Trends in Languages

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About me

- Independent Consultant
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- Focus on
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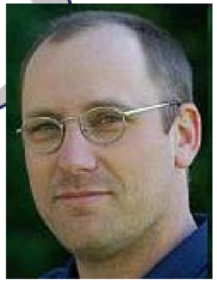

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- Intro and Overview
- Typing
- OO +/vs. Functional
- Metaprogramming
- DSLs
- Concurrency
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- **Intro and Overview**
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Why this talk?

- Language World **is changing**
  - Mainstream Languages evolve (Java, C#)
  - Diverisfication: Ruby, Erlang, Scala, Groovy, ...

- I want to illustrate interesting **trends**

- Explain some of the **controversy** and **backgrounds**.

- **Note on the form:** Unlike most of my other slides, these slides are **very terse** and cannot be understood very well without me talking. Please consider reading the following German article instead:

  http://www.voelter.de/data/articles/trends2007.pdf

Languages Mentioned in this Talk

Language	Mentioned because…
Java	Current Language that misses many of the features explained
C++	Structural Types (Templates)
Scala	Type Inference, Structural Types , Functional Programming, DSLs, Concurrency
C# 3.0	Type Inference
Ruby	Duck Typing, Meta Programming, DSLs
Groovy	Metaprogrammierung, DSLs
Fortress	DSLs, Concurrency
Erlang	Concurrency

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Strongly Typed vs. Weakly Typed

- Does a language **have types** at all?
- Are those typed **checked** at all?
- **C weakly typed:**
  - *(void*)*
  - Interpret string as a number, and vice versa
  - The compiler has a „hole“
- Community agrees that **weak typing is bad.**
- **Opposite:** Strongly Typed.
  - When are types checked?

Strongly Typed: Dynamic vs. Static

- A strongly typed language **can check typed at**
  - Compile time: **Statically** Typed Language
  - Runtime: **Dynamically** Typed Language
- Most **mainstream** languages use **static** typing:
  - Java
  - C#
  - (C++)
- Dynamic Typing associated with **„scripting languages“**
  - What is a „scripting language“
  - Is Smalltalk a scripting language? It is dynamically typed!
  - Term is not very useful!
- **Static Backdoor:** Casting
  - Defers type check to runtime

Strongly Typed: Dynamic vs. Static II

- „**Static is better**, because the compiler finds more errors for you“
- „**Dynamic is better**; more expressive code, and you have to test anyway.“
- **XOR?** No, context dependent:
  - Safety Critical Software: Static Typing
  - Agile Web Applications: Dynamic Typing
- But there‘s **more**...

Duck Typing

- A form of **Dynamic Typing**
  "if it walks like a duck and quacks like a duck,
  I would call it a duck"
  - where **not the declared type** is relevant
  - but the **ability** at runtime **to handle** messages/method calls

- A handler for a message (method implementation) can be
  - Defined by its type
  - Be object-specific
  - Added at runtime via meta programming

- A **predefined callback** („doesNotUnderstand") is invoked in case a message cannot be handled.

- **Examples:** Smalltalk, Ruby

Structural Types: Duck Typing for Static Languages

- **Compiler** checks, whether something can satisfy context requirements.
  - Formal type is not relevant
- **Example I:** C++ Templates
- **Example II:** Scala

```
class Person(name: String) {
  def getName(): String = name
  …
}

def printName(o: { def getName(): String }) {
  print(o.getName)
}

printName( new Person("markus") )  // prints "markus"
```

Scala

Type Inference: Omit derivable types

- **Compiler Smarts:** You only have to write down those types the compiler cannot derive from the context
- **Example:** (Hypothetical) Java

```
// valid Java
Map<String, MyType> m = new HashMap<String, MyType>();
// Hypothetical Java with Type inference
var m = new HashMap<String, MyType>();
```

Java

```
// valid Scala
var m = new HashMap[String, MyType]();
```

Scala

- **Example II:** C# 3.0, LINQ

```
Address[] addresses = …

var res = from a in addresses
          select new {    name = a.name(),
                          tel = a.telephoneNo()    };

foreach (var r in res) {
  Console.WriteLine("Name: {0}, Num: {1}", r.name, r.tel);
}
```

C# 3

Dynamic Typing in static languages? Maybe!

