ICS 52: Introduction to Software Engineering

Fall Quarter 2004

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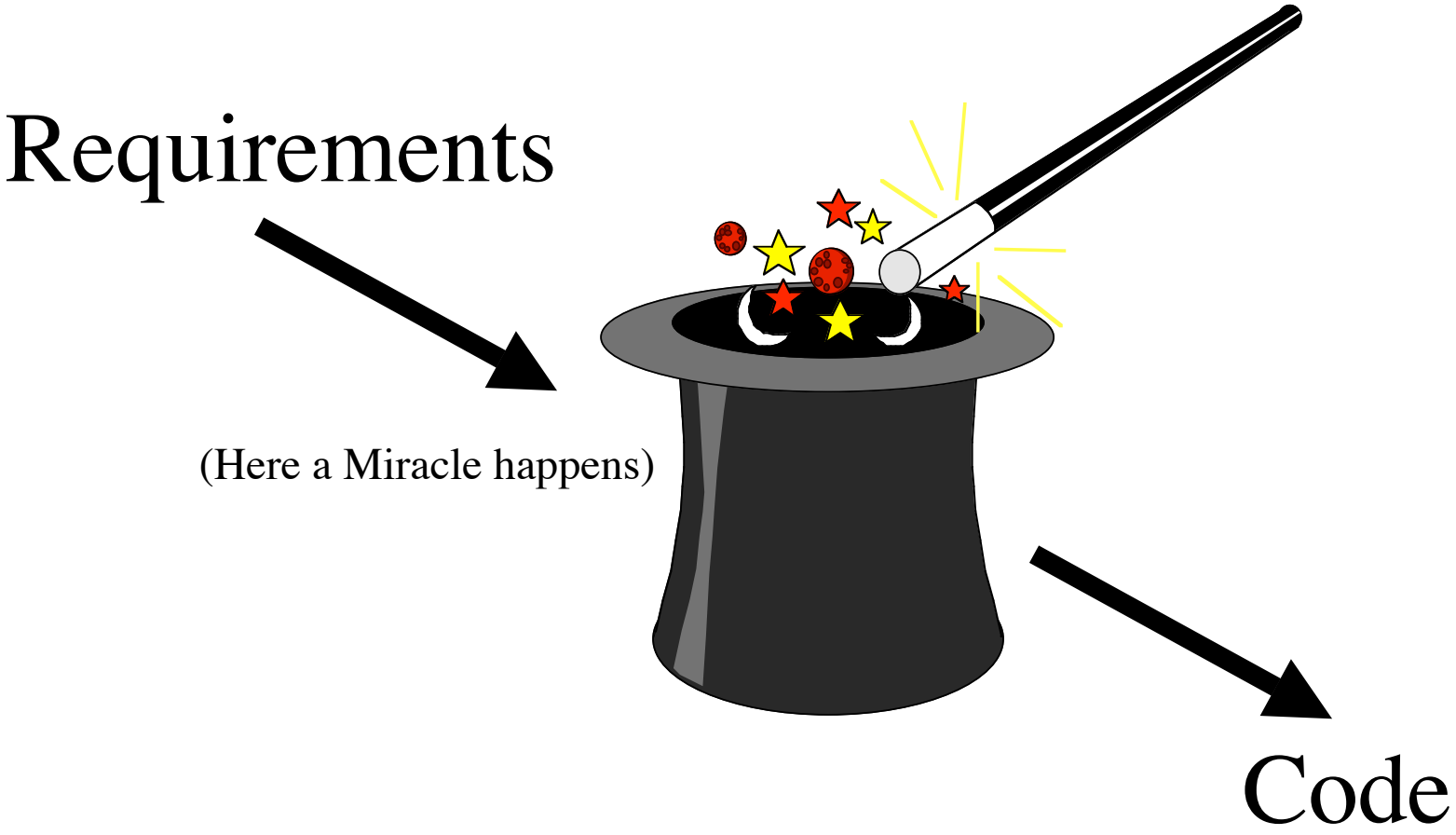
Lecture Notes

