Parallel and Distributed Computing for an Adaptive Visual Object Retrieval System

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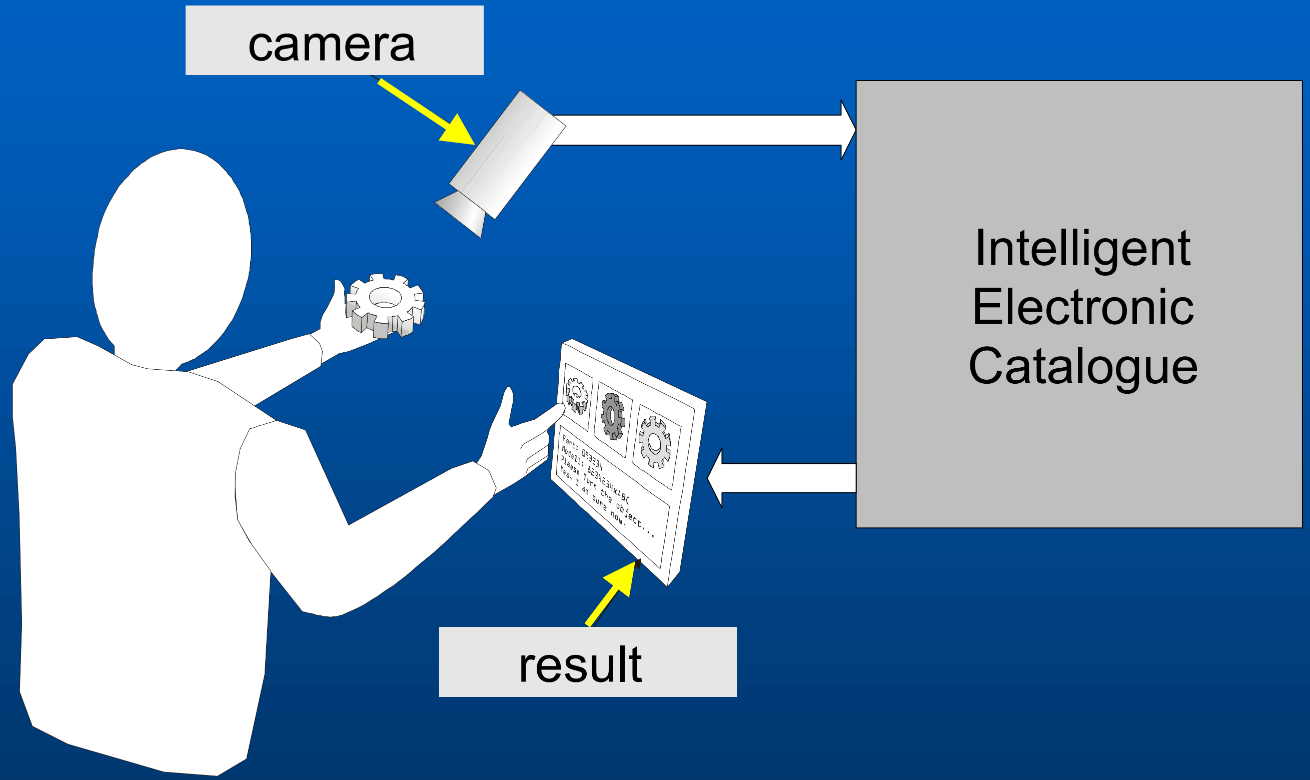
Outline

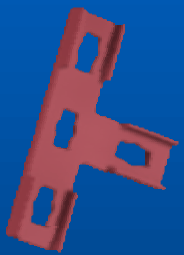
- Introduction
- Related Work
- System Description
- Dataflow Concept
- Distributed Processing
- Experimental Results
- Conclusion

Visual Object Retrieval



Requirements

- adaptive to meet different requirements
  - flexibility
  - modularity
- sophisticated algorithms
  - image processing
  - classification / AI
- support for
  - parallelism
  - distribution
  - heterogeneous environments
  - load balancing



Related Work - Image Processing

Visual programming environments for computer vision and image processing

- Application Visualization System
- Khoros / Cantata
- IrisExplorer
- WiT, Mavis, VISSION ...

