Grid Computing for Fire Evolution Simulation

Diploma Thesis

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Outline

Fire Dynamics Simulatior (FDS) and Grid Computing

- Grid computing overview
- Middleware overview - Agents/Actors
- Fire Dynamics Simulator
- Experiments and results

Grid computing overview

What is the Grid? – History

- Idea began as *networked operating systems*
- Became *distributed operating systems*
- Transformed into *heterogeneous computing, parallel distributed computing, metacomputing*
- Finally, became *Computing on the Grid*
- Three checkpoint list identifying a grid
  1. a grid should coordinate resources that are not subject to centralized control
  2. such a coordination should be done using standard, open, general-purpose protocols and interfaces
  3. the purpose of the above should be to deliver nontrivial qualities of service

What is the Grid? – Definitions

- *a distributed computing infrastructure for advanced science and engineering*
- *a computational grid is a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities*
- *collections of computational and data storage resources linked by communication channels for shared use*
- *a set of tools and technologies that allow users "easy" access to resources and applications*
- provide *computational, data, application* and *information services*
- analogous to electricity grids

Architecture

Four (or five) layers:

- Fabric
- Core grid middleware
  - Connectivity
  - Resource
- User-level middleware (Collective)
- Applications

Future trends

- Nature of applications
- Programming models and tools
- System architecture
- Algorithms
- Resource management
- Security
- Analysis
- End systems
- Network protocols

DEISA

- Effort to connect existing european supercomputers to a grid
- Consists of both homogeneous and heterogeneous platforms
- Uses GEANT network
- Load balancing, data sharing and co-scheduling services

Middleware overview

Agents

- *an agent is a computer system that is situated in some environment and that is capable of autonomous action in this environment in order to meet its design objectives*
- *a software component that is autonomous (has a degree of control over its own actions), proactive (does not only react in response to external events but also exhibits a goal-directed behavior and, where appropriate, is able to take initiative) and social (it is able to, and need to, interact with other agents in order to accomplish its task)*
- Mobile agents

Agent platforms

Some agent platforms

	Product	Type
1	Bee-gent	Language or environment for agent development
2	JADE	Distributed Agent platform
3	Kaariboga	Language or environment for agent development
4	Voyager	Support software
5	Pro-active	GRID platform

Agent platforms (cont.)

Questionnaire-Based rating of platforms:

	General			Security				Development				Standards		
	OS Independent	Documentation	Mobile agents	Authentication	Data encryption	Authorization	Access restriction	Monitoring	Debugging	RAD	Architecture	FIPA	GLOBUS	Grid services
Bee-gent	Y	Y	Y	1	2	4	4	4	4	3	4	1	4	4
JADE	Y	Y	Y	1	4	2	4	2	2	4	3	1	4	2
Kaariboga	Y	Y	Y	4	4	4	3	4	4	4	4	4	4	4
Proactive	Y	Y	Y	2	2	2	2	2	2	4	2	4	2	1
Voyager	Y	Y	Y	1	1	4	4	4	4	4	4	4	4	4

Actors

- autonomous reasoning agents
- act concurrently
- focus on response to incoming messages
- cannot sense their environment

Ptolemy

- actor-oriented design
- fits applications for which heterogeneity and concurrency are of great importance
- focus on embedded systems

gLite

European grid middleware

- computing element
- data management subsystem
- accounting subsystem
- logging and bookkeeping information and monitoring
- security
- workload management

Fire Dynamics Simulator

Fire Dynamics Simulator

- solves numerically a form of Navier-Stokes equations for fluids
- because of the complexity involved FDS operates on sub-areas instead of the whole volume around the area of interest

Simulation Circle

1. represent the objects in the flow domain and provide the “mesh” or “grid”
2. run the simulation for the “mesh”
3. extract and visualize the data from the results produced from the simulation

Step 1: Input file (1)

- area dimensions
- mesh definition
- surfaces information
- material reaction information

