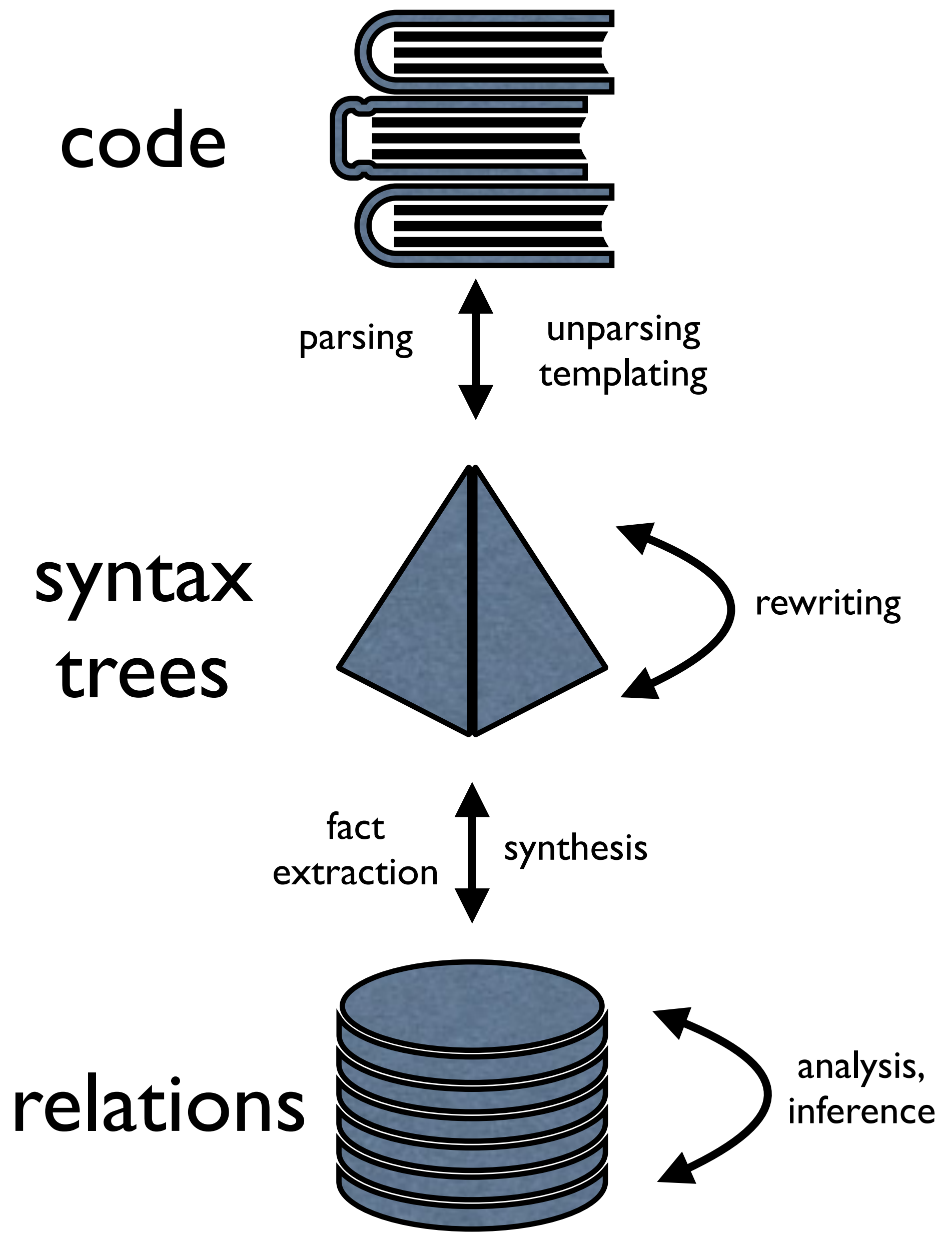
```
Rascal [DEBUG, oberon0]
rascal>
```

Rascal + LSP + VScode (2021)

- The world changed again; now **VScode** is the defacto standard for code editing. Plus SWAT.engineering (2017) has interest.
- **Microsoft Language Server Protocol** is very much like ToolBus and IMP but with JSON-RPC instead of ATerms or Java services.
- Yet another "port" of the Meta-Environment, no conceptual difference
- Beyond the LSP:
  - terminals for REPLs
  - web servers plus web clients for interactive visualizations
  - Immediate language workbench: first level extensions

Rascal Design (2009)





EASY: Extract, Analyze, Synthesize

Tutorial

```
visit (t) {
  case p ⇒ q
  case r ⇒ s
}
```

```
int fac(int n) {
  if (n ⩽ 1) return 1;
  return n * fac(n - 1);
}
```

```
solve (t) {
  t = t o t;
}
```

Rascal is a nominally-typed procedural programming language with familiar keywords like **if**, **for**, **while** and **return,** and some extras like **visit,** case patterns.