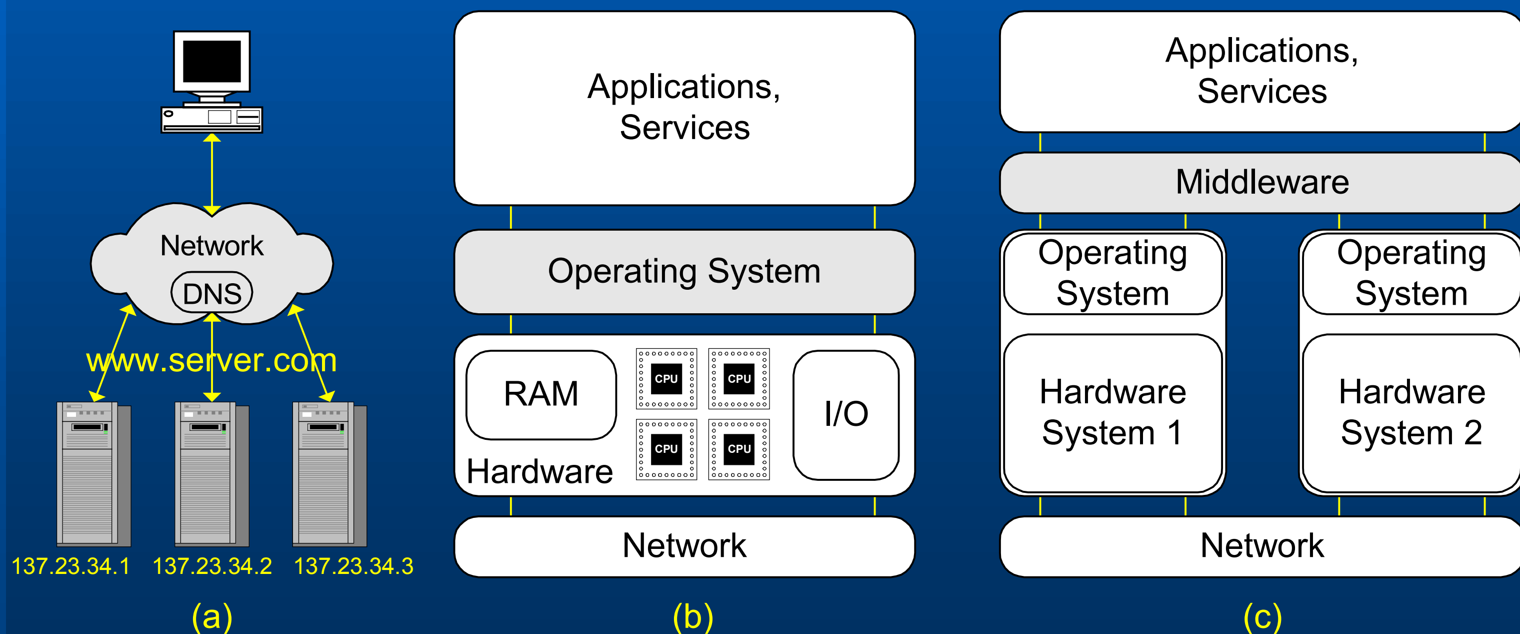
- VuSystem
- Matlab / Simulink, Labview

Parallel & Distributed Computing

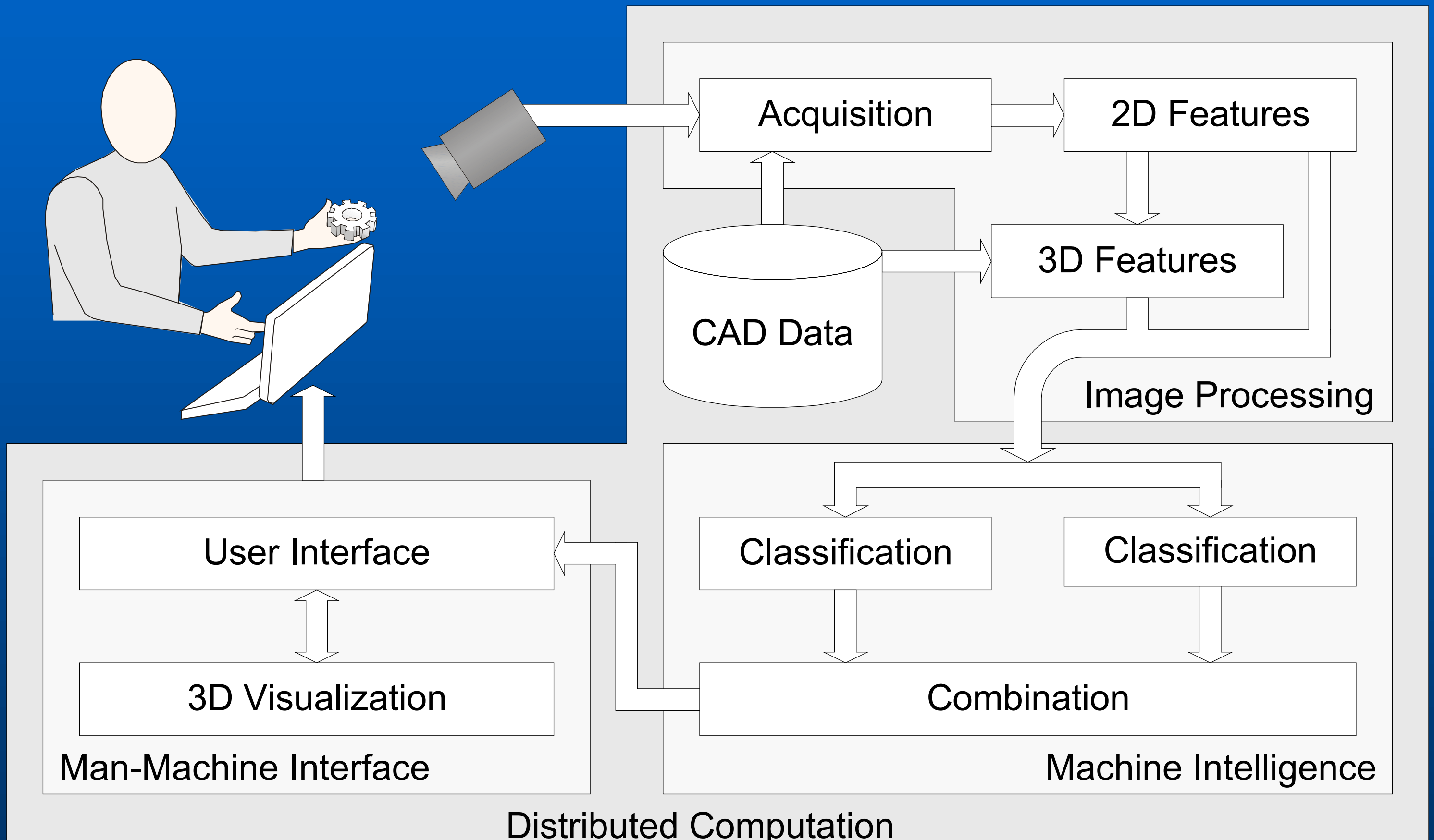
- Multiprocessor systems
  - Uniform Memory Access (UMA)
  - Non-Uniform Memory Access (NUMA)
  - Symmetric Multiprocessors (SMP)
- Coupled Computing System
  - Cluster of Workstations (COW)
    - Message Passing Interface (MPI)
    - Parallel Virtual Machines (PVM)
  - **Network of Workstations (NOW)**

