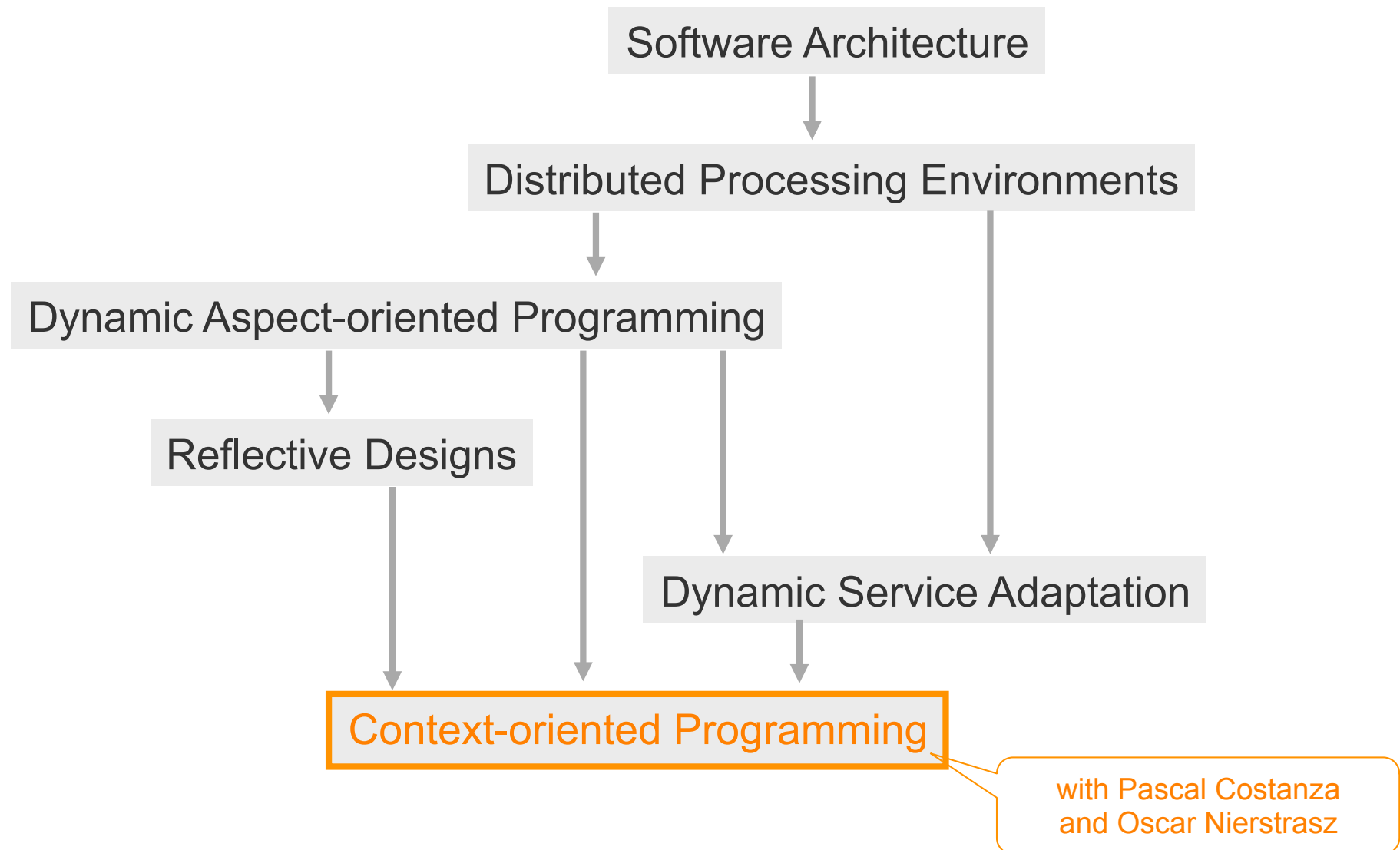


Dynamic Software Composition for Run-time System Evolution (Context-oriented Programming at HPI)

Robert Hirschfeld
Hasso Plattner Institute
University of Potsdam
Germany
<http://www.hpi.de/swa/>

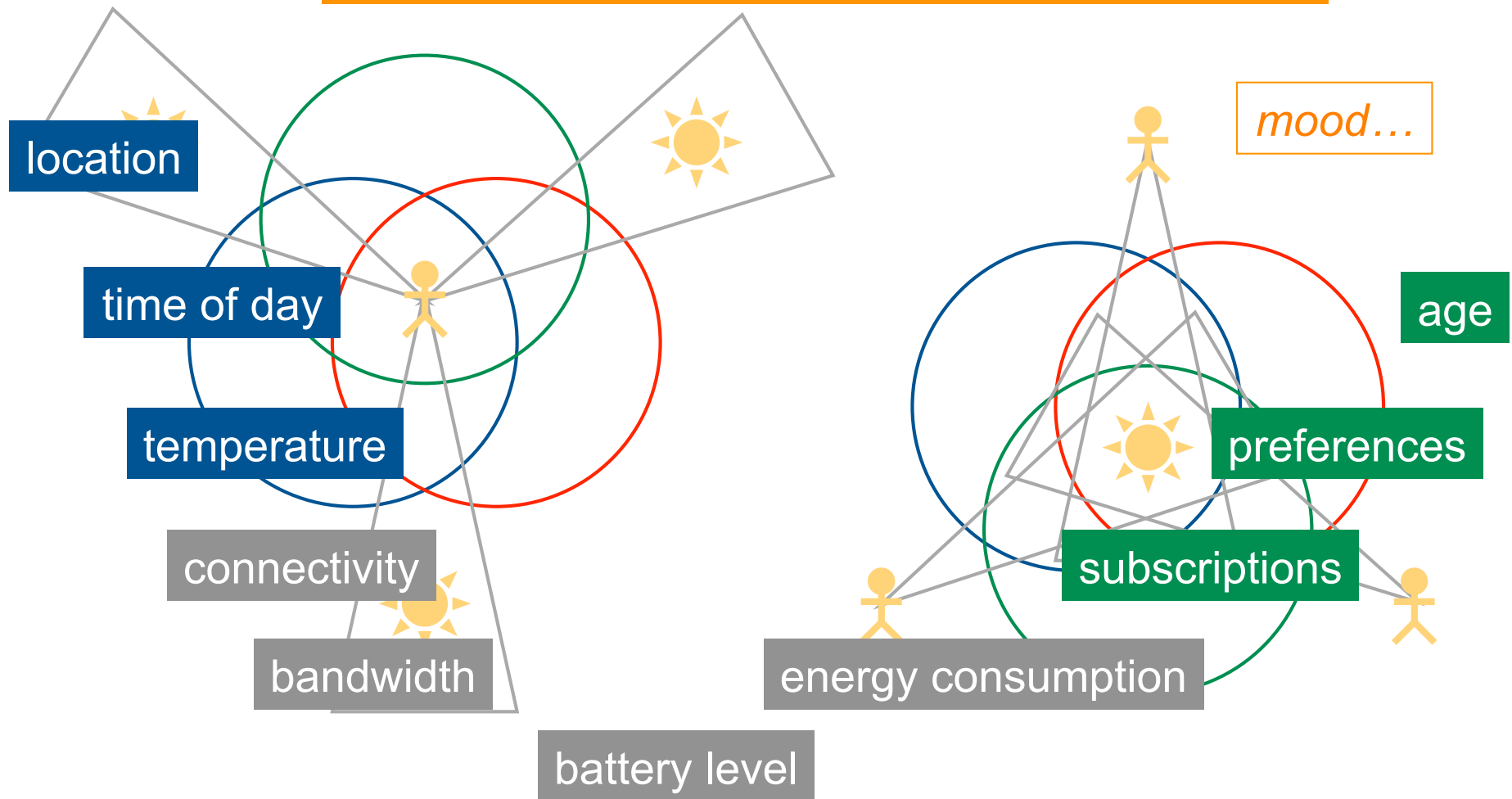
Shonan Village Center, Hayama, Kanagawa, Japan
2015-09-07

Some History...

