

Health Informatics

Where we are now, and where we may be going

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Informatics

Informatics is an emerging discipline that has been defined as the study, invention, and implementation of structures and algorithms to improve communication, interpretation, understanding and management of information in order to help solve application-specific problems

In our case, the application is healthcare

Quite a new course!

- Changes to C4B
 - Medical image analysis → C6C
 - Expert systems/AI temporarily “retired”
- I believe there’s a need for such a course!
 - Software systems are the most complex humanly-engineering artefacts in the world!
 - Why medicine?

Fundamental observation

- IT is increasingly pervasive in healthcare delivery (and other complex applications)
- As more imaging and signal modalities become available to clinicians, communications become faster, and computers more powerful, doctors are drowning in data; but what they want is information to guide patient management.
- To do this, systems need to become smarter. Here we examine two currently complementary (though fundamentally linked) aspects to achieving this:
 - Systems capable of reasoning, understanding & offering advice
 - Systems capable of analysing signals and images

Synopsis

1. Introduction & rationale
2. eScience & the Grid
3. Making systems intelligent: AI
4. Intelligent inference systems
5. Image segmentation
6. Shape & measurement
7. Image registration & fusion
8. Molecular medicine

Modern Healthcare

- Continuing surge in knowledge about medicine
 - New ways to diagnose, treat and cure disease
- Continuing ignorance
 - Mental illness, stroke management, arthritis
 - Malaria & other tropical diseases
 - Detect early/cure heart disease and cancer
- Ageing population
 - Life expectancy (in the West) is increasing
 - The body is already outliving the brain
- Social, political, economic challenges
 - Irrespective of political leaning, healthcare costs are dominating western economies
 - Expectation vs reality
 - developed and undeveloped worlds

“medicine is a humanly impossible task”

- “It is now humanly impossible for unaided healthcare professionals to deliver patient care with the efficacy, consistency and safety that the full range of current knowledge could support”
<http://www.openclinical.org/>
- Exponential growth in knowledge and techniques, eg over past 20 years:
 - New imaging modalities CT, MRI, PET, fMRI, MEG
 - Entirely new drug therapies, particularly for cancer and brain disease
 - Molecular medicine

Staying abreast

- Doctors are already working to their limits, and beyond, never mind staying abreast
- Continuing education is vital yet requirements are spotty compared to the USA

Concentration of expertise

- As knowledge becomes deeper and broader, expertise is becoming more widely distributed
- 'Twas ever thus
 - large teaching centres in UK, USA, France, ...
 - postcode medicine
- Trend has accelerated
- Example: mammography in the USA

Population expectations

- Less and less prepared to accept, without challenge, expert pronouncements
- Press reports fuel expectation of *average* treatment that cannot be satisfied by NHS, particularly for a greying population
- More people expect more, high quality treatment, want to participate in management of their condition, want access to specialised knowledge, and they want it now!

Patient management

- Increasingly a team process
 - Multidimensional meeting
 - Dialogue of the “hard of hearing”
- The team is increasingly distributed widely
- The team is increasingly a *Virtual Organisation*
- The timescales are shortening
- While medicine is becoming ever more complex

Patient management = a highly and increasingly complex example of business-on-demand

Health Informatics is changing

- Move to evidence-based medicine
 - Reasoning becomes explicit
 - Based on signals, images, clinical signs, ...
 - (team-based) decision making under uncertainty
- Treatment of disease to anticipation of disease
 - Early diagnosis → better prognosis
 - Prophylactic medicine – the positive role of insurance companies
- Opportunities arising from genomics (and proteomics) to detect and unravel individual variation, stratify patients into disease and treatment groups
 - “Personalised medicines”

Information Technology assumptions

- Moore's law* will continue, at least for a while
 - *Processing power doubles every 18 months
 - 10 years = 6 doubles = 250Xpower of today's computers at comparable cost
- Ubiquitous computers
 - Palm tops have 20 X power&memory of the computers I used for robotics research 10 years ago
- Ubiquitous comms
 - Blue tooth to PACS to the GRID
- Grids will become a major force
 - National & International "virtual organisations" eg BIRN
- Improving software methodologies, large systems
- Increasingly intelligent software, based on AI methods
- Health professionals will be increasingly IT literate
 - IT devices will be used
 - IT devices will replace paper & pencil

