ICCS'05 WORKSHOP

on
Dynamic Data Driven Application Systems (DDDAS)

A new paradigm for applications/simulations and measurements methodology

INTRODUCTION and AGENDA

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What is DDDAS (Symbiotic Measurement & Simulation Systems)

OLD (serialized and static)

Theory (First Principles)

Simulations (Math. Modeling Phenomenology)

Measurements Experiments Field-Data User

NEW PARADIGM (Dynamic Data-Driven Simulation Systems)

Theory (First Principles)

Simulations (Math. Modeling Phenomenology)

Experiment Measurements Field-Data (on-line/archival) User

Challenges:

Application Simulations Development Algorithms
Measurement Instruments Interfaces Computing Systems Support

Dynamic Feedback & Control Loop
Some Technology Challenges in Enabling DDDAS

• Application development
  - interfaces of applications with measurement systems
  - dynamically select appropriate application components
  - ability to switch to different algorithms/components depending on streamed data

• Algorithms
  - tolerant to perturbations of dynamic input data
  - handling data uncertainties

• Systems supporting such dynamic environments
  - dynamic execution support on heterogeneous environments
  - Extended Spectrum of platforms: assemblies of Sensor Networks and Computational Grid platforms
  - GRID Computing, and Beyond!!!
What is Grid Computing?

translated problem solving
on dynamic and heterogeneous resource assemblies

Example: “Telescience Grid”, Courtesy of Ellisman & Berman /UCSD&NPACI
DDDAS: Beyond Grid Computing
New Capabilities in Applications and Measurements

DATA ACQUISITION

ADVANCED VISUALIZATION

ANALYSIS

COMPUTATIONAL RESOURCES
Why **Now** is the Time for DDDAS

- Technological progress has prompted advances in some of the challenges
  - **Computing speeds advances** (uni- and multi-processor systems), Grid Computing, Sensor Networks
  - **Systems Software**
  - **Applications Advances** (parallel & grid computing)
  - **Algorithms advances** (e.g.: parallel & grid computing, numeric and non-numeric techniques: adaptive, asynchronous algorithms, dynamic meshing, data assimilation, 3DVAR/4DVAR, chaotic Monte-Carlo)

- **Ongoing DDDAS project make advances in:**
  - **Applications, Algorithms, Instrumentation, Systems Software**
The NGS Program develops technology for **integrated feedback & control**

**Runtime Compiling System (RCS)** and Dynamic Application Composition

- **Dynamic Analysis Situation**
- **Launch Application(s)**
- **Application Model**
- **Application Program**
- **Application Intermediate Representation**
- **Dynamically Link & Execute**
- **Distributed Programming Model**
- **Compiler Front-End**
- **Compiler Back-End**
- **Application Components & Frameworks**
- **Performance Measurements & Models**
- **Distributed Computing Resources**
- **Adaptable computing Systems Infrastructure**
- **Distributed Platform**

- MPP
- NOW
- SP
Towards Enabling DDDAS

- Performance Engineering
- Dynamic Compilers & Application Composition
- Dynamic Data-Driven Application Systems
- Symbiotic Measurement & Simulation Systems

Multidisciplinary Program

Applications Modeling & Measurements

Systems Software
Research and Technology Roadmap

*(emphasis on multidisciplinary research)*

**Application Composition System**
- Application multi-resolution models
- Automatic selection on solution methods
- Modeling languages
- Interfaces, data-representation & exchange

**Application RunTime System**
- Distributed programming models
- Application performance interfaces
- Dynamic compiler optimized mapping
- Debugging tools

