ICS 52: Introduction to Software Engineering

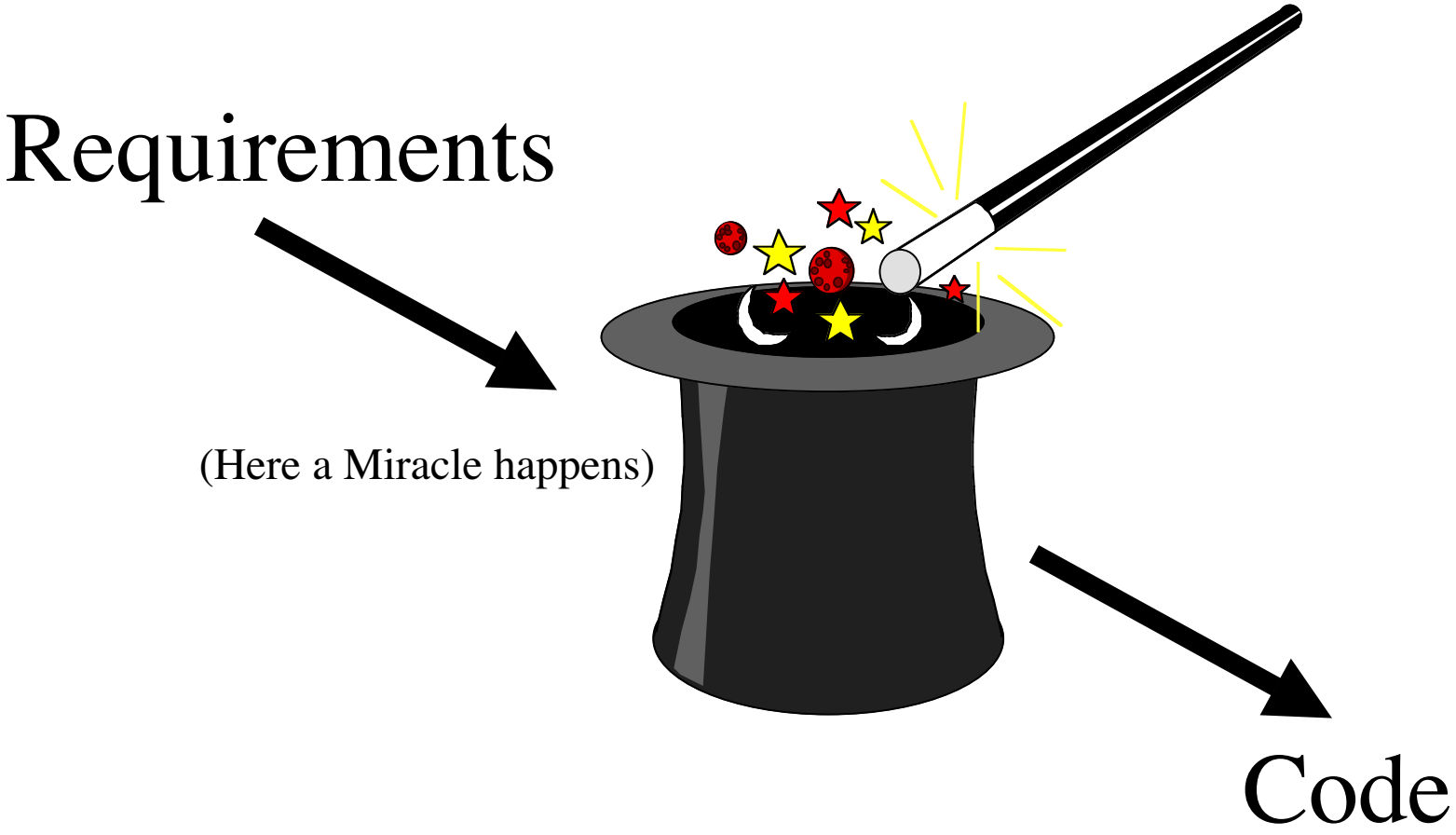
Fall Quarter 2001

Professor Richard N. Taylor

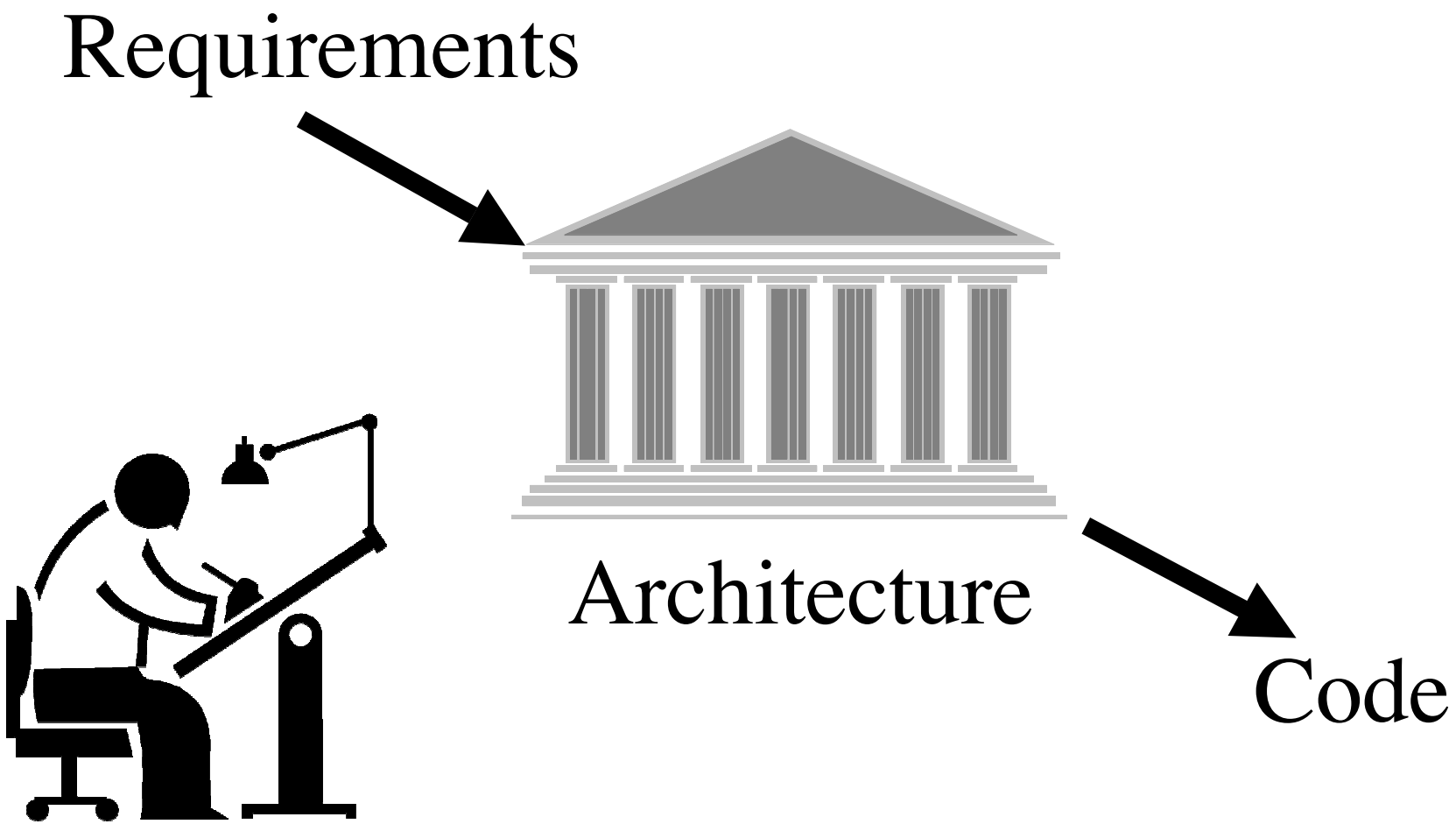
Lecture Notes: Software Architecture

http://www.ics.uci.edu/~taylor/ics52_fq01/syllabus.html

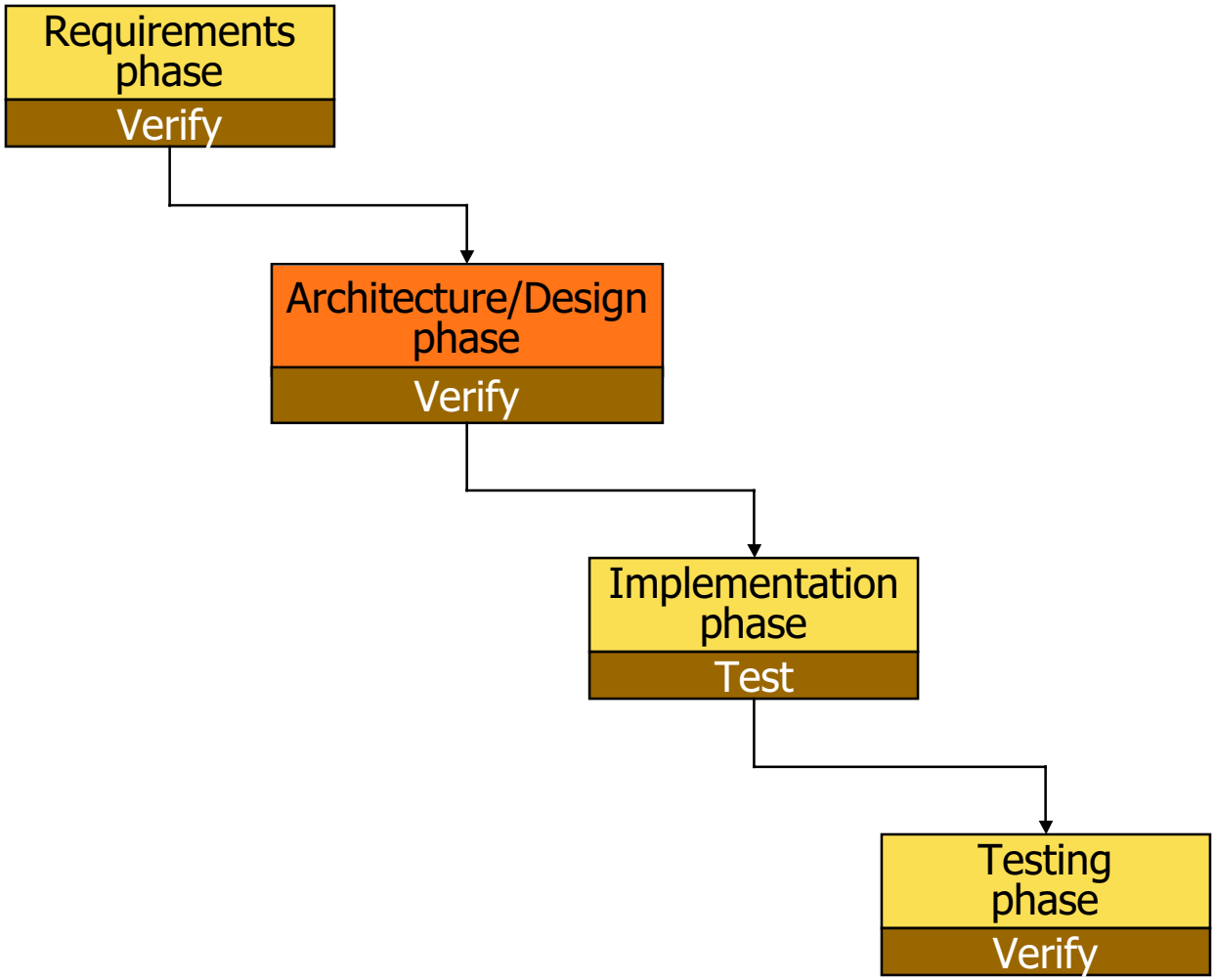
"Magician Coder" View of Development



A Professional View



ICS 52 Life Cycle



Architecture of Buildings

- Types (Domains): office building, shepherd's shelter, detached home, apartment building, aircraft hanger
  - Domain-specific software architectures
- Styles: colonial, Victorian, Greek revival, Mediterranean, Bauhaus
  - Software system organization paradigms
- Building codes: electrical, structural, ...
  - Constraints on how the building can be legally built
- Blueprints and drawings
  - Formal specification of supporting details

Architectural Design

Buildings

Elements
- Floors
- Walls
- Rooms

Types
- Office building
- Villa
- Aircraft hanger

Styles
- Colonial
- Victorian
- Southwestern

Rules and regulations
- Electrical
- Structural

Software

Elements
- Components
- Interfaces
- Connections

Types
- Office automation
- Game
- Space shuttle control

Styles
- Pipe and filter
- Layered
- Implicit invocation

Rules and regulations
- Use of interfaces
- Methods of change

Design

- Architectural design
  - High-level partitioning of a software system into separate modules *(components)*
  - Focus on the interactions among parts *(connections)*
  - Focus on structural properties *(architecture)*
    - » "How does it all fit together?"
- Module design
  - Detailed design of a component
  - Focus on the internals of a component
  - Focus on computational properties
    - » "How does it work?"

