Styles and Greenfield Design

Software Architecture

Heterogeneous Styles

- More complex styles created through composition of simpler styles
- C2

  Implicit invocation + Layering + other constraints
- Distributed objects

  OO + client-server network style

  CORBA

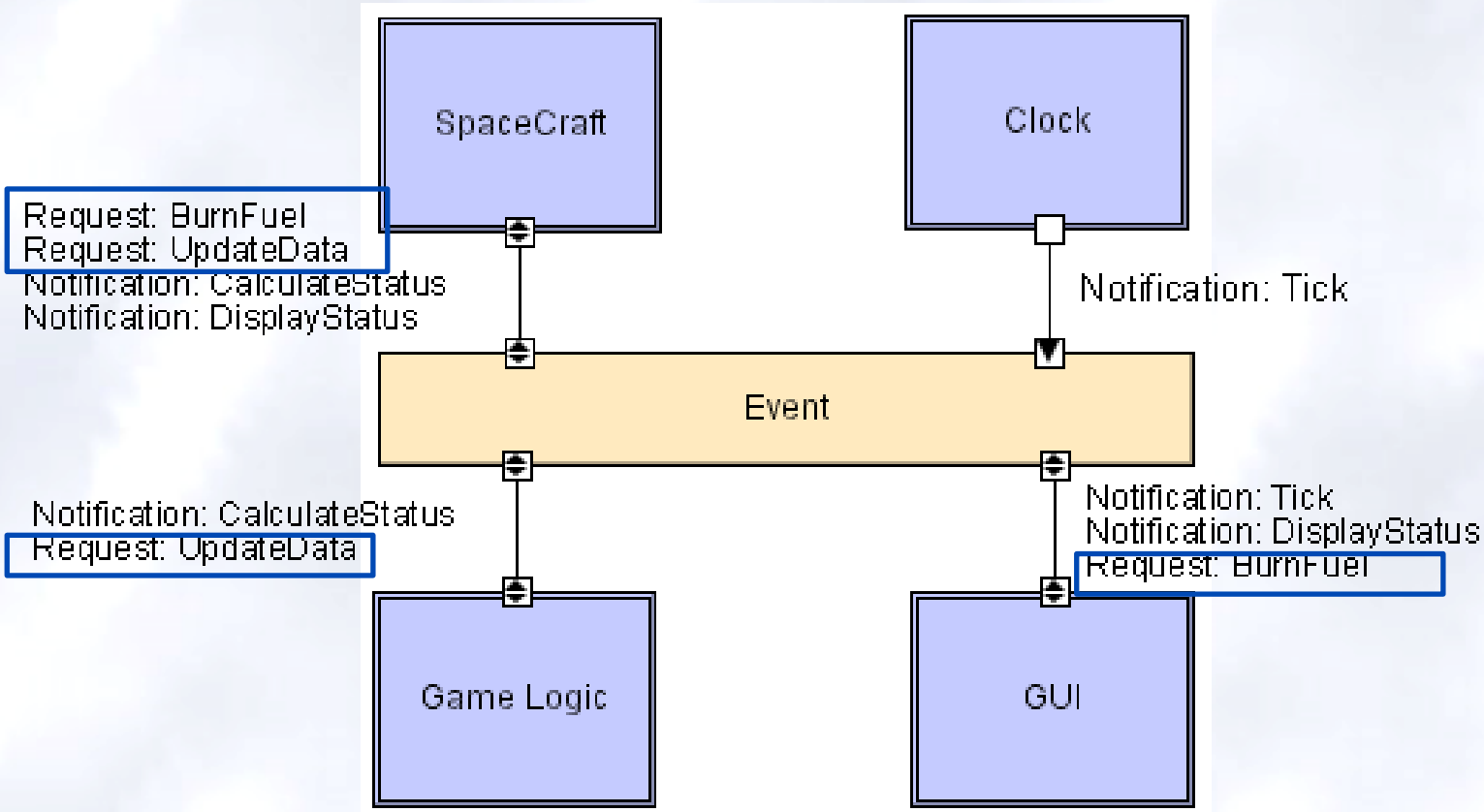
C2 Style

An indirect invocation style in which independent components communicate exclusively through message routing connectors. Strict rules on connections between components and connectors induce layering.