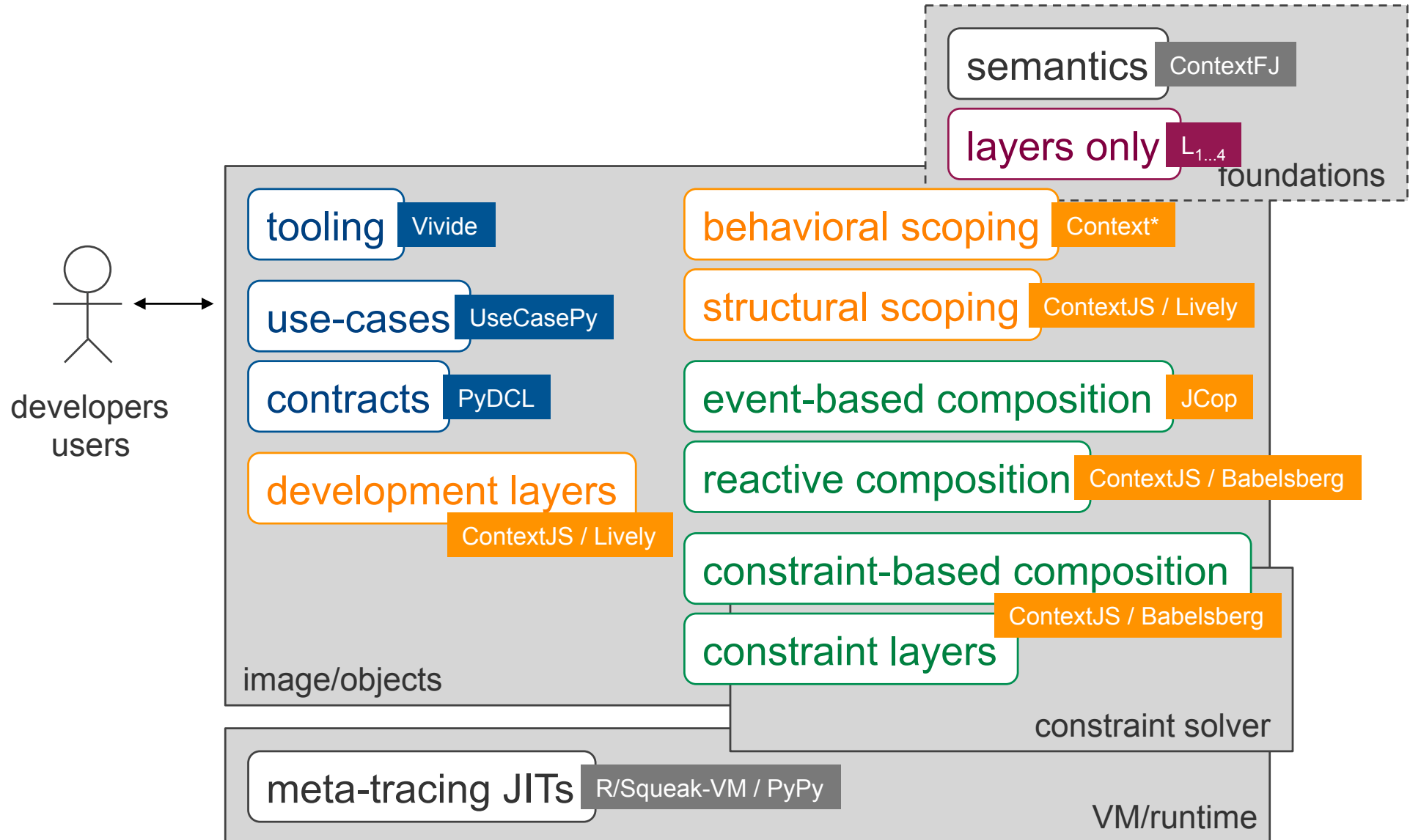


Context

context = everything computationally accessible



Outline



Behavioral Variations

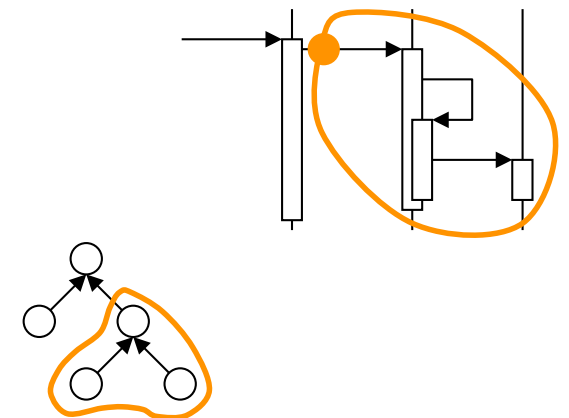
- **Behavioral** (dynamic) scoping
 - Dynamic extent of execution
 - Almost **all COP extensions**
- **Structural** (topological) scoping
 - ContextJS
 - **Development layers**
- Open implementation (OI) for scoping strategies
 - Allows for domain-specific scoping
 - Mainly applied to UI framework structures
 - Lively: Morphic
 - Webwerkstatt : Parts

behavioral scoping Context*

structural scoping ContextJS / Lively

development layers

ContextJS / Lively



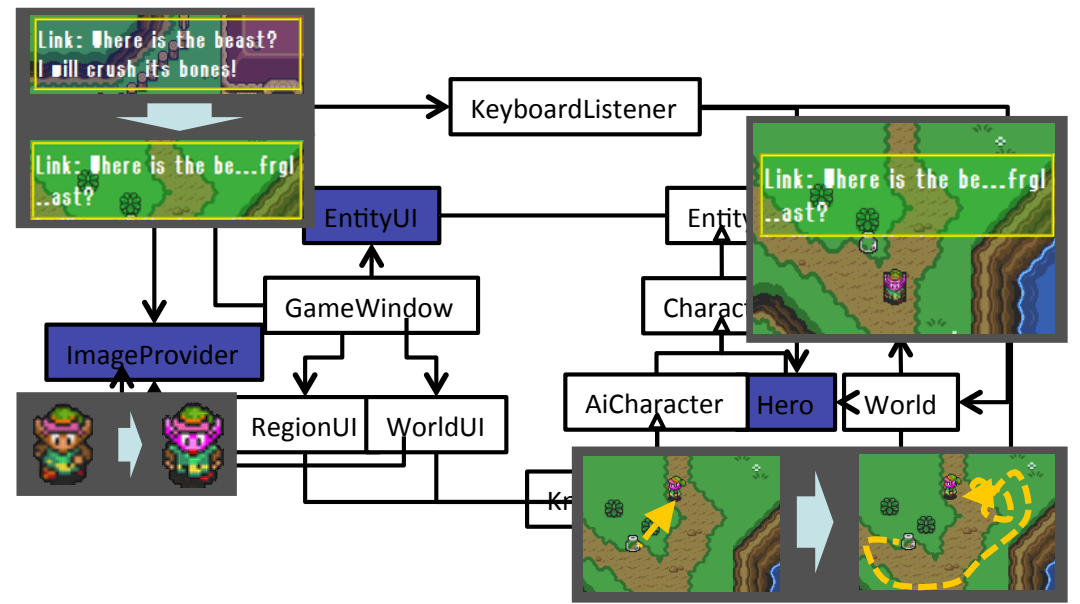
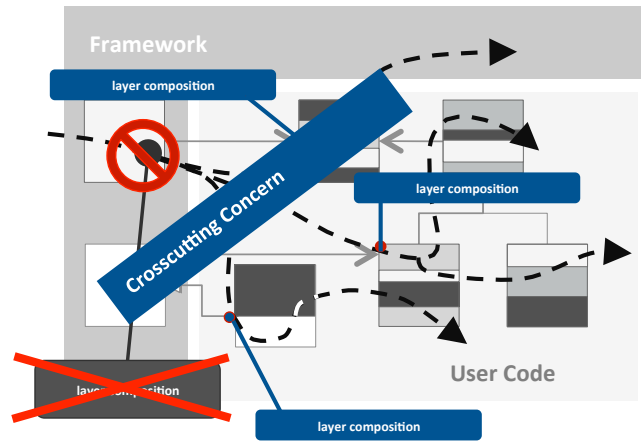
Reactive Approaches

event-based composition JCop

reactive composition ContextJS / Babelsberg

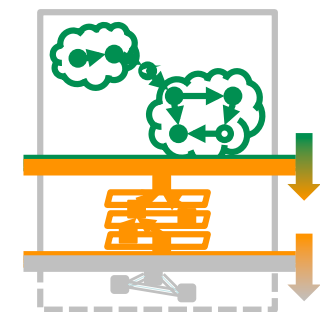
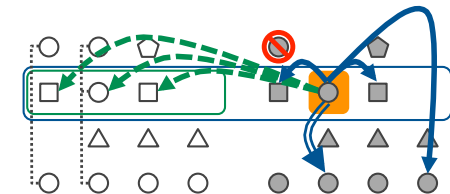
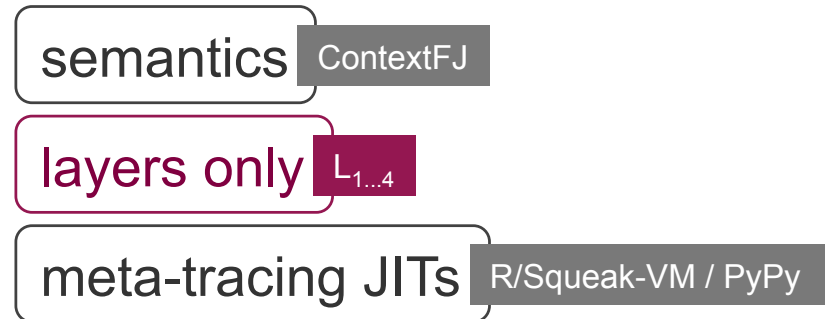
constraint-based composition ContextJS / Babelsberg

constraint layers



Foundations

- Semantics and types
 - ContextFJ
- **Symmetry**
 - No classes, only layers
 - No base system
 - $L_{1..4}$
- Sideways composition very expensive
 - **Runtime support for optimizations**
 - Meta-tracing JITs
 - R/Squeak-VM
 - Higher performance → more (meta-level) flexibility



$$\frac{PT(m, C, L_0) \text{ undefined} \quad mbody(m, C, \bar{L}', \bar{L}) = \bar{x}.e \text{ in } D, \bar{L}''}{mbody(m, C, (\bar{L}'; L_0), \bar{L}) = \bar{x}.e \text{ in } D, \bar{L}''}$$