Step 1: Input file (2)

```
&HEAD CHID='2subRm01z',TITLE='ATF Room Fire Test'  /
/
&GRID IBAR=48, JBAR=24, KBAR=24  /
&PDIM XBAR0=0.0,XBAR=4.7,YBAR0=0.0,YBAR=2.5,ZBAR0=0.0,ZBAR=2.5 /
/
&TIME DT=0.01,TWFIN=5.0 /
&MISC SURF_DEFAULT='SHEET METAL',
      DATABASE='database4.data',
      REACTION='POLYURETHANE' /

&SURF ID='burner',HRRPUA=1000. /

&OBST XB=2.60,3.20,0.95,1.55,0.0,0.10, SURF_IDS='burner',
                         'INERT', 'INERT' / burner
&OBST XB=3.65,3.75,0.0,0.87,0.0,2.5 / wall1
&OBST XB=3.65,3.75,0.87,1.63,2.0,2.5 / wall1
&OBST XB=3.65,3.75,0.87,1.63,0.0,2.0, T_REMOVE=2.5,
                         RGB=0.7,0.8,0.8 / door wall1
&OBST XB=3.65,3.75,1.63,2.5,0.0,2.5 / wall1

&VENT CB='XBAR' , SURF_ID='OPEN' / open right side of 2nd room

&PL3D DTSAM=5. / Plot 3D file every 5 secs
&PART DTPAR=0.5,NIP=100 /
```

Step 2: Simulation

FDS internals:

- Hydrodynamics model
- Combustion model
- Radiation model
- Boundary conditions

Step 3: Results

Visualizations (2D and 3D) of results with Smokeview (examples to come)

Alter egos

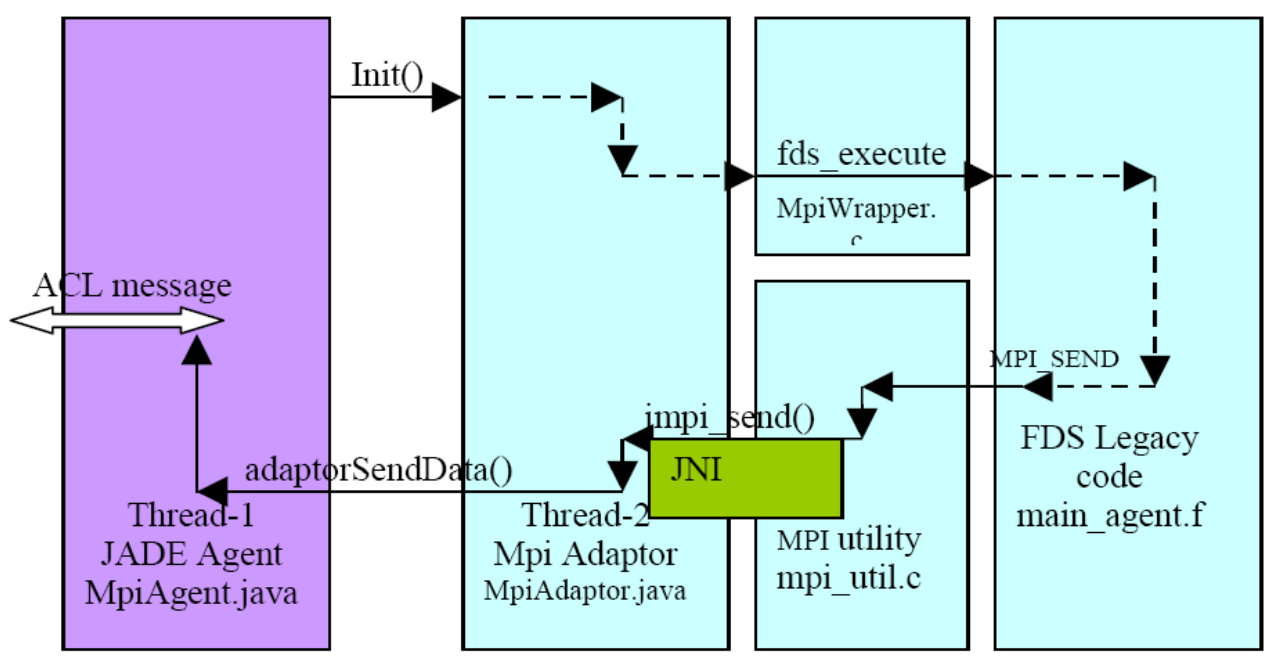
- Serial (original) version - one processor
- MPI version - multiple processors/cluster
- Agent version - multiple processor/grid

