Software architecture

Service-Oriented Architecture

Jeremy Gibbons

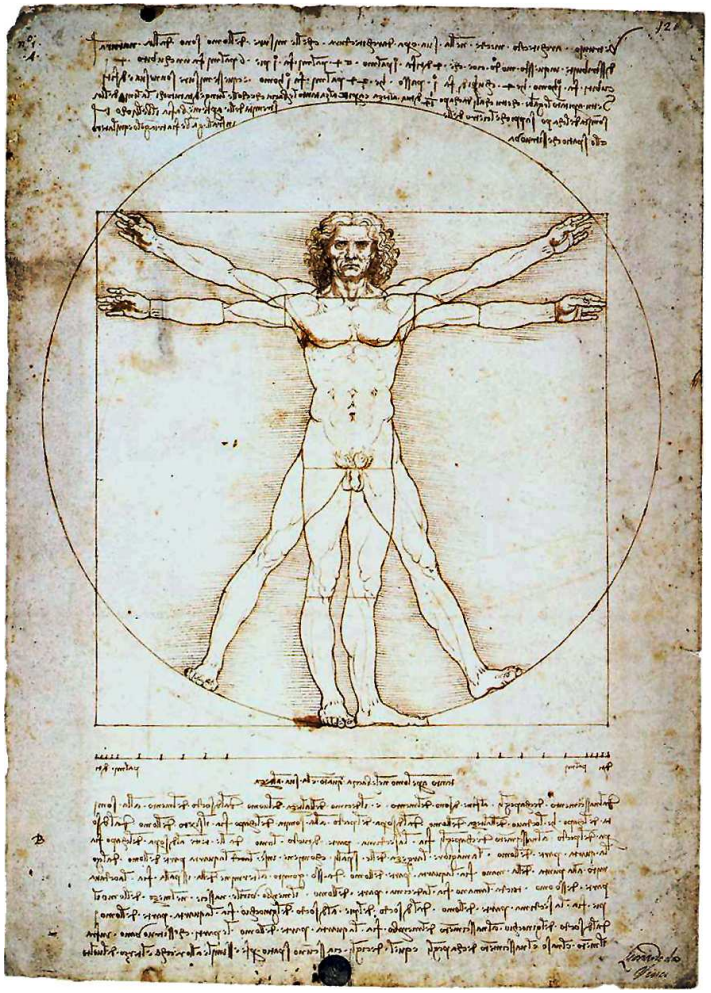
Contents

1 Software architecture

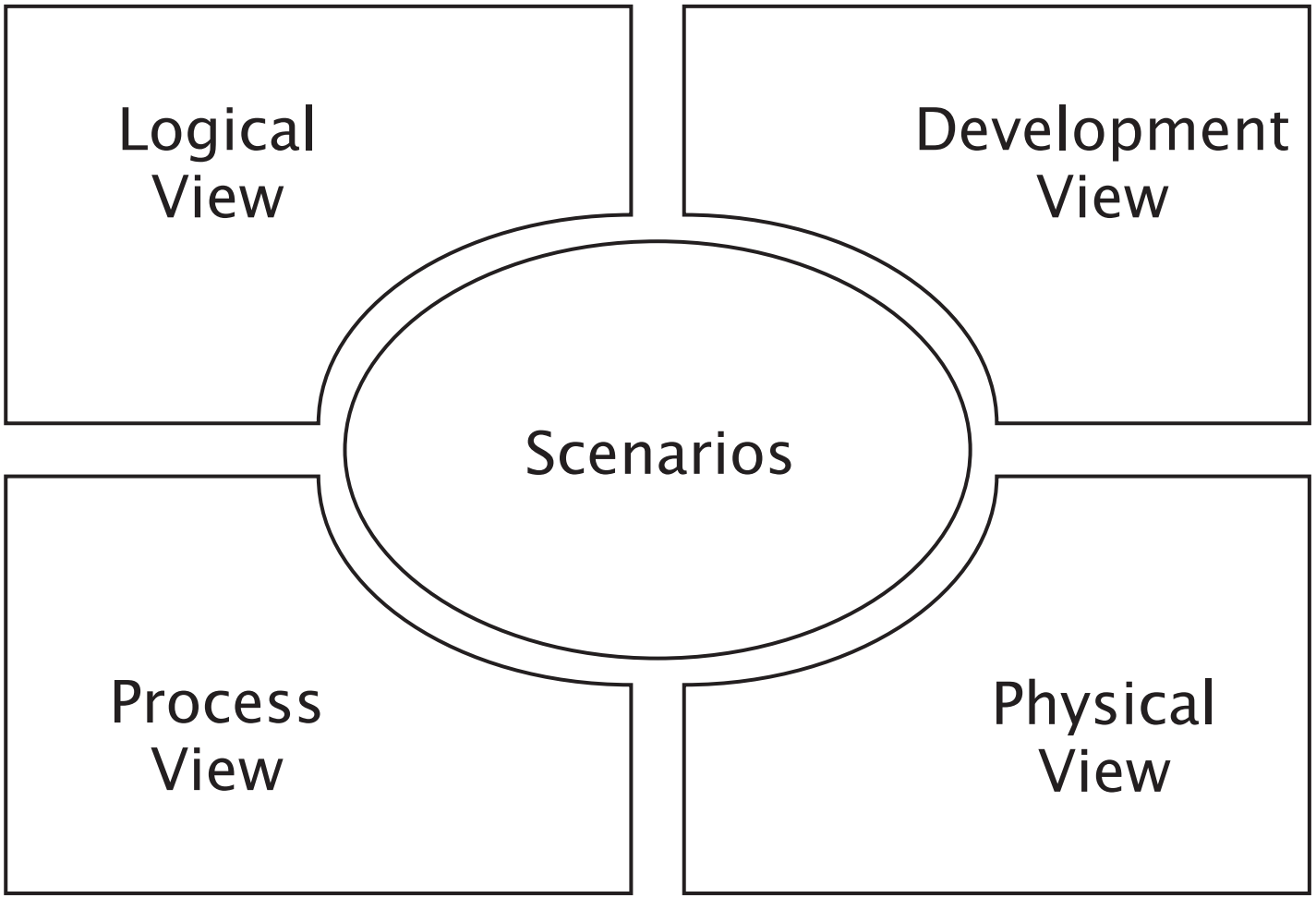
- design beyond the level of algorithms and data structures
- as abstract datatypes themselves are design beyond the level of individual statements
- gross organization; global control structure; protocols for communication, synchronization and data access; physical distribution...
- Garlan and Shaw, 1994, and much subsequent work
  eg architectural *patterns*
- orthogonal to underlying technology: WS, CORBA...