Related Work - Load Balancing

- Network
- Operating System
- Middleware



The Axiom System



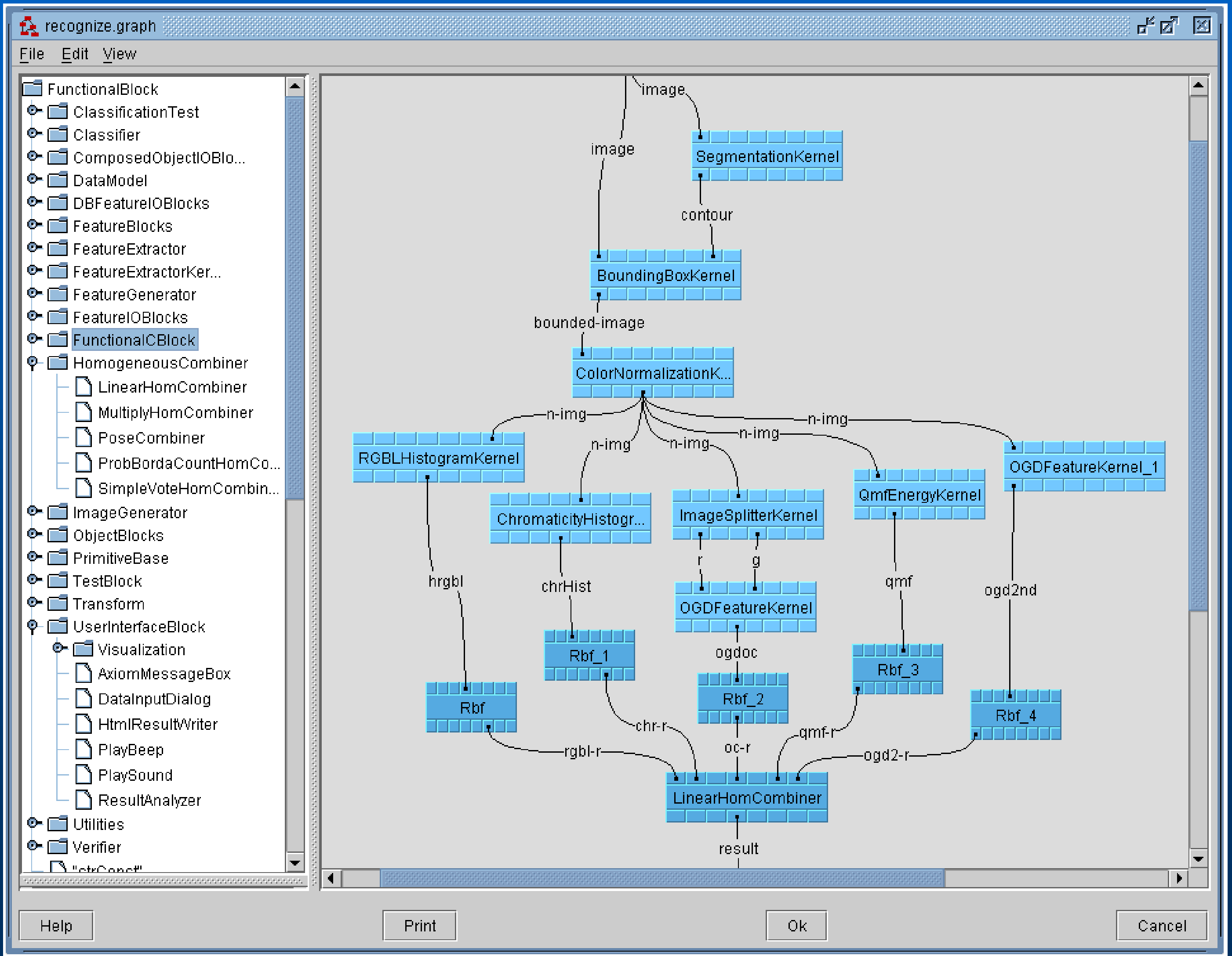
Axiom - Adaptive expert system for intelligent object mining

Dataflow Concept

- natural specification:
  dataflow graph, functional program
- C++ library for computer vision
  object oriented, encapsulates operations
  `http://ltilib.sourceforge.net`

- Functional Object Retrieval Control Syntax
  - similar to Scheme language
  - processing blocks written in Java or C++
  - sequential functional and parallel dataflow programs