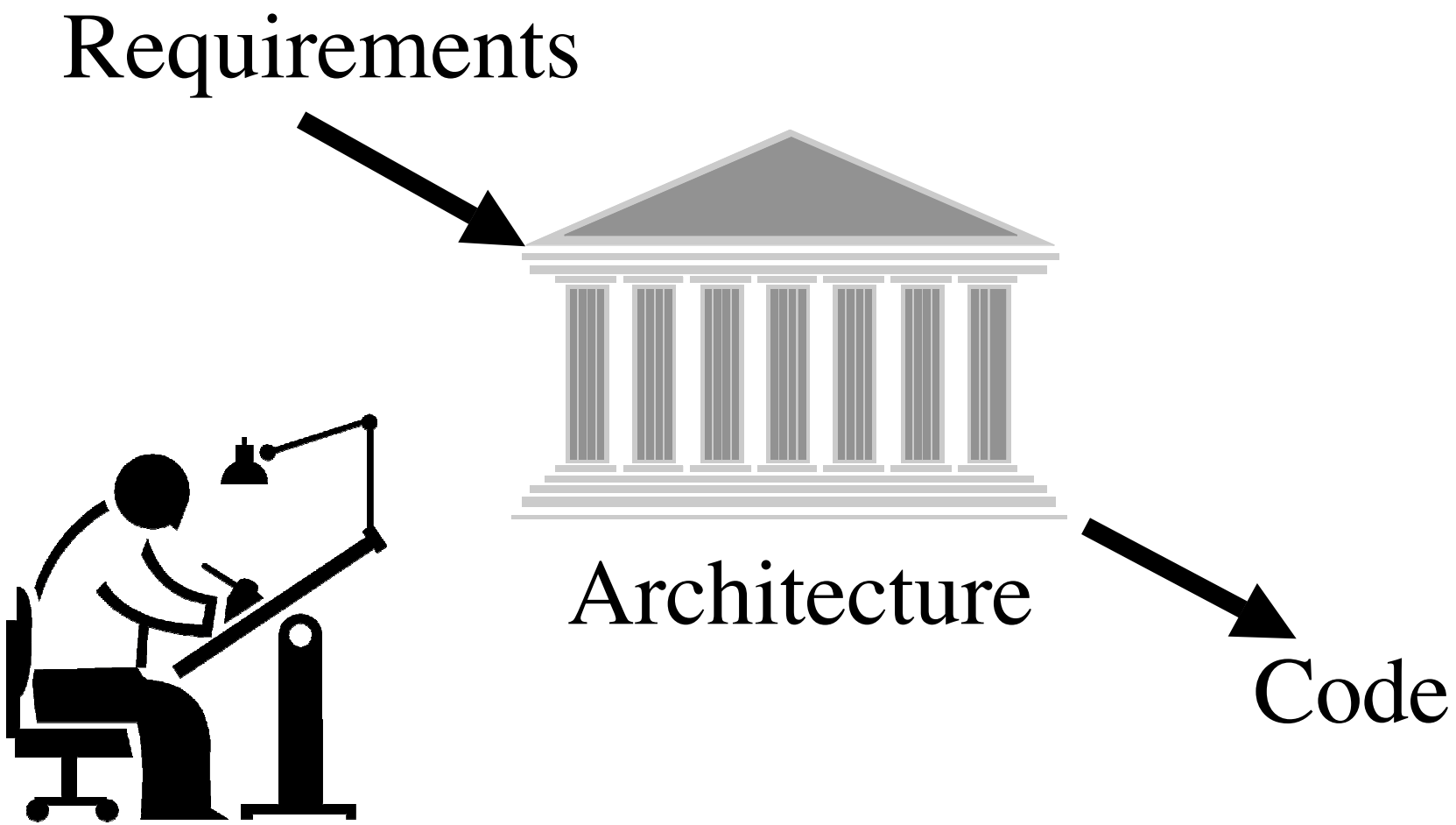
Week 3: Architectures

http://www.ics.uci.edu/~taylor/ICS_52_FQ04/syllabus.html

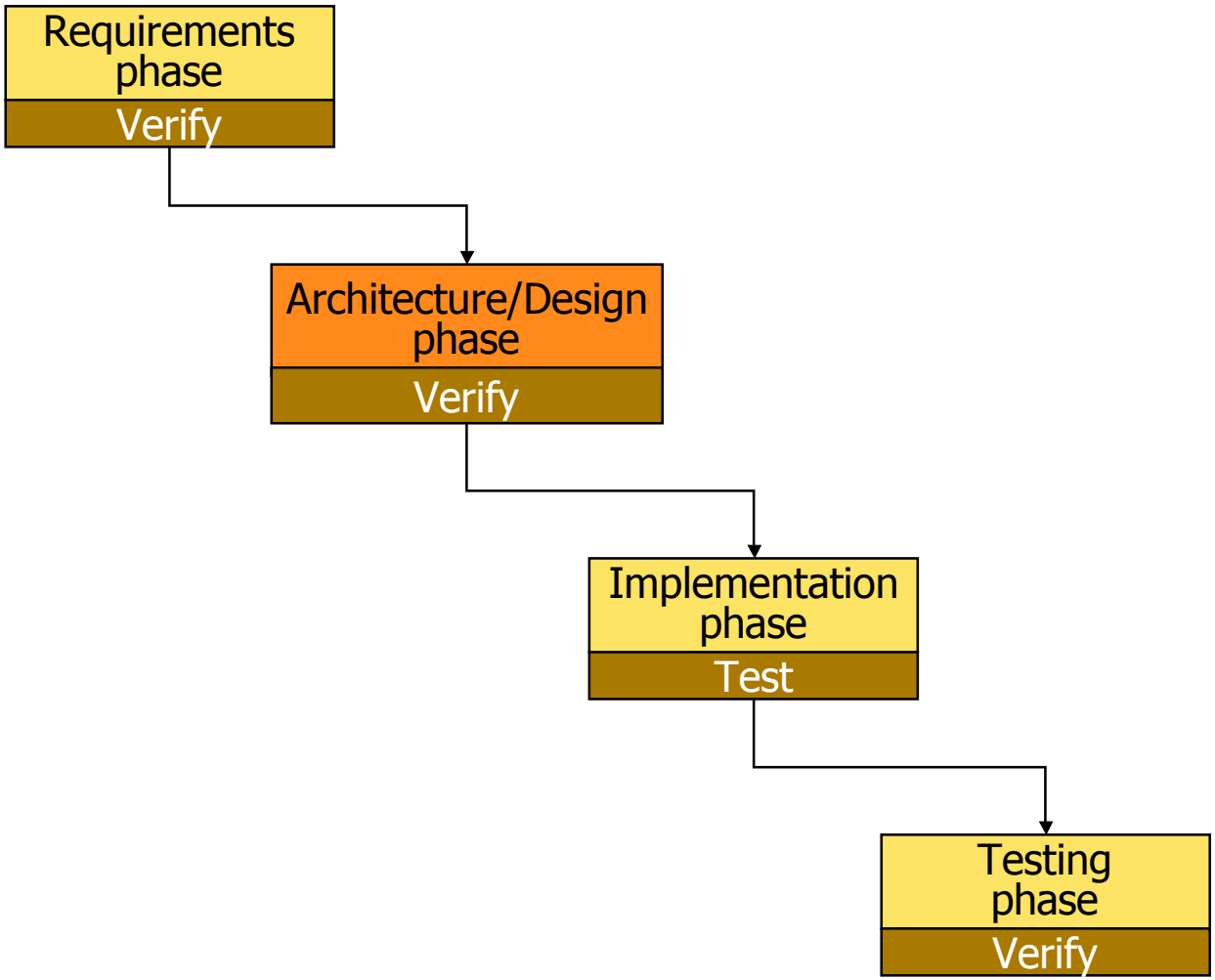
"Magician Coder" View of Development



A Professional View



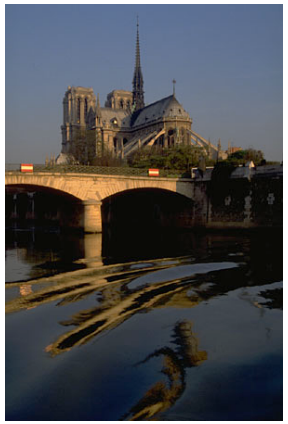
ICS 52 Life Cycle



ICS 52 Software Life Cycle

- Requirements specification
  - Interview customer (TA)
  - Focus on “what”, not “how”
- Architectural and module design
  - Based on provided “official” requirements specification
  - Based on design recovery
  - Focus on system structure and interfaces
- Implementation
  - Based on provided “official” design
  - Based on the existing code base
  - Focus on good implementation techniques
- Testing
  - Based on provided “official” implementation
  - Focus on fault scenarios and discovery

Bridges…



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 (software system) 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

