International Workshop on Aliasing, Confinement and Ownership in object-oriented programming (IWACO)

Ownership Domains in the Real World

"Papers have been written enough, let us see systems!"
— Reinhard Wilhelm

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Motivation for this work

"While many ownership systems look promising on small examples, the question of practical usage for large and complicated applications remains unanswered" – Stefan Nägeli

Hidden Motivation for this Work

How to stop worrying

*about **iterators***

and start living

with real object-oriented code

with apologies to Dale Carnegie

Ownership Domains

- Among many ownership type systems
  - Each object can have one or more domains
  - Each object is in exactly one domain
- Previously implementation
  - Used language extensions
  - Ran on research infrastructure

Ownership Domains with Annotations

- Use Java 1.5 annotations (JSR 175)
- Move to Eclipse infrastructure
- Advantages of using annotations
  - Improved tool support
  - Incrementally annotate large code bases
- Disadvantages
  - Many restrictions imposed by JSR 175
  - Heavy syntactic baggage
  - See details in paper

Annotation Language, Tool Support

- Examples here use simplified syntax
  - See paper for Java 1.5 version
  - Code slightly simplified for presentation

Ownership Domains Case Studies

- Introduction

  Case Studies
- Ownership Domains Expressiveness
- Ownership Domains Challenges

Case Studies: Subject Systems

- JHotDraw
  - 15 KLOC developed by experts
  - Only added annotations
  - Minor refactoring to use annotation system
  - ~ 60 remaining type errors
- HillClimber
  - 15 KLOC developed by undergraduates
  - Annotations helped discover code smells
  - Introduced refactoring to reduce coupling
  - ~ 40 remaining type errors

Overall Annotation Process

- Iterative based on
  - Improved understanding
  - Refactoring the code
  - Visualizing the annotations
- Annotations helped improve code quality
  - Expose tight coupling
  - Guide to reduce coupling
- Visualizing annotations improved them
  - Group related objects
  - Make more objects **owned**