Comparison to Programming (of Modules)

Architecture	Modules
interactions among parts	implementations of parts
structural properties	computational properties
system-level performance	algorithmic performance
outside module boundary	inside module boundary

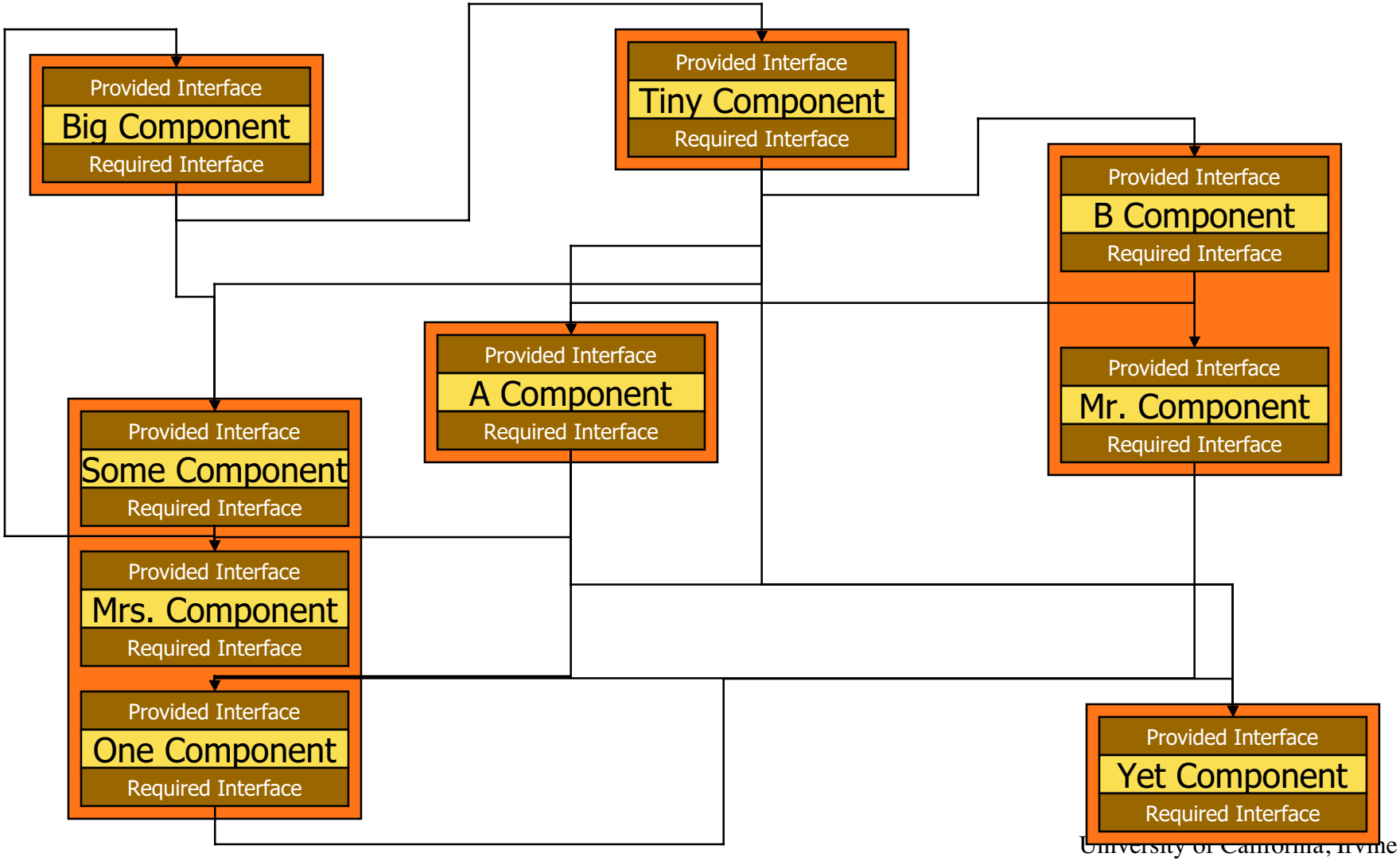
Software Architecture Topics

- Essential elements
- Repertoire of architectural styles
- Choosing and/or modifying a style
- Designing within a style
- Architecture in support of application families

Software Architecture: Essentials

- Components
  - What are the elements?
  - What aspects of the requirements do they correspond to? Where did they come from?
  - Examples: filters, databases, objects, ADTs
- Connections
  - How do components communicate?
  - Examples: procedure calls, messages, pipes, event broadcast
- Topology
  - How are the components and connections organized topologically?
- Constraints (including constraints on change)

We Can Do Anything…



…But Style Has Proven to Help

- Architectural styles restrict the way in which components can be connected
  - Prescribe patterns of interaction
  - Promote fundamental principles
    - » Rigor, separation of concerns, anticipation of change, generality, incrementality
    - » Low coupling
    - » High cohesion
- Architectural styles are based on success stories
  - Almost all compilers are build as “pipe-and-filter”
  - Almost all network protocols are build as “layers”

