Fundamentals of Concern Manipulation

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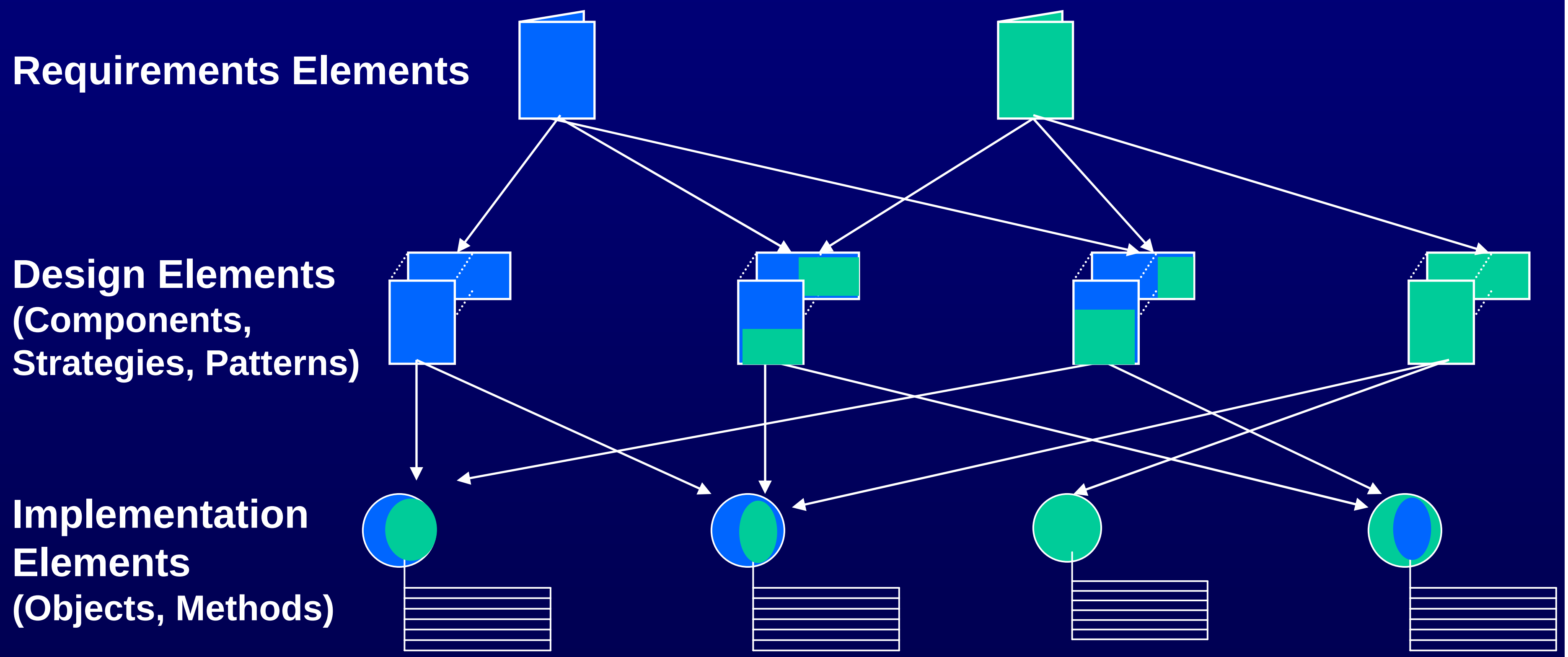
Concern

- Area of interest in a body of software
- (*intension*, *extension*) pair
  - intension specifies meaning
    - query, predicate
  - extension lists applicable software elements
  - extension = intension(body of software)
- Diverse

Multiple, Related Artifacts



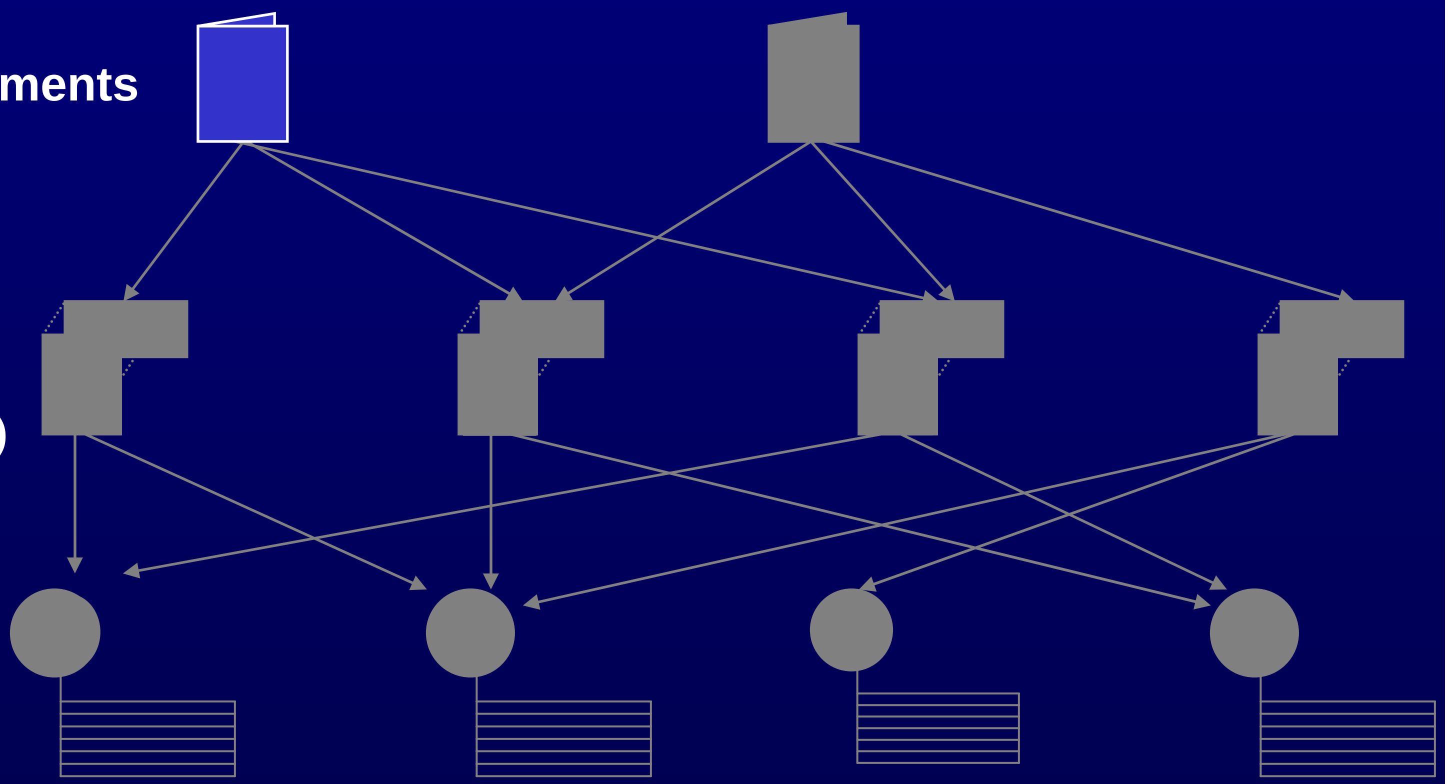
Requirements have widespread and diffuse representation in implementation