Agentized FDS

- Legacy code (FORTRAN)
- C bindings for FORTRAN code
- Internal interface in Java for communication with C code
- External interface in Java for communication between different nodes (using JADE)

Agentized FDS Architecture

- MpiAgent
- MpiAdaptor
- MpiWrapper
- mpi_util



Experiments and Results

Local Machines

Cyclone cluster (MPI runs):

1 Master node :

- H/W:

  1 PIV 2.66 GHz, 512 RAM, 80G IDE disk, 100 MBit Lan

- S/W:

  OS: Gentoo Linux, kernel 2.6.8
  Job Control : OpenPBS Server Release 2.3
  Monitor : Ganglia Monitor Server & scheduler
  Web Server : Apache 1.3
  Clock Synchronization : NTP
  Common fs: NFS v3 (server)

  Clustering : LAM - MPI 7.1.1, communication via SSH, lamd booting via OpenPBS tm module.

11 Slave nodes :

- H/W:

  1 PIV 2.66 GHz, 512 RAM, 80G IDE disk, 100 MBit Lan

- S/W:

  OS: Gentoo Linux, kernel 2.6.8
  Job Control : OpenPBS client (pbsmom)
  Monitor : Ganglia Monitor client
  Clock Synchronization : NTP
  Common fs: NFS v3 (client)

  Clustering : LAM - MPI 7.1.1, communication via SSH, lamd booting via OpenPBS tm module.

Local Machines (cont.)

Computational Nodes (agent runs):

Node 2 :

- H/W:
  1 PIV 2.44 GHz, 512 RAM, 80G SCSI disk, 100 MBit Lan
- S/W:
  OS: Gentoo Linux, kernel 2.6.8
  Jade

Node 3 :

