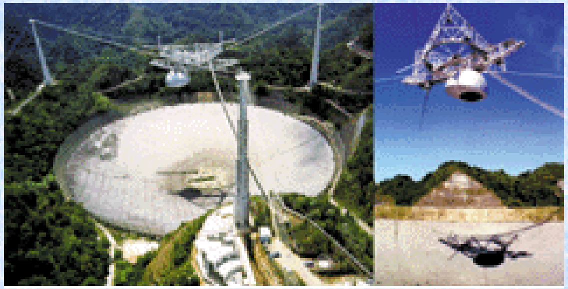
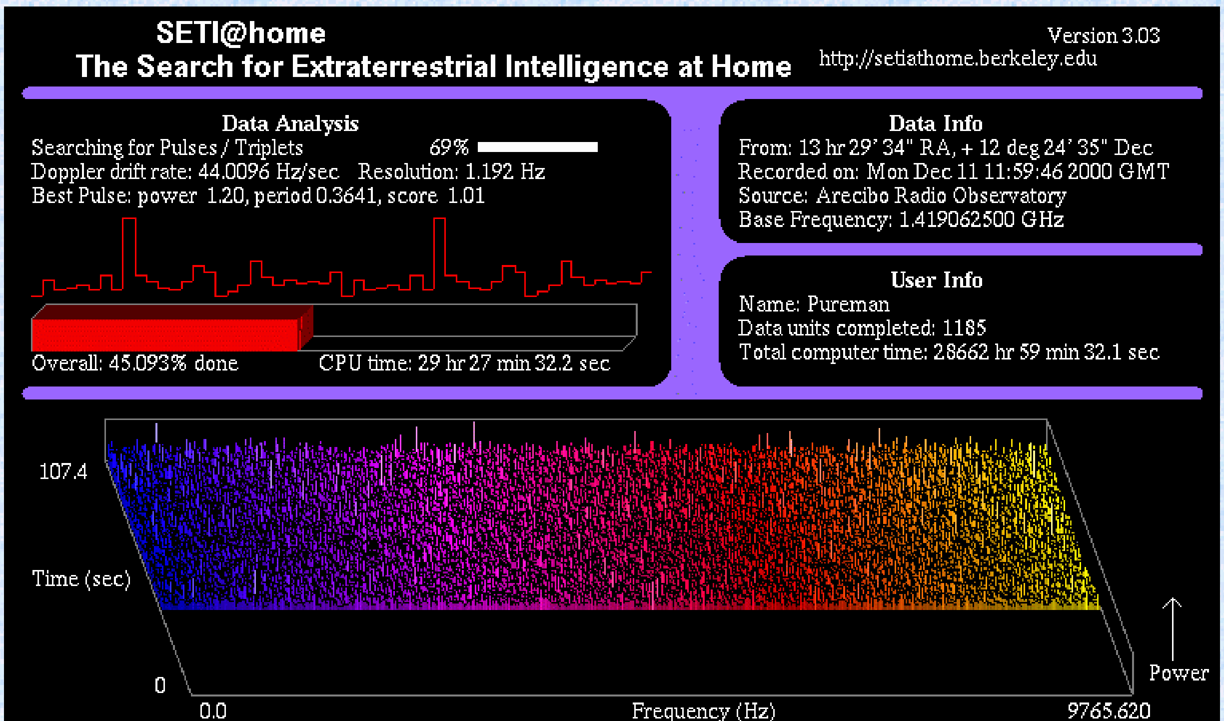
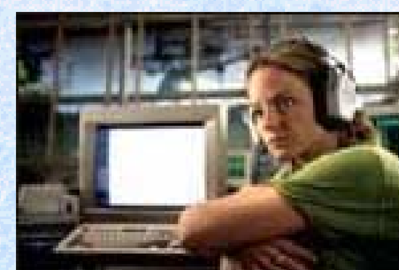
ALiCE: A Lightweight Grid Middleware

Teo Yong Meng
Department of Computer Science
National University of Singapore
teoym@comp.nus.edu.sg
http://www.comp.nus.edu.sg/~teoym

SETI@Home




SETI@home
The Search for Extraterrestrial Intelligence at Home
Version 3.03
http://setiathome.berkeley.edu
Data Analysis
Searching for Pulses / Triplets
69%
Doppler drift rate: 44.0096 Hz/sec
Resolution: 1.192 Hz
Best Pulse: power 1.20, period 0.3641, score 1.01
Overall: 45.093% done
CPU time: 29 hr 27 min 32.2 sec
Data Info
From: 13 hr 29' 34" RA, + 12 deg 24' 35" Dec
Recorded on: Mon Dec 11 11:59:46 2000 GMT
Source: Arecibo Radio Observatory
Base Frequency: 1.419062500 GHz
User Info
Name: Pureman
Data units completed: 1185
Total computer time: 28662 hr 59 min 32.1 sec
107.4
Time (sec)
0
0.0
Frequency (Hz)
9765.620
Power



Cost of Idle Computing Cycles

Desktop Processor Utilisation

	$ / processor (desktop)	$ / used	$ / used processor	cost of unused cycles
one desktop	$1200	$300	$150	$1050
1000 desktops	$1,200,000	$300,000	$150,000	**$1,050,000**

Source: Adapted from Internet Infrastructure & Services by Bear, Stearns & Co., May 2001. Based on IDA tender price, the cost of a Pentium PC desktop is estimated to be $1200.

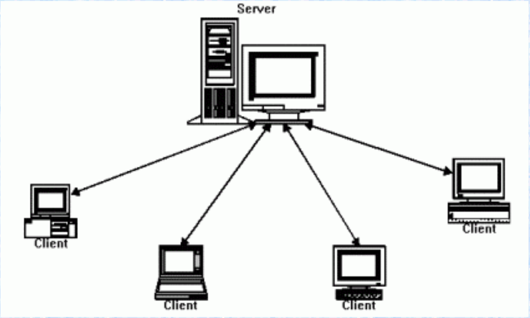
Assumptions:

1. Desktop utilization is 25%; 8 hrs/24 hrs = 33%; factoring in lunch, restroom, etc. a desktop can be idle up to 90%
2. When a processor is in used, assume a peak utilization of 50%

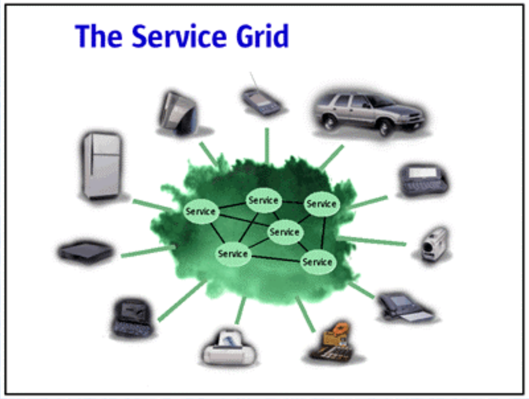
Outline

- Grid computing overview
- Overview of Globus
- ALiCE Middleware
  - Key features
  - Producer-consumer model
  - Template-based grid programming
  - ALiCE applications
  - ALiCE vs Globus
- Supercomputer, Physical and Virtual Cluster