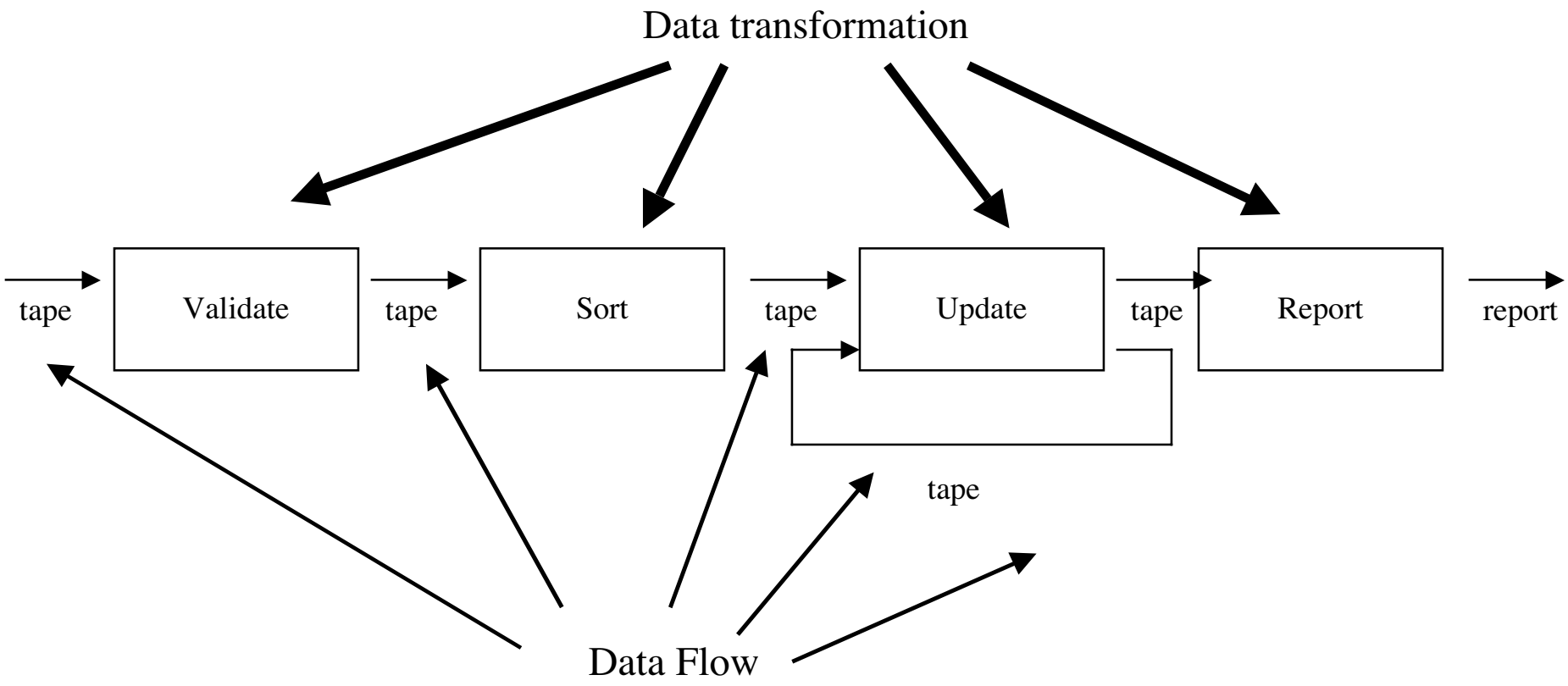
Common Architectural Idioms

- Data flow systems
  - (1) Batch sequential & (2) pipe-and-filter
- (3) Data and/or service-centric systems: the Client-Server style
- The (pre-1994) WWW
  - Database servers
- (4) Hierarchical systems
  - Main program and subroutines;
- (5) Data abstraction/OO systems
- (6) Peer-to-Peer
- (7) Layered systems
- (8) Interpreters
- (9) Implicit invocation (event-based)
- (10) Three-level architectures

Note: not all of these are of equal value, current use, or intellectual depth

Many of the following slides are from David Garlan, Mary Shaw, and Jose Galmes: Experience with a Course on Architectures for Software Systems, Part II: Educational Materials

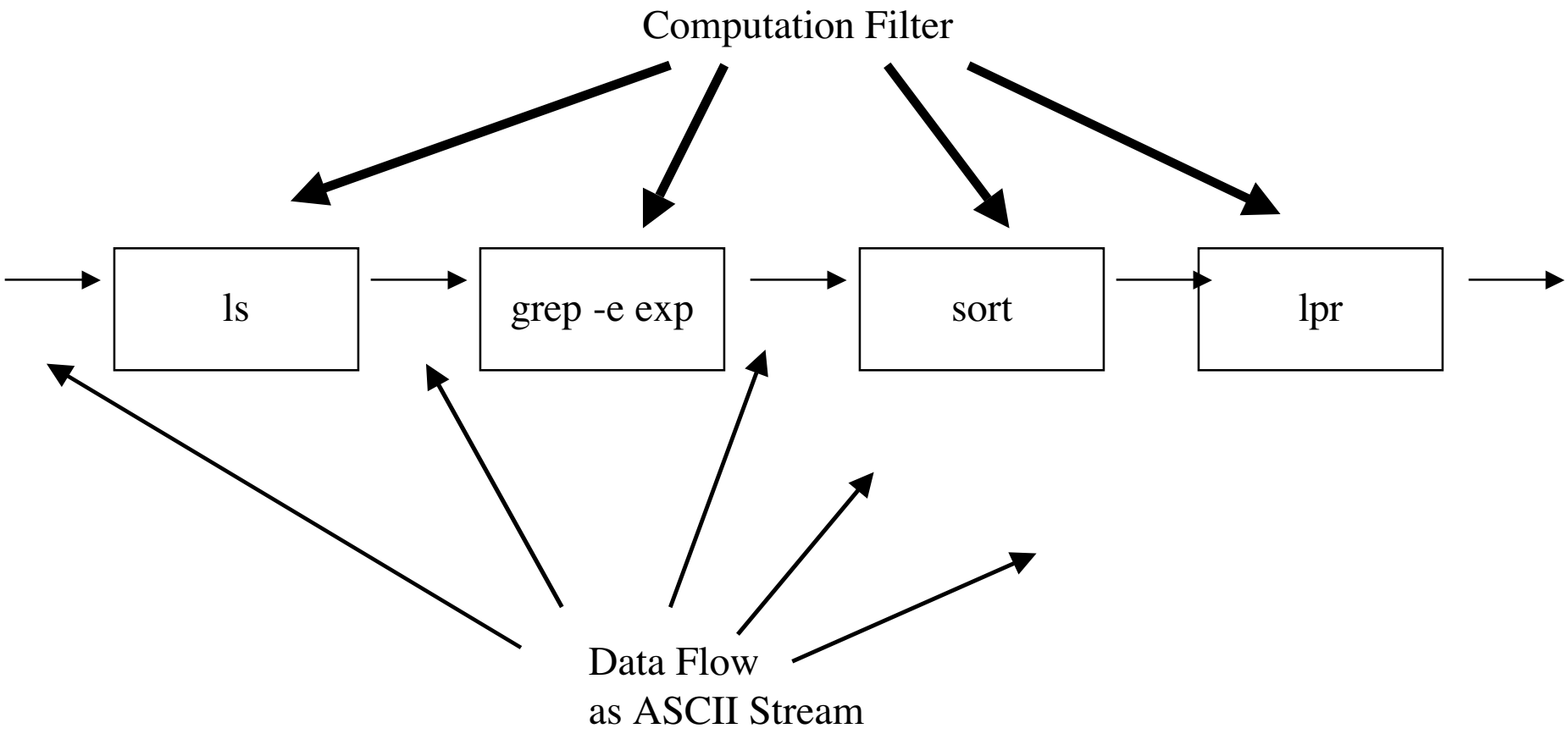
Style 1: Batch Sequential



Batch Sequential

- Components
  - components are independent programs
  - each component runs to completion before next step starts
- Connections
  - Data transmitted as a whole between components
- Topology
  - Connectors define data flow graph
- Typical application: classical data processing