Behavioral Scoping

COP

w/ Pascal Costanza and Oscar Nierstrasz

```
class Person {
  private String name, address;
  private Employer employer;

  Person(String newName,
         String newAddress,
         Employer newEmployer) {
    this.name = newName;
    this.employer = newEmployer;
    this.address = newAddress;
  }

  String toString() {return "Name: "+name;}
```

```
layer Address {
  String toString() {
    return proceed()+"; Contact: "+address;
  }
}
```

```
layer Employment {
  String toString() {
    return proceed()+"; [Employer] "+employer;
  }
}
```

```
class Employer {
  private String name, address;

  Employer(String newName,
         String newAddress) {
    this.name = newName;
    this.employer = newEmployer;
  }

  String toString() {return "Name: "+name;}
```

```
layer Address {
  String toString() {
    return proceed()+"; Visitors: "+address;
  }
}
```

```
class Person {
```

```
private Employer hpi = new Employer("HPI", "14440 Potsdam");
private Person robert = new Person("Robert Hirschfeld", "14471 Potsdam", hpi);
```

```
Person
```

```
System.out.println(robert);
```

```
this
```

```
this
```

```
this
```

```
}
```

Output: Name: Robert Hirschfeld

```
String toString() {return "Name: "+name;}
```

```
String toString() {return "Name: "+name;}
```

```
layer Address {
  String toString() {
    return proceed()+"; Contact: "+address;
  }
}
```

```
layer Address {
  String toString() {
    return proceed()+"; Visitors: "+address;
  }
}
```

```
layer Employment {
  String toString() {
    return proceed()+"; [Employer] "+employer;
  }
}
```

```
class Person {
```

```
private Employer hpi = new Employer("HPI", "14440 Potsdam");
private Person robert = new Person("Robert Hirschfeld", "14471 Potsdam", hpi);
```

```
Person
```

```
    with (Address) {
        System.out.println(robert);
    }
    this
    this
    this
}
```

Output: Name: Robert Hirschfeld; Contact: 14471 Potsdam

```
String toString() {return "Name: "+name;}
```

```
String toString() {return "Name: "+name;}
```

```
layer Address {
    String toString() {
        return proceed()+"; Contact: "+address;
    }
}
```

```
layer Address {
    String toString() {
        return proceed()+"; Visitors: "+address;
    }
}
```

```
layer Employment {
    String toString() {
        return proceed()+"; [Employer] "+employer;
    }
}
```

```
class Person {
```

```
    private Employer hpi = new Employer("HPI", "14440 Potsdam");
    private Person robert = new Person("Robert Hirschfeld", "14471 Potsdam", hpi);
```

```
    Person with (Employment) {
        with (Address) {
            System.out.println(robert);
        }
    }
    this }
    this }
    this }
}
```

Output: *Name: Robert Hirschfeld; Contact:14471 Potsdam; [Employer] Name: HPI; Visitors: 14440 Potsdam*

```
String toString() {return "Name: "+name;}
```

```
String toString() {return "Name: "+name;}
```

```
layer Address {
    String toString() {
        return proceed()+"; Contact: "+address;
    }
}
```

```
layer Address {
    String toString() {
        return proceed()+"; Visitors: "+address;
    }
}
```

```
layer Employment {
    String toString() {
        return proceed()+"; [Employer] "+employer;
    }
}
```

```
class Person {
```

```
private Employer hpi = new Employer("HPI", "14440 Potsdam");
private Person robert = new Person("Robert Hirschfeld", "14471 Potsdam", hpi);
```

```
Person with (Address) {
    with (Employment) {
        System.out.println(robert);
    }
}
this }
this }
this }
}
```

Output: Name: Robert Hirschfeld; [Employer] Name: HPI;
Visitors: 14440 Potsdam; Contact: 14471 Potsdam

```
String toString() {return "Name: "+name;}
```

```
String toString() {return "Name: "+name;}
```

```
layer Address {
    String toString() {
        return proceed()+"; Contact: "+address;
    }
}
```

```
layer Address {
    String toString() {
        return proceed()+"; Visitors: "+address;
    }
}
```

```
layer Employment {
    String toString() {
        return proceed()+"; [Employer] "+employer;
    }
}
```

```
class Person {
```

```
private Employer hpi = new Employer("HPI", "14440 Potsdam");
private Person robert = new Person("Robert Hirschfeld", "14471 Potsdam", hpi);
```

```
Person with (Address) {
    with (Employment) {
        System.out.println(robert);
    }
}
this
this
this
```

Thread-1

Output-1: Name: Robert Hirschfeld; [Employer] Name: HPI;
Visitors: 14440 Potsdam; Contact: 14471 Potsdam

```
String with (Employment) {
    with (Address) {
        System.out.println(robert);
    }
}
layer
String
re
```

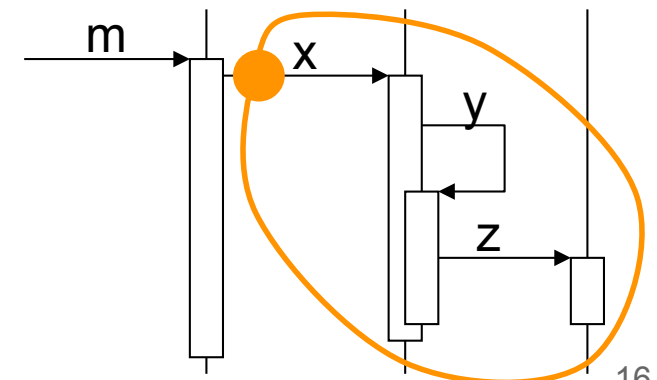
Thread-2

Output-2: Name: Robert Hirschfeld; Contact: 14471 Potsdam;
[Employer] Name: HPI; Visitors: 14440 Potsdam

```
layer
String
return proceed()+"; [Employer] "+employee;
```

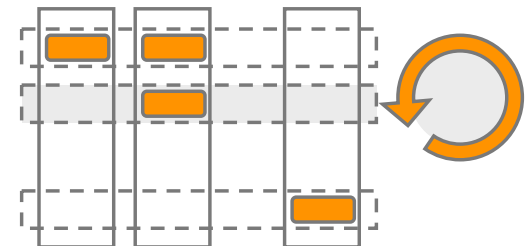
Dynamically-scoped Layer Activation

- Constructs
 - `with (...)` {...}
 - `without (...)` {...}
 - `next (...)`
- Activate (deactivate) layers for the **current thread**
 - **No interference** with other layer activations/deactivations in other threads
 - Layers are activated/deactivated only for the **dynamic extent** of the associated code block (dynamic scoping)
 - **Activation order** determines method precedence



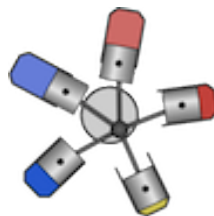
COP Basics Summary

- **Behavioral variations**
 - Partial class, method, and layer definitions
- **Layers**
 - Groups of related context-dependent behavioral variations
- **Activation**
 - Activation and deactivation of layers at run-time
- **Context**
 - Anything computationally accessible
- **Scoping**
 - Well-defined explicitly-controlled scopes



COP Extensions (Some...)

- ContextS
- ContextS2
- ContextJS
- JCop (ContextJ)
- ContextPy
- PyDCL
- UseCasePy
- PyContext
- ContextR
- ContextG
- ContextAmber
- $L_{1...4}$



- ContextL
- ContextScheme
- ContextJ*
- ContextErlang
- EventCJ
- Lambic
- Ambience
- COP.JS
- deIMDSCO/cj
- Phenomenal Gem
- Subjective-C
- Context Petri Nets



Structural Scoping & Development Layers

Strect

w/ Jens Lincke

Lively Webwerkstatt

HeatingSystem

Heat: 6.4681 [kW/s]
 Stopped: false
 Factor: 20
 Max: 5 [kW]

```

if ( $.heat < full && #fuel $.gas > $.Max * at &&
    #HeatStorage $.Energy < 0.3 * #HeatStorage $.Max) {
    var gas = $.Max
    #Fuel $.Gas -- g
    $.Heat += gas
}
        
```

\$.Factor
\$.Heat
\$.Max
\$.Stopped

SerializationInspector

min refs: 0 min full size: 20000

Object	Name	ClassName
0	root	lively.morphic
1	submorphs	object
2	146	PartsBinBrowser
3	attributeConnections	lively.morphic
4	0	object
5	0	AttributeConne
6	0	lively.morphic
7	0	
8	0	
9	0	
10	0	
11	0	
12	0	
13	0	
14	0	
15	0	
16	0	
17	3	
18	0	
19	0	
20	0	
21	0	
22	1	shape
23	1	stringifiedShapeNode
24	0	
25	0	
26	0	
27	0	
28	0	
29	2	shape
30	2	stringifiedShapeNode

URL: http://lively-kernel.org/repository/webwerkstatt/users/jenslincke/thesis/data/svn_log_jenslincke.xml

Filter: *\$ Min: 1

maximize SpreadsheetScripter.metainfo, markoroeder, Mon May 09 2011 21:35:07 GMT+0200 (CEST)