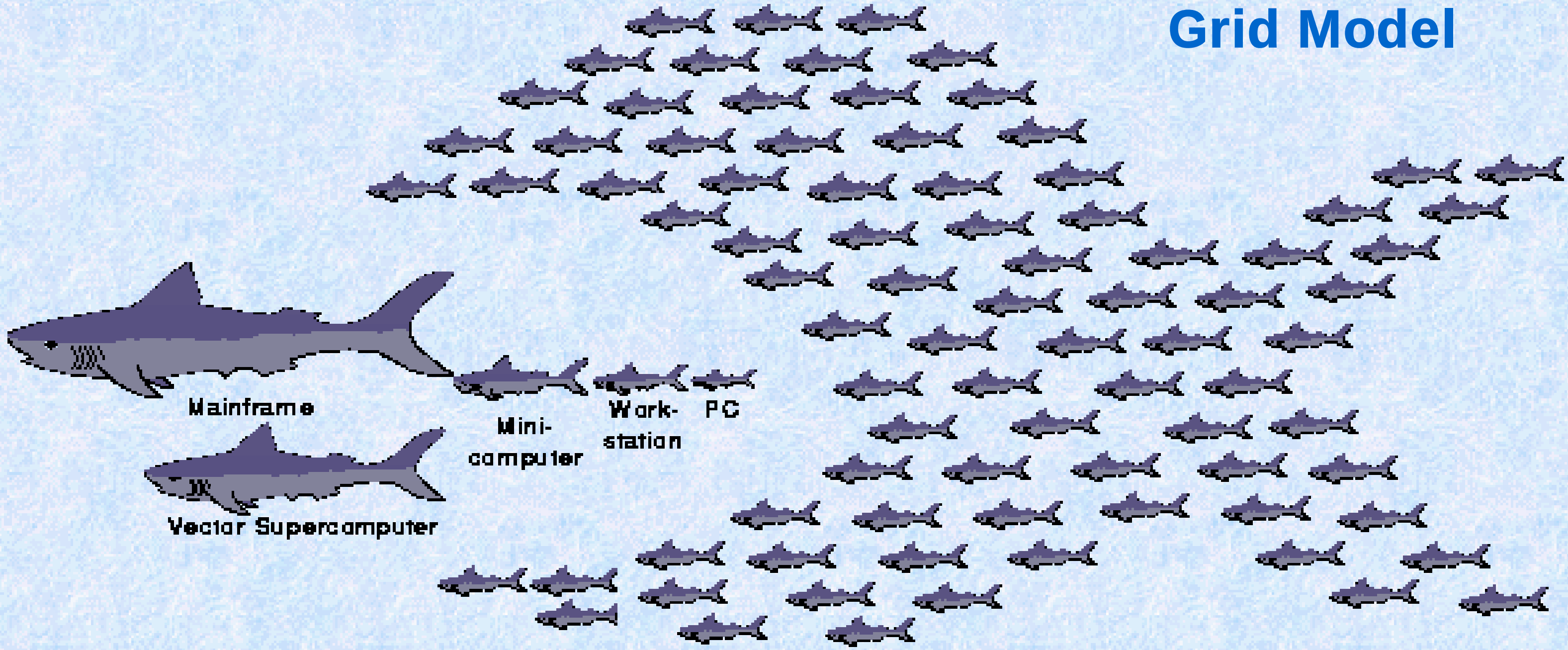
Grid Computing (1)



Client/Server Model



Grid Model



NOW

Grid Computing (2)

- Flexible, secure, coordinated resource sharing among dynamic collections of individuals, institutions, and resource

  From “The Anatomy of the Grid: Enabling Scalable Virtual Organizations”

- Enable communities (“virtual organizations”) to share geographically distributed resources as they pursue common goals -- assuming the absence of…
  – central location,
  – central control,
  – omniscience,
  – existing trust relationships

Grid Computing (3)

- **Resource sharing**
  - Computers, storage, sensors, networks, databases, …
  - Sharing always conditional: issues of trust, policy, negotiation, payment, …

- **Coordinated problem solving**
  - Beyond client-server: distributed data analysis, computation, collaboration, …

- **Dynamic, multi-institutional virtual orgs**
  - Community overlays on classic org structures
  - Large or small, static or dynamic

Grid Computing (4)

Advantages

- sharing and **aggregation** of resources
- **leveraging** on resources you don't own
- "**computing on demand**"
  - focus on business rather than technology
  - reduce business costs
- **remote access** to expensive resources (proprietary data sets,..)
- capability and scalability
- fault tolerance
- .....

Challenges

- heterogeneity
- distributed ownership
- dynamic behavior – internet based on best effort packet delivery
- security
- ease of use
- ....

Design Complexities

ease of use

decentralization

availability

shared data

security

Grid System

consistency

maintainability

atomicity

performance

mobility

scalability

Too many objectives

Not enough principles!

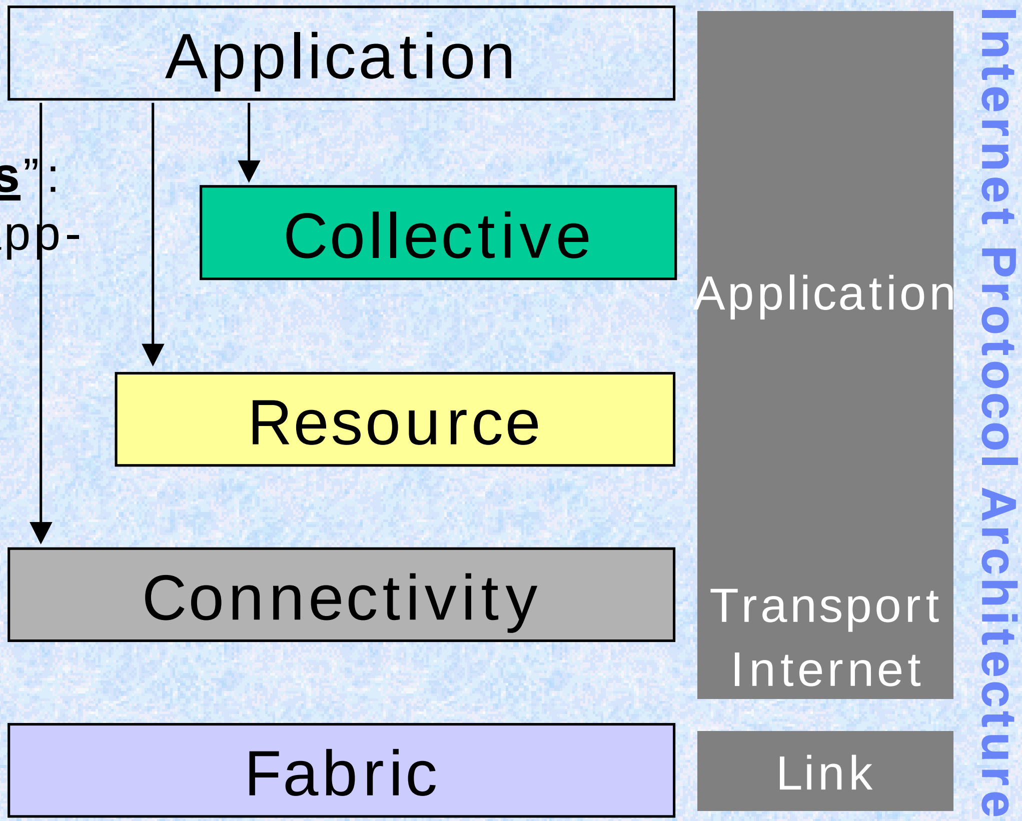
Three Main Obstacles in Grid Computing

1) New approaches to problem solving
   – Data Grids, distributed computing, peer-to-peer, collaboration grids, ...