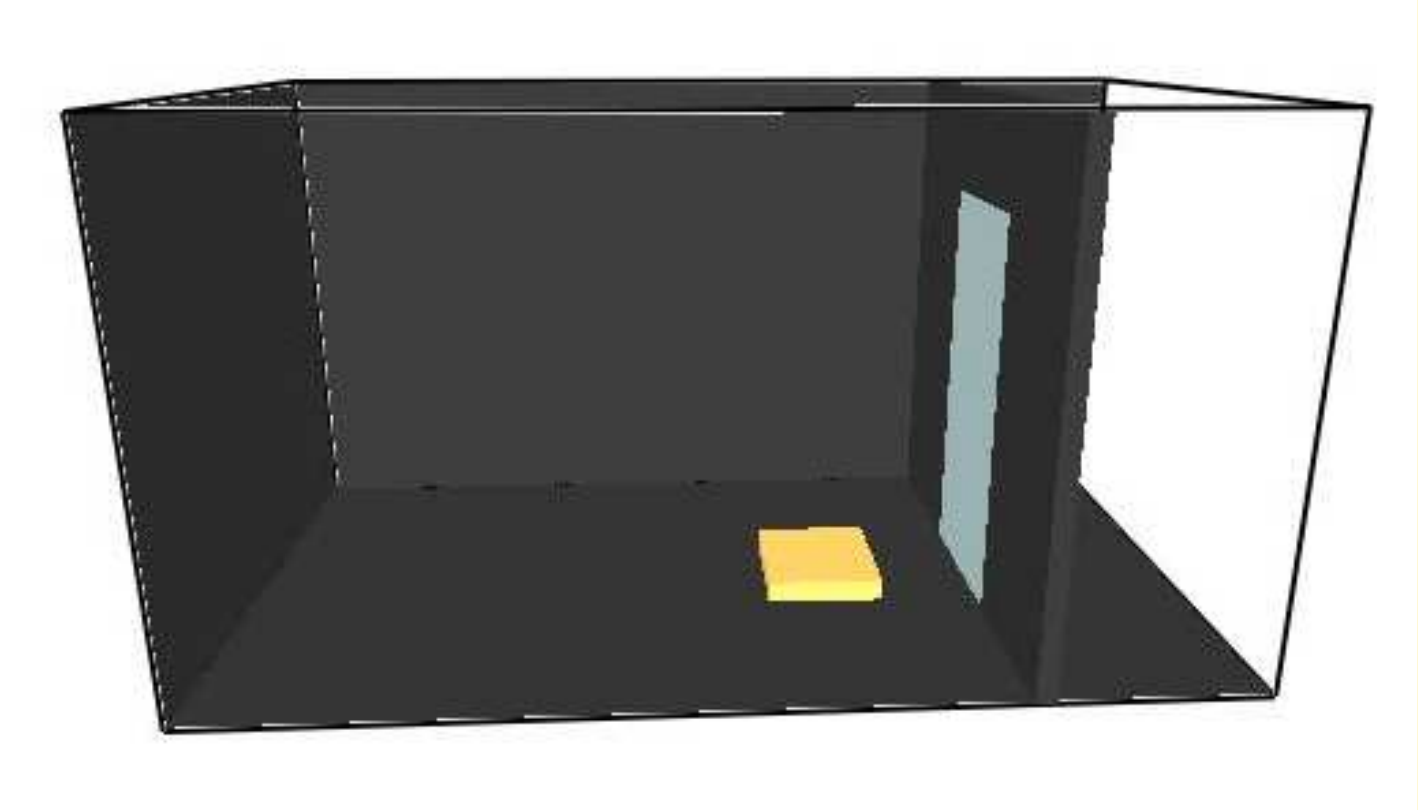
- H/W:
  1 PIV 1.8 GHz, 256 RAM, 80G IDE disk, 100 MBit Lan
- S/W:
  OS: SuSE Linux 9.2, kernel 2.6.4
  Jade

Experiments overview

- Two room input file
- Six variations
  1) single mesh
  2) two meshes
  . . .
  6) six meshes

Experiments overview (cont.)

The two room example



Procedure (performance measurements)

- run all versions (serial, parallel-MPI, parallel-agent) many times at different times and days to achieve statistically distributed workloads on the computers used
- parse the overall summary stored in one of the output files called {jobname}.out and get the time consumed for the MAIN procedure (this is what we refer to as the representative time for the entire simulation)
- gather all different results for every simulation and for every submesh and calculate the average time for all three runs
- calculate the maximum average time for the different submeshes
- calculate the sum of average times for the different submeshes

Results (1)

Average timings for serial version

Zones	Iterations	CPU time	Sum
1	505	178.45	178.45
2	502	183.77	183.77
3	502	182.31	182.31
4	502	181.24	181.24
5	502	171.58	171.58
6	502	189.52	189.52

Results (2)

Average timings for MPI version

Zones	Iterations	CPU time	Sum
1	505	182.33	182.33
2	503	93.99, 99.61	193.60
3	502	92.16, 74.03, 29.78	195.97
4	503	92.53, 74.28, 16.29, 16.18	199.27
5	502	44.64, 44.88, 74.53, 16.54, 16.07	196.66
6	502	51.26, 51.70, 41.32, 39.91, 18.24, 18.04	220.47