- One **could add dynamic (runtime) dispatch** to static languages with the following approach (discussion with Anders Hejlsberg for SE Radio)

```
// language-predefined interface, like Serializable
interface IDynamicDispatch {
  void attributeNotFound(AttrAccessInfo info)
  void methodNotFound(MethodCallInfo info
}
```

Java?

```
class MyOwnDynamicClass implements IDynamicDispatch {
  // implement the …notFound(…) methods and
}

val o = new MyOwnDynamicClass

o.something() // compiler translates this into an
              // invocation via reflection. If it fails,
              // call methodNotFound(…)
```

Java?

- Combine this, eg. with load-time meta programming…

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OO and Functional

- OO is clearly the **mainstream**.
- That is changing (very) slowly ... especially **functional programming** is taking up speed.
- What is functional programming (as in Erlang, Lisp, F#)
  - Function Signatures are **types**
  - Function **Literals** are available (lambda expressions)
  - Functions are **values**: assignable to variables and parameters → Higher Order Functions
- You can find **elements** of this in Ruby, Groovy, C# 3 and Scala
- Scala's primary goal is to unify OO and functional
- (also: **side-effect free;** important later wrt concurrency)

From Primitive To Workable

- **Primitive** functional programming can be done with
  - Function pointers (as in C/C++)
  - Delegates (C# < 3)
  - Command Pattern/Inner Classes in Java

- Better solution: **Closures**
  (aka lamda expressions, blocks, anonymous functions)

```
[1,2,3,4,5,6].each { |element| puts (element * 2) }
```

Ruby

- **Anonymous Functions** (Function Literals)

```
x: Int => x + 1
```

Scala

Higher Order Functions

- **Function Signatures** (Function Types)

```
Int => Int    // Int Parameter, Return Type Int
(Int, Int) => String  // Two Int Parameter, returns String
```

Scala

- Function Signatures/Types are important for **Higher Order Functions:**
  - Functions that take other functions as arguments
  - ... or return them

```
def apply(f: Int => String, v: Int) => f(v)
```

Scala

Currying

- **Evaluate** a function **only for some of its arguments**, returning **a new function** with fewer arguments.

```
object CurryTest extends Application {
  def filter(xs: List[Int], p: Int => Boolean): List[Int] =
…
  def modN(n: Int)(x: Int) = ((x % n) == 0)

  val nums = List(1, 2, 3, 4, 5, 6, 7, 8)
  Console.println(filter(nums, modN(2)))
  Console.println(filter(nums, modN(3)))
}
```

Scala

- ***modN(2)*** results in an anonymous function that is **similar** to the following one:

```
mod2(x: Int) = ((x % 2) == 0
```

Scala

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What is Metaprogramming?

- A program can **inspect** and **modify** itself or other **programs**.
- **Not** a **new** concept: Lisp, CLOS
  - But returning to fame these days...
- Two different **flavours**:
  - **Static/Compile Time** metaprog. : handled by compiler
  - **Dynamic** metaprog.: done at runtime
    (fits well with Duck Typing ... you can call what‘s there)
- Static Meta Programming is a relative **niche concept**
  (aka hygienic macro system)
  - C++ Template Metaprogramming (aargh!)
  - Template Haskell
  - Converge
  - Boo

Dynamic Metaprogramming

- Is available in **many dynamic OO languages**, such as Smalltalk, Ruby, Groovy
- Dynamically **add a new method** to a class:

```
class SomeClass
    define_method(“foo”){ puts "foo" }
End

SomeClass.new.foo // prints “foo“
```

Ruby

- What happens in Duck languages, if you call a **method** that‘s **not available**? Remember, no compiler type check!

```
class Sammler {
   def data = [:]
   def propertyMissing =
      {String name, value-> data [name] = value }
   def propertyMissing =
      {String name-> data [name] }
}
```

Groovy

```
def s = new Sammler()
s.name = "Voelter"
s.vorname = „Markus“
s.name  // is „Voelter“
```


Meta Object Protocols

- MOPs support „overwriting“ the interpreter typically via the concept of **meta classes**.
- Here we **overwrite** what it means to **call a method**:

```
class LoggingClass {
  def invokeMethod(String name, args) {
    println "just executing "+name
    // execute original method definition
  }
}
```

Groovy

- Yes, this looks like the **AOP** standard example ☺
- In fact, AO has **evolved from MOPs** (in CLOS)
- And now we‘re **back to MOPs** as a way for „simple AO“... strange world ...

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What are DSLs?

