

Mammography & the Grid

e-Diamond and MiAKT

MICCAI tutorial, September 26, 2004

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What might the Grid offer?

- Distributed power, bandwidth & security etc
- Federated database: eDiamond
- Statistical power
- New approaches to CPD
- Distributed intelligence & semantic web: MiAKT
- Support for continuous monitoring
- On-demand epidemiology
- Personalisation
- Coping with the mobile population
- Accommodate massive ranges of spatiotemporal scales
- Drug discovery and image-based clinical trials
- ...

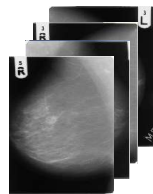
What might the Grid offer?

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UK Breast Screening – Today

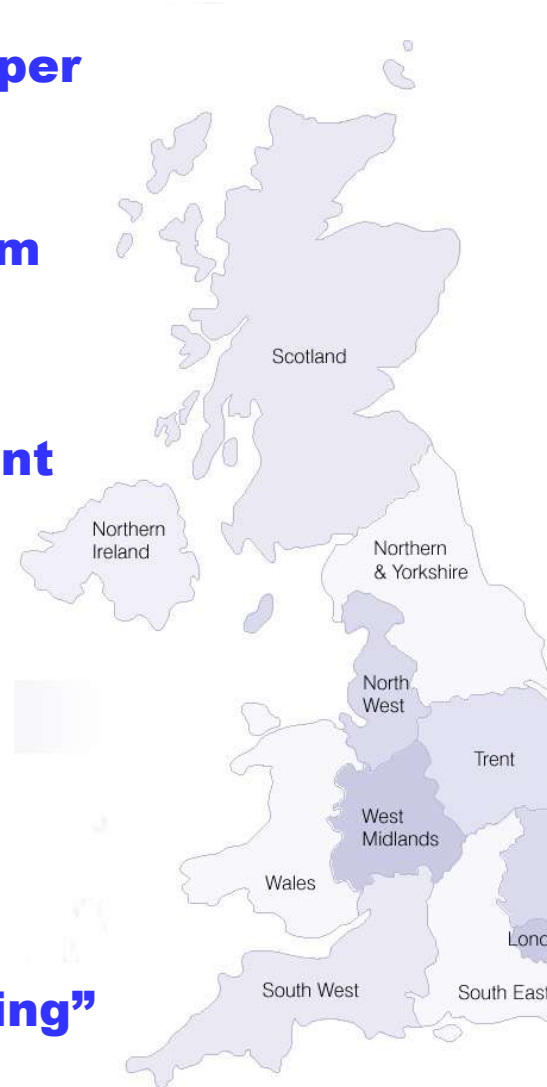


Paper



Film

1.5M - Screened in 2001-02
65,000 - Recalled for Assessment
8,545 – Cancers detected
300 - Lives per year Saved



Began in 1988

**Women 50-64
 Screened
 Every 3 Years
 1 View/Breast**

**Scotland,
 Wales,
 Northern Ireland
 England
 (8 Regions)**

**92 Breast
 Screening
 Centres**

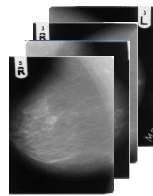
**Each centre sees
 5K-20K images/yr**

230 – Radiologists “Double Reading”

Statistics from NHS Cancer Screening web site



Digital

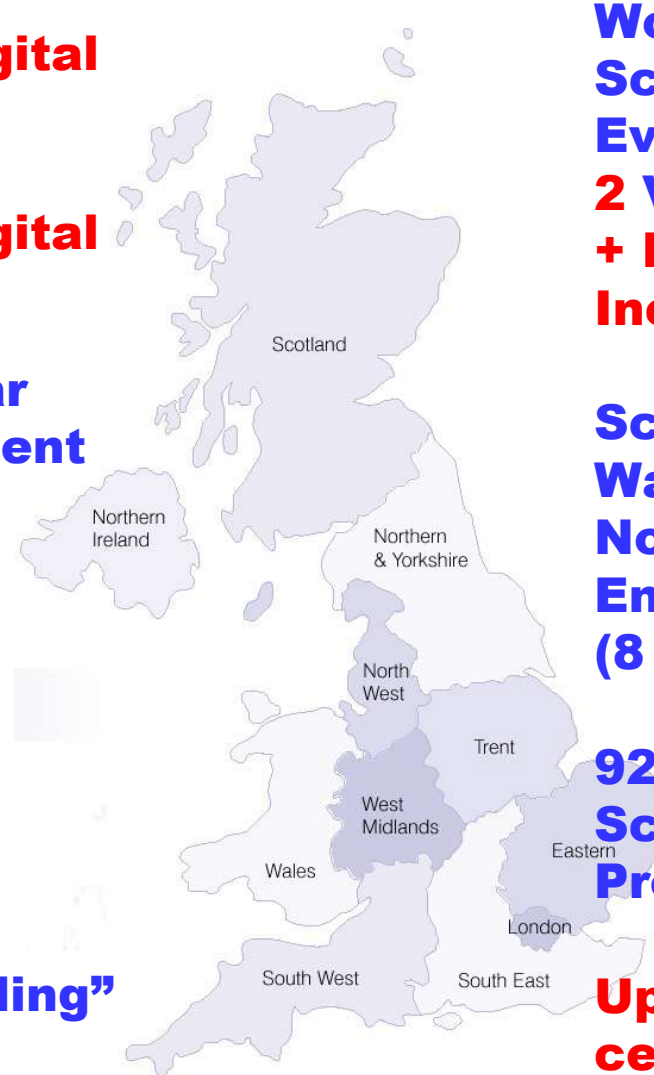


Digital

2,000,000 - Screened every Year
120,000 - Recalled for Assessment
10,000 - Cancers
1,250 - Lives Saved



