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The Potential and Reality of the GRID for Image Science

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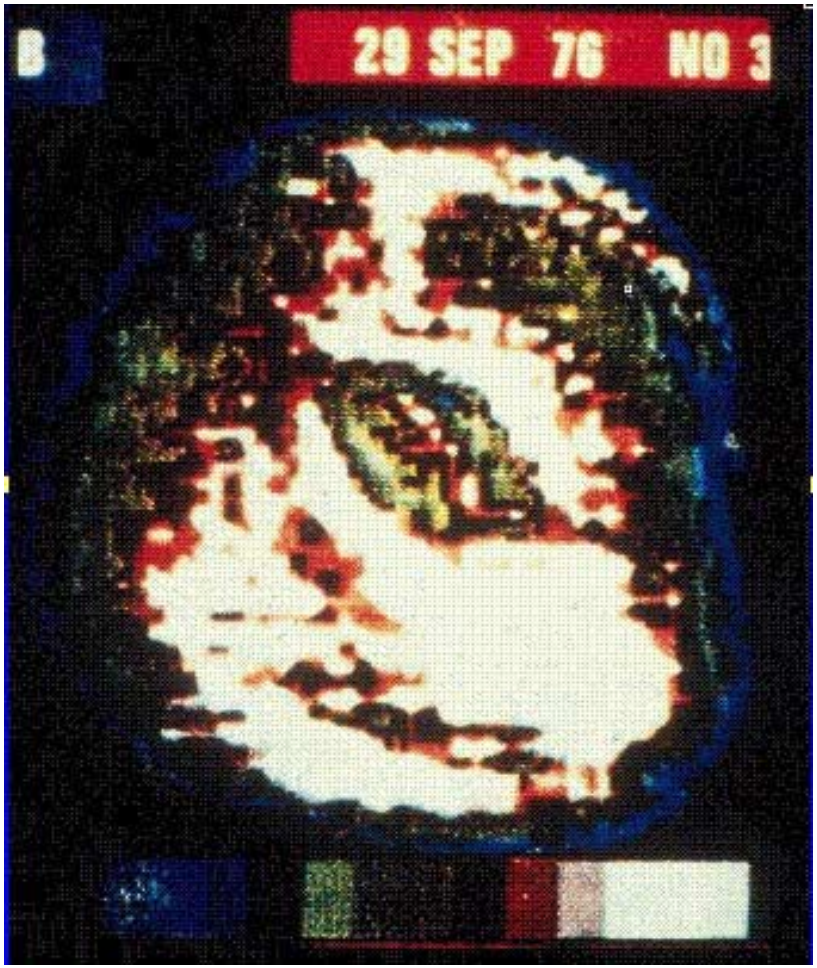
Current Trend in Medical Imaging

- Convergence to digital
- Multi-modality
- Increased data throughput and spatio-temporal resolution
- Rely on function as well as morphology
- Increased emphasis on early detection of disease with serial and cross modality studies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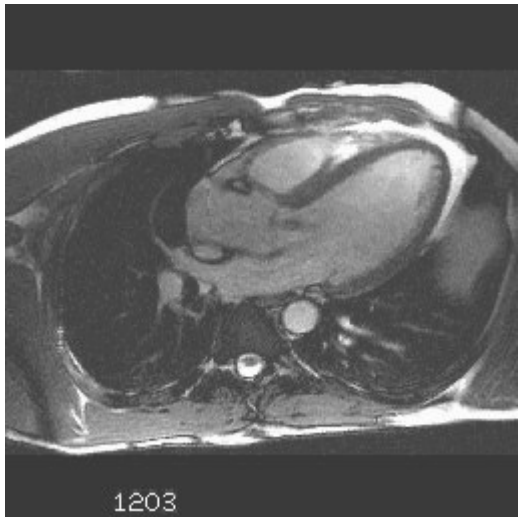

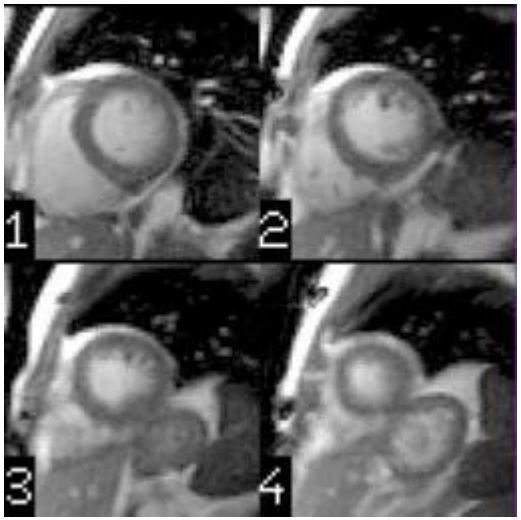

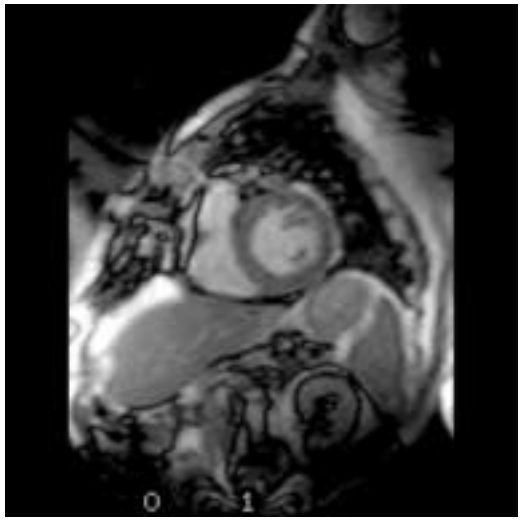

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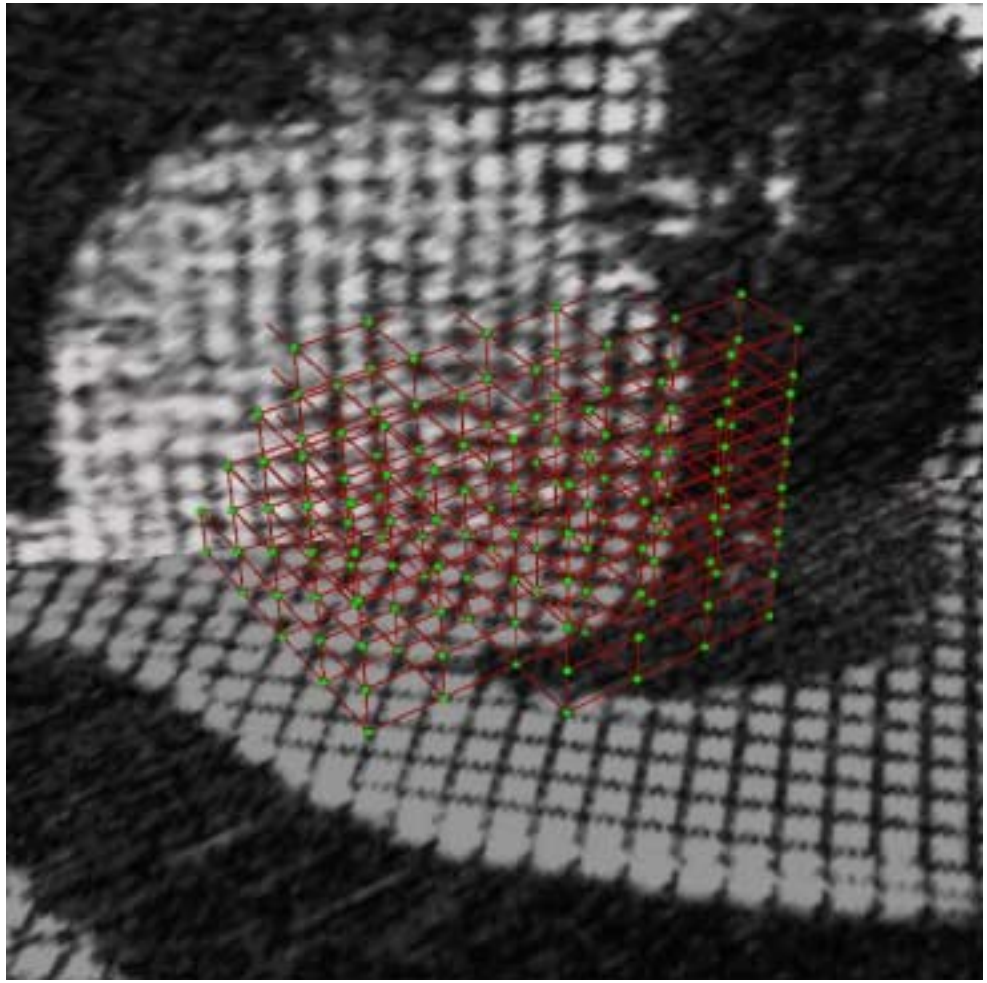
Free-form Deformation



