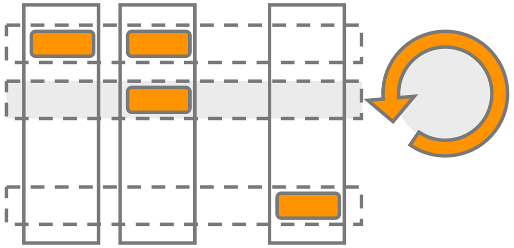
NII Shonan Meeting Seminar 052
Engineering Adaptive Software Systems (EASSy)



Dynamic Software Composition for Run-time System Evolution

(Context-oriented Programming at HPI)

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http://www.hpi.de/swa/

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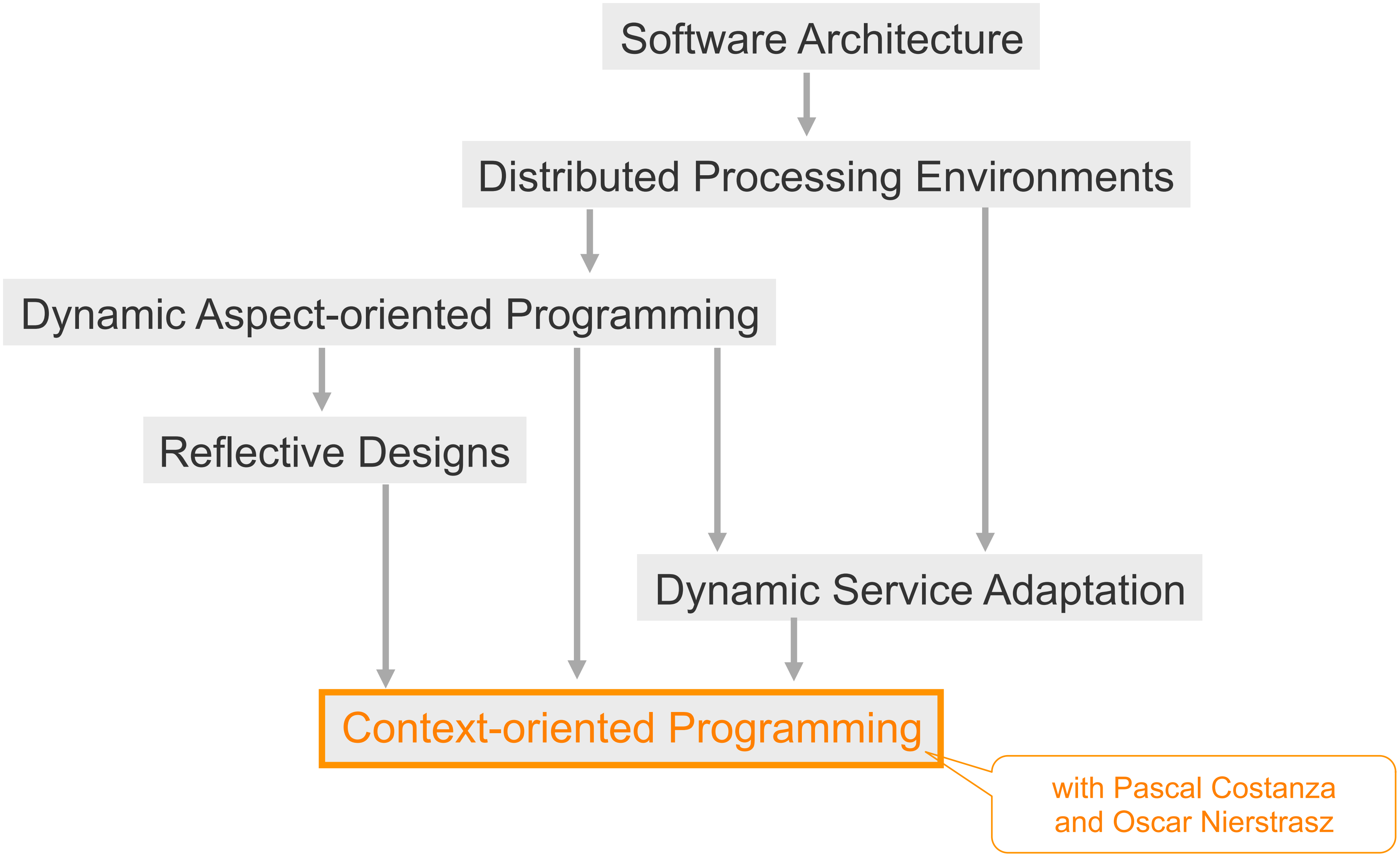
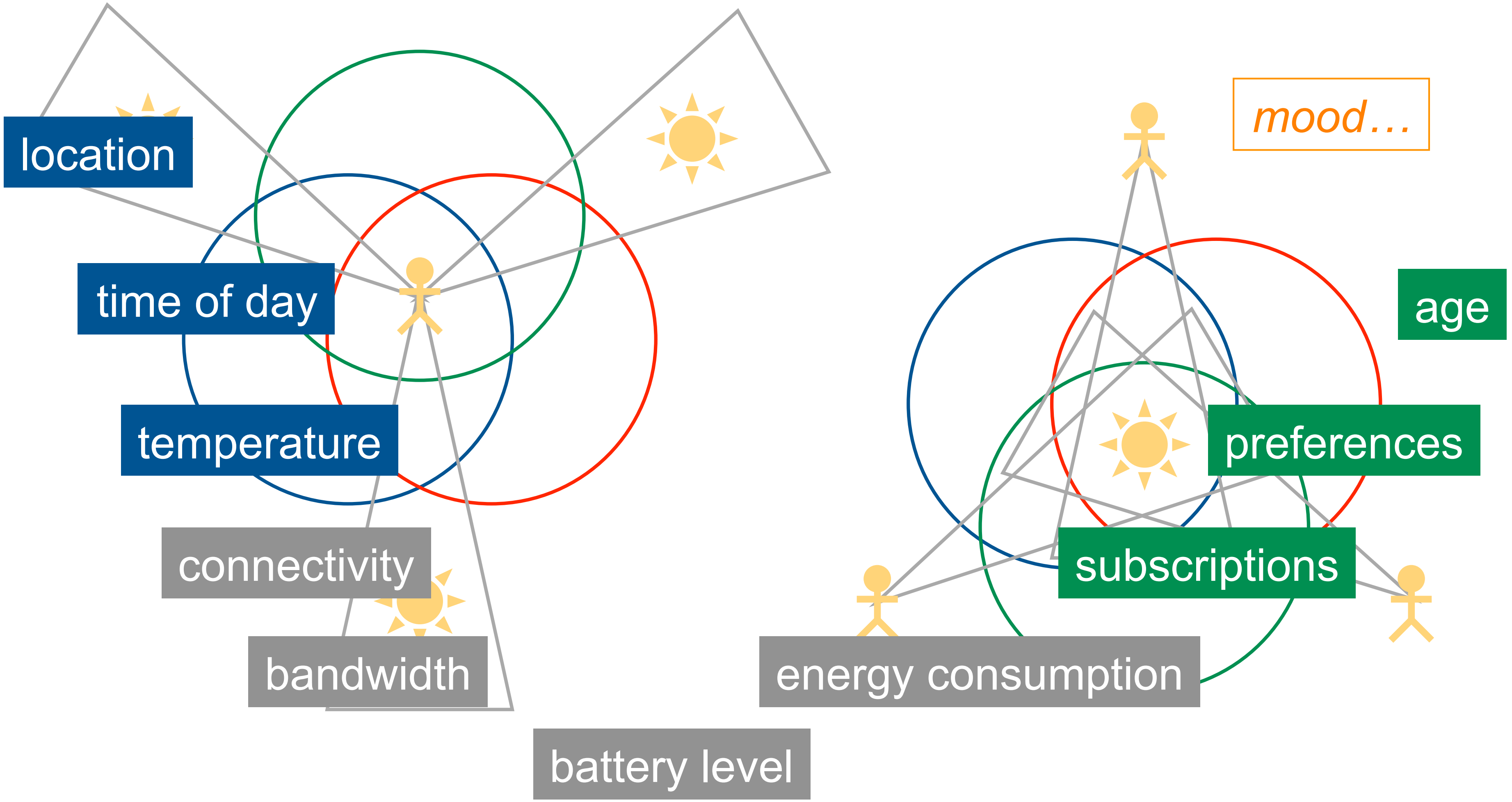
2015-09-07

