Architecture Patterns and Styles

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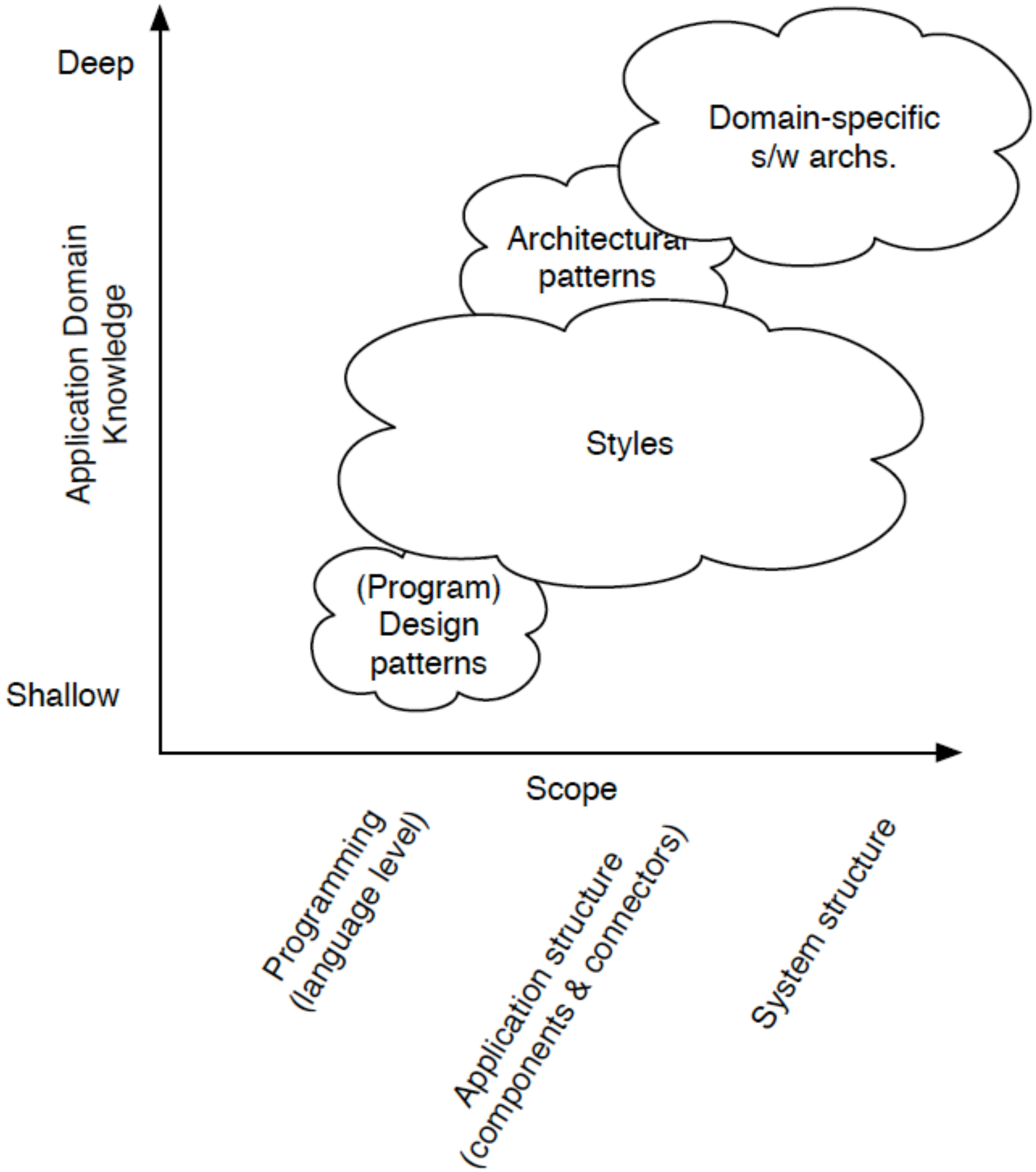
CS 441: Software Engineering

How do we design architecture?

