TRACC

The Transportation Research and Analysis Computing Center at Argonne National Laboratory

Dr.-Ing. Hubert Ley
Dr. David Weber
Transportation Research and Analysis Computing Center
Argonne National Laboratory

October 23, 2008
About Argonne: One of DOE’s Largest Research Facilities

http://www.anl.gov/

- Located 25 miles from the Chicago Loop, it was the first national laboratory, chartered in 1946
- Operated by the University of Chicago for the U.S. Department of Energy
- Major research missions include basic science, environmental management, and advanced energy technologies
- About 3,000 employees, including about 1,000 scientists and engineers, of whom 750 hold doctorate degrees
- Annual operating budget of about $475 million (80% from DOE)
- Since 1990, Argonne has worked with more than 600 companies and numerous federal agencies.
TRACC: Location and Connectivity

Internet2 Network

Maximum capacity 64 10 Gb/s channels

94% of DOT University Transportation Centers connected
TRACC – High Performance Computing for Transportation Research and Applied Technology

- Thermal Management *
- Crashworthiness *
- Occupant Safety Assessment and Crash Biomechanics *
- Bridge Hydraulics *
- Bridge Structural Analysis *
- Intelligent Transportation Systems *
- Aerodynamics *
- Traffic Modeling *
- Road Weather Research *

* indicates areas of focus and expertise.
TRACC: Create a National User Facility to Meet DOT Advanced Computation Needs

- TRACC: Transportation Research and Analysis Computing Center
  - DOT and DOE transportation research programs, private industry and state and regional transportation agencies are moving to simulation based design and analysis for improvements in efficiency, economics and safety
  - Higher fidelity analysis in areas such as crashworthiness, aerodynamics, combustion, thermal management, weather modeling and traffic simulation require access to state-of-the-art computational and visualization facilities
  - ANL has the necessary expertise in high performance computing and transportation system analysis to provide both a national HPC user facility and a focal point for computational research for transportation applications
The TRACC computational cluster is a customized LS-1 system from Linux Networx consisting of 512 core 128 compute nodes, each with two dual-core AMD 2216 Opteron CPUs and 4GB of RAM, a DataDirect Networks storage system consisting of 240TB of shared RAID storage, expandable to 750TB, a high-bandwidth, low-latency InfiniBand network for computations, and a high-bandwidth Gigabit Ethernet management network. The system will also include the highest-performance compiler and MPI library available for the AMD Opteron architecture, with a peak performance of ~2 TFlops.
TRACC Is Being Built as a National DOT Supercomputer Facility

TRACC High Performance Compute Cluster
- 512 core / 128 compute nodes
- (two dual-core AMD 2216 Opteron CPUs 4GB of RAM)

240TB Global Parallel File System Disk Storage

High-bandwidth connectivity to the Illinois Wired/Wireless Infrastructure for Research and Education (I-WIRE) and Internet2.

Argonne Nuclear Engineering Division Linux Cluster
- 10Gb Dedicated Access

Argonne LCRC JAZZ Linux Cluster
- 10Gb Dedicated Access

LTO-3 160TB Archive/Backup Tape Storage

TRACC Training Center
Computational Structural Mechanics Applications

Bridge Response

- The dynamic response of bridges during extreme loading conditions—such as high winds and severe storms—is a major concern for the FHWA.
- This type of loading involves coupling of aerodynamic loading and the structural movement of the bridge.
- Both modeling and simulation and experiments are needed to characterize this behavior.
- The use of coupled computational structural mechanics and computational fluid dynamics codes on the TRACC high performance cluster computer will lead to a basic understanding of this phenomena and provide insight for improved designs.
Example: 2-D STAR-CD model for reduced scale inundated bridge deck
To accurately determine the structural response of bridges to loadings from traffic, high winds, river currents and earthquakes, it is necessary to develop high fidelity numerical (finite element) models and perform transient dynamic analysis using state-of-the-art cluster computers.

The figure on the left shows the Bill Emerson Memorial Bridge that spans the Mississippi River between Illinois and Missouri near Cape Girardeau, Missouri; the figure on the right is a high fidelity model consisting of over 500,000 elements representing the important structural elements of the bridge.
Bridge Pier Scour

- Bridge pier foundations can be vulnerable to **scour**, i.e., removal of river bed material due to rapid flows.
- Significant scour depth can affect the **stability of pier foundations** causing bridge failure, resulting in transport disruption, economic loss and an occasional loss of life (see Figure).
- The factors influencing scour are **complex** and vary according to type of structure.
- High fidelity modeling and simulation is required to accurately predict scour and determine **time to structural failure** and **failure modes**.
Response of Roadside Hardware to Vehicle Crashes

Problem

- Crash testing of a large variety of vehicles into roadside hardware is an extremely expensive proposition (~$500,000 & 10,000 man-hours/test).
- Complexity and a current diverse fleet of automobiles and trucks as well as the next generation vehicles such as hybrid, electric and fuel cell automobiles add significantly to future crash testing cost.