Some History…

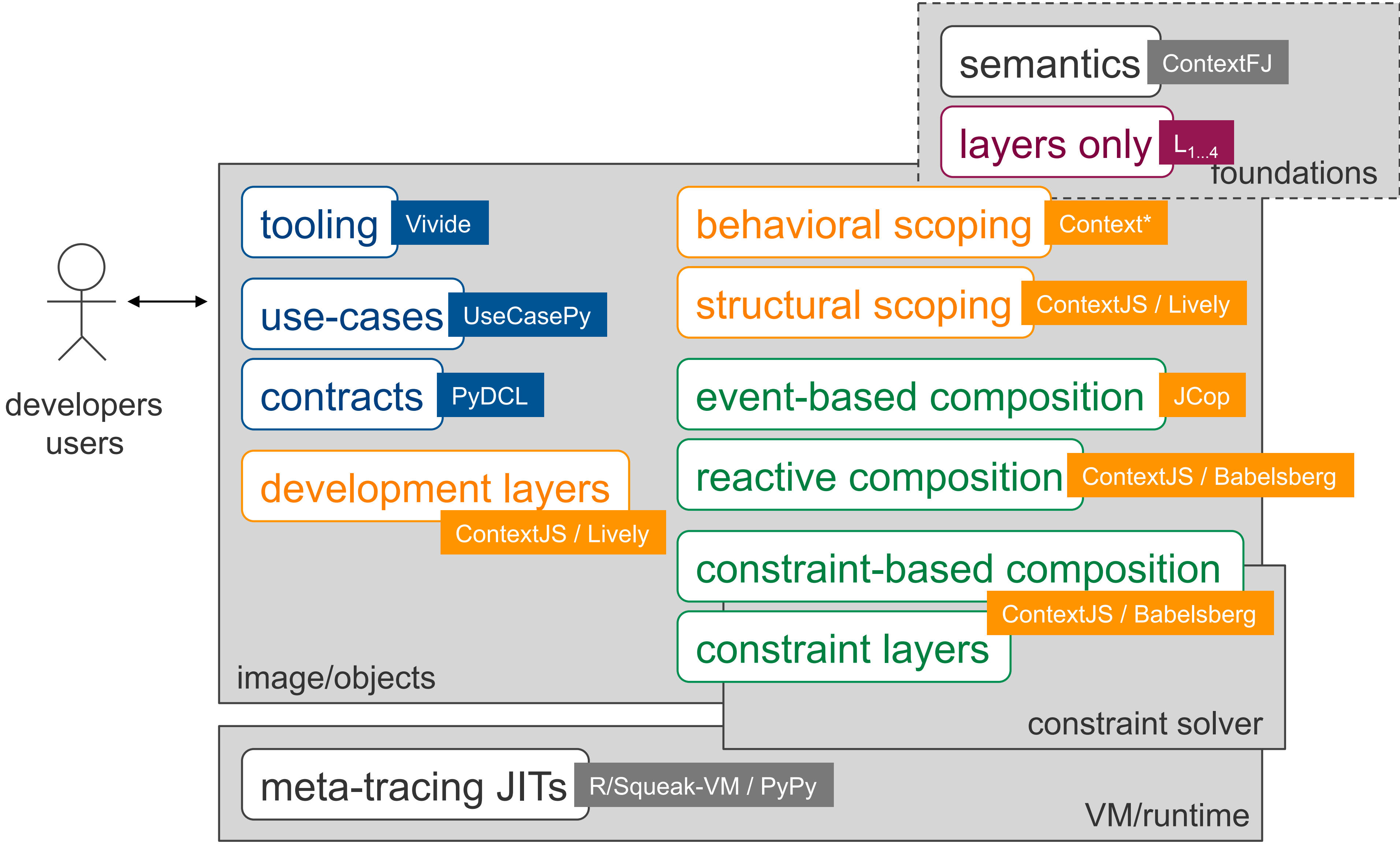


Context

context = everything computationally accessible



Outline


semantics
ContextFJ
layers only
$L_{1...4}$
foundations
tooling
Vivide
use-cases
UseCasePy
contracts
PyDCL
development layers
ContextJS / Lively
behavioral scoping
Context*
structural scoping
ContextJS / Lively
event-based composition
JCop
reactive composition
ContextJS / Babelsberg
constraint-based composition
ContextJS / Babelsberg
constraint layers
constraint solver
image/objects
developers
users
meta-tracing JITs
R/Squeak-VM / PyPy
VM/runtime

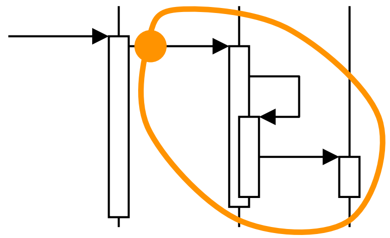
Behavioral Variations

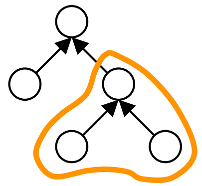
- Behavioral (dynamic) scoping
  - Dynamic extent of execution
  - Almost all COP extensions
- Structural (topological) scoping
  - ContextJS
  - Development layers
- Open implementation (OI) for scoping strategies
  - Allows for domain-specific scoping
  - Mainly applied to UI framework structures
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

behavioral scoping — Context*

structural scoping — ContextJS / Lively

development layers — ContextJS / Lively





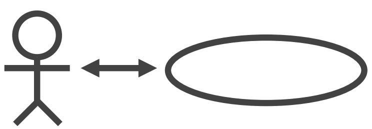
Development Support

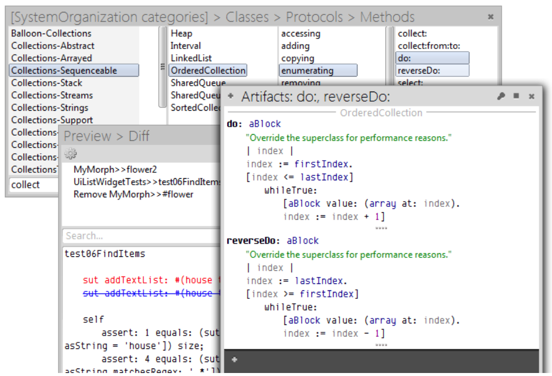
tooling | Vivide

use-cases | UseCasePy

contracts | PyDCL

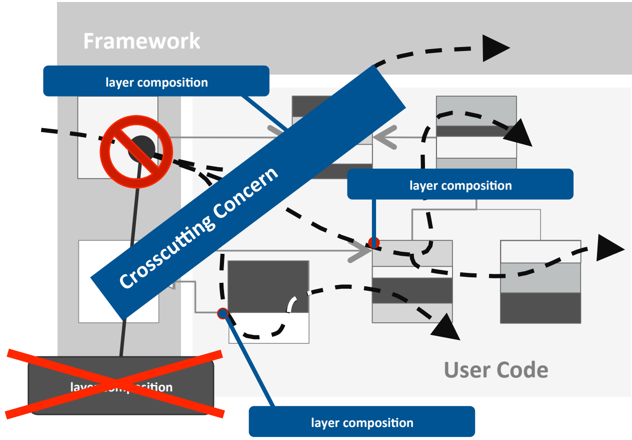
- More applied → more useful
- In PL work tool support often neglected
  - Usually too expensive, especially early…
    → Need for explorative tool building support
    - Vivide
- Crosscutting nature of layers lends itself nicely to crosscutting software engineering concerns
  - Explicit use-cases representation
    - UseCasePy
  - Dynamic contract layers
    - PyDCL