C2 Style (cont'd)

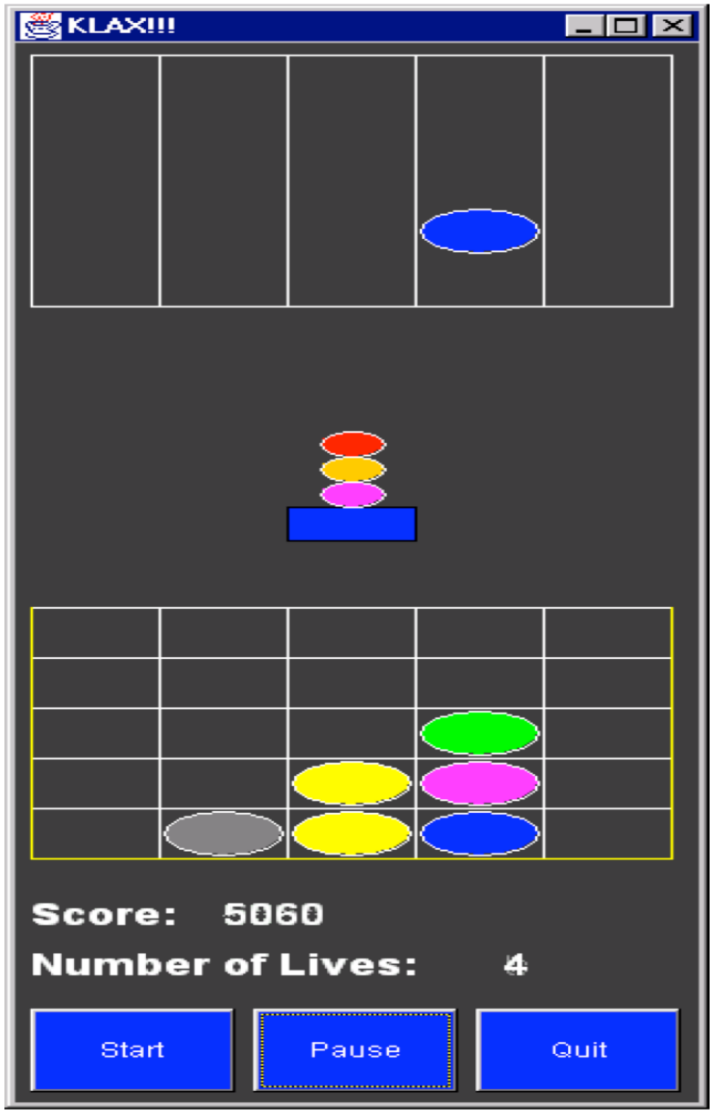
- Components: Independent, potentially concurrent message generators and/or consumers
- Connectors: Message routers that may filter, translate, and broadcast messages of two kinds: notifications and requests.
- Data Elements: Messages – data sent as first-class entities over the connectors. Notification messages announce changes of state. Request messages request performance of an action.
- Topology: Layers of components and connectors, with a defined "top" and "bottom", wherein notifications flow downwards and requests upwards.