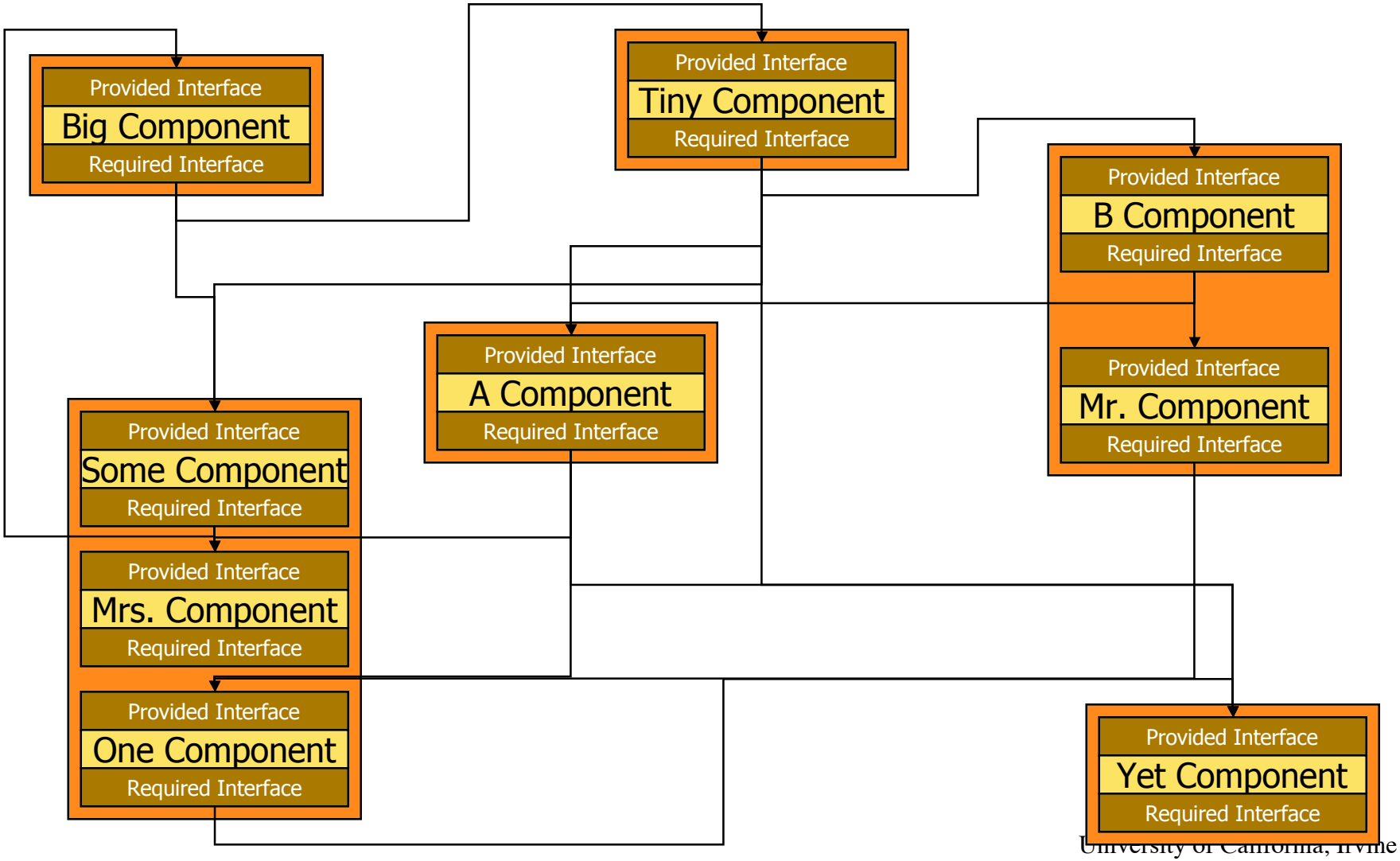
Software Architecture Topics

- 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
  - For many years most compilers were built as “pipe-and-filter”
  - Almost all network protocols are built as “layers”
  - Many business systems are built as “three-tier” systems