A Requirement is a Concern

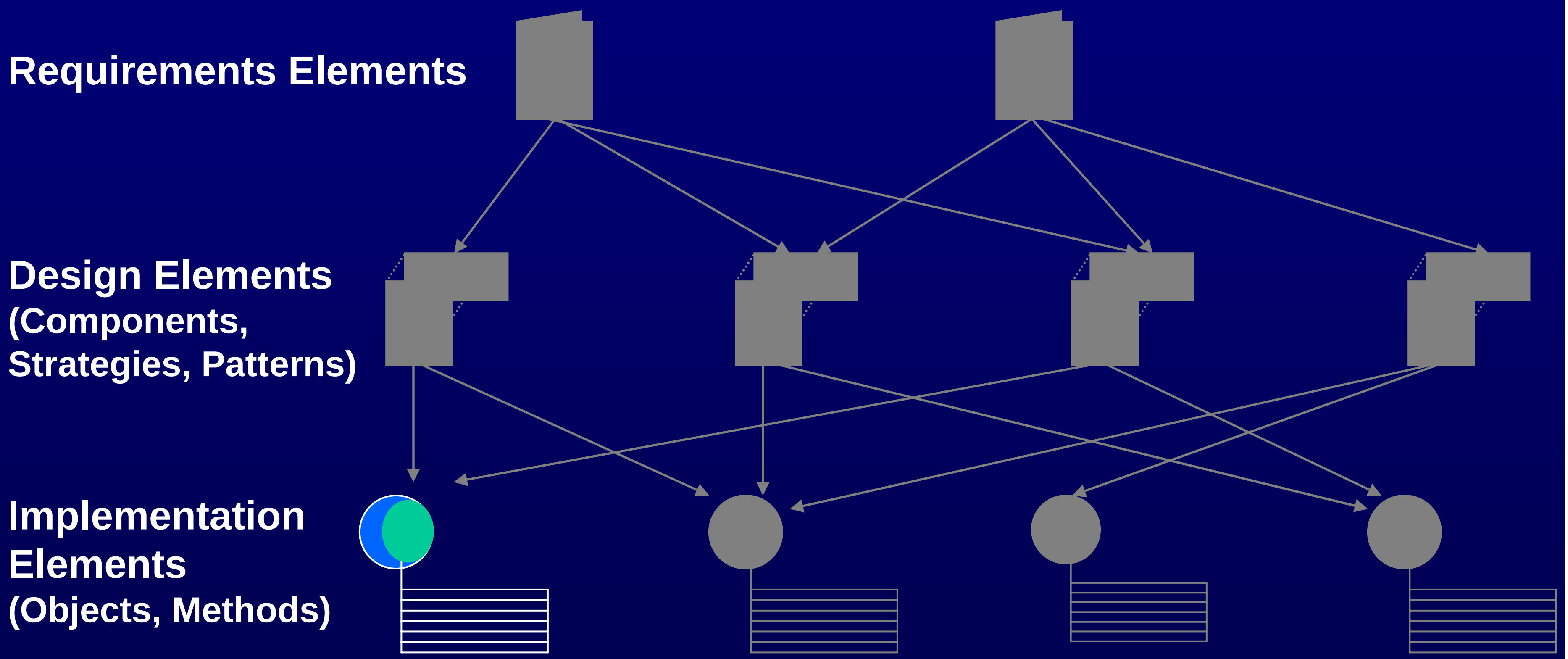
Requirements Elements

Design Elements
(Components, Strategies, Patterns)

Implementation Elements
(Objects, Methods)