Significance to US DOT (FHWA)

High fidelity crashworthiness simulations provide economical alternatives to evaluate crashes and provide data to optimize the design of roadside hardware which is sensitive to vehicle characteristics (mass and height of center of gravity), bumper and hood geometry, and roadside geometry (slopes, embankments, ditches, etc.).
Multiple Vehicle Crash Simulation

• Multi-vehicle crash simulations (using LS_Dyna code) performed on cluster computers represents the state-of-the-art
• Subdividing the complete model into smaller domains (via domain decomposition) and computing each domain on a single processor significantly reduces total compute time
Visualization of High fidelity Simulations

- Visualization is an essential element to understanding the complexities involved in crash analysis.
- Virtual reality hardware (CAVE, 1-wall CAVE, Head Mounted VR, etc.) drastically reduces the time needed to understand crash analyses.
Emergency Evacuations of the Chicago Business District

- This project has been implemented to model the effects of a no-notice event on the multi-modal regional transportation system in the Chicago metropolitan area.
- The chosen scenario postulates a radioactive release following an explosion at the base of the Sears Tower.
- This project deals with the dynamic effect on the transportation system.
**Fundamental Capabilities of the TRANSIMS Approach**

- **Multi-modal transportation** (vehicles, buses, trains, walking, bicycles, …)
- Extremely **large simulation areas**, e.g. Chicago (10,000 square miles)
- Fully time-aware routing of **each individual traveler** for all travel modes
- Microsimulation for large metropolitan areas to determine the interactions between travelers and vehicles to determine **second by second movements**
  - Determination of **vehicle interactions**, such as lane changes, speed changes, passenger loading and unloading, …
  - **Interaction with the road network**, e.g. with traffic signals, speed limits, turn lanes, transit vehicles, …
- This approach overcomes the limitations of traditional traffic forecasting models:
  - Delivering **transportation system performance** as a full function of time instead of static solution for a few time periods (e.g. am and pm peaks)
  - Microscopic interaction between vehicles and travelers delivers **accurate results** compared to simple volume delay functions and aggregate data.
- Main challenges: **Massive demands on computation time** and a need for extremely detailed input data
10,000 Square Miles Simulation Area
Available Data Sources and the Types of Data Needed

- CMAP and TRACC Network Improvements
- Main focus is on network topology, in particular:
  - Connectivity
  - Number of Lanes
  - Functional Classes
  - Speed Limits
  - Coded Length
  - Capacities, etc.
- For visualization and more precise modeling:
  - Exact geographic locations
  - Shapes along links
  - Correct integration of transit links and stops, etc.
Google Maps and Street View
Network Editing
Network Editing
Network Cleaning

- Based on high resolution imagery
- GIS-based editing procedures
Current Status

- Each individual lane is modeled
- Pocket lanes are modeled
- Lane Connectivity
- Signals
  - Phasing
  - Timing
- Parking
- Many more details
**The Regional Road Network**

- ~10,000 square miles
- Road network
  - 40,000 links
  - 14,000 intersections
  - 110,000 locations
- ~26.5 million vehicle trips
- ~1.5 million transit trips
- Trip tables
  - Break-down by purpose (work, truck, airport, and many more)
Some Preliminary Results

- The metropolitan road network accommodates the trips reasonably well (~1% problems)
- Traffic volumes per lane are shown as an indicator of congestion (e.g. 8:00 to 8:15)
- The TRACC cluster has reduced computing time for 27 million routes to less than 15 minutes using just 48 processors (of 512)
Example Case Study: Evacuation with Transit to a Shelter

- Scenario:
  - The Emergency Response Team secures a few suitable transit stations
  - People in the Evacuation Area are directed to walk to these stations
  - Transit transportation is provided to take them to a shelter location (e.g. United Center)

- TRANSIMS is already able to simulate for each individual person:
  - Delays in leaving buildings
  - Walking towards the closest evacuation stop
  - Flow of buses within congested roads and/or on reserved lanes
  - And more …
Scenario 4: Evacuation via Transit to Shelters
NCSA Visualization Example
**TRACC Contact Information**

- **Director’s Office**
  - Dave Weber, Director: dpweber@anl.gov
  - Mike Boxberger: boxberger@anl.gov

- **Systems Administration**
  - Jon Bernard: bernard@anl.gov

- **Traffic Simulation**
  - Hubert Ley: hley@anl.gov

- **Computational Structural Mechanics**
  - Ronald Kulak: kulak@anl.gov

- **Computational Fluid Dynamics**
  - Tanju Sofu: tsofu@anl.gov