LaTeX Outline

compare print

- Examples? [03_sdlis]
- but... [03_sdlisupport1]
- LT: Maybe make the
- REVIEWER 2: "In t
- [04_malleable_tools.tex:49]
- but... [04_malleable_tools.tex:62]
- add figure of StyleEditor [04_malleable_tools.tex:99] @done (13-12-04 14:10)
- add figure of dragging object with halo? [04_malleable_tools.tex:100] @done (13-12-04 14:10)
- Problems with serializing scripts? [04_malleable_tools.tex:106]
- Active Content -> Application Content -> (just) Content [04_malleable_tools.tex:114]
- make clear how we can live with changes [04_malleable_tools.tex:183]
- Should I present the Syntax and Semantics of ContextJS in a more abstract way? [05_devilays]
- How did Maite present the Syntax of ContextJ? [05_devilays.tex:51]
- write section "Adapting Core Behavior from Scripted Tools" [05_devilays.tex:286]
- implement section "Repository of Parts" [07_partsbin.tex:8]
- insert ref to code duplication [07_partsbin.tex:50]
- only random number based UUIDs can be generated in the browser. [07_partsbin.tex:57]
- write section "Scripting Parts - Summary" [07_partsbin.tex:80]
- write section "Case Study: Server Side Scripting" [08_casestudies.tex:58]
- Ref? [08_casestudies.tex:334]
- show tracing result [08_casestudies.tex:472]
- to be fair, we could write down non COP tracer code that manages dynamic scope somehow
- case-study chapter: write summary for [08_casestudies.tex:739]
- Reviewer 1: 'What is the purpose of this "related work" section except mentioning some relat

World

name: 10 Rectangle [lively.morphic.Shapes.Rectangle]

ignore -> <- do not ignore

__SourceModuleName__: Global.lively.morphic....

__Position__: [object Object]

__Extent__: [object Object]

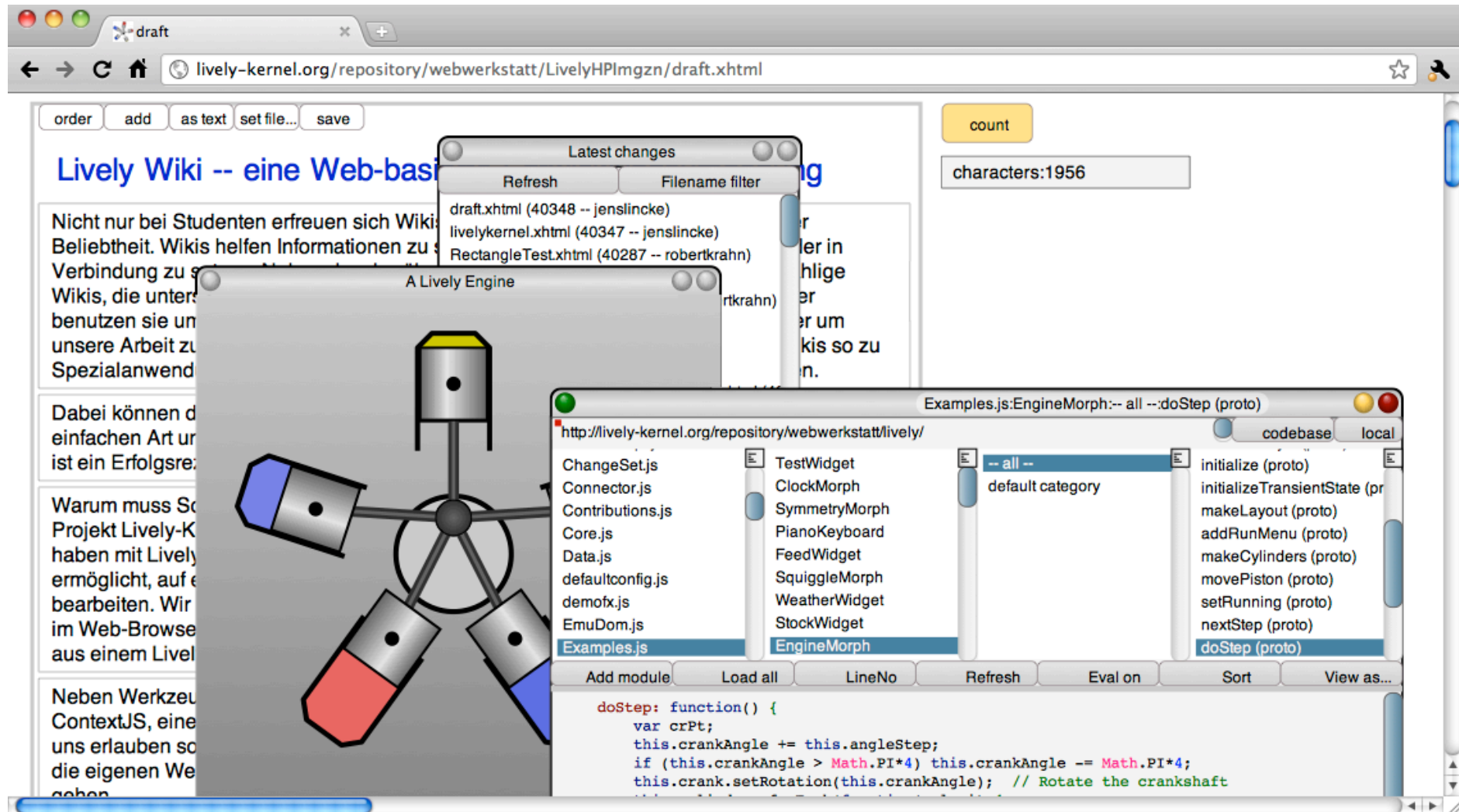
__Fill__: [object Object]

renderContextTable: [object Object]

__LivelyClassName__: lively.morphic.Shapes....

7 Point
4 undefined
2 lively.morphic.EventHandler
2 Color
2 lively.morphic.Shapes.Recte
1 ChangeSet
1 lively.morphic.HandMorph
1 lively.morphic.World

Lively Kernel and Lively Wiki



The screenshot shows a web browser window with the URL `lively-kernel.org/repository/webwerkstatt/LivelyHPIimgzn/draft.xhtml`. The page displays a Lively Wiki entry titled "Lively Wiki -- eine Web-basierte..." with German text. A diagram of a crankshaft is visible in the center. Overlaid on the page are several windows:

- Latest changes:** A window showing a list of recent file changes:
 - draft.xhtml (40348 -- jenslincke)
 - livelykernel.xhtml (40347 -- jenslincke)
 - RectangleTest.xhtml (40287 -- robertkrahn)
- Examples.js:EngineMorph:-- all --:doStep (proto):** A code editor window showing a list of modules on the left and a code editor on the right. The code editor displays the following JavaScript code:


```
doStep: function() {
  var crPt;
  this.crankAngle += this.angleStep;
  if (this.crankAngle > Math.PI*4) this.crankAngle -= Math.PI*4;
  this.crank.setRotation(this.crankAngle); // Rotate the crankshaft
```

Self-supporting Development Environments

- Collaboratively evolve tools and environment
 - Adapt tools while using them
 - From within
 - Share easily
- Design goals for self-supporting development environments (SSDEs)
 - Innovative repair
 - Short feedback loops → immediacy
- Technical problem
 - Changes to core functionality might break the environment (also for everyone)

ContextJS

- Library-based COP extension to JavaScript
- Open implementation (OI) for layer composition
 - Behavioral scoping
 - **Structural scoping**

```
EventCounter = {
  n: 0,
  count: function(evt) {
    this.n = this.n + 1;
  }
}
```

```
EventCounter.count = function(evt) {
  alert("evt: " + evt);
  this.n = this.n + 1;
}
```

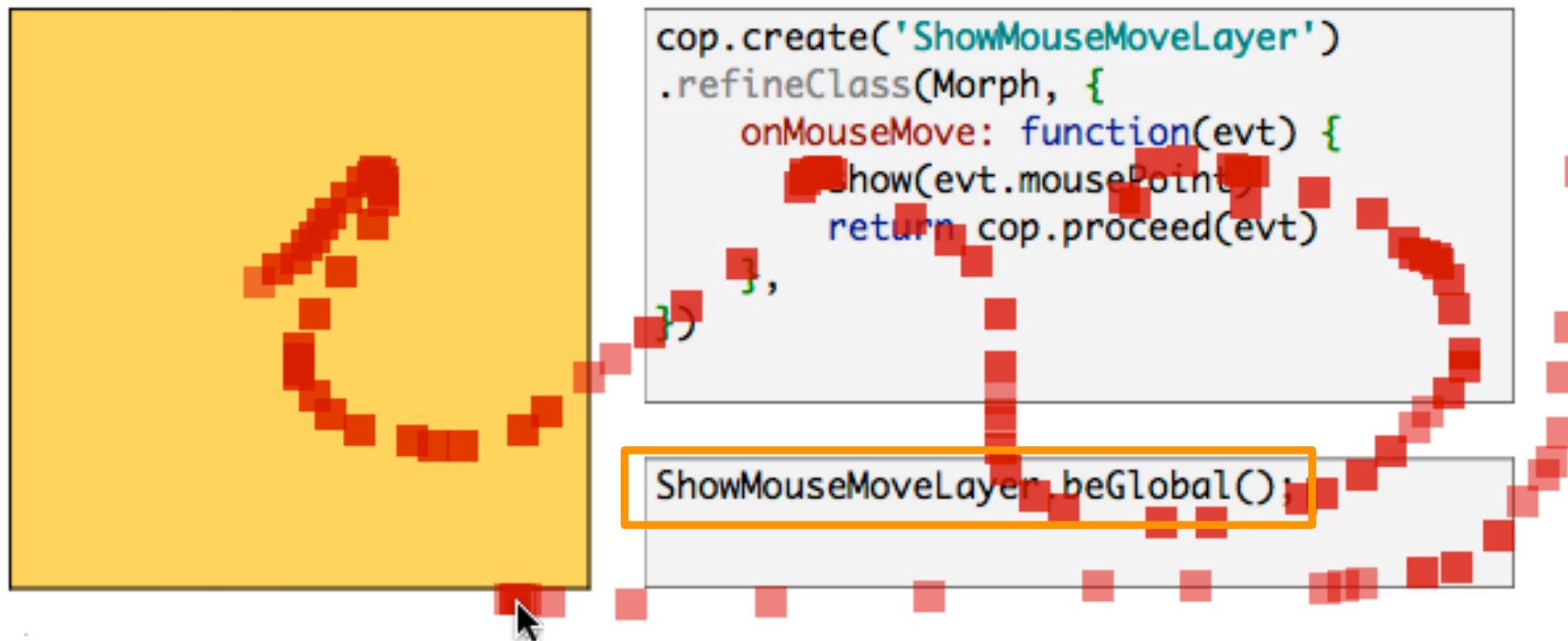
```
cop.create("DevLayer").refineObject(EventCounter, {
  count: function(evt) {
    alert("evt: " + evt);
    this.n = this.n + 1;
  }
})
```

```
cop.proceed(evt);
```