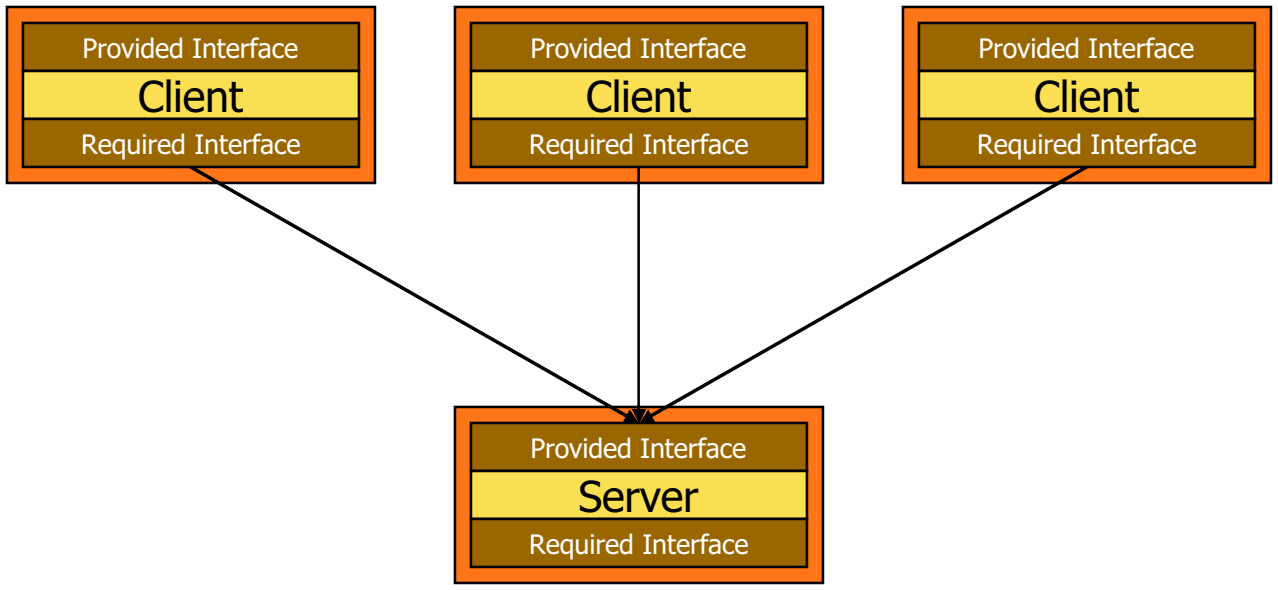
Style 2: Pipe and filter



Pipe and filter

- Components
  - Like batch sequential, but components (filters) incrementally transform some amount of the data at their inputs to data at outputs
  - Little local context used in processing input stream
  - No state preserved between instantiations
- Connections
  - Pipes move data from a filter output to a filter input
  - Data is a stream of ASCII characters
- Topology
  - Connectors define data flow graph
- Pipes and filters run (non-deterministically) until no more computation possible
- Typical applications: many Unix applications

Style 3: Client-Server



Connections are remote procedure calls or remote method invocations

Client-Server Systems

- Components
  - 2 distinguished kinds
    - » Clients: towards the user; little persistent state; active (request services)
    - » Servers: “in the back office”; maintains persistent state and offers services; passive
- Connectors
  - Remote procedure calls or network protocols
- Topology
  - Clients surround the server

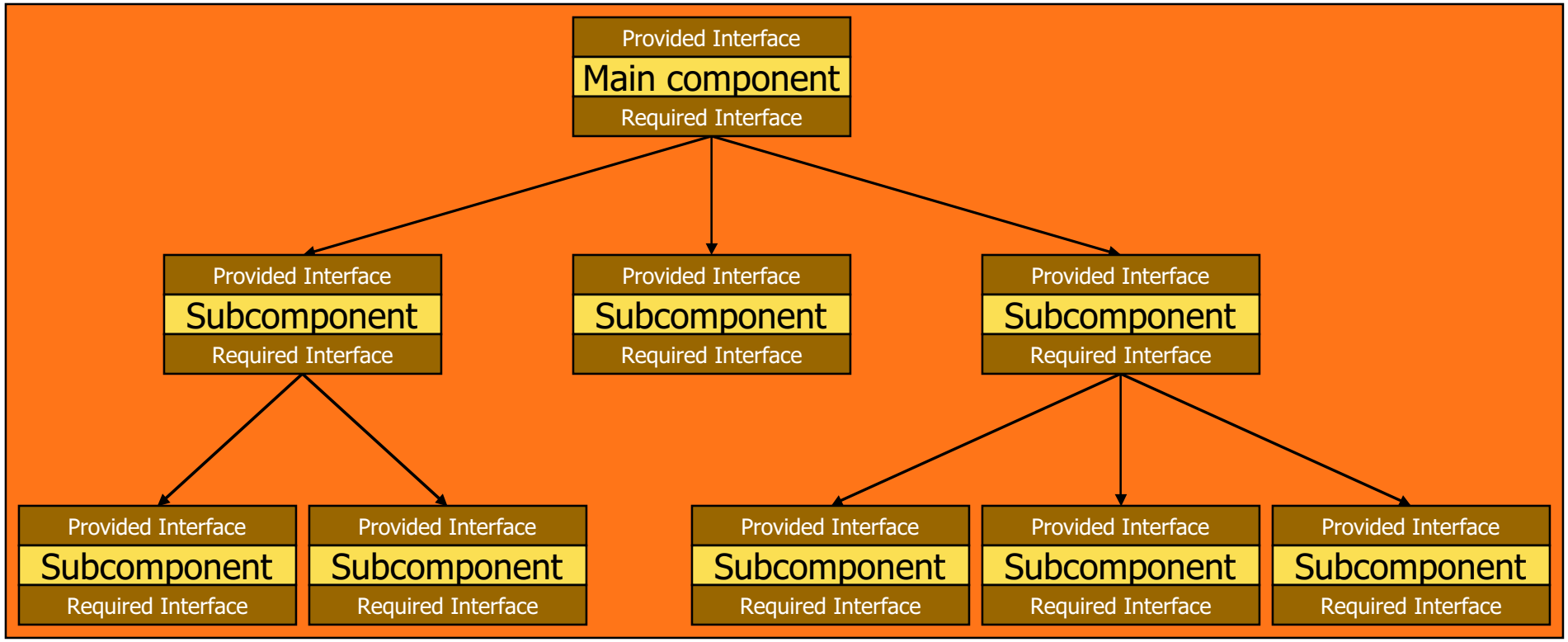
The pre-1994 WWW as a Client-Server Architecture

- Browsers are clients
- Web servers maintain state
- Connections by HTTP/1.0 protocol