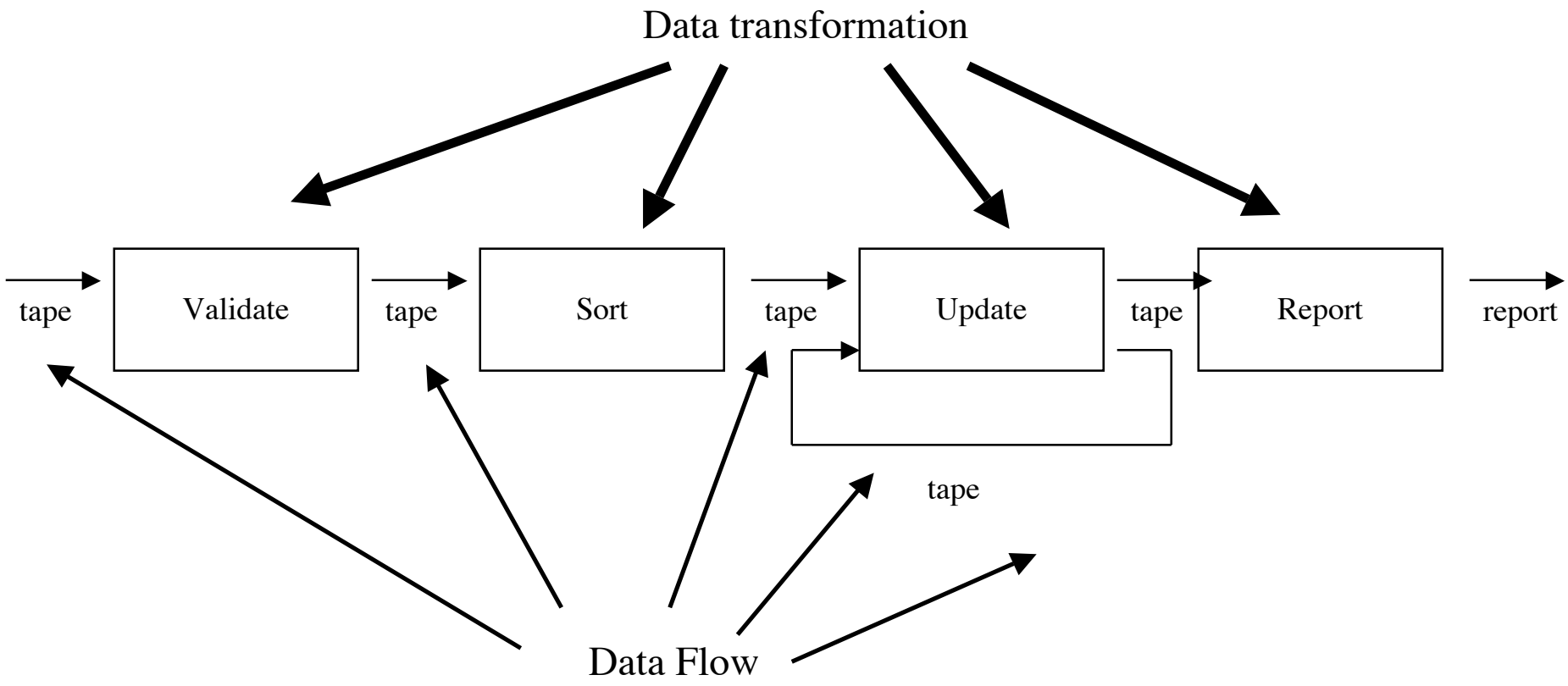
Common Simple Architectural Idioms

- 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

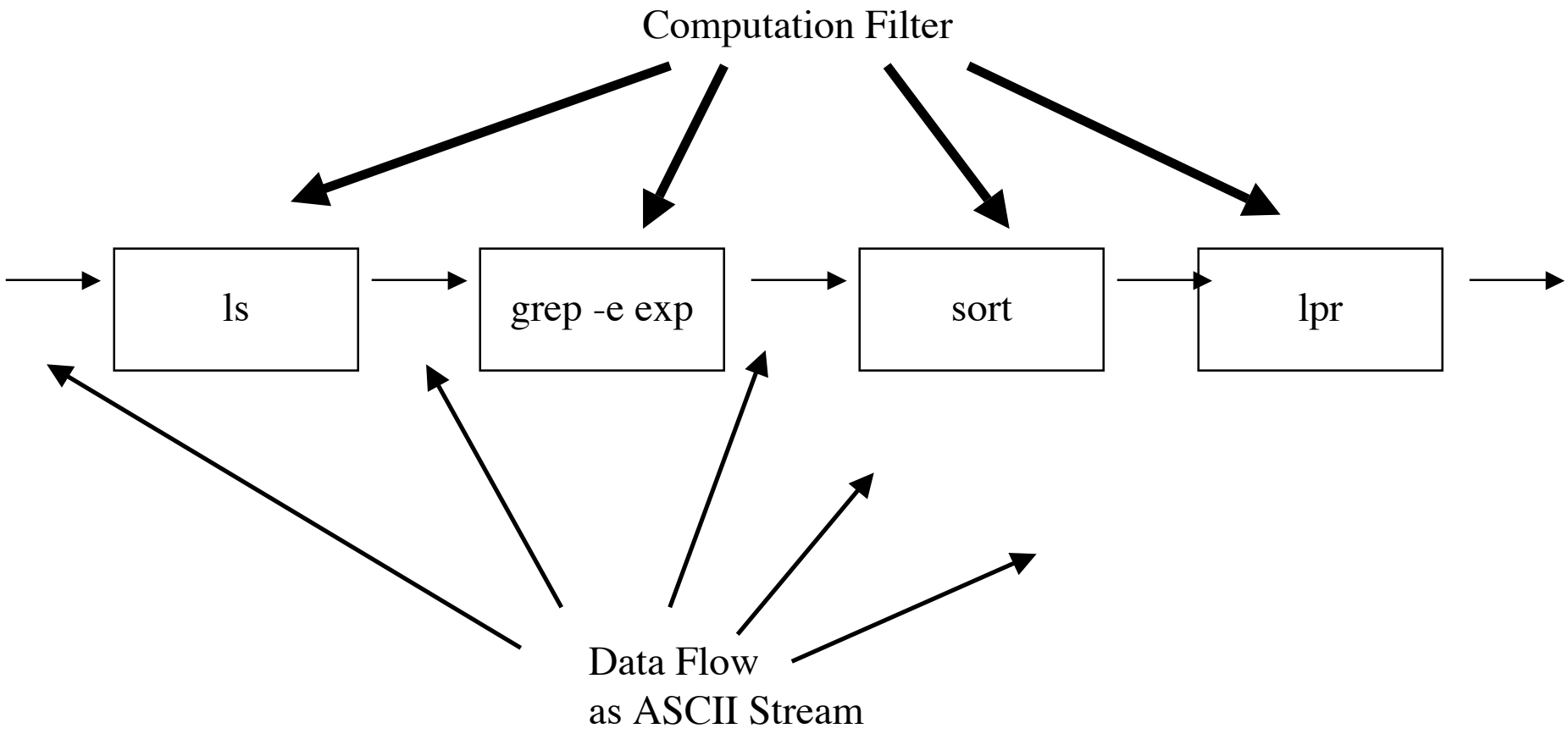
Style 1: Batch Sequential



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

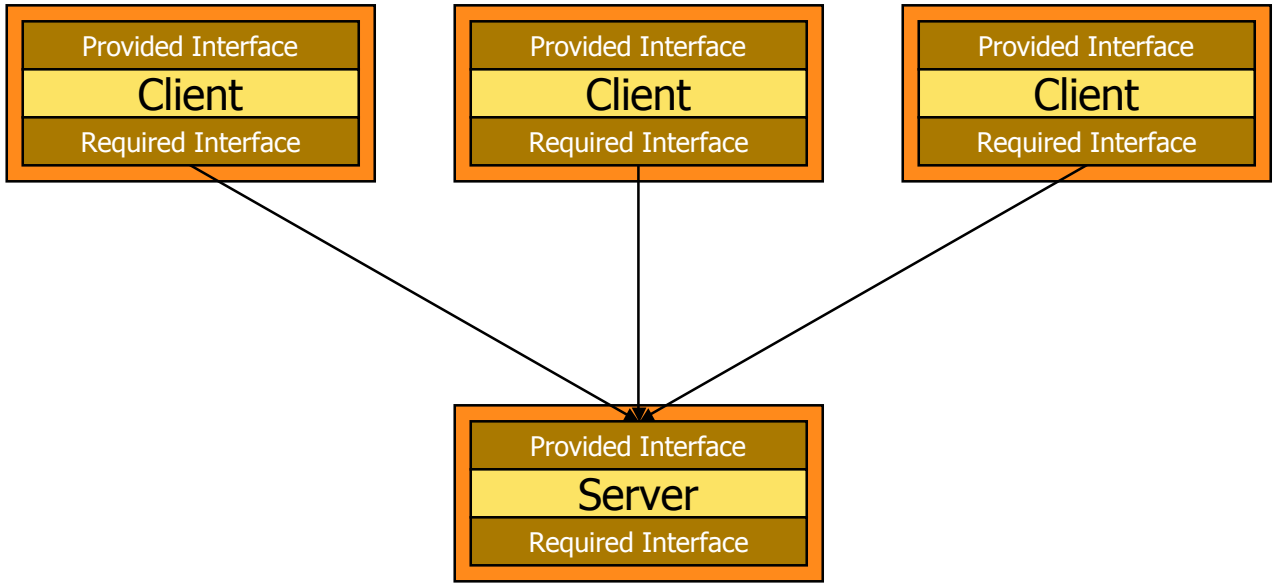
Style 2: Pipe and filter



