Project AutoMate
Enabling Autonomic Applications on the Grid

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CAIP Research Review
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Outline

• Autonomic Grid computing – motivations and overview
• AutoMate: A framework of enabling autonomic applications
  – ACCORD: Autonomic component framework
  – RUDDER: Decentralized deductive engine
  – SESAME: Context sensitive dynamics access management
  – Pawn: Peer-to-Peer messaging infrastructure
  – SQUID: Decentralized discovery service
• Application Scenarios
  – Autonomic interactions oil reservoir optimization
  – Autonomic runtime management
  – Autonomic design
  – ...

Conclusions
Grids, The Vision

• Imagine a world
  – *in which computational power (resources, services, data, etc.) is as readily available as electrical power*
  – *in which computational services make this power available to users with differing levels of expertise in diverse areas*
  – *in which these services can interact to perform specified tasks efficiently and securely with minimum of human intervention*
    • on-demand, ubiquitous access to computing, data, and services
    • new capabilities constructed dynamically and transparently from distributed services

• New idea?
  • *a large part this vision was originally proposed by Fenando Corbato (The Multics Project, 1965, [www.multicians.org](http://www.multicians.org))*

• The Computational Grid
  – *Potential for aggregating resources*
    • computational requirements
  – *Potential for seamless interactions*
    • new applications formulations
Current Trends: Smaller/Cheaper/Faster/Powerful/Connected ….

- Explosive growth in computation, communication, information and integration technologies
  - computing is ubiquitous, pervasive – communication is/will be
- Pervasive “anytime-anywhere” access environments
  - ubiquitous access to information via PCs, PDAs, Cells, smart appliances, etc. (billions of devices, millions of users)
  - peers capable of producing/consuming/processing information at different levels and granularities
  - embedded devices in clothes, phones, cars, mile-markers, traffic lights, lamp posts, refrigerators, medical instruments …
- “On demand” computational/storage resources, services
Enabling Grid Computing – The Exponentials

- Network vs. computer performance
  - Computer speed doubles every 18 months
  - Storage density doubles every 12 months
  - Network speed doubles every 9 months
  - Difference = order of magnitude per 5 years

- 1986 to 2000
  - Computers: x 500
  - Networks: x 340,000

- 2001 to 2010
  - Computers: x 60
  - Networks: x 4000

Scientific American (Jan-2001)

“When the network is as fast as the computer's internal links, the machine disintegrates across the net into a set of special purpose appliances”

(George Gilder)

Ack. I. Foster
Drivers: Evolution of the Scientific/Business Process

• Evolution of the scientific process
  – Pre-electronic
    • Theorize &/or experiment, alone or in small teams; publish paper
  – Post-electronic
    • Construct and mine very large databases of observational or simulation data
    • Develop computer simulations & analyses
    • Exchange information quasi-instantaneously within large, distributed, multidisciplinary teams

• Evolution of business process
  – Pre-Internet
    • Central corporate data processing facility
    • Business processes not typically compute-oriented
  – Post-Internet
    • Enterprise computing is highly distributed, heterogeneous, inter-enterprise (B2B)
    • Outsourcing becomes feasible => service providers of various sorts
    • Business processes increasingly computing- and data-rich

⇒ Need to manage dynamic, distributed infrastructures, services, and applications
⇒ Seamless aggregations and interactions
The Grid...

“Resource sharing & coordinated problem solving in dynamic, multi-institutional virtual organizations”
The Bad News… Complexity, Cost

- Administration of individual systems is increasingly difficult
  - 100s of configuration, tuning parameters for DB2, WebSphere
- Heterogeneous systems are becoming increasingly connected
  - Integration becoming ever more difficult
- Architects can't intricately plan interactions among components
  - Increasingly dynamic; more frequently with unanticipated components
- More of the burden must be assumed at run time
  - But human system administrators can't assume the burden; already
    - 6:1 cost ratio between storage admin and storage
    - 40% outages due to operator error
## Rapid Changes, Increased Complexity