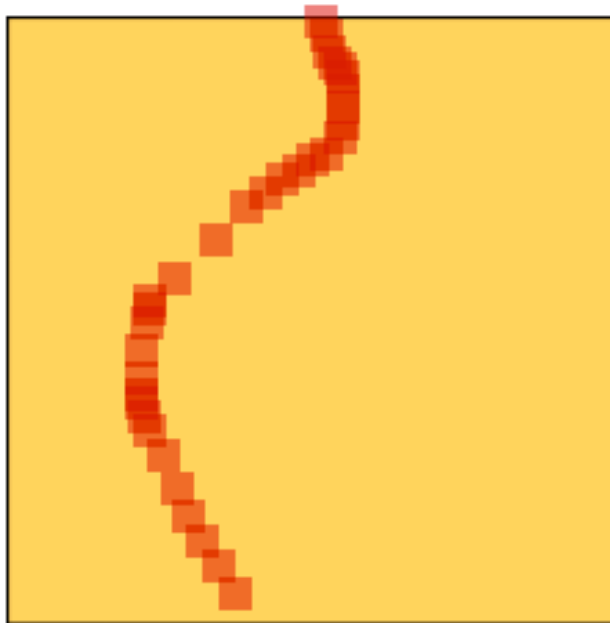
```
DevLayer.beGlobal();
```

```
debugArea.setWithLayers([DevLayer])
```

Example 1: Visualizing Events



Example 1: Visualizing Events



```
cop.create('ShowMouseMoveLayer')  
.refineClass(Morph, {  
  onMouseMove: function(evt) {  
    show(evt.mousePoint)  
    return cop.proceed(evt)  
  },  
})|
```

```
$morph('DebugArea').setWithLayers([ShowMouseMoveLayer])
```

Example 2: Text Coloring

Hello World

```
M Workspace
cop.create('TextColorLayer').refineClass(lively.morphic.Text, {
  processCommandKeys: function(evt) {
    var key = evt.getKeyChar();
    if (key) key = key.toLowerCase();
    if (evt.isShiftDown()) { // shifted commands here...
      switch (key) {
        case "5": { this.emphasizeSelection({color: Color.black}); return true; }
        case "6": { this.emphasizeSelection({color: Color.red}); return true; }
        case "7": { this.emphasizeSelection({color: Color.green}); return true; }
        case "8": { this.emphasizeSelection({color: Color.blue}); return true; }
      }
    }
    return cop.proceed(evt);
  }
});
```

```
this.setWithLayers([...])
```

```
TextColorLayer.beGlobal()
```

Example 3: Developing Auto-completion

this.onMouse

- onMouse
- onMouseDown
- onMouseDownEr
- onMouseMove
- onMouseMoveEr
- onMouseOut

DevArea

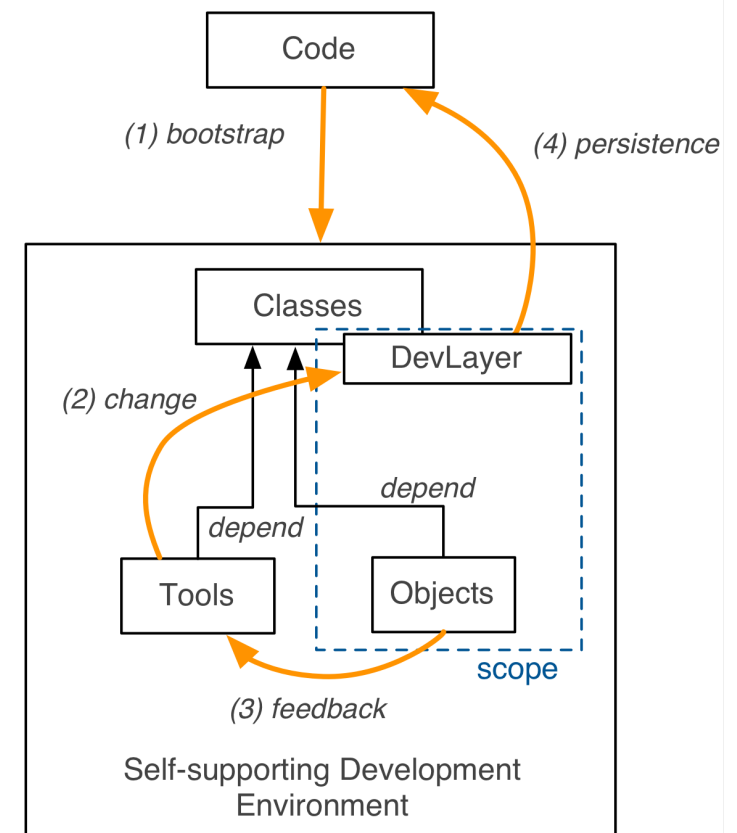
```
cop.create('WordCompletionLayer').refineClass(lively.morphic.Text, {
  onKeyPress: function(evt) {
    var key = evt.getKeyChar();
    if (!key.match(/\w/)) {
      this.hideWordCompletionMorph();
      return;
    }
    var range = this.getSelectionRange()
    var cursor = range[0];
    // ....
  }
});
```

Workspace

```
$morph('DevArea').setWithLayers([WordCompletionLayer]);
```

Structural Scoping Summary

- Application of **COP to SSDEs**
 - Organize changes into layers
 - Apply changes during development to only objects of interest
 - Structural scoping
 - Development layers
- **Evolution of tools** in SSDEs can be direct, interactive, and safe
- Future work
 - Refactoring of layers back into base