230 - Radiologists “double Reading”
50% - Workload Increase



**Women 50-70
Screened
Every 3 Years
2 Views/Breast
+ Demographic
Increase**

**Scotland,
Wales,
Northern Ireland
England
(8 Regions)**

**92 Breast
Screening
Programmes**

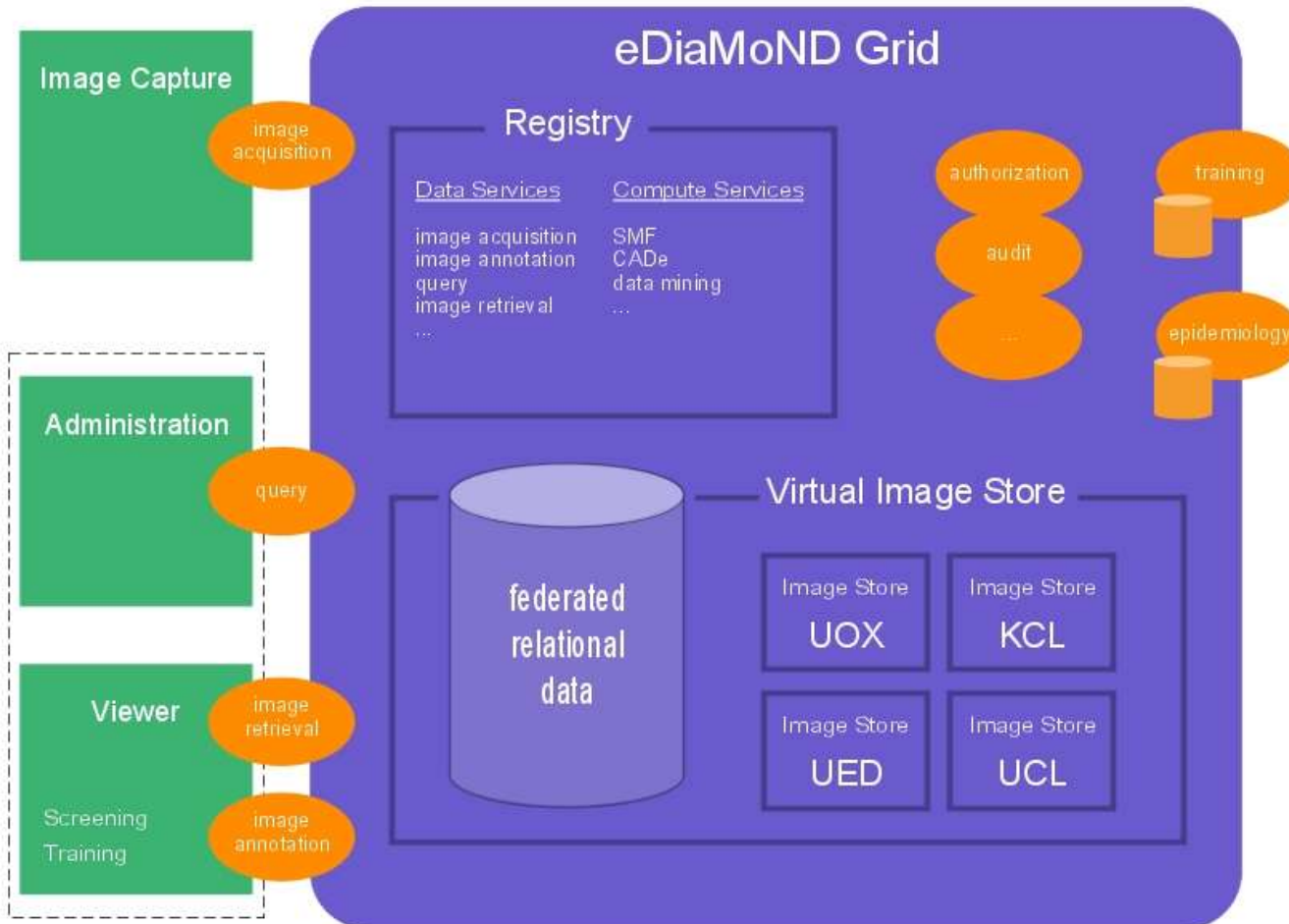
**Up to 50K/yr per
centre**



end-user project goals

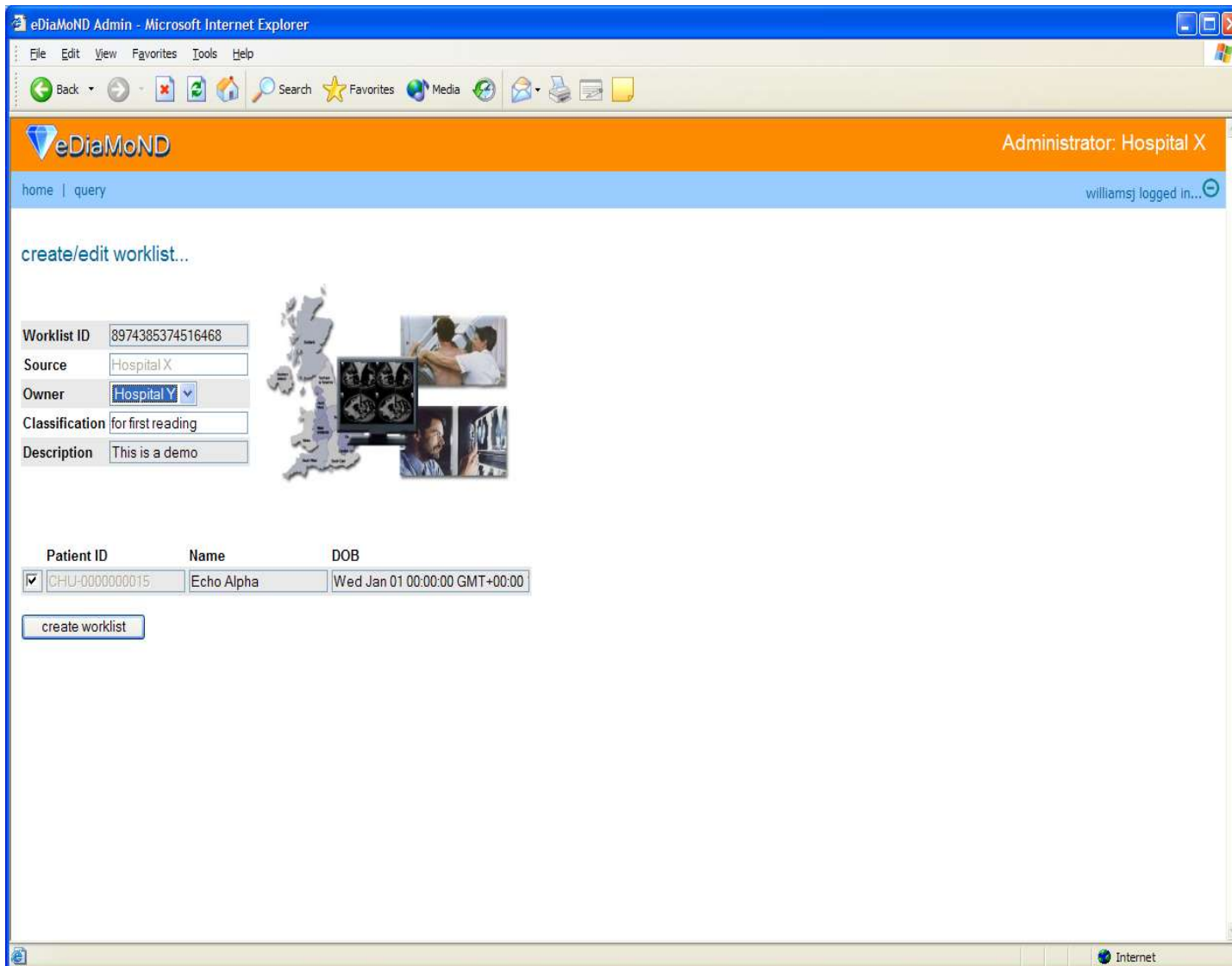
- Architecture
 - IBM Hursley, Oxford eScience Centre
- Acquisition workstation
 - Mirada Solutions
- Teaching tool for radiologists, radiographers
 - St George's Hospital
- Tele-diagnosis
 - Edinburgh Breast Screening Unit, W. of Scotland
- Algorithm development: data mining
 - Oxford medical vision, Oxford Radcliffe Breast Care Unit, Mirada
- Epidemiology
 - Guy's Hospital, London
- Quality control
 - Oxford Medical Vision Laboratory, Mirada Solutions

Clinicians want to ***use*** the Grid & they profoundly wish to remain ignorant about how it works



Key functions are:

- Image acquisition (EDAS)
- query – by several classes of user
- Image retrieval – individually or as a collection
- Diagnostic reports
- Image processing & data mining



eDiaMoND Admin - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites Media

eDiaMoND Administrator: Hospital X

home | query williamsj logged in...

create/edit worklist...

Worklist ID: 8974385374516468
Source: Hospital X
Owner: Hospital Y
Classification: for first reading
Description: This is a demo