C2 LL



notifications flow downwards
requests upwards

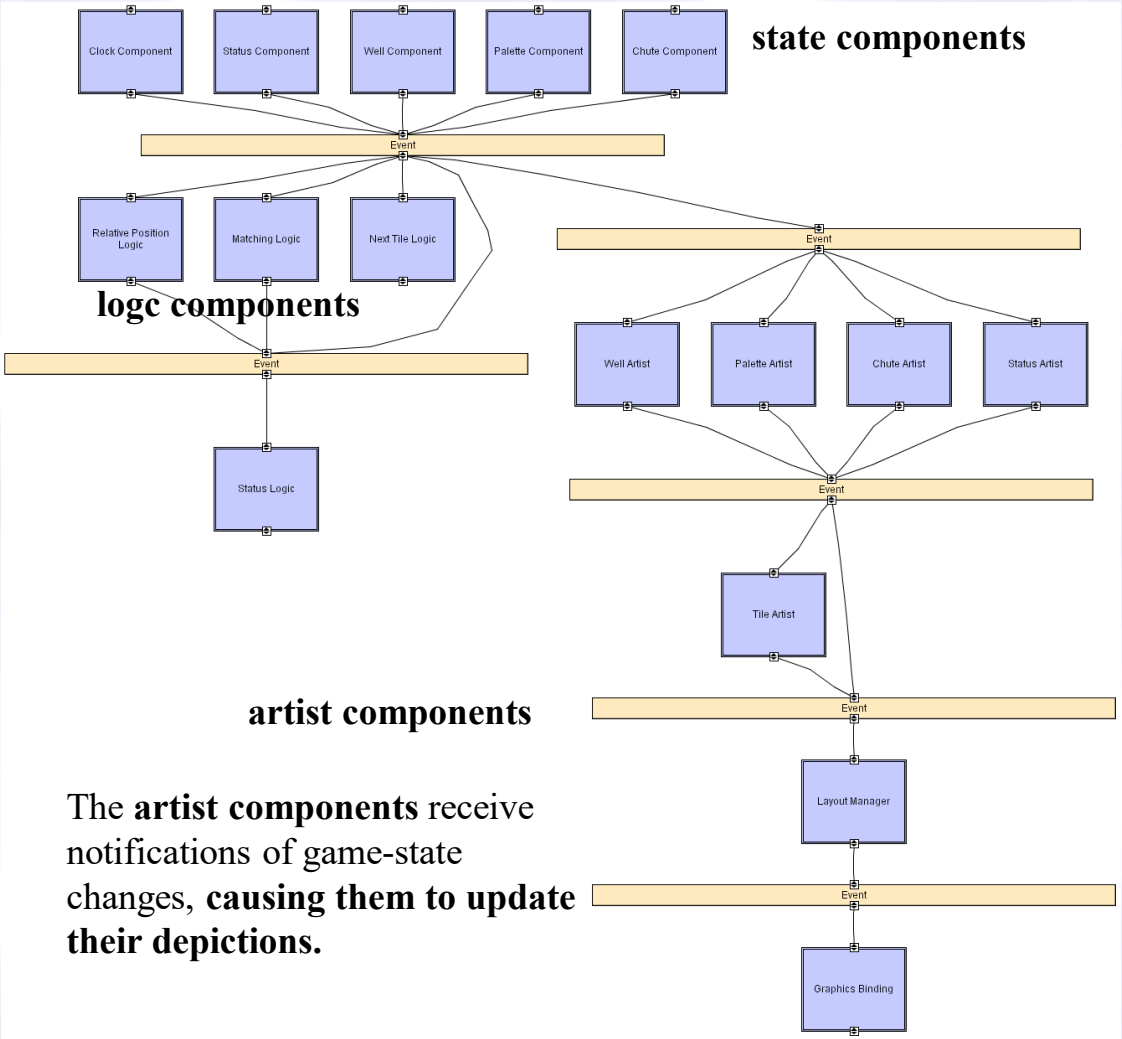
KLAX



KLAX in C2

The game state components receive no notifications, but respond to requests and emit notifications of internal state changes. They play the role of servers, or perhaps of blackboards.
Notifications are directed to the next level, where they are received by both the **game logic components** and the artist component.

The **game logic components** request changes of game state in accordance with game rules, and interpret game state change notifications to determine the state of the game in progress.