Ownership Domains Case Studies

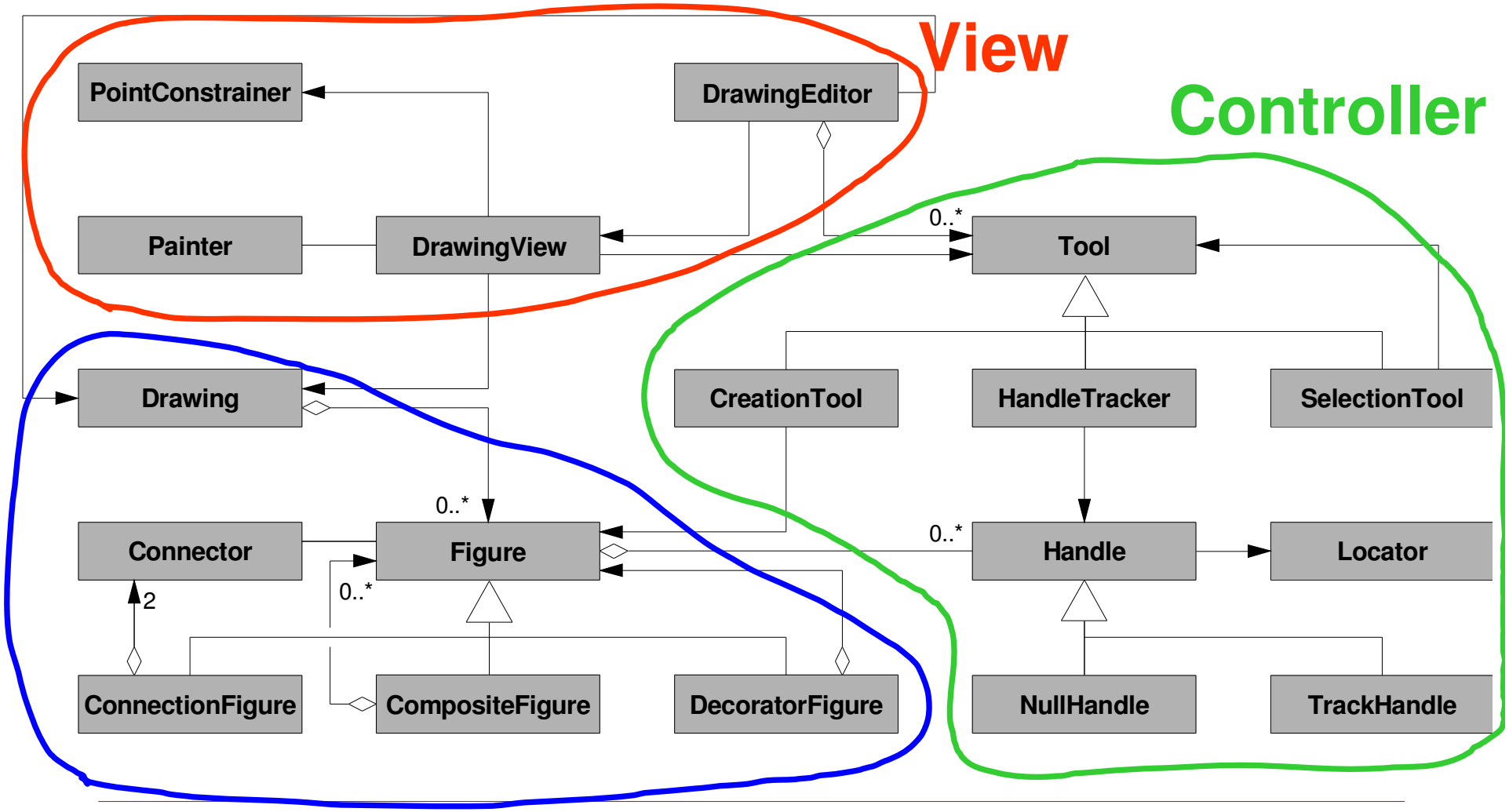
- Introduction
- Case Studies

  Ownership Domains Expressiveness
- Ownership Domains Challenges

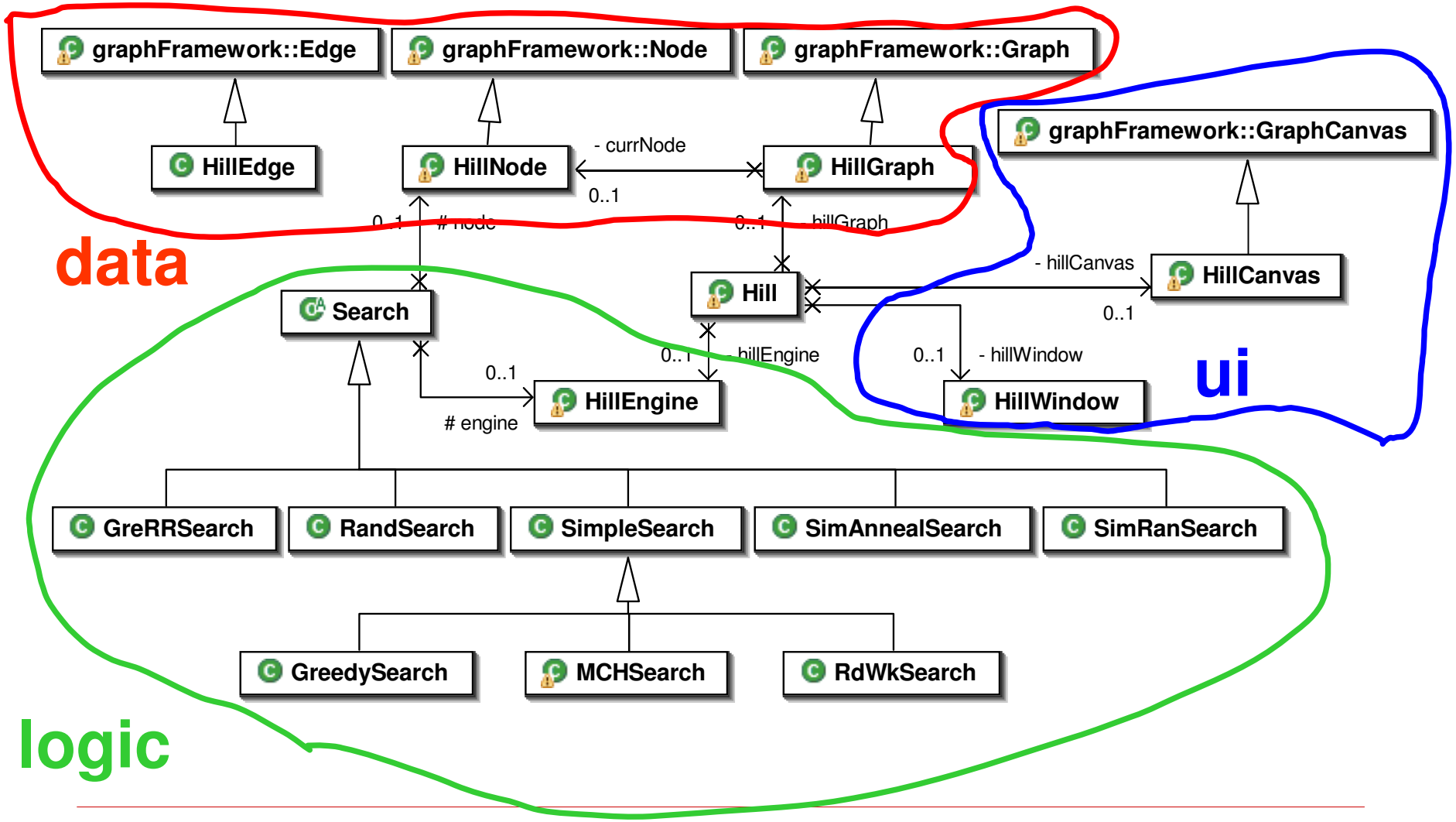
Ownership Domains Expressiveness

- Specify architectural tiers
- Enforce instance encapsulation
- Expose implicit communication
- Expose tight coupling
- Expose and enforce object lifetime
- Promote decoupling code
- Help identify singletons

JHotDraw Ownership Domains



HillClimber Ownership Domains



Specifying architectural tiers

```
class DrawApplication<M,V,C> ... implements DrawingEditor<M,V,C> ... {
}

class MDI_DrawApplication<M,V,C> extends DrawApplication<M,V,C> ... {
}

class JavaDrawApp<M,V,C> extends MDI_DrawApplication<M,V,C> {
}

class Main {
  domains Model, View, Controller;
  ...
  View JavaDrawApp<Model,View,Controller> app = new JavaDrawApp();

  public void run() {
    app.open();
  }

  public static void main(lent String args[shared]) {
  lent Main system = new Main();
    system.run();
  }
}
```

Enforcing instance encapsulation

```
/**
 * The interface of a graphical figure. A figure knows its display box
 * and can draw itself. A figure can be composed of several figures.
 * A figure has a set of handles to manipulate its shape or attributes.
 * A figure has one or more connectors that define
 * how to locate a connection point.
*/
interface Figure<M> extends Storable <M> {
 ...
}
```

Enforcing instance encapsulation

```
/**
 * A Figure that is composed of several figures.
 */
abstract class CompositeFigure<M>
          extends AbstractFigure<M> implements FigureChangeListener<M> {

 domain owned;

/**
 * The figures that this figure is composed of
 */
 owned Vector<M Figure<M> > fFigures;

/**
 * Adds a vector of figures.
 */
void addAll(M Vector<M Figure<M>> newFigures) {
  // Cannot assign object M Vector newFigures to owned Vector fFigures
  // this.fFigures = newFigures;

  fFigures.addAll(newFigures);
}
```

Nested parameter (Figure takes 'M' parameter)

Cannot override field marked with 'owned'