1.1 Vitruvian Triad: firmitas, utilitas, venustas

- Vitruvius: Roman, 1st century BC
- *Ten Books on Architecture*
- function (utilitas, ‘utility’)
- form (venustas, ‘beauty’)
- fabrication (firmitas, ‘soundness’)
- architectural principles
- retrospective
- perhaps a bit idealist

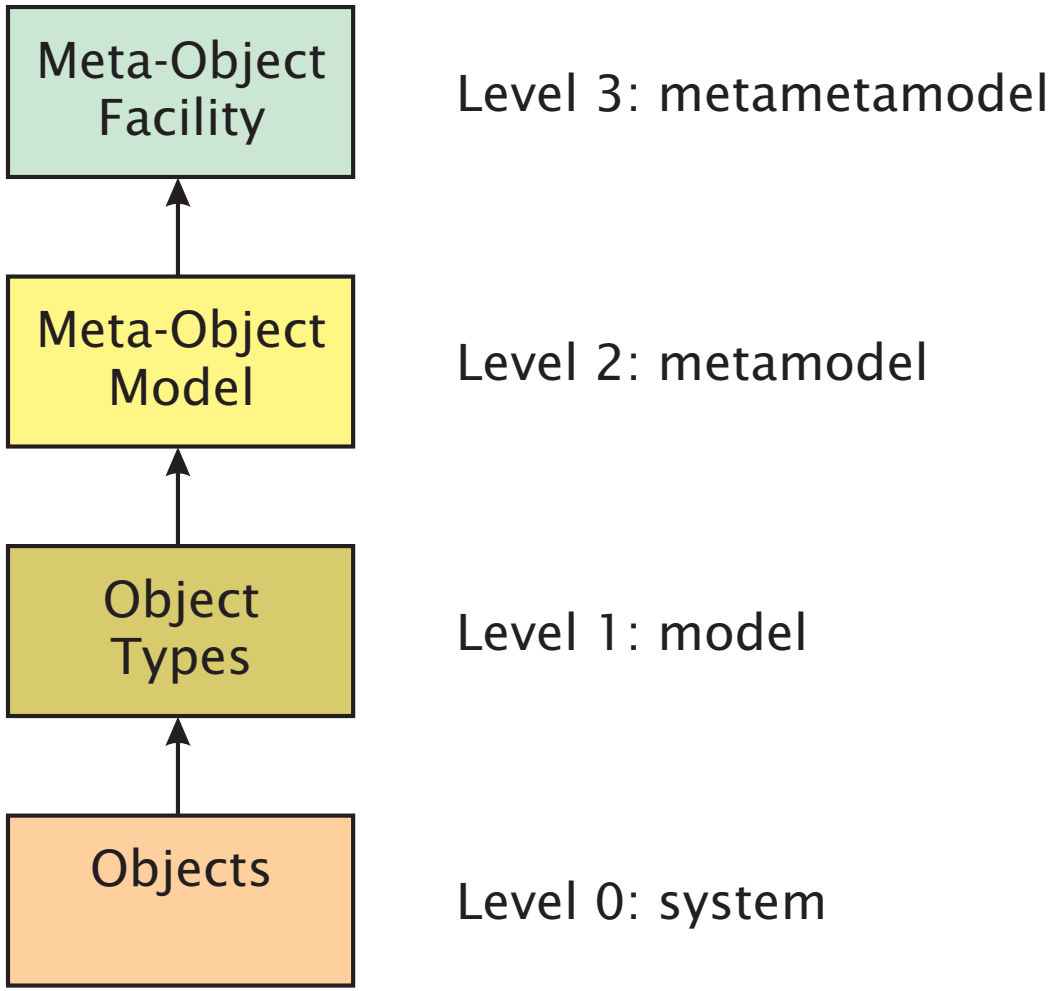


1.2 The 4+1 View Model of Architecture

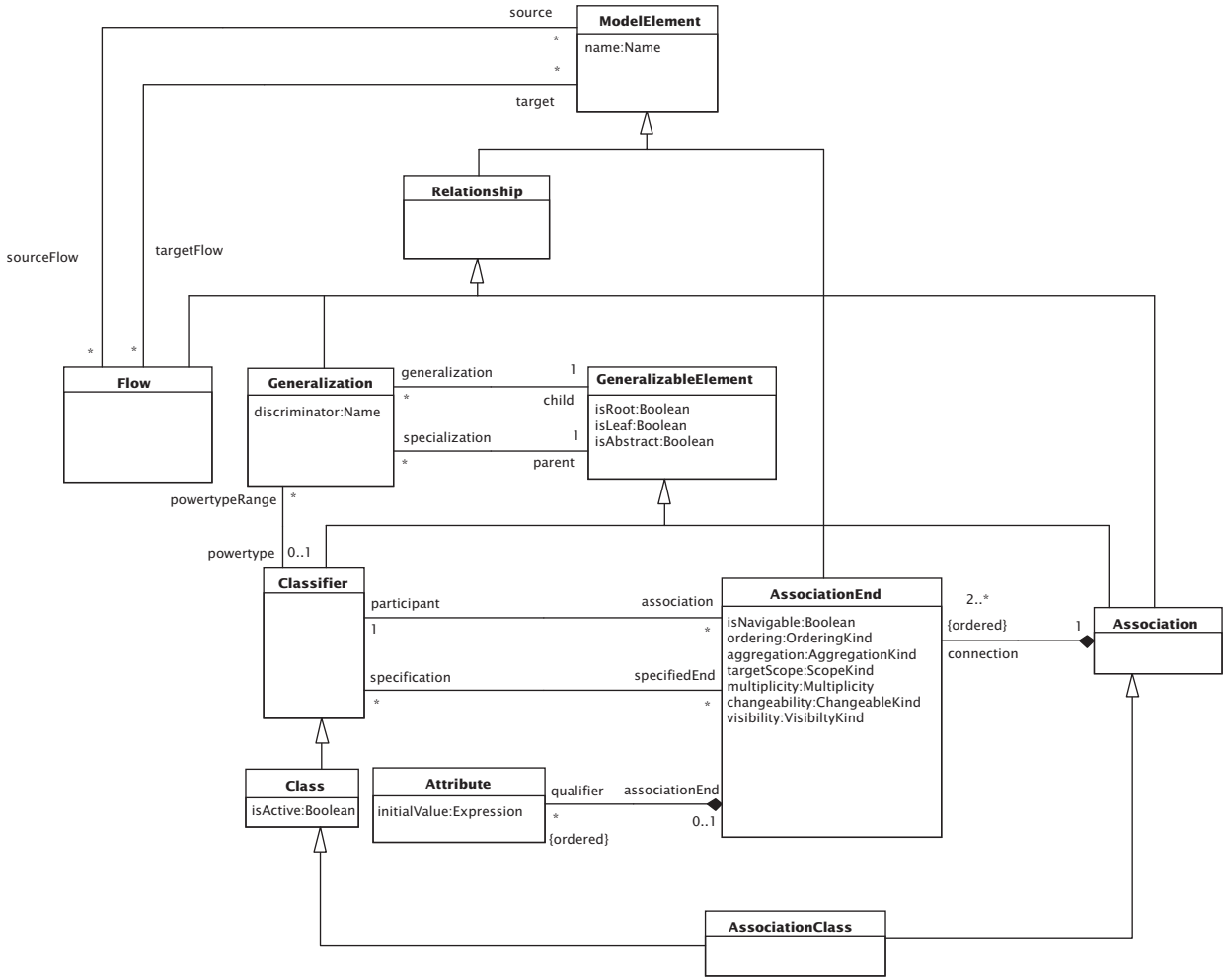


(Philippe Kruchten, *IEEE Software* 12(6) 1995)