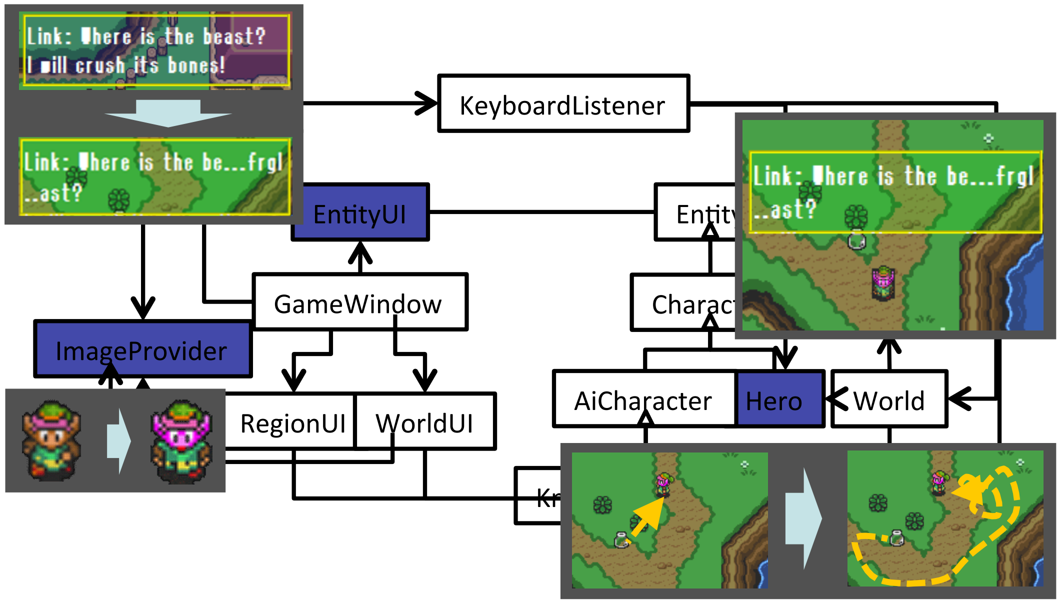




Reactive Approaches

- event-based composition — JCop
- reactive composition — ContextJS / Babelsberg
- constraint-based composition — ContextJS / Babelsberg
- constraint layers





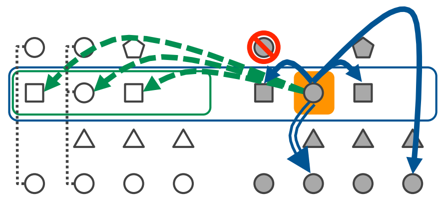
Foundations

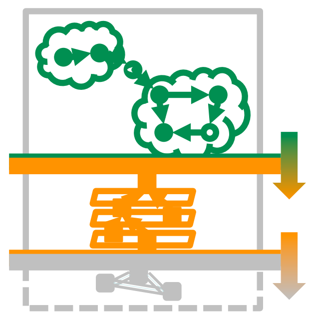
semantics ContextFJ

layers only $L_{1...4}$

meta-tracing JITs R/Squeak-VM / PyPy

- 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





$$\frac{PT(\mathtt{m}, \mathtt{C}, \mathtt{L}_0)\ \text{undefined} \qquad mbody(\mathtt{m}, \mathtt{C}, \overline{\mathtt{L}}', \overline{\mathtt{L}}) = \overline{\mathtt{x}}.\mathtt{e}\ \mathtt{in}\ \mathtt{D}, \overline{\mathtt{L}}''}{mbody(\mathtt{m}, \mathtt{C}, (\overline{\mathtt{L}}'; \mathtt{L}_0), \overline{\mathtt{L}}) = \overline{\mathtt{x}}.\mathtt{e}\ \mathtt{in}\ \mathtt{D}, \overline{\mathtt{L}}''}$$

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,
           Stringe newAddress) {
    this.name = newName;
    this.employer = newEmployer;
  }

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

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

```
class Person {
  priva
  priva

  Pers

    this
    this
    this
  }

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

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

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    }
  }
}
```

```
class Employer {

                                   er;

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

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

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

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

Output: Name: Robert Hirschfeld

```
class Person {
  priva
  priva

  Pers

    this
    this
    this
  }

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

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

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

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

            Output:    Name: Robert Hirschfeld; Contact: 14471 Potsdam
```

```
class Person {
  priva
  priva

  Pers

    this
    this
    this
  }

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

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    String toString() {
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}
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Person robert = new Person(”Robert Hirschfeld", ”14471 Potsdam", hpi);

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

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

```
class Person {
  priva
  priva

  Pers

    this
    this
    this
  }

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

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

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

```
class Employer {

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

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

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

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

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

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

Thread-1

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

Output-1: Name: Robert Hirschfeld<u>; [Employer] Name: HPI</u>*; Visitors: 14440 Potsdam; Contact:14471 Potsdam*

Thread-2

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

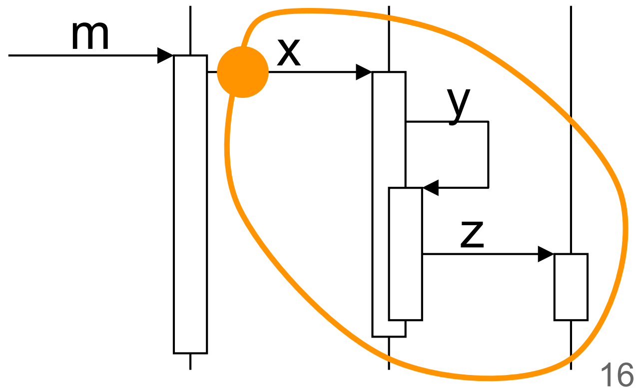
Output-2: Name: Robert Hirschfeld*; Contact:14471 Potsdam*<u>; [Employer] Name: HPI</u>*; Visitors: 14440 Potsdam*

```
class Person {
  priva
  priva

  Pers

    this
    this
    this
  }

  Strin

  laye
    Stri
      re
    }
  }

  laye
    Stri
      return proceed()+"; [Employer] "+employer;
    }
  }
}
```

```
class Employer {
;}
ss;
```

