Aspect Oriented Programming

Programming Languages Seminar

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Mostly taken from Bedir Tekinerdogan's slides

Outline

- Introduction
- Problems
- Terminology
- Aspect-Oriented Programming Languages/Frameworks
  - Compositional Filters
  - AspectJ
  - Hyper/J
  - DemeterJ
- Conclusions

Introduction

- Evolution of Programming Languages
  - Assembly/Machine Languages
  - Formula Translation
  - Procedural Programming
  - Structured Programming
  - Functional Programming
  - Logic Programming
  - Programming with abstract data types
- Evolution of Software Design
  - Monolithic ---> Modular

Design Principles → Modularity

- **Abstraction**
  - Focus only on relevant properties
- **Decomposition**
  - Divide software into separately named and addressable modules
- **Encapsulation**
  - Group related things together.
- **Information Hiding**
  - Hide implementation details from the outside
- **Separation of Concerns**
  - Ensure that each module only deals with one concern
  - Low Coupling
    - aim for low coupling among the modules
  - High Cohesion
    - aim for high cohesion within one module

Separation of Concerns

Cohesion

- <u>Maximize</u> cohesion within a component
  - i.e. Cohesive component performs only **one concern / task**
  - required changes can be easily localized and will not propagate

Coupling

- Highly coupled components have many dependencies/interactions
- <u>Minimize</u> coupling between components
  - reduces complexity of interactions
  - reduces ‘ripple’ effect

Advantages of separation of concerns

- Understandability
- Maintainability
- Extensibility
- Reusability
- Adaptability

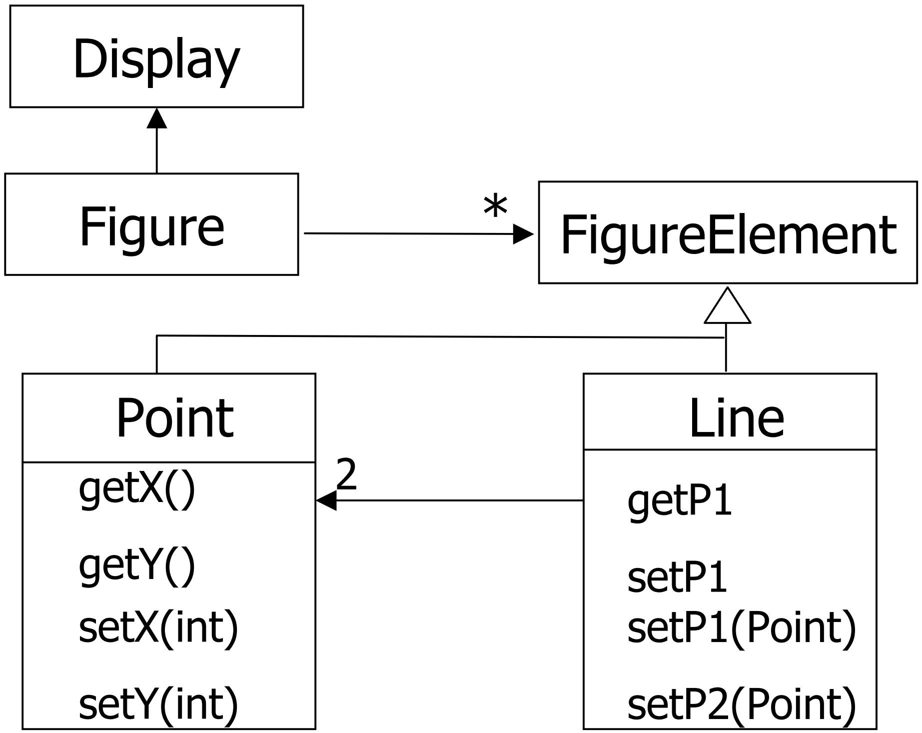
Separation of Concerns directly supports quality factors.

Lack of Separation of Concerns negatively impacts quality factors.

Example - Figure Editor

- A *figure* consists of several *figure elements*. A figure element is either a *point* or a *line*. Figures are drawn on *Display*. A point includes X and Y coordinates. A line is defined as two points.