An Object (Data) Implementation Concern

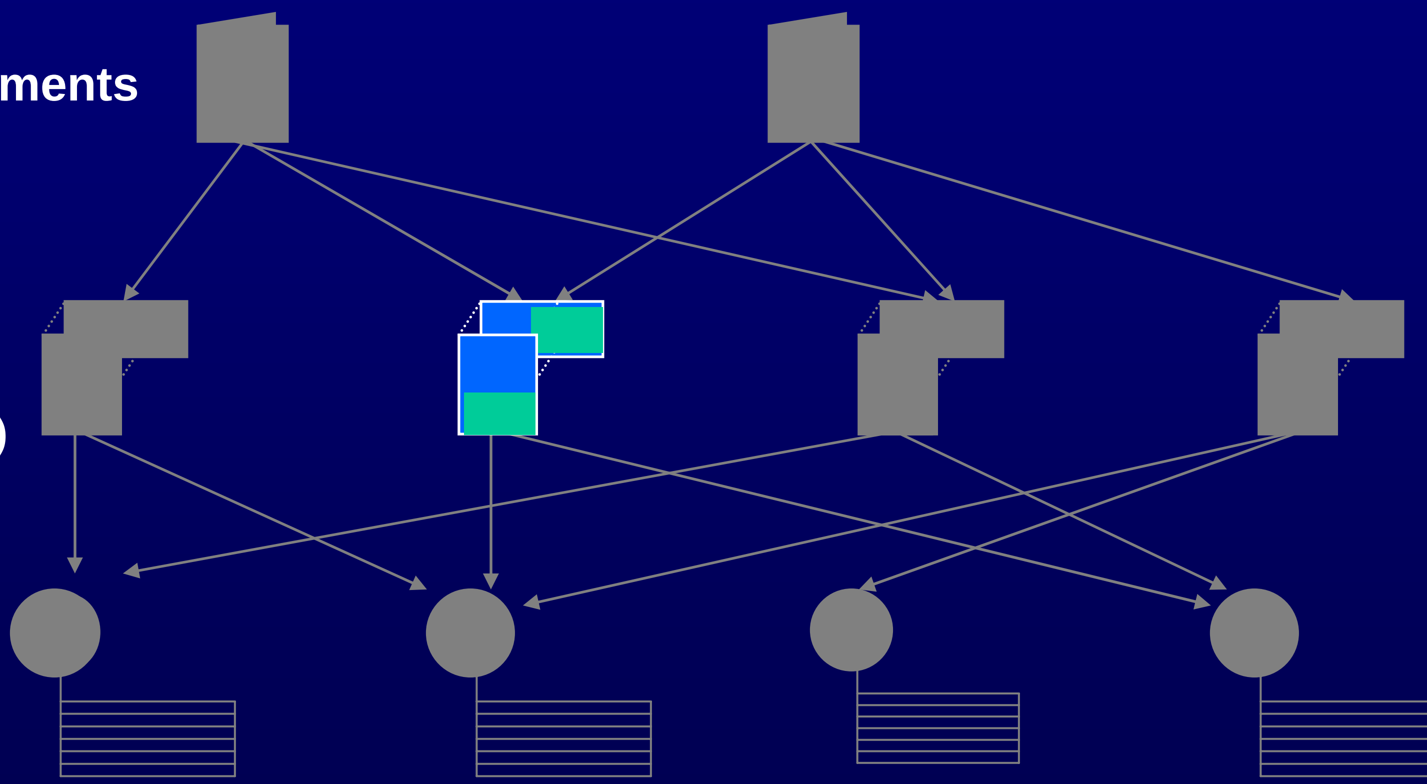


A Component Design Concern

Requirements Elements

Design Elements
(Components,
Strategies, Patterns)

Implementation
Elements
(Objects, Methods)

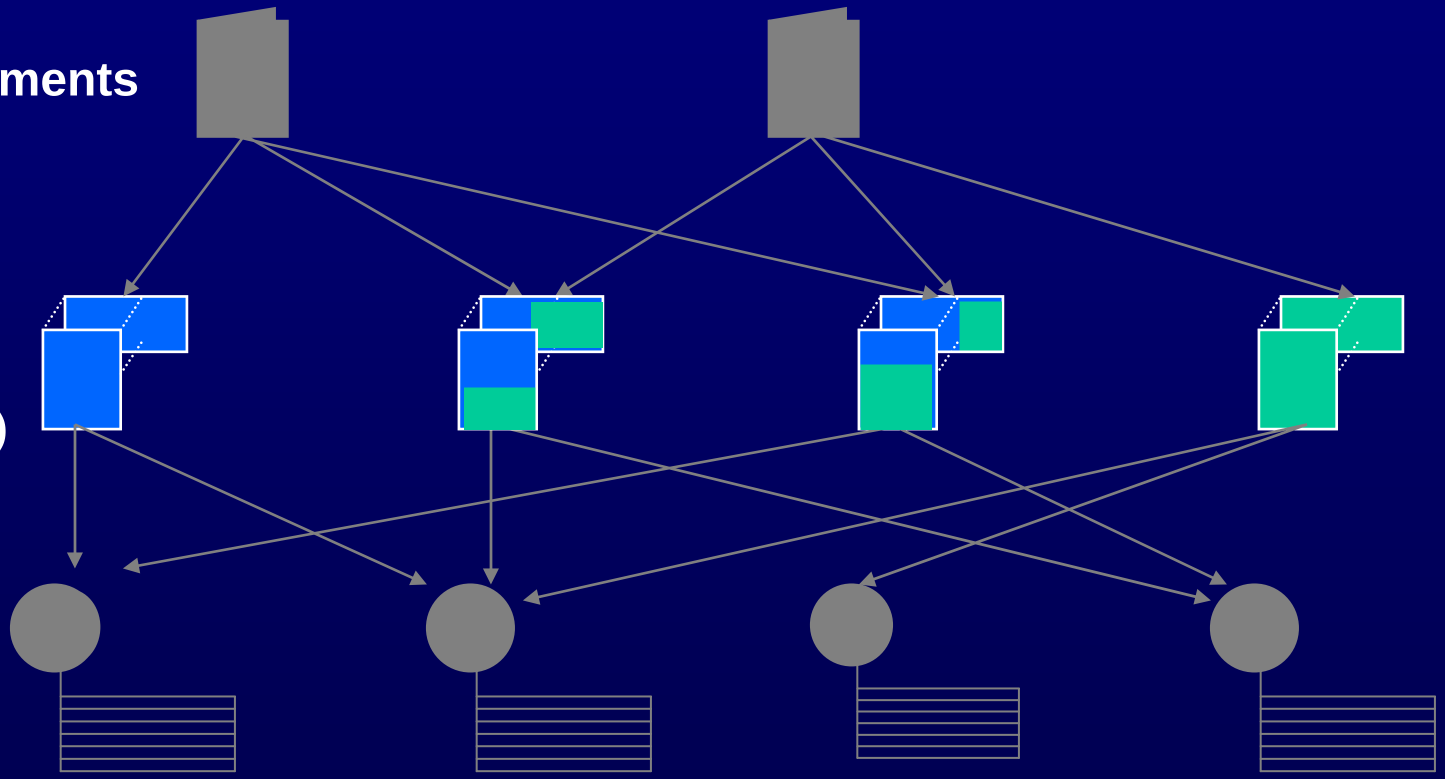


All Design Artifacts

Requirements Elements

Design Elements
(Components, Strategies, Patterns)