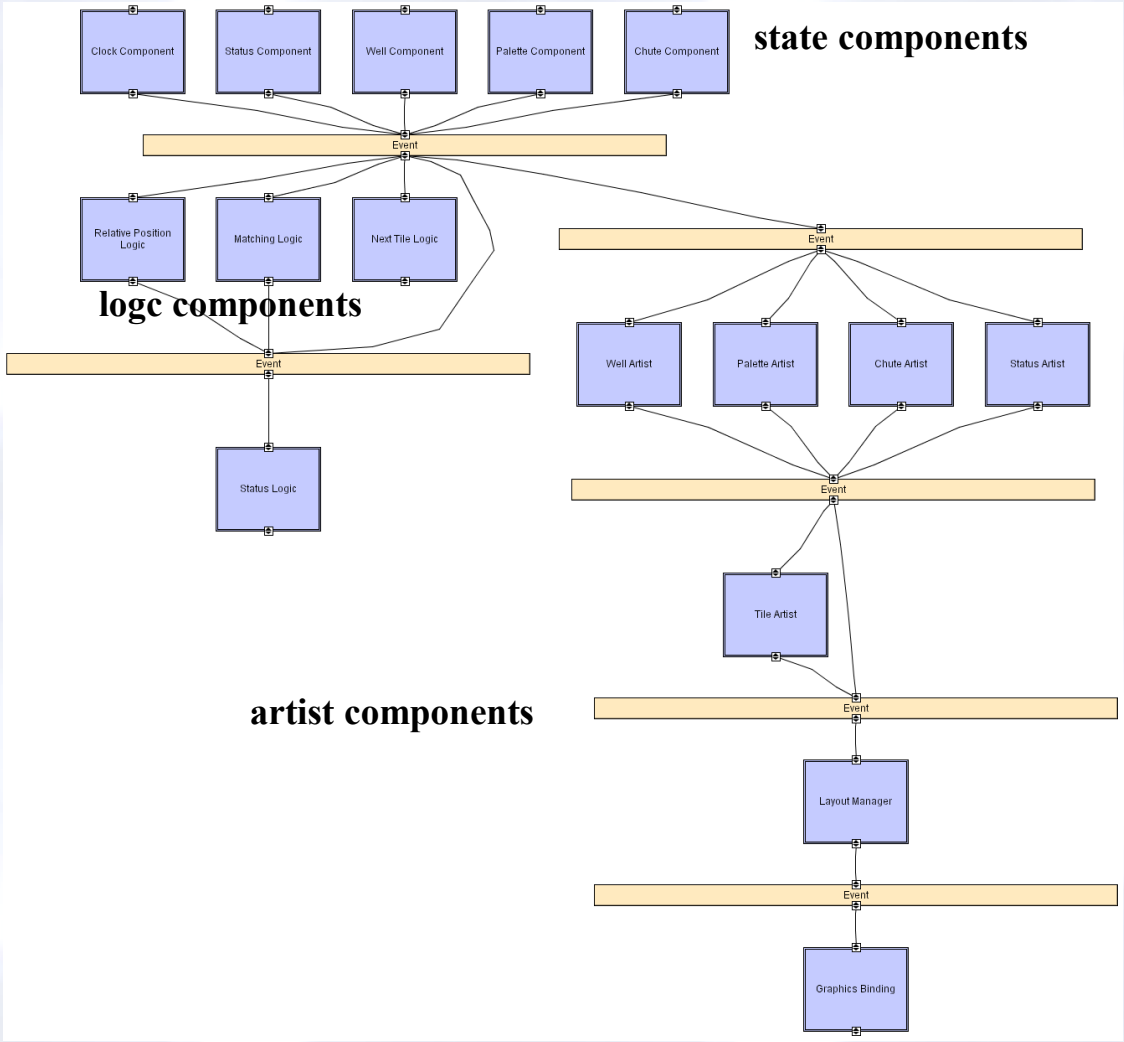


The **artist components** receive notifications of game-state changes, **causing them to update their depictions.**

KLAX in C2

C2 advantages:
Easy to create different games.