Programming Panel



FORCS Code

```
(let contour (features.SegmentationKernel image))
(let bounded-image
  (features.BoundingBoxKernel image contour))
(let n-img (images.ColorNormalizationKernel
             bounded-image))
(let hrgbl (features.RGBLHistogramKernel n-img))
(let chrHist
  (features.ChromaticityHistogramKernel n-img))
(let lnk.1 (images.ImageSplitterKernel n-img))
(let r (nth 1 lnk.1))
(let g (nth 2 lnk.1))
(let ogdoc (features.OGDFeatureKernel r g))
(let qmf (features.QmfEnergyKernel n-img))
(let ogd2nd (features.OGDFeatureKernel_1 n-img))
(let rgbl-r (neural.rbf.Rbf hrgbl))
(let chr-r (neural.rbf.Rbf_1 chrHist))
```

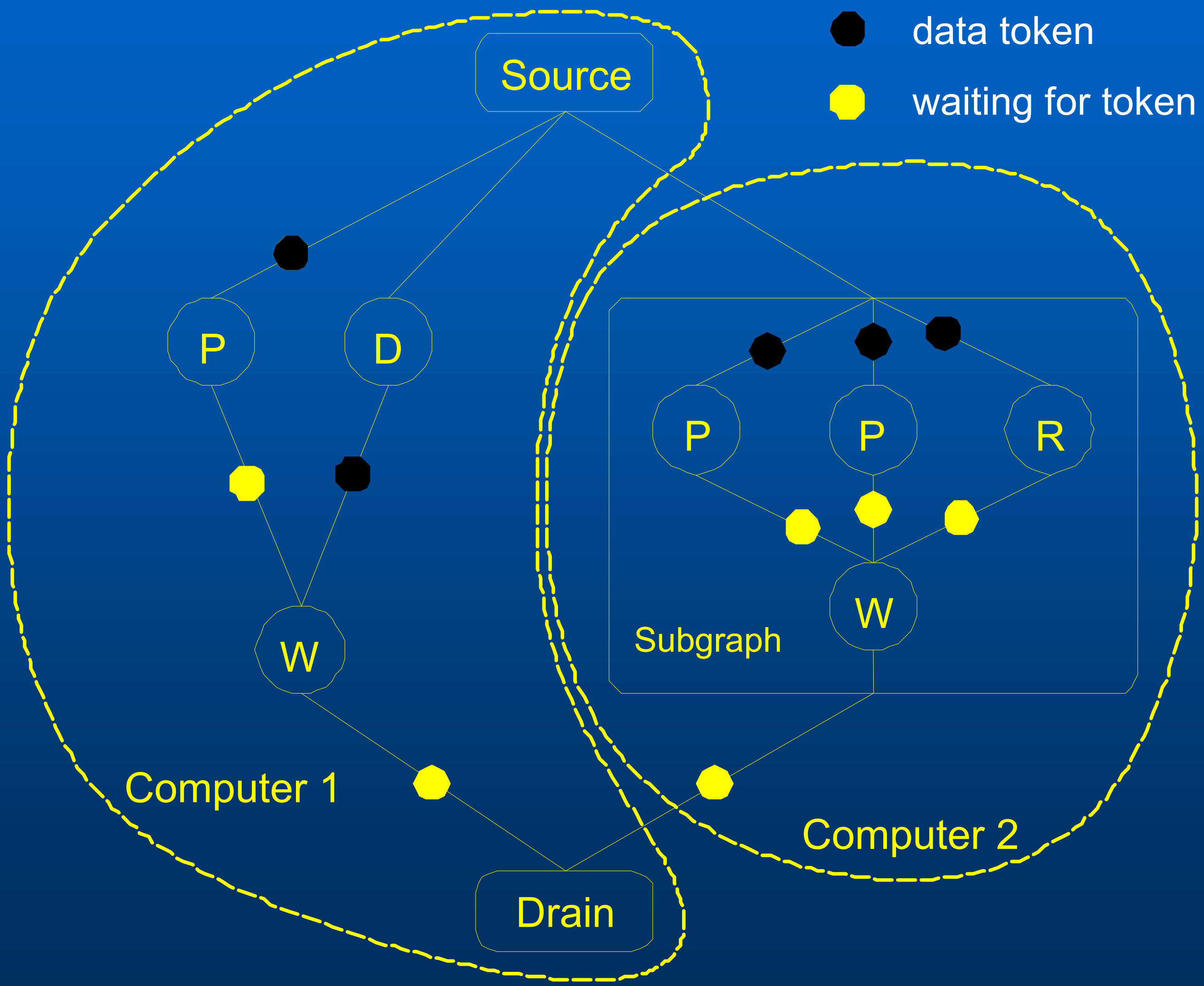
Distributed Processing

Waiting

Ready

Processing

Done



Distribution with Middleware

- Distributed Computing Environment (DCE)
- Distributed Component Object Model (DCOM)
- Java Remote Method Invocation (RMI)
- Microsoft .NET
- Message Oriented Middleware

- Common Object Request Broker Architecture (CORBA)