Tutorial

```
int fac(0) = 1;
default int fac(int n) = n * fac(n-1);
```

Pattern matching is everywhere!

Tutorial

```
data Num = zero();
data Num = succ(Num pred);
```

extensible syntax

extensible functions

```
Num fac(zero()) = succ(zero());
Num fac(s:succ(n)) = mult(s,fac(n));
```

(abstract) syntax is everwhere in Rascal

Tutorial

```
lexical Id = [a-z]+;

syntax Exp

  = Id id

  | “(“ Exp “)”

  > Exp lhs “*” Exp rhs

  > Exp lhs “+” Exp rhs;


Exp e = [Exp] “1 + 2 * 3”;

e = e.rhs;

Exp simplify((Exp) `<Exp a> * (<Exp b> + <Exp c>)`)
  = (Exp) `<Exp a> * <Exp b> + <Exp a> * <Exp c>`;
```

syntax definitions with precedence define parsers and data-types at once.

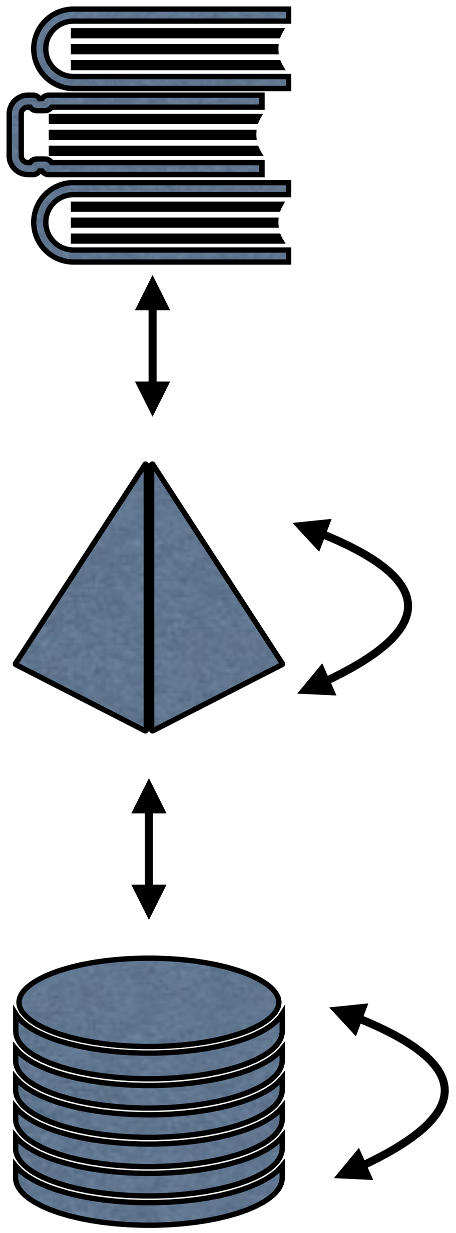
fields

parse a string

concrete tree match

concrete tree expression

Tutorial



```
// import a syntax definition
import lang::myLanguage::Syntax;
// define a location:
loc example = |project://demo/examples/fac.program|;
// parse the contents of the location
Program cu = parse(#Program, example);
// traverse the tree, find all assignments, create a binary relation
rel[str name, loc place]
  assigned = { <"<id>", id.src> | /(Stat) `<Id id> = <Exp e>` := cu };
  declared = …
  declaredButNeverAssigned = declared.name - assigned.name;
  warnings = {warning("<n> was declared but never assigned.", p) | <n,p> ← declared,
    n in declaredButNeverAssigned};
```