- Creativity
  - This requires extensive experience, broad training, ...
- Principles, process, and methods
  - Goals, activities, and principles
  - Process
  - Design methods: object-oriented design, functional design, and quality-driven design
- Reuse
  - Horizontal reuse: **architecture patterns and styles**
  - Vertical reuse: product-line architectures

Architecture Patterns and Styles

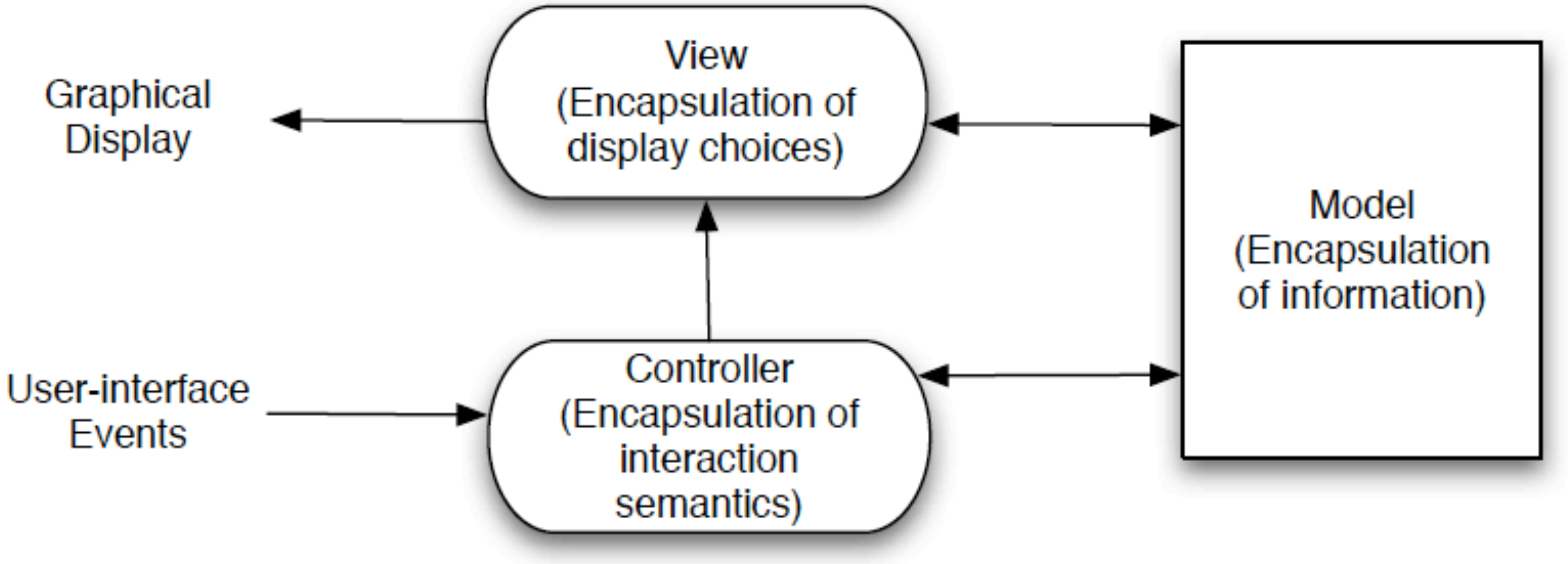
- Architecture pattern: a named collection of architecture design decisions that are applicable to a **recurring design problem**, parameterized to account for different software development contexts in which that problem appears.
- Architecture style: a named collection of architectural design decisions that (1) are applicable in a given development **context**, (2) **constrain** architectural design decisions that are specific to a particular system within that context, and (3) elicit **beneficial** qualities in each resulting system.


Deep
Application Domain Knowledge
Shallow
Domain-specific s/w archs.
Architectural patterns
Styles
(Program) Design patterns
Scope
Programming (language level)
Application structure (components & connectors)
System structure

Architecture Patterns and Styles

- Architecture patterns
  - Model-View-Controller
  - Sense-Compute-Control
- Architecture styles
  - Pipe-and-filter
  - Implicit invocation
  - Blackboard
  - Layered
- Some other patterns and styles
  - State-Logic-Display (Three-Tier), Client-Server, Interpreter, REST, etc.