1.3 Models and metamodels



1.4 UML metamodel (part)



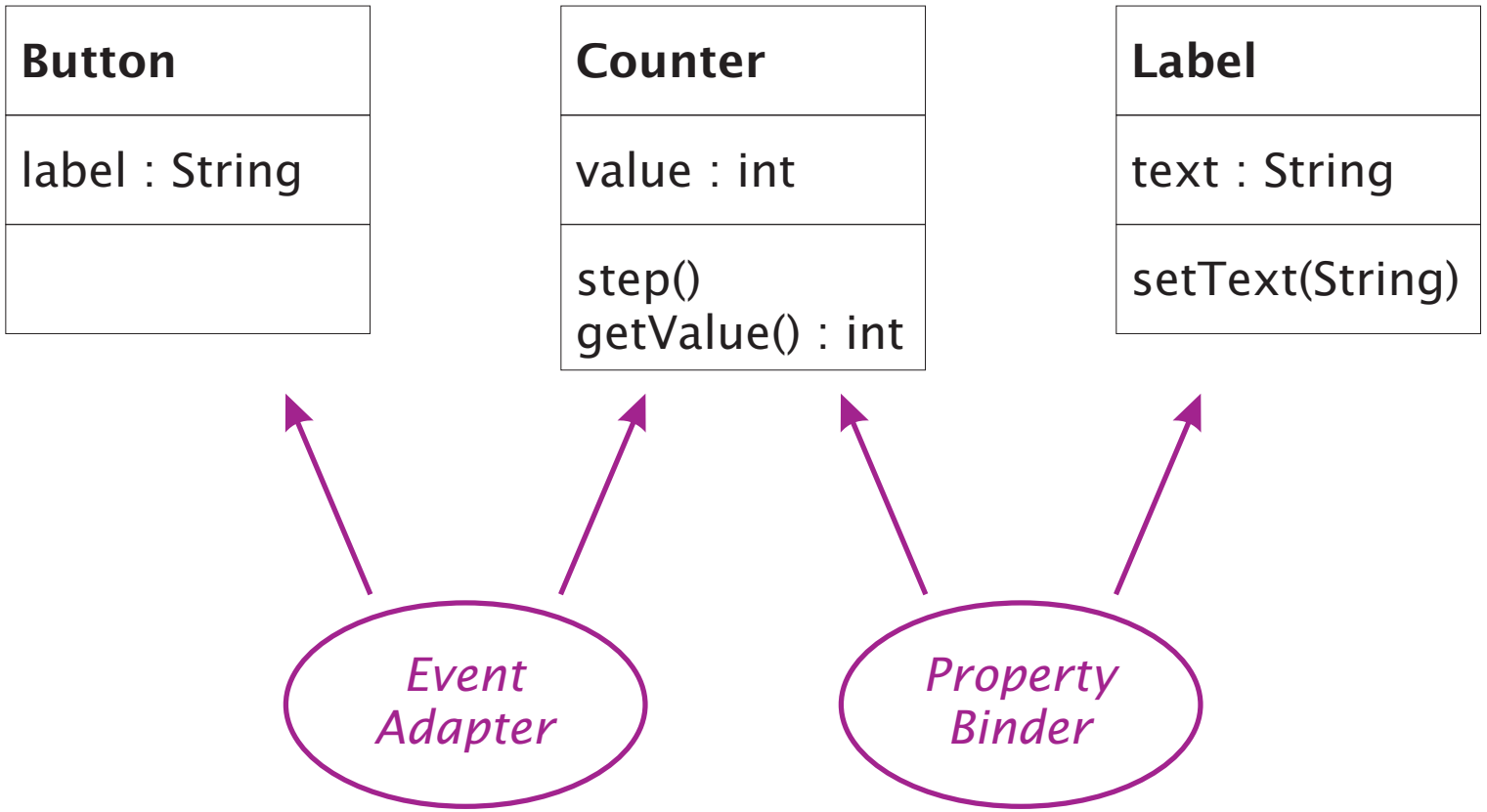
1.5 Components and connectors

- *components*: sequential, single-threaded *computations*
- *connectors*: concurrent, multi-threaded *coordination*
