

*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**

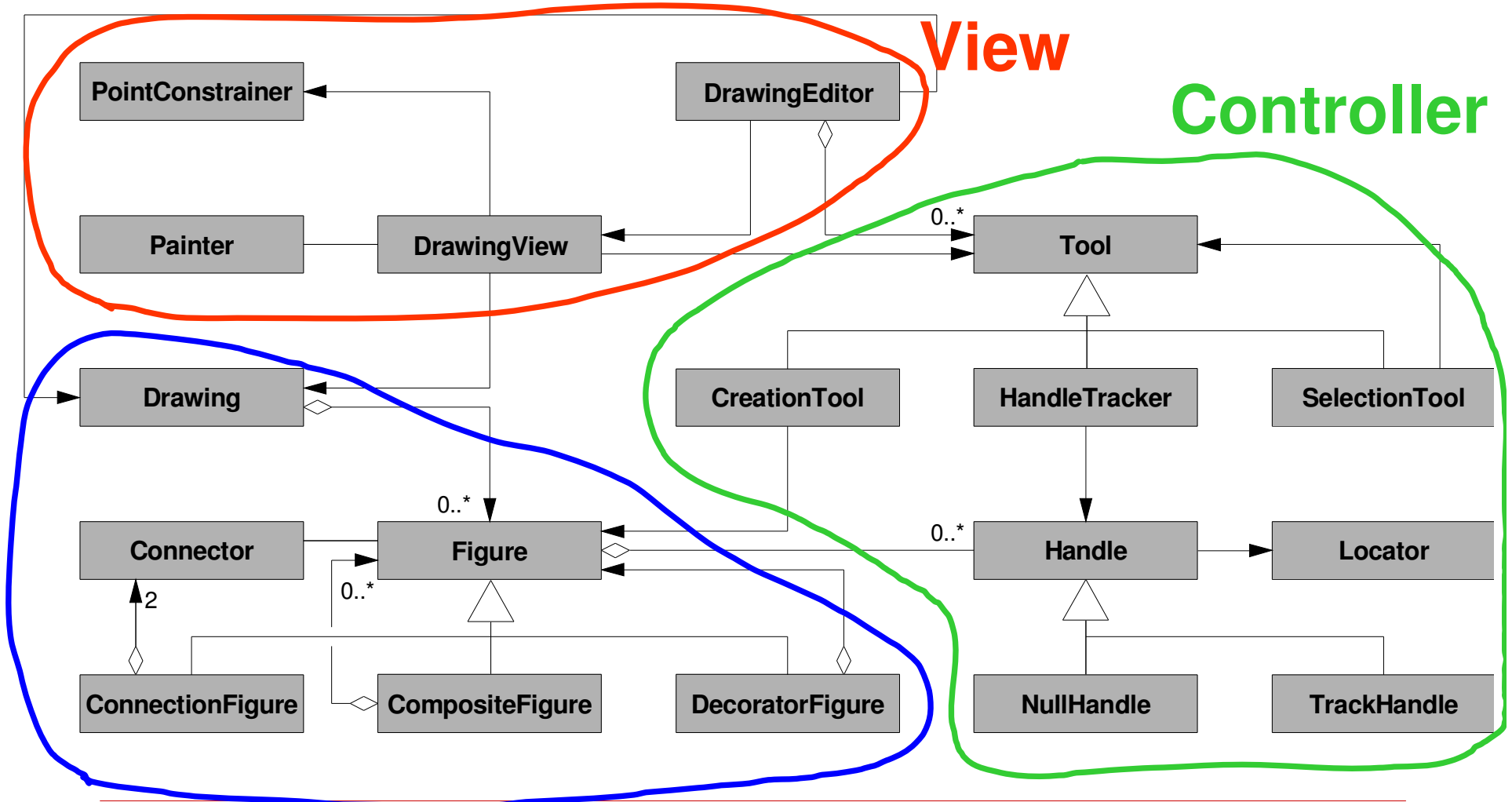
Ownership Domains Case Studies

- Introduction
- Case Studies
- **Ownership Domains Expressiveness**
- Ownership Domains Challenges