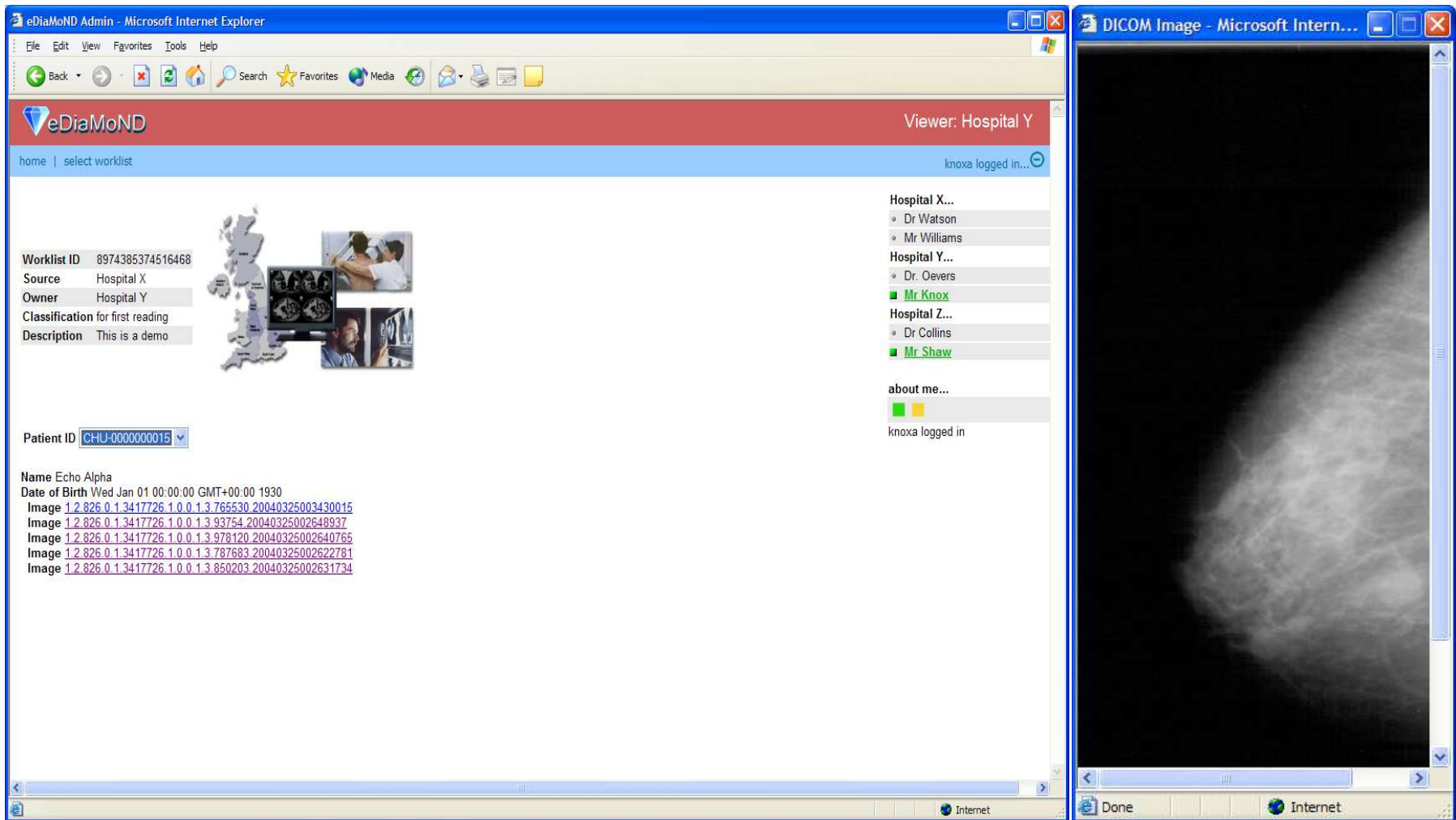
Patient ID Name DOB

<input checked="" type="checkbox"/>	CHU-0000000015	Echo Alpha	Wed Jan 01 00:00:00 GMT+00:00
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create worklist

Authorised personnel at hospital X can create and edit a worklist

The images in the worklist can be owned by Hospital Y



The screenshot shows two overlapping browser windows. The left window is titled "eDiaMoND Admin - Microsoft Internet Explorer" and displays the application's main interface. The right window is titled "DICOM Image - Microsoft Intern..." and shows a grayscale DICOM image.

eDiaMoND Admin - Microsoft Internet Explorer

Viewer: Hospital Y

home | select worklist knox logged in...

Worklist ID: 8974385374516468
Source: Hospital X
Owner: Hospital Y
Classification for first reading
Description: This is a demo

Map of the United Kingdom with a red dot indicating the location of Hospital X. Below the map are two small images: one showing a person at a computer and another showing a person at a desk.

Patient ID:

Name: Echo Alpha
Date of Birth: Wed Jan 01 00:00:00 GMT+00:00 1930
Image: [1.2.826.0.1.3417726.1.0.0.1.3.765530.20040325003430015](#)
Image: [1.2.826.0.1.3417726.1.0.0.1.3.93754.20040325002648937](#)
Image: [1.2.826.0.1.3417726.1.0.0.1.3.978120.20040325002640765](#)
Image: [1.2.826.0.1.3417726.1.0.0.1.3.787683.20040325002622781](#)
Image: [1.2.826.0.1.3417726.1.0.0.1.3.850203.20040325002631734](#)

DICOM Image - Microsoft Intern...


about me...
knox logged in





Once there is a worklist created at Hospital X, DICOM images owned by Hospital Y can be viewed by an authorised person at Hospital Z, eg for second reading

http://edibm01.hursley.ibm.com:8085/eDiaMoNDAdmin/pictures/portal-demo.svg - Microsoft Internet Explorer




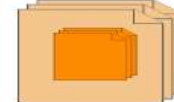
File Edit View Favorites Tools Help


Back Search Favorites Media





Hospital X 
4




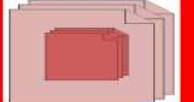
1 0











Hospital Y 
4




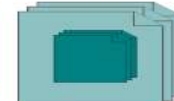
0 1

Hospital Z 
4

0 0

Work visible from Hospital Y:

Classification	Items	Owner	Source	Description
for first reading	1	Hospital Y	Hospital X	This is a demo

Internet

This is a view of the Grid as it would appear to the Grid maintenance centre



- control digitisation of films (or input of directly digital images)
- facilitate addition of annotations
- attach annotations to digitised images
- create/maintain local database
- serve *pro tem* as visualisation platform



Reporting and Annotation

Lesion-Image Items

1,2.826.0.1.3417... Lesion Item: R MLO
1,2.826.0.1.3417...

Area Measurements

<blank> Area Measurement: Not selected ... Show

Add Remove Add Remove

Lesion ID: CHU-0000000015-LSN-0000000001

Architectural Distortion Special Cases: Tubular Density/Solitary Dilated Duct

Associated Findings: Skin Thickening

Best illustration of finding: N/A

Biopsy Assessment: Skin Retraction
Nipple Retraction
Skin Thickening
Trabecular Thickening

Calcification Distribution: Skin Lesion

Calcification Morphology: Axillary Adenopathy

CC Difficulty: ***

CC Location: Inner Posterior

Typicality of Presentation:

Cytology Assessment:

Mass Density:

Mass Margins: Indistinct (Ill Defined) Margins

Mass Shape: Oval

- support entry of patient data
- reports on location and type of lesion
- ...