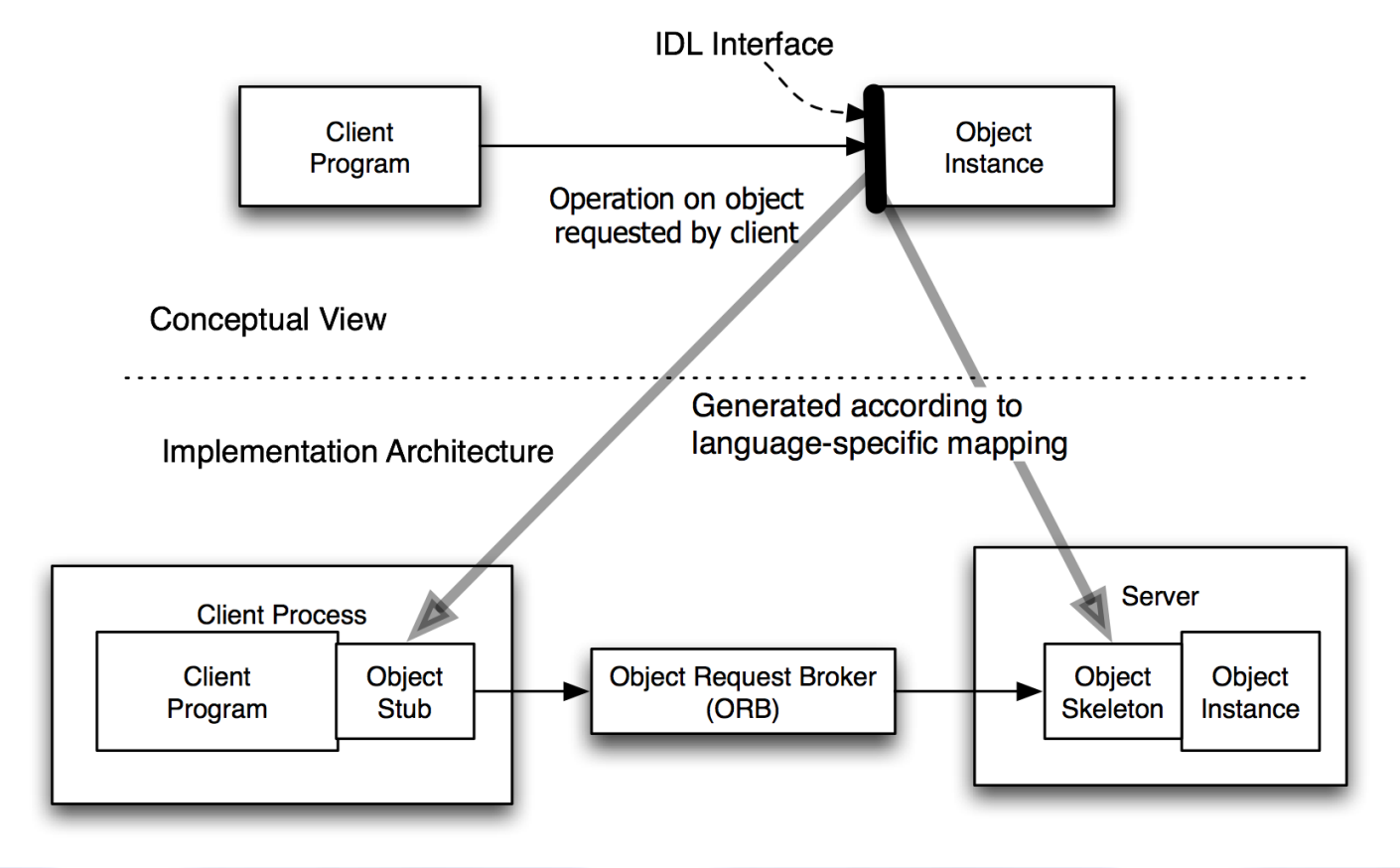
Eg.
Letters drop down to form a word.