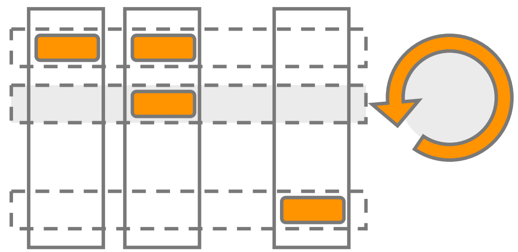
Dynamically-scoped Layer Activation

- 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
- $L_{1\ldots4}$

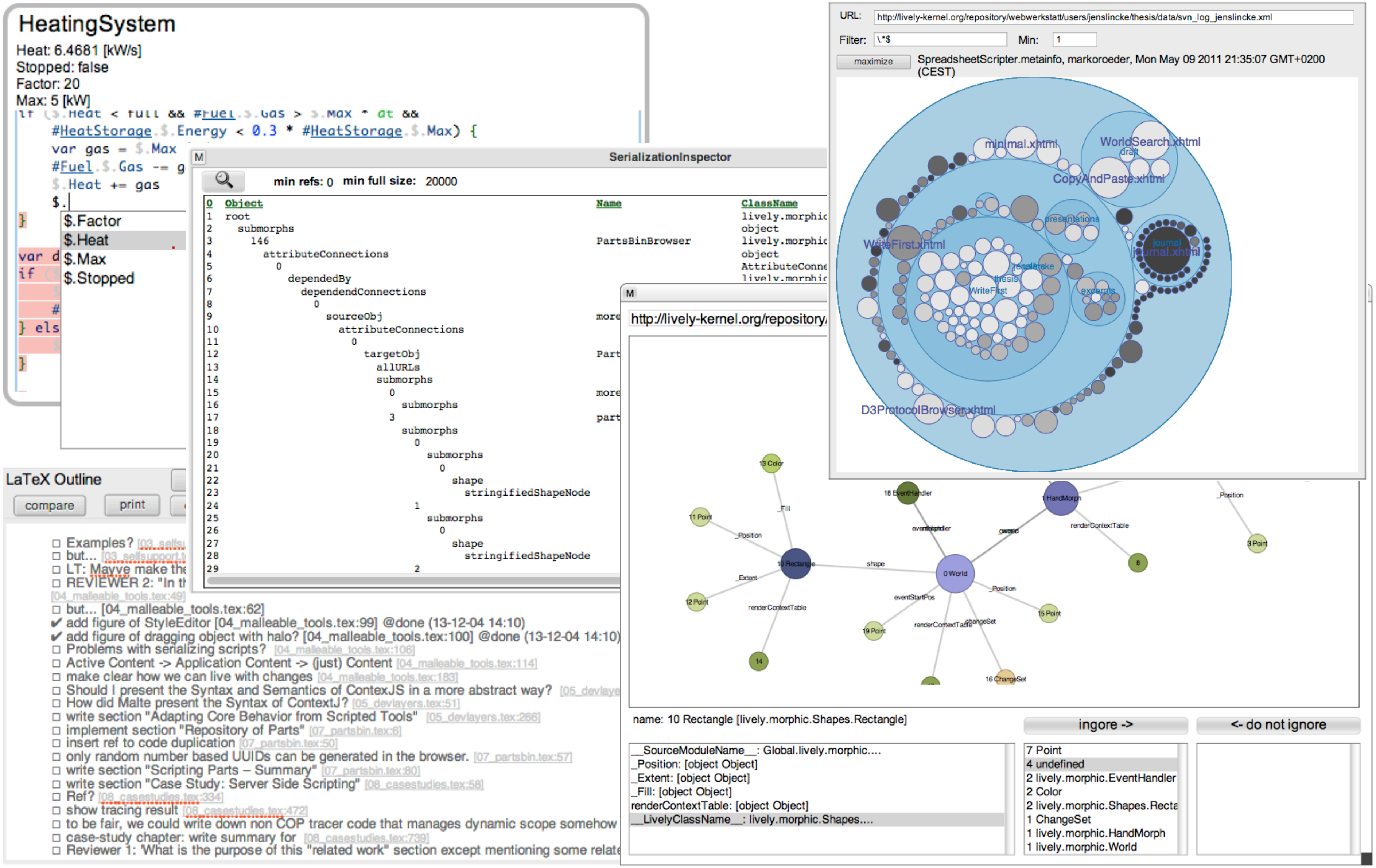
- ContextL
- ContextScheme
- ContextJ*
- ContextErlang
- EventCJ
- Lambic
- Ambience
- COP.JS
- delMDSCO/cj
- Phenomenal Gem
- Subjective-C
- Context Petri Nets