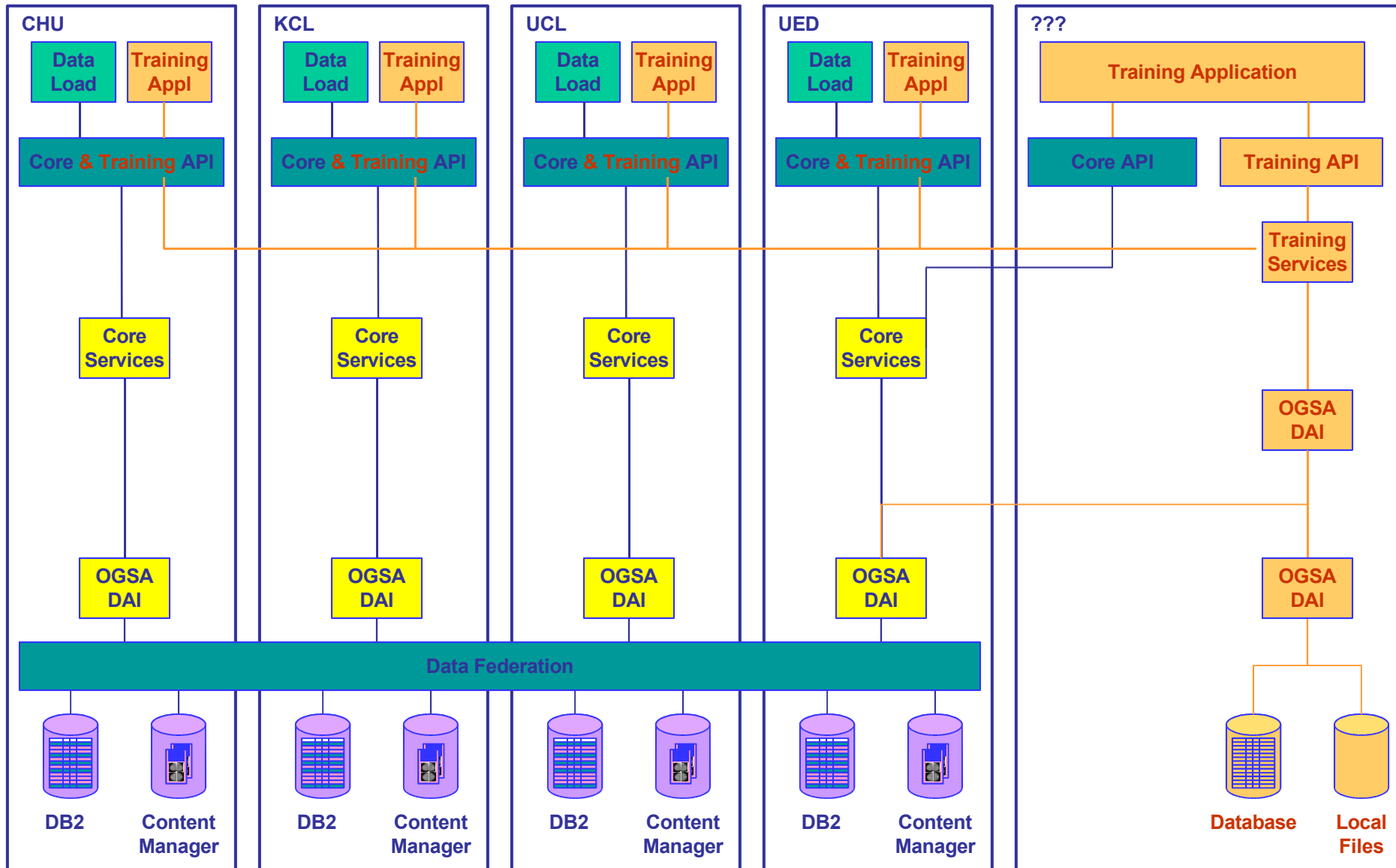
Reporting varies from centre to centre

Several people contribute at different times to the report & have differing levels of authority

Several people can access & use the report

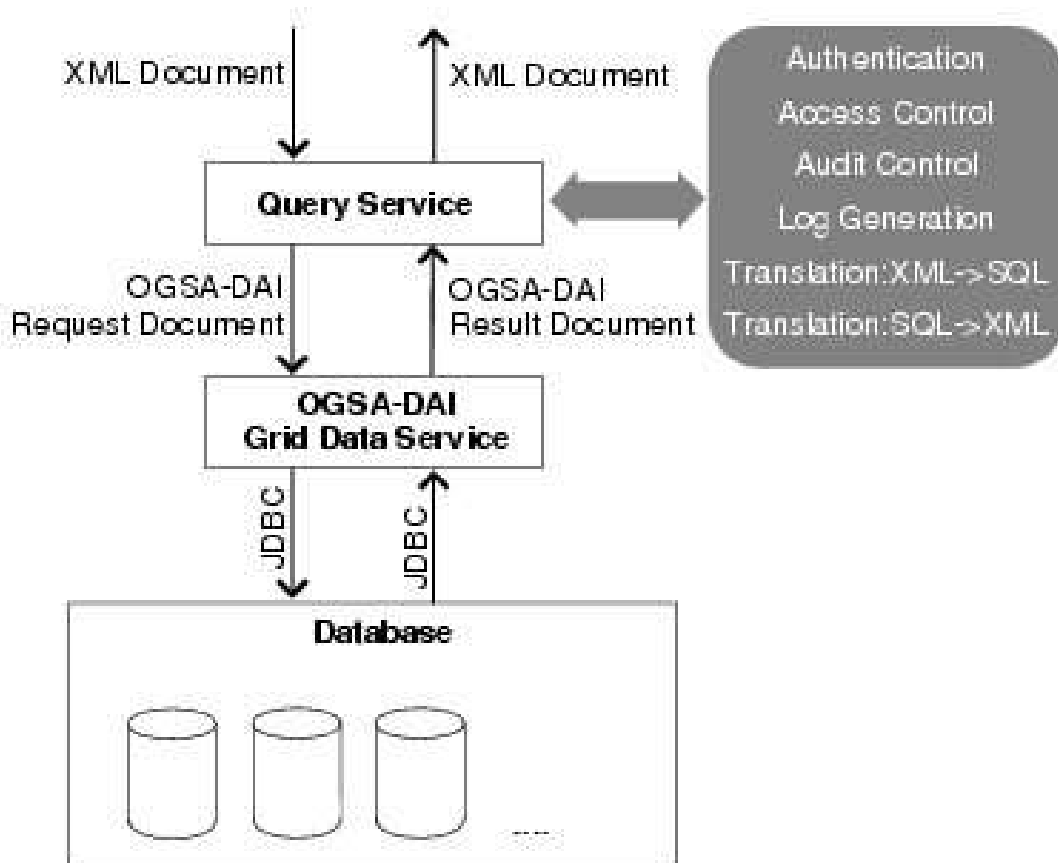
- **Virtual image store**
 - Each breast care unit maintains its own image store (relational database of patient data & image metadata)
- **Open standards**
 - OGSA (Open Grid Services Architecture) GT3
- **OGSA-DAI**
 - Data Access & Integration (UK project)
 - Enables data resources such as databases to be incorporated in OGSA
 - OGSA-DAI services represent non-image & image data
 - “Staging” of data & creation of a worklist
- **IBM’s DB2 & Content Manager**

Application Development Methodology

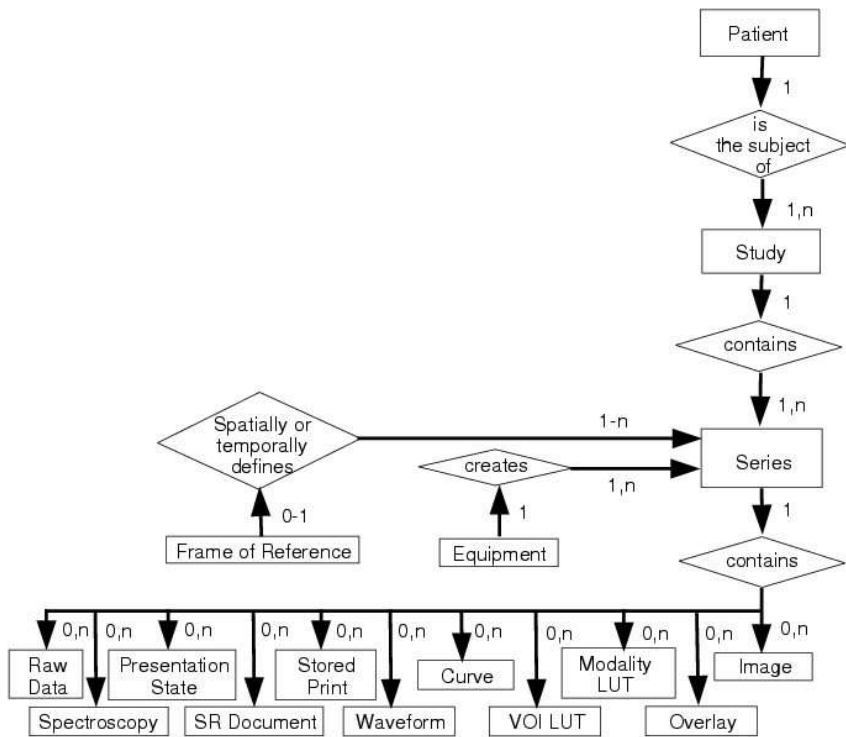


- Large data sets
 - Images
 - screening forms as DICOM Structured Report Documents
- Multimodality
- Data heterogeneity
- Multi-view, temporal and bilateral sets
- Infrastructure support
- Security