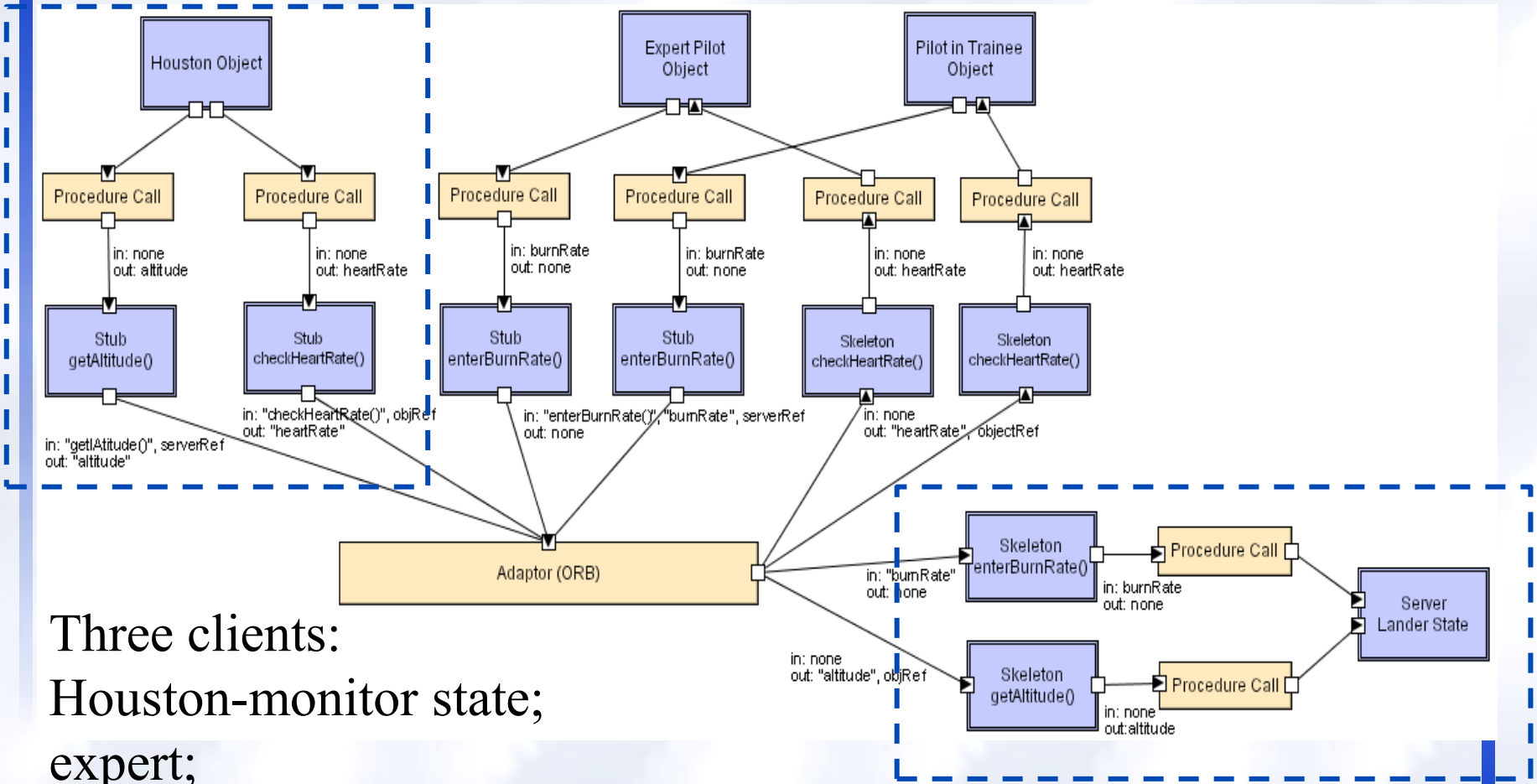
Distributed Objects: CORBA

- "Objects" (coarse- or fine-grained) run on **heterogeneous hosts**, written in **heterogeneous languages**. Objects provide services through well-defined interfaces. Objects invoke methods across host, process, and language boundaries via remote procedure calls (RPCs).
- Components: Objects (software components exposing services through well-defined provided interfaces)
- Connector: (**Remote**) Method invocation
- Data Elements: Arguments to methods, return values, and exceptions
- Topology**: General graph of objects** from callers to callees.
- Additional constraints imposed: Data passed in remote procedure calls must be **serializable**. Callers must deal with exceptions that can arise due to network or process faults.
- Location, platform, and language "transparency". CAUTION

CORBA Concept and Implementation



CORBA LL



Three clients:
Houston-monitor state;
expert;
trainee

Server: maintain state

CORBA

- On one hand, using CORBA allows systems to be implemented using components written in different languages on different platforms, and the CORBA middleware automatically masks most of the differences.

- For developers faced with integrating modern technologies with legacy systems, the allure is almost too good to pass up.