Implementation Elements
(Objects, Methods)

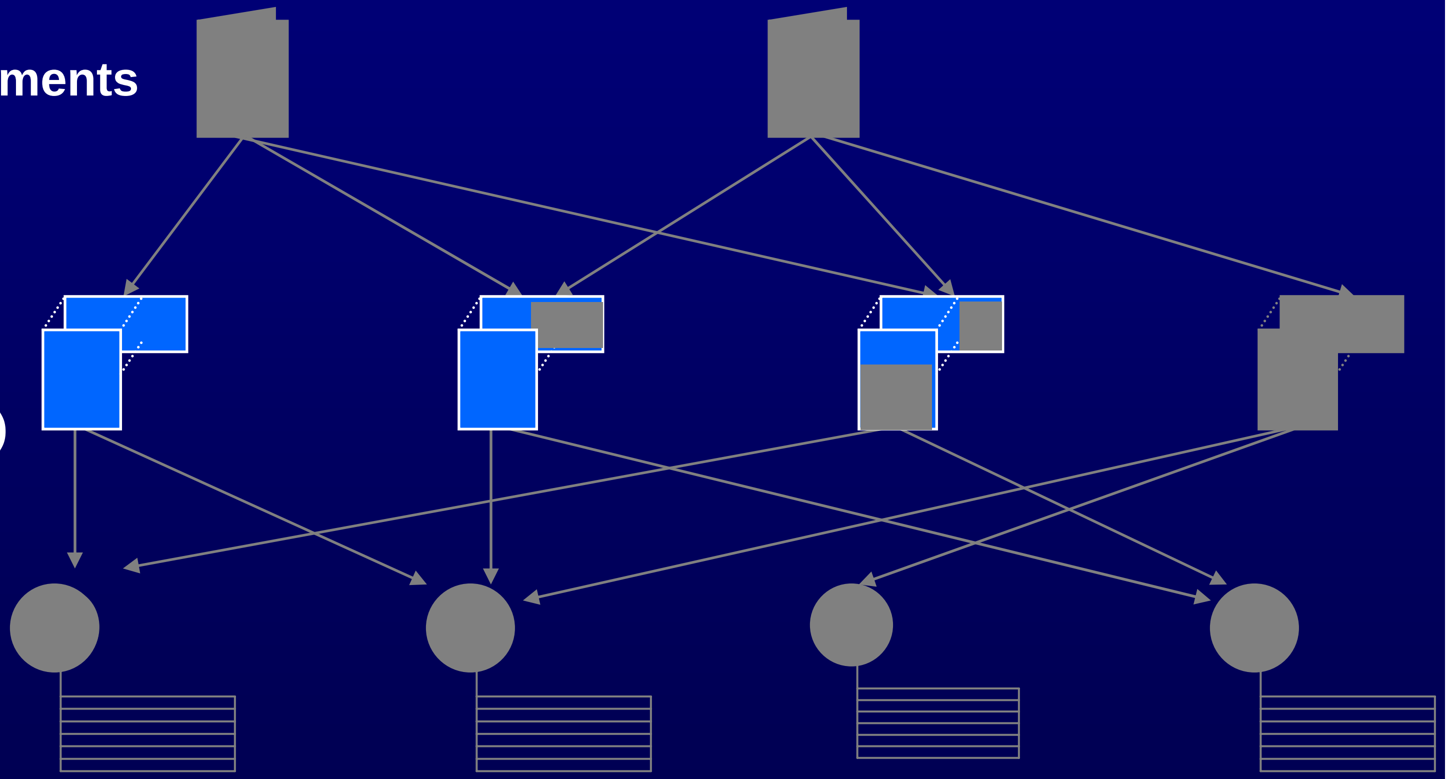


A Design Aspect

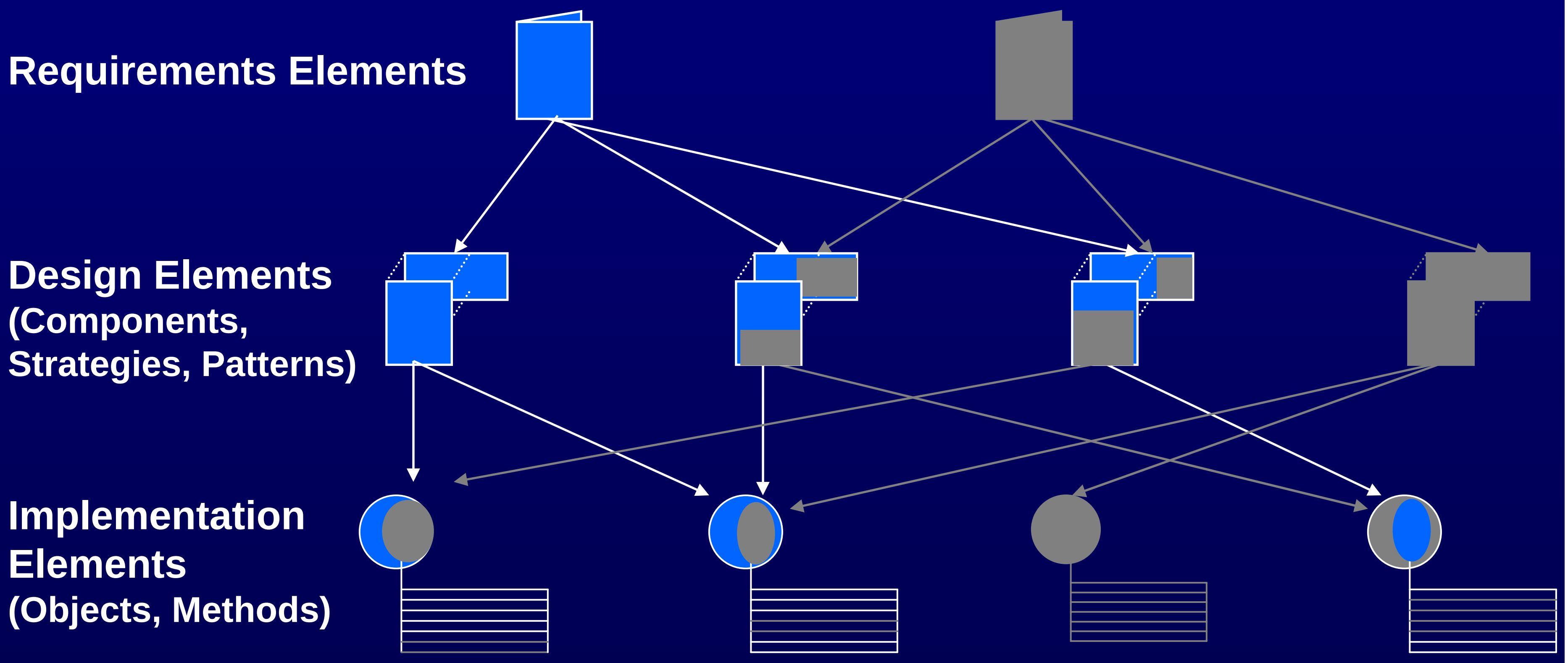
Requirements Elements

Design Elements
(Components, Strategies, Patterns)

Implementation Elements
(Objects, Methods)

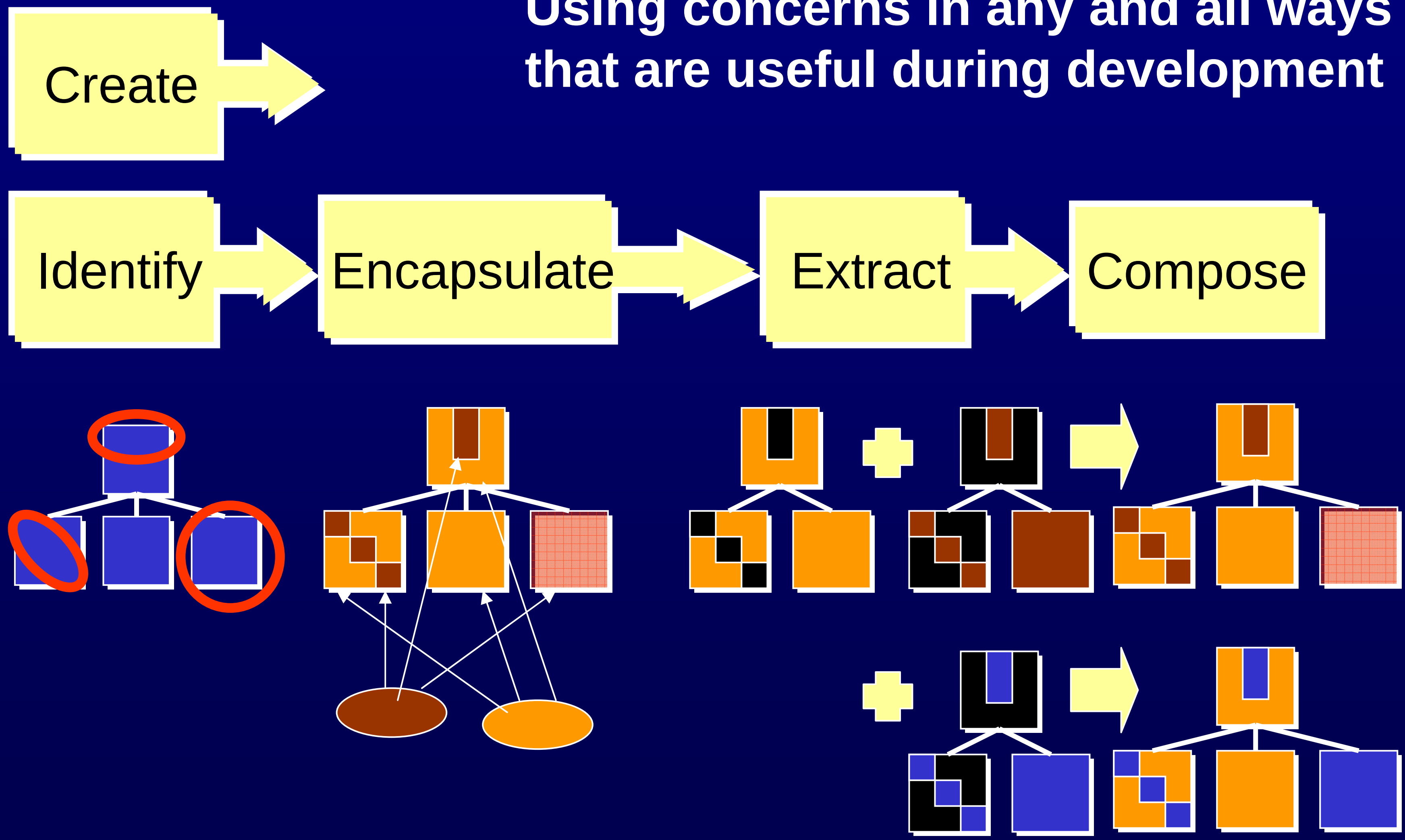


A Requirement Concern



Concern Manipulation

Using concerns in any and all ways that are useful during development



Implications

Using concerns in any and all ways that are useful during development

Tools

- Diverse, but uniform experience
- Specific artifacts (perhaps)
- Specific paradigms, symmetric or asymmetric

Core Concepts

- Uniform, shared
- Artifact type neutral
- Paradigm neutral, symmetric

Components

Uniform User Experience

- Uniform user experience across tools, e.g.,
  - First-class, ubiquitous **concerns**
  - Central **concern model**
  - Same **queries** for exploring, mining, defining concerns, pointcuts, composition, …

⇨Uniform set of core concepts

  - Supported by shared underlying components

Artifact Type Neutrality

- In realistic systems, concerns include elements from artifacts of different kinds:
  - Requirements
  - Design
  - Code
  - Documentation, Help files
  - Data files (XML, properties, icons, …)
  - Deployment artifacts (JAR, WAR, ZIP, …)
  - …
- Large, open set