Example - Figure Editor - Design

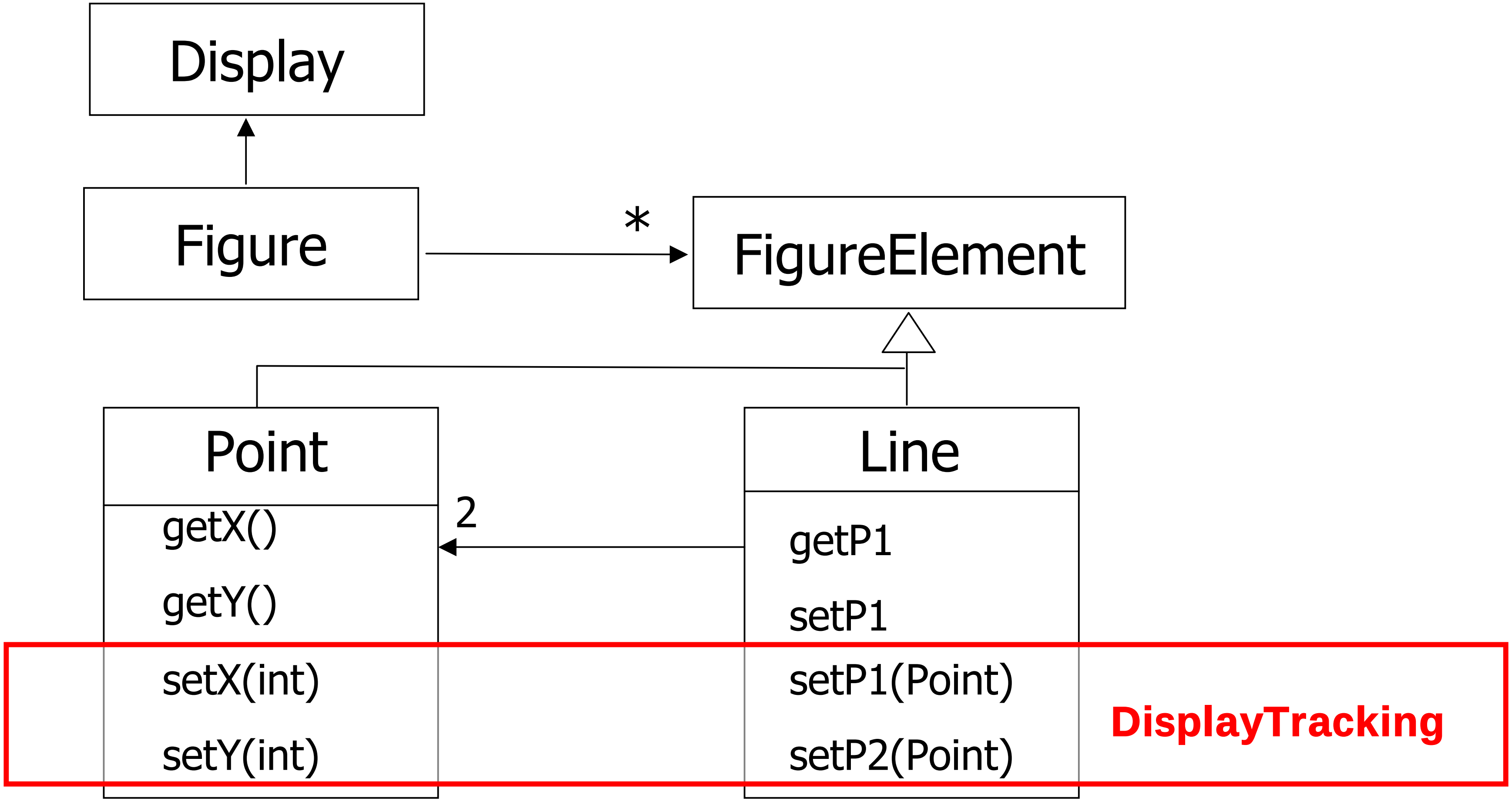


Components are
- Cohesive
- Loosely Coupled
- Have well-defined interfaces (abstraction, encapsulation)

Nice Modular Design!