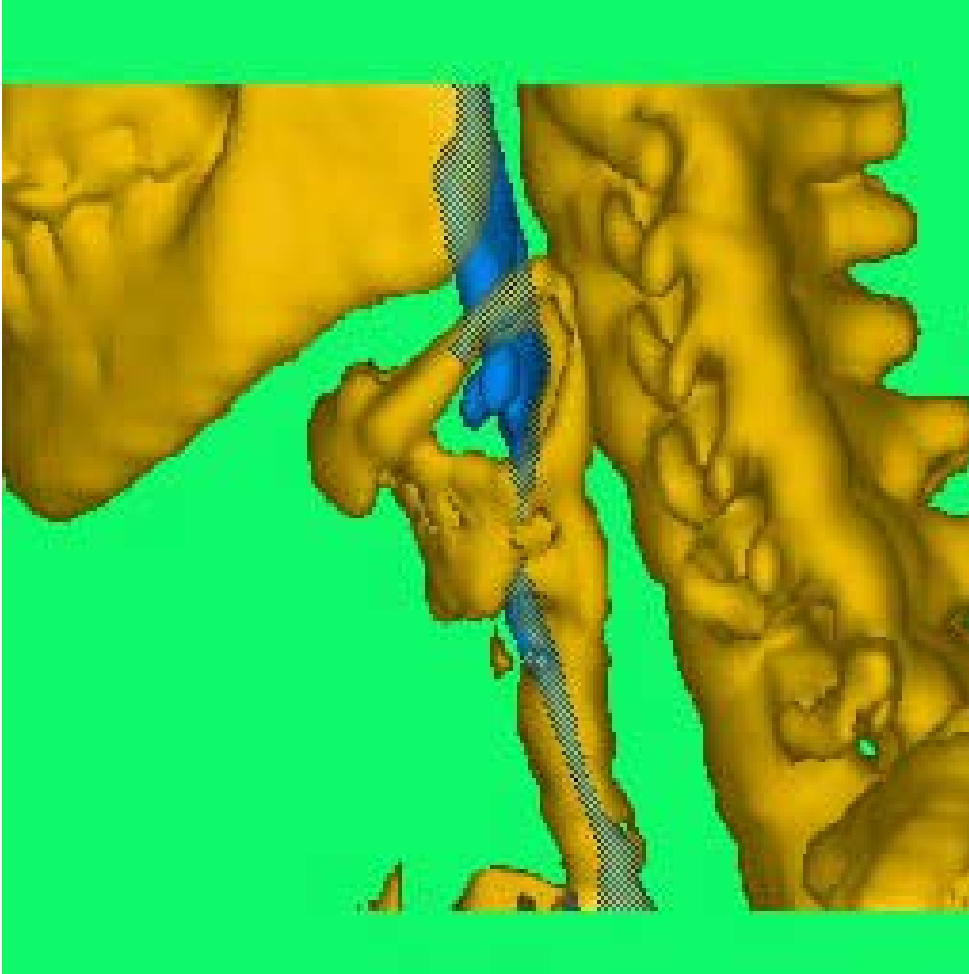


Image courtesy Prof Richard Kitney, Imperial

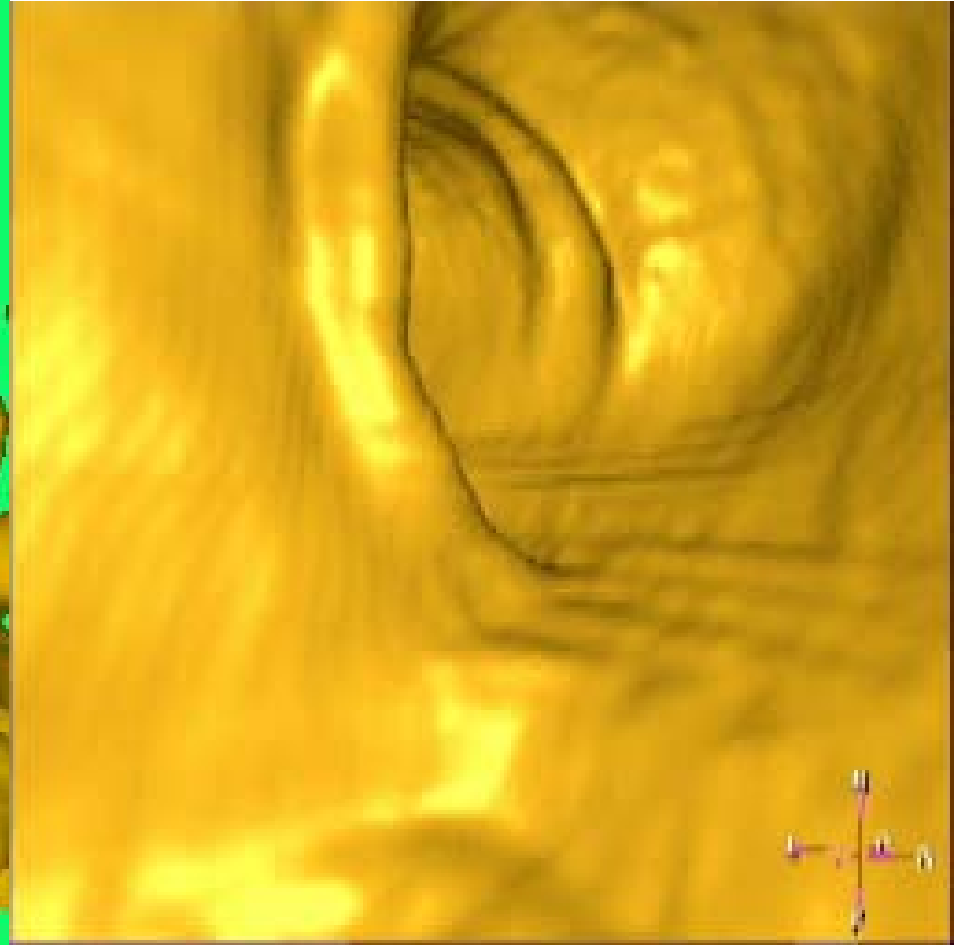
Current reality of health informatics is very different...

- Predominantly visualisation, little analysis
 - Registration (CT-PET), overwhelmingly rigid
 - Predominantly manual segmentation
 - Shape analysis is virtually non-existent

3D visualisation



CT virtual colonoscopy



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- Intensive therapy units are intensively staffed
- PACS* – but images only, text separately
- Patient records and BNF on screen for primary physicians
- Teleradiology doesn't exist
- No fielded AI systems
- Surgery has been largely unaffected by Informatics
 - few planning systems, no post-surgical prediction,
 - ...
- Industry is conservative

*picture archiving and communication systems

From Internet to eScience & the Grid

- Networked computers
- Internet
- Limitations of the Internet → the Grid
- Main features of the emerging Grid
- Healthcare applications of the Grid:
 - eDiaMoND: mammography database
 - Dynamic atlas of images
 - Distributed signal processing

Networked computers

- Why connect computers together?
 - Fail-safe computing (during the cold war)
 - Dedicated “compute” engines (eg US Weather)
 - Client-server model
 - email
- Local area networks – Ethernet
 - Standard based on 7 layers: transport, ..., application
 - Ethernet server → card → internal to a laptop
- Wide area networks – Internet
 - a network of networks
 - Explosive growth in ownership of personal computers and cheap communications (in the USA) encouraged people to connect their PC to the Internet

Ethernet = a standard comprising 7 layers of hardware through to software

application
presentation
session
transport
network
Data link
Physical

1.Physical Layer describes the physical properties of the various communications media, electrical properties and interpretation of the exchanged signals. Ex: size of Ethernet coaxial cable, the type of BNC connector used, and the termination method.

2.Data Link Layer describes the logical organization of data bits transmitted on a particular medium. Ex: defines the addressing and checksumming of Ethernet packets.

3.Network Layer describes how a series of exchanges over various data links can deliver data between any two nodes in a network. Ex: defines the addressing and routing structure of the Internet.