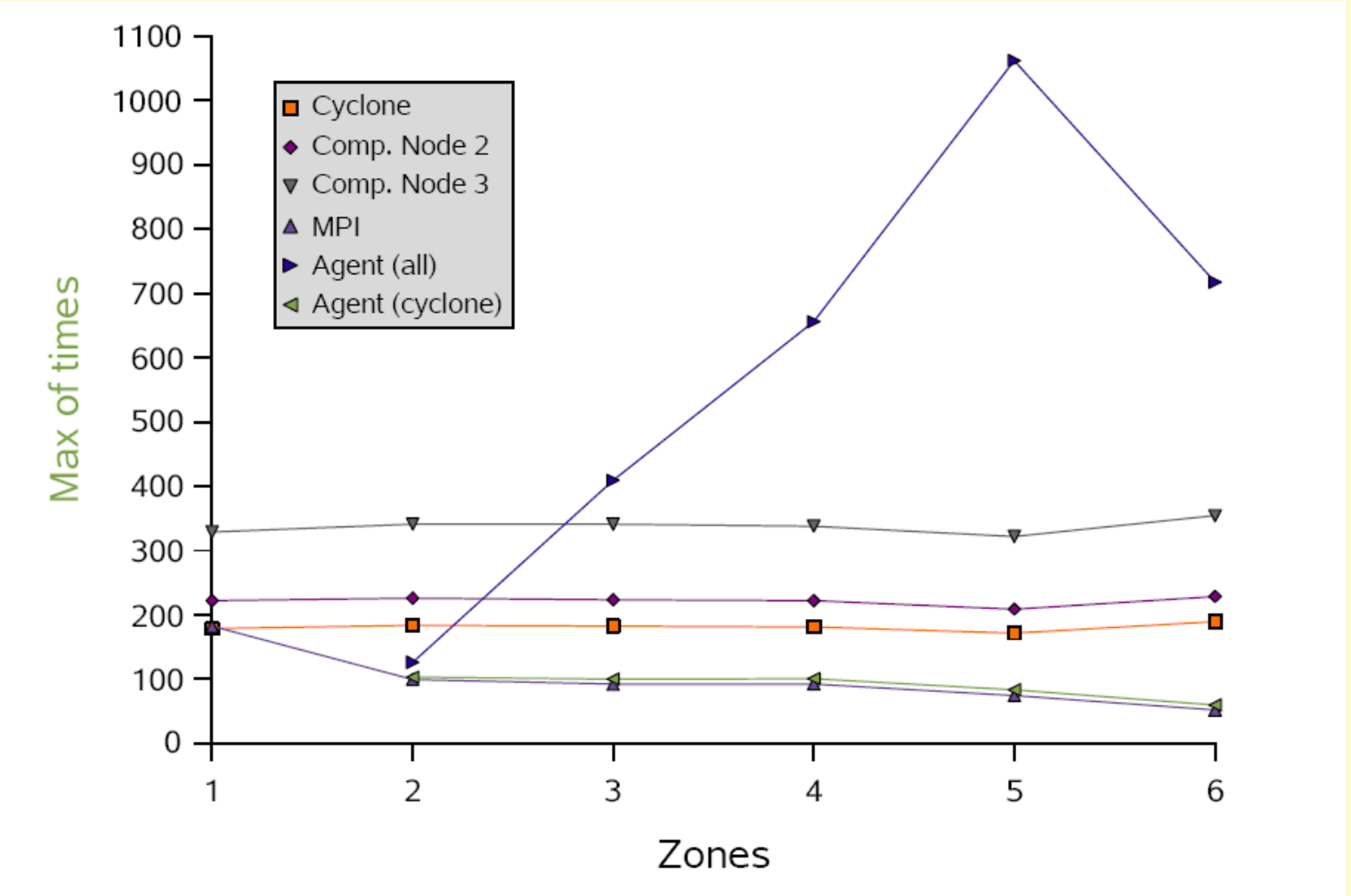
Results (3)