2) Structuring and writing programs
   – Abstractions, tools **Programming Problem**

3) Enabling resource sharing across distinct institutions **Systems Problem**
   – Resource discovery, access, reservation, allocation; authentication, authorization, policy; communication; fault detection and notification; ...

Globus Layered Grid Architecture



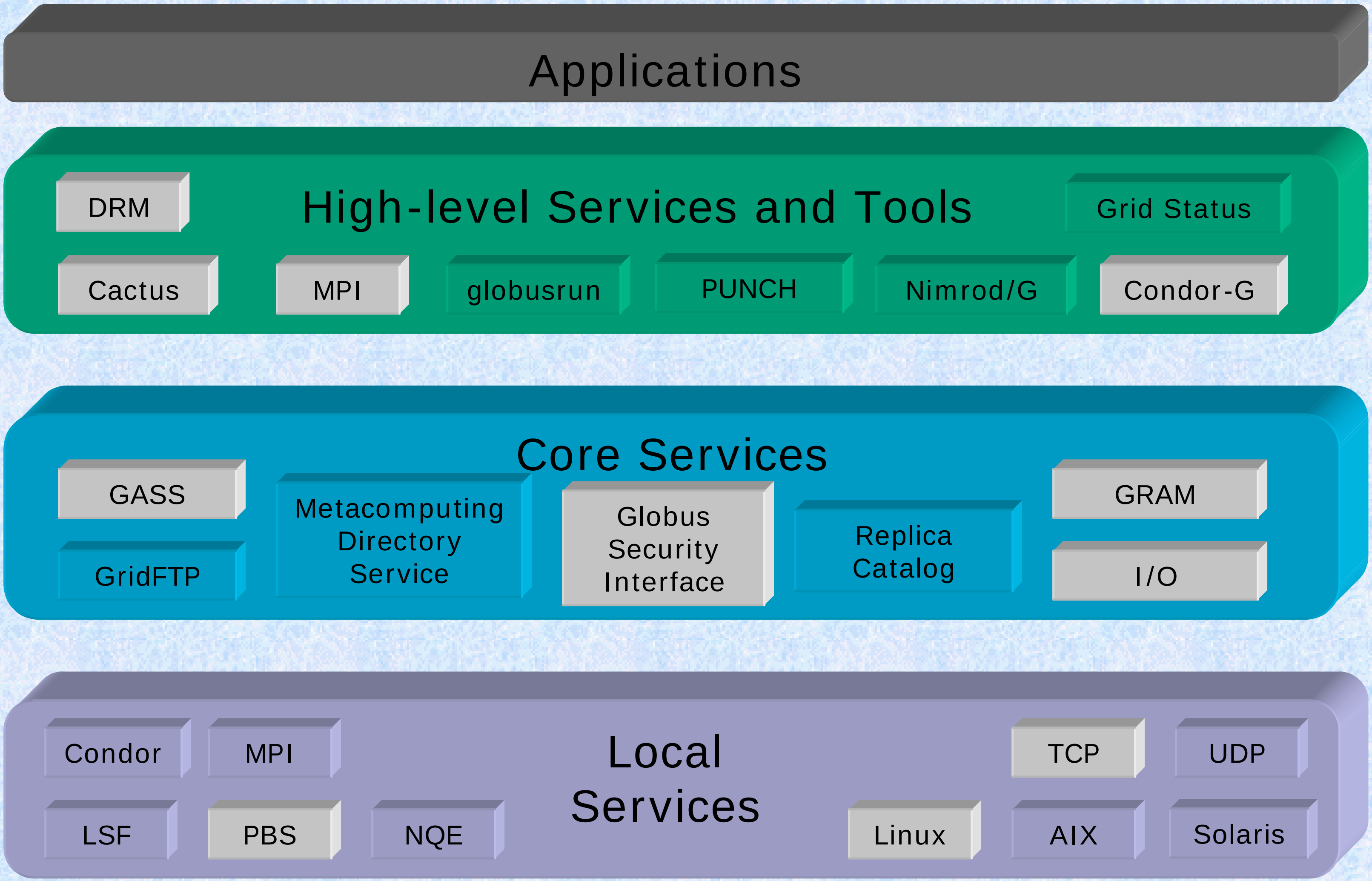
"**Coordinating <u>multiple resources</u>**": ubiquitous infrastructure services, app-specific distributed services

"**Sharing <u>single resources</u>**": negotiating access, controlling use

"**Talking to things**": communication (Internet protocols) & security

"**Controlling things locally**": Access to, & control of, resources

Globus Layered Grid Architecture



Globus Toolkit

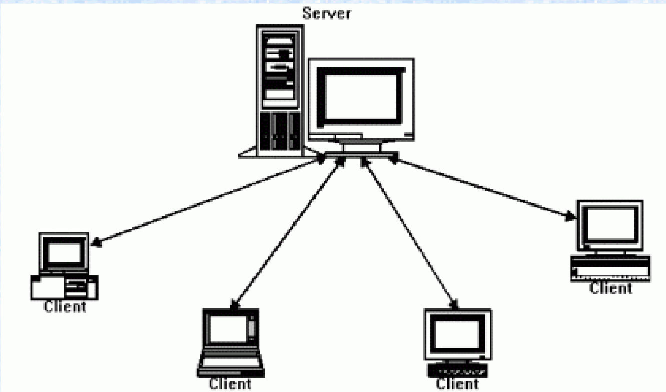
- Software toolkit
  - defines a set of services (grid protocols and APIs)
  - (partially) implemented as of a collection of tools

- Focus is on inter-domain issues, not clustering
  - supports collaborative resource use spanning multiple organizations
  - integrates with intra-domain services

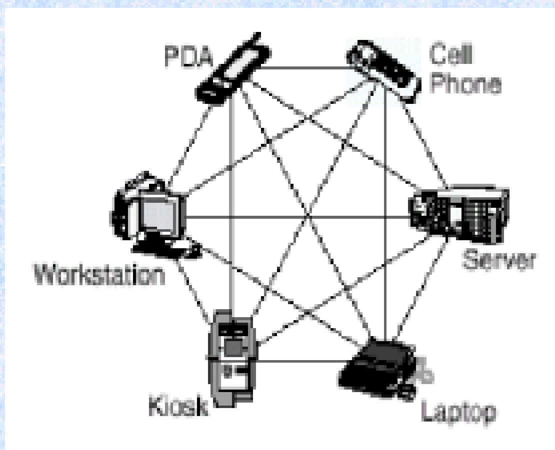
ALiCE Grid Computing

- Key features
- Producer-consumer model
- Template-based programming
- ALiCE Applications
- Globus vs ALiCE
- Supercomputer, physical and virtual grid

What is ALiCE (Adaptive and scaLable Internet-based Computing Engine)?