Exposing implicit communication

```
/**
 * Drawing is a container for figures. Drawing s
 * events to DrawingChangeListeners whenever a pa
 * invalidated. The Observer pattern is used to decouple the      ing
 * from its views and to enable multiple views.
 */
interface Drawing<M,V> ...{

/**
 * Adds a listener for this drawing.
 * DrawingView implements DrawingChangeListener,
 * so the objects are in 'V' domain paramete
 */
void addDrawingChangeListener(V DrawingChangeListener<M,V> listener);

/**
 * Adds a figure and sets its container to refer to this drawing.
 * @param figure to be added to the drawing
 * @return the figure that was inserted (might be different from the
     figure specified).
 */
 M Figure<M> add(M Figure<M> figure);

}
```

Drawing needs 'V' domain parameter

DrawingChangeListener Implemented by DrawingView (in View domain)

Exposing tight coupling

```
/**
 * Handles are used to change a figure by direct manipulation.
 * Handles know their owning figure and they provide methods to locate
 * the handle on the figure and to track changes.
 * Handles adapt the operations to manipulate a figure to a common
   interface.
*/
interface Handle<M,V,C> {

  /**
   * @deprecated As of version 4.1, use invokeStart(x, y, drawingView)
   */
  void invokeStart(int x, int y, Drawing<M> drawing);

  /**
   * Tracks the start of the interaction.
   * @param x the x position where the interaction
   * @param y the y position where the interaction started
   * @param view the handles container
   */
void invokeStart(int x, int y, V DrawingView<M,V,C> view);

}
```

Assuming Drawing only needs 'M' parameter

DrawingView argument requires all three parameters!

Exposing tight coupling

```
interface Handle<M,V,C> {
  void invokeStart(int x, int y, V DrawingView<M,V,C> view);
  M Undoable<M,V,C> getUndoActivity();
}
```

Assuming Handle only needs 'M' and 'C' parameters

```
interface Handle<M,C> {
  void invokeStart<V> (int x, int y, V DrawingView<M,V,C> view);
  M Undoable<M> getUndoActivity();
}
```

Convert class domain parameter 'V' to method domain parameter

Exposing object lifetime

```
/**
 * AbstractHandle provides default implementation for Handle interface.
 */
abstract class AbstractHandle<M,C> implements Handle<M,C> {

  // The following would not typecheck since 'V' not bound
  V DrawingView<M,V,C> view;

/**
 * @param x the x position where the interaction started
 * @param y the y position where the interaction started
 * @param view the handles container
 */
void invokeStart<V>(int x, int y, V DrawingView<M,V,C> view) {
  // Cannot store argument view in field this.view
  ...
}
```

Convert domain parameter 'V' to method domain parameter

Exposing object lifetime

```
class ResizeHandle<M,V,C> extends LocatorHandle<M,V,C> {

@Override
void invokeStart(int x, int y, V DrawingView<M,V,C> view) {
setUndoActivity(createUndoActivity(view));
...
}

/**
 * Factory method for undo activity. To be overriden by subclasses.
 */
M Undoable<M,V,C> createUndoActivity(V DrawingView<M,V,C> view) {
  unique ResizeHandle.UndoActivity<M,V,C> undoActivity = new
    ResizeHandle.UndoActivity(view);
  return undoActivity;
}

static class UndoActivity<M,V,C> extends UndoableAdapter<M,V,C> {
  UndoActivity(V DrawingView<M,V,C> newView) {
    super(newView);
...}
}

}
```

Exposing object lifetime

```
class UndoableAdapter<M,V,C> implements Undoable<M,V,C> {

 owned Vector<M Figure> myAffectedFigures;

 V DrawingView<M,V,C> myDrawingView;

 UndoableAdapter(V DrawingView<M,V,C> newDrawingView) {
  myDrawingView = newDrawingView;
 }

 void setAffectedFigures(lent FigureEnumeration<M> newAffectedFigures) {
  // the enumeration is not reusable therefore a copy is made
  // to be able to undo-redo the command several time
  rememberFigures(newAffectedFigures);
}

 void rememberFigures(lent FigureEnumeration<M>
   myAffectedFigures = new Vector<Figure>();
   myAffectedFiguresCount = 0;
   while (toBeRemembered.hasMoreElements()) {
    myAffectedFigures.addElement(toBeRemembered.nextElement());
    myAffectedFiguresCount++;
   }
  }
 }
```