Structural Scoping & Development Layers

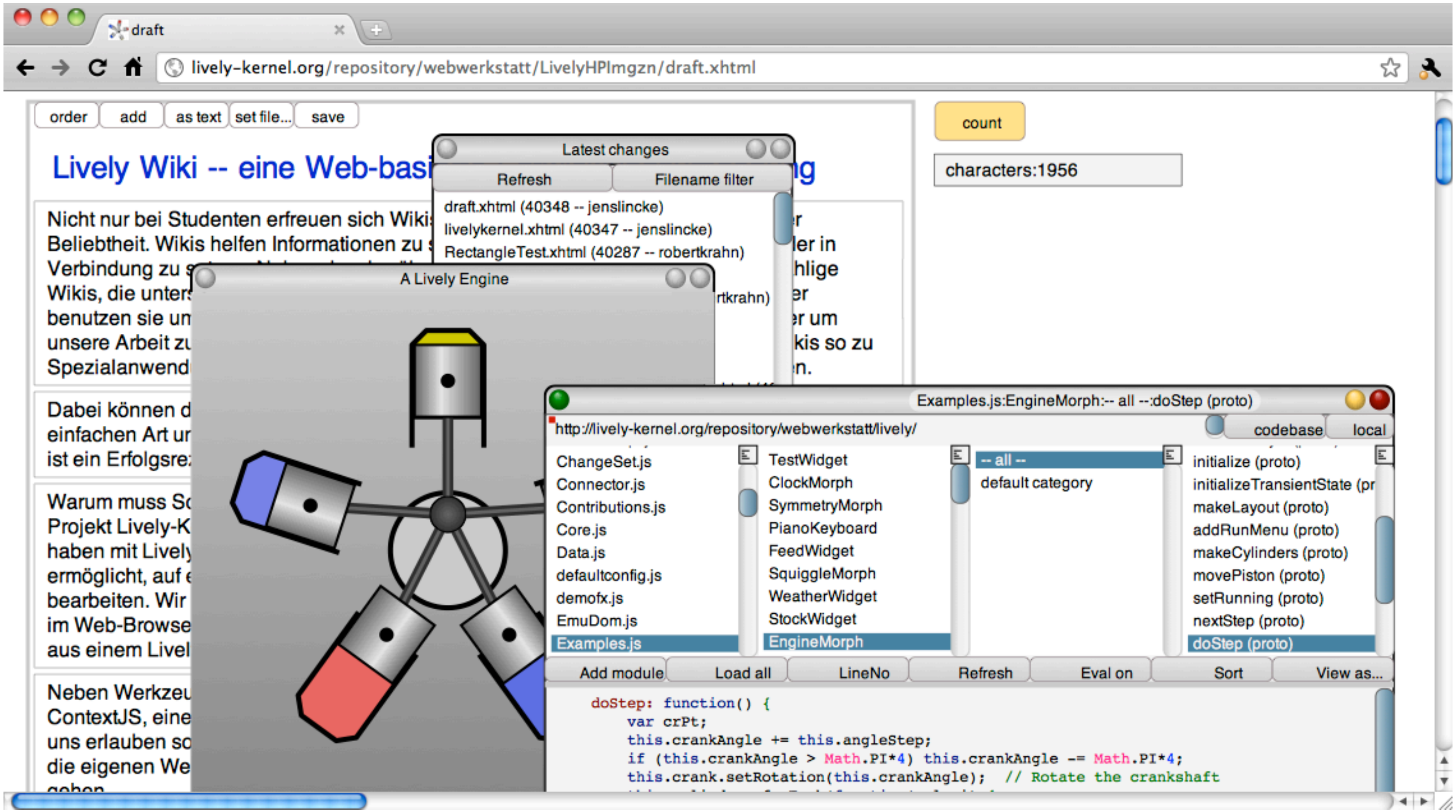
Strct

w/ Jens Lincke

Lively Webwerkstatt



Lively Kernel and Lively Wiki



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

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

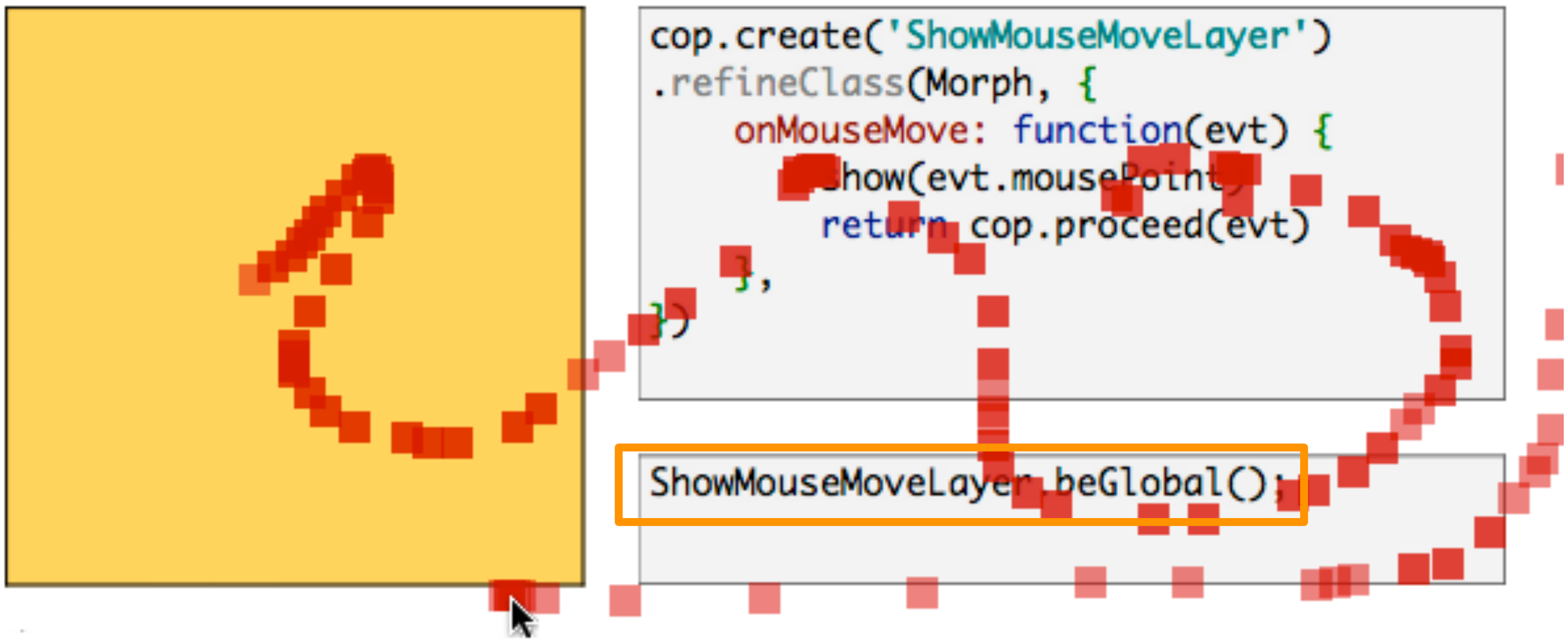
```
cop.create("DevLayer").refineObject(EventCounter, {
        count: function(evt) {
                alert("evt: " + evt);
                this.n = this.n + 1;
        }
})
```

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

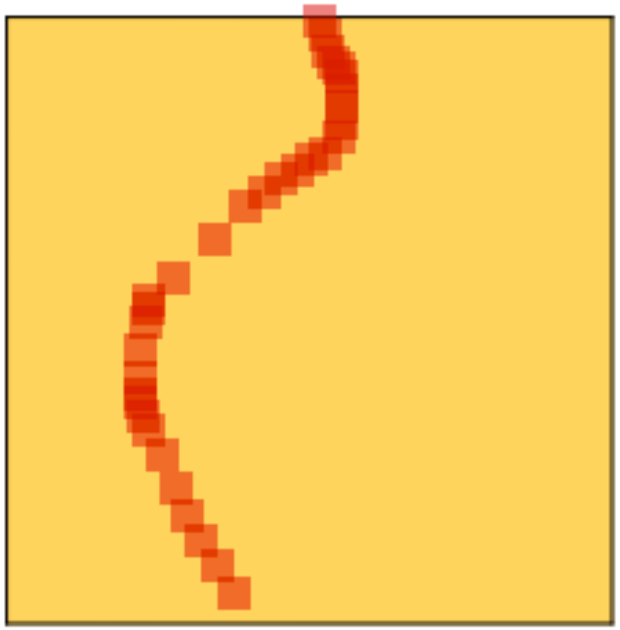
```
DevLayer.beGlobal();
```

```
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])
```

HPI

Example 2: Text Coloring

Hello World

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

Workspace

```
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];

        // ....
```

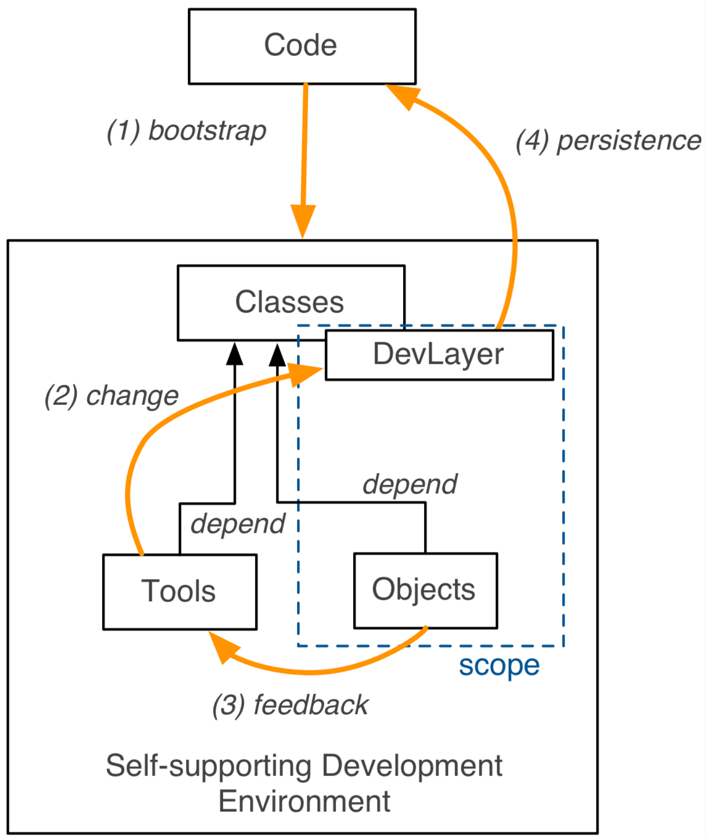
```
$morph('DevArea').setWithLayers([WordCompletionLayer]);
```

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 can be direct, interactive, and safe