Ownership Domains Expressiveness

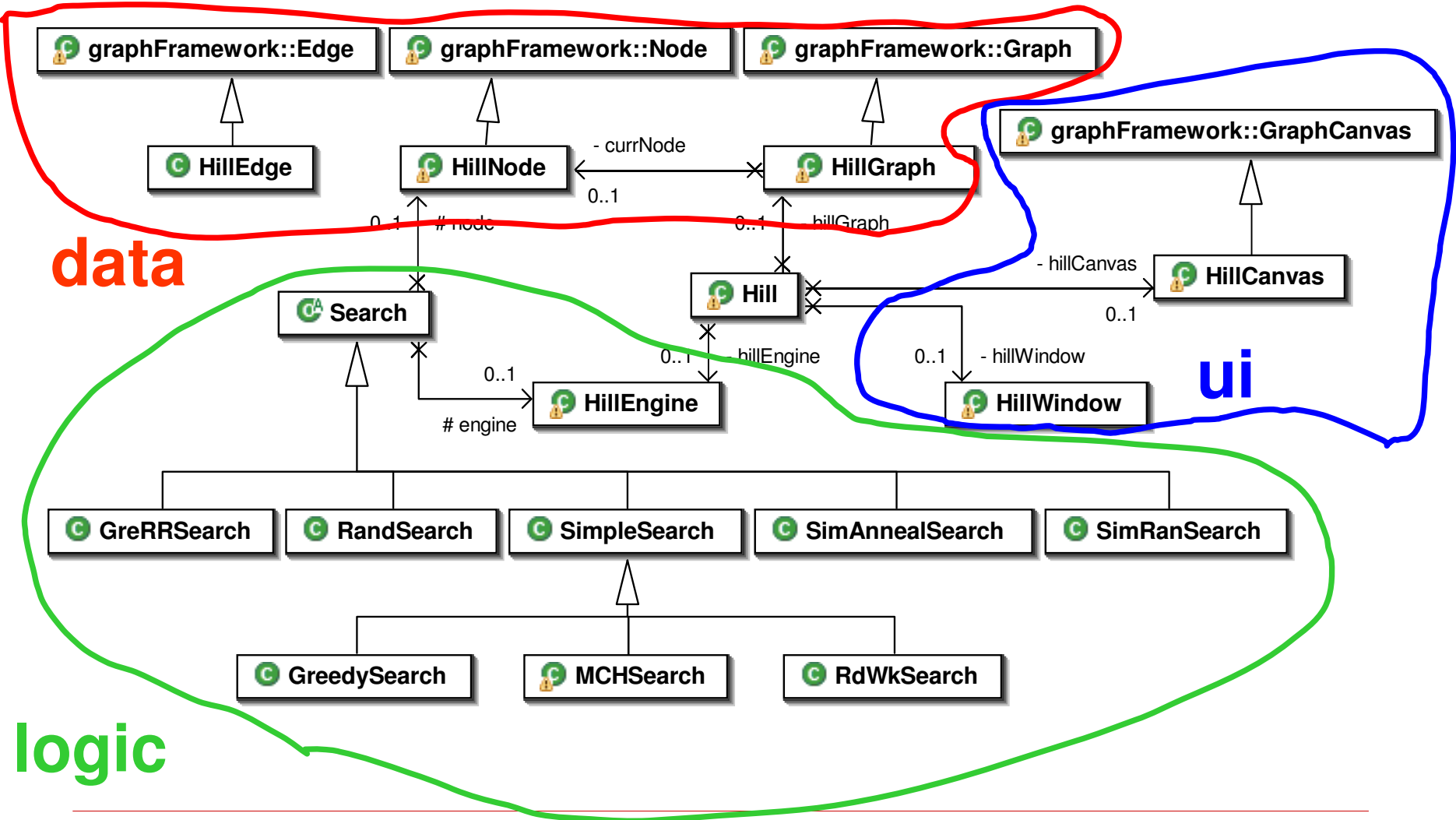
- Specify architectural tiers
- Enforce instance encapsulation
- Expose implicit communication
- Expose tight coupling
- Expose and enforce object lifetime
- Promote decoupling code
- Help identify singletons

JHotDraw Ownership Domains



Model

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 sends
 * events to DrawingChangeListeners whenever a part
 * is invalidated. The Observer pattern is used to decouple the drawing
 * 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 parameter.
 */
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, int Drawing<M> drawing);

    /**
     * Tracks the start of the interaction.
     * @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(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();  
}
```

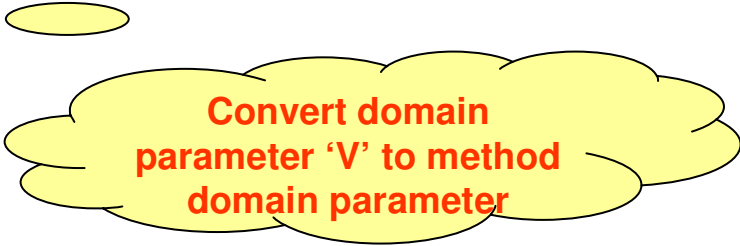
Convert class domain parameter 'V' to method domain parameter

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 overridden 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;
```

Minor violation of MVC design: hold on to the view

```
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);  
}
```

'lent' enforces alias to FigureEnumeration is temporary

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

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;  
}
```

Require all three domain parameters, just because HillGraph does...

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

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();
```