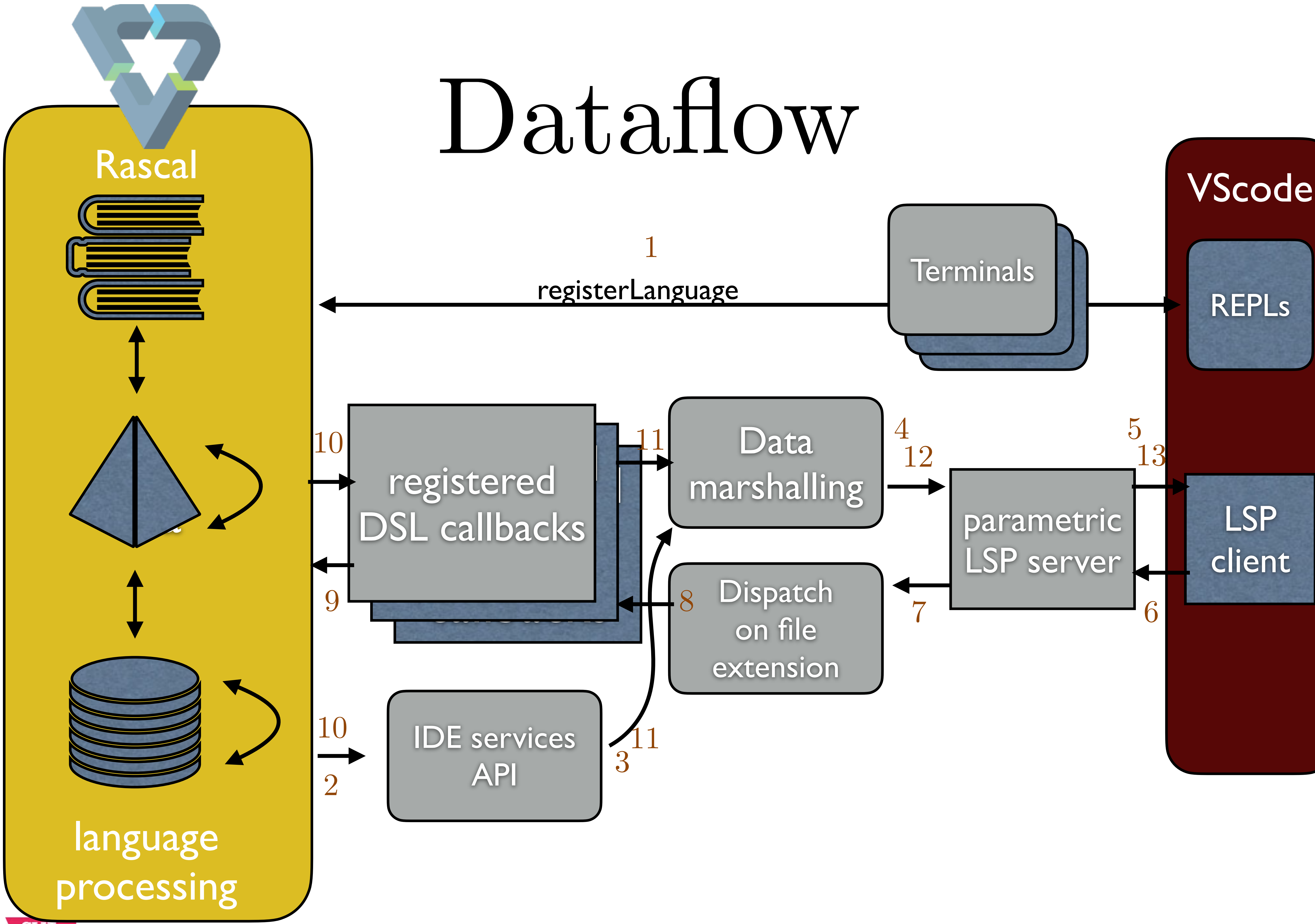
Tutorial: LSP in Rascal

```
module util::LanguageServer

alias Parser            = Tree (str input, loc origin);

alias Summarizer        = Summary (loc origin, Tree input);

alias Outliner          = list[DocumentSymbol] (Tree input);

alias Completer         = list[Completion] (Tree input, str prefix, int offset);

alias Builder           = list[Message] (list[loc] sources, PathConfig pcfg);

alias LensDetector      = rel[loc src, Command lens] (Tree input);

alias CommandExecutor   = void (Command command);

alias InlayHinter       = list[InlayHint] (Tree input);

data LanguageService    = parser(Parser parser) | summarizer(Summarizer summarizer) | …

data Language = language(PathConfig pcfg, str name, str ext, str module, str contributor);

module MyLanguage

set[LanguageService] myServices() { return …; }

void main() {

  registerLanguage(language(pcfg, “MyLanguage”, “ml”, “Main”, “myServices”));

}
```