- connectors should be first-class entities (cf workflow)
- paradigm of system assembly by *superimposition*
- communication, coordination, monitoring, control

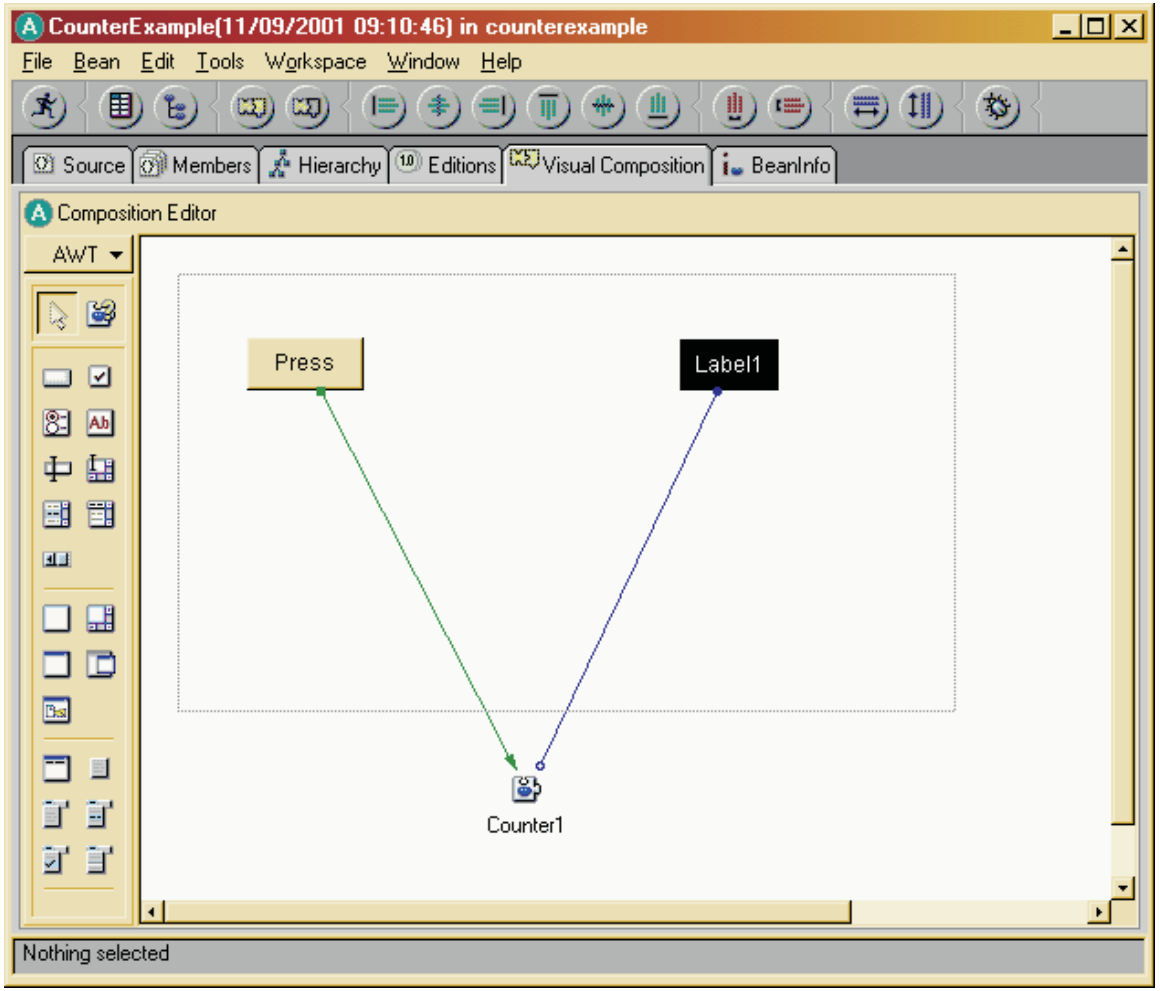
Counter-example

User presses button; counter steps; label displays counter value.