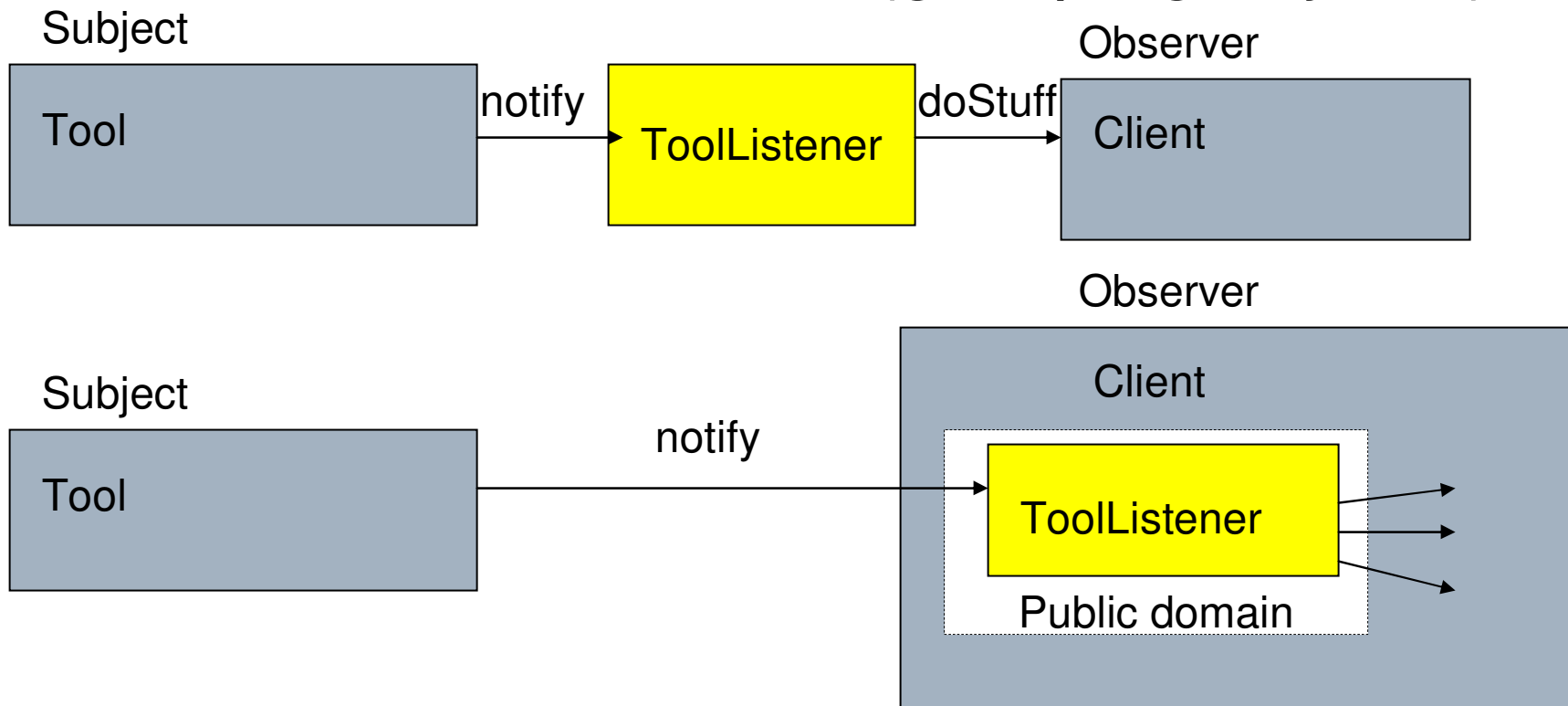
```
public void run() {  
    app.open();  
}
```

```
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)



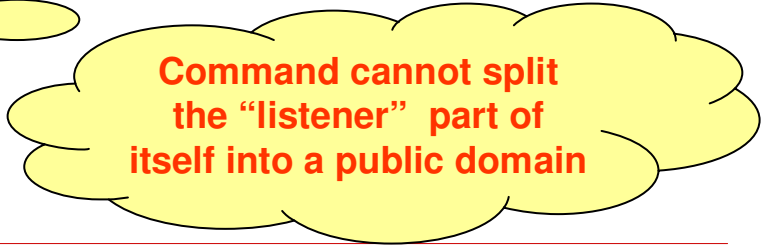
One object vs. two conceptual objects

- 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> fs1) {  
        fselectionListeners.add(fs1);  
    }  
}
```

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> fs1) {  
        fSelectionListeners.add(fs1);  
    }  
}
```

Static code can be challenging

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> (Vl 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(int Vector<M Undoable<M,V,C>> s) {  
        s.removeAllElements();  
    }  
  
    void clearStackAny(int Vector<? Undoable<?,?,?>> s) {  
        s.removeAllElements();  
    }  
  
    void clearStack(int 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)