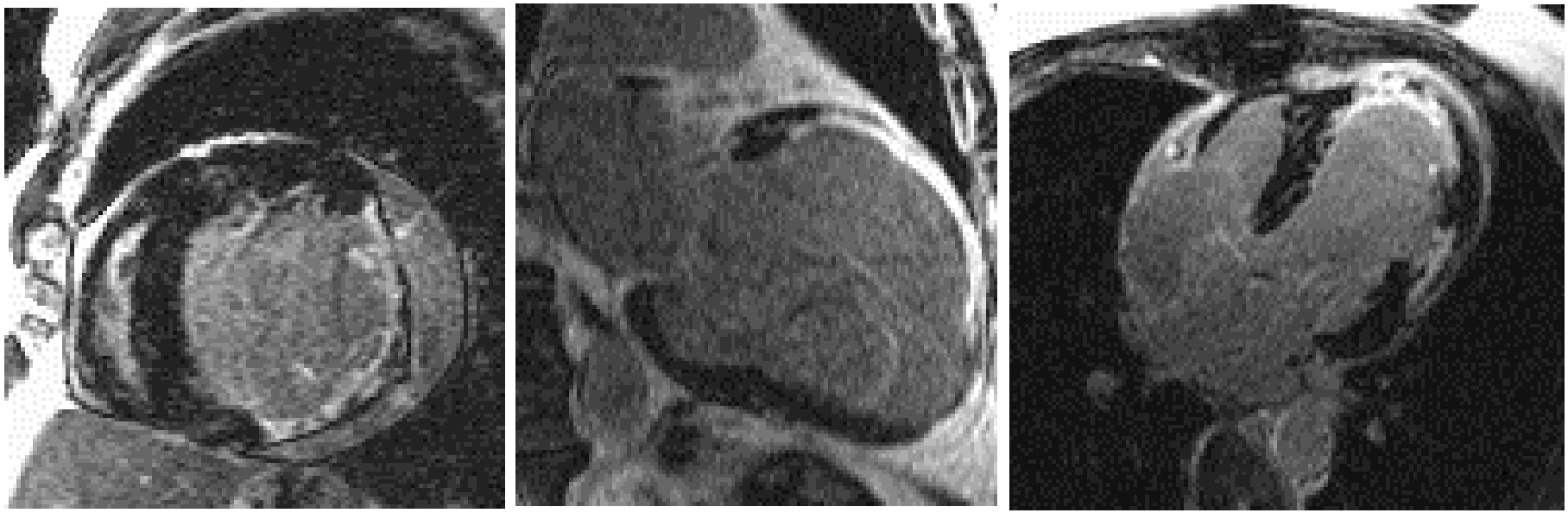
Raghavendra Chandrashekara

Myocardial Viability

Image 10 minutes post contrast,

Inversion pulse with TI to null the normal myocardium.

Acquisition by segmented FLASH breath-hold sequence.



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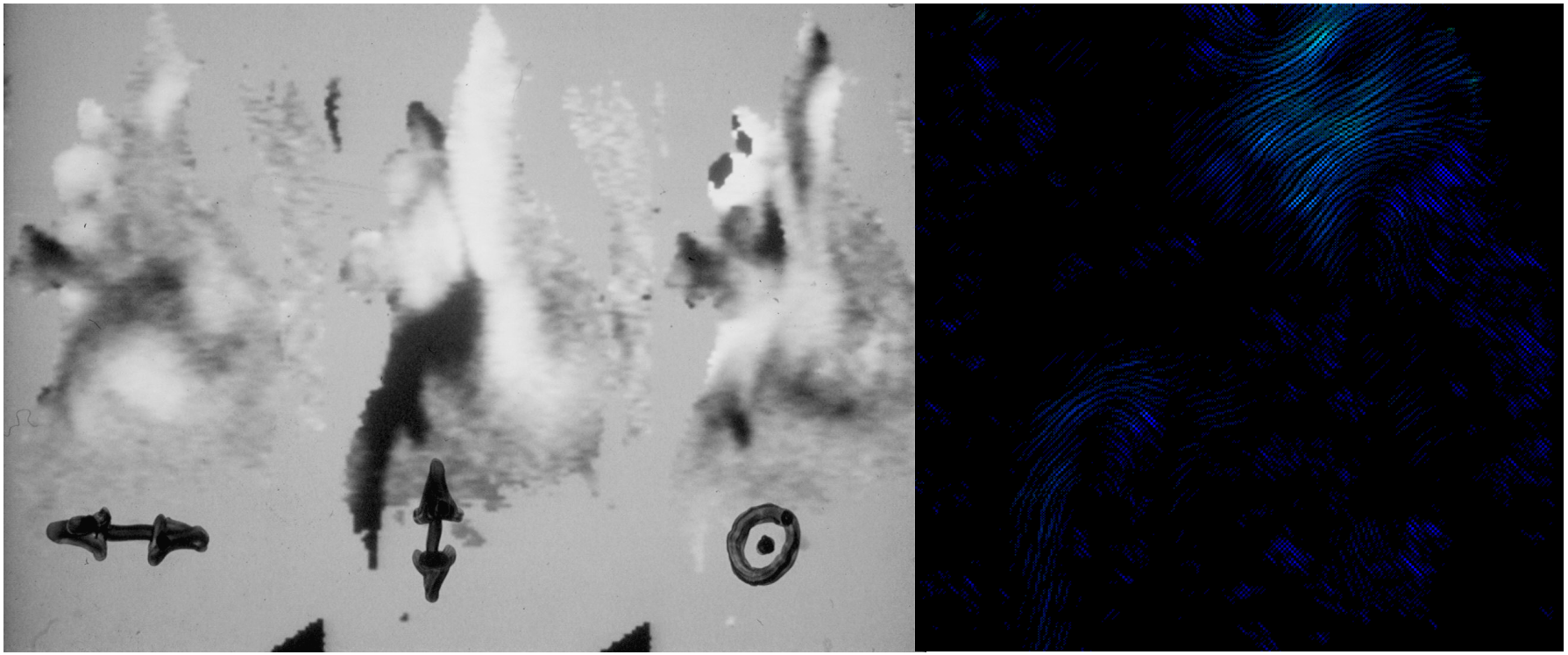

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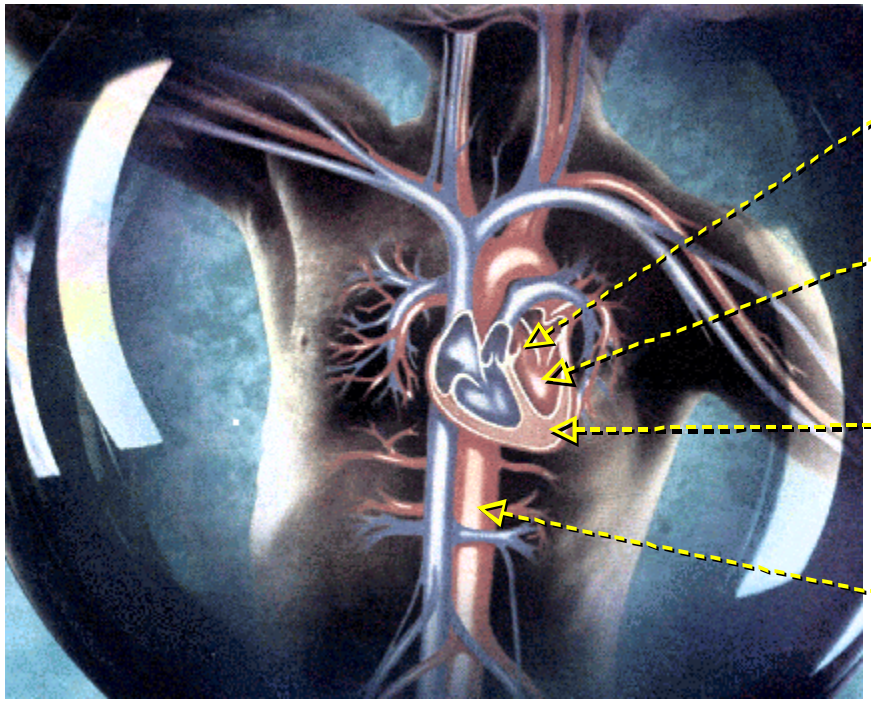

Velocity, flow pattern, regurgitation

Velocity, flow pressure, flow pattern , cardiac output

Morphology, perfusion, diffusion, mechanical properties

Morphology, vessel compliance, blood flow, chemical content, endothelium function

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Challenges

- Large distributed, heterogeneous data sets
- Handling legacy data and resource evolution
- Collaboration, access control, authentication, ethical and security issues
- Many image processing steps can not be fully automated
- User-friendly interfaces
- Usability and fault tolerance
- Coherent migration path for new imaging, modelling and analysis methods

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Standardisation of Image Storage and Communication

- PACS – picture archiving and communication system

  The term "digital radiology" was introduced by Paul Capp in the early 1970s. Lack of technological development to support the requirements of digital radiologists, however, prevented the concept from becoming popular until the early 1980s.

- DICOM – digital imaging and communications in medicine

  transfer of medical images in a multi-vendor environment, facilitate the development and expansion of picture archiving and communication systems (PACS) and interfacing with medical information systems.

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Opportunities of Gird in Image Science

- Database and digital library/atlas
- Image mining, decision support and learning
- Collaboration and large scale modelling
- Multi-modality integration and data fusion
- Visualisation and augmented reality
- Remote instrumentation

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Existing Grid Projects of Interest

BIRN,

IP4G

Mammogrid

NDMA

eProtein

…

eDiamond

MIAS

IXI

NC Biogrid

proTurbo

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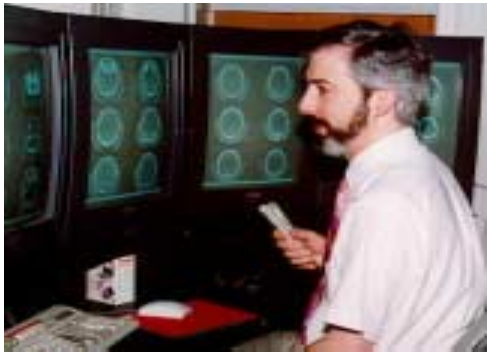
Reference images