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

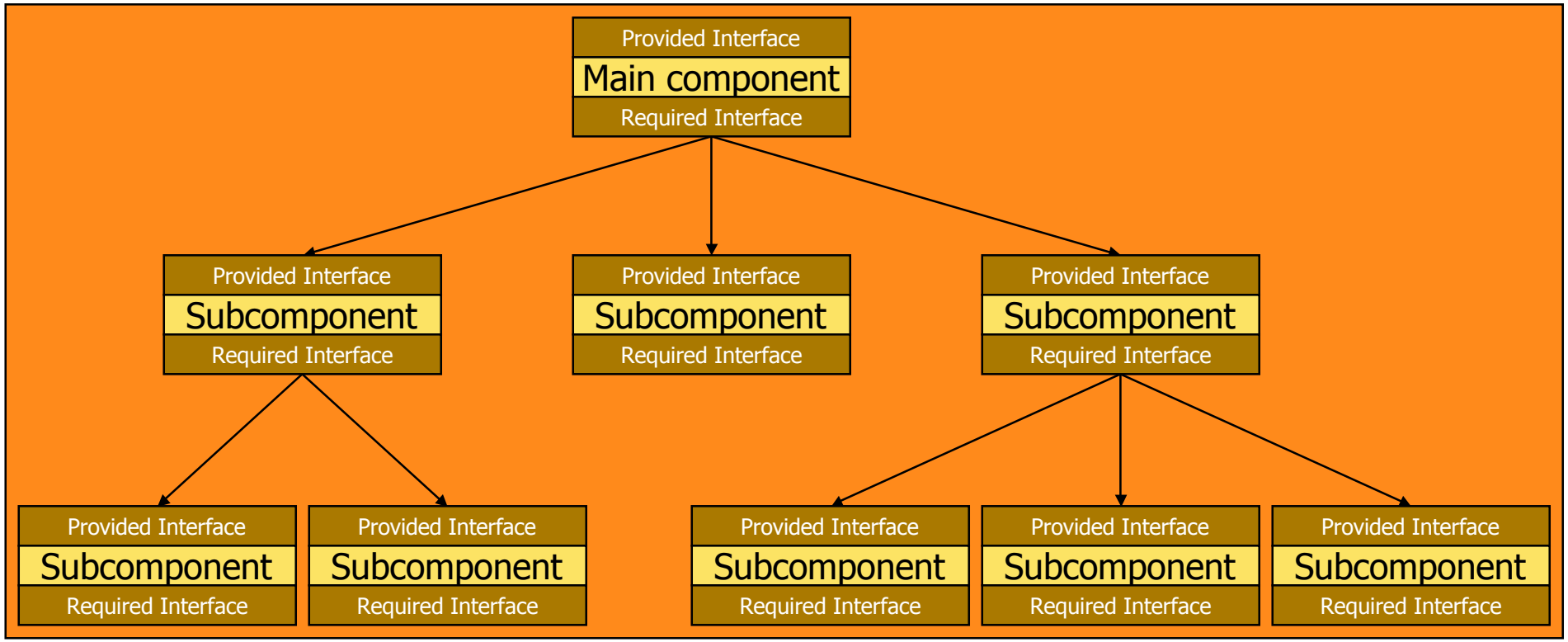
Example: The pre-1994 WWW Architecture

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

Example: 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



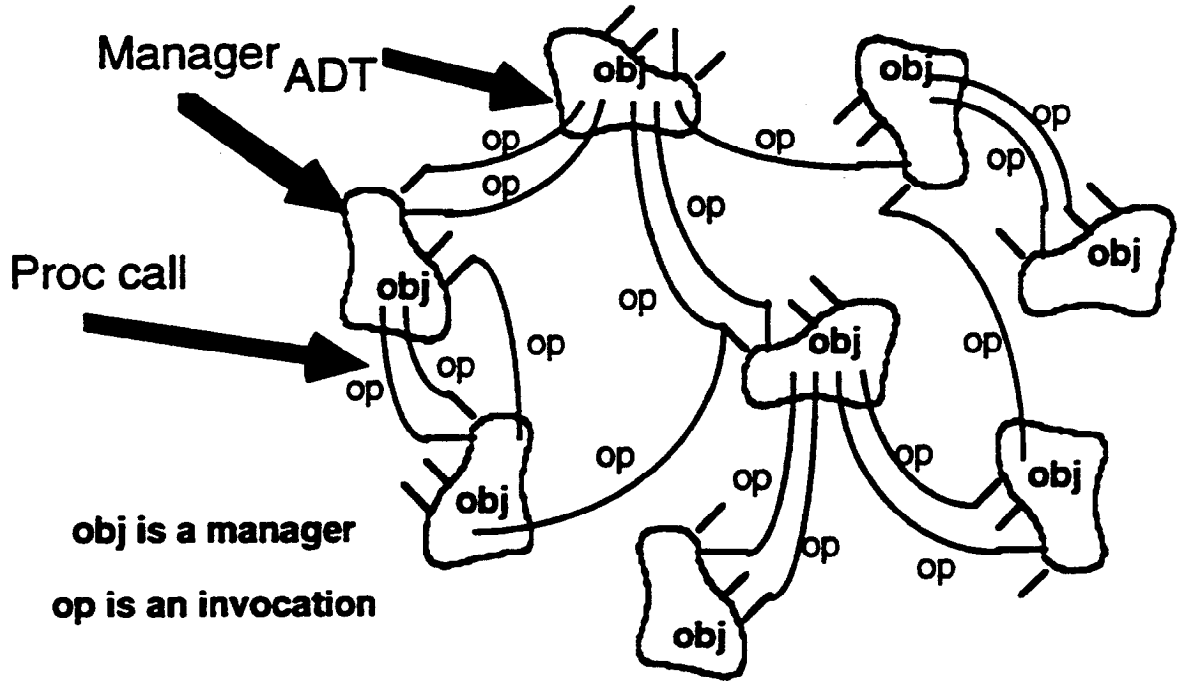
Connections are function or method calls