Connectors for coordination



Visual programming



1.6 Product line architectures

- “set of programs studied in terms of the common and special properties of the individual members” (Parnas)
- family of related but different products
- separate the generic from the specific
- eg mobile phones
- eg engine management

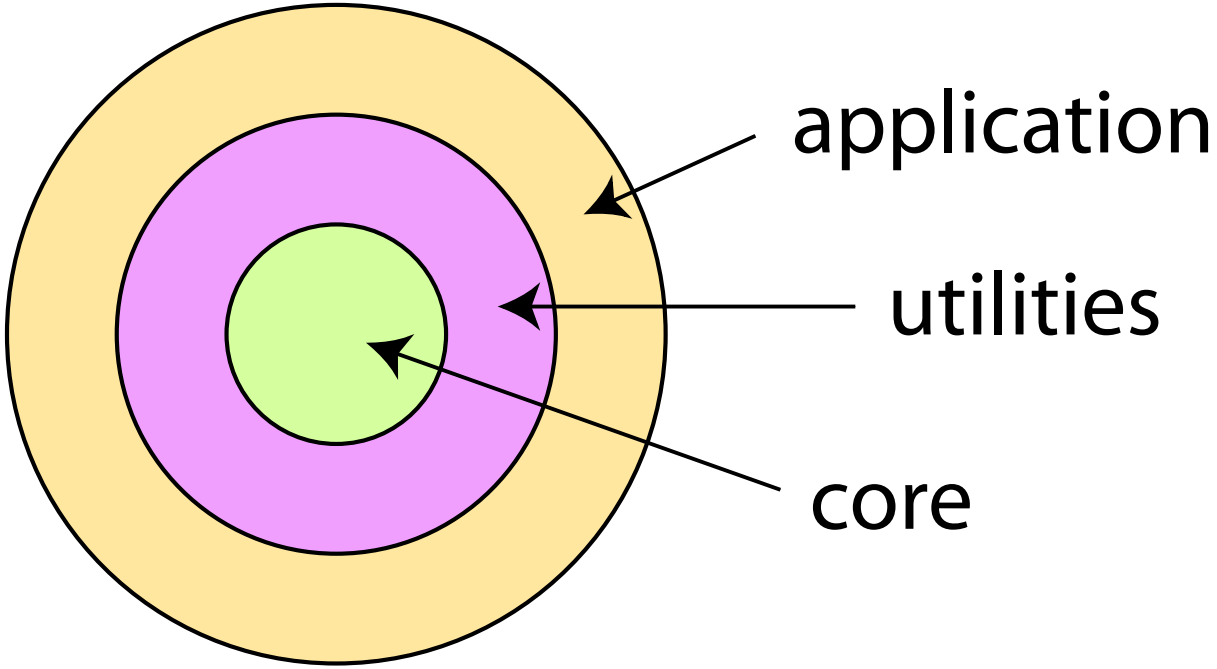
1.7 BMW car configurator

(idea from Roberto Lopez on SPL)

2 Client–server

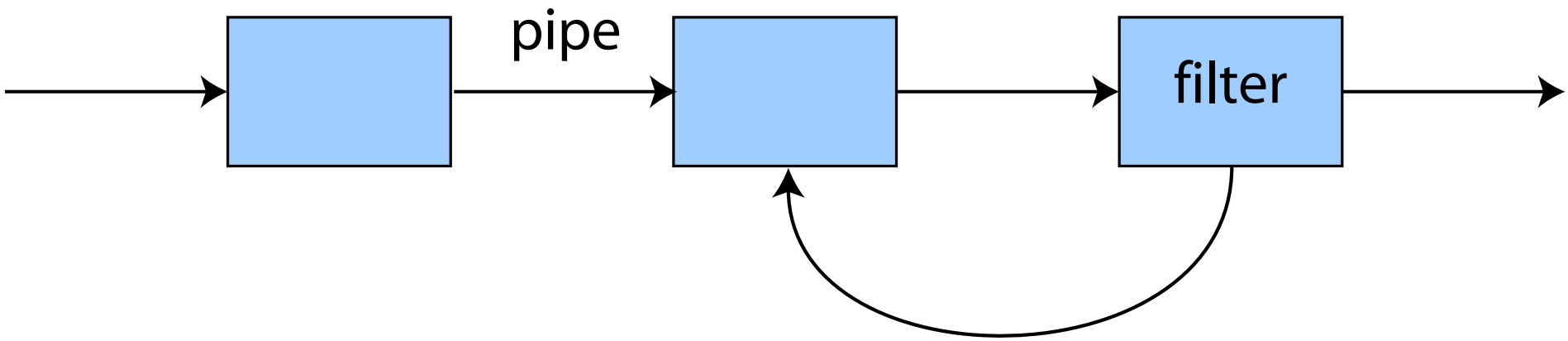
- most common and familiar architecture for distributed systems
- *server* offers a set of services, and waits for service requests
- *client* sends request to server, awaits response
- client is triggering process, initiates synchronization, may be finite; server is reactive, typically runs indefinitely
- multi-tier client–server architectures (eg with client-side proxies and server-side gateways) are *layered*...

3 Layered



- hierarchical organization
- each layer provides a *service* to the layer above, and is a *client* of the layer below
- strictly, only adjacent layers interact (although a layer may import certain services and re-export them); each layer implements a *virtual machine*
- loosely, upper layer may access any lower layer; then layers are translucent rather than opaque
- eg layered communications protocols: OSI seven-layer model
- challenges: often efficiency considerations encourage breaking abstraction boundaries