Patient scan & Instructions

Atlas

Create Atlas



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Dynamic Brain Atlas

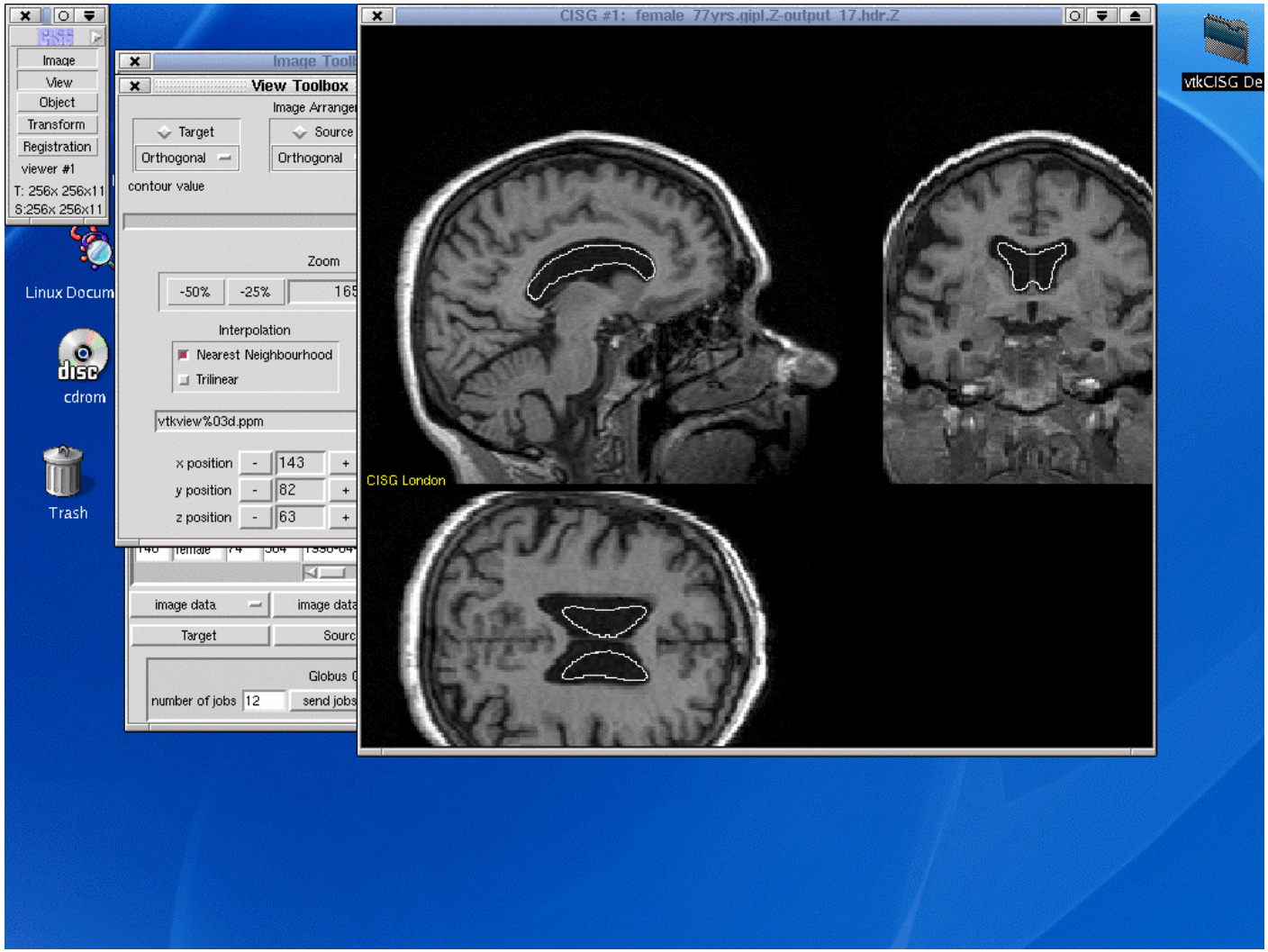

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Image Processing on the GRID

- Use the GRID as primarily a computational resource rather than a data repository
- Image processing framework already suitable
  - Filter graph model
    - data 'flows' from 'source' input filters
    - through 'transform' filters
    - ending at 'sink' output filters.
  - Analogous to DAG workflow in cluster computing scheduling
- Communications cost becomes important
- Web service front-end

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Retrofitting existing frameworks

- Image Processing for the Grid (IP4G)
  - [Hastings, Kurc, Langella, Catalyurek, Pan & Saltz, Proc. CCGRID '03]
- Enable image analysis on disparate data and heterogeneous clusters
- Adapts scheduling middleware to 2 image processing frameworks
  - Datacutter distributed workflow system
  - Visualization Toolkit (VTK) 2D and 3D modelling and presentation
  - NLM Insight (ITK) image registration and segmentation toolkit
- Standard web service that takes in a description of the workflow, data, and image computation

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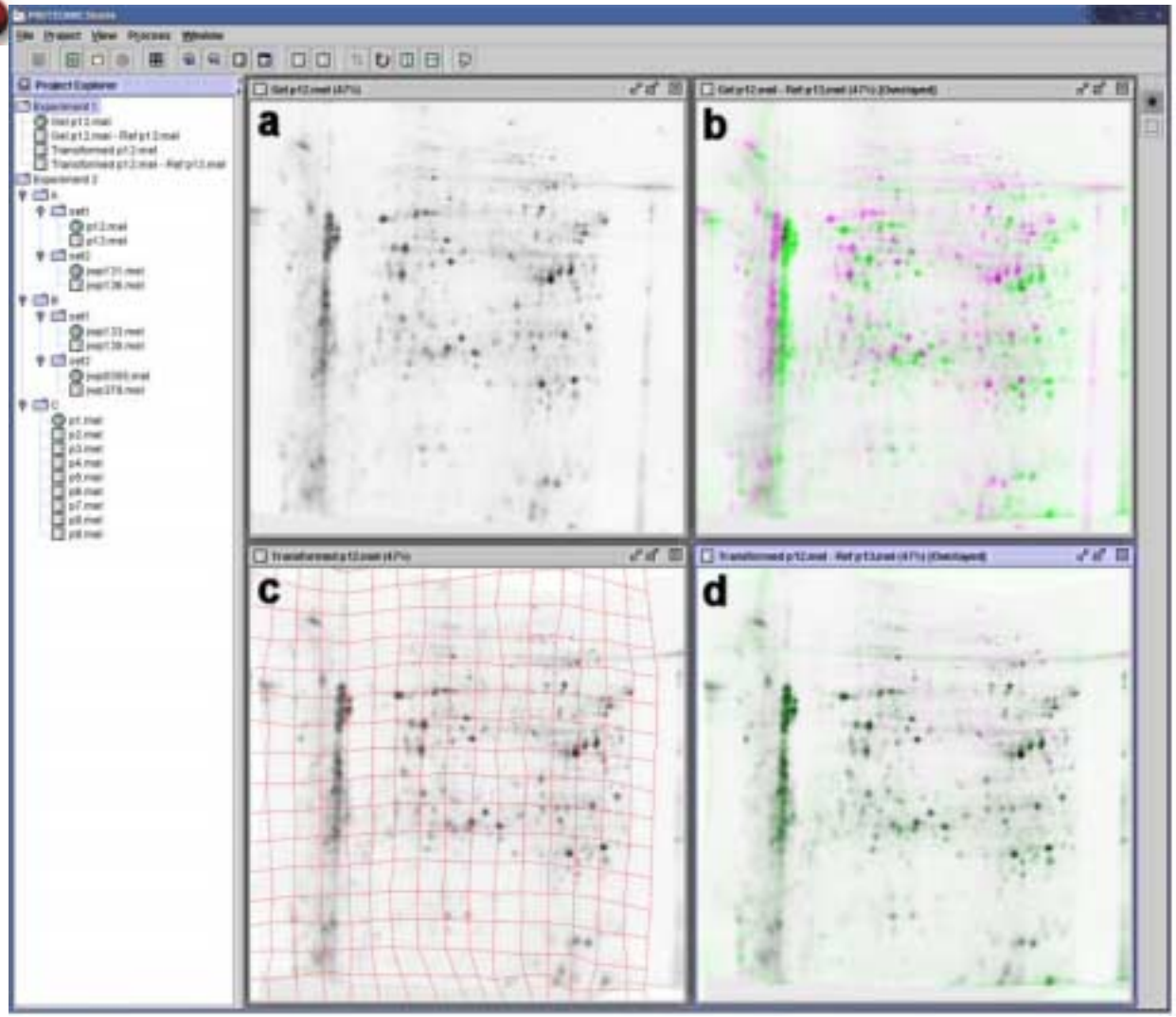