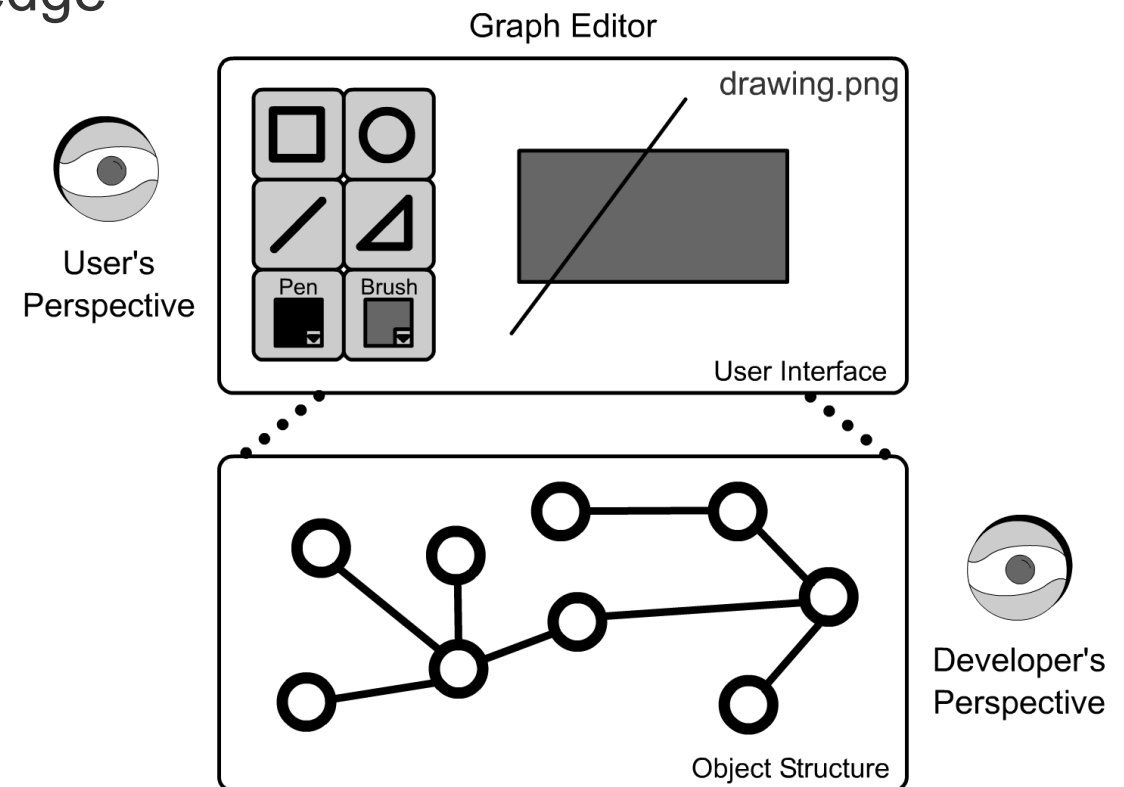
Explicit Use-case Representation

UUC

w/ Michael Perscheid

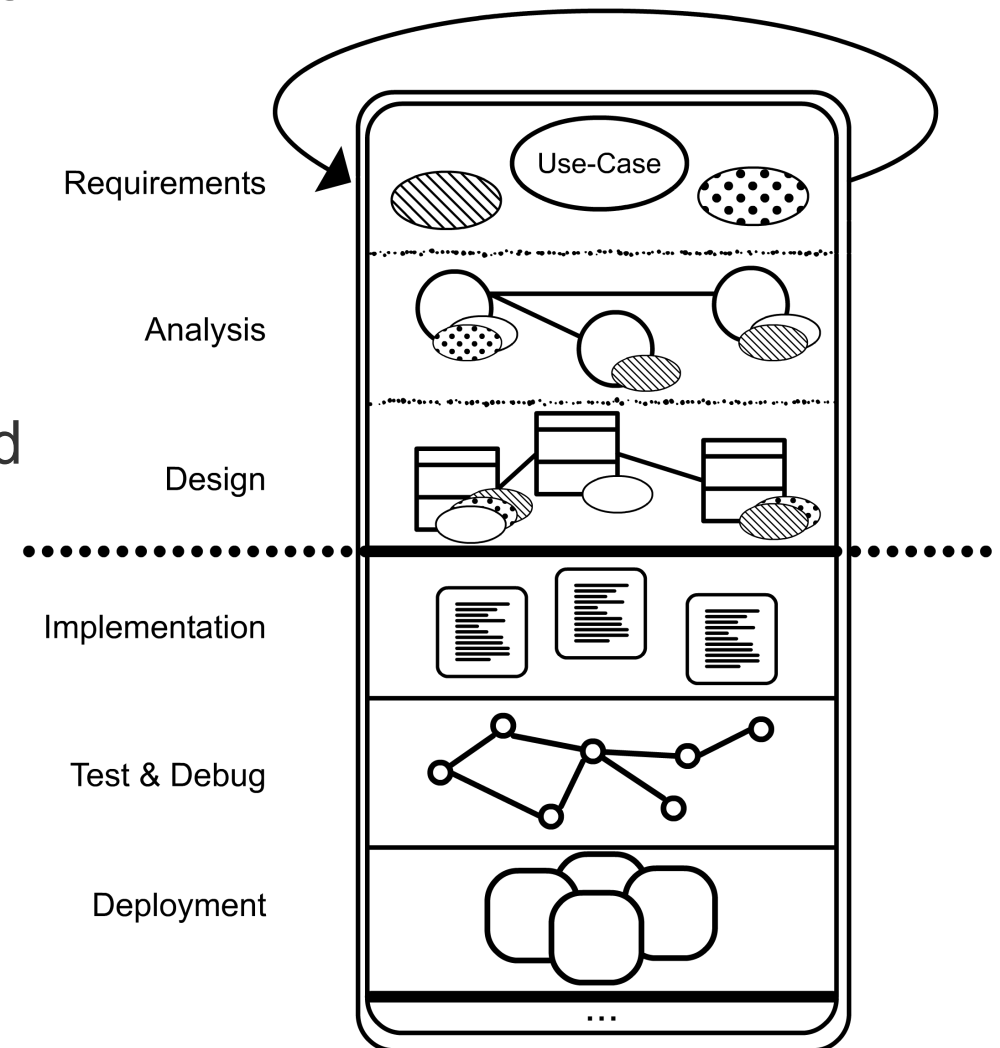
Use-cases in Software Development

- **Users** perceive program behavior without implementation knowledge
- **Developers** also know internals and implementation details
- Use-cases describe interaction at system **boundary**
- Use-cases **link** both perspectives



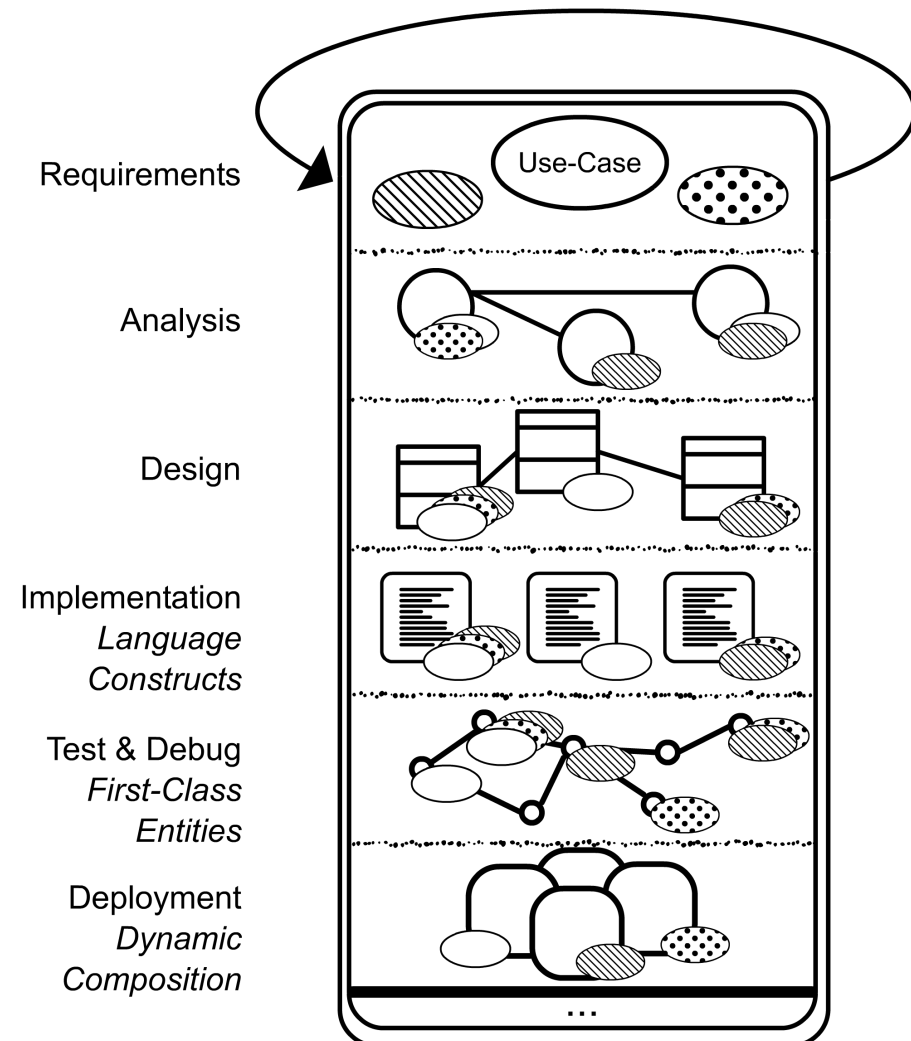
Use-cases in Software Development

- Use-cases and variants are **integral part** of most contemporary development processes
- **Traceability** to use-cases **lost** in later more code- and deployment-centric development activities
- → **Lack of understanding** about which parts of the system contribute to which use-case



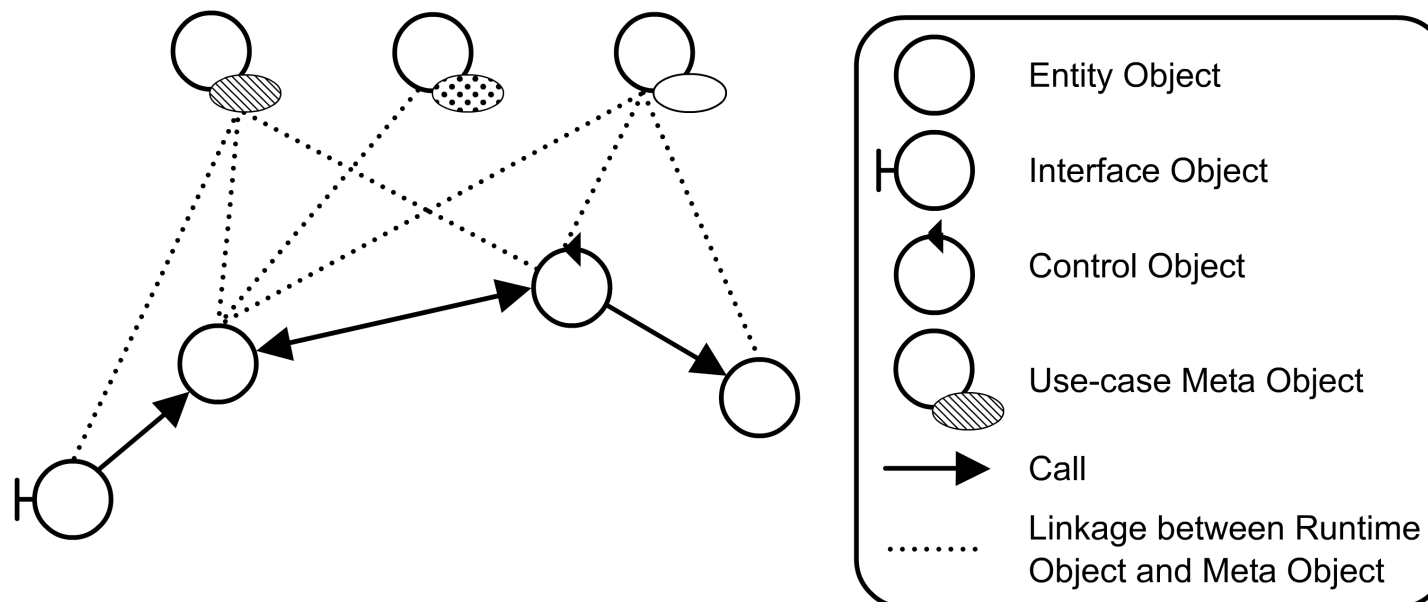
Use-case-centered Development

- Explicit use-case representation in object-oriented languages
- Use-cases in source code, as deployment units, and at run-time