<table>
<thead>
<tr>
<th>Time</th>
<th>Platform(s)</th>
<th>Network Operations Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-1980</td>
<td>Mainframe/ IBM era</td>
<td>10:1 people/machine ratio</td>
</tr>
<tr>
<td>1970-1990</td>
<td>Minicomputer/ DEC era</td>
<td>1:1 people/machine ratio</td>
</tr>
<tr>
<td>1980-</td>
<td>Workstation/ PC era</td>
<td>1:10 people/machine ratio</td>
</tr>
<tr>
<td>1990-</td>
<td>Enterprise networks/ Cisco era</td>
<td>1:100? people/machine ratio</td>
</tr>
</tbody>
</table>

- **Old network management systems were single vendor solutions optimized for cost in rigid five-year preplanned networks.**
- **New network operations systems must be designed for adaptability and change (new equipment, multiple vendors, new service offerings/provisioning).**

Source: Paul Johnson
The Bad News... Increasing Cost

$3 mil
$2
$1

$1 million Storage Administration

$2 million System

1984

$2 million
$3 mil
$2
$1

$1 million Storage Administration

$2 million System

2000

The Bottom Line….

- Developing application to utilize and exploit the Grid remains a significant challenge
  - Unprecedented scales, complexity, heterogeneity, dynamism and unpredictability, lack of guarantees
  - The problem: a level of complexity, heterogeneity, and dynamism for which our programming environments and infrastructure are becoming unmanageable, brittle and insecure
    - System size, heterogeneity, dynamics, reliability, availability, usability
    - Currently typically proof-of-concept demos by “hero programmers”
  - Requires fundamental changes in how applications are formulated, composed and managed
    - Breaks current paradigms based on passive components and static compositions
    - autonomic components and their dynamic composition, opportunistic interactions, virtual runtime, …
  - Resonance - heterogeneity and dynamics must match and exploit the heterogeneous and dynamic nature of the Grid
Convergence of Biology and Information Technology

The Autonomic Nervous System Monitors and Regulates:

- Without requiring our conscious
- when we run, it increases our heart and breathing rate
Autonomic Computing?

- Nature has evolved to cope with scale, complexity, heterogeneity, dynamism and unpredictability, lack of guarantees
  - self configuring, self adapting, self optimizing, self healing, self protecting, highly decentralized, heterogeneous architectures that work !!!
  - e.g. the autonomic nervous system
    - tells you how fast to beat, checks your blood's sugar and oxygen levels, and controls your pupils so the right amount of light reaches your eyes as you read these words, monitors your temperature and adjusts your blood flow and skin functions to keep it at 98.6ºF
    - coordinates - an increase in heart rate without a corresponding adjustment to breathing and blood pressure would be disastrous
    - is autonomic - you can make a mad dash for the train without having to calculate how much faster to breathe and pump your heart, or if you'll need that little dose of adrenaline to make it through the doors before they close
  - can these strategies inspire solutions?
  - of course, there is a cost
    - lack of controllability, precision, guarantees, comprehensibility, ...
  - A.I. ? – duplication of human thought is not the ultimate goal
An autonomic computing system is one that has the capabilities of being self-defining, self-healing, self-configuring, self-optimizing, self-protecting, contextually aware, and open.
AutoMate: Enabling Autonomic Applications (http://automate.rutgers.edu)

• Objective:
  – To enable the development of autonomic Grid applications that are context aware and are capable of self-configuring, self-composing, self-optimizing and self-adapting.
    • address uncertainty, unreliability, dynamism, incomplete knowledge

• Overview:
  – Definition of Autonomic Components
    • definition of programming abstractions and supporting infrastructure that will enable the definition of autonomic components
    • autonomic components provide enhanced profiles or contracts that encapsulate their functional, operational, and control aspects
  – Dynamic Composition and Coordination of Autonomic Applications
    • models, mechanisms and supporting infrastructure to enable autonomic applications to be dynamically and opportunistically composed from autonomic components
    • composition/coordination based on (dynamically defined) declarative policies, goals and constraints, and aware of available Grid resources (systems, services, storage, data) and components, and their current states, requirements, and capabilities
  – Autonomic Middleware Services
    • design, development, and deployment of key services on top of the Grid middleware infrastructure to support autonomic applications
    • enable components, applications and resources (systems, services, storage, data) to interact as peers
AutoMate: Design Principles

- Separation of policy from mechanism distilling out the aspects of components and enabling them to orchestrate a repertoire of mechanisms for responding to the heterogeneity and dynamics, both of the applications and the Grid infrastructure. The policies that drive these mechanisms are specified separately.
  - Examples of mechanisms are alternative numerical algorithms, domain decompositions, and communication protocols; an example of a policy is to select a latency-tolerant algorithm when network load is above certain thresholds.