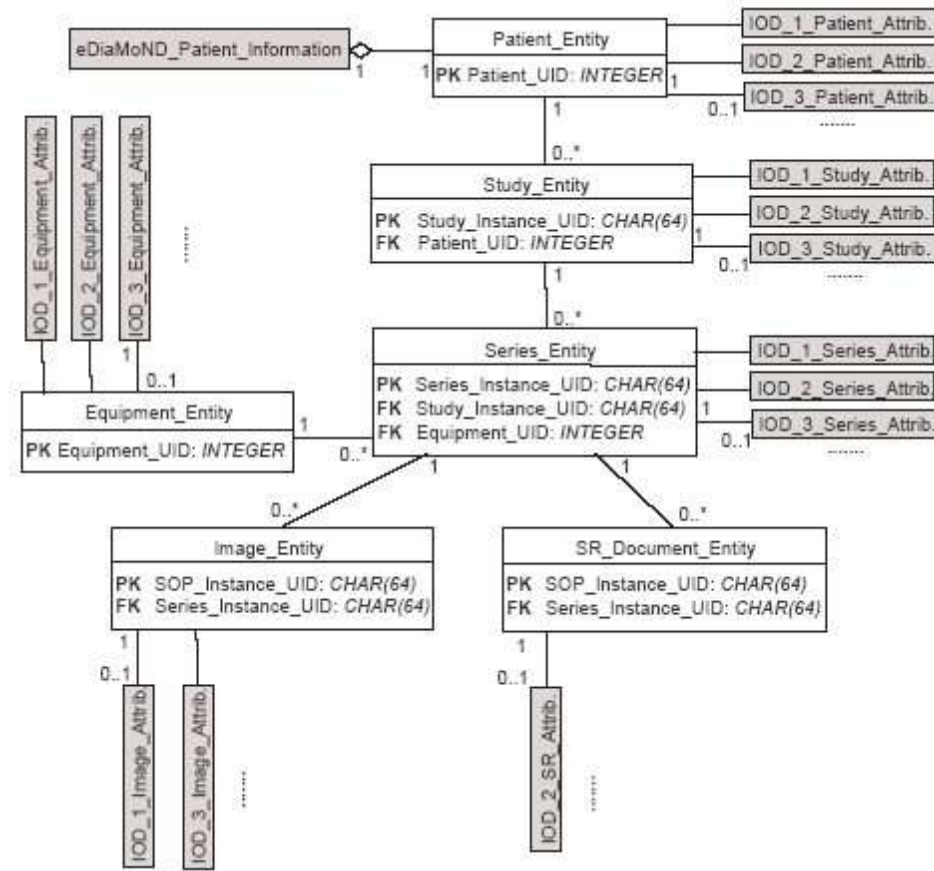
Grid query service architecture



- Interactions with eDiamond database via web services
 - query using XML documents
 - Ascertain the access rights of a user
 - Passed to OGSA-DAI
 - Returns an XML document (easy to translate)
- Access attempts are logged correctly
 - Several users can be mapped to a single database account while maintaining traceability



DICOM entity relationship diagram



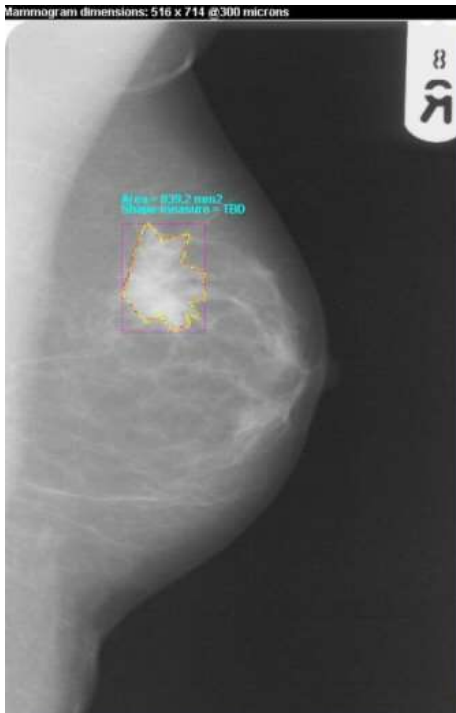
Schema to store DICOM data for eDiamond

- Considerations
 - Ethical & legal
 - NHS network constraints
 - Current & projected IT initiatives
 - Deployment of workflow methods
- Asset attributes
 - Confidentiality
 - Availability
 - Integrity
- human error
- annotation error
- software failures
- IP rights infringed
- data corruption
- theft
- natural disaster
- hacker
- DOS attack (eg virus)
- Unauthorised snoop
- impersonisation

Computer based diagnosis

Training sets

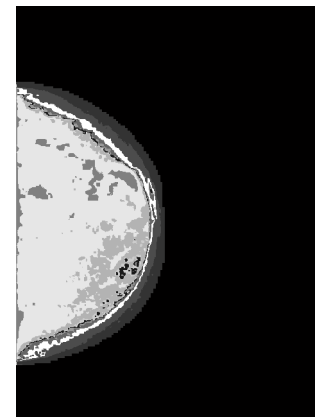
- learn characteristic signs from positive examples (eg cancers)
- normality from a screening population, from which abnormality = tails of the normal population density function (“novelty”)



Regions defined by dense attenuation and significant changes in local phase

Have associated descriptor of the shape of the region (left, here spiculated)

Have associated texture descriptors learned from training set (textons from filter response \blacktriangleleft hidden MRF (right)



Training sets

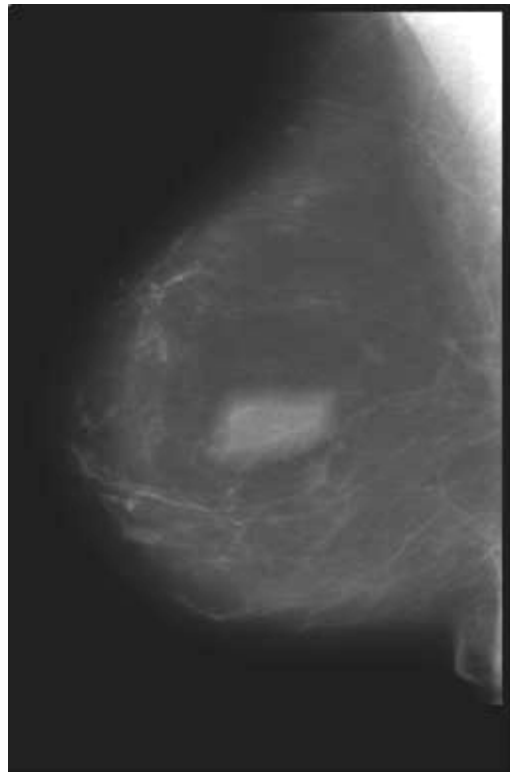
- Subtle distinctions need to be learned
- Images are complex, with poor SNR
- Need many feature dimensions to guarantee acceptable sensitivity/specificity
- “curse of dimensionality”
- Conclude: need vastly more exemplars for learning than can ever be provided in even the largest centres



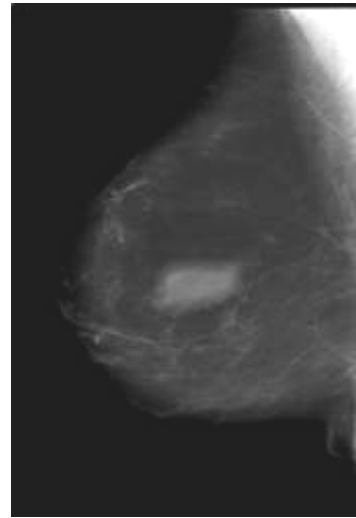
Can the Grid provide the required power?

- Screening results in about 6 cancers per 1000 cases
- A typical centre sees 10,000-15,000 screening cases annually, that is, 60-90 cancers
- The Grid potentially provides the statistical power at acceptable bandwidth and with guarantees on secure image/data transmission