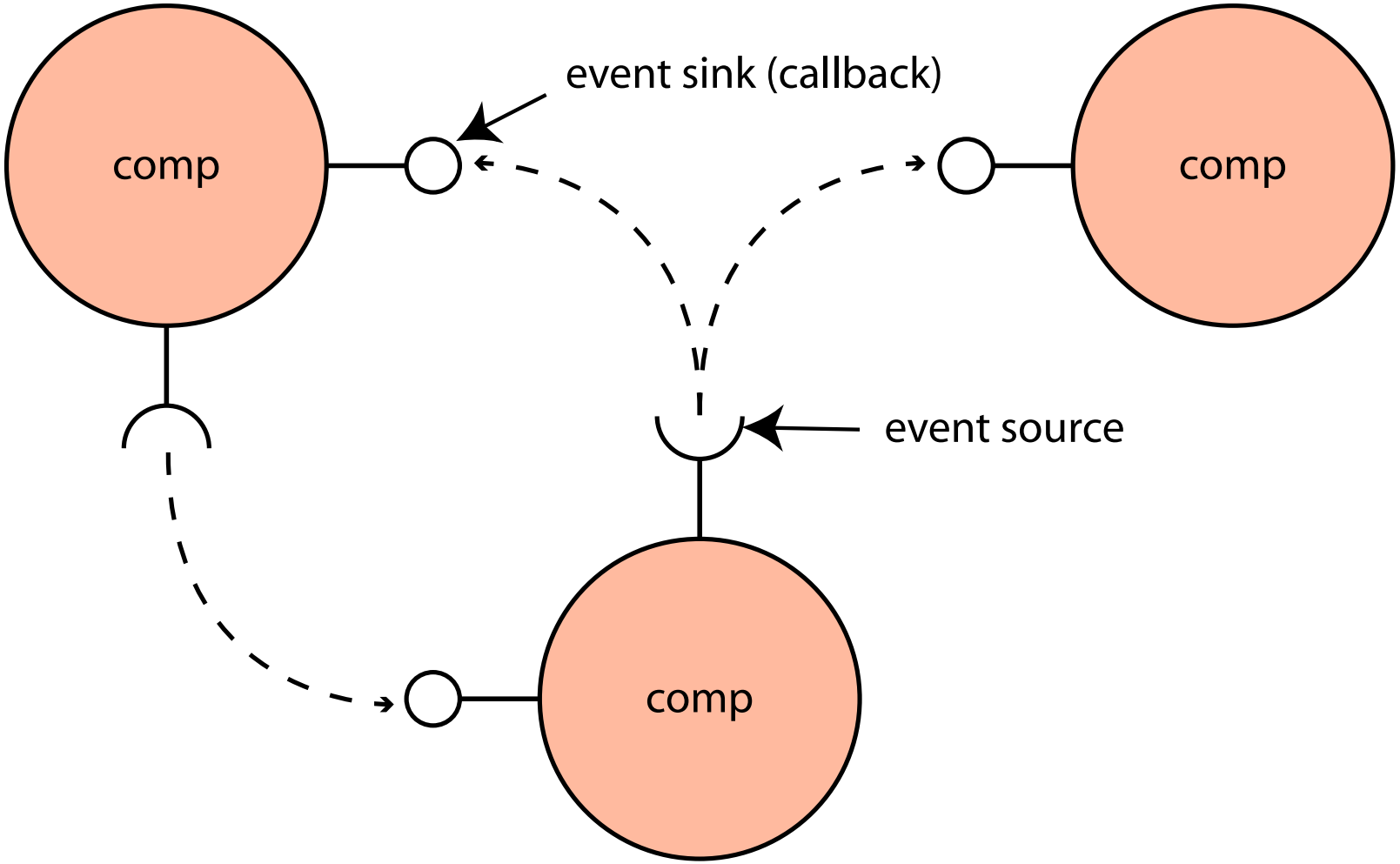
4 Pipes and filters



- *filter* reads a stream of data from input(s), writes a stream of data to output(s)
- *pipe* connects output of one filter to input of another

- filter typically applies a local transformation to the data
- execution usually incremental, on demand: filter may start writing before finishing reading, so filters may compute in parallel
- filters are independent: no shared state, no dependence on characteristics of upstream or downstream neighbours
- specializations: linear *pipelines*, *bounded* buffering, *typed* data, degenerate *batched sequential*
- eg Unix processes; compiler phases; signal processing; systolic arrays

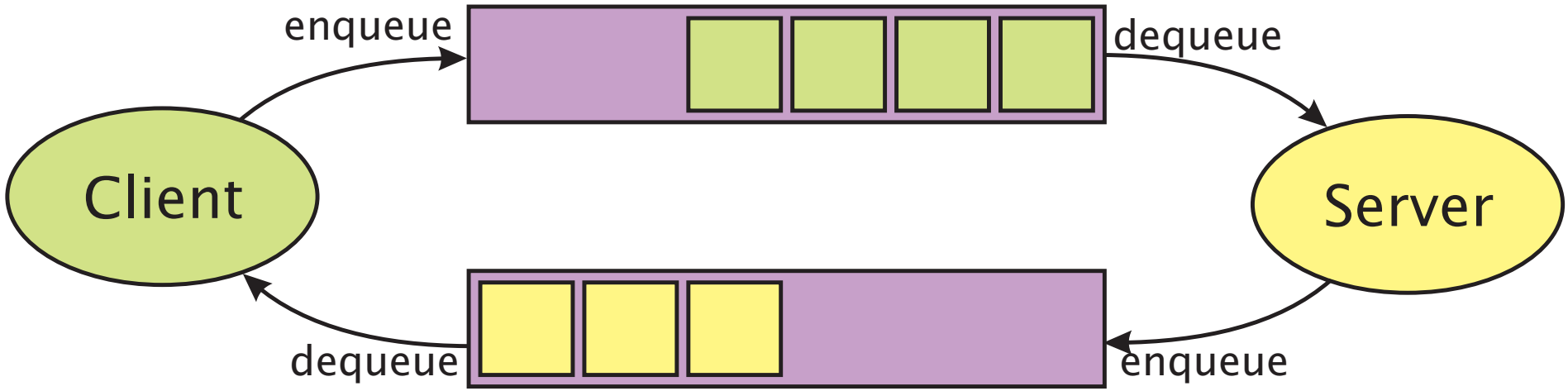
5 Event-based, implicit invocation



- instead of explicitly invoking a (perhaps remote) procedure, component triggers an *event*
- other components register interest in such events, perhaps by specifying a *callback*
- when event is triggered, *event manager* (or perhaps the triggering component itself) invokes all appropriate registered callbacks
- event source needs no knowledge of event sinks
- challenges: non-determinacy, asynchrony, passing data
- eg database triggers, user interfaces, the OBSERVER pattern, 'pub–sub', EDA, CEP