Load balancing

CORBA load balancing

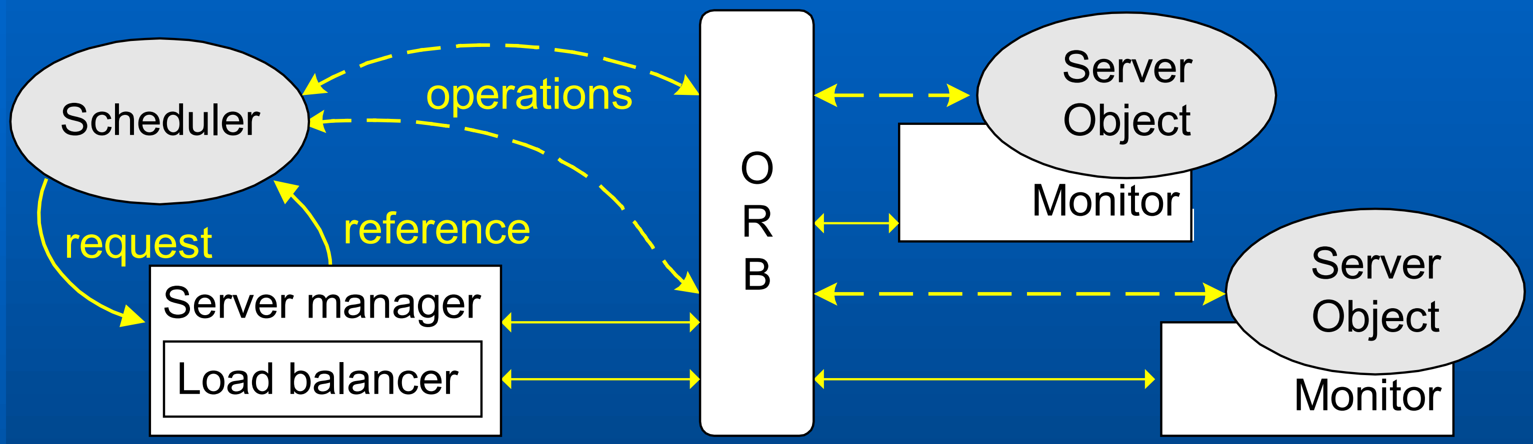
- request for proposal
- proprietary solutions
- simple techniques

TAO (Othman, Schmidt, 2001)

VisiBroker (Inprise, 2001), Orbix (Iona, 2000)

(Post, 2002), (Lindermeier, 2002), (Schnekenburger, 1997)

Communication Architecture



Monitor

- one monitor per host
- software monitoring
- monitoring of entire host

Load balancer

CPU-load and clock rate

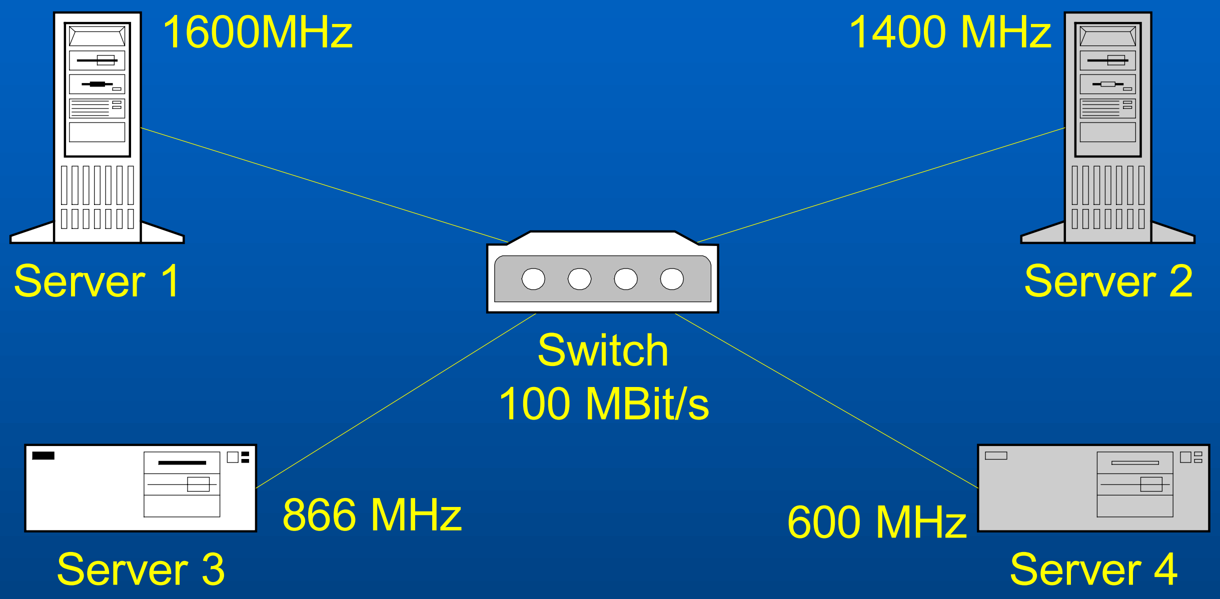
$$CPU_n = \left(CPU_{n-1} * f_{decay}\right) + \left(1 - f_{decay}\right)\left(\frac{T_{USER} + T_{SYS}}{\sum\limits_{USER,SYS,NICE,IDLE} T}\right)$$

$$CPU_{free} = \left[\alpha * \left(l_{\max Avg} - l_{Avg}\right) + \left(1 - \alpha\right) * l_{Act}\right] * f_{CPU}$$

server memory and round trip time

$$W_{ges} = w_{CPU} * CPU_{free} + w_{mem} * MEM_{free} - w_{RTT} * t_{RTT}$$

Testbed



Server 1	100%	Server 2	69%
Server 3	42%	Server 4	23%
			234%

Scimark2 Benchmark

Scenario

Axiom training sequence:

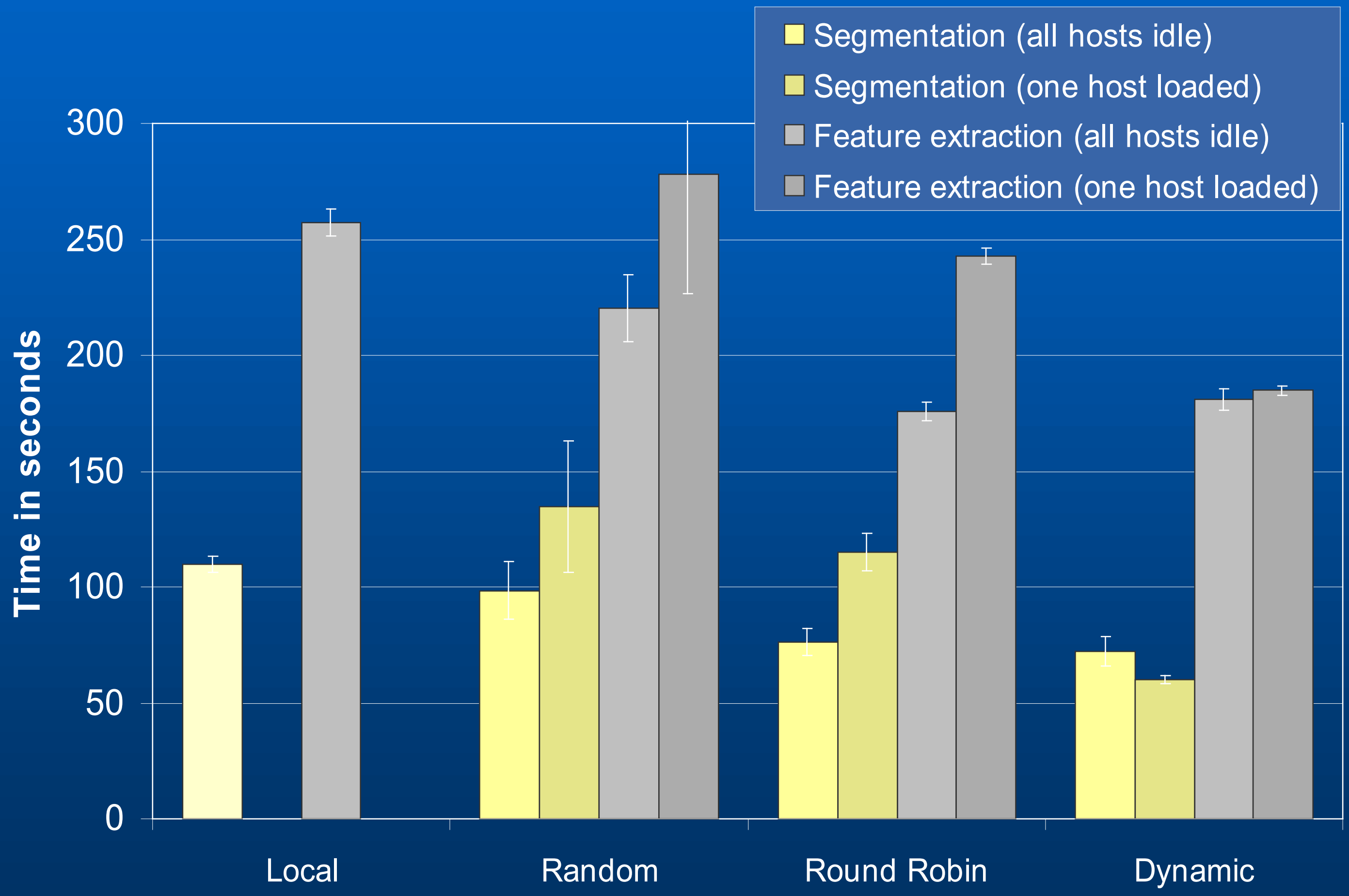
- segmentation of 50 single images
- extraction of local features from 16 single images