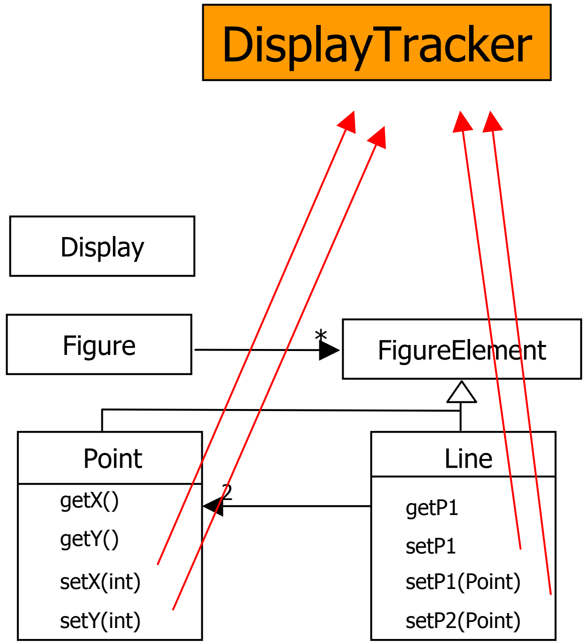
Crosscutting Concern - Example

Notify ScreenManager if a figure element moves



Example: Display Tracking

Crosscutting Concern



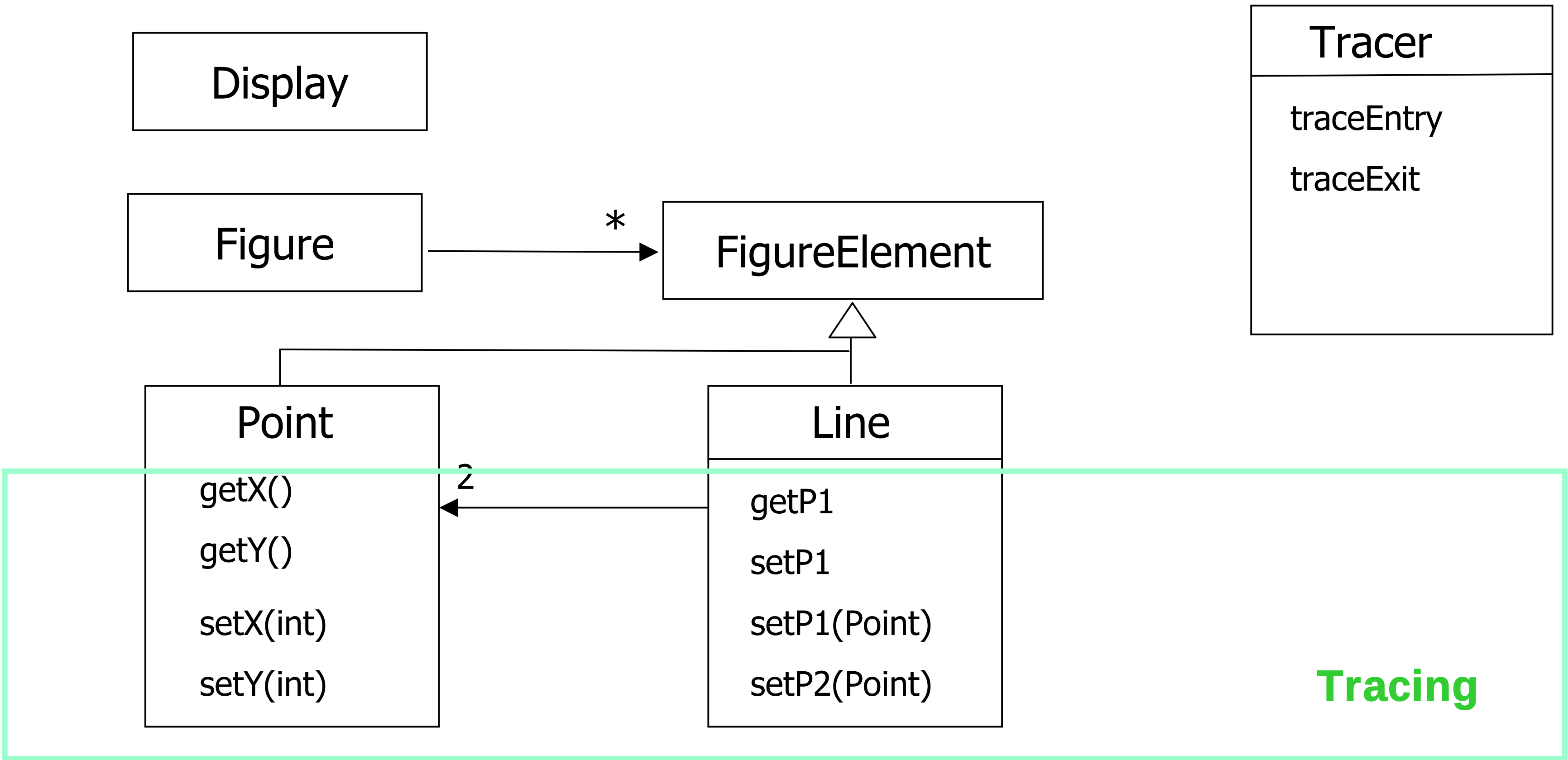

```
class DisplayTracker {

  static void updatePoint(Point p)
  {
          this.display(p);
          ....
  }
  static void updateLine(Line l)
  {
          this.display(l);
          ....
  }
```

```
class Point {
  void setX(int x) {
     DisplayTracker.updatePoint(this);
     this.x = x;

  }
}
```

```
class Line {
  void setP1(Point p1 {
    DisplayTracker.updateLine(this);
    this.p1 = p1;

  }
}
```