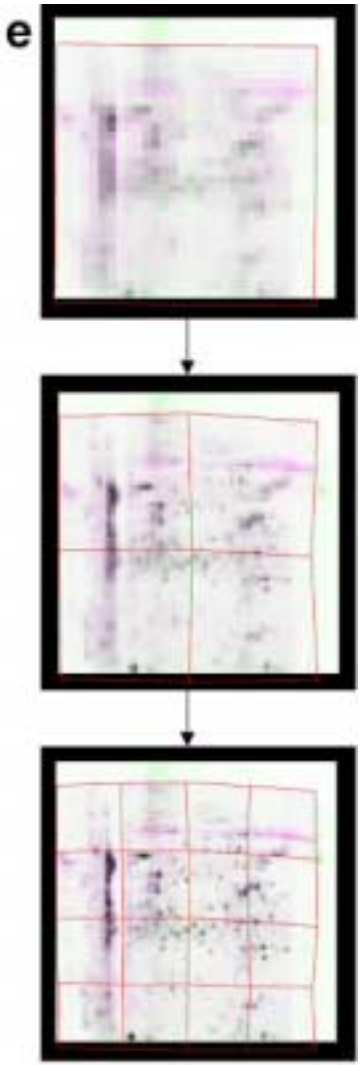

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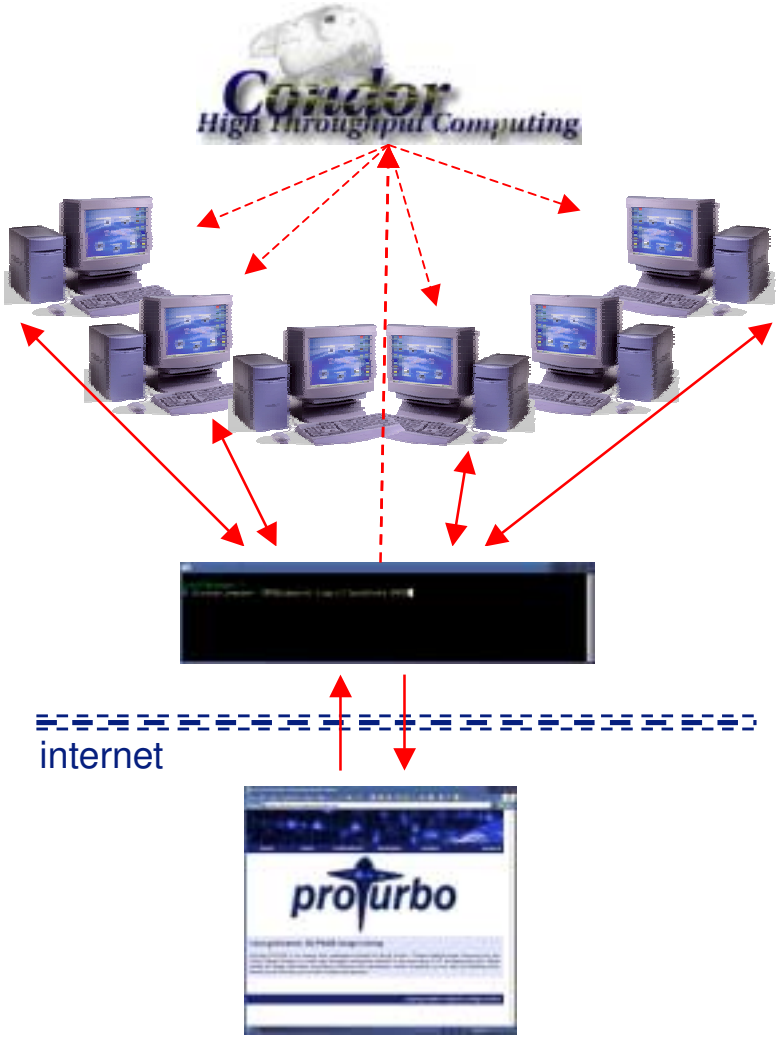
Architecture

- Characteristics of 2D gel analysis tasks:
  - Short duration (seconds to minutes)
  - Many different inputs to run on a handful of algorithms
  - Longer tasks would require parallel decomposition
- Master / worker task farming approach ideal
- Remote submission



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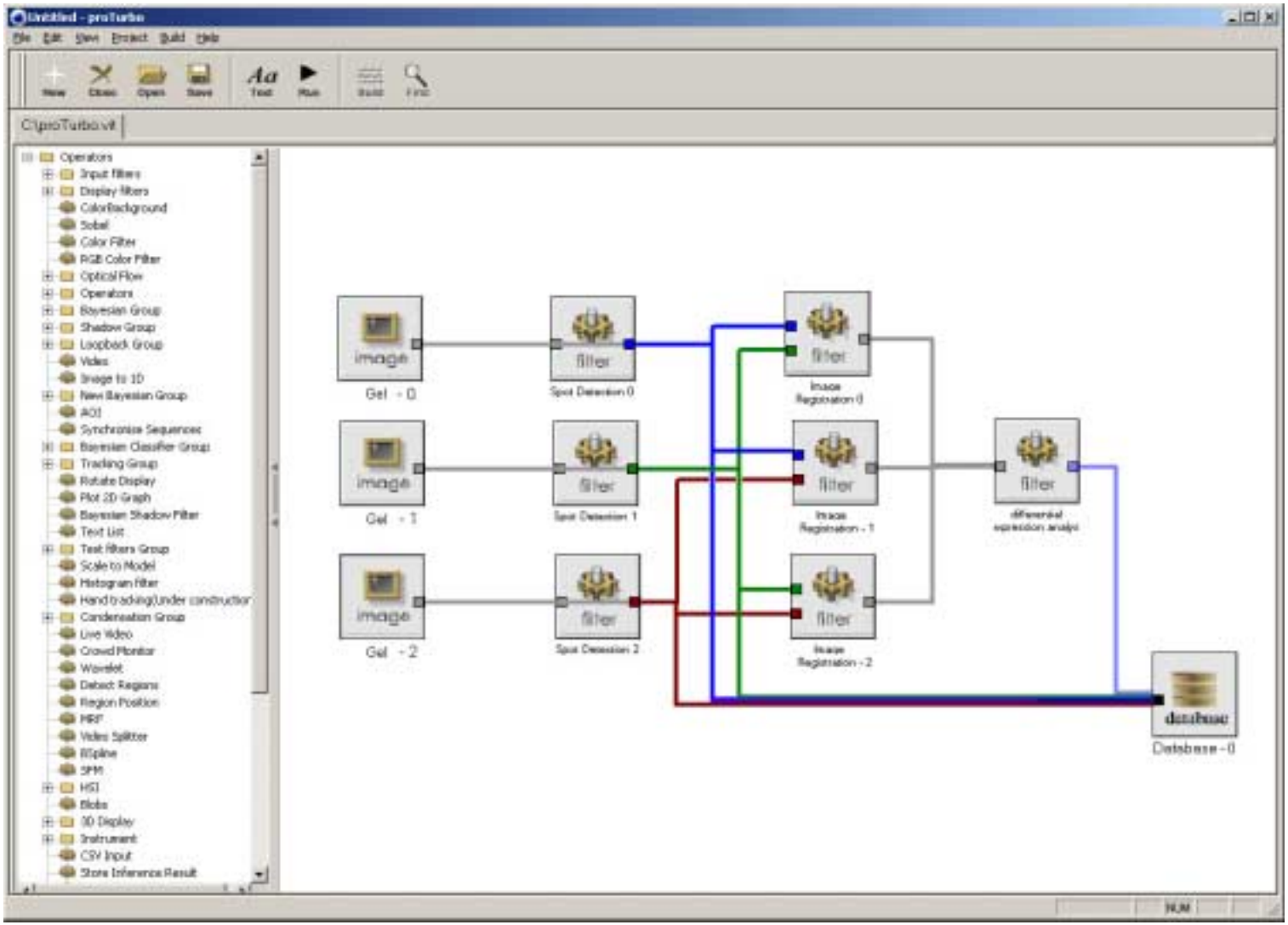

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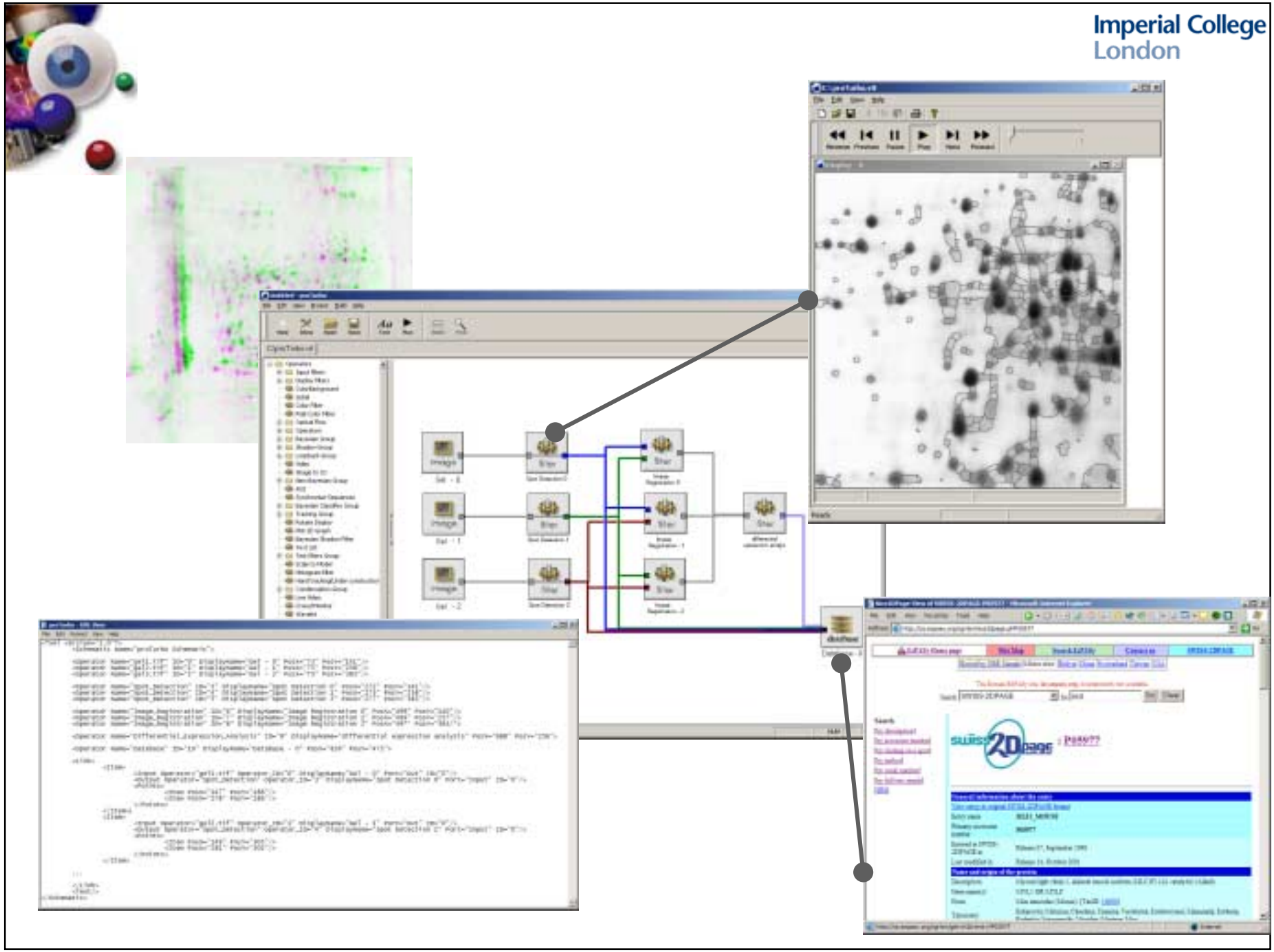