5.1 Message-oriented

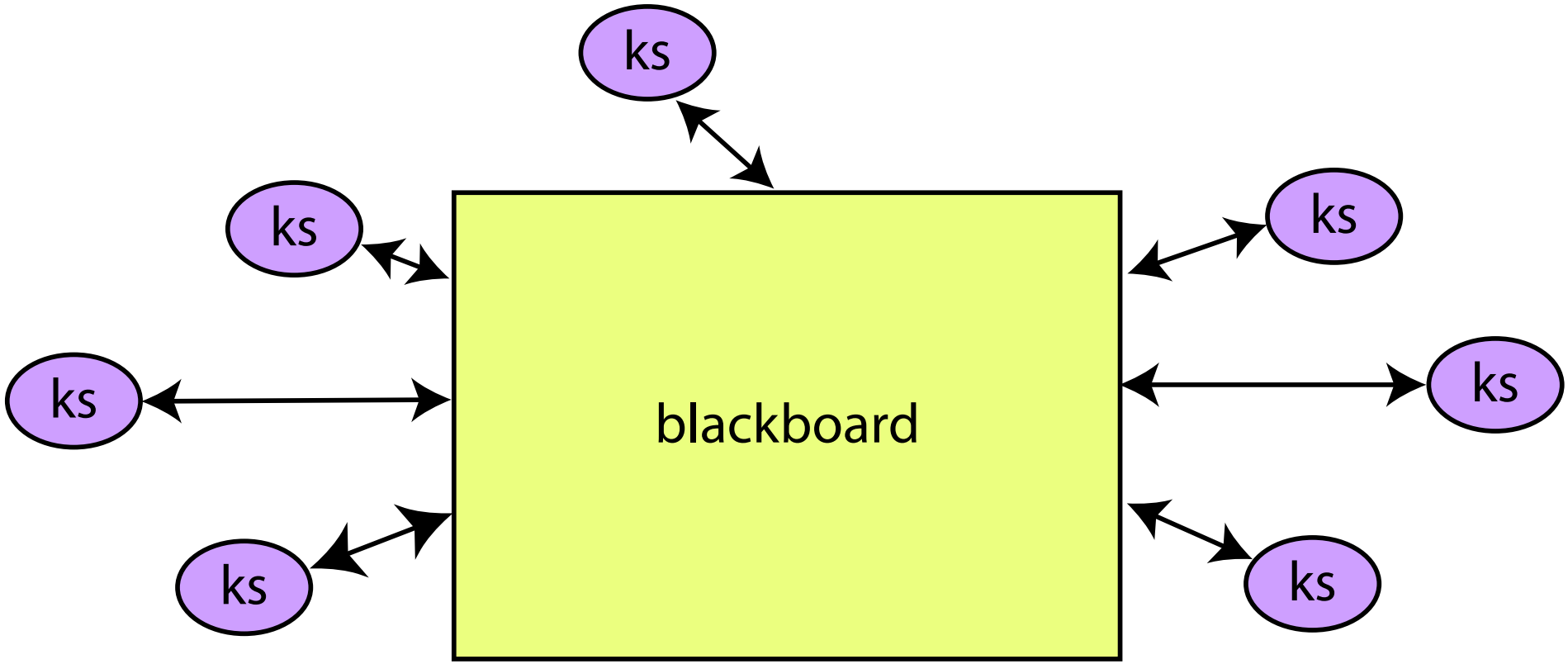
- decouples components by interposing *message queues*
- induces *asynchronous communication*: components need not be simultaneously connected
- message consumers often notified by events
- may require (and typically provides) persistent storage for queued messages, improving reliability
- eg MQSeries, MSMQ, JMS, WS-ReliableMessageing



5.2 Complex event processing

- inference of higher-level events from lower-level
- eg (bells + tux + gown + rice) nearby ⇒ wedding
- abstraction, correlation, causality, timing
- algorithmic trading, fraud detection, embedded systems
- see `www.complexevents.com`

6 Repository



- central *store* maintains global state
- independent *knowledge sources* interact with central store
- KS responds opportunistically when stored state makes it applicable
- (alternatively, actions may be triggered by input types; then more like a database with stored procedures)
- eg Blackboard systems (HEARSAY-II speech recognizer)

6.1 Tuple spaces

- a style of *coordination language*: separate communication from computation
- tuple space is *bag* of tagged data
- tagged data is added, examined and removed by concurrent processes (with locking)
- tuples may represent *tasks* and *results*
- eg *Linda*, *Chemical Abstract Machine*, *JavaSpaces*, *Space-Based Architecture*...