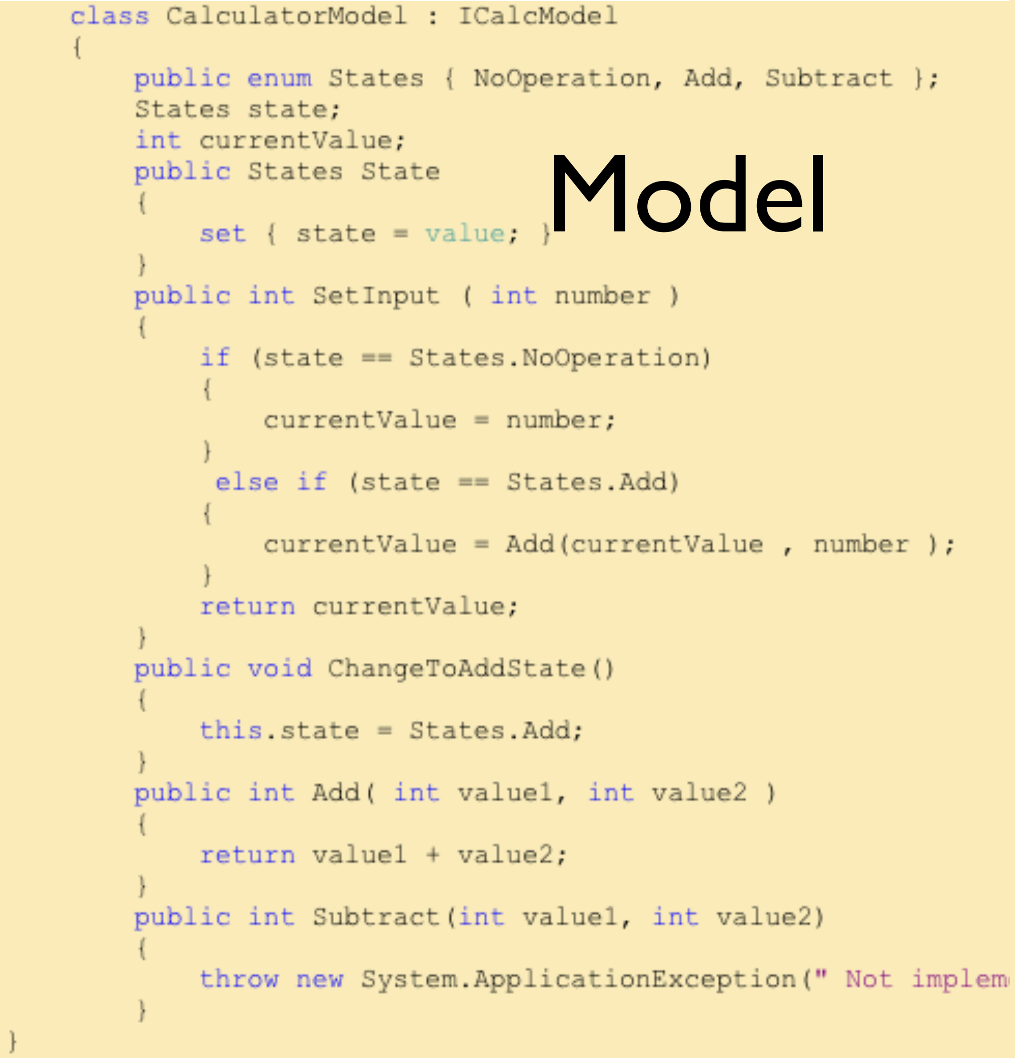
Model-View-Controller (MVC)


Graphical Display
View (Encapsulation of display choices)
Model (Encapsulation of information)
User-interface Events
Controller (Encapsulation of interaction semantics)

- Model: the information used by the application.
- View: screen presentation of the information.
- Controller: defines the way the user interface reacts to user input and maintains view-model consistency.
- Model-View: the subscribe/notify relationship.
- View and Controller may be combined in some cases.