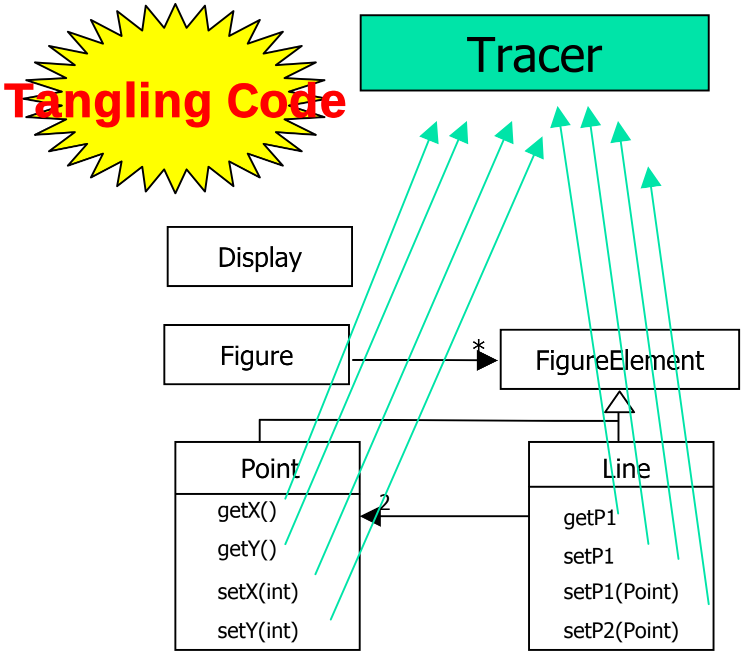
Example - Tracing - Design

Trace the execution of all operations...