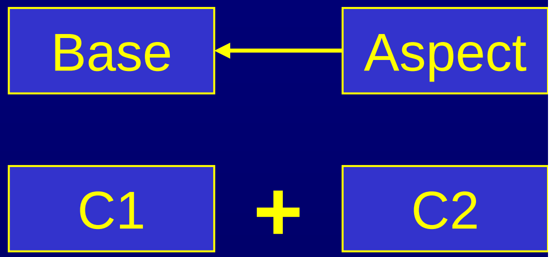
⇨Core concepts should be artifact type neutral

Paradigm Neutrality

- Many AOSD paradigms
  - Symmetric and asymmetric
  - Static and dynamic join points
  - Member level and code level join points
  - Various query paradigms (e.g., patterns, logic, …)
  - …

⇨ Core concepts should be paradigm-neutral
  - General enough to support multiple paradigms
  - Some may be for the tool *implementer*, rather than user
    - Paradigm-specific concepts are surfaced to the user by tools

Symmetry



- Is there a distinguished base?
  - E.g., aspect applied to base, or peer concerns being composed
  - Are elements being composed of same kind?
  - Paradigms differ in their choice
  - Important scenarios for both
    - Impact of scenario-model mismatch is significant

⇨ One model that can handle both:
  - Symmetric underlying model
  - Asymmetric façade

Symmetric Model, Asymmetric Facade

- Symmetric model supports general concerns → concern composition
  - Works for concerns that are peers or in base-aspect (or base-extension) relationship
  - Paradigm-neutral
- Asymmetric Façade critical for convenience:
  - Paradigm-specific, supported by tools
  - Translate to symmetric model

Artifact Model

Core concepts for representing different kinds of artifacts

- Entities
  - Modifiers, Classifiers
  - Attributes
- Relationships

- Container spaces
  - Containers
    - Elements

- Type spaces
  - Types
    - Fields
    - Methods

Spaces are *declaratively complete* (contain definitions of names used)

E.g., Java classpath, collection of UML model files

Space Example

Base

```
class Emp {
   int id() { … }
   String name() { … }
   …
}
```

Report

```
class Emp {
   void print(OStream o) {
      o.println(id() + “: ” + name();}
}
```

- *Base* defines the representation of employees
- *Report* implements a reporting feature

Intertype Declaration

```
class Emp {
   int id() { … }
   String name() { … }
   …
}
```

```
aspect Report {
   void Emp.print(OStream o) {
      o.println(id() + ": " + name();}
}
```

Asymmetric

Declarative Completeness: *Abstract*

space Base

```
class Emp {
   int id() { … }
   String name() { … }
   …
}
```

space Report

```
abstract class Emp {
   void print(OStream o) {
      o.println(id() + ": " + name();}
   abstract int id();
   abstract String name();
}
```

library space

```
class String { … }
…
```

Symmetric

Declarative Completeness: *Requires*

space Base

```
class Emp {
  int id() { … }
  String name() { … }
  …
}
```

space Report

```
requires int Emp.id();
         String Emp.name();
class Emp {
  void print(OStream o) {
    o.println(id() + ": " + name();}
}
```

library space

```
class String { … }
…
```

Symmetric

Included Spaces?

space Base

```
class Emp {
    int id() { … }
    String name() { … }
    …
}
```

space Report

```
class Emp {
    void print(OStream o) {
        o.println(id() + ": " + name();}
}
```

library space

```
class String { … }
…
```

Symmetric/
Asymmetric
Synthesis

Language Binding

- To be applied, these concepts must be bound to actual artifact types:
  - E.g., file system:
    - Container space ➔ Root Directory
    - Container ➔ Directory
    - Element ➔ File
  - E.g., Java
    - Type space ➔ Class path
    - Type ➔ Class, Interface, …
- In practice: artifact-type-specific plug-ins

Methoids

- Use patterns to define material inside element bodies, treating the matching material as extractable elements

```
class C {
    int x;
    void foo() {
        …
        x = 3;
        …
        x = y+7;
    }
}
```

methoid setX:
kind = “set”
field = “x”

```
class C {
    int x;
    void foo() {
        …
        setX(3);
        …
        setX(y+7);
    }
    void setX(int x) {
        this.x = x;
    }
}
```

Methoids

- Allow uniform handling of code-level join points
  - Methoid occurrences are elements for searching, composition, …
- Open-ended characterizations (mapping-specific)
  - E.g., useful language constructs:
    - get/set of specific instance variables
    - method calls, entries and exits
    - synchronization block entries and exits
    - throws and catches of specific exception types
    - downcasting and instanceof
  - Can specify arguments, set to local state
    - Perhaps specially-constructed (e.g., thisJoinPoint)
- Various inlining options and, perhaps, restrictions (mapping-specific)

Correspondence

- Elements to be composed together

Base

```
class Emp {
   int id() { … }
   String name() { … }
   …
}
```

Log

```
aspect Log {
   pointcut ops():
      execution (* Emp.*(..)):
   before (): ops() { logEntry(); }
   void logEntry() { … }
}
```

{ (Emp.id, Log.logEntry), (Emp.name, Log.logEntry) }

Correspondence

- Elements to be composed together

space Base

```
class Emp {
   int id() { … }
   String name() { … }
   …
}
```

space Log

```
class Log {
   void logEntry() { … }
}
```

merge (Emp.*, Log.logEntry)

Correspondence Query

{ (Emp.id, Log.logEntry), (Emp.name, Log.logEntry) }

Concerns

- Intension (query) and extension (set of elements)
- First-class
  - Explicitly modeled, used for exploration, composition, …
  - Relationships among concerns
  - Composition relationships
- Heterogeneous
- Written explicitly as modules, or mined

Concern versus Space

Concern	Space
Any elements	Containers/Types
No name usage restrictions	Declaratively complete

Extraction

Query

- Diverse query languages
  - Each usable wherever desired
- Core concepts
  - Selection of:
    - Elements, based on names, modifiers, classifiers, attributes, containment
    - Methoids, based on their patterns
    - Relationships, based on their names and characteristics of their end points
    - Correspondences
  - Navigation via relationships
    - Including transitive closure
  - Predicates and set operations
  - *Variables and unification*
    - E.g., (class p1.<C>, class p2.<C>)