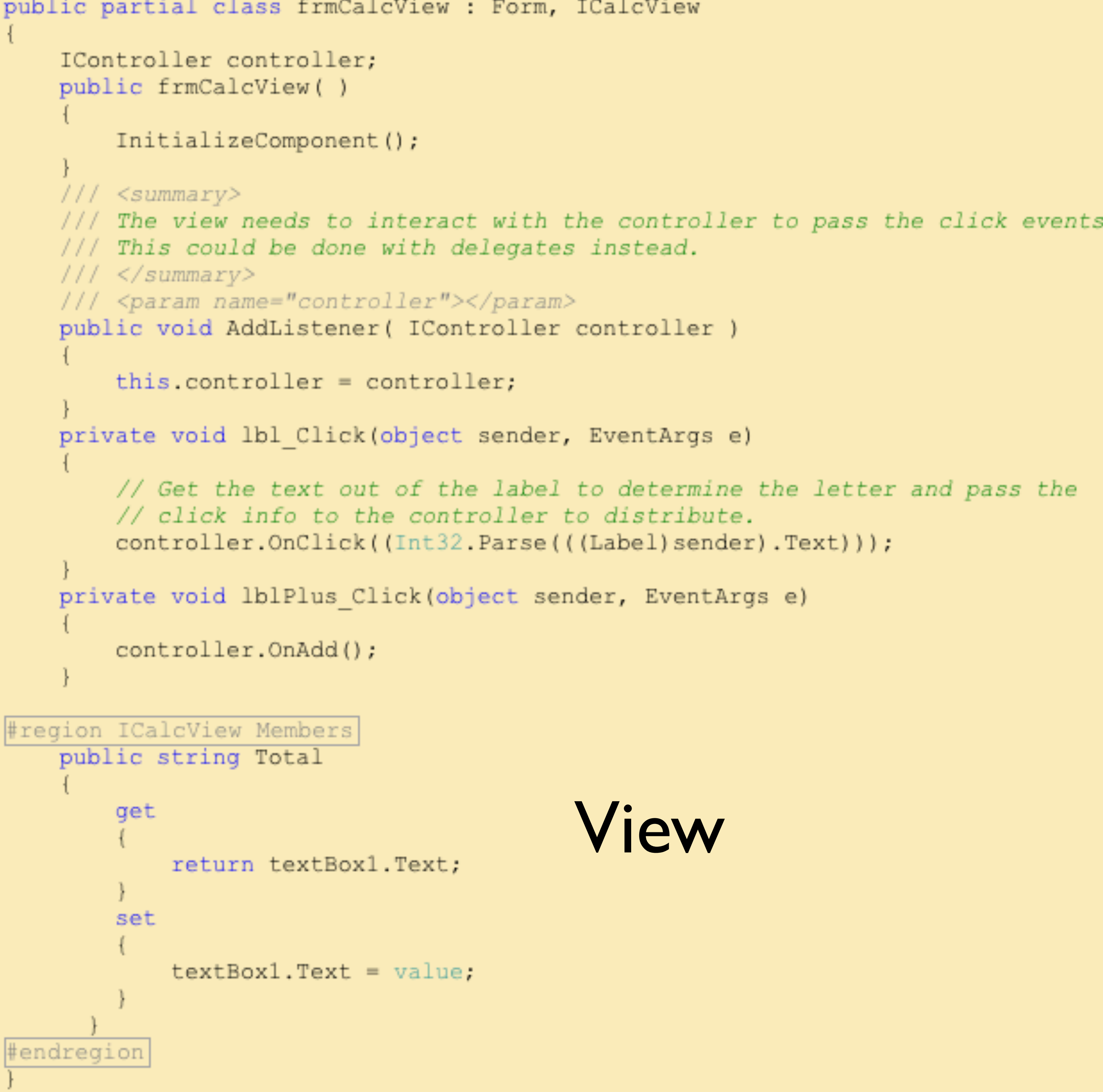
MVC, cont.

- Typically, a MVC application works as follows:
  - The user interacts with the application.
  - The controller handles the input event from the user interface.
  - The controller may ask the model to update its information in response to the user input, or ask the view to re-draw without updating the model.
  - If the model is updated, the view is notified (indirectly).
  - The application waits for additional user inputs.