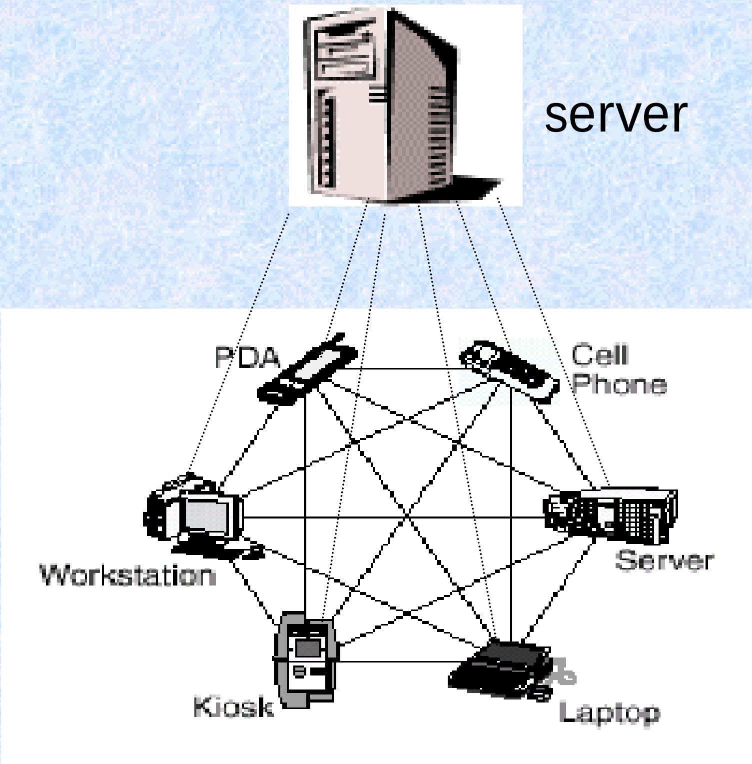


Client/Server Model



Grid Model

ALiCE
Brokered Grid Model



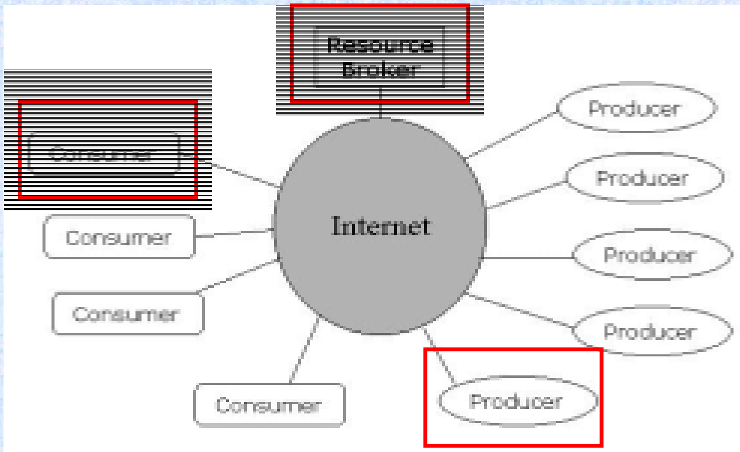
ALiCE (Adaptive and scaLable internet-based Computing Engine)

- Support for development and deployment of grid applications
- Template-based programming to mask complexity of grid infrastructure
- Job-parallelism to maximize **throughput**
- (Java) object-parallelism to maximize **performance**
- Distributed load-balancing algorithm
- Task replications for fault-tolerant and meeting performance deadline
- Differentiated levels of security (code, data and result) at varying costs
- Implemented in **Java** and **Java Jini™/JavaSpaces™**

ALiCE Producer-Consumer Model

Consumers (C)
- interface to users
- launch point for applications
- collection point for results (visualization)

Resource Broker (RB)
- authentication
- application execution control
- resource management
    - scheduling
    - load balancing
- ...

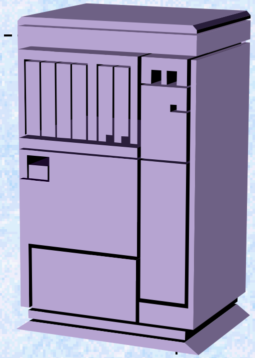


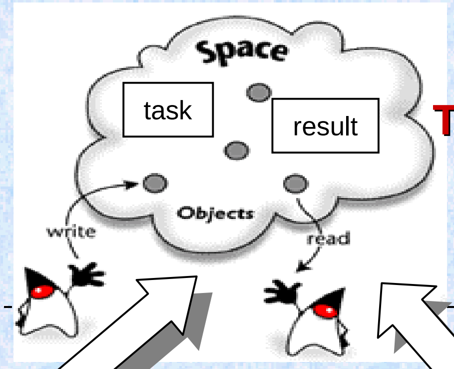
Producers (P)
- provide computing power
- executes tasks

ALiCE IMPLEMENTATION

Resource Broker

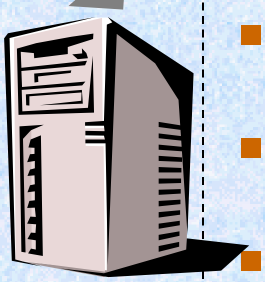
- Java SDK 1.3
- Java Jini 1.1/ JavaSpaces