A DSL is a **focused**, **processable language** for describing a **specific concern** when building a **system** in a specific **domain**. The **abstractions** and **notations** used are **tailored** to the **stakeholders** who specify that particular concern.

- Domain can be **business** or **technical** (such as architecture)
- The „program“ needs to be **precise** and **processable**, but not necessarily **executable**.
  - Also called **model** or **specification**

Internal DSLs vs. External DSLs

- **Internal DSLs** are defined as part of a host language.
  - DSL „program“ is **embedded** in a host language program
  - It is typically **interpreted** by facilities in the host language/program (→ metaprogramming)
  - DoF for syntax customization is **limited by host language**
    - Only useful in languages with a **flexible syntax** (such as Ruby) or no syntax (Lisp ☺)

- **External DSLs** are defined independent of any programming language
  - A program **stands on its own**.
  - It is either **interpreted** by a custom-build interpreter, or **translated** into executable code
  - DoF for syntax customization **only limited by custom editor** (i.e. not really limited at all: graphical, textual, tables, combinations of those...)

Dynamic Internal DSL Examples: Ruby

- **Ruby** is currently the **most suitable language** for internal DSLs.

```
class Person < ActiveRecord::Base
  has_one :adress
  has_many :telecontact
end

class Address < ActiveRecord::Base
end
```

Ruby

- *has_one* and *has_many* are actually **invocations of class methods** of the *ActiveRecord::Base* super class.

- Alternative Syntax:

```
has_one(„adress“)
```

Ruby

- The original notation is an example of **Ruby's flexible syntax** (optional parens, symbols)

Dynamic Internal DSL Examples: Ruby II

- The *has_one* and *has_many* invocations dynamically **create accessors for properties** of the same name:

```
p = Person.new
a = Adress.new
p.adress = a
p.adress == a
```

Ruby

- The methods are implemented via **meta programming**.
- They do all kinds of magic wrt. to the database backend used in Rails.

Dynamic Internal DSL Examples: Groovy Builders

- The following Groovy program **constructs an HTML document.**

```
def build = new groovy.xml.MarkupBuilder(writer)
build.html {
  head {
    title 'Hello World'
  }
  body(bgcolor: 'black') {
    h1 'Hello World'
  }
}
```

Groovy

- Implemented via clever use of
  - *methodMissing/ propertyMissing*
  - Hash Literals
  - Closures

Static Internal DSL Examples: Scala

- The following uses *loop/unless* as if it were a Scala language feature (which it is not!)

```
var i = 10;
loop {
  Console.println("i = " + i)
  i = i-1
} unless (i == 0)
```

Scala

- In fact, it is implemented as a library relying on **automatic closure construction** and the use of **methods in operator notation**.

```
def loop(body: => Unit): LoopUnlessCond =
  new LoopUnlessCond(body);

private class LoopUnlessCond(body: => Unit) {
  def unless(cond: => Boolean): Unit = {
    body
    if (!cond) unless(cond);
  }
}
```

Scala

Static Internal DSL Examples: Boo

- Boo has a full **hygienic macro system** (open compiler)

```
public interface ITransactionable:
     def Dispose(): pass
     def Commit(): pass
     def Rollback(): pass
```

Boo

```
macro transaction:
     return [|
         tx as ITransactionable =  $(transaction.Arguments[0])
         try:
              $(transaction.Body)
              tx.Commit()
         except:
              tx.Rollback()
              raise
         finally:
              tx.Dispse()
     |]
```

Boo

- Use it like **native language syntax!**

```
transaction GetNewDatabaseTransaction():
         DoSomethingWithTheDatabase()
```

Boo

Static Internal DSL Examples: Boo II

- See how the *Expression* type is used to **pass in AST / syntax elements** (in this case, an expression)

```
[ensure(name is not null)]
class Customer:
        name as string
        def constructor(name as string): self.name = name
        def SetName(newName as string): name = newName
```

Boo

```
[AttributeUsage(AttributeTargets.Class)]
class EnsureAttribute(AbstractAstAttribute):
        expr as Expression
        def constructor(expr as Expression):
            self.expr = expr
        def Apply(target as Node):
            type as ClassDefinition = target
            for member in type.Members:
                method = member as Method
                block = method.Body
                method.Body = [|
                    block:
                          try:
                              $block
                          ensure:
                              assert $expr
                |].Block
```

Boo

Boo examples taken from Ayende Rahien and Oren Eini's InfoQ article *Building Domain Specific Languages on the CLR*