4.Transport Layer describes the quality and nature of the data delivery. Ex: this layer defines if and how retransmissions will be used to ensure data delivery.

5.Session Layer describes the organization of data sequences larger than the packets handled by lower layers. Ex: this layer describes how request and reply packets are paired in a remote procedure call.

6.Presentation Layer describes the syntax of data being transferred. Ex: this layer describes how floating point numbers can be exchanged between hosts

7.Application Layer describes how real work actually gets done. Ex: this layer would implement file system operations.

Internet : the “Web”

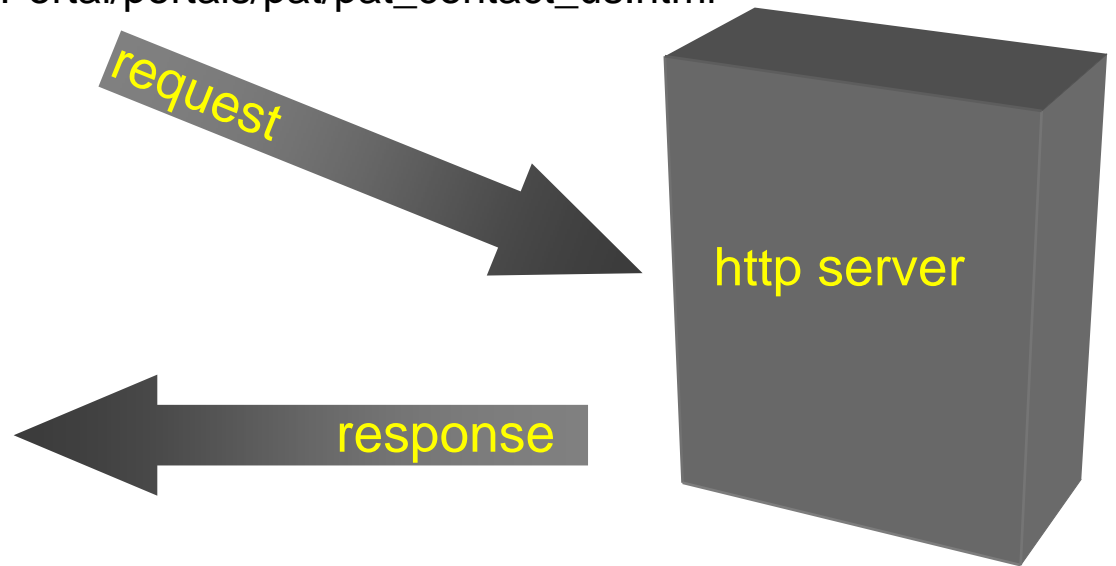
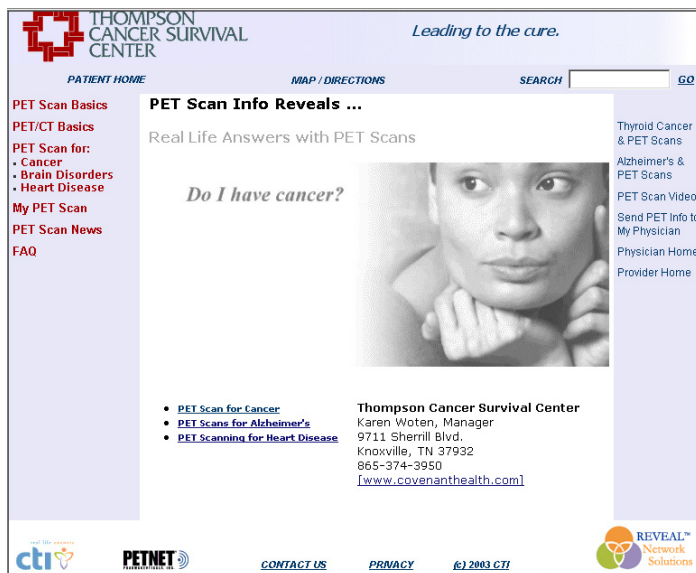
- 3 standards
 - html : hypertext markup language
 - http: hypertext transfer protocol
 - tcp/ip: transmission control protocol & internet protocol
- www is a network application that uses tcp/ip
- http enables resources to be communicated over the Web