Task Pool

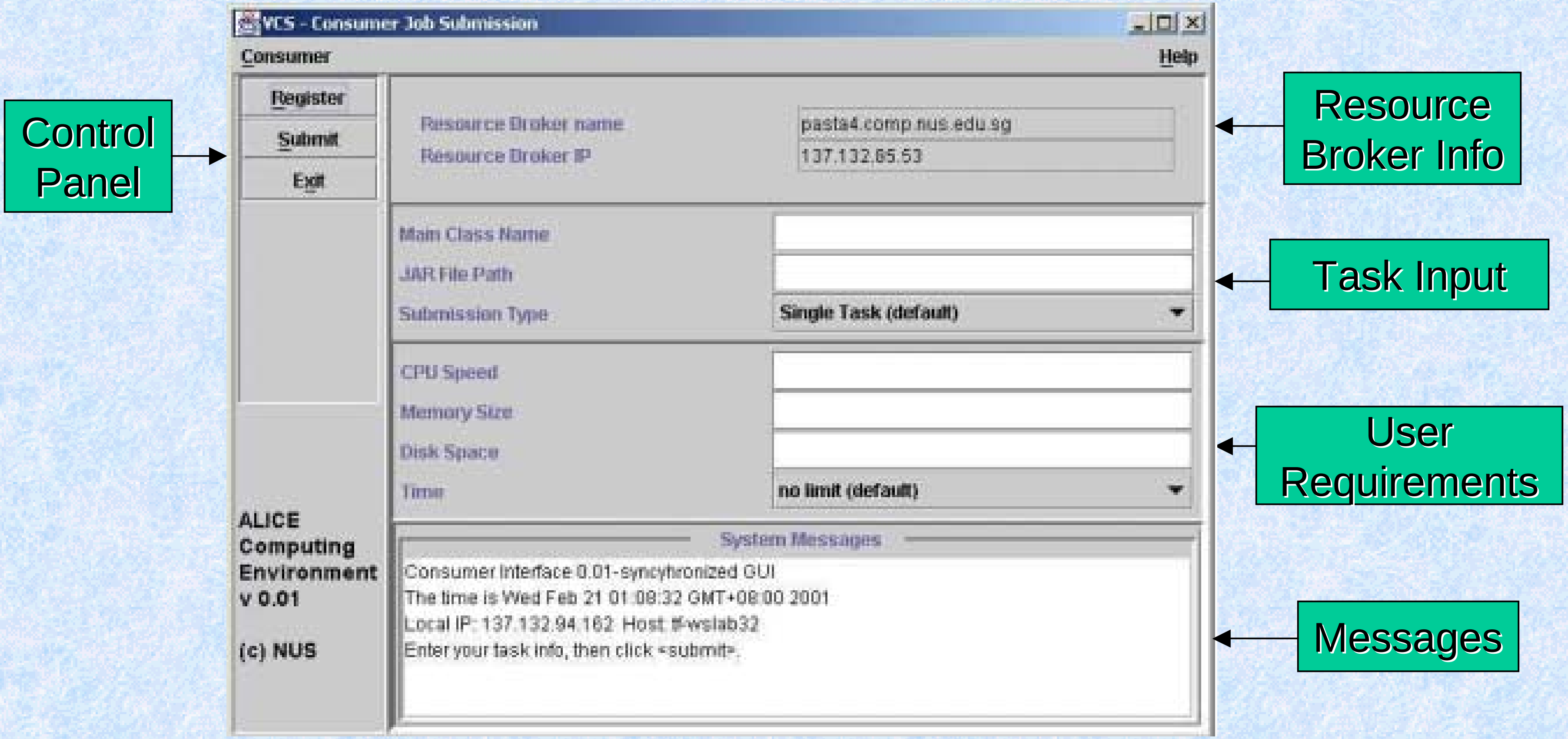
- Java SDK 1.3
- Java Jini 1.1/ JavaSpaces
- Swing



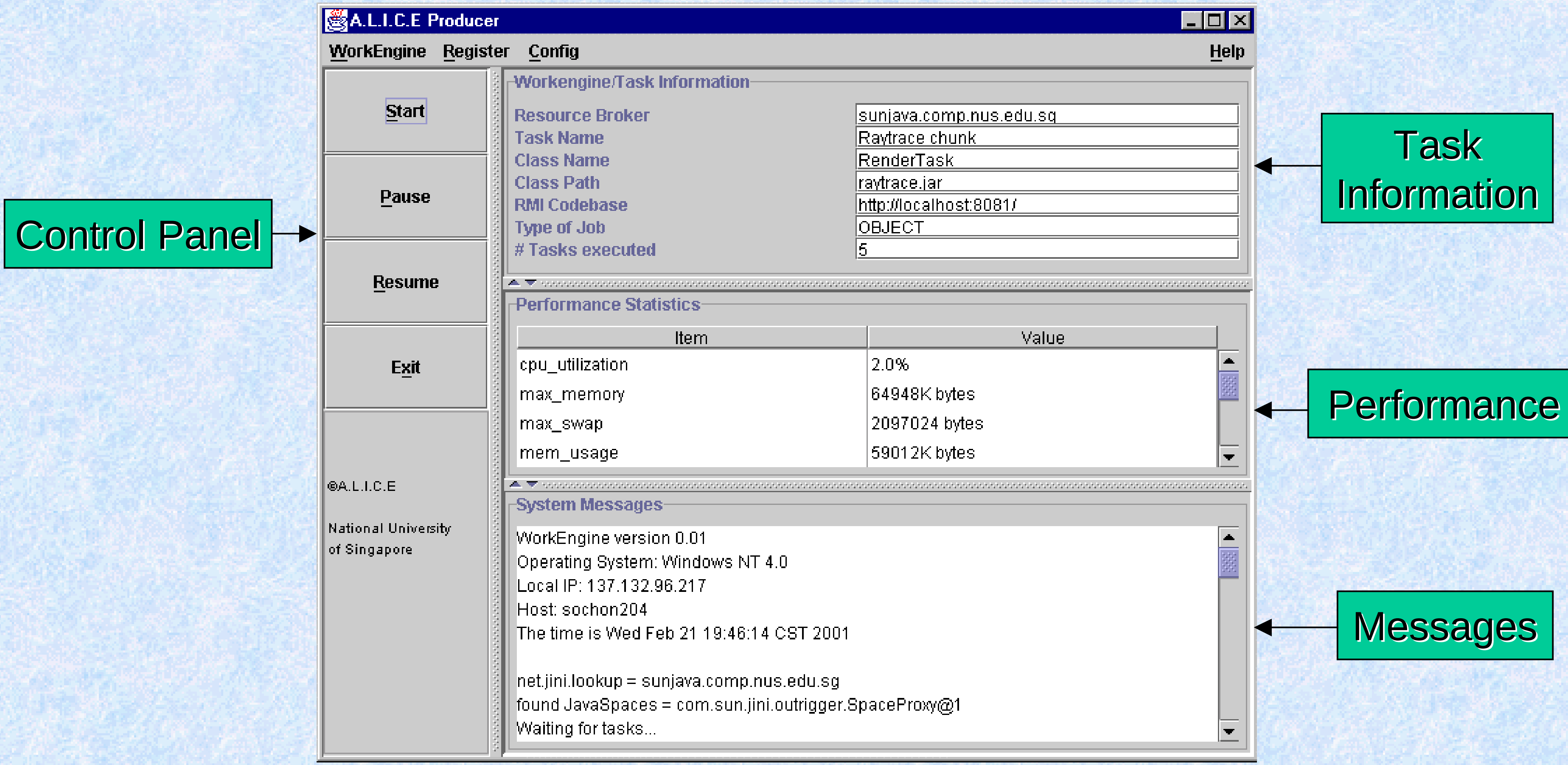
- Java SDK 1.3
- Java Jini 1.1/ JavaSpaces
- Java Reflection API
- Swing