Tutorial: IDE services

```
module util::IDEServices // accessing Eclipse or VScode features from LSP callbacks (asynchronously)


java void browse(loc uri); // uses WebView  in VScode

java void edit(loc uri);   // opens editor in VScode

java void applyDocumentsEdits(list[DocumentEdit] edits); // applies edits (with undo stack and/or preview)

java void showInteractiveContent(Content content); // serves interactive content in WebView window

java void showMessage(Message message);            // pop-up

java void logMessage(Message message);             // via log4j and logging API in LSP

java void registerDiagnostics(list[Message] messages); // Problems view

java void unregisterDiagnostics(list[loc] resources);

java void registerLanguage(Language lang); // adds a new language to the IDE
```

Dataflow



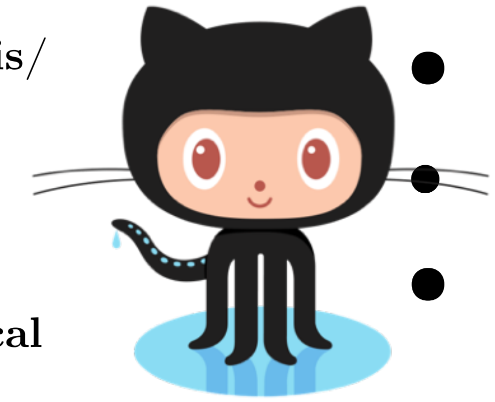
Rascal
language processing
1
registerLanguage
Terminals
VScode
REPLs
10
registered DSL callbacks
11
Data marshalling
4
12
parametric LSP server
5
13
LSP client
9
8
Dispatch on file extension
7
6
10
2
IDE services API
3
11

Demo

- Very small language
- Simple intermediate model
- Live programming
- IDE with
  - syntax highlighting,
  - outline,
  - checker,
  - commands

Selected Rascal Libraries

- analysis::text::search - Lucene based indexing/search
- analysis::flow - parametric dataflow analysis
- **lang::java - JDT-based Java analysis in Rascal**
- lang::box - Box-based string formatting DSL
- **TypePal - declarative name/type analysis/inference**
- FlyBytes - JVM bytecode analysis/generation
- **CLAiR - C++ language analysis in Rascal**
- PHP-air - PHP language analysis in Rascal
- Python-air - Python language analysis in Rascal



- Lua-air - LUA language analysis in Rascal
- JS-air - JavaScript language analysis in Rascal
- AlleAlle - relation model find with theories (parametric model checker)
- **Bacatá - Jupyter Notebook Generator**
- Rascal-ecore - live (bidirectional) rascal <-> ecore
- **Maracas - Java API breaking change analysis and breaking change impact analysis**
- Salix - Elm-style interactive GUIs in Rascal

Example DSLs

- Rebel2 - state-machine based scalable transaction systems (IDE, simulator, model-checking, code-generation)
- Derric - (Binary) File Formats (IDE, debugger, code-generation, file recovery algorithms)
- LiveQL - DSL for questionnaires
- Jeff - OO language with effect handling
- Marvol - DSL to make the NOA robot dance
- Amalga - mini-language for image algorithm expression
- (e)Flint - DSL for the expression of norms (laws)
- Bird - (Binary) File Formats
- Nescio - DSL for anonymization of binary data (coupled to Bird)
- ScriptButler - an IDE and game engine for puzzle game design
- Ludoscope Mini - a textual DSL and engine for level design.

Further Pointers

- http://www.rascal-mpl.org - Rascal homepage
- http://github.com/usethesource - Github organization for Rascal
- https://marketplace.visualstudio.com/items?itemName=usethesource.rascalmpl
- https://docs.rascal-mpl.org/ - Documentation
- https://stackoverflow.com/questions/tagged/rascal - >400 StackOverflow answers
- https://github.com/cwi-swat - lots of experimental Rascal libraries and apps
- https://www.swat.engineering - language engineering services
  (look out for job opportunities)

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