Database Centered Systems

- Components
  - Central data repository
  - Schema (how the data is organized) designed for application
  - Independent operators
    - » Operations on database implemented independently, one per transaction type
    - » interact with database by queries and updates
- Connections
  - Transaction stream drives operation
  - Operations selected on basis of transaction type
  - May be direct access to data; may be encapsulated

Style 4: Hierarchy: Main Program and Subroutines



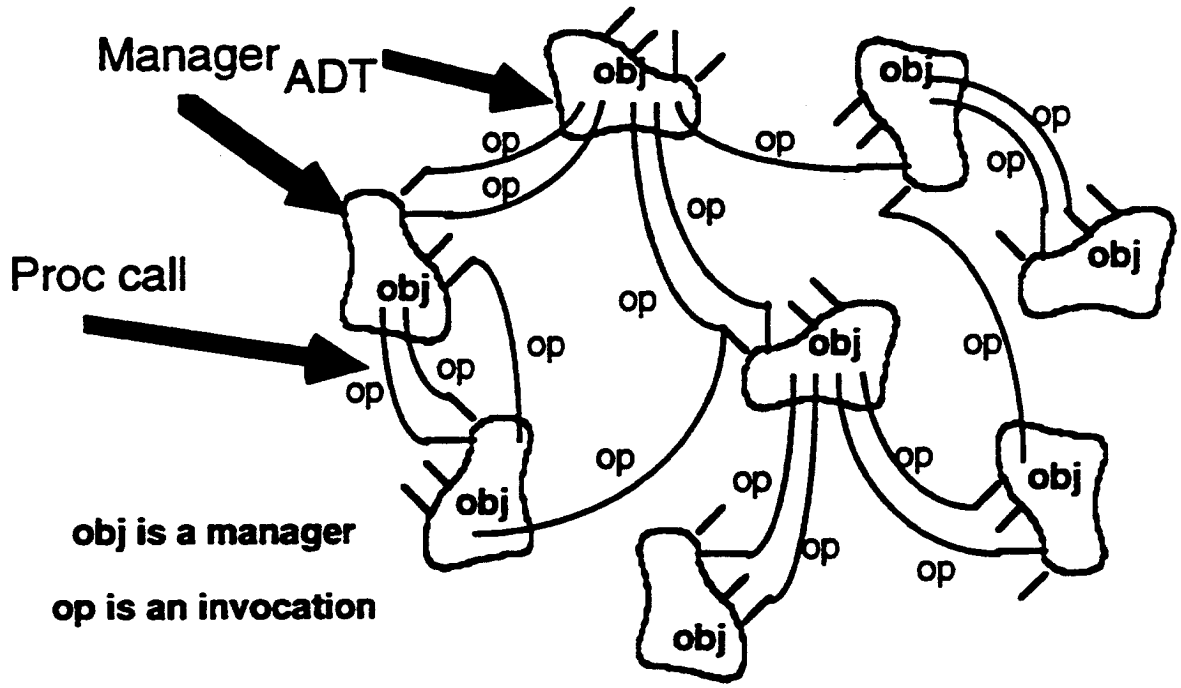
Connections are function or method calls

Main Program and Subroutines

- Components
  - Computational elements as provided by programming language
  - Typically single thread
- Connections
  - Call/return as provided by programming language
  - Shared memory
- Topology
  - Hierarchical decomposition as provided by language
  - Interaction topologies can vary arbitrarily

Style 5: Data Abstraction/OO Systems

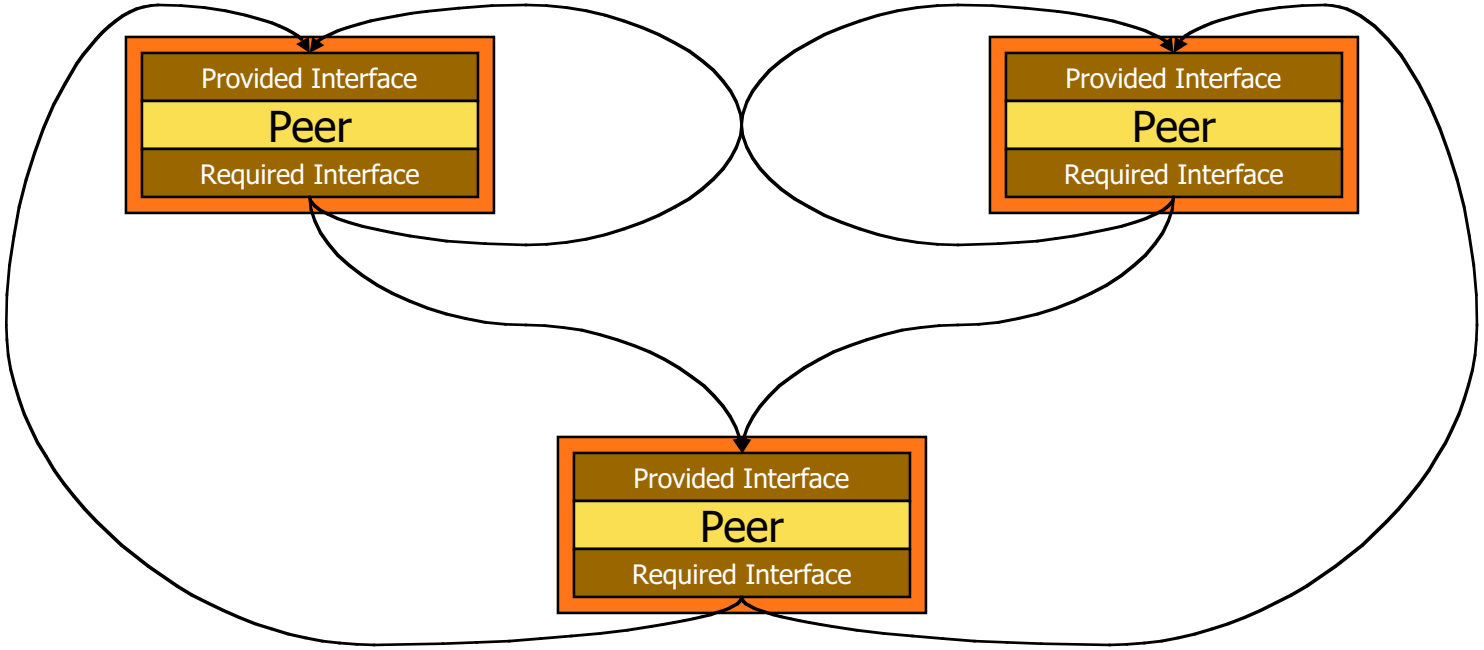
Data Abstraction or Object-Oriented



Data Abstraction/OO Systems

- Components
  - Components maintain encapsulated state, with public interface
  - Typically single threaded, though not logical
- Connections
  - Procedure calls ("method invocations") between components
  - Various degrees of polymorphism and dynamic binding
  - Shared memory a common assumption
- Topology
  - Components may share data and interface functions through inheritance hierarchies
  - Interaction topologies can vary arbitrarily