- Context, constraint and aspect based composition techniques applied to applications and middleware as an alternative to the current ad-hoc processes for translating the application's dynamic requirements for functionality, performance, quality of service, into sets of components and Grid resource requirements.

- Dynamic, proactive, and reactive component management to optimize resource utilization and application performance in situations where computational characteristics and/or resource characteristics may change.
  - For example, if adaptive mesh refinement increases computational costs, we may negotiate to obtain additional resources or to reduce resolution, depending on resource availability and user preferences.
AutoMate: Architecture

- **Key components:**
  - **Accord**: Autonomic application framework
  - **Rudder**: Decentralized deductive engine
  - **Squid**: P2P discovery service
  - **SESAME**: Dynamic access control engine
  - **Pawn**: P2P messaging substrate
AutoMate: Architecture

- AutoMate System Layer:
  - builds on the Grid middleware and OGSA and extends core Grid services to support autonomic behavior
  - provide specialized services such as peer-to-peer semantic messaging, events and notification

- AutoMate Component Layer:
  - addresses the definition, execution and runtime management of autonomic components
  - provides supporting services such as discovery, factory, lifecycle, context, etc.

- AutoMate Application Layer:
  - builds on the component and system layers to support the autonomic composition and dynamic (opportunistic) interactions between components

- AutoMate Engines:
  - decentralized (peer-to-peer) networks of agents in the system.
    - context-awareness engine composed of context agents and services and provides context information at different levels to trigger autonomic behaviors
    - deductive engine composed of rule agents which are part of the applications, components, services and resources, and provides the collective decision making capability to enable autonomic behavior
    - trust and access control engine composed of access control agents and provides dynamic context-aware control to all interactions in the system

- AutoMate Portals
  - provide users with secure, pervasive (and collaborative) access to the different entities
  - using these portals users can access resource, monitor, interact with, and steer components, compose and deploy applications, configure and deploy rules, etc.
ACCORD: Autonomic Components

- Autonomic components export information and policies about their behavior, resource requirements, performance, interactivity and adaptability to system and application dynamics
  - functional aspects
    - abstracts component functionality, such as order of interpolation (linear, quadratic, etc.)
    - used by the compositional engine to select appropriate components based on application requirements
  - operational aspects
    - abstracts a component's operational behavior, including computational complexity, resource requirements, and performance (scalability)
    - used by the configuration and runtime engines to optimize component selection, mapping and adaptation
  - control & coordination aspects
    - describes the adaptability of the component and defines sensors/actuators and policies for management, interaction and control.
Autonomic components encapsulate access policies, rules, a rule agent, and an access agent

- enables components to consistently and securely configure, manage, adapt and optimize their execution based on rules and access policies.
- rules/policies can be dynamically defined (and changed) in terms of the component's interfaces (based on access policies) and system and environmental parameters
- rule execution may change the state, context and behavior of a component, and can generate events to trigger other rule agents
- rule agent manages rule execution and resolves rule conflicts
ACCORD: Autonomic Component – Prototype implementation (EuroPar 03)
ACCORD: Autonomic Composition/Coordination Engine

- Dynamically synthesize a service/composition plan at runtime based on dynamically defined goals, constraints and context
  - annotate services/components with semantic information describing its functionality and interfaces (extend WSDL with semantic metadata)
  - use relational algebra to choreograph ad hoc interactions at runtime
  - use constraints to define and evaluate composition/service plans
  - provide mechanism to evaluate and rank plans based on user defined cost models
1 Composition request
   - Objective
   - Constraints
   - Semantic metadata