- Future work
  - Refactoring of layers back into base



Explicit Use-case Representation

UC

w/ Michael Perscheid

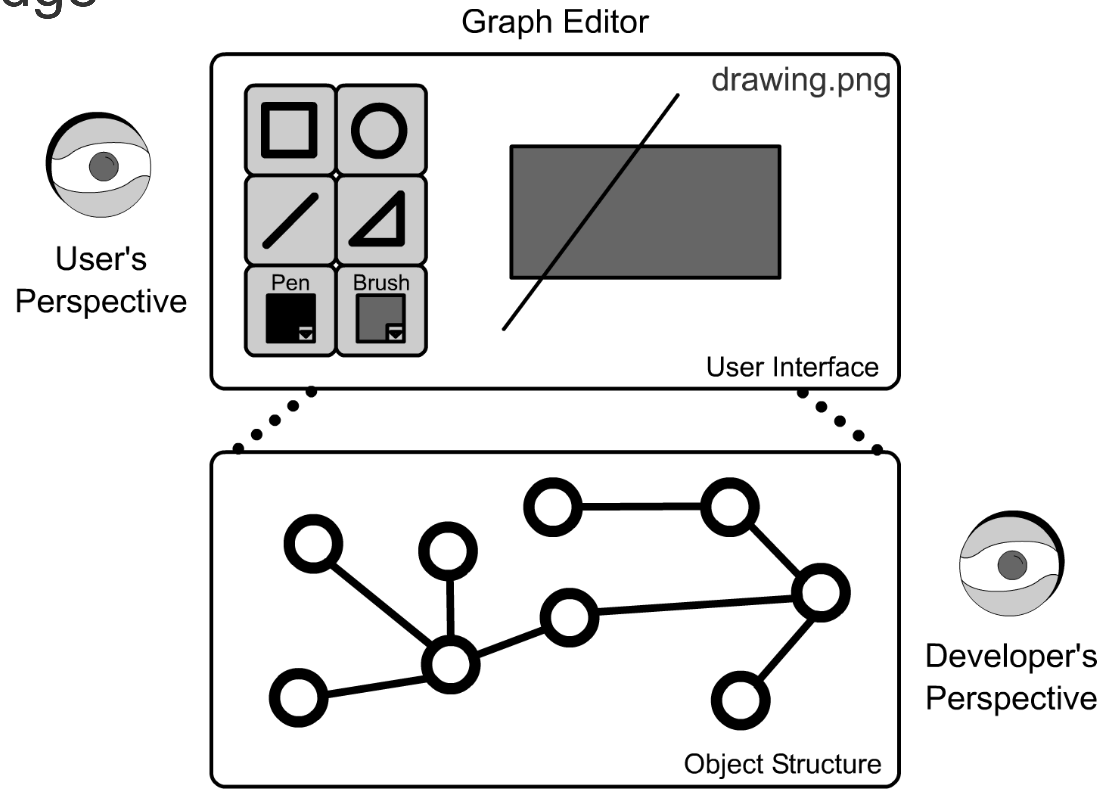
Use-cases in Software Development

- Users perceive program behavior without implementation knowledge

- Developers also know internals and implementation details

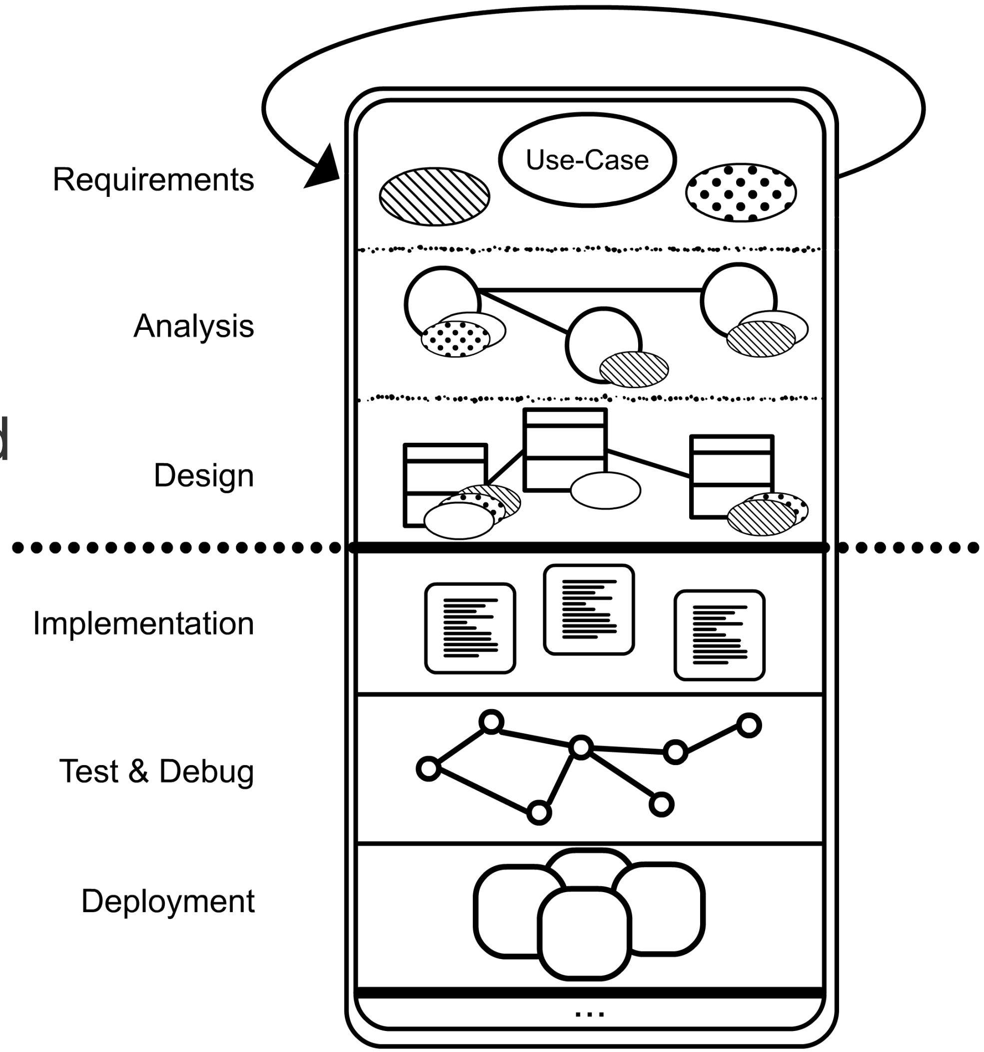
- Use-cases describe interaction at system boundary

- Use-cases link both perspectives



Use-cases in Software Development

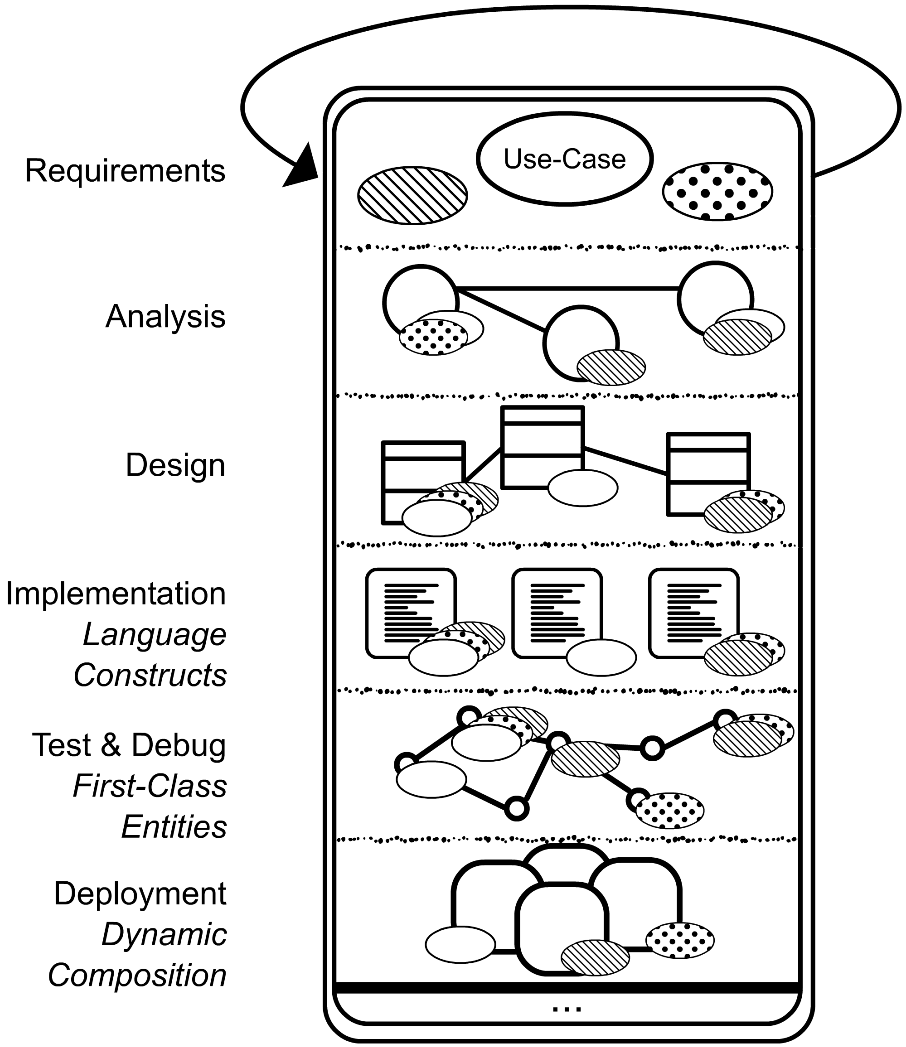
- Use-cases and variants are integral part of most contemporary development processes
- Traceability to use-cases lost in later more code- and deployment-centric development activities
- → Lack of understanding about which parts of the system contribute to which use-case