Example - Tracing

Scattered Concern

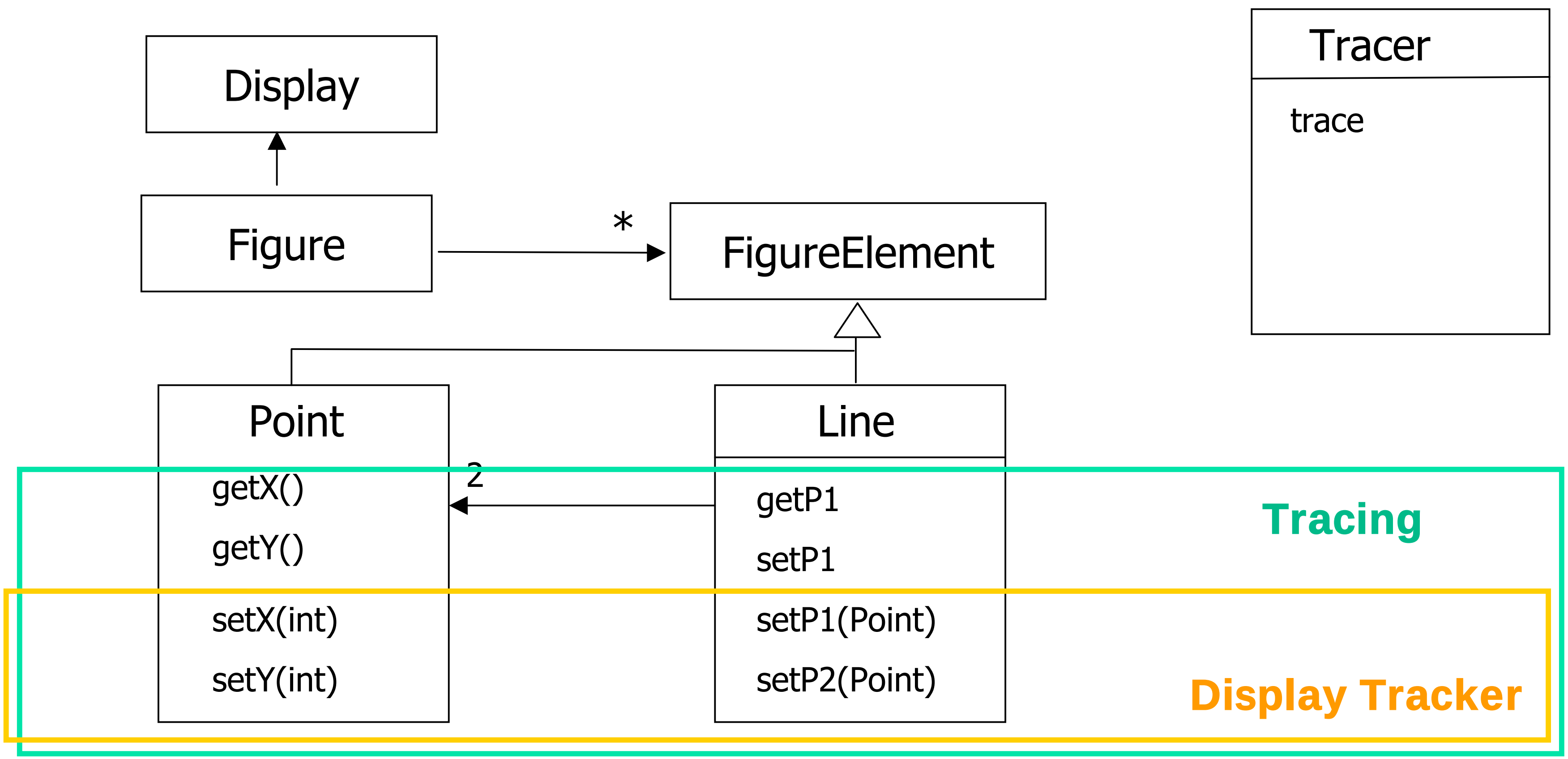



```
class Tracer {

  static void traceEntry(String str)
  {
         System.out.println(str);
  }
  static void traceExit(String str)
  {
         System.out.println(str);
  }
}
```

```
class Point {
 void setX(int x) {
 Tracer.traceEntry("Entry Point.set");
   _x = x;
 Tracer.traceExit("Exit Point.set");
}
}
```

```
class Line {
  void setP1(Point p1 {
   Tracer.traceEntry("Entry Line.set");
    _p1 = p1;
   Tracer.traceExit("Exit Line.set");
}
}
```

Example – Tracing and Display Tracking



Crosscutting, Scattering and Tangling

- Crosscutting
  - concern that *inherently* relates to multiple components.
  - results in scattered concern and tangled code
  - non-functional requirements likely to crosscut
- Scattering
  - Single concern affects multiple modules
- Tangling
  - multiple concerns are interleaved in a single module

Example of crosscutting concerns

- Synchronization
- Real-time constraints
- Error-checking
- Object interaction constraints
- Memory management
- Persistency
- Security
- Caching
- Logging
- Monitoring
- Testing
- Domain specific optimization
- ...