5 Rank and return composition plans

2 Connect and select services
   - based on constraints
   - based on keywords
   - based on input arguments

3 Create interaction links
   - using relational join based on semantic annotations

4 Synthesize composition plans as paths in the ad hoc service graph
ACE Architecture

- **Translator**
  - Parse WSDL description
  - Update relevant tables
  - Add semantic metadata

- **Graph Generator**
  - Define interactions links
  - Desirability factor is associated with link

- **Constraint Analyzer**
  - Valid links are selected
  - Represented as simple SQL queries

- **Plan Generator**
  - Appropriate plans are generated
  - Plans are ranked based on cost factor
ACCORD: Opportunistic Interactions

- Interactions based on local goals and objectives
  - **local goals and objectives are defined as constraints to be satisfied**
  - **constraints can updated and new constraints can defined at any time**
- Dynamic and ad-hoc
  - **interactions use “semantic messaging” based on proximity, privileges, capabilities, context, interests, offerings, etc.**
- Opportunistic
  - **constraints are long-term and satisfied opportunistically (may not be satisfied)**
- Probabilistic guarantees and soft state
  - **no explicit synchronization**
  - **interaction semantics are achieved using feedback and consensus building**
RUDDER: The AutoMate Deductive Engine

• RUDDER is a decentralized deductive engine composed of distributed specialized agents (component rule agents, composition/coordination agents, context agents and system agents) that exist at different levels of the system, and represents their collective behavior.

• Objectives
  – Providing mechanisms for dynamically defining, configuring, deploying rules, and rule conflicts management
  – Runtime management services, supporting autonomic composition, adaptation, optimization and execution
RUDDER Architecture

Middleware Services
• Goal-directed focus: focus on the objective and choose the method to achieve it
• Context sensitivity: make decisions about what to try and retry based on present conditions
An agent has beliefs about the world and desires to satisfy, driving it to form intentions to act

- **Beliefs:** about the environment and other agents
- **Desire or goals to achieve**
- **Intention or plans to act upon to achieve its desires**

**Human** → **Belief, Desire, Intentions Agent**

**Beliefs** - perceived understanding of the world

**Goals or desires**

**Accumulated experience and behaviours**

**Execution Engine**

**Beliefs** - database of perceived world knowledge

**Goals or desires**

**Intentions** - currently executing plans

**Pre-compiled plans**
Autonomic Application Construction

Middleware Services
SESAME: Context Aware Access Management

- **Objective:**
  - support dynamic, seamless and secure interactions between the participating entities (i.e. components, services, application, data, instruments, resources and users)
  - Autonomic Computing – Self Protecting (Context aware, Dynamic)

- **Issues:**
  - access rights in highly dynamic and heterogeneous Grid environments depends on the entity's privileges, capabilities, context and state
    - e.g. the ability of a user to access a resource or steer a component depends on users' privileges (e.g. owner), current capabilities (e.g. resources available), current context (e.g. location, time, secure connection) and the state of the resource or component

- **Approach**
  - extend Role Based Access Control (RBAS) to make access control decision based on dynamic context information
  - dynamically adjust Role Assignments and Permission Assignments based on context
SESAME: Operation

- Dynamically adjusts the user-role and role-permission relationships based on context information

  - Each component is assigned a role subset (by the authority service) from the entire role set on authentication
  - Each component maintains permission subsets for each role that will access the component
  - During an interaction, state machines are maintained by the delegated access control agent at the subject (Role State Machine) to navigate the role subset, and the object (Permission State Machine) to navigate the permission subset for each active role
  - State machines define the currently active role permissions
  - Access agent navigates the role/permission subsets to react to changes in the context
SESAME: Illustrative Example

- The access control agent maintains the role state machine for each component and defines its active role based on its current context.
- When the subject component accesses another component, it will first get its current role from its role state machine, and then use this role to access the component.
- At the accessed component, a permission state machine is defined (if it does not already exist) for the active role.
- For example, active roles X, Y, and Z have their own permission state machines at component. The access control agent at the accessed component will maintain this permission state machine to define the current permissions for a role based in its current context and state.
SQUID: A Decentralized Information Discovery/Coordination

• Overview/Motivation:
  – Efficient information discovery and coordinations in the absence of global knowledge of naming conventions is a fundamental problem in large, decentralized, distributed resource sharing environments such as the Grid.
    • A document is better described by keywords than by its filename, a computer by a set of attributes such as CPU type, memory, operating system type than by its host name, and a component by its aspects than by its instance name.
  – Heterogeneous nature and large volume of data and resources, their dynamism (e.g. CPU load) and the dynamism of the Grid make the information discovery a challenging problem.