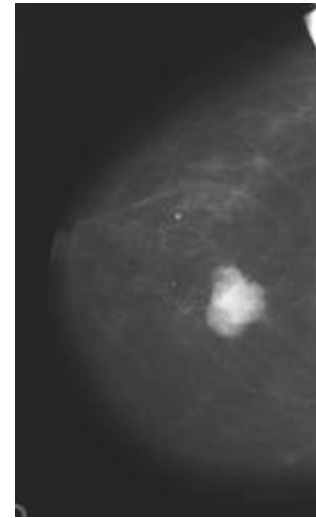




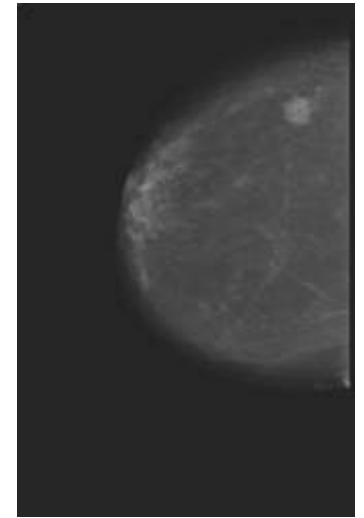
Query image



Response 1



Response 2



Response 3

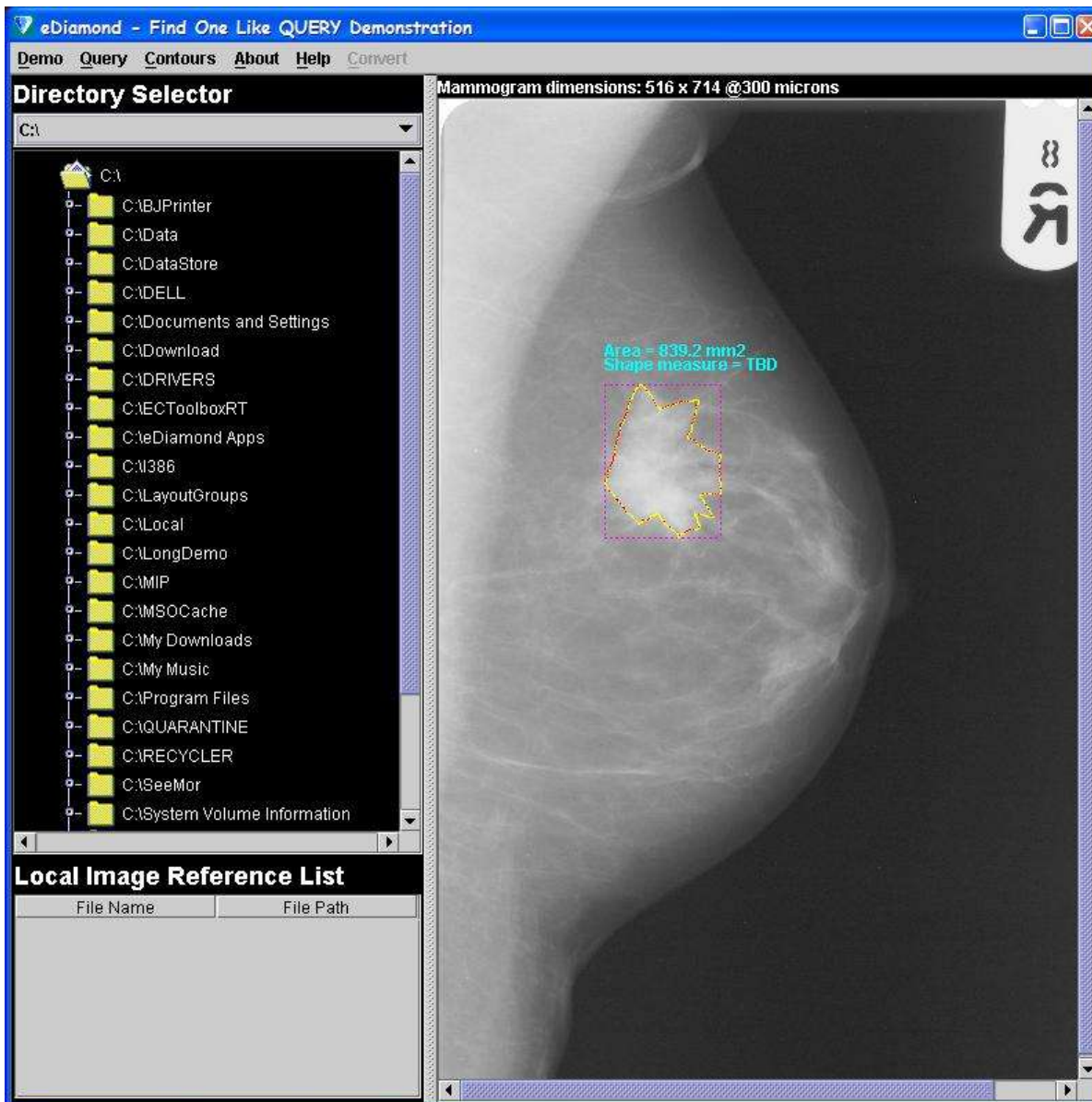


```
graph TD; QI[Query image] --> DB[eDiamond federated database]; DB --> R1[Response 1]; DB --> R2[Response 2]; DB --> R3[Response 3];
```

eDiamond federated database

Search features include: boundary, shape, texture inside & outside, ...

Image data mining: *FindOneLikeIt*



Grid-enabled find-one-like-it from the Mirada EDAS

Search features include:
boundary, shape, texture
inside & outside, ...

VirtualMammo Grid

- VirtualMammo is a CPD tool for radiographers
 - Distributed in USA by ASRT
 - Recently made freely available for NHS staff by Mirada
- VirtualMammo models image formation
 - User can experiment with changing tube voltage, exposure time, ...
 - Distributed with a “canned” set of cases

Mirada-Solutions - VirtualMamm: CE Single User Licence
 File | Help | About | Contact Us
 C:\Images\08RC (0x0.0cm, 3x114.0mA)

Normal equipment
 Ideal Grid
 Ideal Grid and Tube
 Energy
 Hotlight
 Density

Simulate 'ideal' x-ray equipment

View the 'hotlight' and 'density' options

See the effects on patient exposure

Change the tube voltage

Alter the film-screen characteristics

Change the automatic exposure control

Exposure (mAs): $I_x = 114$

Tube Voltage (kVp): 25 26 30

Activate AEC
 AEC to front AEC to mid AEC to back

Gradient: 0.2
 Speed: 11
 Change Film-Screen

see setting: Base = 1.5

$I(\text{SMF}|\text{exp}=115\text{mAs})$

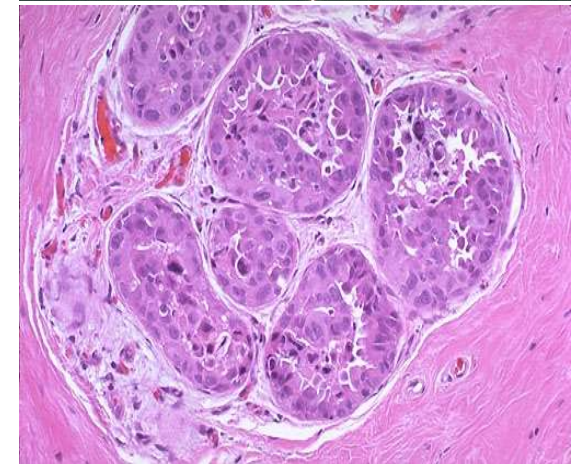
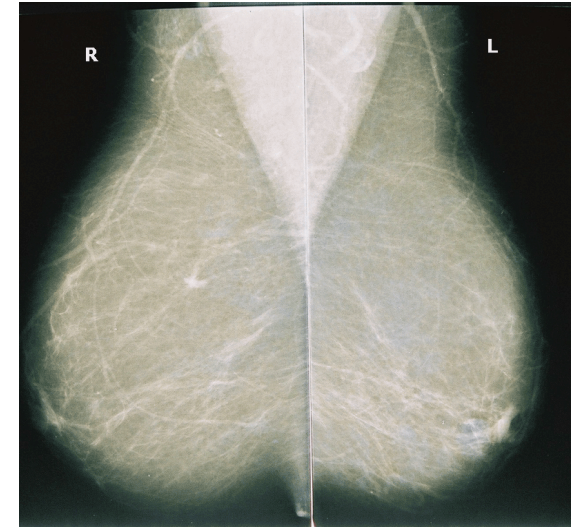
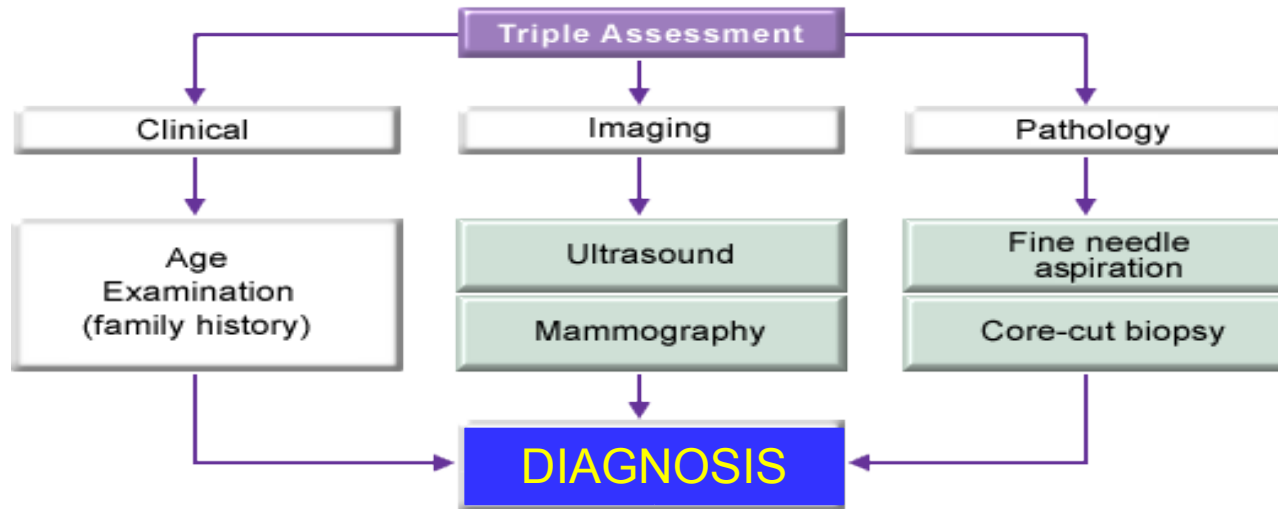
$I(\text{SMF}|\text{exp}=66\text{mAs})$

See me anytime for a demonstration

Why VirtualMammo *Grid*?