Mapping filter graphs to machines

- Static (compile time) scheduling
- Geometric decomposition of each task
  - Either row, column, row-cyclic, column-cyclic, block or block-cyclic
- Augment graph with extra pathways:
  - Add edges for data re-partitioning between nodes
  - Add nodes and edges for merged tasks
  - Weight edges by communications cost
- Constrained shortest path search to optimum parallelism strategy

Image compression

- IEEE testing report Ethernet performance degrades at over 37% load e.g.
  - For a 10 second analysis taking 1 image a maximum of 6 simultaneous workers could be sustained
- Image compression is therefore essential
  - Lossy methods (e.g. JPEG) remove information according to a visual cortex model
  - Near-lossless methods guarantee each pixel ± an error value
  - JPEG-LS (Hewlett Packard) proved to have the optimum compression / complexity trade-off

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Probabilistic Task Replication

- Tasks fail due to evicted workers
  - Reprocessing a few failures significantly affects job completion time
- Replicate tasks
  - When tasks < workers
  - Those tasks most likely to fail
- Statistical approach
  - Estimate speed of workers (normally distributed)
  - Estimate frequency of evictions (Poisson distributed)
  - Derive probability each job will fail

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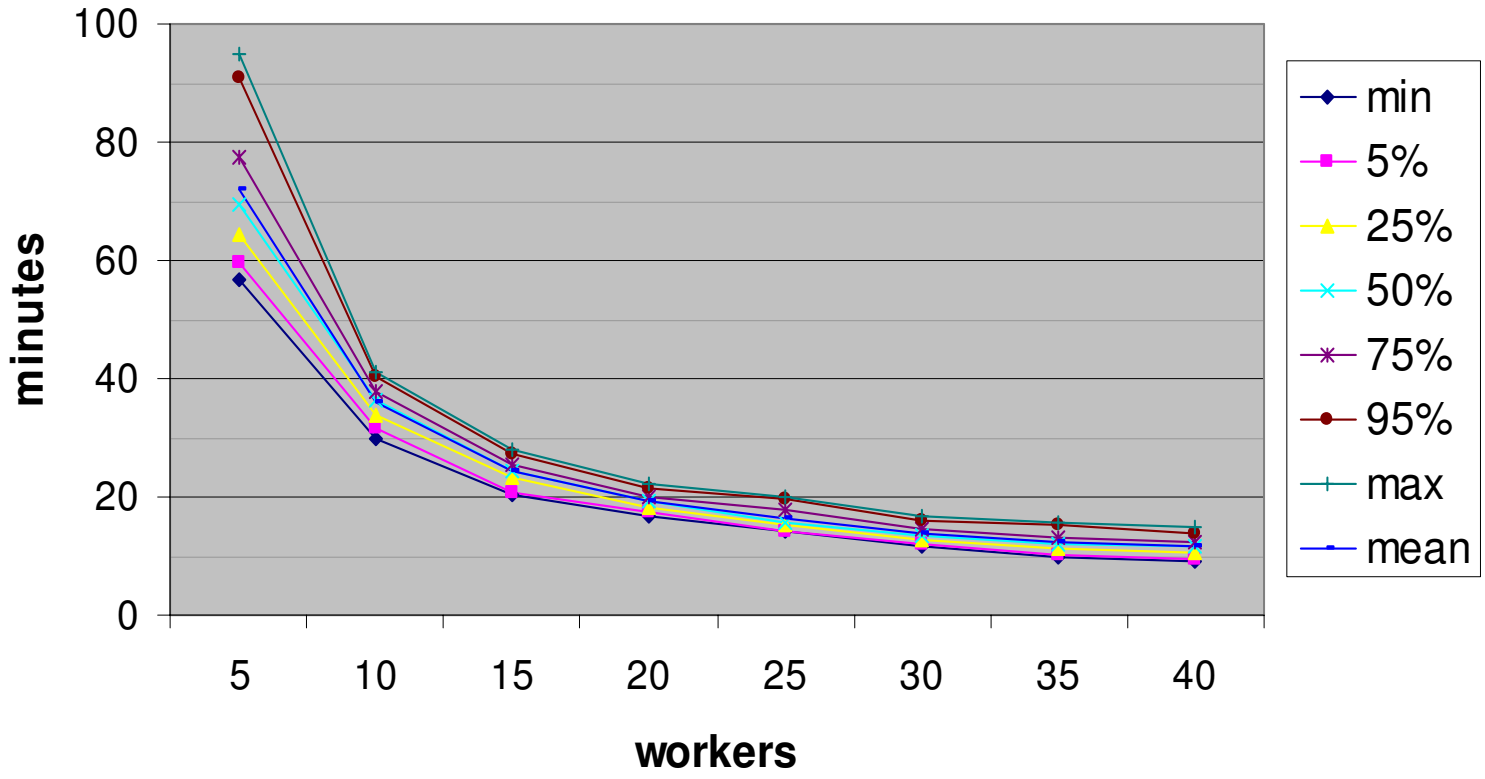
Probabilistic Task Replication

- 1400Mhz Computer: 5 hours for 3540 tasks
- Worker groups of size 5 – 40 were considered.



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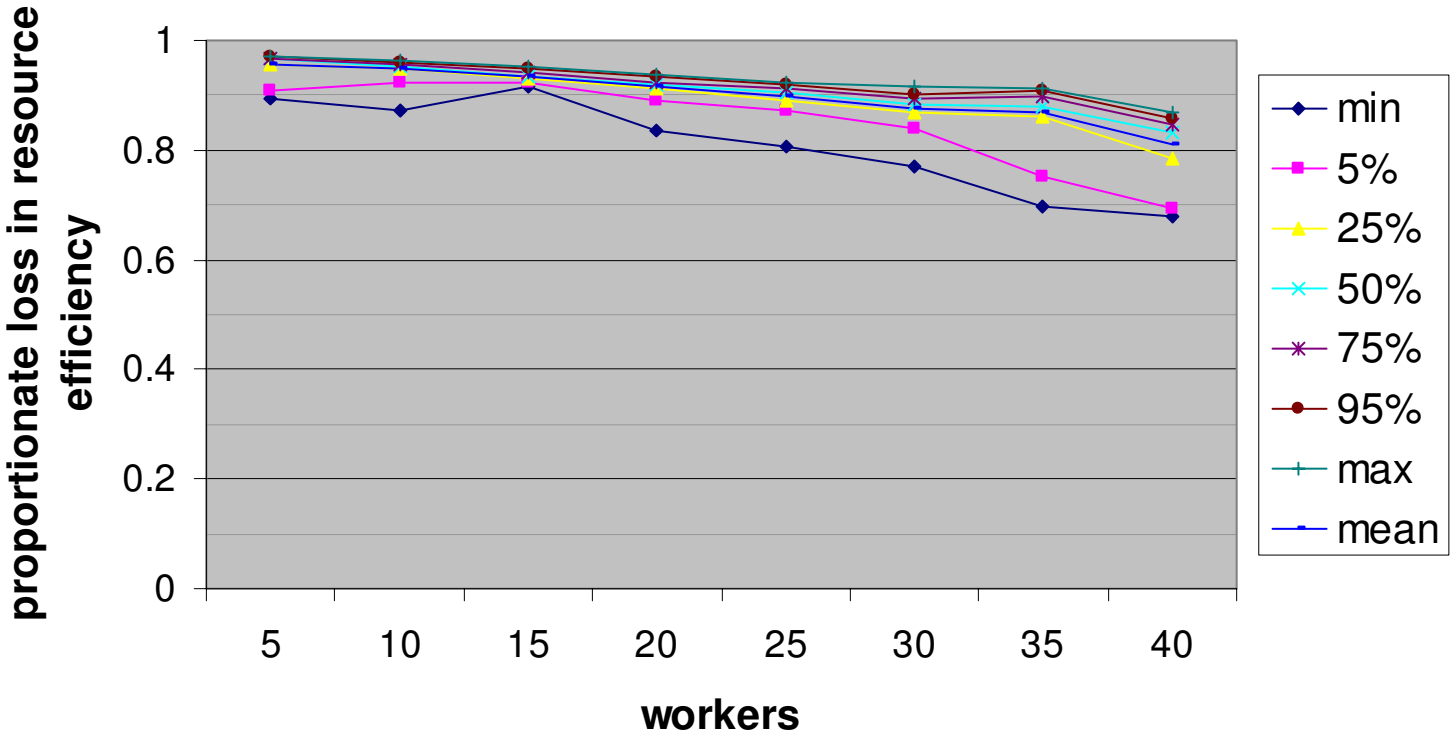
Probabilistic Task Replication

- Loss of resource efficiency for 5 – 40 workers (in respect to a single worker)