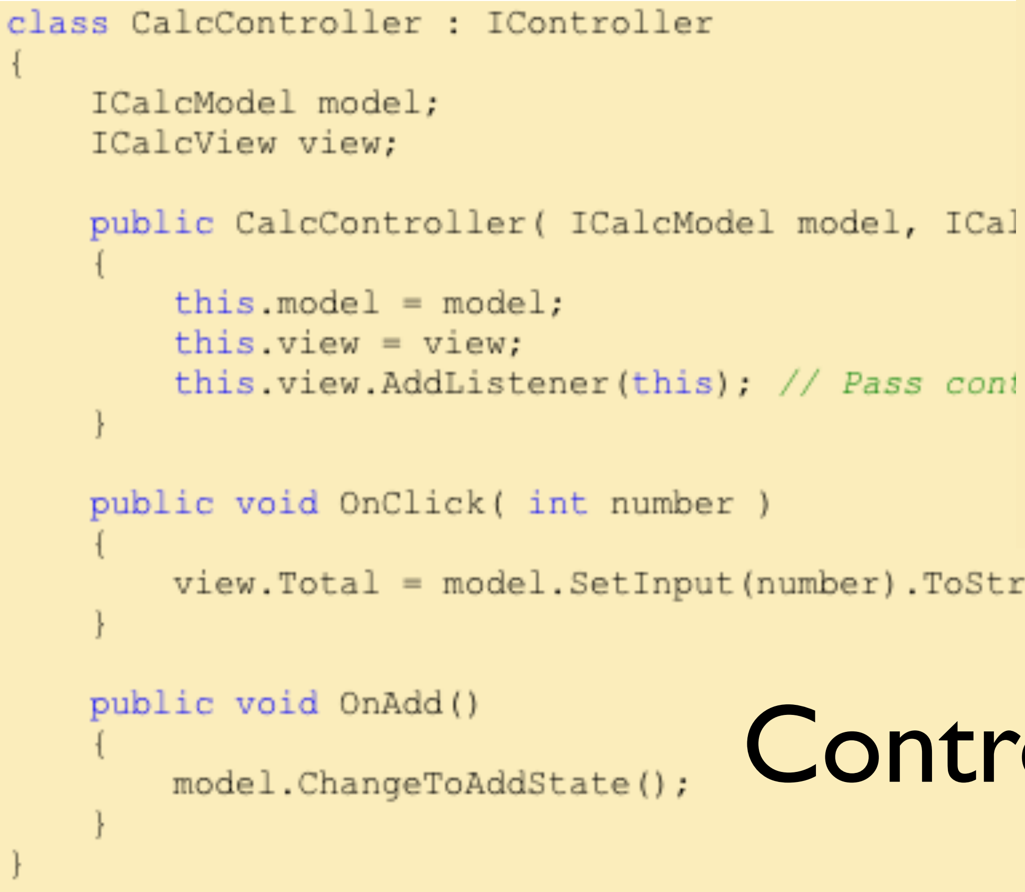
Model

```
    class CalculatorModel : ICalcModel
    {
        public enum States { NoOperation, Add, Subtract };
        States state;
        int currentValue;
        public States State
        {
            set { state = value; }
        }
        public int SetInput ( int number )
        {
            if (state == States.NoOperation)
            {
                currentValue = number;
            }
             else if (state == States.Add)
            {
                currentValue = Add(currentValue , number );
            }
            return currentValue;
        }
        public void ChangeToAddState()
        {
            this.state = States.Add;
        }
        public int Add( int value1, int value2 )
        {
            return value1 + value2;
        }
        public int Subtract(int value1, int value2)
        {
            throw new System.ApplicationException(" Not implem
        }
}
```



```
public partial class frmCalcView : Form, ICalcView
{
    IController controller;
    public frmCalcView( )
    {
        InitializeComponent();
    }
    /// <summary>
    /// The view needs to interact with the controller to pass the click events
    /// This could be done with delegates instead.
    /// </summary>
    /// <param name="controller"></param>
    public void AddListener( IController controller )
    {
        this.controller = controller;
    }
    private void lbl_Click(object sender, EventArgs e)
    {
        // Get the text out of the label to determine the letter and pass the
        // click info to the controller to distribute.
        controller.OnClick((Int32.Parse(((Label)sender).Text)));
    }
    private void lblPlus_Click(object sender, EventArgs e)
    {
        controller.OnAdd();
    }

#region ICalcView Members
    public string Total
    {
        get
        {
            return textBox1.Text;
        }
        set
        {
            textBox1.Text = value;
        }
    }
#endregion
}
```