- On the other hand, using CORBA comes with a price. The use of CORBA provides these interoperability benefits, but it also induces applications to be built in the **distributed objects** style.

The components in a distributed objects style are required to explicitly specify provided interfaces; objects are constantly created/unlined/destroyed, hence hard to understand.

Observations

- Different styles result in
  - Different architectures
  - Architectures with greatly differing properties
- A style does not fully determine resulting architecture
  - A single style can result in different architectures
  - Considerable room for
    - Individual judgment
    - Variations among architects
- A style defines domain of discourse
  - About problem (domain)
  - About resulting system

Style Summary (1/4)

Style Category & Name	Summary	Use It When	Avoid It When
Language-influenced styles			
Main Program and Subroutines	Main program controls program execution, calling multiple subroutines.	Application is small and simple.	Complex data structures needed. Future modifications likely.
Object-oriented	Objects encapsulate state and accessing functions	Close mapping between external entities and internal objects is sensible. Many complex and interrelated data structures.	Application is distributed in a heterogeneous network. Strong independence between components necessary. High performance required.
Layered			
Virtual Machines	Virtual machine, or a layer, offers services to layers above it	Many applications can be based upon a single, common layer of services. Interface service specification resilient when implementation of a layer must change.	Many levels are required (causes inefficiency). Data structures must be accessed from multiple layers.
Client-server	Clients request service from a server	Centralization of computation and data at a single location (the server) promotes manageability and scalability; end-user processing limited to data entry and presentation.	Centrality presents a single-point-of-failure risk; Network bandwidth limited; Client machine capabilities rival or exceed the server's.

Style Summary, continued (2/4)

Data-flow styles			
Batch sequential	Separate programs executed sequentially, with batched input	Problem easily formulated as a set of sequential, severable steps.	Interactivity or concurrency between components necessary or desirable. Random-access to data required.
Pipe-and-filter	Separate programs, a.k.a. filters, executed, potentially concurrently. Pipes route data streams between filters	[As with batch-sequential] Filters are useful in more than one application. Data structures easily serializable.	Interaction between components required. Exchange of complex data structures between components required.
Shared memory			
Blackboard	Independent programs, access and communicate exclusively through a global repository known as blackboard	All calculation centers on a common, changing data structure; Order of processing dynamically determined and data-driven.	Programs deal with independent parts of the common data. Interface to common data susceptible to change. When interactions between the independent programs require complex regulation.
Rule-based	Use facts or rules entered into the knowledge base to resolve a query	Problem data and queries expressible as simple rules over which inference may be performed.	Number of rules is large. Interaction between rules present. High-performance required.

Style Summary, continued (3/4)

Interpreter			
Interpreter	Interpreter parses and executes the input stream, updating the state maintained by the interpreter	Highly dynamic behavior required. High degree of end-user customizability.	High performance required.
Mobile Code	Code is mobile, that is, it is executed in a remote host	When it is more efficient to move processing to a data set than the data set to processing. When it is desirous to dynamically customize a local processing node through inclusion of external code	Security of mobile code cannot be assured, or sandboxed. When tight control of versions of deployed software is required.

Style Summary, continued (4/4)

Implicit Invocation			
Publish-subscribe	Publishers broadcast messages to subscribers	Components are very loosely coupled. Subscription data is small and efficiently transported.	When middleware to support high-volume data is unavailable.
Event-based	Independent components asynchronously emit and receive events communicated over event buses	Components are concurrent and independent. Components heterogeneous and network-distributed.	Guarantees on real-time processing of events is required.
Peer-to-peer	Peers hold state and behavior and can act as both clients and servers	Peers are distributed in a network, can be heterogeneous, and mutually independent. Robust in face of independent failures. Highly scalable.	Trustworthiness of independent peers cannot be assured or managed. Resource discovery inefficient without designated nodes.
More complex styles			
C2	Layered network of concurrent components communicating by events	When independence from substrate technologies required. Heterogeneous applications. When support for product-lines desired.	When high-performance across many layers required. When multiple threads are inefficient.
Distributed Objects	Objects instantiated on different hosts	Objective is to preserve illusion of location-transparency	When high overhead of supporting middleware is excessive. When network properties are unmaskable, in practical terms.