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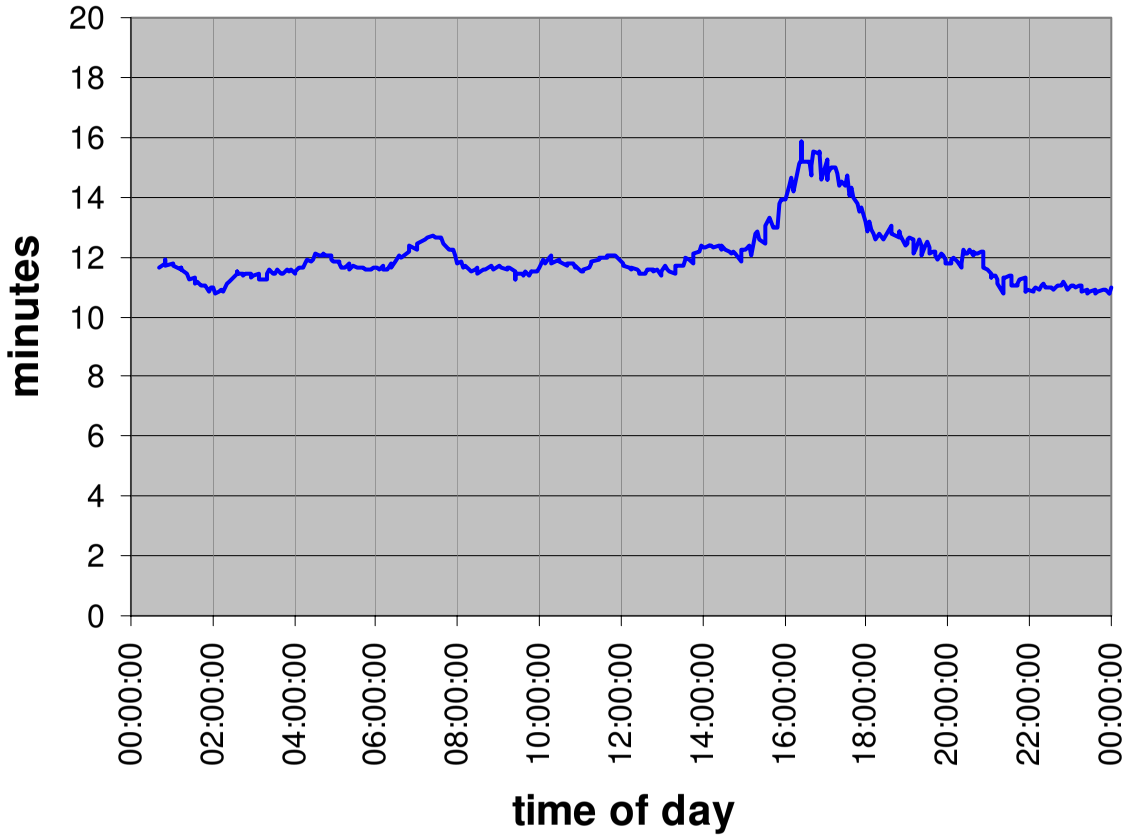

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Interrelated factors of heart disease

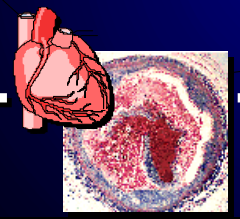
Diet

Obesity

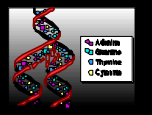
Smoking

Age

Exercise



Genetic traits



Neurogenic factors

Hypertension

Cholesterol, lipid metabolism

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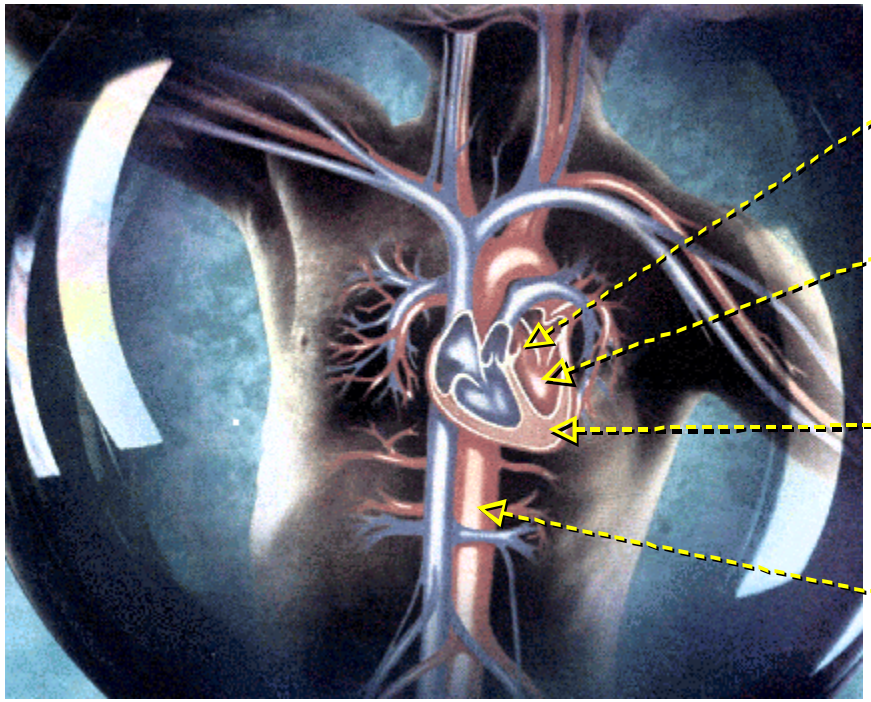

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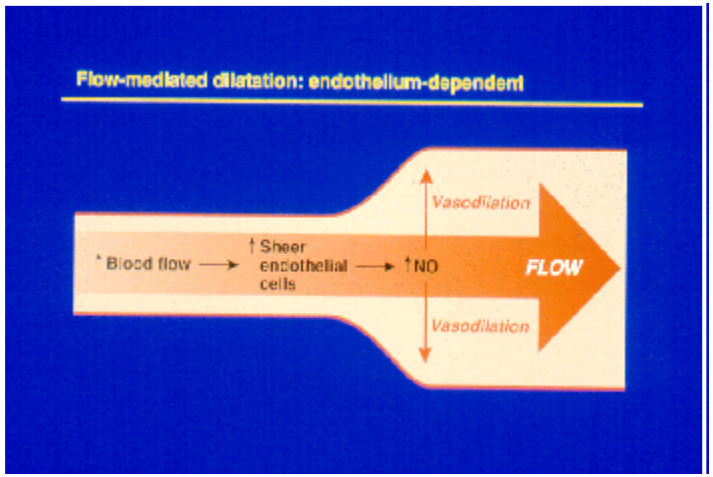
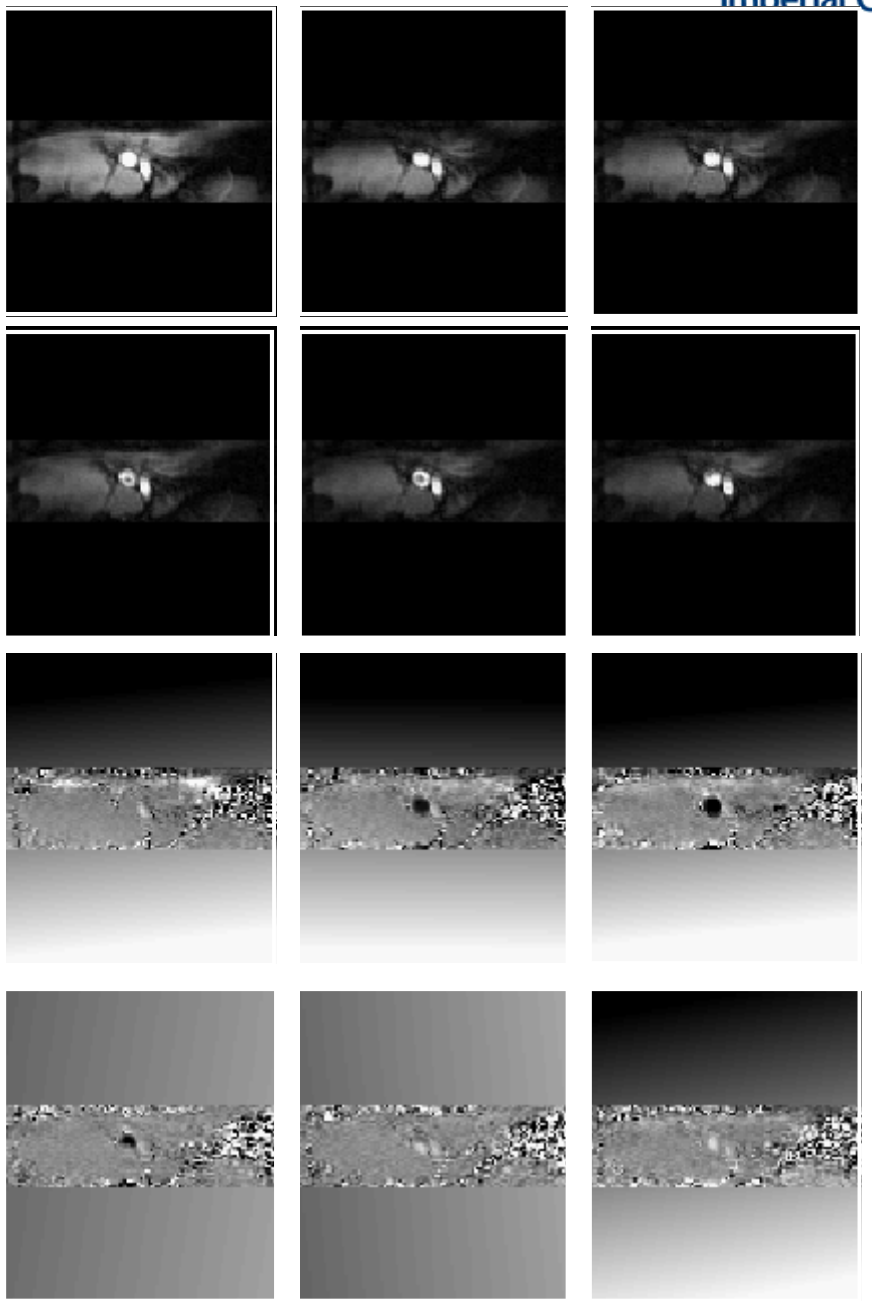
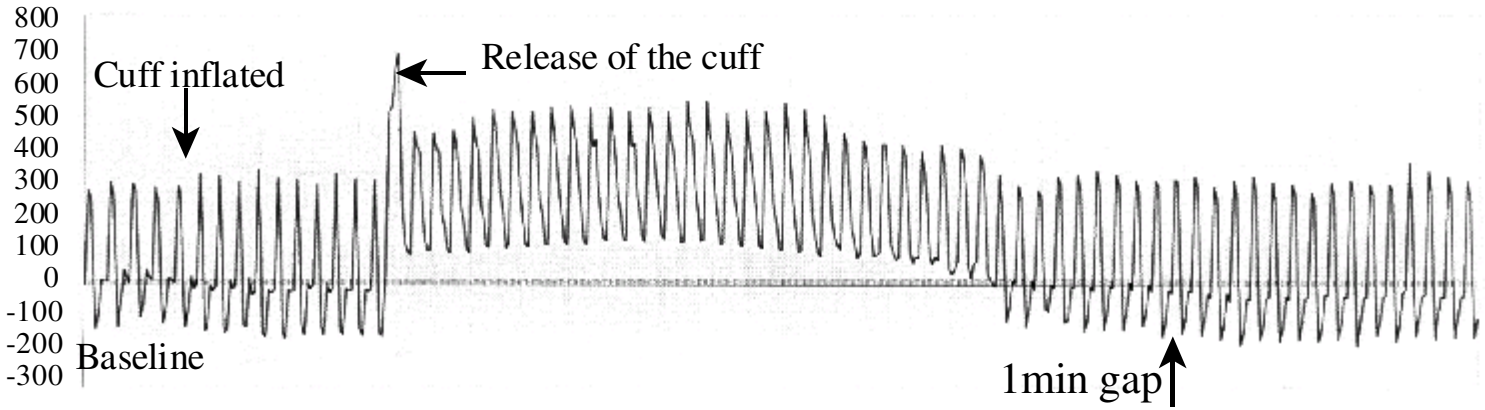
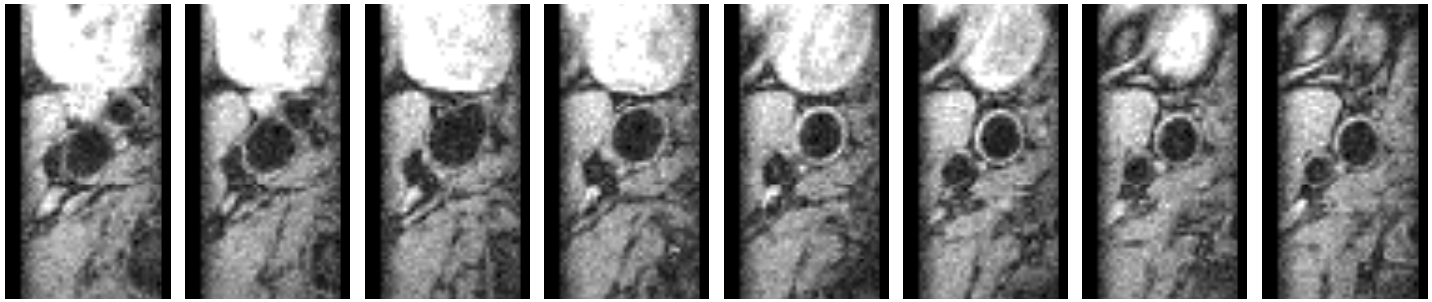