Average timings for agent version

Zones	Iterations	CPU time	Sum
2	503	98.91, 126.22	225.13
3	502	101.82, 106.80, 409.06	617.68
4	503	103.63, 100.39, 22.73, 655.85	882.59
5	502	50.82, 51.82, 100.30, 25.36, 1062.28	1290.58
6	502	58.47, 59.28, 58.55, 57.32, 717.35, 700.26	1651.24

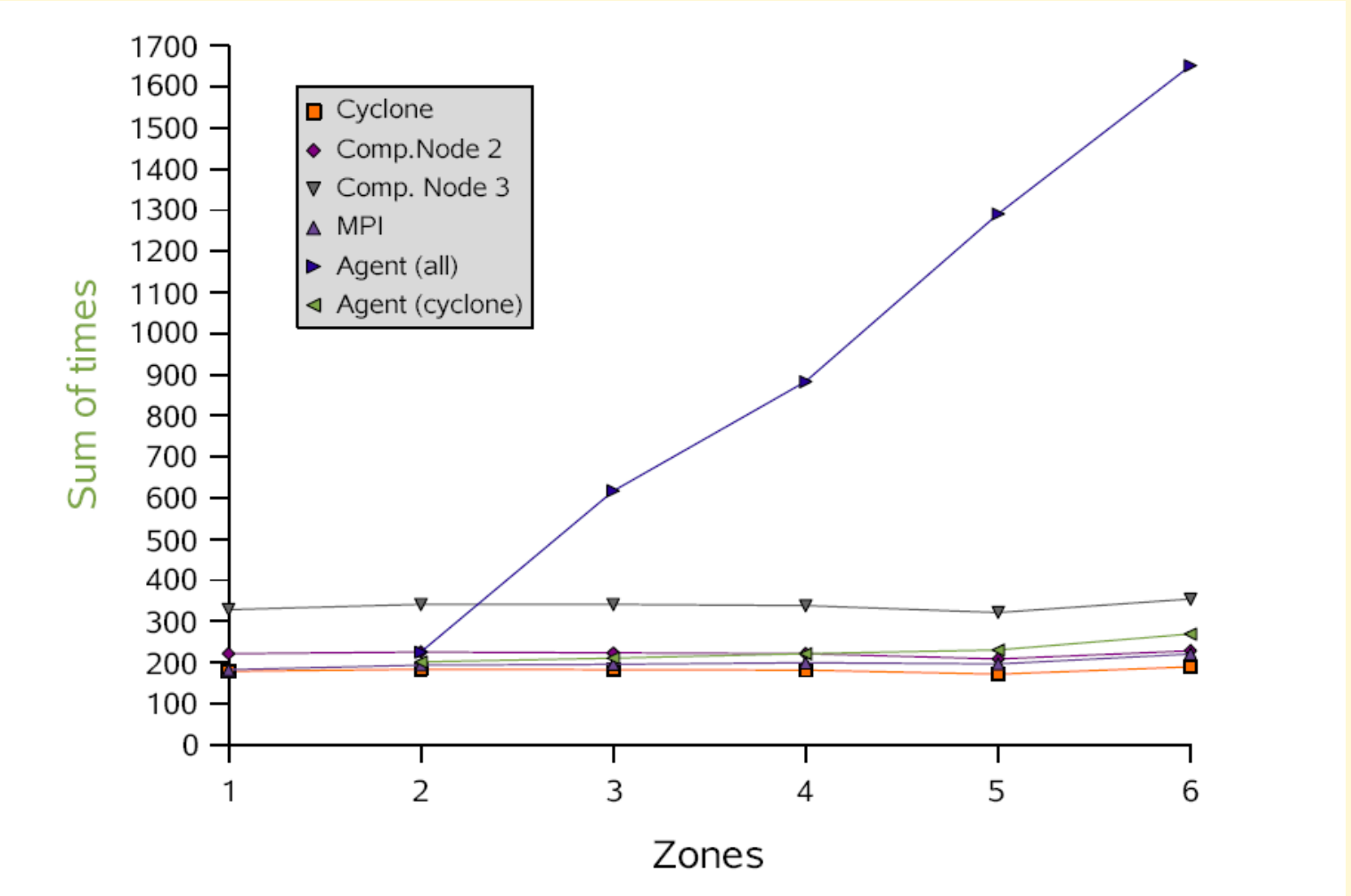
Results (4)