**Measurement System**
- Measurement instrumentation
- Application interfaces
- Measurement data formats/models

**Y1**  
Exploratory

**Y2**

**Y3**  
Development

**Y4**  
Integration & Demos

**Y5**

Providing enhanced capabilities for Applications
Tally Points

• ITR Program was initiated to start new research, not previously funded by existing NSF programs
• ITR was used to spawn a significant number on ~DDDAS projects
• majority of funds for DDDAS from ITR - additional funding sources for other programs: NGS, SES, Sensors, BITS, etc
• About 40 projects
• Project sizes: $400K-$12M, majority $1-3M, one: $12M
• ITR funds on DDDAS: ~$60M (cumulative)
• Funded projects are the success record for follow-on program
• Workshops: NSF/2000; ICCS’03, ICCS’04; ICCS05
W16a: Dynamic Data Driven Application Systems I
Mon, May 23; 1:40 PM - 3:20 PM; Room: MSC W301

- **Data Driven Applications Systems: New Capabilities for Application Simulations and Measurements**
  Frederica Darema, National Science Foundation, USA

- **Dynamic Data Driven Methodologies for Multiphysics System Modeling and Simulation**
  by John Michopoulos, Charbel Farhat, Elias Houstis, Panayota Tsompanopoulou, Haiping Zhang, Thomas Gullaud

- **Towards Dynamically Adaptive Weather Analysis and Forecasting in EAD**
  by Beth Plale, Dennis Gannon, Dan Reed, Sara Graves, Kelvin Droegemeier, Bob Wilhelmson, Mohan Ramamurthy

- **Towards a Dynamic Data Driven Application System for Wildfire Simulation**
  by Jan Mandel, Lynn S. Bennethum, Mingshi Chen, Janice L. Coen, Craig C. Douglas, Leopoldo P. Franca, Craig J. Johns, Minjeong Kim, Andrew V. Knyazev, Robert Kremens, Vaibhav Kulkarni, Guan Qin, Anthony Vodacek, Jianjia Wu, Wei Zhao, Adam Zornes

- **Multiscale Interpolation, Backward in Time Error Analysis for Data-Driven Contaminant Simulation**
• Ensemble-Based Data Assimilation for Atmospheric Chemical Transport Models
  by Adrian Sandu, Emil M. Constantinescu, Wenyuan Liao, Gregory R. Carmichael, Tianfeng Chai, John H. Seinfeld, Dacian Dăescu

• Towards Dynamic Data-Driven Optimization of Oil well Placement
  by Parashar, M., Matossian, V., Bangerth, W., Klie, H., Rutt, B., Kurc, T., Catalyurek, U., Saltz, J., Wheeler, M.

• High-Fidelity Simulation of Large Scale Structures
  by Christoph Hoffmann, Ahmed Sameh, Ananth Grama

• A Dynamic Data Driven Grid System for Intra-operative Image Guided Neurosurgery
  by Majumdar, A., A. Birnbaum, D. Choi, A. Trivedi, S. K. Warfield, K. Baldridge, P. Krysl

• Structure-based Integrative Computation and Experimental Approach for the Optimization of Drug Design
  by Morikis, D., Floudas, Ch.

• Simulation and Visualization of Air Flow Around Bat Wings During Flight
• Integrating Fire, Structure and Agent Models  
  by Chaturvedi, R., S.A. Filatyev, J.P. Gore, A. A. Mellema  

• A Dynamic, Data-Driven, Decision Support System for Emergency Medical Services  
  by Gaynor, M., Margo Seltzer, Steve Moulton  

• Dynamic data Driven Coupling of Continuous and Discrete Methods in 3D Tracking  
  by Metaxas, D., Tsechpenakis, G.  

• Semi-Automated Simulation Transformation for DDDAS  
  by Brogan, D., Reynolds, P., Bartholet, R., Carnahan, J., Loitiere, Y.  

• The Development of Dependable and Survivable Grids  
  by Andrew Grimshaw, Marty Humphrey, John C. Knight, Anh Nguyen-Tuong, Jonathan Rowanhill, Glenn Wasson, Jim Basney  

• On the Fundamental Tautology of Validating Data-Driven Models and Simulations  
  by John Michopoulos, Sam Lambrakos
backup slides