Simple Composition Example 1

basic

```
class Sys
   int interval;
   void init() {…};

class RoomSensor
   void report() {…};
   void update(int) {…};

class AtticSensor
   void report() {…};
   void update(float) {…};

… more sensors …
```

alarm

```
aspect Alarm
   after execution(
      * *.update(int)): { … });
   after execution(
      * *.update(float)): { … });
```

composed result 1

```
class RoomSensor
   Alarm a = …;
   void u_b(int) { /* basic*/}
   void update(int i) {
            u_b(i); a.update(i); }
… }
```

Simple Composition Example 2

basic

```
class Sys
   int interval;
   void init() {…};

class RoomSensor
   void report() {…};
   void update(int) {…};

class AtticSensor
   void report() {…};
   void update(float) {…};

… more sensors …
```

merge …

alarm

```
class Alarm
   void update(int);
   void update(float);
```

composed result 2

```
class RoomSensor
   void u_b(int) { /* basic*/}
   void u_a(int) { /* alarm*/}
   void update(int i) {
           u_b(i); u_a(i); }
… }
```

Simple Composition Example 3

basic

```
class Sys
   int interval;
   void init() {…};

class RoomSensor
   void report() {…};
   void update(int) {…};

class AtticSensor
   void report() {…};
   void update(float) {…};
… more sensors …
```

merge …

alarm

```
class Alarm
   void update(int);
   void update(float);
```

composed result 3

```
class RoomSensor
   Alarm a = …;
   void u_b(int) { /* basic*/}
   void update(int i) {
         u_b(i); a.update(i); }
… }
```

Dynamic Join Points

- Dynamic join points are typically handled by:
  - Generation of dynamic residues
  - Static composition (at join point shadows)

Levels of Composition Specification

Level	Specification	Paradigm
Tool Level	merge basic, alarm as C	Paradigm-specific
Component Level	merge order(1, 2) facet: space basic, alarm as C encapsulating(member) exposed exclusively precedence(1)	Paradigm-neutral
Assembly Level	<type name="Sys" attributes="public"/> <method within="C:Sys" name="init" types="()"> <from within="basic:Sys" name="init" types="()"/> <field within="C:Sys" name="interval" type="int"> <from within="basic:Sys" name="interval" type="int"/> …	

Weaving Directives

- What elements are to be joined?
  - Correspondence
- How are they to be joined
  - Selection
  - Ordering
  - Structure
- Making assumptions explicit
  - Encapsulation, Opacity
- Resolving multiple weaving directives
  - Exclusivity, Precedence

```
merge order(1, 2) facet:
  space basic, alarm as C
  encapsulating(member)
  exposed
  exclusively  precedence(1)
```

Identifying Correspondences

- Explicit: queries
  – (class basic:*Sensor, alarm:Alarm)

    { (RoomSensor, Alarm), (AtticSensor, Alarm) }

  – (method basic:*Sensor.update(<type>), alarm:Alarm.update(<type>))

    { (RoomSensor.update(int), Alarm.update(int)), (AtticSensor.update(float), Alarm.update(float)) }

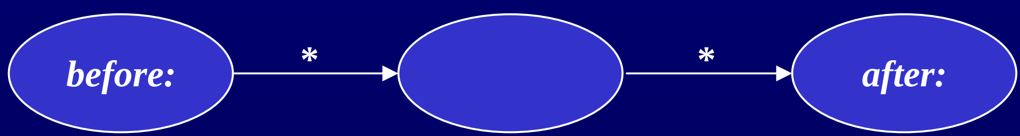
- Implicit (depending on encapsulation)
  – Like-named types within corresponding spaces
  – Like-named members within corresponding types

Selection

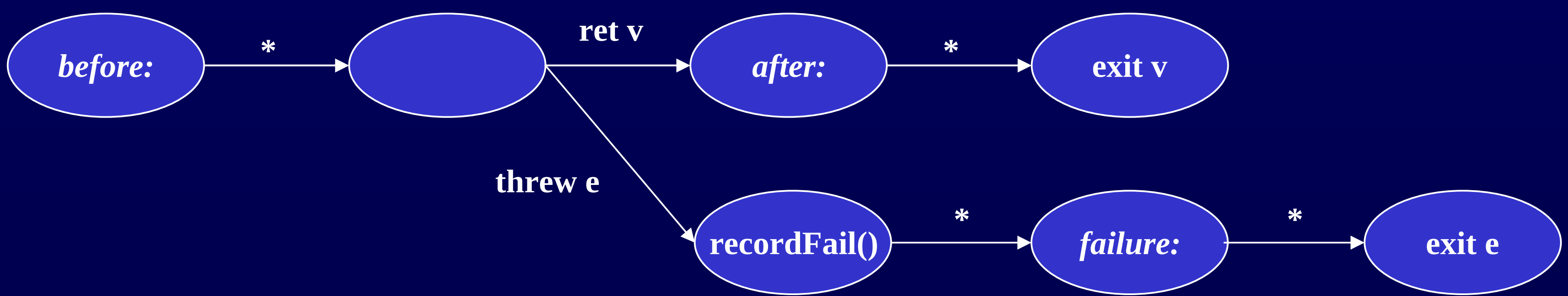
- *Which* inputs in the correspondence should participate in the result:
  - merge
  - override
  - overridemember
  - aroundmethod
  - any
  - unique
  - … (this is an open-ended list)

Ordering

- For *override/around*: which input dominates
- For *merge* of methods: order of execution
  – Generalized as *method combination graphs*