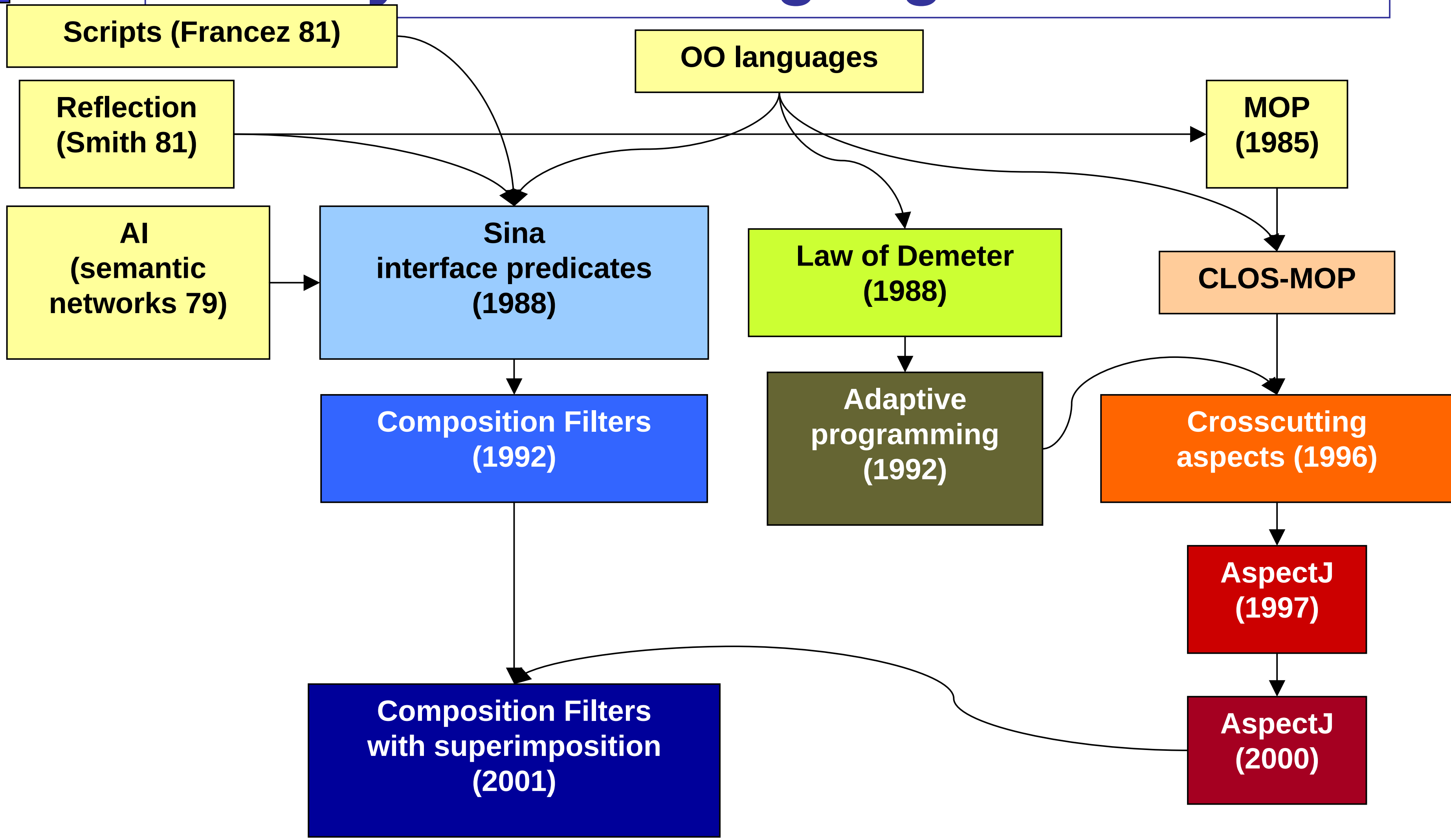
Aspect-Oriented Software Development

- Provides better separation of concerns by explicitly considering crosscutting concerns (as well)
- Does this by providing explicit abstractions for **representing** crosscutting concerns, i.e. **aspects**
- and **composing** these into programs, i.e. **aspect weaving** or **aspect composing**.
- As such AOSD improves modularity
- and supports quality factors such as
  - maintainability
  - adaptability
  - reusability
  - understandability
  - ...

Basic AOP technologies

- Composition Filters
  - University of Twente, The Netherlands
- AspectJ
  - XEROX PARC, US
- DemeterJ/DJ
  - Northeastern University, US
- Multi-dimensional separation of Concerns/HyperJ
  - IBM TJ Watson Research Center, US

History of AOP languages



http://trese.cs.utwente.nl

AspectJ

- A general purpose AO programming language
  - just as Java is a general-purpose OO language
  - unlike examples in ECOOP’97 paper
    - domain specific languages for each aspect
- an integrated extension to Java
  - accepts all java programs as input
  - outputs .class files compatible with any JVM
  - integrated with tools

Example – Without AOP

```
class Line {
  private Point _p1, _p2;

  Point getP1() { return _p1; }
  Point getP2() { return _p2; }

  void setP1(Point p1) {
    Tracer.traceEntry(“entry setP1”);
    _p1 = p1;
    Tracer.traceExit(“exit setP1”);
  }

 void setP2(Point p2) {
    Tracer.traceEntry(“entry setP2”);
    _p2 = p2;
    Tracer.traceExit(“exit setP2”);
  }
class Point {
  private int _x = 0, _y = 0;

  int getX() { return _x; }
  int getY() { return _y; }

  void setX(int x) {
   Tracer.traceEntry(“entry setX”);
    _x = x;
   Tracer.traceExit(“exit setX”)
  }
  void setY(int y) {
   Tracer.traceEntry(“exit setY”);
    _y = y;
   Tracer.traceExit(“exit setY”);
  }
}
```

```
class Tracer {

  static void traceEntry(String str)
  {
        System.out.println(str);
  }
  static void traceExit(String str)
  {
        System.out.println(str);
  }
}
```