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

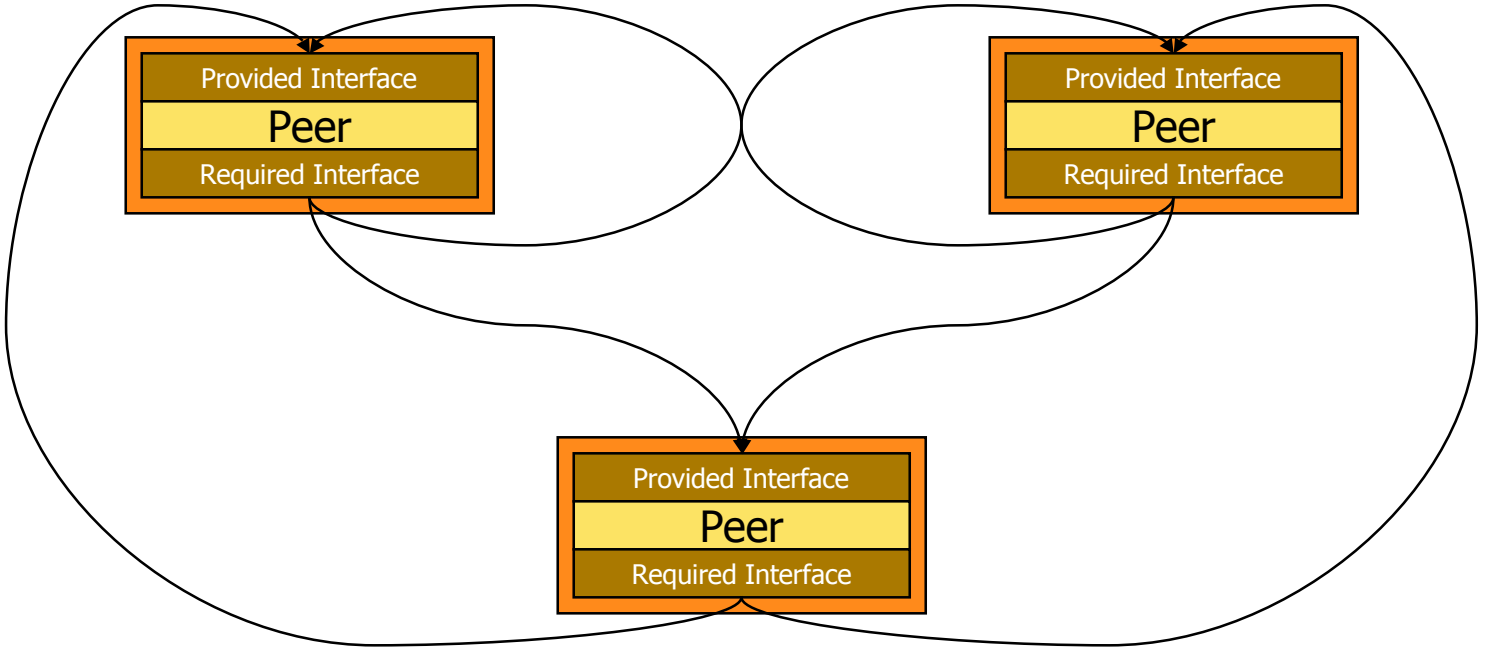
Data Abstraction or Object-Oriented



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



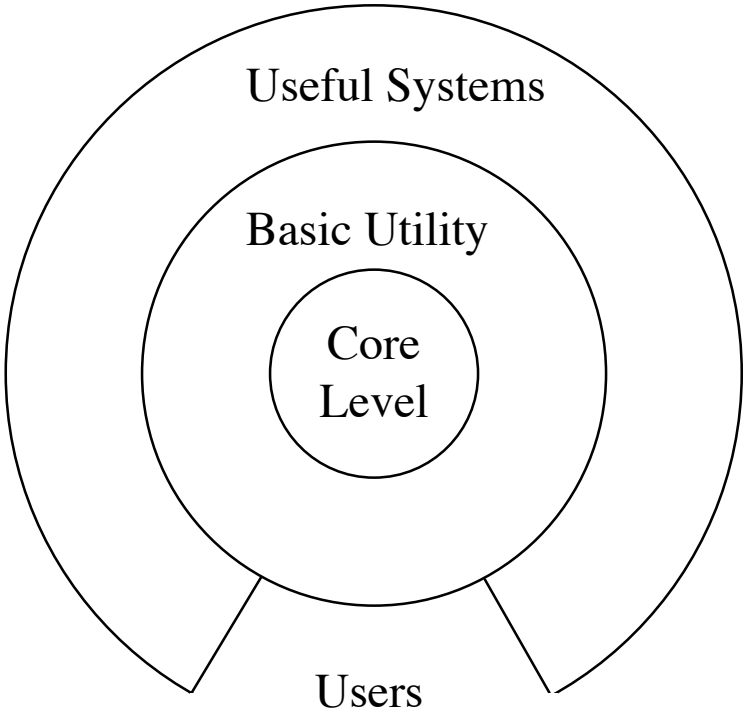
Connections are remote procedure calls or remote method invocations

Peer-to-Peer Architectures

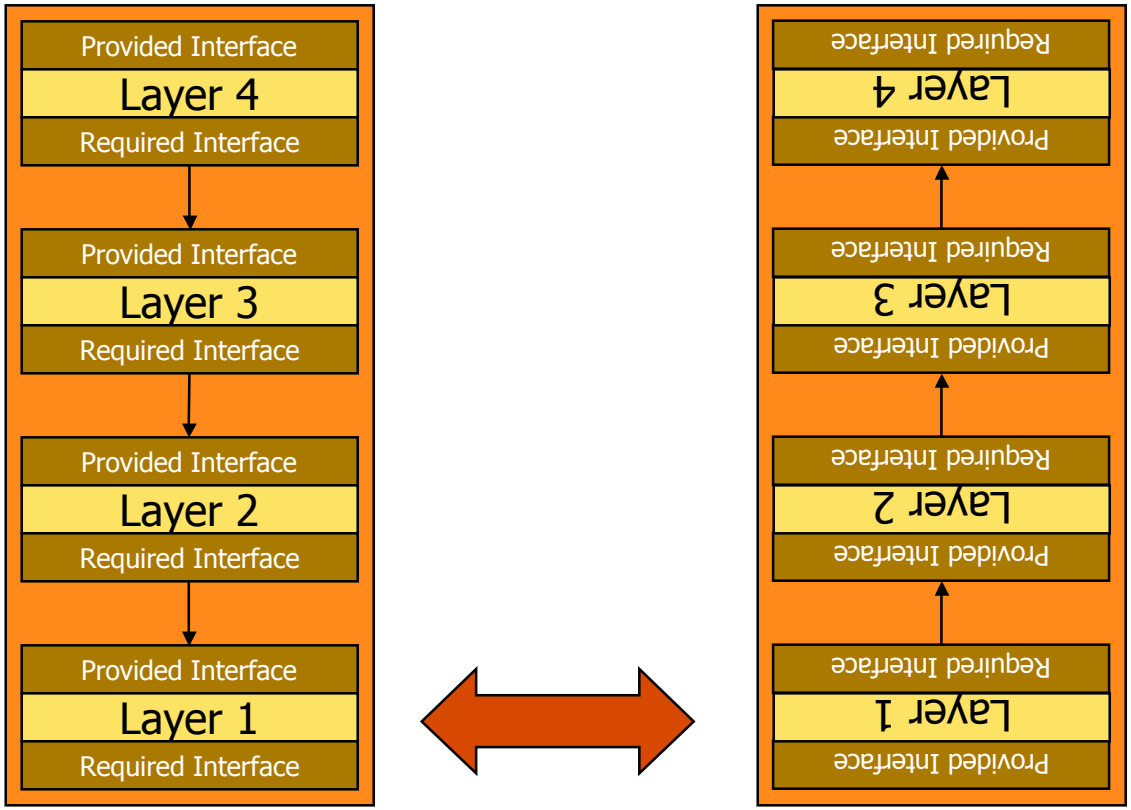
- Components
  - Autonomous
  - Act as both clients and servers
- Connectors
  - Asynchronous and synchronous message passing ("remote procedure calls")
  - By protocols atop TCP/IP
  - No shared memory (except as an optimization when the configuration allows)
- Topology
  - Interaction topologies can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