Style 6: Peer-to-Peer

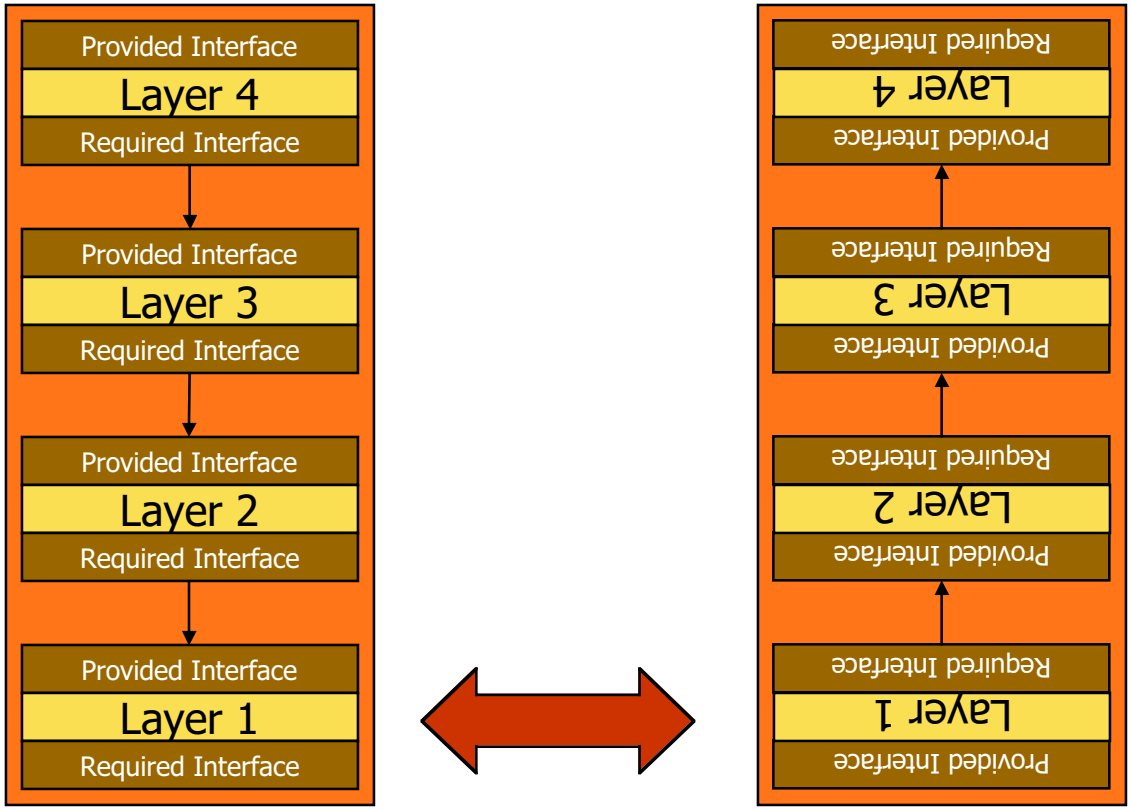


Connections are remote procedure calls or remote method invocations

Peer-to-Peer Architectures

- Components
  - Autonomous
  - Act as both clients and servers
- Connectors
  - Asynchronous and synchronous message passing ("remote procedure calls")
  - By protocols atop TCP/IP
  - No shared memory (except as an optimization when the configuration allows)
- Topology
  - Interaction topologies can vary arbitrarily and dynamically

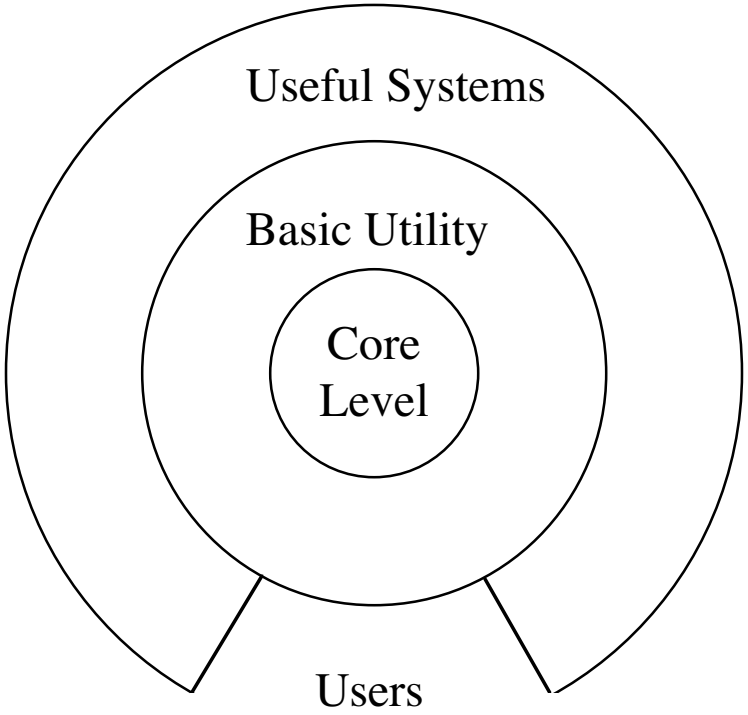
Style 7: Layered Systems, Take 1



Connections are function or method calls + "something in between"