Consumer **Producer**

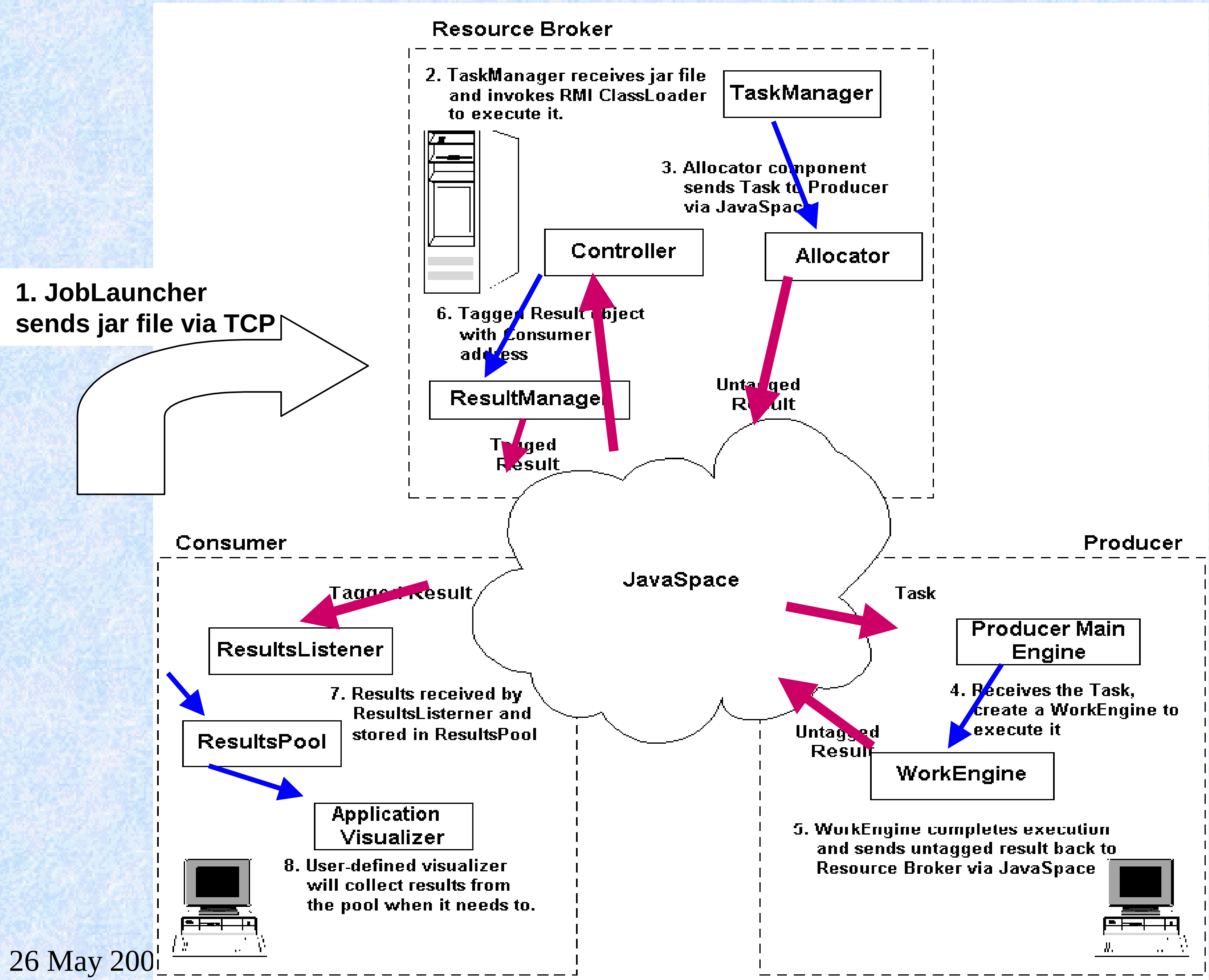
ALiCE Consumer GUI



ALiCE Producer GUI



Job Execution



Types of Applications Supported

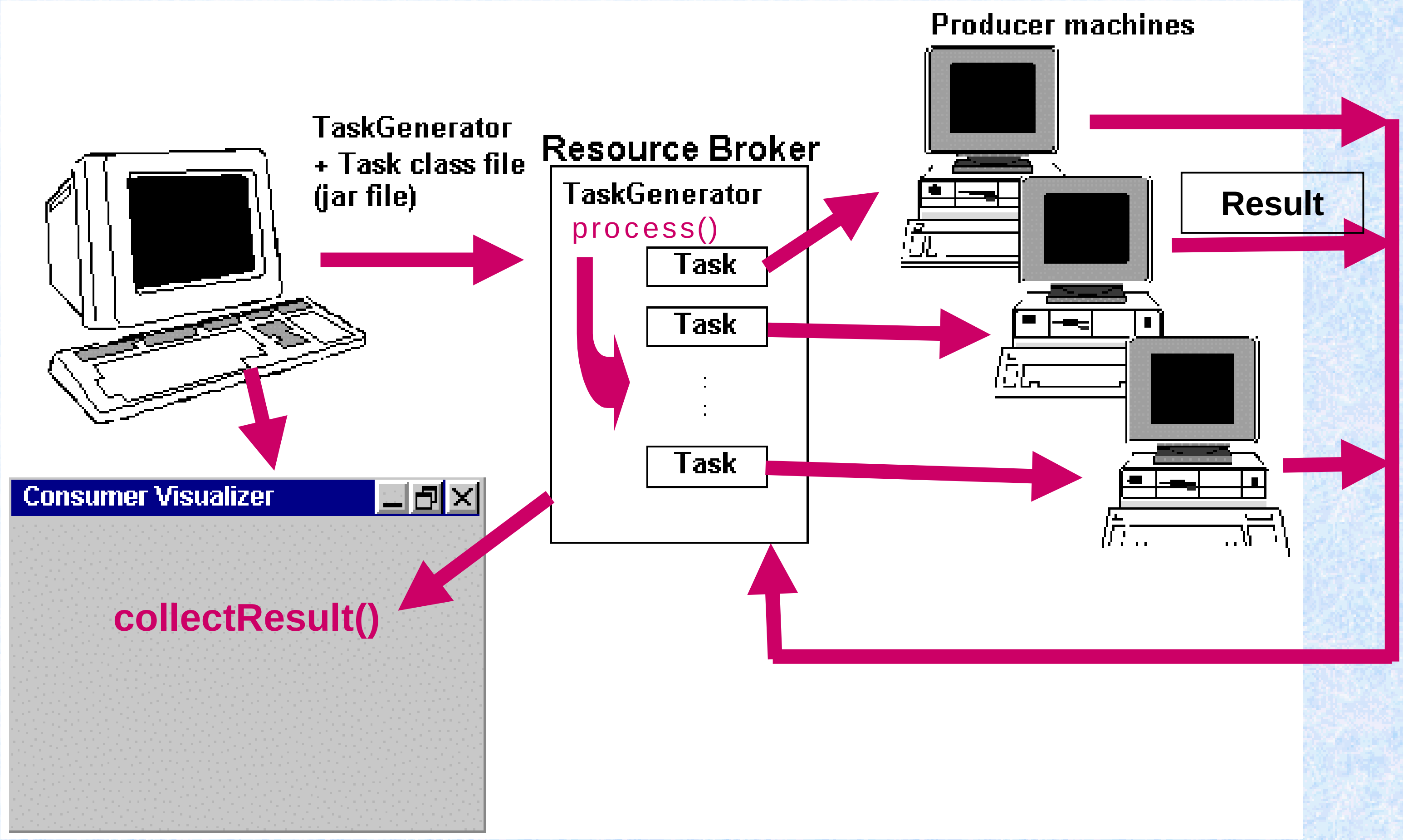
1. **Sequential Jobs (parametric computation)**
   - supports single-tasking programs with well-defined methods like main() or run()