Layered Systems, Take 2

Inter-level interfaces
usually procedure calls

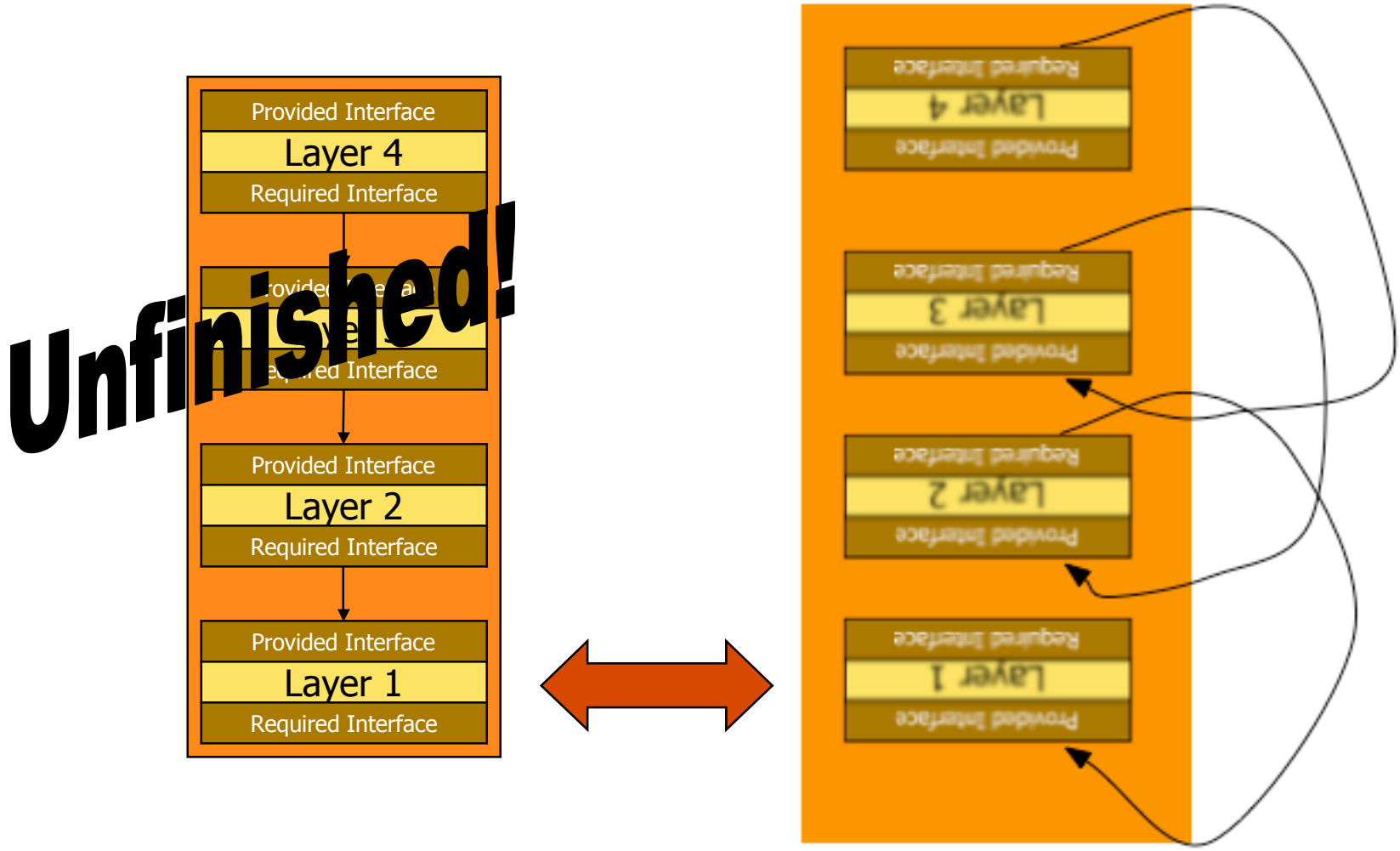


Style 7: Layered Systems, Take 1



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

Style 7: Layered Systems, Take 1.1

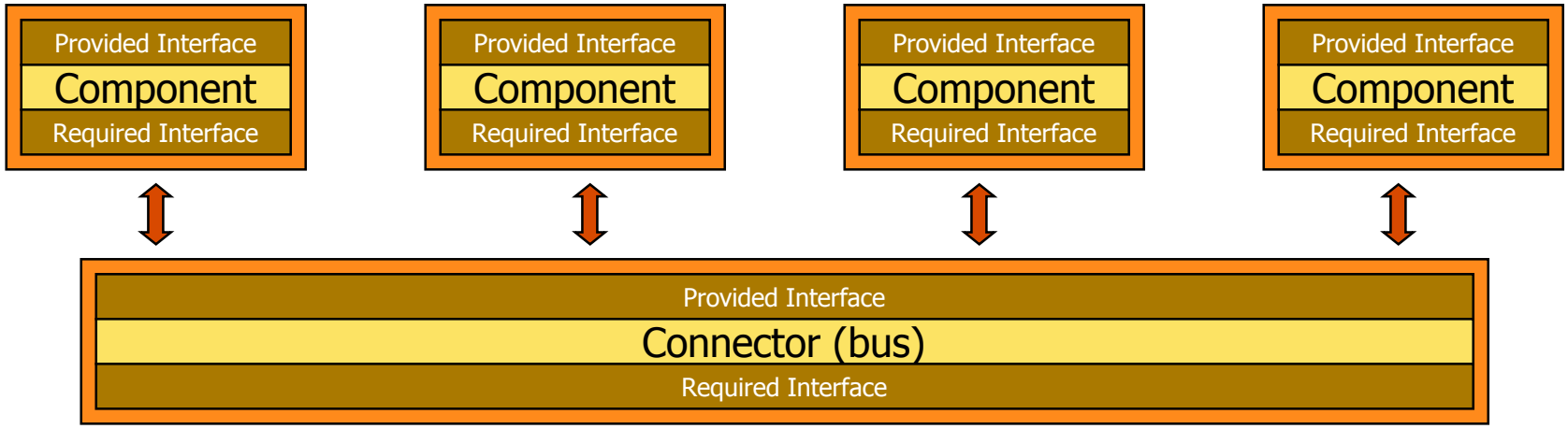


Connections are function or method calls + "something in between"

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 (Event-based)