Minor violation of MVC design: hold on to the view

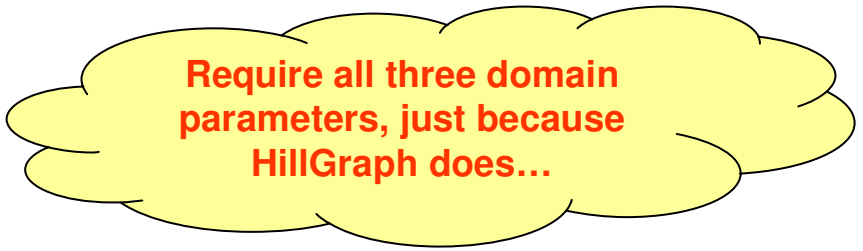
'lent' enforces alias to FigureEnumeration is temporary

Promoting the decoupling of code

- Programming to an interface
- Using the Mediator pattern

When not programming to interface

```
class HillNode<ui,logic,data>  extends Node<data> {

   data HillGraph<ui,logic,data> hillGraph;
}
```



When programming to interface

```
class HillGraph<ui,logic,data> extends Graph<data>
            implements IHillGraph<data> {
}
```

Extract interface IHillGraph that only requires 'data' parameter

```
interface IHillGraph<data>  extends IGraph<data> {
}
```

Program to IHillGraph interface

```
class HillNode<data>  extends Node<data> {
   data IHillGraph<data> hillGraph;
}
```

As a result, HillNode only need 'data' domain parameter

Not using a mediator

```
abstract class Entity<data>  {
  data Graph<data>  graph; // parent graph

...
}

class Node<data>  extends Entity<data>  {
 ...
 int getHeight() {
    return graph.getCanvas().getFontMetrics()...;
  }
}
```

Not using a mediator – bad attempt

```
abstract class Entity<data>  {
  data IGraphCanvas canvas; // 'ui' unbound
...
}

class Node<data>  extends Entity<data>  {
 ...
 int getHeight() {
   return canvas.getFontMetrics()...;
  }
}
```

Defining a mediator

```
/**
 * Mediator interface
 */
interface ICanvasMediator {
  shared FontMetrics getFontMetrics();
}
/**
 * Mediator implementation class
 */
class CanvasMediatorImpl<ui,data> implements ICanvasMediator {

Ui GraphCanvas<ui,data> canvas = null;

CanvasMediatorImpl(ui GraphCanvas<ui,data> canvas) {
 this.canvas = canvas;
}

shared FontMetrics getFontMetrics() {
     return this.canvas.getFontMetrics();
}

}
```

Using a mediator

```
class GraphCanvas<ui,data> extends ... {
 data CanvasMediatorImpl<ui,data> mediator;
 ...
 data ICanvasMediator getMediator() {
   return mediator;
}

abstract class Entity< data> {
   data ICanvasMediator mediator;
 ...
}
class Node<data> extends Entity<data> {
 ...
  /**
   * Gets the height of this node.
   *
   */
  protected int getHeight() {
    return mediator.getFontMetrics().getHeight() + ...;
  }
}
```

Identifying singletons

```
class Iconkit {
 static unique Iconkit fgIconkit = null;

 /**
  * Constructs an Iconkit that uses the given editor
  * to resolve image path names.
  */
 unique
 public Iconkit(unique Component component) {
  ...
  fgIconkit = this;
 }

 /**
  * Gets the single instance
  */
 public unique static Iconkit instance() {
   return fgIconkit;
  }
}
```