Layered Systems, Take 2

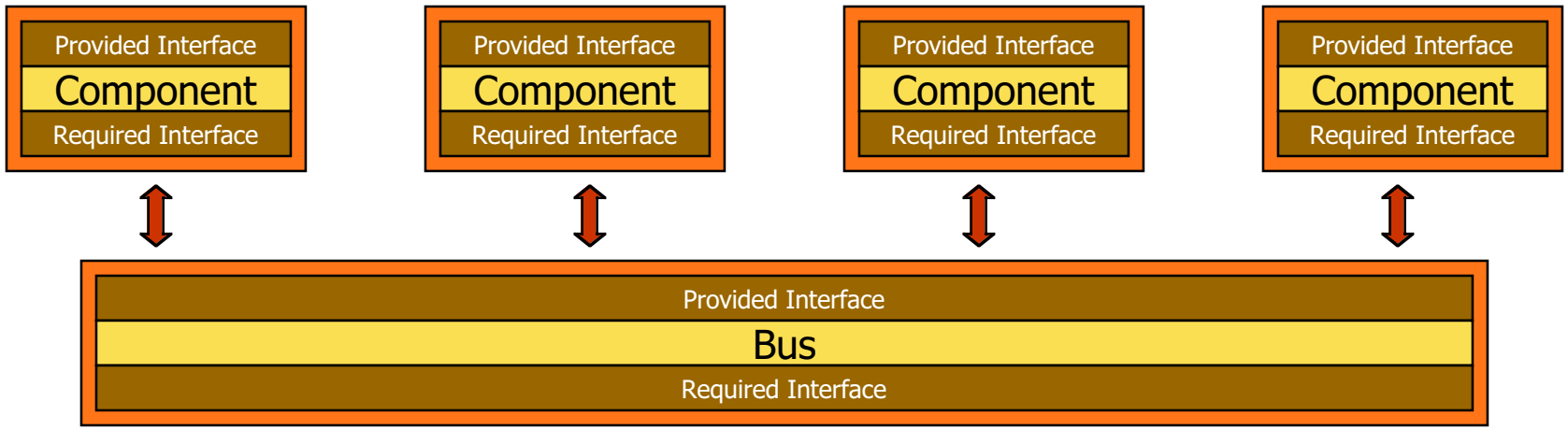
Inter-level interfaces
usually procedure calls



Layered Systems

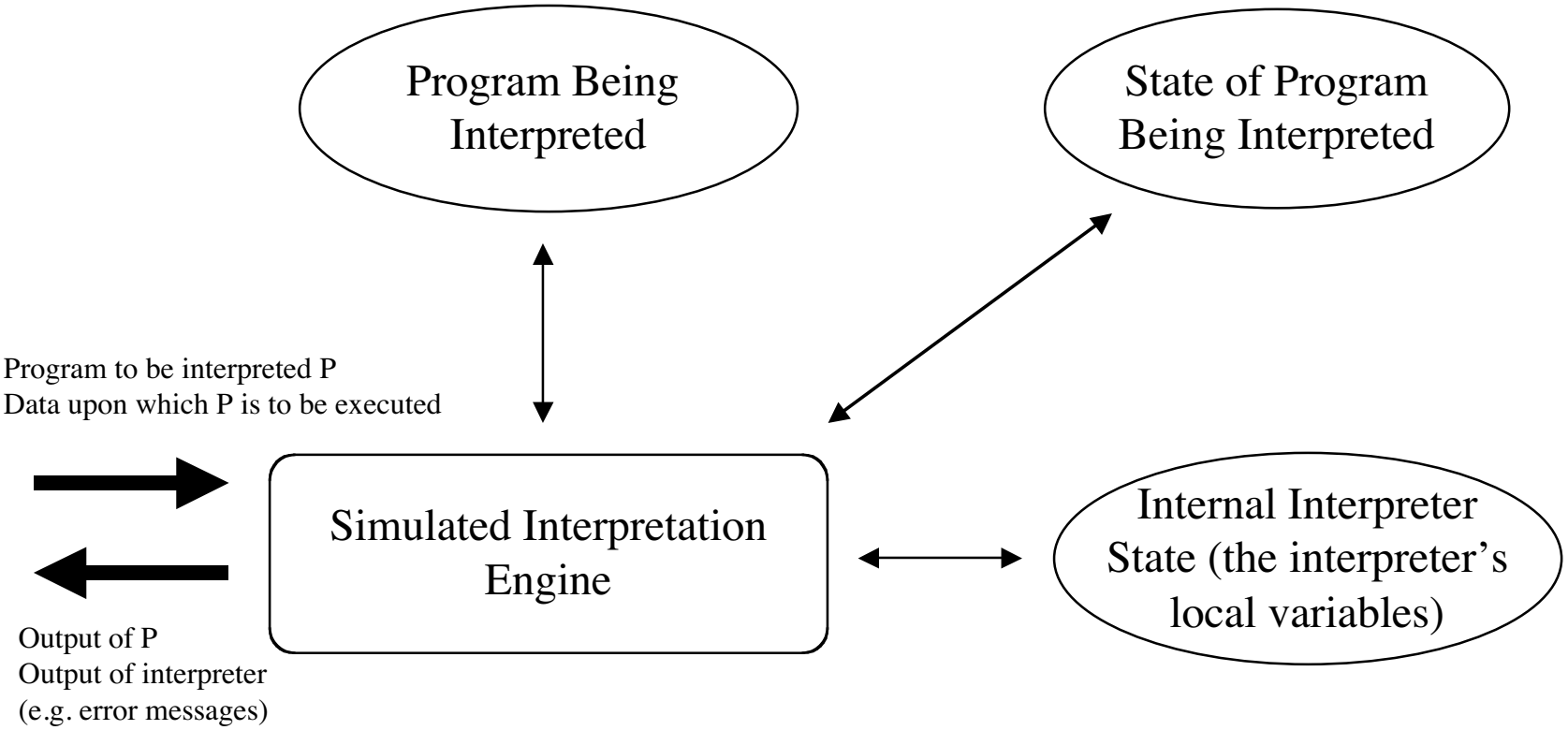
- Components
  - Each layer provides a set of services
- Connections
  - Typically procedure calls
  - A layer typically hides the interfaces of all layers below, but others use "translucent" layers
- Topology
  - Nested
- Typical applications: support for portability, systems with many variations ("core features" v. extended capabilities)

Style 8: Implicit Invocation



Connections are events on the software bus

Style 9: Interpreters



Interpreters

- Components
  - Execution engine simulated in software (with its internal data)
  - Program being interpreted
  - State of program being interpreted
- Connections
  - program being interpreted determines sequence of actions by interpreter
  - shared memory
- Topology
- Typical applications: end-user customization; dynamically changing set of capabilities (e.g. HotJava)

Style 10: "Three Level Architectures"

- User interface
- Application Logic
- Database (server)

Where do Architectures and Components Come From?

- Architectures: typically driven by kind of application
  - Often possible to solve one problem many different ways
- Components: many design strategies
  - ICS 52 component strategy:
    - » Component design by information hiding
    - » Designing systems for ease of extension and contraction
    - » An OO design approach
  - Rationale: design systems that have a long, useful lifetime

Choosing the Right Style

- Ask questions on whether a certain style makes sense
  - The Internet as a blackboard
    - » Does that scale?
  - Stock exchange as a layers
    - » How to deal with the continuous change?
  - Math as hierarchy
    - » How to properly call different modules for different functions?
- Draw a picture of the major entities
- Look for the natural paradigm
- Look for what “feels right”