View

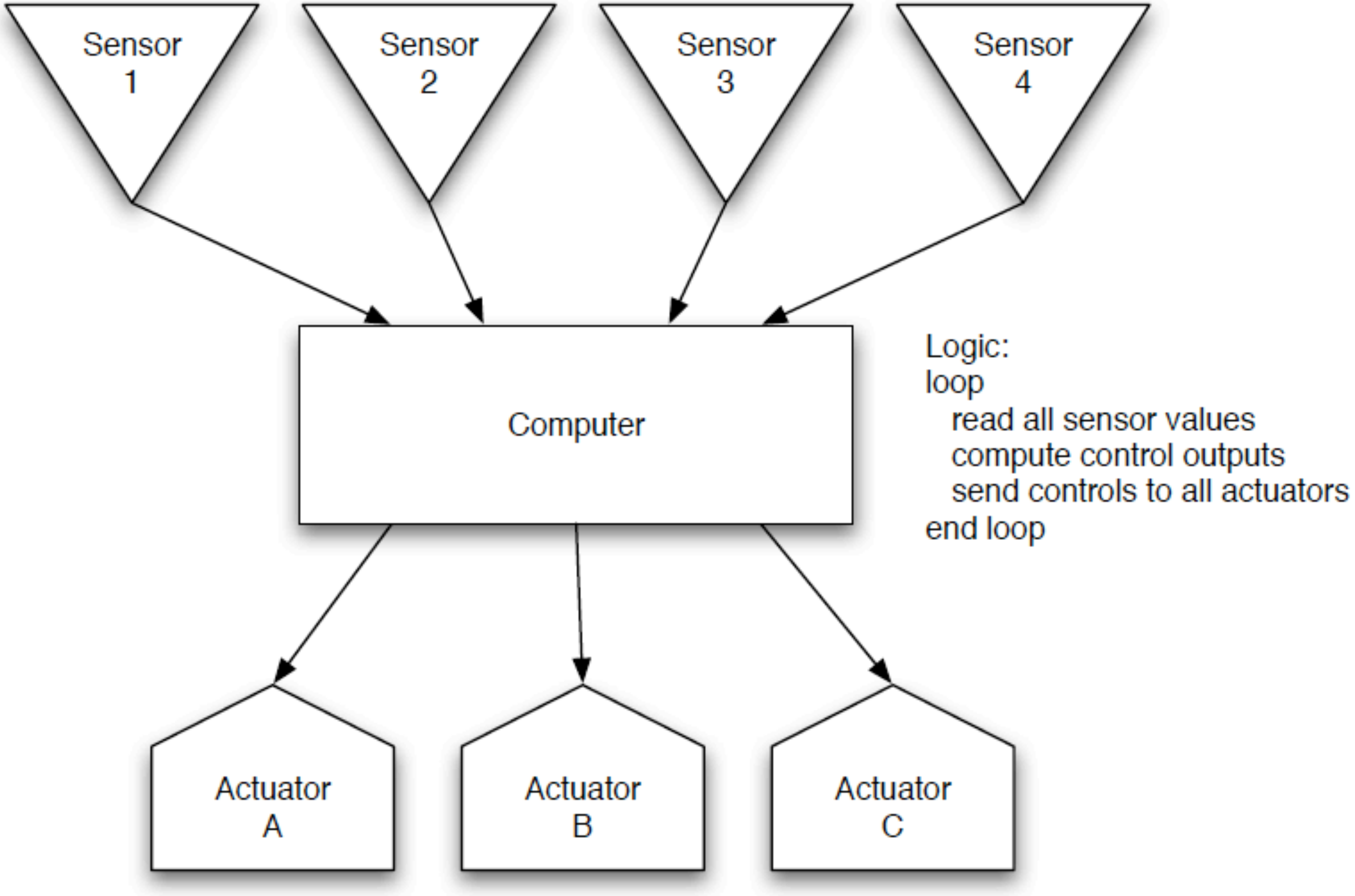


```
class CalcController : IController
{
    ICalcModel model;
    ICalcView view;

    public CalcController( ICalcModel model, ICal
    {
        this.model = model;
        this.view = view;
        this.view.AddListener(this); // Pass cont
    }

    public void OnClick( int number )
    {
        view.Total = model.SetInput(number).ToString();
    }

    public void OnAdd()
    {
        model.ChangeToAddState();
    }
}
```

Controller

Source: https://www.codeproject.com/Articles/25057/Simple-Example-of-MVC-Model-View-Controller-Design

Sense-Compute-Control

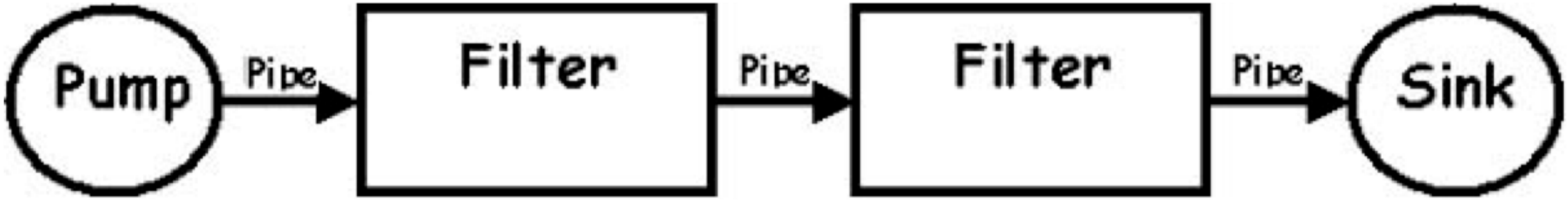


```
Logic:
loop
   read all sensor values
   compute control outputs
   send controls to all actuators
end loop
```