SciMark 2 Benchmark

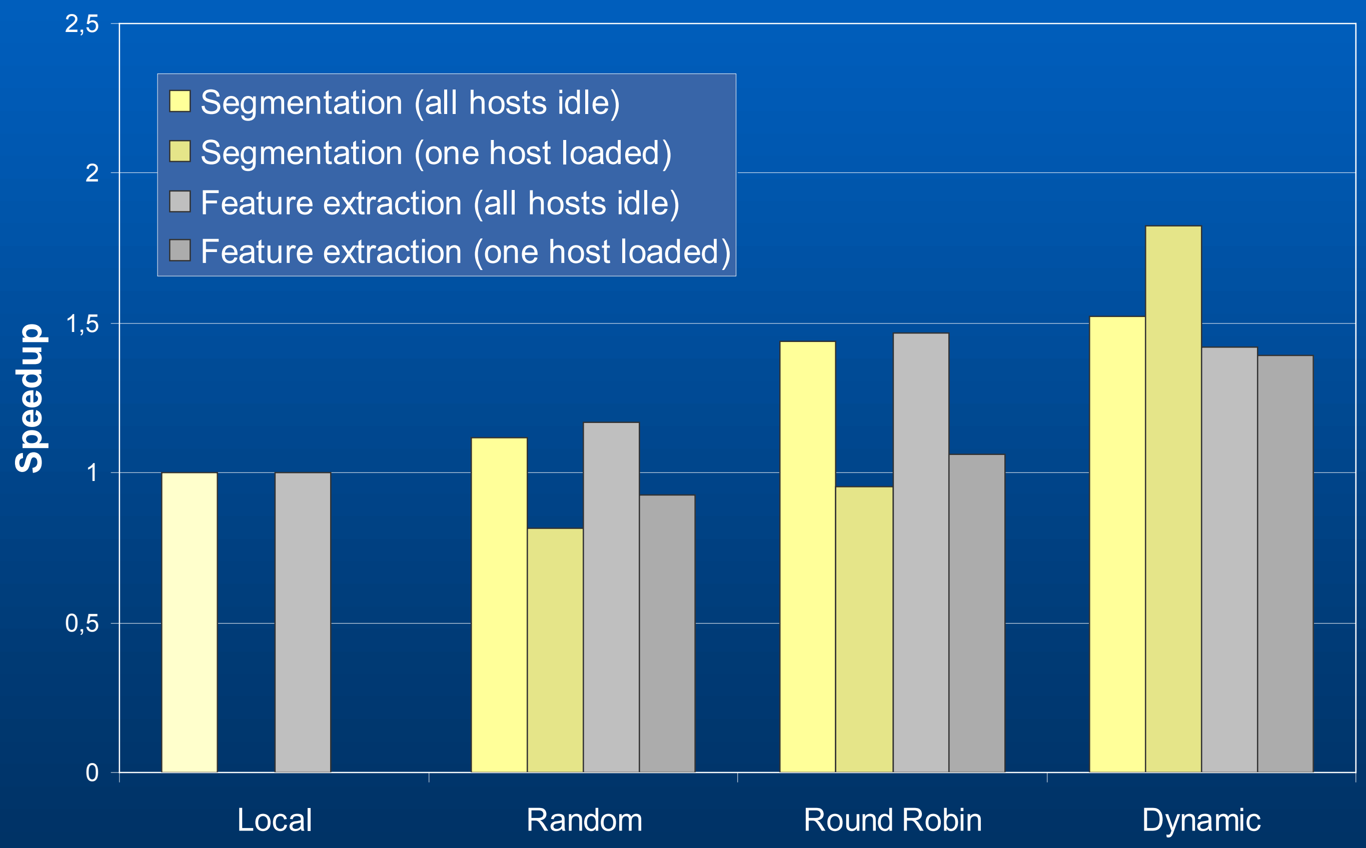
- all hosts idle
- one hosts with additional task

$$S(p) = \frac{T(1)}{T(p)} = \frac{T(1)_{\min}}{T(4)}$$

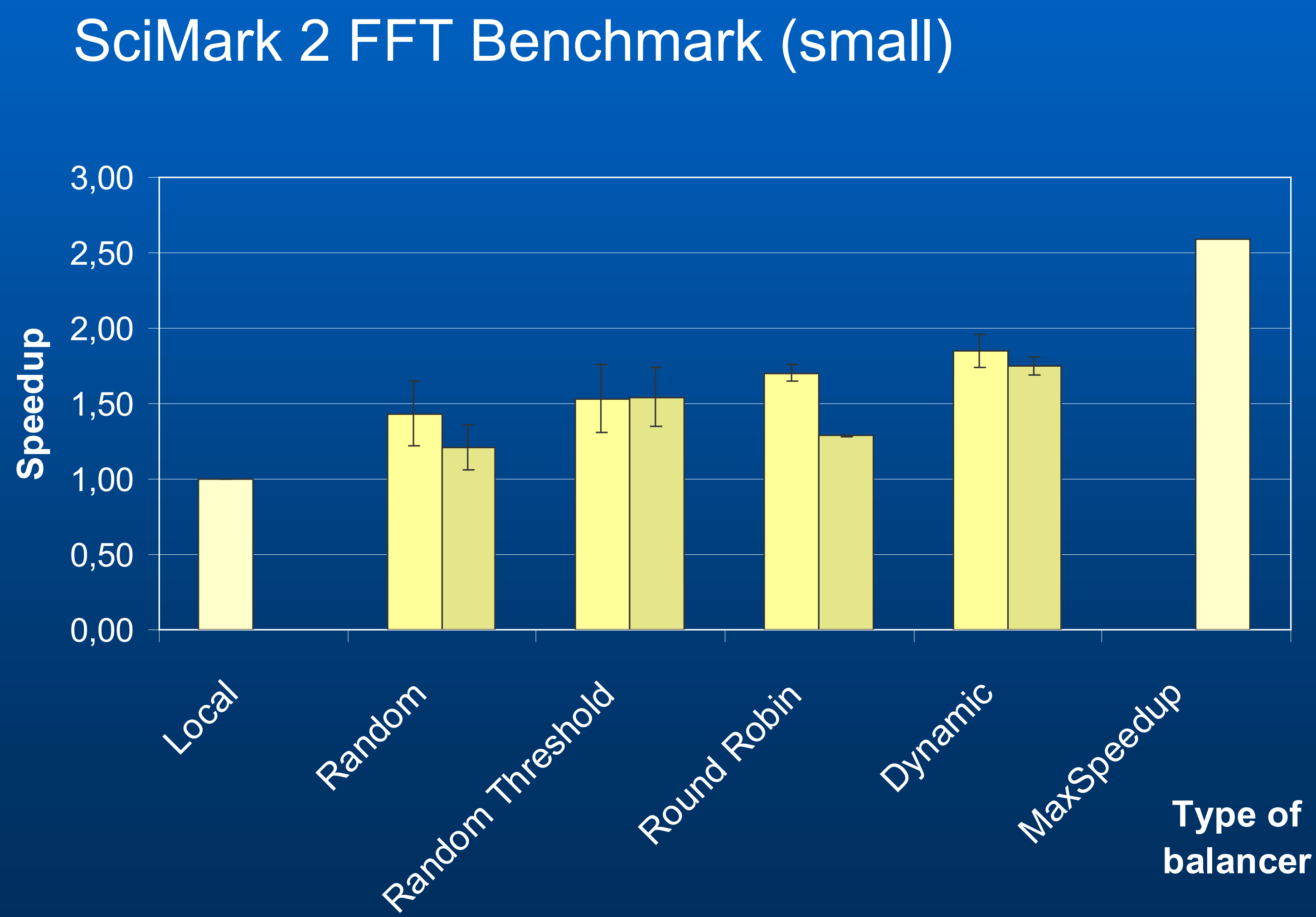
Experimental Results (I)