2. **Parallel Jobs - Object-level Parallelism**
   - supports various parallel programming models via programming templates
   - allows task and result objects to be exchanged between consumers and producers through resource broker

Template-based Programming

Template	Function
TaskGenerator	• Invoked at resource broker • Method to send tasks to producer
ResultCollector	• Visualizer to be invoke at consumer • Method to retrieve results
Task	• Specify functions to execute at producer • Return a Result object
Result	• Interface for producer to instantiate and return result

Job Execution



Task Generator Template

```
// Task Generator Template
import alice.application.*; // import the templates

public class CLASSNAME extends TaskGenerator {

// place your variables here


// Constructor
 public CLASSNAME(){};

 // The no parameter constructor is a MUST.

public void init() {
 // place your initialization code here
}// init()

/**
   * generateTasks() - generates tasks
   *
   **/
 public void generateTasks() {
```

```
// This is where the tasks are generated
// Usually tasks are generated in a loop,
// and in this loop each task is sent for
// processing by calling the
//
// "public void process(Task t)" method

 } // generateTasks()


  /**
    * main method
    **/
  public static void main(String args[]) {
     CLASSNAME m = new CLASSNAME();
     m.init();
     m.generateTasks();
  }

} // end class
```

Result Collector Template

```
// Template for ResultCollector
//
import alice.application.*; // import the
templates

public class CLASSNAME extends
ResultCollector {

      // place your variables here
      //

    public static void main(String args[])
{

      CLASSNAME MV = new CLASSNAME();
      MV.init();
      MV.collectAllResults();
    }

 // the no argument constructor MUST exist
    public CLASSNAME() {
    }

    public void init() {
      // place your init codes here
      //
    }
```

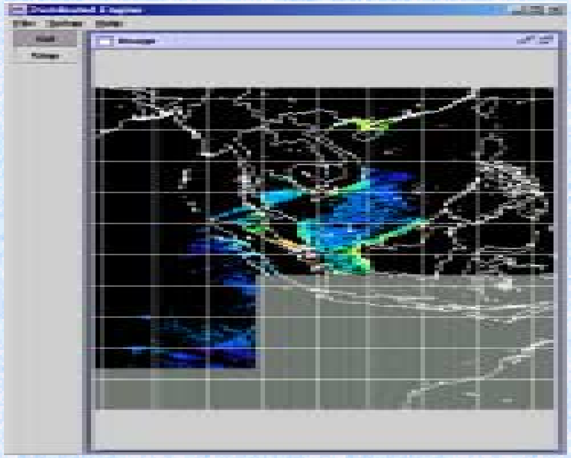
```
public void collectAllResults() {


 // Here is the result handling code.
 // Usually result handling involves a loop
 // that repeatedly calls the collectResult()
 // method of the ResultCollector superclass.
 //
 // This method returns a Result Object.
 //
 // The contents of this Result Object can be
 // inspected for result handling/processing.



    }
}
```

Task Template

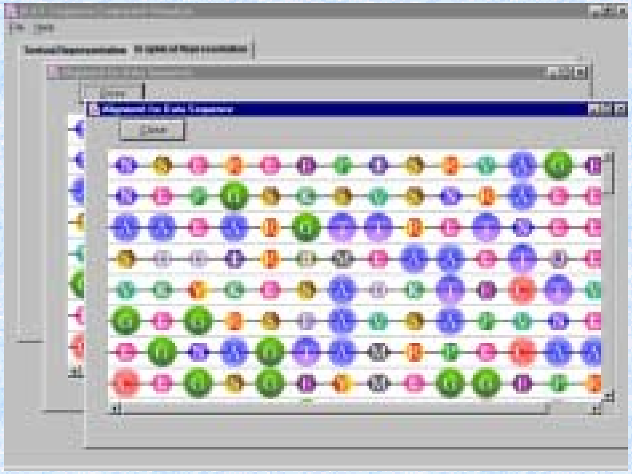
```
// Template for Task

import alice.application.*; // import the templates

public class CLASSNAME implements Task {

    // place your variables here
    //
    public CLASSNAME() {}
     public Result execute() {
          // This is where you do your calculation
        // The results are stored in the Result class
        // which functions as a datastructure
        // with which you can store results of any Object type
     }

public String toString() {
    // returns a String that can be used to ID your task
}
}
```

ALiCE Applications

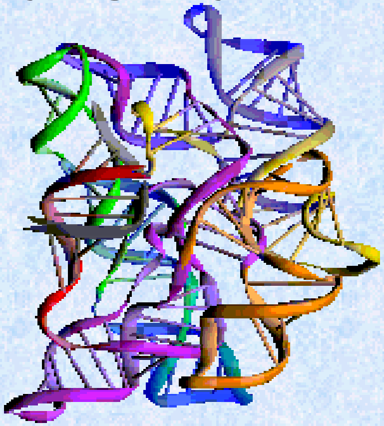
georectification of satellite images (CRISP)

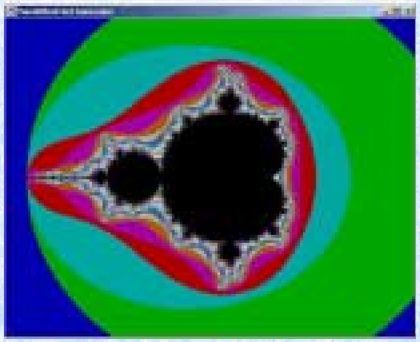


protein alignment and matching (BII)



Primer Search in Chromosome Sequences (Nanyang Polytechnics)