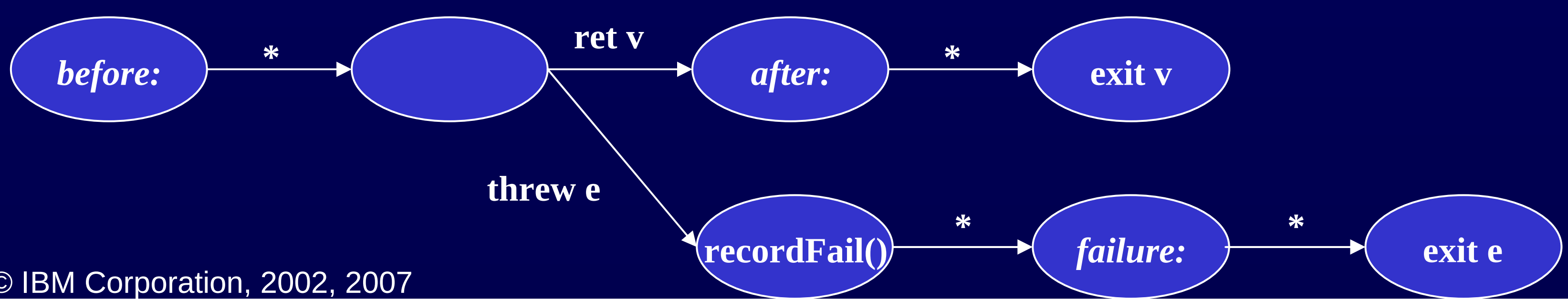


(method basic:*Sensor.update(<type>),
after:: alarm:Alarm.update(<type>))



Method Combination Graphs

- Nodes call methods or exit
- Various choices for arguments
  - Incoming arguments, return values
  - Target and its instance variables (e.g., aspect or role table)
  - Static variables, special "meta" variables
- Various conditions on edges
  - Normal return versus exception
  - Some value checks on variable values (allows multiple dispatch)
- Call auxiliary methods for complex processing
- Non-determinism, supporting composability

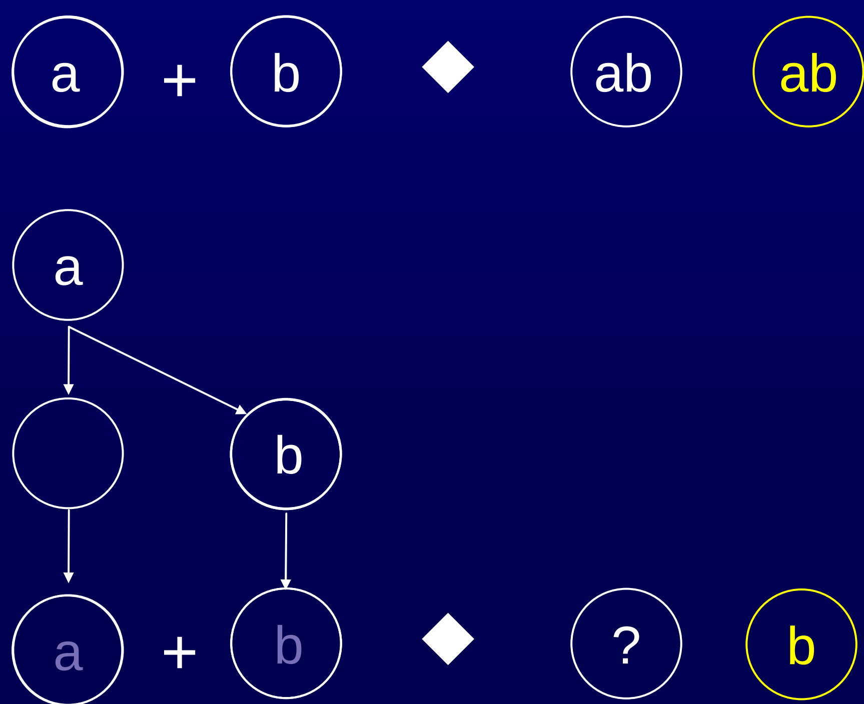


Structure

- *How* inputs participate in the result
  - How do the lifetimes and identities of the participants relate? E.g.:
    - Single result type or collaborating group (e.g., object & aspect)?
    - Do references to the input map to the output or not?
  - How is *this* treated? To what does it refer?
  - What happens to *static*?
  - What are the linkage conventions?
- facet, copy, aspect, … (another open point)
- FOAL '02 paper on "member-group relationships"

Opacity

- Is the type hierarchy structure assumed to be known and taken into account?



the space is *opaque*

the space is *exposed*

Levels of Composition Specification

Tool Level

merge basic, alarm as C

Paradigm-specific

Component Level

merge order(1, 2) facet:
space basic, alarm as C
encapsulating(member)
exposed
exclusively precedence(1)

Paradigm-neutral

Assembly Level

<type name="Sys" attributes="public"/>
<method within="C:Sys" name="init" types="()">
<from within="basic:Sys" name="init" types="()"/>
<field within="C:Sys" name="interval" type="int">
<from within="basic:Sys" name="interval" type="int"/>
…

Assembly Directives by Example

```
public class Driver {

public void f(String arg) {
    System.out.println("body of f()");
  }

  public void g(String arg) {
    System.out.println("body of g()");
  }
}
```

```
public class Trace {

  public void before(Object arg,
                     String mName) {
    System.out.println(">>> before " ...);
  }

  public void after(Object arg,
                    String mName) {
    System.out.println(">>> after " ...);
  }
}
```

Copy

```
public class Driver {
```

Create

```
  public void original_f(String arg) {
    System.out.println("body of f()");
  }
  public void g_original_g(String arg)
  {...}

  public void trace_before(Object arg,
                           String mName) {
    System.out.pl(">>> before " ...);
  }
  public void trace_after(...) { ... }

  public void f(String arg) {
    trace_before(arg, "Driver.f");
    original_f(arg);
    trace_after(arg, "Driver.f");
  }
  public void g(String arg) { ... }
}
```

Create using method combination graphs

Conclusion

- Core concepts for concern manipulation
  - Artifacts, concerns, queries and composition
  - Artifact-type neutral
  - Paradigm neutral
- Wide open research area
  - Validation and improvement
    - Mapping (and implementing) different paradigms
    - Mapping (and implementing) more artifact types
  - Asymmetry, included spaces, concern/space relationship
  - Extraction
  - New issues, e.g., versioned artifacts, dynamic AOSD
  - …

Thank you!