- Much of medical training resembles apprenticeship
- Examples are drawn from teacher's personal experience to illustrate points raised in class
 - a canned set of cases is not enough
- But most teachers only see a small percentage of the cases of interest ..
- Need to be able to generate SMF “on demand” perhaps after data mining for suitably annotated images ... ie Grid enable it

The application domain: breast cancer management



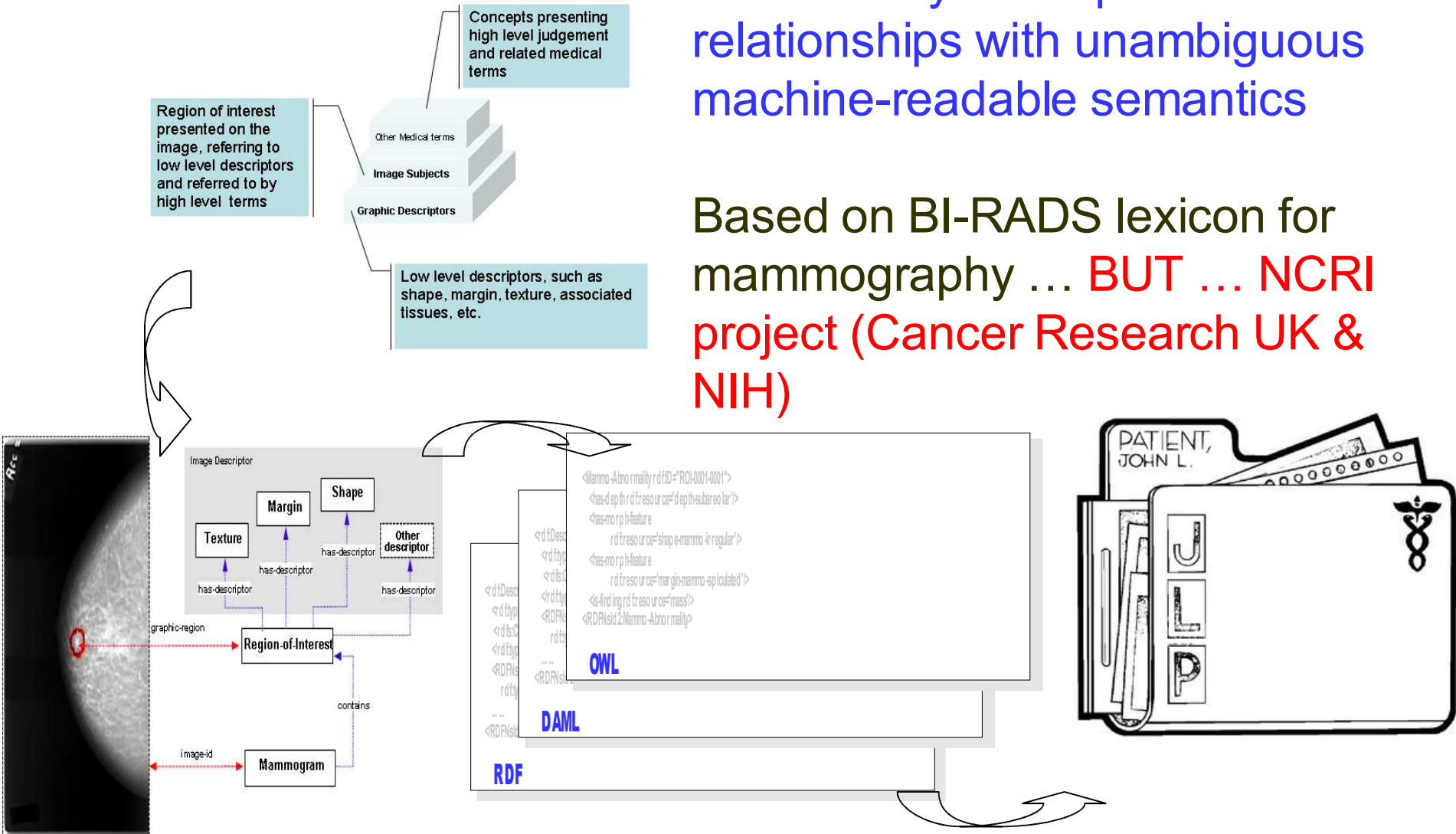
Diagnosis is reached after image analysis AND reasoning about image contents and patient data

Joint initiative between two major projects in the UK:
MIAS (Medical Image analysis) and
AKT (Advanced Knowledge Technologies)

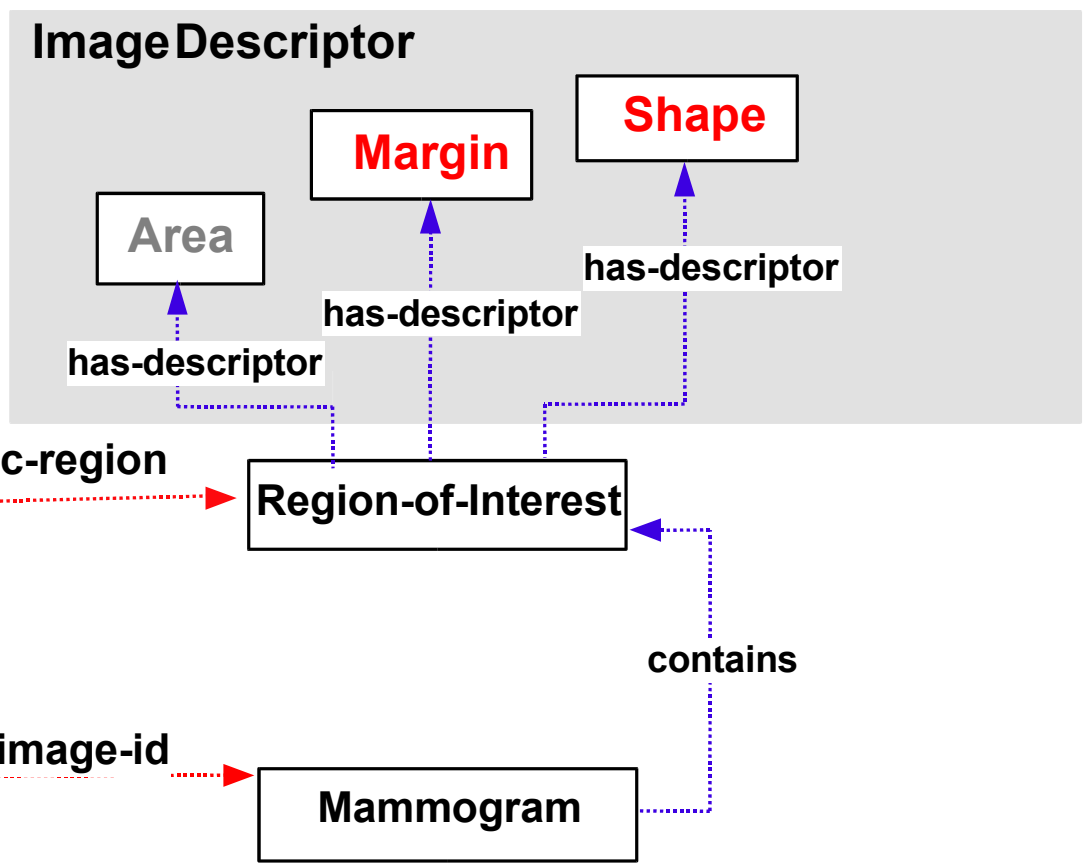
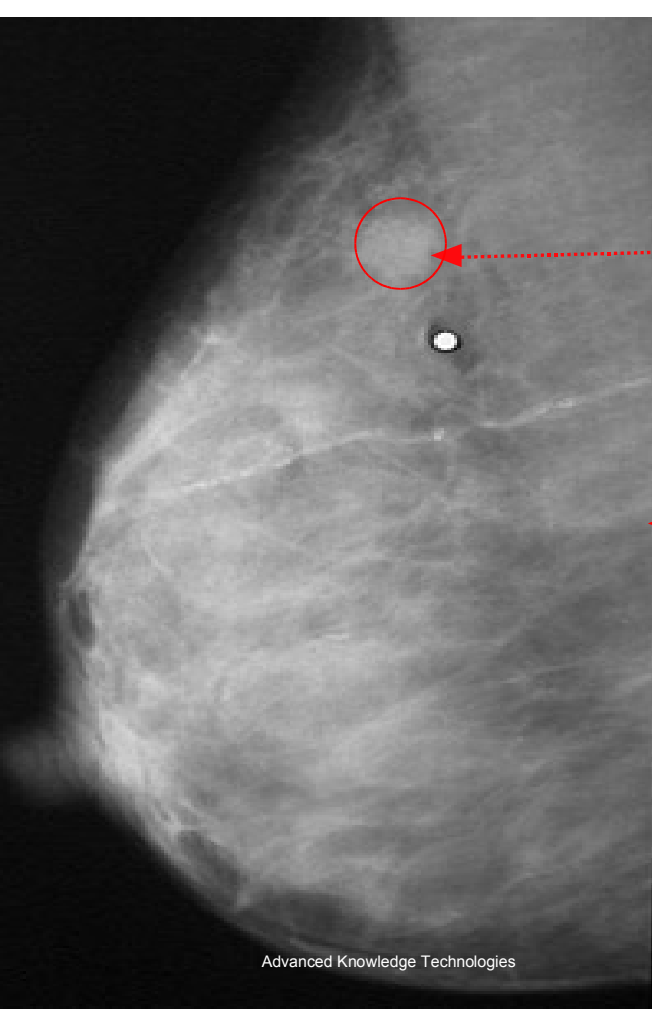
Ontology for breast cancer