Sense-Compute-Control

- Typically used in structuring embedded real-time control applications (e.g. robotic control, automotive applications).
- Typically, clock-driven.
- Timely response is essential.
- Note that there is implicit feedback in such applications via the external environment.

Pipe-and-Filter



Also known as the data flow style.

Pipe-and-Filter

- Separate programs are executed, potentially **concurrently**; data is passed as a **stream** from one program to the next.
- Filters transform input data streams into output data streams.
- Pipes transmit outputs of one filter to inputs of another.
- Constraints
  - Filters are mutually independent and do not share state.
  - A standard input and output stream
- Benefits
  - Filters can be easily composed for a large variety of tasks.
- Example: the Unix shell
  - E.g. ls | grep "5555" | more

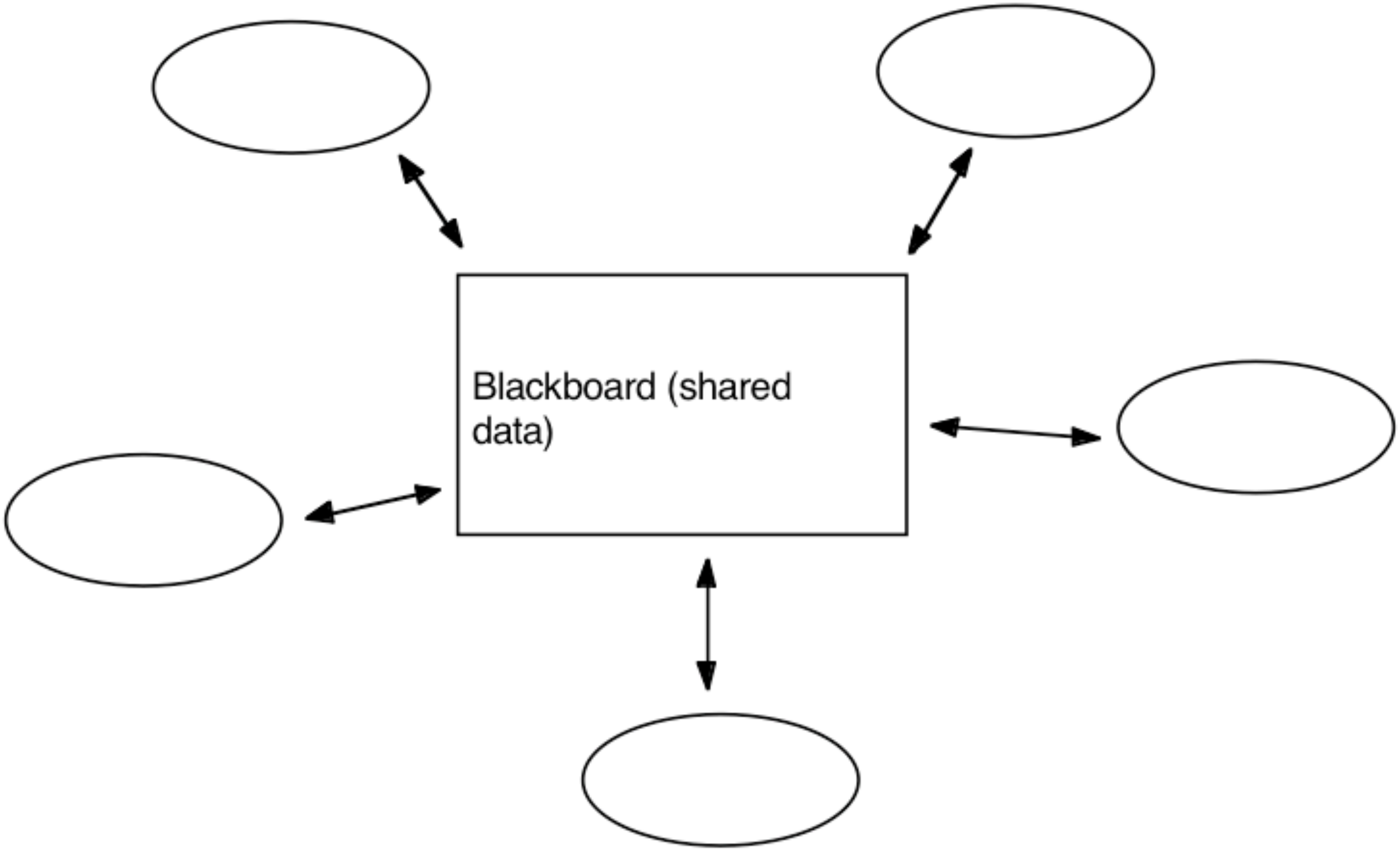
Implicit Invocation

- Instead of invoking a procedure directly, a component can announce (or broadcast) one or more events. Other components in the system can register an interest in an event by associating a procedure with the event. When the event is announced the system itself invokes all of the procedures that have been registered for the event. Thus an event announcement ``implicitly" causes the invocation of procedures in other modules.
- Variations: Publish-Subscribe, Event-Based.

Implicit Invocation

- Usually requires the external support (e.g. operating systems, middleware, programming language features) to handle generation/notification of events.
- Constraints