Tangling Code

Scattered Concern

Example – With AOP

```
class Line {
  private Point _p1, _p2;

  Point getP1() { return _p1; }
  Point getP2() { return _p2; }

  void setP1(Point p1) {
    _p1 = p1;
  }
  void setP2(Point p2) {
    _p2 = p2;
  }
}

class Point {
   private int _x = 0, _y = 0;

  int getX() { return _x; }
  int getY() { return _y; }

  void setX(int x) {
    _x = x;
  }
  void setY(int y) {
    _y = y;
  }
}
```

```
aspect Tracing {

  pointcut traced():
    call(* Line.* ||
    call(* Point.*);

  before(): traced() {
    println("Entering:" +
            thisjopinpoint);

  void println(String str)
  {<write to appropriate stream>}

  }
}
```

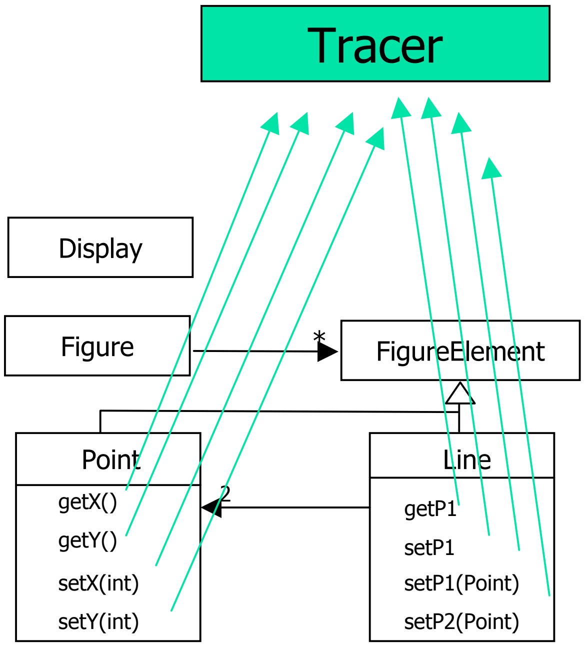
Aspect is defined in a separate module
Crosscutting is localized
No scattering; No tangling
Improved modularity

Aspect Language Elements

- join point (JP) model
  - certain principled points in program execution such as method calls, field accesses, and object construction
- means of identifying JPs
  - picking out join points of interest (predicate)
  - ***pointcuts:*** set of join points
- means of specifying behavior at JPs
  - what happens
  - ***advice*** declarations

Modularizing Crosscutting

- Joinpoints: any well-defined point of execution in a program such as method calls, field accesses, and object construction
- Pointcut: predicate on joinpoints selecting a collection of joinpoints.




```
pointcut traced():
    call(* Line.*) ||
    call(* Point.*);
```

Joinpoints

- method call join points
  - when a method is called
- method reception join points
  - when an object receives a message
- method execution join points
  - when the body of code for an actual method executes
- field get joint point
  - when a field is accessed
- field set joint point
  - when a field is set
- exception handler execution join point
  - when an exception handler executes
- object creation join point
  - when an instance of a class is created

Some primitive pointcuts

- call(Signature)
  - picks out method or constructor call based on Signature
- execution(Signature)
  - picks out a method or constructor execution join point based on Signature

- get(Signature)
  - picks out a field get join point based on Signature
- set(Signature)
  - picks out a field set join point based on Signature
- handles(TypePattern)
  - picks out an exception handler of any of the Throwable types of TypePattern

- instanceOf(ClassName)
  - picks out join points of currently executing objects of class ClassName
- within(ClassName)
  - picks out join points that are in code contained in ClassName
- withinCode(Signature)
  - picks out join points within the member defined by methor or constructor (Signature)

- cflow(pointcut)
  - picks out all the join points in the control flow of the join points picked out by the pointcut

Advice

- Piece of code that attaches to a pointcut and thus injects behavior at all joinpoints selected by that pointcut.

- example:

  before (args): pointcut
  { Body }

  where *before* represents a before advice type (see next slide).