http

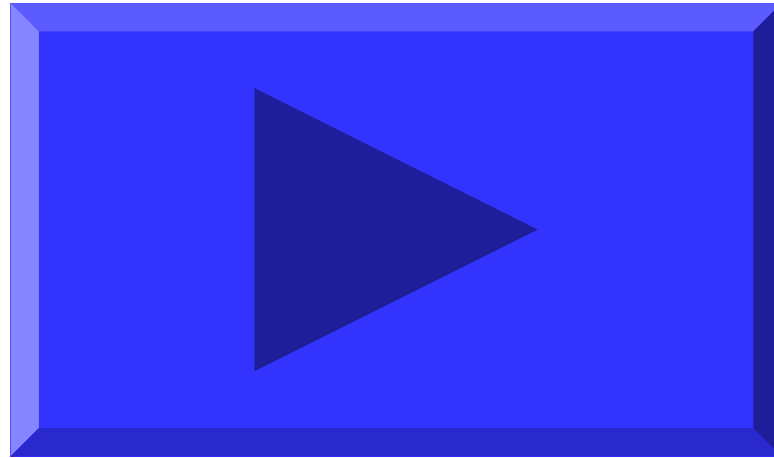
A client web browser sends a request for a resource to a web server and this sends back a response.

The http response carries the sought resource back to the web browser

http://www.covenanthealth.com/PatientPortal/portals/pat/pat_contact_us.html



http is **stateless**: each interaction is independent of any other, so the request header includes: security information, type of pages user can browse, limits, ...



What information is provided?

- Patient
 - disease, how imaging works, what to expect, where to learn more, ...
- Physician
 - Reimbursement, clinical studies, up-to-the-minute news, tricky cases, ...
- Provider
 - Ordering doses, scheduling visits, reminders, gathering statistics, ...

Internet's explosive growth

- Currently 750 Million devices connected to the Internet
 - Expected to reach 1 Bn by 2005, 1.5Bn by 2007
 - Number is split equally between Europe, Asia, and North America
- Images, digital cameras, and family snaps
- Google ...
 - 20,000 PCs in 6 centres plus load balancing software
- Business use of the Internet
 - Products, services, and corporate propaganda
 - Ticketless airlines, theatres, ... disintermediation
 - Downloads
 - Service centres
 - recruitment

“information” from the web

- There are no constraints on **who** can post information on the web
- Few constraints on **what** can be posted
- Some constraints on what can be downloaded (eg from sites catering to paedophiles)
- There is **limited security** especially on Microsoft’s Internet Explorer
- Very little “information” is authoritative

What are Grids?

- Dynamically assembled resources
 - For storage, or for computation
 - 50,000 PCs* beats any supercomputer**
 - We need this power for integrated systems biology

- Standards

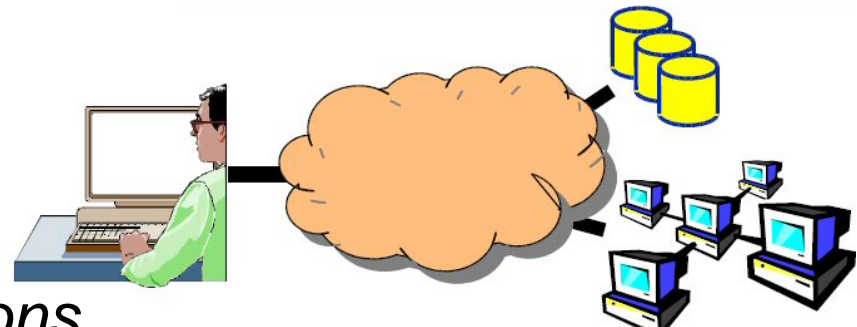
- Secure transmission
- WebServices

- Federation

- Databases & local curation
- Users in *Virtual Organisations*

* 1Bn computers connected to Internet by end 2005

**Google uses 20,000 in 6 centres plus load balancing



Developing example in Neuroscience is USA *Biomedical Informatics Research Network* <http://nbirn.net> organised as functional + morphological + mouse