Ownership Domains Case Studies

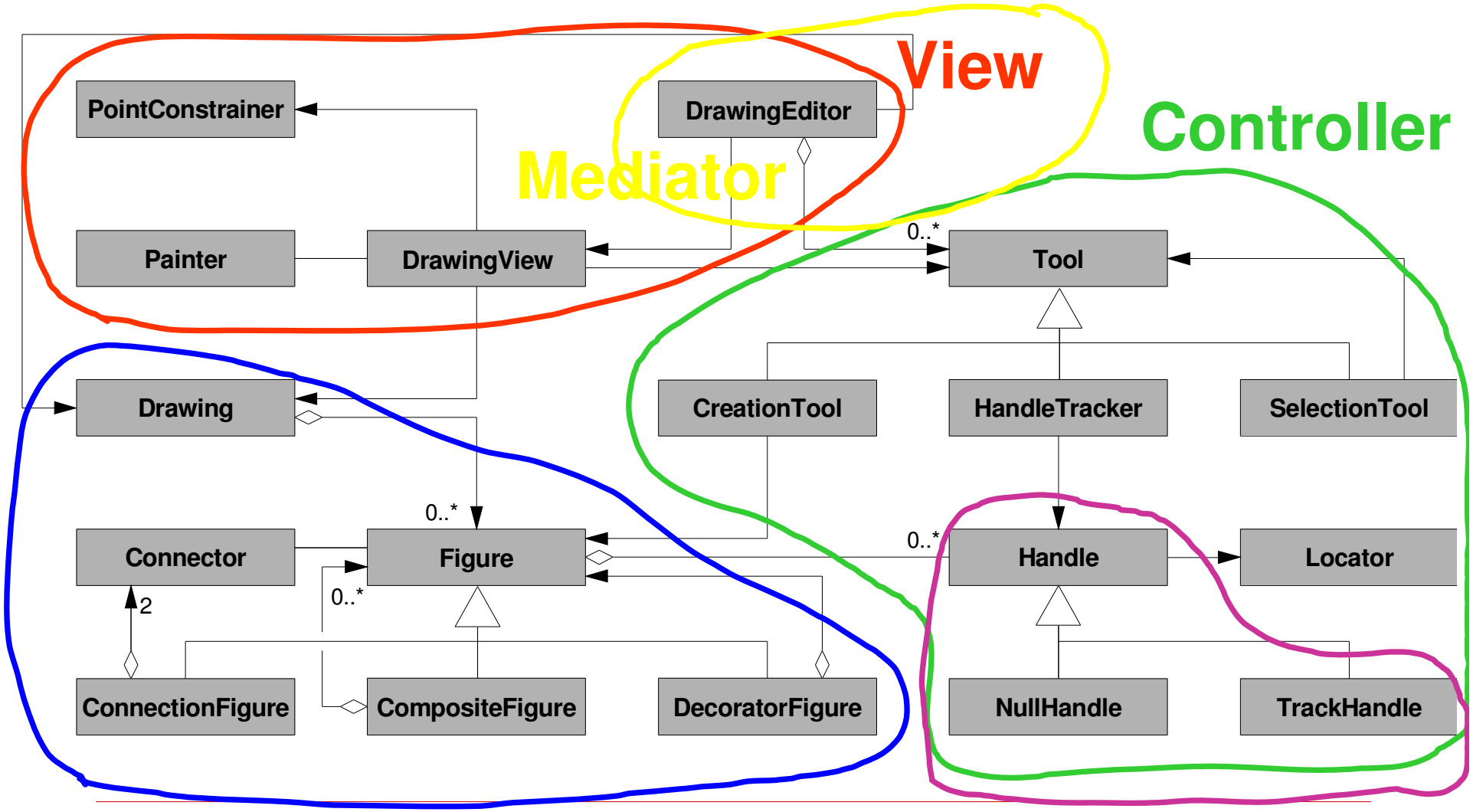
- Introduction
- Case Studies
- Ownership Domains Expressiveness

Ownership Domains Challenges

Ownership Domains Challenges

- Ownership domains vs. ownership intent
- Fake class to declare top-level domains
- One object vs. two conceptual objects
- Annotating listener objects
- Annotating static code
- Having non-verbose annotations

Ownership domains may not correspond to the “ownership design intent"