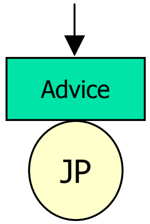
- Can take parameters with pointcuts

Advice Types

Advice code executes

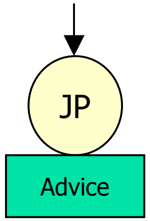
- *before*, code is injected before the joinpoint

  before (args): pointcut
  { Body }



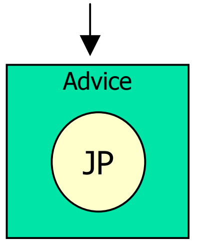
- *after*, code is injected after the joinpoint

  after (args): pointcut
  { Body }



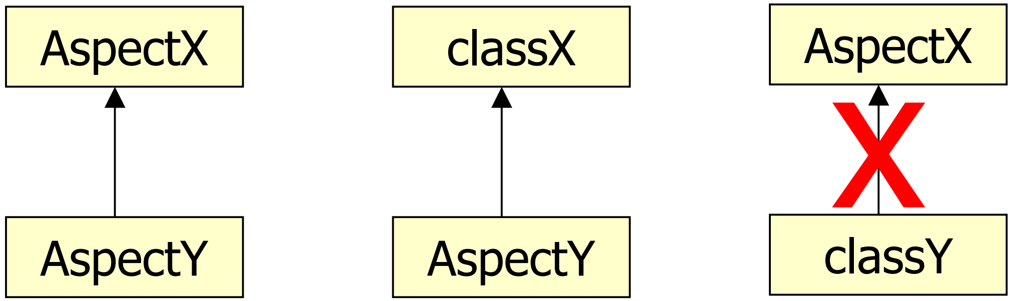
- *around,* code is injected around (in place of) code from joinpoint

  ReturnType around (args): pointcut
  { Body }



Aspect

- A modular unit of cross-cutting behavior.
- Like a class, can have methods, fields, initializers.
- can be abstract, inherit from classes and abstract aspects and implement interfaces.
- encapsulates pointcuts and advices
- can introduce new methods / fields to a class



Example - AspectJ

```
class Line {
  private Point _p1, _p2;

  Point getP1() { return _p1; }
  Point getP2() { return _p2; }

  void setP1(Point p1) {
    _p1 = p1;
  }
  void setP2(Point p2) {
    _p2 = p2;
  }
}

class Point {
   private int _x = 0, _y = 0;

  int getX() { return _x; }
  int getY() { return _y; }

  void setX(int x) {
    _x = x;
  }
  void setY(int y) {
    _y = y;
  }
}
```

```
aspect Tracing {

  pointcut traced():
    call(* Line.* ||
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  before(): traced() {
    println("Entering:" +
            thisjopinpoint);

   after(): traced() {
    println("Exit:" +
            thisjopinpoint);


  void println(String str)
  {<write to appropriate stream>}

  }
}
```

aspect

pointcut

advice

Code Weaving

- Before compile-time (pre-processor)
- During compile-time
- After compile-time
- At load time
- At run-time

Example - AspectJ

```
aspect MoveTracking {
  private static boolean _flag = false;

  public static boolean testAndClear() {
    boolean result = _flag;
    _flag = false;
    return result;
  }

  pointcut moves():
    receptions(void Line.setP1(Point)) ||
    receptions(void Line.setP2(Point));

  static after(): moves() {
    _flag = true;
  }
}
```

DemeterJ / DJ

Law Of Demeter

- Each unit should only have limited knowledge about other units: only about units “closely” related to the current unit.
  - “Each unit should only talk to its friends.”
  - “Don’t talk to strangers.”
- Goal: Reduce behavioral dependencies between classes.
- Loose coupling

Applying LoD

- A method must be able to traverse links to obtain its neighbors and must be able to call operations on them.
- But it should not traverse a second link from the neighbor to a third class.
- Methods should communicate only with preferred suppliers:
  - immediate parts on this
  - objects passed as arguments to method
  - objects which are directly created in method
  - objects in global variables
  - No other calls allowed

---> Scattering

Solution is Adaptive Programming

- Encapsulate operation into one place thereby avoiding scattering
- Specify traversal over (graph) structure in a succinct way thereby reducing tangling.
- Navigation **strategy**

Use of Visitors

```
import edu.neu.ccs.demeter.dj.*;
// define strategy

String strategy="from BusRoute through BusStop to Person"

class BusRoute {
    // define class graph
    static Classgraph cg = new ClassGraph();
    int printCountWaitingPersons(){ // traversal/visitor weaving
        //define visitor
        Visitor v = new Visitor()
                public void before(Person host){ r++; … }
                public void start() { r = 0;}
                …
        }
        cg.traverse(this, strategy, v);
        ...
}
```