Use-case-centered Development

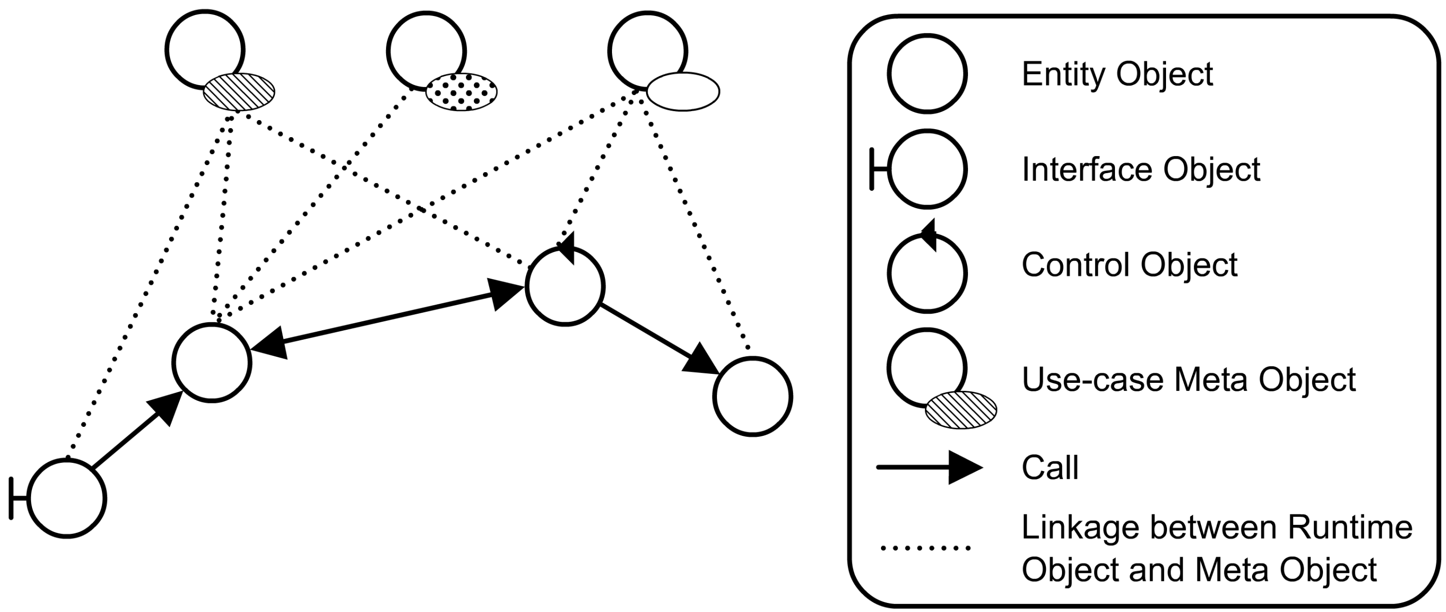
- Explicit use-case representation in object-oriented languages