Flow-mediated dilatation: endothelium-dependent
Vasodilation
↑Blood flow
↑Sheer endothelial cells
↑NO
FLOW
Vasodilation



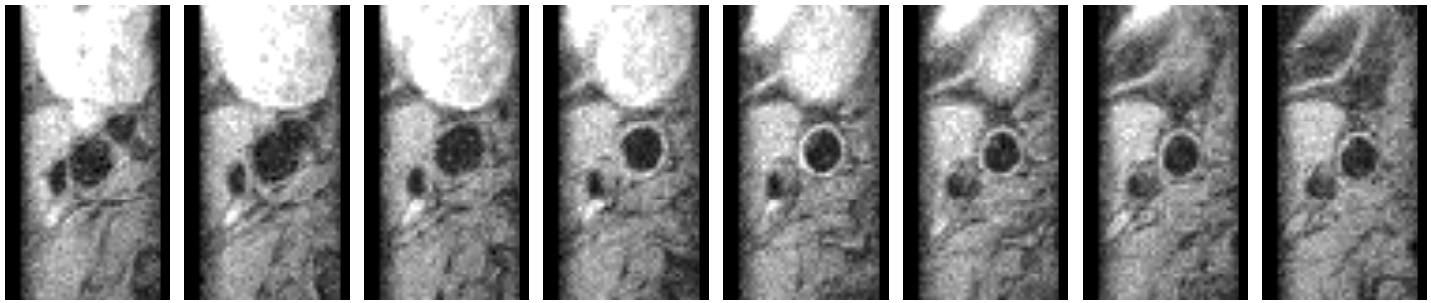
Femoral artery time-related velocity flow curve