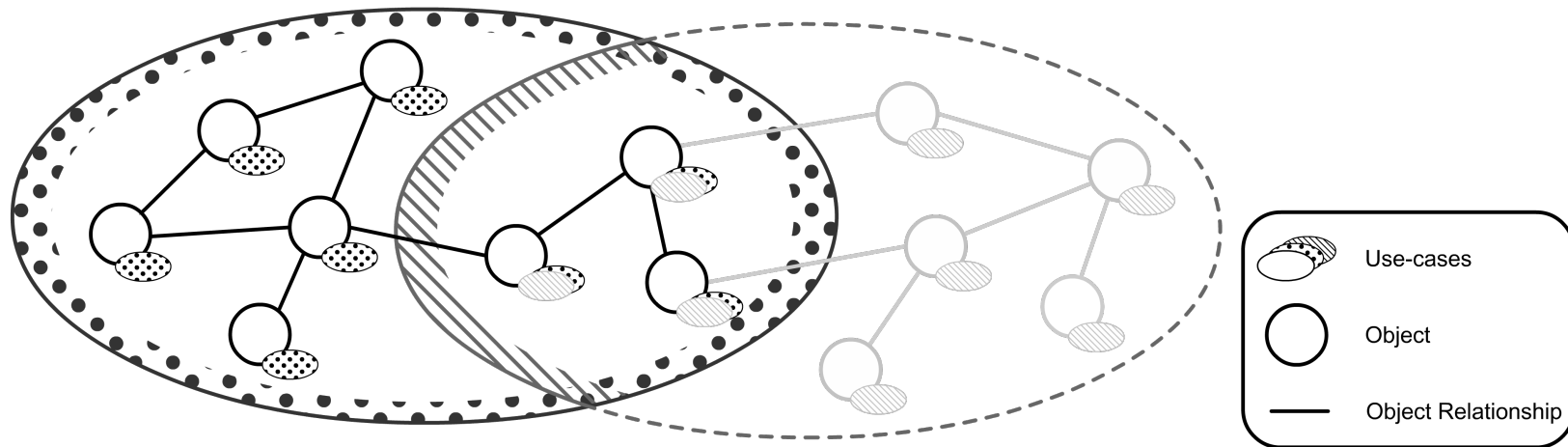
First-class Entities at Run-time

- Based on source code annotations
- Use-cases as **meta objects**
- Central registry of use-case descriptions
- **Available at run-time** for introspection and intercession



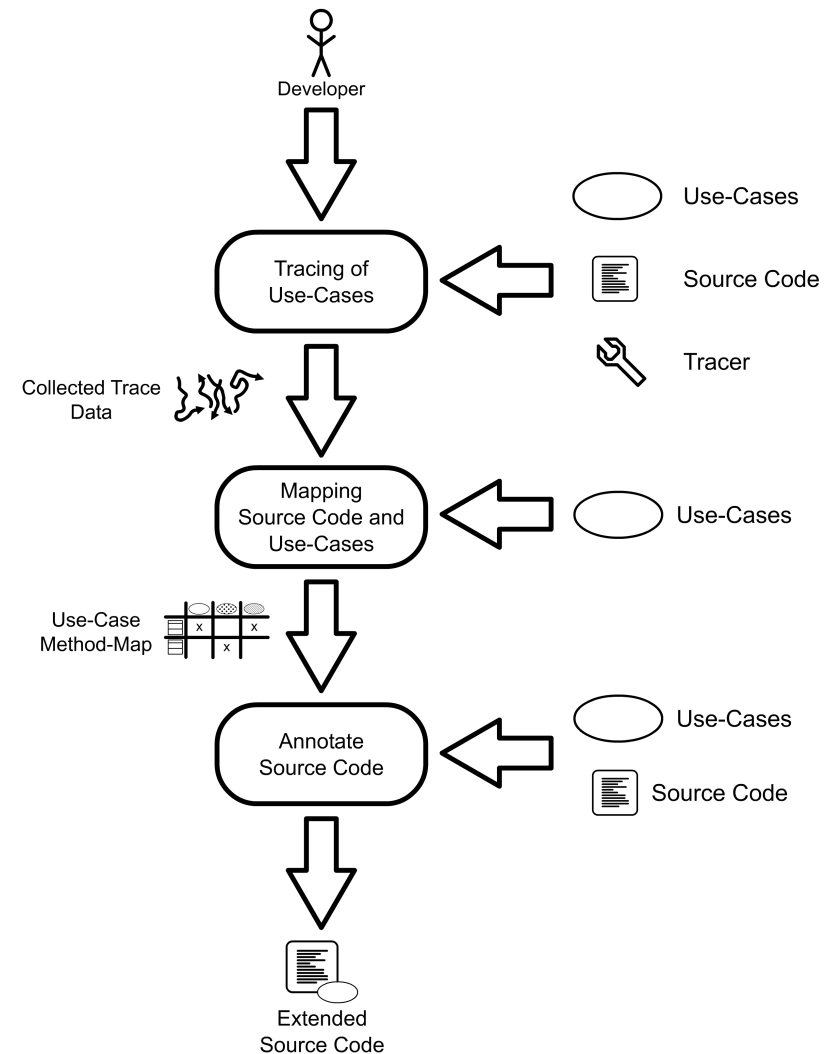
Dynamic Composition

- Based on selection of a set of desired use-cases
- Requires use-case-aware method dispatch
- Allows for use-cases as **deployment units**



Use-case Discovery

- Introduce use-case-centered development to **existing systems**
- Based on **feature location** techniques
- Tracer observes execution of use-cases from the users' point of view
- Semi-automatic and automatic implementations



Use-case Layers Summary

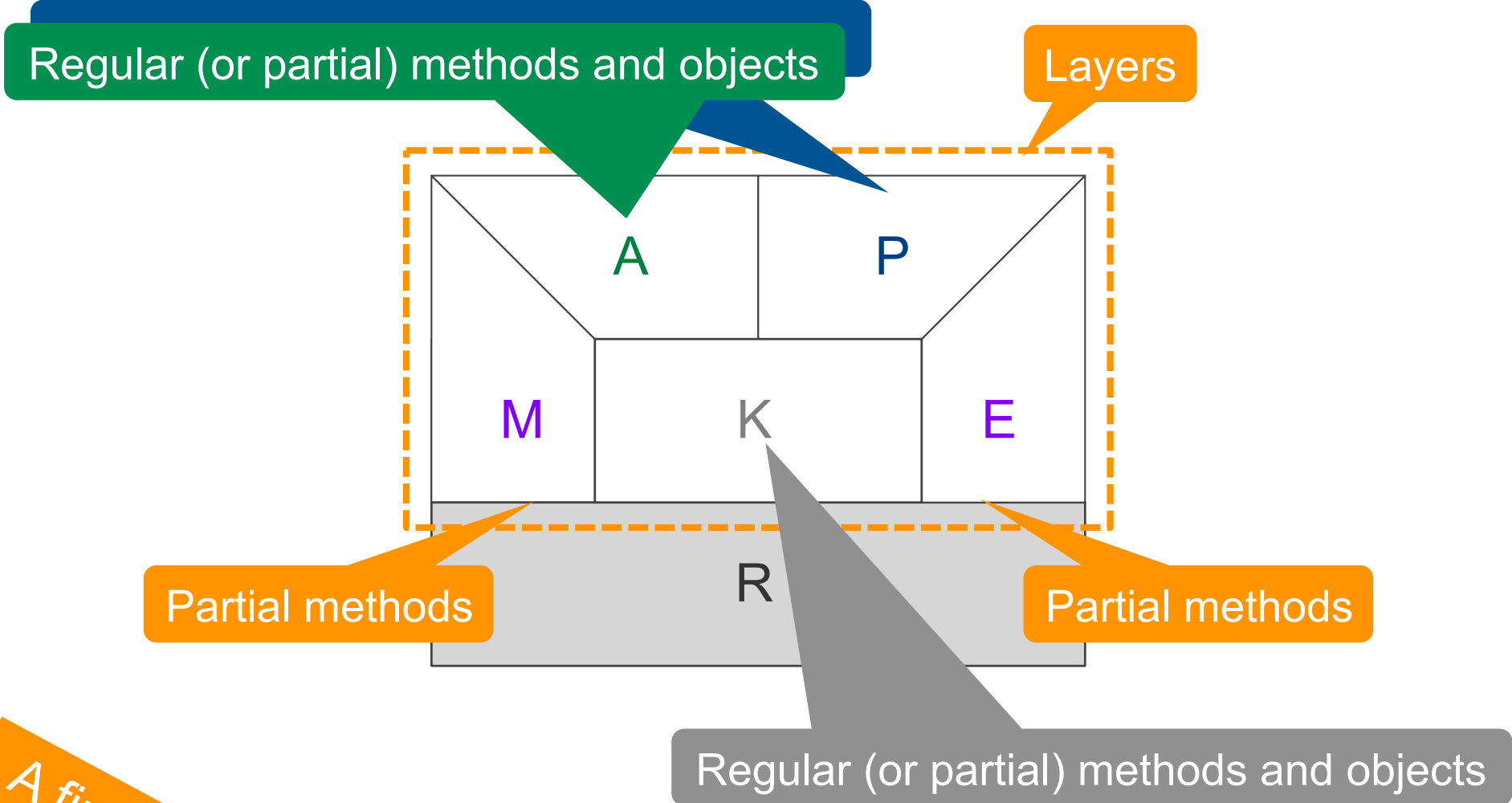
- Use-case-centered development allows for **explicit representation** of use-cases in code and at run-time
 - Available during implementation, testing, and deployment
 - **Use-case discovery** migrates existing systems to use-case-centered development
- Future work
 - User studies
 - Improved analysis techniques
 - Better tool support