Index of key concepts and their relationships with unambiguous machine-readable semantics

Based on BI-RADS lexicon for mammography ... **BUT ... NCRI project (Cancer Research UK & NIH)**



Ontology-mediated annotation



Enrichment of Region of Interests
by the computer or by the **user**

Browser interface

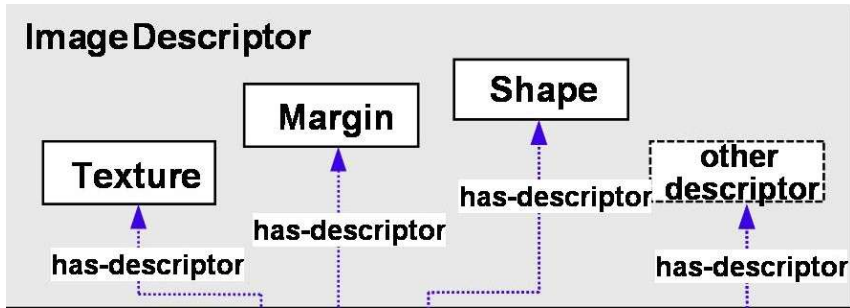
The screenshot displays the MIAKT Demonstrator interface, which is divided into three main sections:

- Concept Browser (Left):** A hierarchical tree view of the ontology. The root is "BC_Domain_Top", which branches into categories like "Medical_Exam", "Medical_Descriptor", "Patient", "Image_Descriptor", and "Findings".
- Central Ontology Diagram:** A network graph showing relationships between concepts. "BC_Domain_Top" is the central node, with "is-a" relationships to various sub-concepts such as "Patient", "Medical_Exam", "Triple_Assessment_Proc", "Medical_Imag", "Lateral_Side", "Breast_Disease", "Image_Descriptor", "Metadata", "MRI_Process_Descriptor", "MRI_Contrast_Media", "Medical_Descriptor", and "Clinician".
- Right-Hand Panel:** A detailed view of instances. It shows the "Instance 00071_patient" with properties like "type: Patient", "has_age: 57", and "involved_in: ta-soton-1070478266177". Below this, it lists "Instance ta-soton-1070478266177" and "Instance 00071_mammography" with their respective properties. At the bottom, four mammography images are displayed, labeled "Right_Lateral_Image", "Right_CC_Image", "Left_Lateral_Image", and "Left_CC_Image".

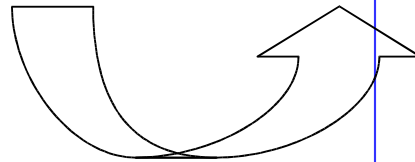
Key interactive elements are highlighted with red circles:

- The "Invoke task: Find Patients With Same Age" button.
- The "Invoke task: Find TripleAssessments with same Lateral View" button.
- The text "FIND SIMILAR..." overlaid on the instance details.

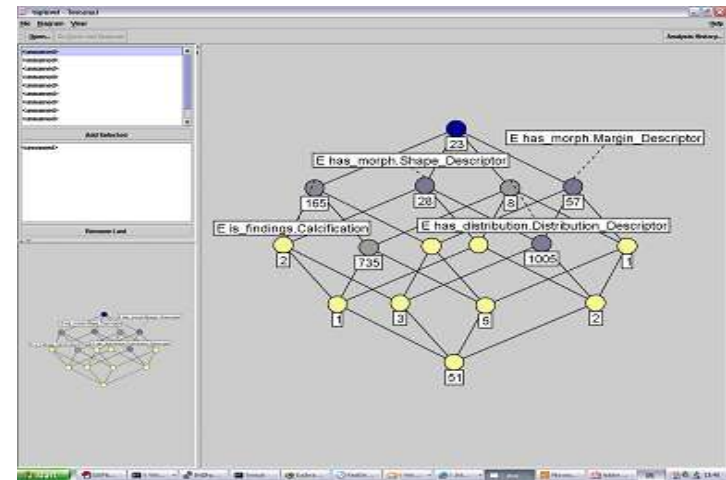
Navigating records using a lattice browser



- Shape: oval, tubular, lobulated, ...
- Margin: circumscribed, obscured, ...



- Re-express the annotations using description-logic instances
- Use them to construct the lattice via **Formal Concept Analysis**
- Nest line diagrams with regard to different features
- Associate individual patient record with nodes on the line diagram



Acknowledgements and where to look for further information

- This talk was distilled from my collaborations with many scientists, all of whom I thank:
- **The eDiamond team** at IBM Hursley (especially Dave Watson, Alan Knox, John Williams); Oxford eScience Centre (especially Andy Simpson, Mark Slaymaker, David Power, Eugenia Politou, Sharon Lloyd); Mirada Solutions Limited (Tom Reading, Dave McCabe, Caryn Hughes, Ralph Highnam, Chris Behrenbruch); UCL & St George's; Churchill Hospital, Oxford; Edinburgh University & Ardmillan; KCL & Guy's
- **The Mammogrid team**: Roberto Amendolia and colleagues at CERN, Richard McClatchey and colleagues at UWE, Chris Tromans and Maud Poissonier at Oxford, and Ruth Warren at Cambridge
- **For VirtualMammo**: Mirada Solutions Ltd (Caryn Hughes, Kranti Parekh, Hugh Bettesworth, Ralph Highnam)
- **For semantic web**: the MiAKT consortium headed by Professor Nigel Shadbolt (Southampton), Dave Hawkes (UCL)
- **For cancer modelling**: The Life Science Doctorate programme at Oxford led by David Gavaghan, John Ryan, Peter Donnelly and JMB
- **For spatiotemporal analysis**: the Integrated Biology group in Oxford led by Dr. David Gavaghan (Oxford)