More legal characters: useful for DSLs

- Most languages still basically use 7-bit ASCII.
- A **larger set of legal characters** provides more degress of freedom for expressing domain-specific concepts.
- To be able to enter these characters Fortress provides a **Wiki-like** syntax (like Tex, or Mathematica)

$$
\begin{array}{l}
\mathit{conjGrad}[\![\text{Elt } \textbf{extends} \text{ Number}, \textbf{ nat } \text{N}, \\
\quad\quad \text{Mat } \textbf{extends} \text{ Matrix}[\![\text{Elt}, N \times N]\!], \\
\quad\quad \text{Vec } \textbf{extends} \text{ Vector}[\![\text{Elt}, \text{N}]\!] \\
\quad]\!](A : \text{Mat},\ x : \text{Vec}) : (\text{Vec},\ \text{Elt}) \\
\quad \mathit{cgit}_{\text{max}} = 25 \\
\quad z : \text{Vec} = 0 \\
\quad r : \text{Vec} = x \\
\quad p : \text{Vec} = r \\
\quad \rho : \text{Elt} = r^{\text{T}} r \\
\quad \textbf{for } j \leftarrow \textbf{seq}(1 : \mathit{cgit}_{\text{max}}) \textbf{ do} \\
\quad\quad q = A\, p \\
\quad\quad \alpha = \dfrac{\rho}{p^{\text{T}} q} \\
\quad\quad z := z + \alpha\, p \\
\quad\quad r := r - \alpha\, q \\
\quad\quad \rho_0 = \rho \\
\quad\quad \rho := r^{\text{T}} r \\
\quad\quad \beta = \dfrac{\rho}{\rho_0} \\
\quad\quad p := r + \beta\, p \\
\quad \textbf{end} \\
\quad (z,\ \|x - A\, z\|)
\end{array}
$$

Fortress

External DSLs

- Aka **Model-Driven Software Development**.
- **Notation:**
  - Textual (antlr, Xtext)
  - Graphical (GMF, MetaEdit+)
  - Or even a mixture (Intentional)
- **Execution:** Interpretation vs. Code Generation
  - Or even a mixture?
- Other advantages:
  - Language Specific Tooling (syntax coloring and completion)
  - Domain Specific Constraints
- But this is another talk...

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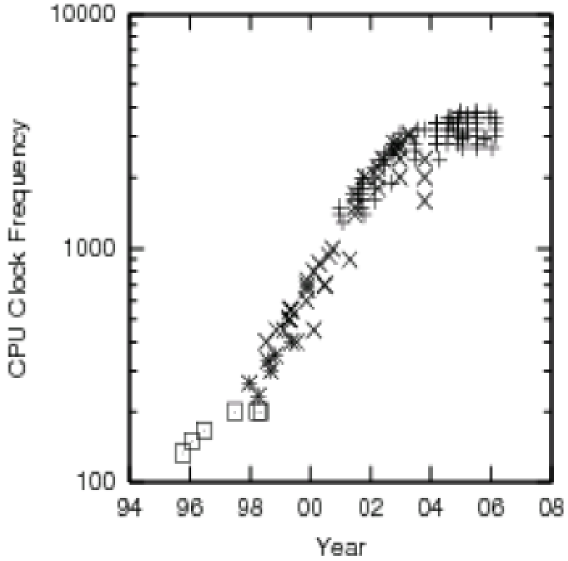
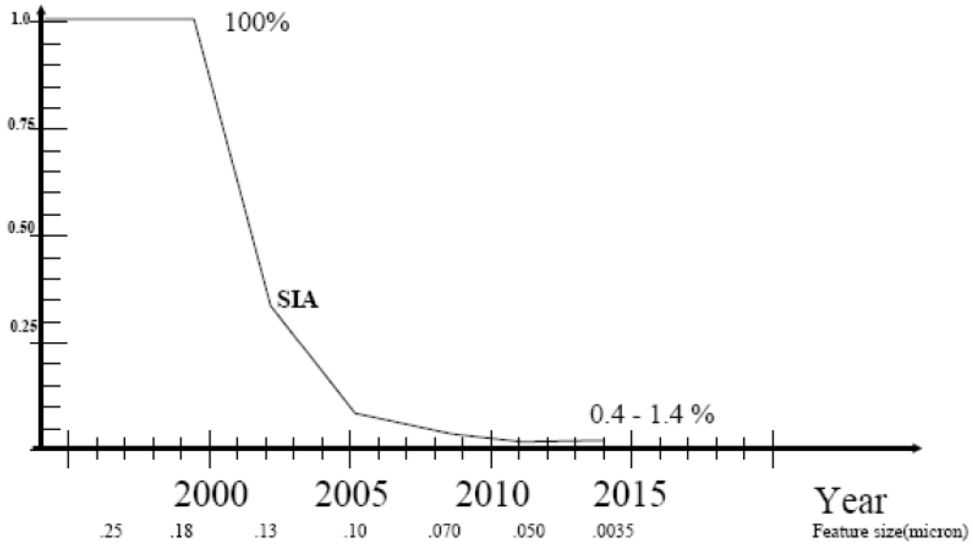
Why?