• Key features
  – P2P system that supports complex queries containing partial keywords, wildcards, and range queries.
  – Guarantees that all existing data elements that match a query will be found with bounded costs in terms of number of messages and number of nodes involved.
  – The system can be used as a complement for current resource discovery mechanisms in Computational Grids (to enhance them with range queries).
SQUID: Design

• Overall architecture is a distributed hash table (DHT), similar to typical data lookup systems (e.g. Chord, CAN)
• Key innovation is a locality preserving, dimension reducing indexing scheme that effectively maps the multidimensional information space to physical peers
  – data elements described using a sequence of keywords (common words in the case of P2P storage systems, or values of globally defined attributes - such as memory and CPU frequency - for resource discovery in computational grids)
    • keywords form a multidimensional keyword space where the keywords are the coordinates and the data elements are points in the space.
    • two data elements are “local” if their keywords are lexicographically close or they have common keywords
  – use Space Filling Curves to map documents that are local multi-dimensional index space to indices that are local in the 1-dimensional index space
    • load-balancing at join and runtime
  – existing systems, this is done using consistent hashing to uniformly map data element identifiers to indices
    • data elements are randomly distributed across peers without any notion of locality
SQUID: Operation
Pawn: A P2P Messaging Substrate

- A peer-to-peer messaging substrate that extends existing solutions to enable high-level interactions for scientific applications.
  - semantic “associative” interactions
- Architecture
  - Peers, Messages, Services, Interactions
- Key Features
  - Stateful messages
  - Guaranteed messaging semantics
  - Publish/subscribe mechanisms across peer-to-peer domains
  - High-level messaging semantics
    - Sync/Async Messaging
    - PUSH (dynamic injection)
    - PawnRPC
- Builds on Project JXTA
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- Builds on Project JXTA
A Data Intense Challenge: The Instrumented Oil Field of the Future (UT-CSM, UT-IG, RU, OSU, UMD, ANL)

Detect and track changes in data during production
Invert data for reservoir properties
Assimilate data & reservoir properties into the evolving reservoir model
Use simulation and optimization to guide future production

- Production simulation via reservoir modeling
- Monitor production by acquiring time lapse observation of seismic data
- Revise knowledge of reservoir model via imaging and inversion of seismic data
- Modify production strategy using an optimization criteria
Autonomic Oil Well Placement (UT-CSM, UT-IG)

- Optimization algorithm: use VFSA (Very Fast Simulated Annealing)
  - requires function evaluation only, no gradients
- IPARS delivers
  - fast-forward model (guess->objective function value)
  - post-processing
- Formulate a parameter space
  - well position and pressure \((y,z,P)\)
- Formulate an objective function:
  - maximize economic value \(\text{Eval}(y,z,P)(T)\)
- Normalize the objective function \(\text{NEval}(y,z,P)\) so that:

\[
\min \text{NEval}(y,z,P) \iff \max \text{Eval}(y,z,P)
\]
Components of the AORO Application

- **IPARS**: Integrated Parallel Accurate Reservoir Simulator
  - Parallel reservoir simulation framework
- **IPARS Factory**
  - Configures instances of IPARS simulations
  - Deploys them on resources on the Grid
  - Manages their execution
- **VFSA**: Very Fast Simulated Annealing
  - Optimizes the placement of wells and the inputs (pressure, temperature) to IPARS simulations.
- **Economic Modeling Service**
  - Uses IPARS simulations outputs and current market parameters (oil prices, costs, etc.) to compute estimated revenues for a particular reservoir configuration.
- **DISCOVER Computational Collaboratory**
  - Interaction & Collaboration
  - Distributed Interactive Object Substrate (DIOS)
  - Collaborative Portals
Client configures and launches IPARS Factory and VFSA Optimization peers on resource of choice

IPARS Factory discovers and initializes VFSA Optimization Service

IPARS Factory gets initial guess from VFSA Optimization Service launches IPARS instance on resource of choice

One optimal well placement is determined, IPARS Factory launches IPARS run

Current oil price, market state, etc.