Summary of maximum times



Results (5)

Summary of sum of times



Agent validation

- Create ascii files from simulation outputs
- Calculate relative difference (for specific variables):

$$\frac{||f-g||_2}{||f||_2} = \sqrt{\frac{\int\int [f(x,z)-g(x,z)]^2\, dxdz}{\int\int f(x,z)^2 dxdz}}$$

- Integration calculated arithmetically:

$$\int_a^b f(x)dx \simeq \frac{h}{2}(f(x_0)+2f(x_1)+2f(x_2)+\cdots+ \\ +2f(x_{N-2})+2f(x_{N-1})+f(x_N))$$

Comparison results (1)

Serial - MPI				
Zones	Mesh	TEMPERATURE	HRRPUV	MIXTURE_FRACTION
2	1	0.109	0.000	0.261
	2	0.161	0.250	0.255
3	1	0.112	0.000	0.256
	2	0.129	0.200	0.138
	3	0.080	0.000	0.239
4	1	0.198	0.000	0.456
	2	0.251	0.296	0.268
	3	0.041	0.000	0.373
	4	0.092	0.000	0.223
5	1	0.032	0.000	1.284
	2	0.133	0.000	0.357
	3	0.160	0.310	0.222
	4	0.056	0.000	0.208
	5	0.058	0.000	0.168
6	1	0.138	0.000	4.359
	2	0.226	0.000	0.634
	3	0.303	0.317	0.308
	4	0.312	0.797	0.398
	5	0.064	0.000	0.355
	6	0.155	0.000	0.373

Comparison results (2)

Serial - Agent				
Zones	Mesh	TEMPERATURE	HRRPUV	MIXTURE_FRACTION
2	1	0.109	0.000	0.261
	2	0.161	0.250	0.255
3	1	0.112	0.000	0.256
	2	0.129	0.200	0.138
	3	0.080	0.000	0.239
4	1	0.107	0.000	0.254
	2	0.137	0.149	0.126
	3	0.028	0.000	0.193
	4	0.081	0.000	0.183
5	1	0.060	0.000	1.995
	2	0.046	0.000	0.132
	3	0.099	0.234	0.140
	4	0.085	0.000	0.421
	5	0.170	0.000	0.579
6	1	0.136	0.000	4.281
	2	0.224	0.000	0.626
	3	0.295	0.296	0.288
	4	0.306	0.742	0.390
	5	0.066	0.000	0.354
	6	0.144	0.000	0.348

Comparison results (3)

MPI - Agent				
Zones	Mesh	TEMPERATURE	HRRPUV	MIXTURE_FRACTION
2	1	0.000	0.000	0.000
	2	0.000	0.000	0.000
3	1	0.000	0.000	0.000
	2	0.000	0.000	0.000
	3	0.000	0.000	0.000
4	1	0.152	0.000	0.424
	2	0.182	0.222	0.197
	3	0.045	0.000	0.284
	4	0.058	0.000	0.097
5	1	0.044	0.000	0.622
	2	0.117	0.000	0.227
	3	0.120	0.172	0.190
	4	0.126	0.000	0.744
	5	0.148	0.000	0.489
6	1	0.003	0.000	0.040
	2	0.006	0.000	0.016
	3	0.020	0.041	0.040
	4	0.015	0.734	0.024
	5	0.014	0.000	0.055
	6	0.012	0.000	0.030

Demo time

- Sample agent run for two room example (2 seconds simulation time)
- Smokeview presentation (movie)