- Systems need to **scale**: More and More machines

- **Machine performance** needs to improve: Multicore
  - Multicore system can provide **real concurrency** as opposed to „apparent“ concurrency on one core.
  - Multicore systems can only be utilized fully if the available set of cores is utilized effectively.





Diagrams © Joe Armstrong

The role of pure functional programming

- **Pure Functional Programming** uses
  - Only functions without sideeffects
  - No shared state
  - Immutable data structures
- If you share nothing (or the shared stuff is not mutable) there's **no need for locking** or other access coordination protocols → pure functional languages are a good fit
- The **call graph** is the **only dependency structure** in the system (no hidden dependencies using global/shared state)
  - makes the programs easier (or even feasible) to **analyze**
  - And makes **parallelization** simple (you can parallelize any set of sub-callgraphs)

Shared Memory Concurrency

- Mainstream languages use **shared memory**:
  - A process (address space) can host any numer of thread
  - Threads can share data
  - They need to coordinate via locking

- Locking has to be **implemented manually** by developers via an agreed **locking / coordination protocol**
  - Often very **complex** (non-local)
  - **Error prone**, because there‘s little language/tool support
  - **Overspecification:** „Acquire/Release Lock X“
    vs.
    „Pretend this were sequential/atomic“

- Solution: **Express atomicity requirements** with language primitives as opposed to using locking protocol API
  → **Transactional Memory**

Shared Memory Concurrency: Transactional Memory

- Transactional Memory in Fortress:

```
atomic do
  // the stuff here is executed as if
  // there was only this thread
end
```

Fortress

- This formulation **says nothing about specific locks** and their allocation and release:
  - Less error prone
  - More potential for optimizations of compiler and RT system
- Similar in Spirit to **Garbage Collection** (Dan Grossman):
  - Rely on clever compiler and RT system
  - Solution might not always be optimal
  - ... but good enough in 99% of cases
  - and much less (error prone) work.

More bad overspecification

- Overspecification generally **prohibits** a compiler or runtime system from introducing **optimizations**.
- **Example:** Assume you want to do something **for each element** of a collection
- (Old) Java solution enforces total **ordering**. Intended?
  - Compiler cannot remove ordering

```
for ( int i=0; i < data.length; i++ ) {
  // do a computation with data[i]
}
```

Java < 5

- (New) Java solution: no ordering implied
  - Intent is expressed more clearly

```
foreach ( DataStructure ds in data ) {
  // do something with ds
}
```

Java 5

The default is parallel

- In Fortress, a loop is by **default parallel**
  - i.e. the compiler can distribute it to several cores

```
for I <- 1:m, j <- 1:n do
  a[i,j] := b[i] c[j]
end
```

Fortress

- If you need **sequential** execution, you have to **explicitly specify that**.

```
for i <- seq(1:m) do
  for j <- seq(1:n) do
    print a[i,j]
  end
end
```

Fortress

- Fortress does more for concurrency:
  - it knows about **machine resources** (processors, memory)
  - **Allocates** to those resources explicitly or automatically

„Shared Memory is BAD“ (Joe Armstrong)

- Some (many?) claim that the **root of all evil is shared memory** (more specifically: shared, mutable state):
- If you **cannot modify** shared state, no need for locking
  - Fulfilled by pure functional languages
- If you **don‘t even have shared state**, it‘s even better.
  - This leads to message-passing concurrency
  - Aka Actor Modell
- **Erlang:** most prominent example language (these days)
  - Funtional Language
  - Conceived of 20 years ago at Ericsson
  - Optimized for distributed, fault tolerant (telco-)systems
  - Actors/Message Passing based (called Process there ☹)

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Shared Memory is

BAD!