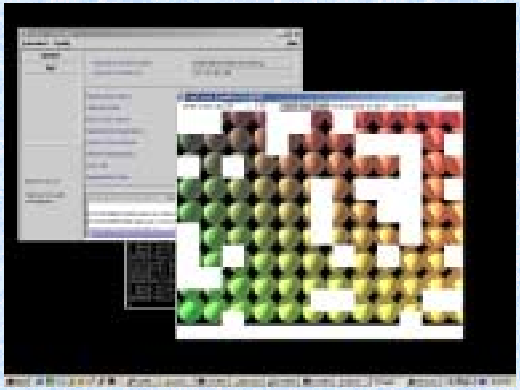


mandelbrot set

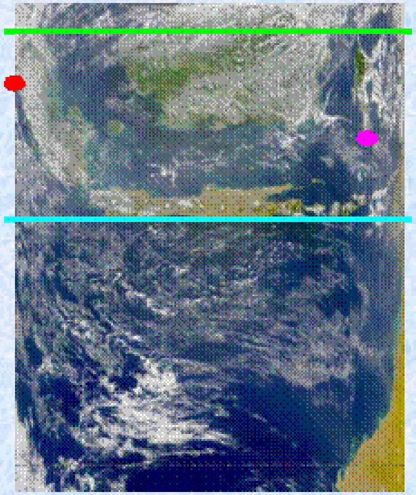
distributed equation solver

N-body problem

distributed ray tracing



Georectification of Satellite Images



Original Image

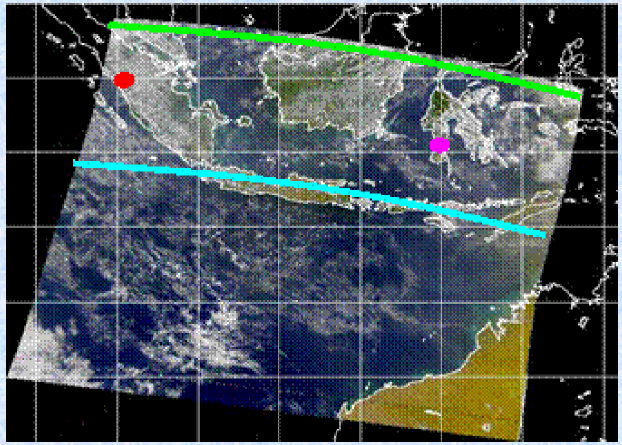
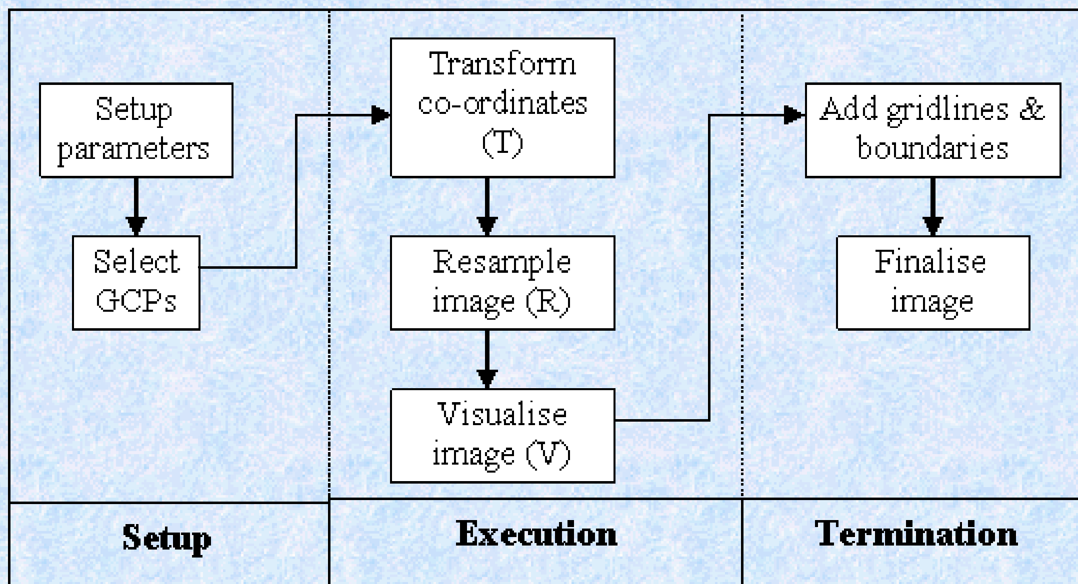


Image after Georectification



Georectification – ALiCE Program

```
public class swTask implements Task {

  public Result execute()  {
     // .. initialise data structures

     for (int j=0;j<chunkHeight;j++) {
       for (int i=0;i<chunkWidth;i++)  {
          /* perform coordinate
               transformation
             & image resampling */
        }
        return result;
     }
  }// end execute()

   // .. other methods
   //
}// end class
```

```
public class swGenerator extends TaskGenerator {

 public void generateTasks() {
    // ... initialise variables

    for (int h=0;h<cHeight;h++) {
      for (int w=0;w<cWidth;w++)       {
        swTask _swTask=new swTask(); // create task
        process(_swTask); // send task to Res. Broker
        taskGenerated++;
      }
    }
  } // end generateTask()

   // .. other methods
   //
} // end class
```

```
public class swTaskListener extends ResultCollector {

  // .. initialise data structure

  public void run() {
    while (resultsCollected<resultsExpected) {
      swTask result=((swTask)swGUI.collectResult()); // collect results
      vResults.add(result); // store result for visualization

      // .. datastructure maintenance code
    }
  } // end run()

  // .. other methods
  //
}// end class
```

ALiCE Applications

Protein Alignment and Matching – 50 MB chromosome database, swissprot (NCBI BLAST d/b server), P2, 450MHz, 256MB memory

- Sequential ~ 2 hours

- ALiCE with 8 producers, 4000 sequences/task

~1400 seconds

N-body problem (n=20,000 bodies) – predicting the motion of astronomical bodies in space. - Sequential – 9428 seconds

- ALiCE: 2 producers = 1109 sec, 8 produces = 457 sec

Globus vs ALiCE

- Globus
  - is a Grid Toolkit (provides set of services)
  - Is an open system (users can develop higher-level services on top of basic services)

    Adv: modularity & reusability of services

    Dis: Grid Infrastructure setup is complex

    app development/deployment is complex
  - is largely platform dependent (mostly UNIX)
  - Resource Management (via GRAM) at Job Level

Globus vs ALiCE

- ALiCE
  – User-Oriented Grid Computing Engine
    - Integrates all services (basic+higher level) to facilitate:
      – Ease of installation, deployment and administration
      – Ease of Grid App Development/Deployment using object programming template

  - Platform Independent (core services implemented in Java)

  - Resource Management at Object-level (fine-grain control)

Supercomputers

June 29, 2000 IBM ASCI White

- 8192 RS/6000 processors, 12.3 TFLOPS
- 6 TB memory, 160 TB disk storage
- US$110m, 106 tons, 28 tractor-trailer trucks

April 20, 2002 NY Times – Japanese Computer is World's Fastest

- NEC
- US$350m, occupies 4 tennis-court
- 640 specialized nodes, 5104 processors
- achieved 35.6 TFLOPS versus 7 TFLOPS in ASCI White

Cost of a Supercomputing, a Physical Cluster and a Virtual Grid of 100,000 PCs

- IBM ASCI White (2000) – US$110m
- NEC (2002) – US$350m
- Physical cluster of 100K Intel P4 ~ US$200m + US$13m (electricity)
- Virtual cluster – cost is distributed and absorbed by PC owners

Acknowledgements

Collaborators:

- Centre for Remote Imaging, Sensing and Processing (CRISP)
- BioInformatics Institute
- Nanyang Polytechnic (School of Life Sciences)
- The Royal Institute of Technology, Sweden

Acknowledgement: Sun Microsystems

Thank you.

Questions & Answers

Prediction is even harder in a field characterized by exponential progress

- "I think there is a world market for maybe five computers" -- Thomas J. Watson, founder and Chairman of IBM, 1943