Scientists/Engineers collaboratively interact with IPARS

Client can configure IPARS params

IPARS connects to VFSA Optimization Services and presents revenue

IPARS Factory generates new well placement

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Current oil price, market state, etc.
Autonomic Oil Well Placement

Contours of $\text{NEval}(y,z,500)(10)$

Permeability

Pressure contours
3 wells, 2D profile

Requires $NY\times NZ$ (450) evaluations. Minimum appears here.

VFSA solution: “walk”:
found after 20 (81) evaluations
Sample Results

Y/Z positions for Y&Z [0,315]

First guess on injection well position

(Final) Iterative guesses optimizing revenue

Fixed Injection well

Production wells

Minimizing cost

Accepted Guesses
Computational Modeling of Physical Phenomenon

• Realistic, physically accurate computational modeling
  – Large computation requirements
    • e.g. simulation of the core-collapse of supernovae in 3D with reasonable resolution \((500^3)\) would require ~ 10-20 teraflops for 1.5 months (i.e. ~100 Million CPUs!) and about 200 terabytes of storage
    • e.g. turbulent flow simulations using active flow control in aerospace and biomedical engineering requires \(5000 \times 1000 \times 500 = 2.5 \times 10^9\) points and approximately 10^7 time steps, i.e. with 1GFlop processors requires a runtime of \(~7 \times 10^6\) CPU hours, or about one month on 10,000 CPUs! (with perfect speedup). Also with 700B/pt the memory requirement is \(~1.75TB\) of run time memory and \(~800TB\) of storage.
  – Dynamically adaptive behaviors
  – Complex couplings
    • multi-physics, multi-model, multi-resolution, …
  – Complex interactions
    • application – application, application – resource, application – data, application – user, …
  – Software/systems engineering/programmability
    • volume and complexity of code, community of developers, …
      – scores of models, hundreds of components, millions of lines of code, …
A Selection of SAMR Applications

Blast wave in the presence of a uniform magnetic field – 3 levels of refinement. (Zeus + GrACE + Cactus, P. Li, NCSA, UCSD)

Mixture of H2 and Air in stoichiometric proportions with a non-uniform temperature field (GrACE + CCA, Jaideep Ray, SNL, Livermore)

Richtmyer-Meshkov - detonation in a deforming tube - 3 levels. Z=0 plane visualized on the right (VTF + GrACE, R. Samtaney, CIT)

Multi-block grid structure and oil concentrations contours (IPARS, M. Peszynska, UT Austin)
Autonomic Computational Science and Engineering

- Simulation of Active Flow Control of Turbulent Flows
- Virtual Groundwater Basin Model

vGrid Application Development

Thermonuclear Combustion Supernovae
Non-Born - Oppenheimer Molecular Quantum Mechanics

Analyse

Plan

Monitor

Execute

vGrid Runtime Management

vGrid Grid Virtualization Services

Temporal Scheduling

Spatial Scheduling

Work

Work

Work

Grid Middleware

TASSEL
Application Runtime Management in V-Grid

**Grid Resource Hierarchy**

- V-Grid
  - Virtual Resource Unit
  - Virtual Resource Unit
  - Virtual Resource Unit

**Virtual Grid Resource Autonomic Runtime Manager (ARM)**

**Application Domain Hierarchy**

- VR: Virtual Resource
- VCU: Virtual Computational Unit

**Loop for each level of Grid/Application hierarchy**

**V-Grid Monitoring**
- (Self-observation, Context-awareness)
  - System states (CPU, Memory, Bandwidth, Availability etc.)
  - Application states
    - (Computation/Communication Ratio, Nature of Applications, Application Dynamics)