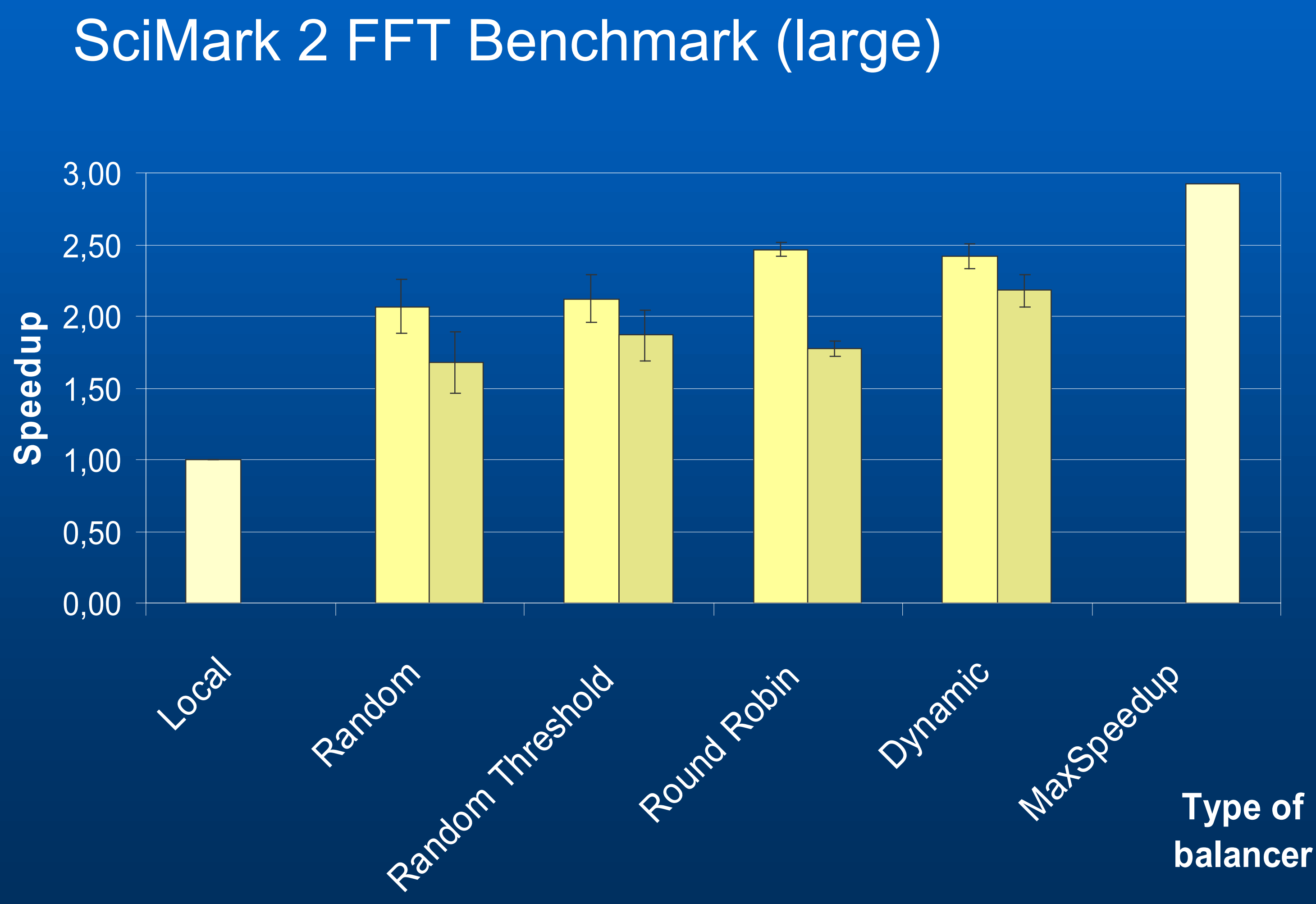
Experimental Results (II)



Experimental Results (III)



Experimental Results (IV)



Conclusion

- computation architecture for a visual object retrieval system
- visual combination of modular blocks
- control syntax
- distributed computing with CORBA-middleware
- dynamic load balancing in heterogeneous environments

Future Work

- automatic data flow graph analysis
- improve load balancing mechanism
- evaluation of system scalability

LTILib URL

http://ltilib.sourceforge.net/