  - Announcers of events do not know which components will be affected by those events.
- Benefits
  - The system is relatively easy to evolve (e.g. addition of new observers).
- Example
  - User interface development

The Blackboard Style

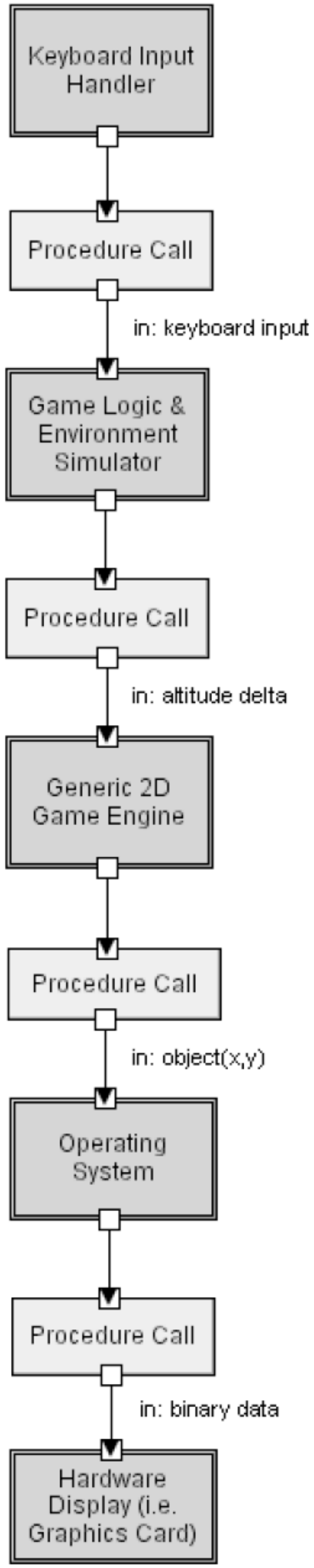


The Blackboard Style

- Two kinds of components
  - Central data structure.
  - A collection of independent components that operate on the central data.
- Constraints
  - The current state of the central data structure is the main trigger of selecting processes to execute.
- Benefits
  - Ease of adaptation, enhanced scalability
- Examples
  - AI systems
  - Compiler

Layered Styles

- An architecture is separated into ordered layers, and each layer exposes an interface to be used by above layers.
- Advantages
  - Changes in a layer affect at most the adjacent two layers.
  - Different implementations of layer are allowed as long as interface is preserved.
- Disadvantages
  - Performance
- Instances: virtual machine.



- A layer offers a set of services (“a machine with a bunch of buttons and knobs”) that may be accessed by programs residing within the layer above it.
- In a strictly virtual machines style, programs at a given level may only access the services provided by the layer immediately below it.
- Benefits: clear dependence structure.
- Typical uses: network protocol stacks, database management systems.

Reference

- Richard N. Taylor, Nenad Medvidovic, and Eric M. Dashofy. Software Architecture: Foundations, Theory, and Practice. John Wiley and Sons. ISBN-10: 0470167742; ISBN-13: 978-0470167748. 2010.