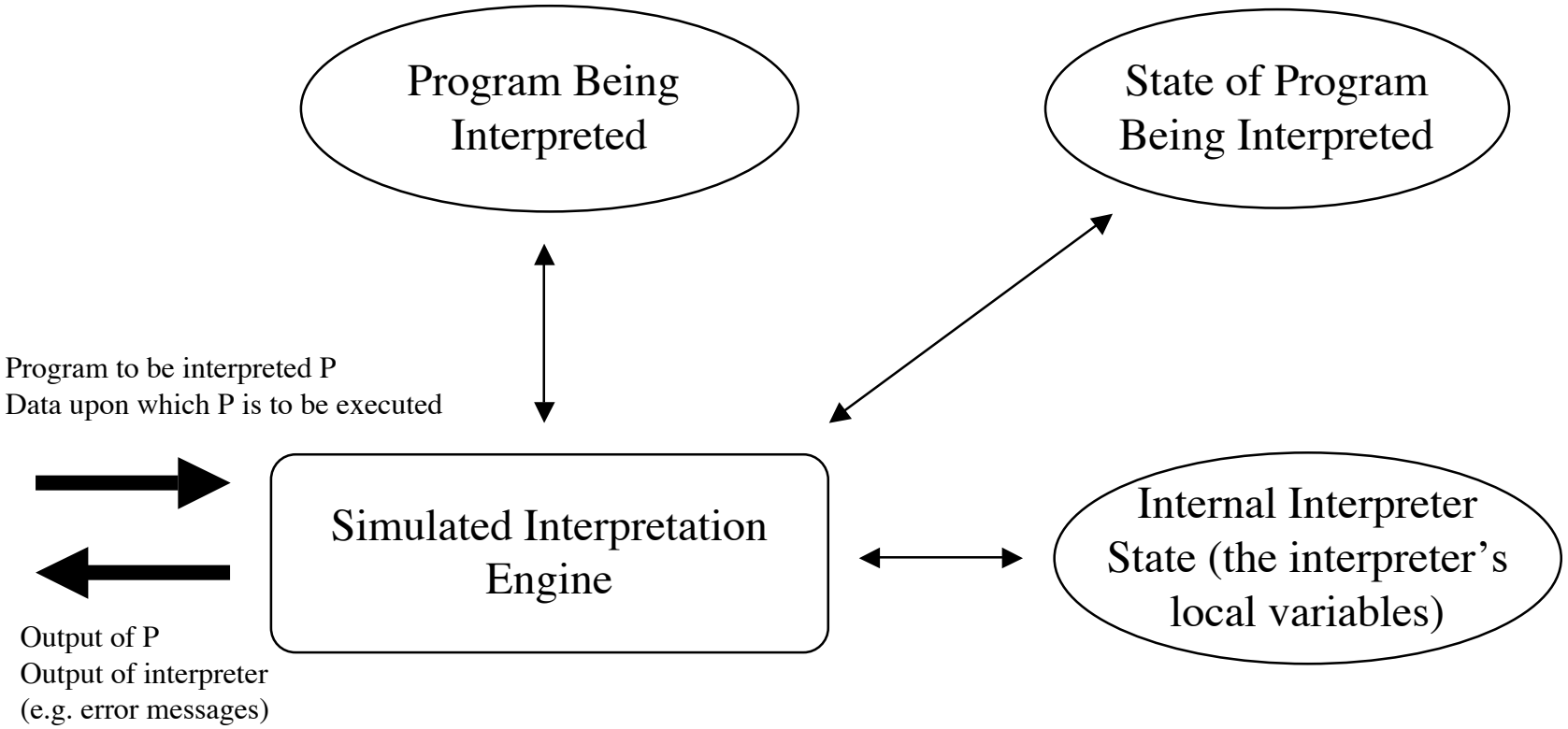


Connections are provided by connectors, with communication via events on the software bus

Event-based/Implicit Invocation

- Components
  - Encapsulate computation
  - Autonomous
- Inter-component communication is via events (only)
- Connectors
  - Encapsulate communication
  - Responsible for routing events to their destinations
  - Asynchronous and synchronous message passing ("remote procedure calls")
  - No shared memory (except as an optimization when the configuration allows)
- Topology
  - Interaction topologies can vary dynamically
  - Components to connectors to components
- Typical applications: decentralized systems, dynamic systems

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”

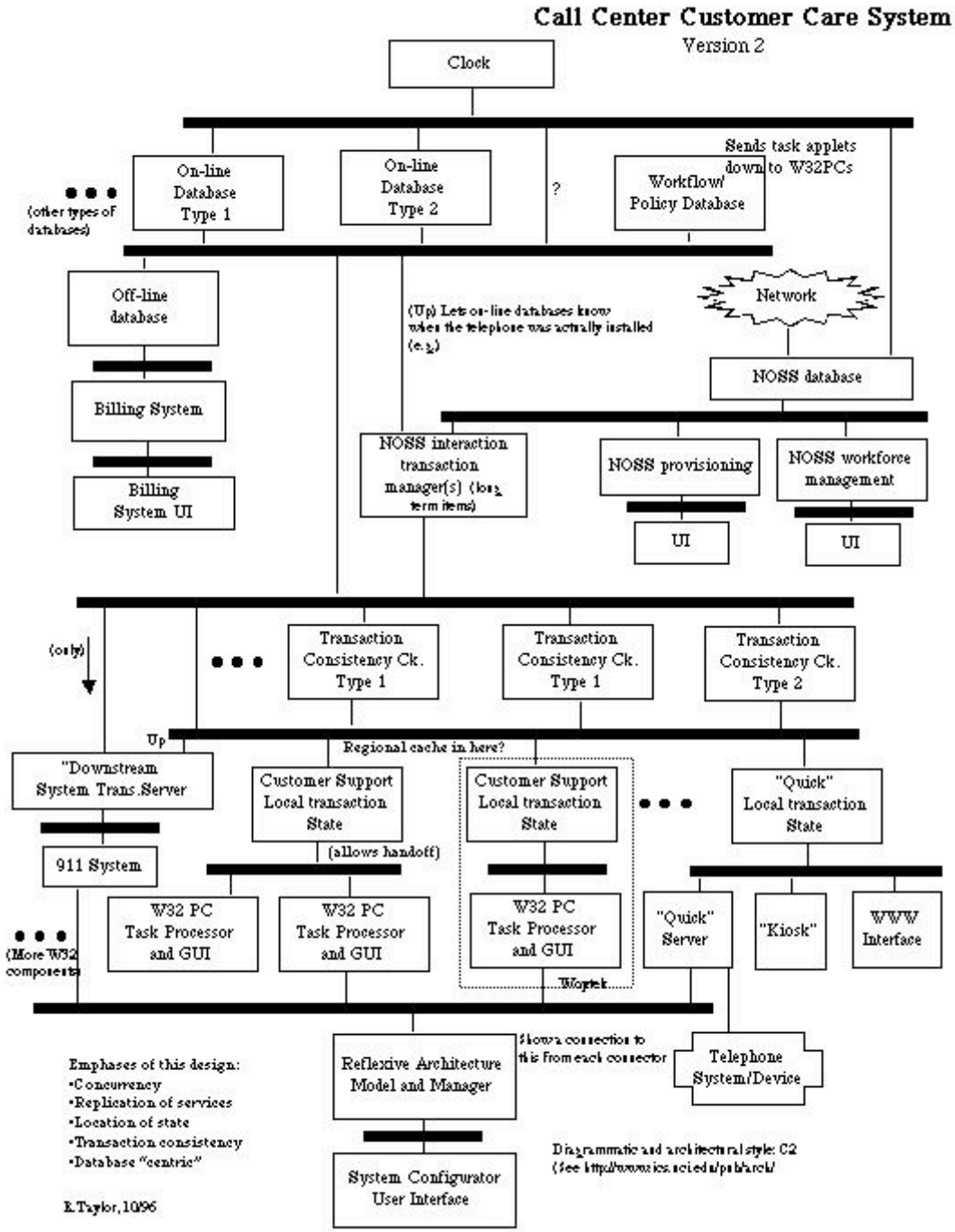
- User interface
- Application Logic
- Database (server)

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”


Call Center Customer Care System
Version 2
Clock
On-line Database Type 1
On-line Database Type 2
?
Workflow/ Policy Database
Sends task applets down to W32PCs
(other types of databases)
Off-line database
Network
(Up) Lets on-line databases know when the telephone was actually installed (e.g.)
NOSS database
Billing System
Billing System UI
NOSS interaction transaction manager(s) (long term items)
NOSS provisioning
UI
NOSS workforce management
UI
(only)
Transaction Consistency Ck. Type 1
Transaction Consistency Ck. Type 1
Transaction Consistency Ck. Type 2
Up
Regional cache in here?
"Downstream System Trans.Server
Customer Support Local transaction State
Customer Support Local transaction State
"Quick" Local transaction State
911 System
(allows handoff)
W32 PC Task Processor and GUI
W32 PC Task Processor and GUI
W32 PC Task Processor and GUI
"Quick" Server
"Kiosk"
WWW Interface
(More W32 components)
Worlds
Reflexive Architecture Model and Manager
Shown connection to this from each connector
Telephone System/Device
Emphases of this design:
•Concurrency
•Replication of services
•Location of state
•Transaction consistency
•Database "centric"
R.Taylor,1096
System Configurator User Interface
Diagrammatic and architectural style: C2
(See http://www.ics.uci.edu/pub/arch/