**V-Grid Deduction**
- (Self-adaptation, Self-optimization, Self-healing)
  - Identify and characterize natural regions
  - Define objective functions and management strategy
  - Define VCU

**V-Grid Execution**
- Partition, Map and Tune
ARMaDA: Application-sensitive Adaptations

- PAC tuple, 5-component metric
- Octant approach: app. runtime state
- GrACE (ISP), Vampire (pBD-ISP, GMISP+SP) partitioners
- ARMaDA framework
  - Computation/communication
  - Application dynamics
  - Nature of adaptation
- RM3D, 64 procs on “Blue Horizon”
  - 100 steps, base grid 128*32*32
  - 3 levels, RF = 2, regrid 4 steps

ARMaDA evaluation for VectorWave-2D application on 32 processors on “Frea”

<table>
<thead>
<tr>
<th>Partitioner</th>
<th>Execution time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFC</td>
<td>637.478</td>
</tr>
<tr>
<td>G-MISP+SP</td>
<td>611.749</td>
</tr>
<tr>
<td>pBD-ISP</td>
<td>592.05</td>
</tr>
<tr>
<td>ARMaDA with SFC start</td>
<td>470.531</td>
</tr>
</tbody>
</table>

\[
P_t = f(A_t, C_t)
\]
ARMaDA: System-sensitive Adaptations

- System characteristics using NWS
- RM3D compressible turbulence application
  - 128x64x64 base (coarse) grid
  - 3 levels, factor 2 refinement
- System/Environment
  - University of Texas at Austin (32 nodes), Rutgers (16 nodes)

<table>
<thead>
<tr>
<th>Procs</th>
<th>Dynamic Sensing (s)</th>
<th>Static Sensing (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>423.7</td>
<td>805.5</td>
</tr>
<tr>
<td>4</td>
<td>292</td>
<td>450</td>
</tr>
<tr>
<td>6</td>
<td>272</td>
<td>424</td>
</tr>
<tr>
<td>8</td>
<td>225</td>
<td>430</td>
</tr>
</tbody>
</table>

\[ C_k = w_p P_k + w_m M_k + w_b B_k \]
Autonomic Forest Fire Simulation

Predicts fire spread (the speed, direction and intensity of forest fire front) as the fire propagates, based on both dynamic and static environmental and vegetation conditions.
Autonomic Design of Nanomaterials

**INPUT: COMPOSITION/PROCESSING**

- **Atomistics**: Simulate non-equilibrium solidification process, crystallization, diffusion and growth
- **Interface Kinetics**
- **Thermodynamics**
- **Composition**
- **Atomistic Structure**
- **Force Fields**

**Nanoscale**: Model the evolution and interaction of topologically complex nanosize metastable structures and their effective behavior.

**Effective Particle Behavior**

**Hardening Mechanisms**

**Topological Characteristics of Nanostructured Particles**

**Microscale**: Model the collective behavior of assemblies of nanostructured particles

**Strength and Ductility of Nanostuctured Particles**

**Optimization**: Optimize metastable nanocomposition based on atomistic, nanoscale and macroscale properties.

**Computational Infrastructure**: To develop autonomic computational infrastructures and runtime management techniques for scalable parallel/distributing computing, automated interaction and data exchange between scales, real time sensing and computational response, collaborative monitoring and steering.

**OUTPUT: OPTIMIZED METASTABLE NANOCOMPOSITES**
Conclusion

- Autonomic applications are necessary to address scale/complexity/heterogeneity/dynamism/reliability challenges
- AutoMate addresses key issues to enable the development of autonomic Grid applications
  - ACCORD: Autonomic application framework
  - RUDDER: Decentralized deductive engine
  - SESAME: Dynamic access control engine
  - Pawn: P2P messaging substrate
  - SQUID: P2P discovery service
- Application scenarios
  - Autonomic optimization of oil reservoirs
  - Autonomic runtime management
- More Information, publications, software, conference
  - http://automate.rutgers.edu
  - automate@caip.rutgers.edu / parashar@caip.rutgers.edu
  - http://www.autonomic-conference.org
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