The technology of Grids

- Large-scale distributed computing
 - Initially, hooking up powerful processors
 - Increasingly, automatically “out-sourcing” provision of storage, cycles to geographically remote, *a priori* unknown, machines capable of providing the needed *service*
 - Optical Wide-area interconnect now faster than internal buses on a computer
- Grid(s) as providers of services
 - Rapidly emerging standards
- Virtual organisations connected by Grids

Virtual Organisation

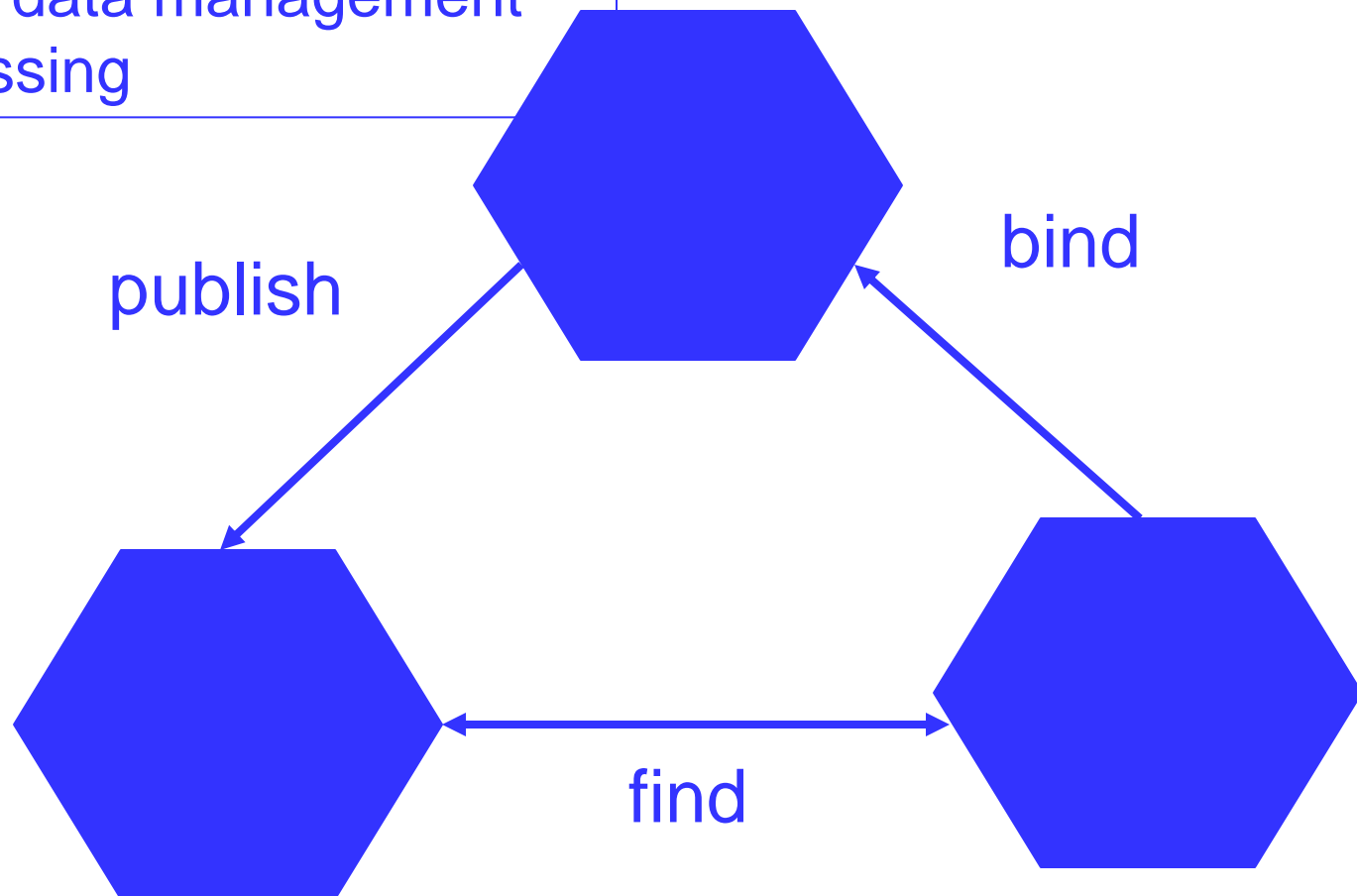
- Group of individuals, institutes, companies, ... who are geographically distributed but who appear to function as one single unified organisation
- Common focus enshrined in a set of services
 - End users in a VO can use the shared services according to the rules of the VO and resource providers
 - VOs can be dynamic: set of users, services, and resources may change
- One typical service is security