7 Peer-to-peer

- clients and servers coincide: *servents*
- typically an expectation that users of services will reciprocate
- minimize centralization, eg of registry, broker or router
- how do servents locate each other? perhaps initial use of registry, then boot-strapping ('hybrid p2p')
- reduces bottlenecks, increases robustness
- *unstructured* vs *structured* overlay networks: arbitrary or deterministic allocation of resources?
- eg file-sharing architectures such as Napster, Gnutella, BitTorrent

7.1 Agent-based

- autonomous components: no central control
- reasoning about environment and interactions
- belief vs knowledge: modal and epistemic logic
- devolved responsibility: action on behalf of user
- maybe mobile

8 Interpreter

- virtual machine in software
- pseudo-program *interpreted*
- multiple levels of ‘state’: interpreting and interpreted
- eg *rule-based system*
  - fixed body of *rules*
  - varying knowledge base of *facts*
  - interpretation of rules by *inference engine*

9 Grid/Cloud/Ubicomp...

- massively parallel, loosely coupled
- ready access to shared resources
  (processor, space, equipment, expertise...)
- pay-per-use, on-demand
- "autonomic" (self-managed)

9.1 Grid computing

- by analogy with electricity grid
- pioneered by SETI@Home

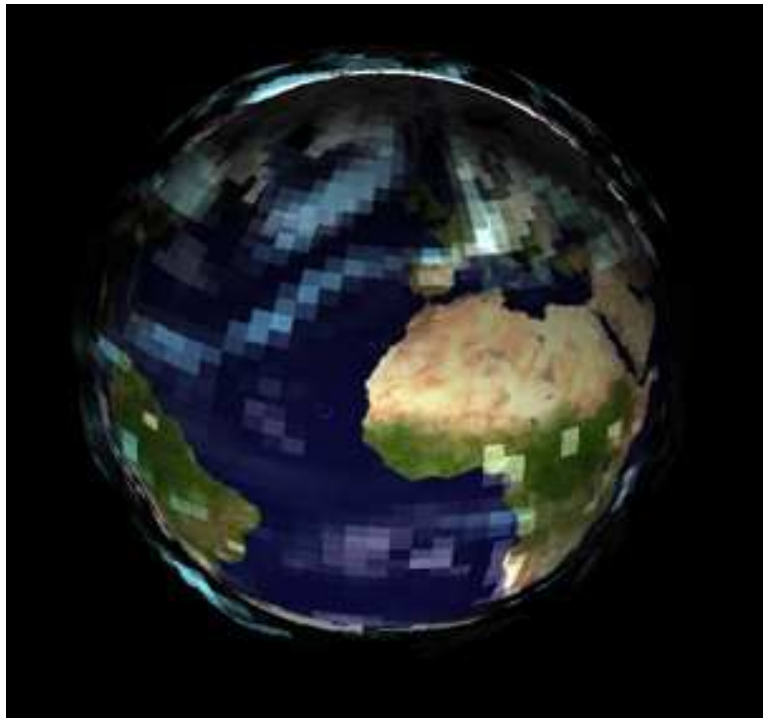
  3 million volunteers downloading and analyzing radio telescope data
- loosely coupled, heterogeneous, geographically dispersed
- *virtual organizations*
- move computation to data rather than vice versa (eg LHC)

9.2 Grid services

- web services for grid computing
- stateful, by necessity (now exploiting WSRF)
- FACTORY pattern for service instantiation
- see Open Grid Services Architecture (OGSA)
  `http://www.globus.org/alliance/publications/papers/ogsa.pdf`

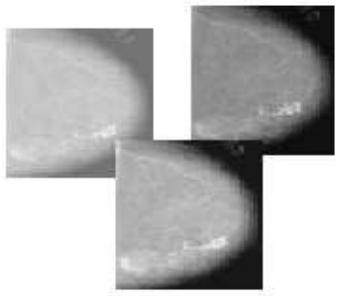
9.3 climate*prediction*.net

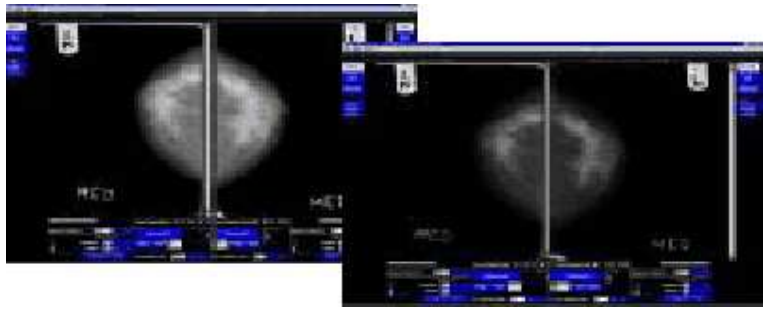
- users donate computer time
- in the style of SETI@home
- but jobs run for weeks, not hours
- running a climate model from the Met. Office
- upload 10Mb of data to servers around the world
- build probabilistic model to predict where we'll be in 2050



9.4 eDiamond

- national database of mammographic images
- applications in training and diagnosis
- Oxford, IBM, various hospitals
- 12MB per image . . .
- major requirements in security, data location, access times





9.5 Cloud computing

- “software as a service”, rented not bought
- services and data hosted online, available anywhere
- data centres, virtualization technologies
- ‘The Cloud’ is a metaphor for the internet (eg in network diagrams)
- eg Amazon WS, Google Apps, Microsoft Azure

9.6 Map-reduce

- Google's programming model for cluster computing
- inspired by functional programming
- works on sets of key/value pairs
- *map* over each pair a function giving intermediate k/v pairs
- for each key, *reduce* all associated values to some summary
- framework handles execution on commodity hardware: partitioning, scheduling, communication, fault-tolerance
- many examples: histograms (wordcount, access stats), distributed grep and sort, reverse web links, inverted index...
- open-source implementation as Apache Hadoop

9.7 Ubiquitous computing

- information processing in everyday objects
- handheld devices, consumer goods, sensors, RFID...
- ad-hoc networks, innovative UIs
- “pervasive computing”, “Internet of Things”, “everyware”
- see MOB

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Web Services	Qualities	Objects	Semantic Web	
tea	tea	tea	tea	
Web Services	Qualities	Objects	Semantic Web	