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Actors / Message Passing in Erlang

- The **only way to exchange information** between actors is via message passing.

- *Spawn* **creates a new process** – it executes the lambda expression passed as an argument

```
Pid = spawn(fun() -> doSomething() end)
```

Erlang

- **Sending** a message (any Erlang data structure) happens via the ! notation

```
Pid ! Message
```

Erlang

Actors / Message Passing in Erlang II

- An Actor's **received messages** are put into a „mailbox"
- A Unix Select-like command ***receive*** takes out one at a time.
- **Pattern Matching** is used to distinguish between the different messages
  - **lower case:** constants
  - **upper case:** free variables that will be bound)

```
loop
  receive
    {add, Id, Name, FirstName} -> ActionsToAddInformation;
    {remove,Id} -> ActionsToRemoveItAgain;
    ...
    after Time -> TimeOutActions
end
```

Erlang

Erlang-Style Message Passing in Scala

- Necessary **ingredients for Actors** include
  - Closures
  - Efficient Pattern Matching

- **Scala** has those features, too.
  - It also provides a way to define new „keywords“ (*receive*) and operators (*!*)

```
receive {
    case Add(name, firstName) => …
    case Remove(name, firstName) =>…
    case _ => loop(value)
}
```

Erlang

- This piece of Scala code doesn‘t just look almost like the Erlang version, it also **performs similarly**.

Best of Both Worlds in Singularity

- **MP disadvantage:** message data copying overhead
- Singularity (Sing#) solution: Best of Both Worlds
  - Use **message passing semtantics** and APIs
  - But **internally** use **shared** memory (memory exchange)
  - Enforce this via **static analysis** in compiler
- Example (pseudocode)

```
struct MyMessage {
  // fields…
}

MyMessage m = new MyMessage(…)

receiver ! m

// use static analysis here to ensure that
// no write access to m
```

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Languages vs. Platforms

- **Virtual Machines:** Let‘s have a **small set of** stable, fast, scalable **platforms** and a **larger variety of languages** for different tasks running on those platforms.
  - **CLR** has always had a clear distinction
  - **JVM** is getting there: JRuby, Jython, Groovy, Scala
    - *invokedynamic*, tail recursion
- The same concept applies to **enterprise platforms:** JEE as an **„operating system“** for enterprise apps has
  - Scalability
  - Deploymnet
  - Manageability, Operations
- ... and use **different languages/frameworks** on top of this „Enterprise OS“
  - This is an advantage of Groovy/Grails vs. Ruby/Rails

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When defining a language, always think about tooling!

- Tooling includes
  - **editing** (coloring, code completion, refactoring, etc.)
  - (static) **analysis**
- Powerful tooling is **simpler** to build for **statically typed** languages
- However, **IDEs for dynamic languages** are feasible, too:
  - Netbeans Ruby support
  - Smalltalk Browsers
- **Metaprogramming** is simpler to do in **dynamic languages**
  - there‘s no tooling to be adapted with the language
  - How can the IDE know about changes to programs at RT?
  - Compile-Time meta programming does not include tooling

When defining a language, always think about tooling! II

- Internal DSLs – implemented mostly in dynamic languages – **do not provide any tool support** for the DSL
  - Main disadvantage of dynamic, internal DSLs
  - Usability for business user limited!?
- In **external DSLs** you build a **custom editor** which then typically provides the well-known IDE productivity features (to one extend or another). Examples include
  - **GMF** for graphical notations
  - **Xtext** for textual notations
- **Static Analysis** becomes a central issue for **concurrency**
  - If concurrency is supported on **language level**, more compiler/analysis support becomes available.
  - MS Singularity Project is a good example

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- The time when only one language rules are over.
- Languages are a **topic of discussion** again
- It‘s about **language concepts**, not little details!
- New Buzzword: **Polyglott Programming** (new concept?) Build a system using several languages,
  - A robust, static, compiled languages for the **foundation**
  - The **more volatile parts** are done with a more productive, often dynamically typed language
  - DSLs are used for **end-user** configuration/customization
- Languages I could have talked about:
  - F# (functional), Ada 2005 (concurrency)

CONTENTS

- Intro and Overview
- Typing
- OO +/vs. Functional
- Metaprogramming
- DSLs
- Concurrency
- Platforms
- Tools
- Summary

THE END.

THANKS!