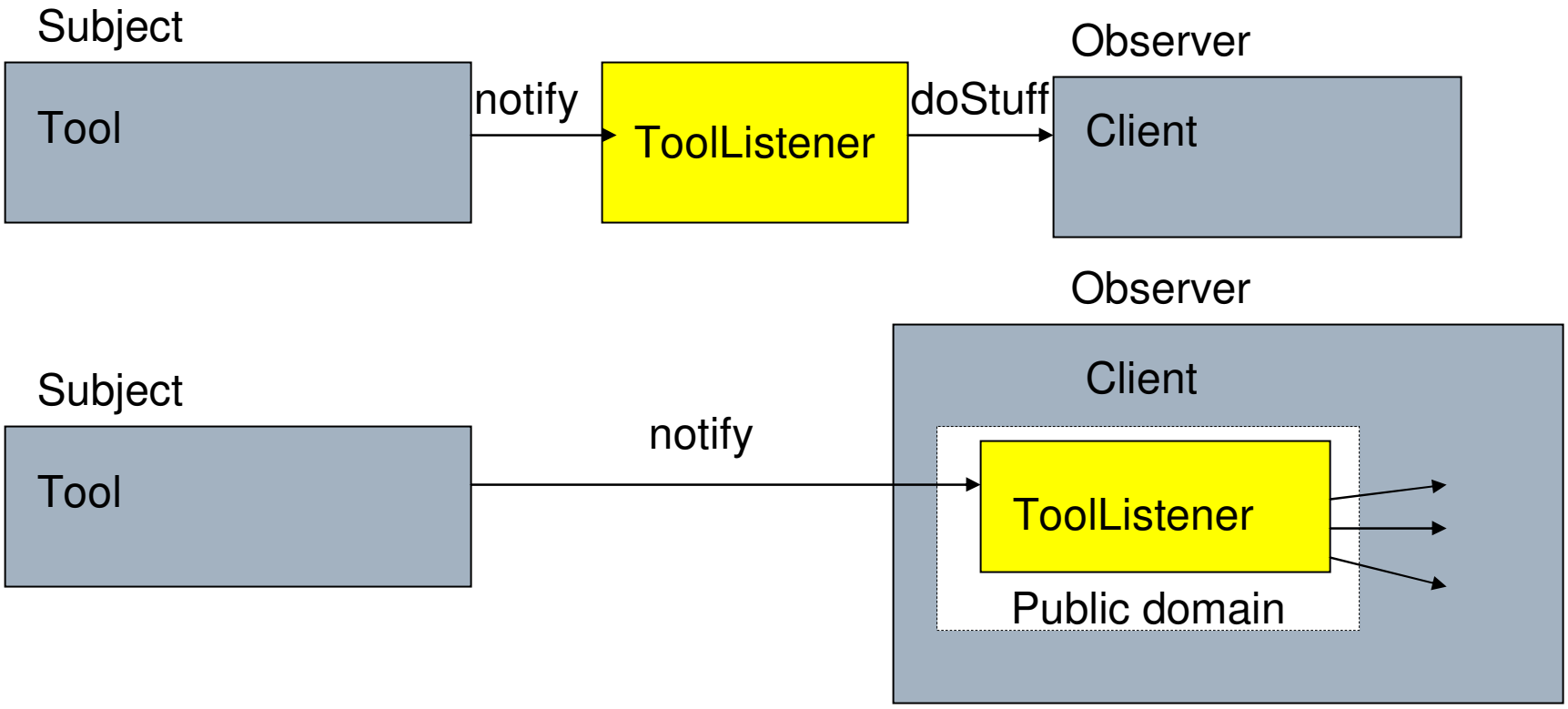


Fake class to declare top-level ownership domains

```
class DrawApplication<M,V,C> ... implements DrawingEditor<M,V,C> ... {
}

class MDI_DrawApplication<M,V,C> extends DrawApplication<M,V,C> ... {
}

class JavaDrawApp<M,V,C> extends MDI_DrawApplication<M,V,C> {
}

class Main {
  domains Model, View, Controller;

  View JavaDrawApp<Model,View,Controller> app = new JavaDrawApp();

  public void run() {
    app.open();
  }

  public static void main(lent String args[shared]) {
  lent Main system = new Main();
    system.run();
  }
}
```

Public domains

- Add expressiveness to type system
- Ideal for visualization (grouping objects)