Monitor Analyze Plan Execute-Knowledge

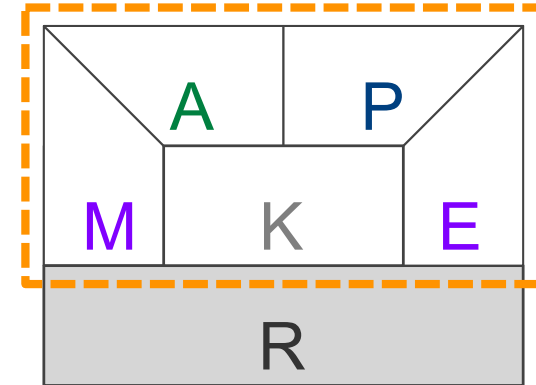
MAPE-K

COP & MAPE-K



A first sketch...

COP & MAPE-K



```

class ResourceManager {
  // ...
  layer MAPE { // not necessary
    static mapeBefore(resource, in, ...) {
      // note = ...;
      monitorBefore(...);
      analyzeBefore(...);
      planBefore(...);
      executeBefore(...);
      return note;
    }
    static mapeAfter(resource, in, note, out, ...) {
      // newOut = ...
      monitorAfter(...); // executeAfter(...);
      analyzeAfter(...); // planAfter(...);
      planAfter(...); // analyzeAfter(...);
      executeAfter(...); // monitorAfter(...);
      return newOut;
    }
  }
}

```

```

class ManagedResource {
  // ...
  process(in) {
    // out := ...;
    return out;
  }
  layer MAPE {
    process(in) {
      note := ResourceManager.mapeBefore(self, in, ...);
      out := next(in);
      out := ResourceManager.mapeAfter(self, in, note, out, ...);
      return out;
    }
  }
}

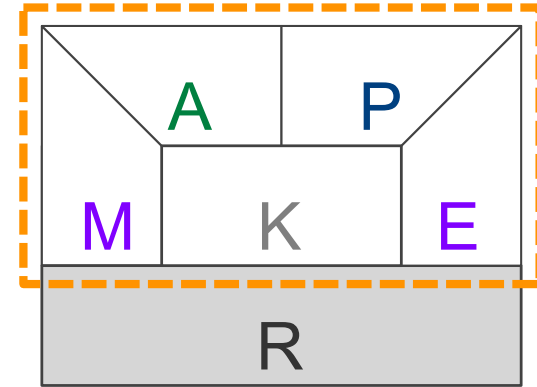
```

A first sketch...

COP & MAPE-K

```

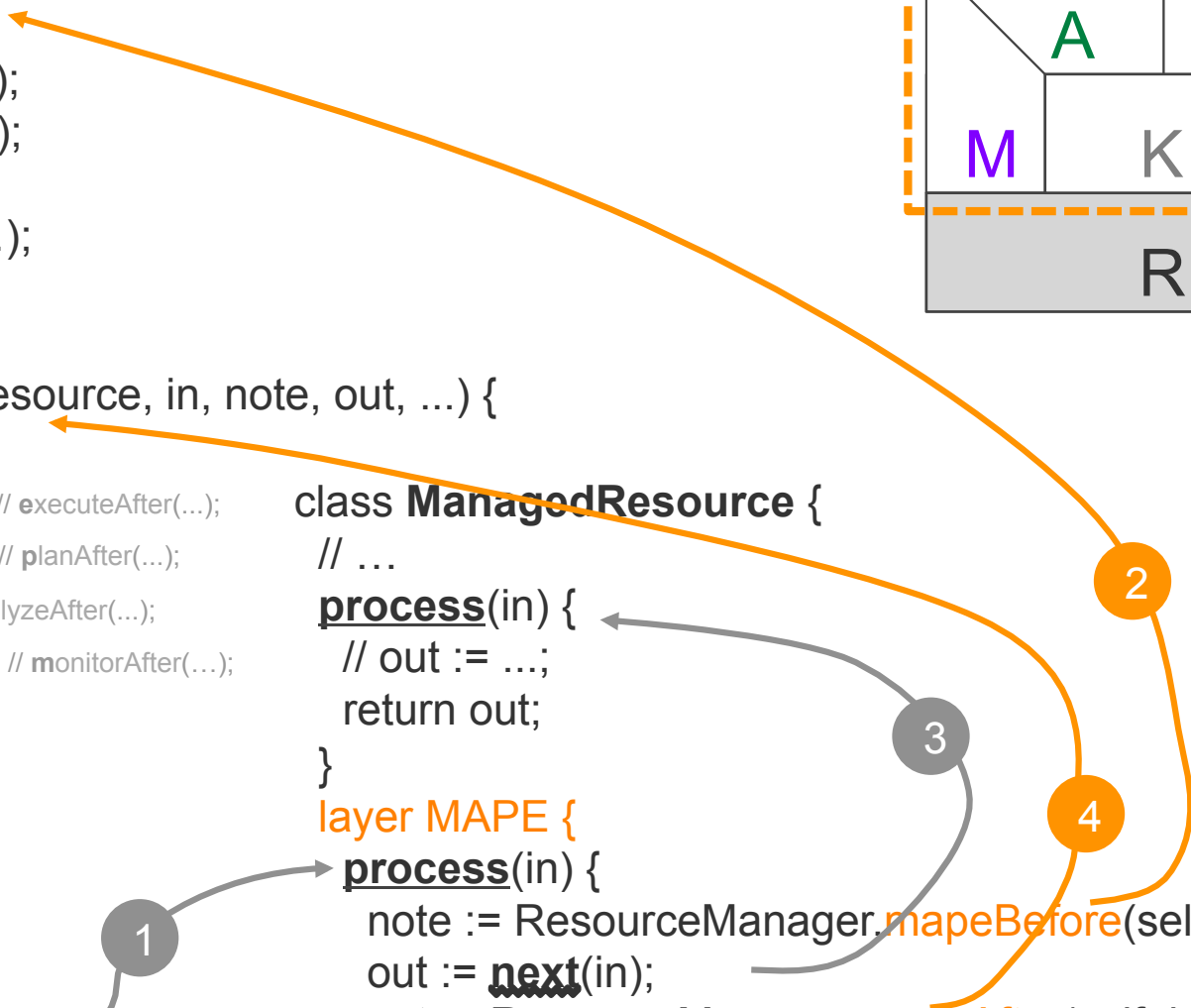
class ResourceManager {
  // ...
  layer MAPE { // not necessary
    static mapeBefore(resource, in, ...) {
      // note = ...;
      monitorBefore(...);
      analyzeBefore(...);
      planBefore(...);
      executeBefore(...);
      return note;
    }
    static mapeAfter(resource, in, note, out, ...) {
      // newOut = ...
      monitorAfter(...); // executeAfter(...);
      analyzeAfter(...); // planAfter(...);
      planAfter(...); // analyzeAfter(...);
      executeAfter(...); // monitorAfter(...);
      return newOut;
    }
  }
}
    
```



```

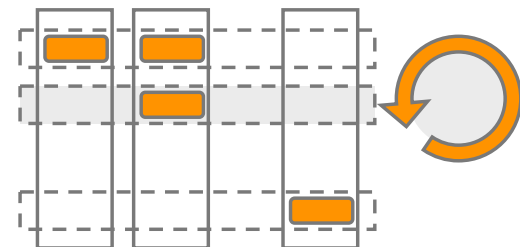
class ManagedResource {
  // ...
  process(in) {
    // out := ...;
    return out;
  }
  layer MAPE {
    process(in) {
      note := ResourceManager.mapeBefore(self, in, ...);
      out := next(in);
      out := ResourceManager.mapeAfter(self, in, note, out, ...);
      return out;
    }
  }
}
    
```

A first sketch...



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Web References

- COP-related publications
 - HPI/SWA
<http://www.hpi.uni-potsdam.de/swa/publications/>
- Selected systems
 - JCop
<https://github.com/hpi-swa/JCop/>
 - ContextJS and Lively Webwerkstatt
<http://lively-kernel.org/repository/webwerkstatt/webwerkstatt.xhtml>
 - EventCJ
<http://prg.is.titech.ac.jp/projects/eventcj/>
 - Lively Kernel
<http://lively-kernel.org/>