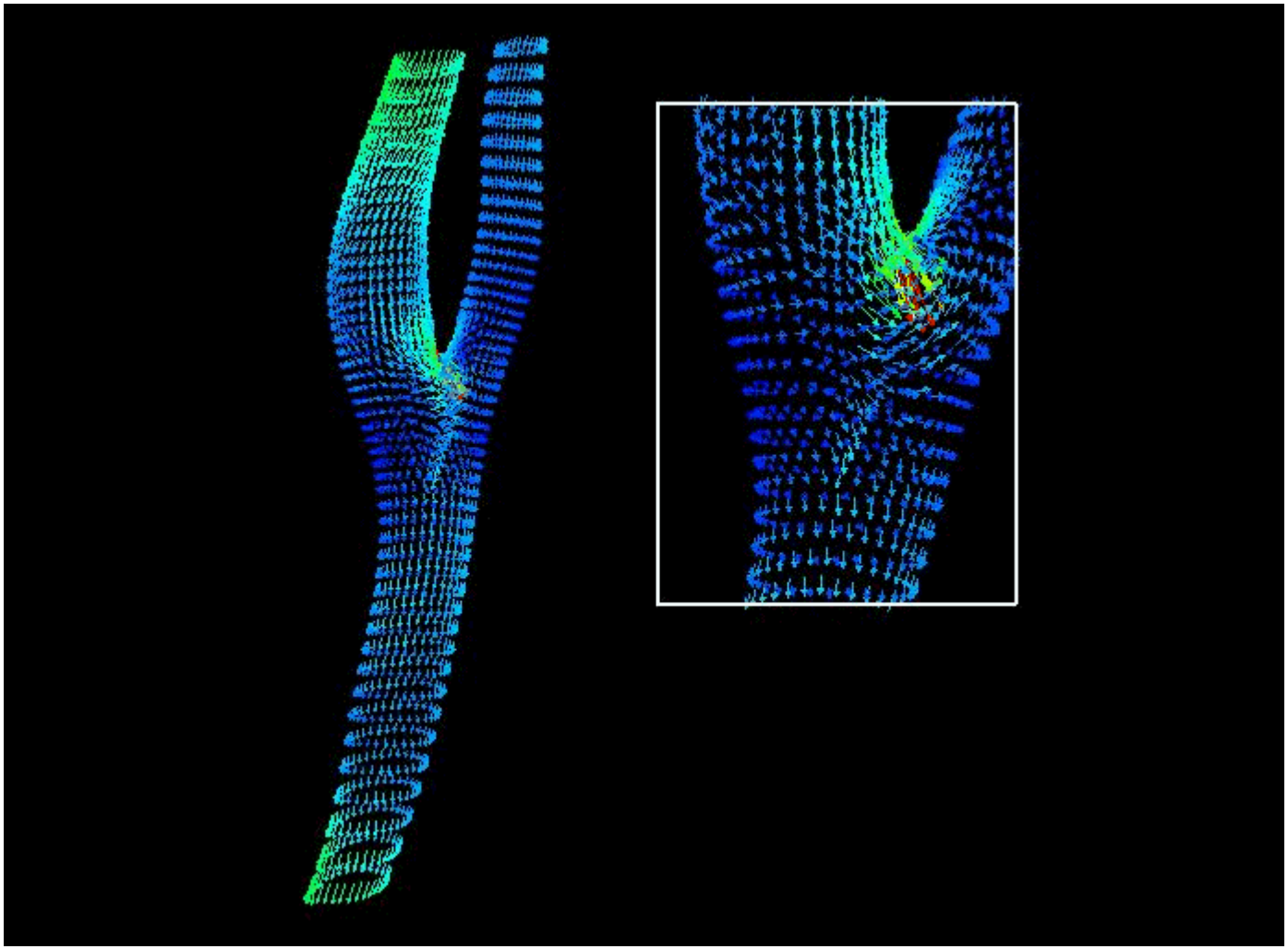


Systole



Diastole





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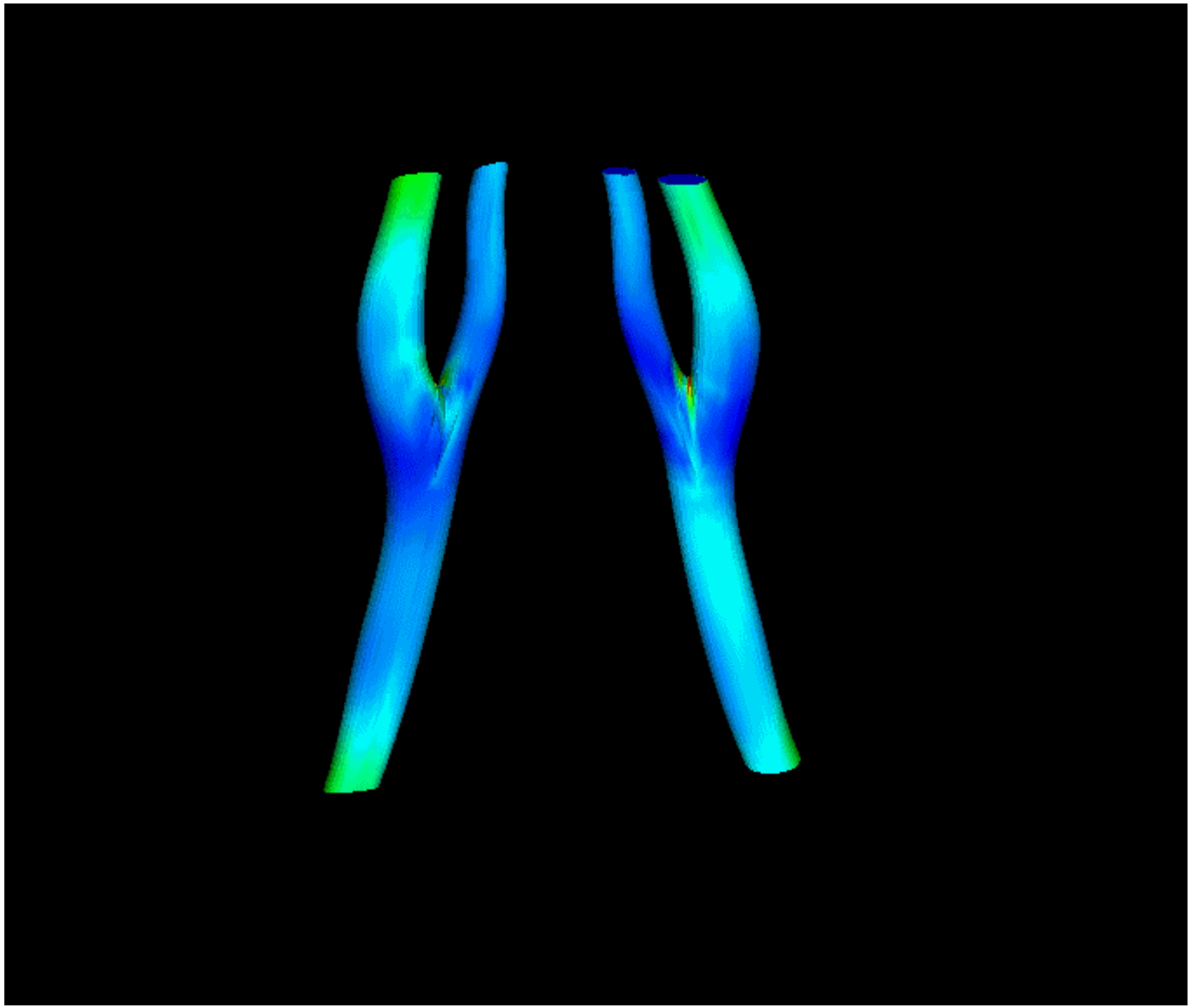

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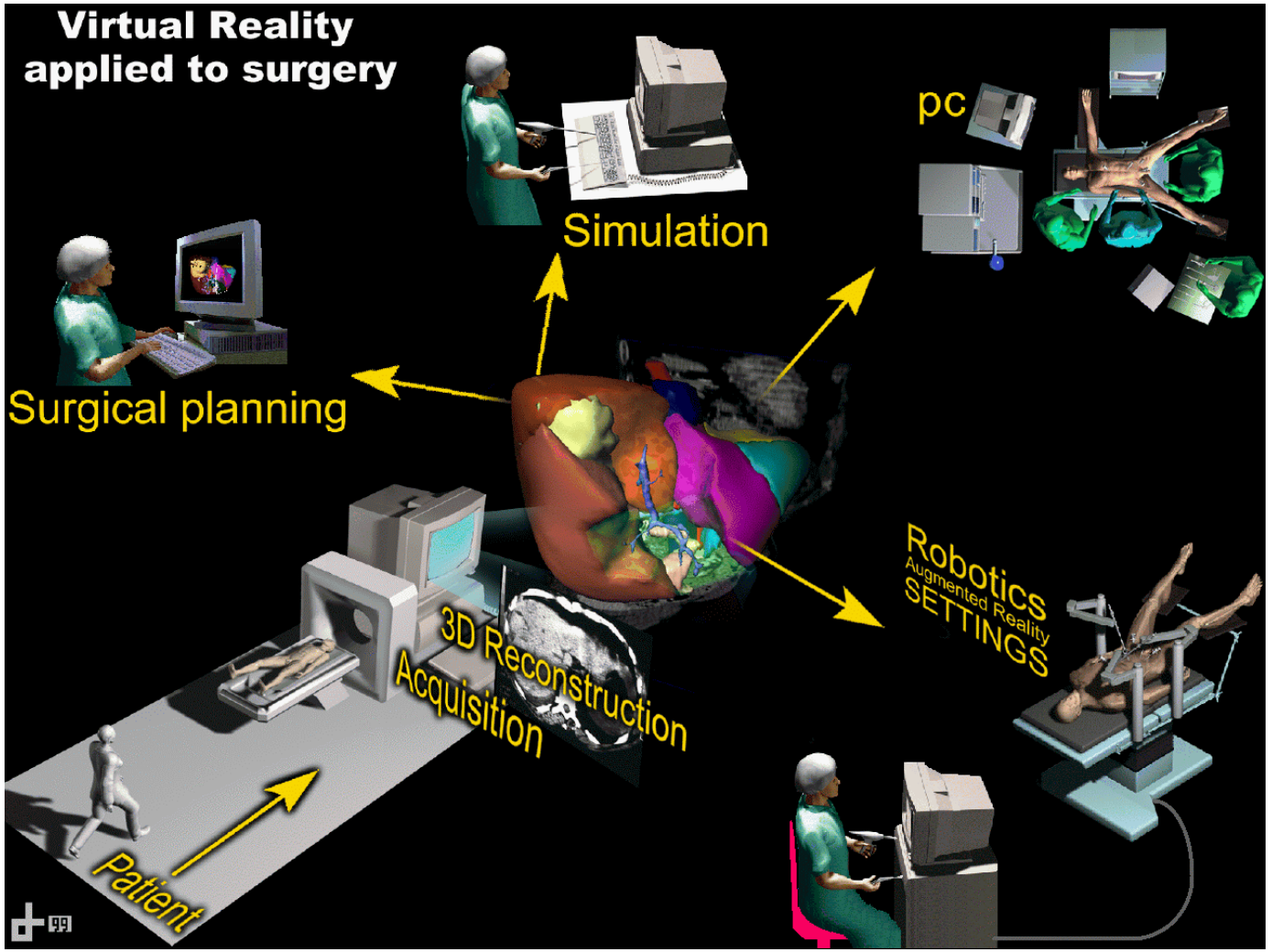

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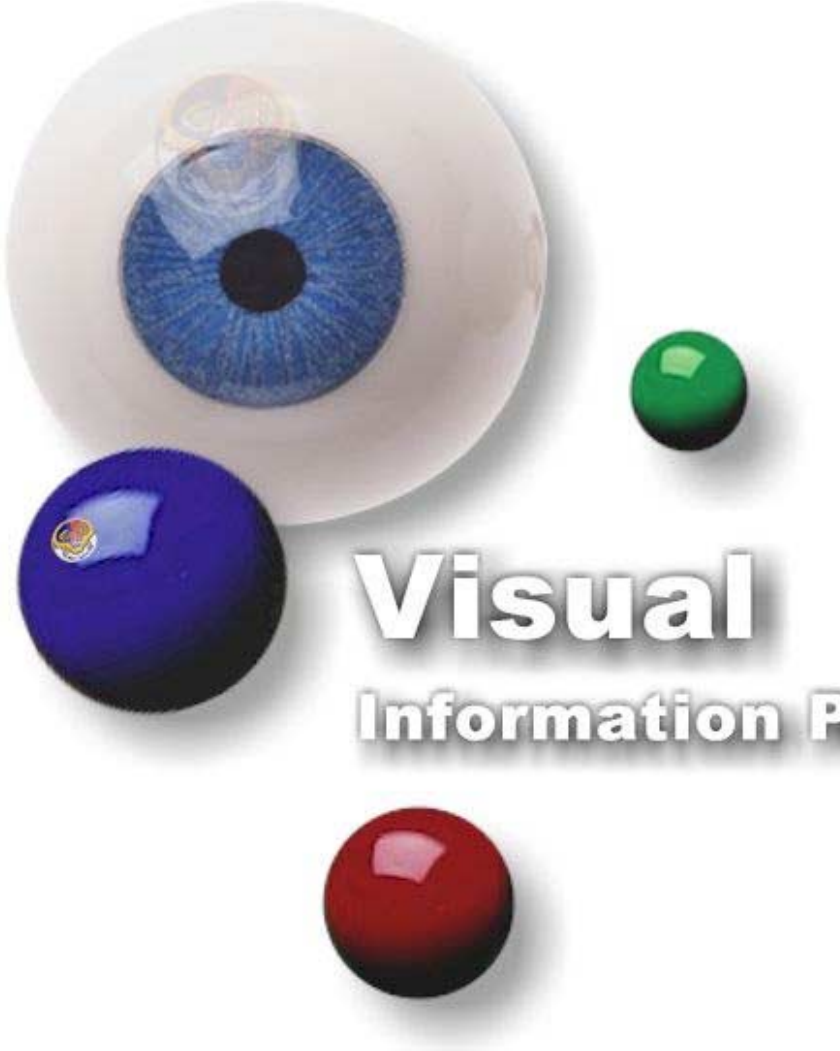

Visual

Information Processing