- Use-cases in source code, as deployment units, and at run-time



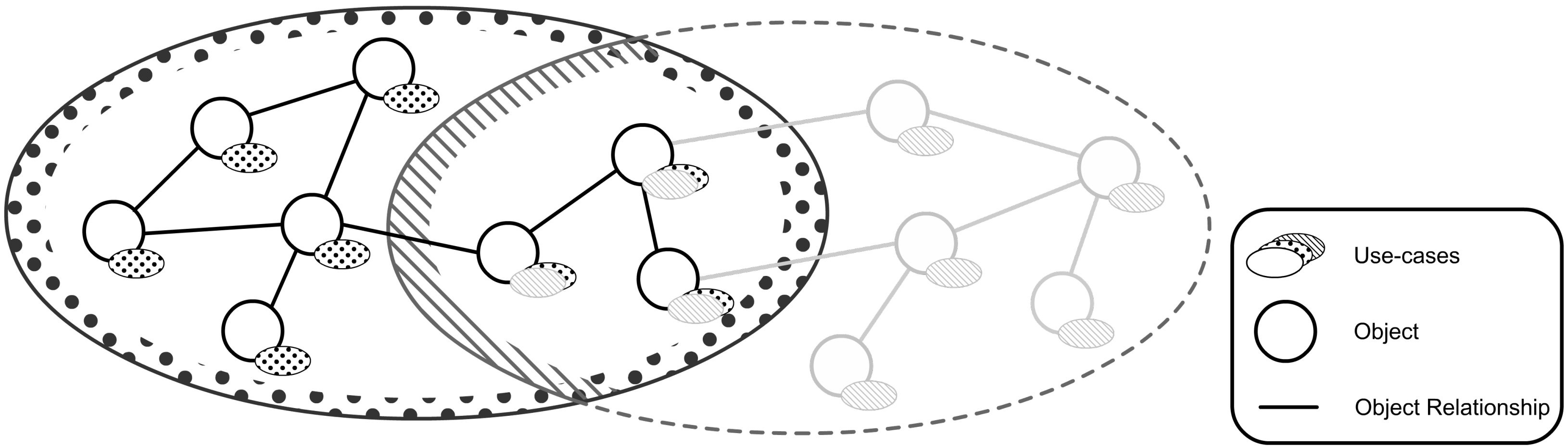
First-class Entities at Run-time

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



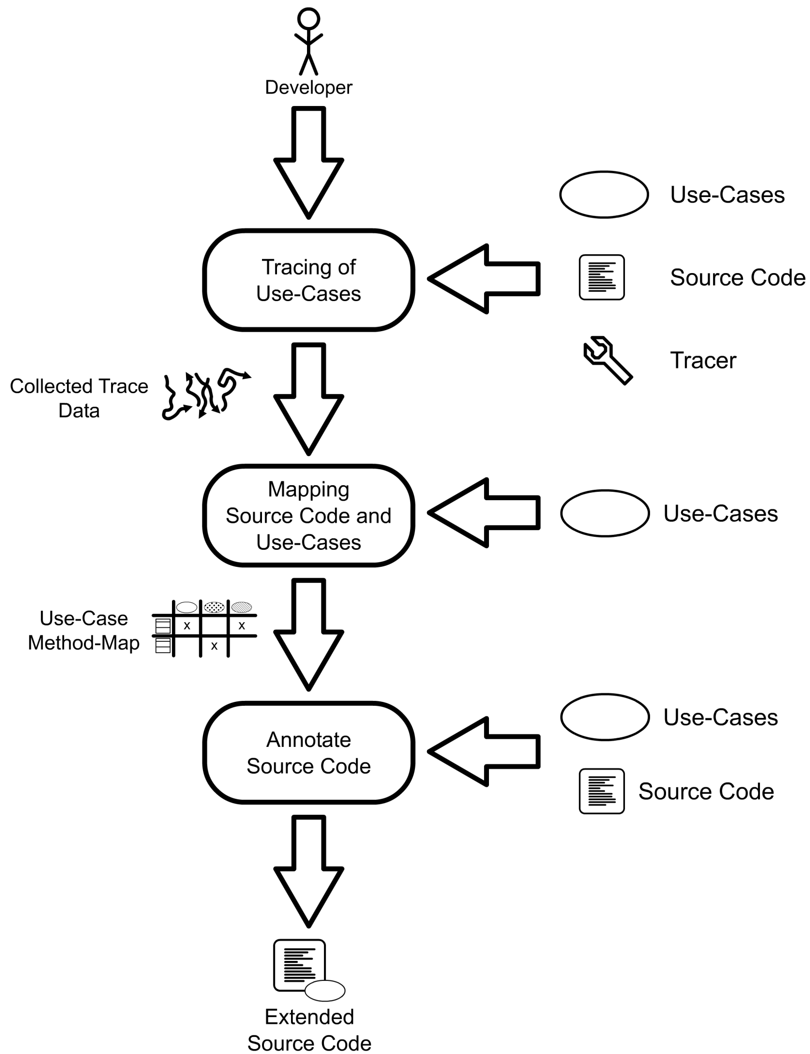
Dynamic Composition

- 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

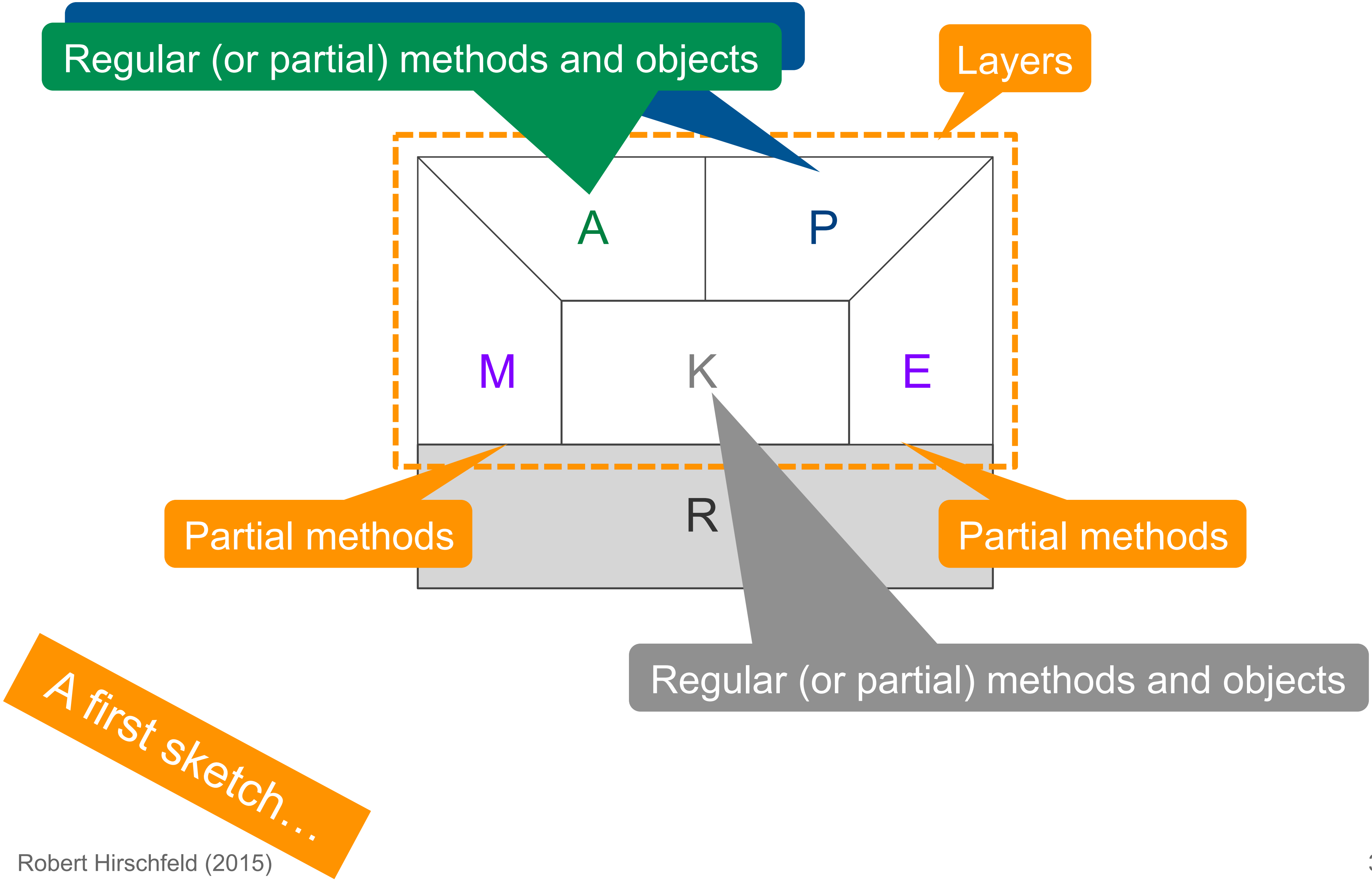
- Future work
  - User studies
  - Improved analysis techniques
  - Better tool support

Monitor Analyze Plan Execute-Knowledge

MAPE-K

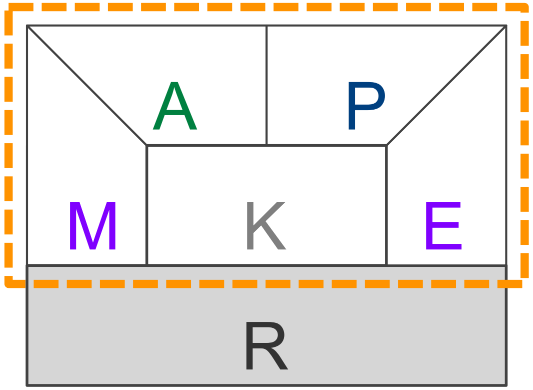
NII Shonan Seminar 052 EASSy

COP & MAPE-K



Regular (or partial) methods and objects
Layers
A
P
M
K
E
R
Partial methods
Partial methods
Regular (or partial) methods and objects
A first sketch…

COP & MAPE-K



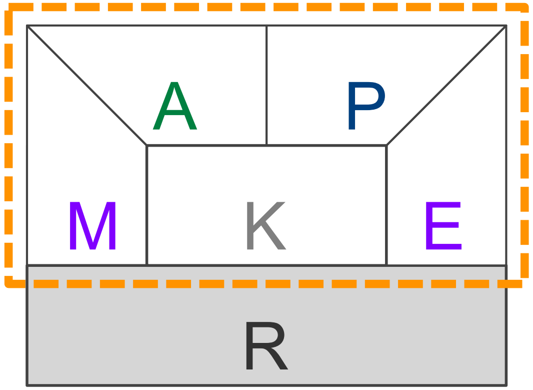

```
class ResourceManager {
  // …
  layer MAPE { // not necessary
    static mapeBefore(resource, in, ...) {
      // note = ...;
      monitorBefore(...);
      analyzeBefore(...);
      planBefore(...);
      executeBefore(…);
      return note;
    }
    static mapeAfter(resource, in, note, out,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

1 2 3 4

A first sketch…

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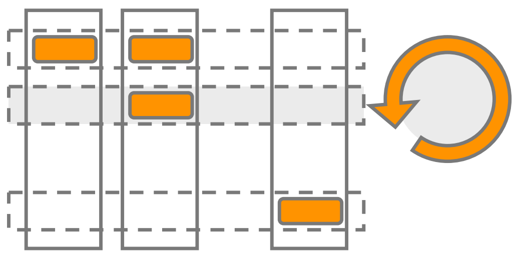

Web References

- 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/