One object vs. two conceptual objects

- Public domains more suitable for composition than inheritance
- Object cannot be “split” into two domains
- Leads to iterative annotation process

```
abstract class AbstractCommand<M,V,C>
        implements Command<M,V,C>,
                   FigureSelectionListener<M,V,C>,
                   ... {

 public domain FIGURESELECTIONLISTENER;

...
}
```

Command cannot split the “listener” part of itself into a public domain

Annotating listener objects

```
class StandardDrawingView<M,V,C> implements DrawingView<M,V,C>, ... {

 /**
  * The registered list of listeners for selection changes
  */
 owned Vector<C FigureSelectionListener<M,V,C>> fSelectionListeners;

 StandardDrawingView(V DrawingEditor<M,V,C> editor, ...) {
    ...
    // DrawingEditor implements FigureSelectionListener
    // editor is in 'V' domain parameter, not 'C'!
    addFigureSelectionListener(editor);
}

 /**
  * Add a listener for selection changes. AbstractCommand implements
  * FigureSelectionListener. Command is in the 'C' domain parameter!
  */
 void addFigureSelectionListener(C FigureSelectionListener<M,V,C> fsl) {
  fSelectionListeners.add(fsl);
  }
}
```

Annotating listener objects – a solution

```
class StandardDrawingView<M,V,C> implements DrawingView<M,V,C>, ... {

 /**
  * The registered list of listeners for selection changes
  */
 owned Vector<? FigureSelectionListener<M,V,C>> fSelectionListeners;

 StandardDrawingView(V DrawingEditor<M,V,C> editor, ...) {
   ...
   // DrawingEditor implements FigureSelectionListener
   // editor is in 'V' domain parameter, not 'C'!
   addFigureSelectionListener(editor);
}

 /**
  * Add a listener for selection changes. AbstractCommand implements
  * FigureSelectionListener. Command is in the 'C' domain parameter!
  */
 void addFigureSelectionListener(? FigureSelectionListener<M,V,C> fsl) {
  fSelectionListeners.add(fsl);
  }
}
```

Static code can be challengin

Hashtable has 3 parameters: key, value, entry.

```
class NullDrawingView<M,V,C> ... implements DrawingView<M,V,C> {

    static @Domain("unique<unique<?,?,?>,unique<?,?,?>,unique>")
    Hashtable<DrawingEditor, DrawingView> dvMgr = new ...
    ...

public synchronized static
   Vx DrawingView<Mx,Vx,Cx>
  getManagedDrawingView<Mx,Vx,Cx> (V1 DrawingEditor<Mx,Vx,Cx> editor) {
    if (dvMgr.containsKey(editor)) {
      Vx DrawingView<Mx,Vx,Cx> drawingView = dvMgr.get(editor);
      return drawingView;
    }
    else {
      Vx DrawingView<Mx,Vx,Cx>newDrawingView=new NullDrawingView(editor);
      dvMgr.put(editor, newDrawingView);
      return newDrawingView;
    }
  }
}
```

Does not typecheck!

Domain parameters declared on class not in scope for static members

Annotations can be verbose

```
class UndoManager<M,V,C> {
  /**
   * Collection of undo activities
   */
  owned Vector<M Undoable<M,V,C>> undoStack;

  void clearStackVerbose(lent Vector<M Undoable<M,V,C>> s) {
    s.removeAllElements();
  }

  void clearStackAny(lent Vector<? Undoable<?,?,?>> s) {
    s.removeAllElements();
  }

  void clearStack(lent Vector<Undoable> s) {
    s.removeAllElements();
  }
}
```

Current annotations needed too verbose

The equivalent of “raw type” on generic type

Related Work

- Earlier HillClimber case study
  - ArchJava + AliasJava language extensions
- Case study by Hächler
  - Evaluated Universes type system
  - Annotate parts of 50,000 LOC system
  - No automated visualization support
- Case study by Nägeli
  - Universes and Ownership Domains
  - Studied design patterns in isolation

Summary

- Re-implementation in Java 1.5
  - Tool support for substantial case studies
  - Access to refactoring tool support crucial
- Two case studies
  - Evaluated ownership domains on real code
  - Identified some interesting outcomes
- Future work
  - Address expressiveness challenges
  - “There is still a lot of road to cover” (reviewer)