Design Recovery

- What happens if a system is already implemented but has no recorded architecture?
- The task of **design recovery** is
  - examining the existing code base
  - determining the system's components, connectors, and overall topology
- A common approach to **architectural recovery** is clustering of the implementation-level entities into architectural elements.
  - Syntactic clustering
  - Semantic clustering

Syntactic Clustering

- Focuses exclusively on the **static relationships among code-level entities**
- Can be performed without executing the system
- Embodies inter-component (a.k.a. **coupling**) and intra-component (a.k.a. **cohesion**) connectivity
- May ignore or misinterpret many subtle relationships, because dynamic information is missing

Semantic Clustering

- Includes all aspects of a system's **domain knowledge** and information about the behavioral similarity of its entities.
- Requires interpreting the system entities' meaning, and possibly executing the system on a representative set of inputs.
- Difficult to automate
- May also be difficult to avail oneself of it

When There's No Experience to Go On…

- The first effort a designer should make in addressing a novel design challenge is to attempt to determine that it is genuinely a novel problem.
- Basic Strategy

  Divergence – shake off inadequate prior approaches and discover or admit a variety of new ideas

  Transformation – combination of analysis and selection

  Convergence – selecting and further refining ideas
- Repeatedly cycling through the basic steps until a feasible solution emerges.

Analogy Searching

- Examine other fields and disciplines unrelated to the target problem for approaches and ideas that are analogous to the problem.
- Formulate a solution strategy based upon that analogy.
- A common "unrelated domain" that has yielded a variety of solutions is nature, especially the biological sciences.

  E.g., Neural Networks

  Genetic algorithms

Brainstorming

- Technique of rapidly generating a wide set of ideas and thoughts pertaining to a design problem

  without (initially) devoting effort to assessing the feasibility.
- Brainstorming can be done by an individual or, more commonly, by a group.
- Problem: A brainstorming session can generate a large number of ideas… all of which might be low-quality.
- The chief value of brainstorming is in identifying categories of possible designs, not any specific design solution suggested during a session.
- After brainstorm the design process may proceed to the Transformation and Convergence steps.

"Literature" Searching

- Examining published information to identify material that can be used to guide or inspire designers
- Many historically useful ways of searching "literature" are available
- Digital library collections make searching extraordinarily faster and more effective
  - IEEE Xplore
  - ACM Digital Library
  - Google Scholar
- The availability of free and open-source software adds special value to this technique.

Morphological Charts

- The essential idea:

  identify all the primary functions to be performed by the desired system (what)

  for each function identify a means of performing that function (how)

  attempt to choose one means for each function such that the collection of means performs all the required functions in a compatible manner. (how and refine)

- The technique does not demand that the functions be shown to be independent when starting out.
- Sub-solutions to a given problem do not need to be compatible with all the sub-solutions to other functions in the beginning.

Removing Mental Blocks

- If you can't solve the problem, change the problem to one you can solve.

  If the new problem is "close enough" to what is needed, then closure is reached.

  If it is not close enough, the solution to the revised problem may suggest new venues for attacking the original.

Controlling the Design Strategy

- The potentially chaotic nature of exploring diverse approaches to the problem demands that some care be used in managing the activity（谨慎措施）
- Identify and review critical decisions
- Relate the costs of research and design to the penalty for taking wrong decisions
- Insulate uncertain decisions

Continually re-evaluate system "requirements" in light of what the design exploration yields

Insights from Requirements

- In many cases new architectures can be created based upon experience with an improvement to pre-existing architectures.
- Requirements can use a vocabulary of known architectural choices and therefore reflect experience.
- The interaction between past design and new requirements means that many critical decisions for a new design can be identified or made as a requirement

Insights from Implementation

- Constraints on the implementation activity may help shape the design
- Externally motivated constraints might dictate
  - Use of a middleware
  - Use of a particular programming language
  - Software reuse
- Design and implementation may proceed cooperatively and contemporaneously
  - Initial partial implementation activities may yield critical performance or feasibility information