Core service areas

- Systems management & automation
- Workload/performance management
- Security
- Availability/service management
- Logical resource management
- Clustering services
- Connectivity management
- Physical resource management

Open Service Architecture

Service provision view of
distributed data management
and processing

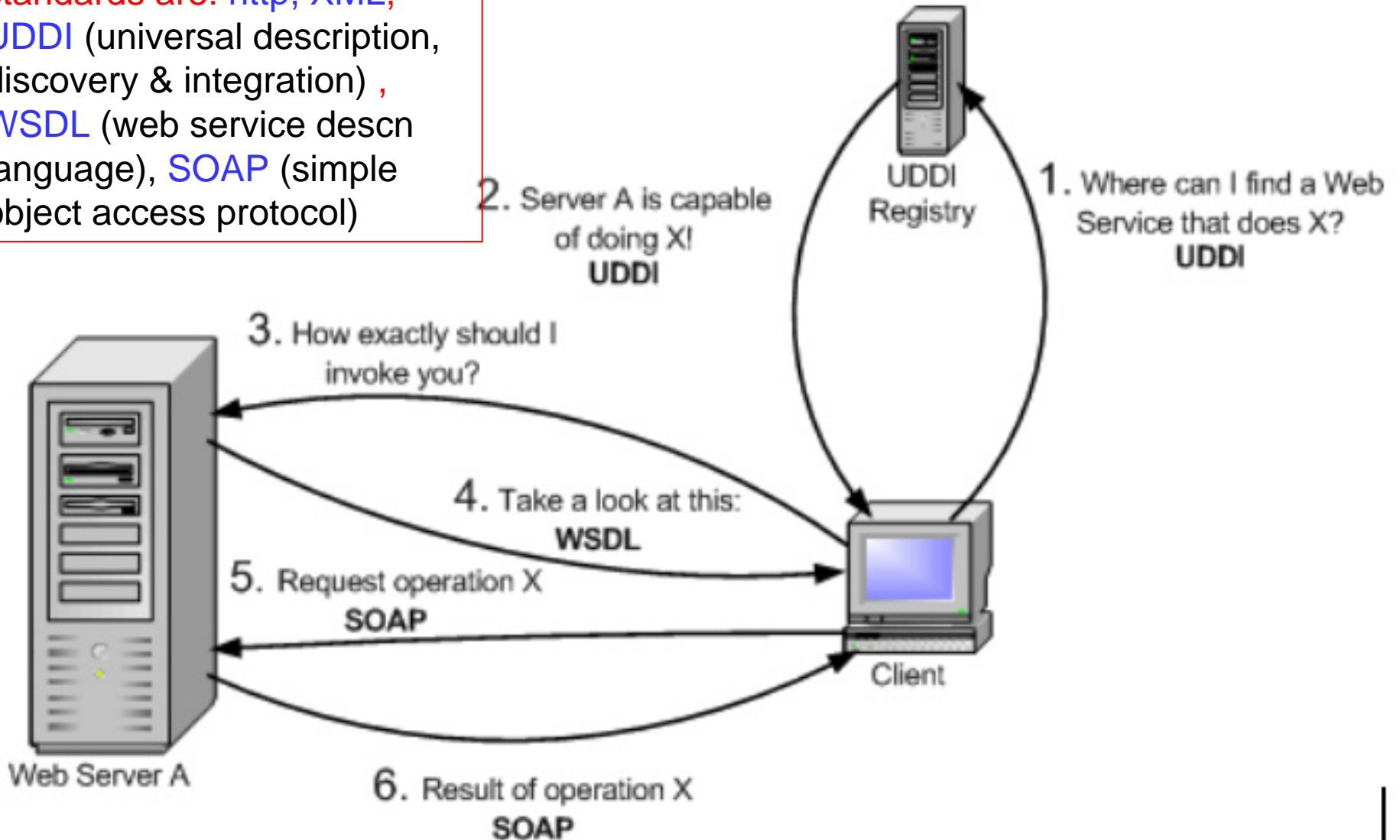


Web service standards

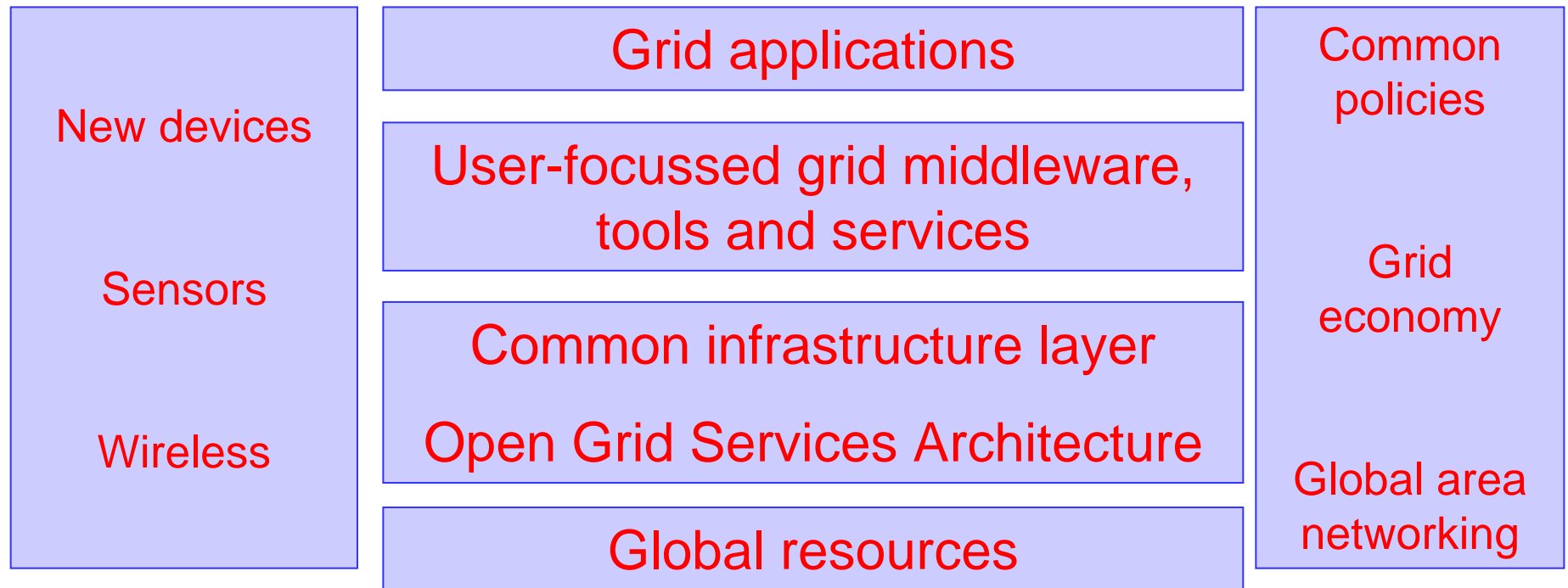
- **UDDI: universal description, discovery & integration**
 - Similar to yellow/white pages – publish services
 - A service requestor makes requests to the registry
- **SOAP: simple object access protocol**
 - Envelope that encapsulates XML data for transfer through Web infrastructure (over http)
 - Provides for remote procedure call
- **WSDL: web service description language**
 - Describes a service in XML

Connecting the Web services together

Current web service standards are: [http](#), [XML](#), [UDDI](#) (universal description, discovery & integration) , [WSDL](#) (web service descn language), [SOAP](#) (simple object access protocol)



Layered architecture of the Community Grid Model



The layered architecture builds on that developed over the past 20 years for local area networking and WAP phones