Making Infrastructure Invisible

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Presentation Outline

“The future is here, it is just not evenly distributed.”
*William Gibson*

- Multidisciplinary infrastructure challenges
- Simplify, simplify, simplify
- One perspective on the future
Rethink the nature of computing at extreme scale, from alternative, quantum computing models, through the transformative effects of manycore parallelism on programming systems and architectures, to massive cloud computing designs that each drive consumer, business and social applications and create value for Microsoft.

**extreme:** (ik-ˈstrēm)
- either of the two limits of a scale or range
- of a high or the highest degree or intensity
- a maximum or minimum value of a function
The Many Computing Eras

- Implicit computing (21st century)
  - Natural interfaces and computing on behalf
  - Embedded intelligence
  - Adaptive, mobile context and client plus cloud
  - Number of cores/person → infinity
Successful Technologies Are Invisible
Intuitive Discovery: Invisible Infrastructure

- Domain-specific services
- Scholarly communications
- Blogs & social networking
- Instant messaging
- Identity
- Notification
- Mail
- Document store
- Storage/data services
- Compute Services and virtualization
- Knowledge management
- Knowledge discovery
- Project management
- Reference management

Source: Tony Hey
Today’s Truisms (2009)

• Bulk computing is almost free
  • ... but software and power are not
• Inexpensive sensors are ubiquitous
  • ... but scientific data fusion remains difficult
• Moving lots of data is {still} hard
  • ... because we’re missing trans-terabit/second networks
• People are really expensive!
  • ... and robust software remains extremely labor intensive
• Research challenges are changing
  • ... and social engineering is not our forte
Changing Nature of Research

• Complex models
  • Multidisciplinary interactions
  • Wide temporal and spatial scales
• Large multidisciplinary data
  • Real-time streams
  • Structured and unstructured
• Distributed communities
  • Virtual organizations
  • Socialization and management
• Diverse expectations
  • Client-centric and infrastructure-centric

Research Infrastructure Challenges

• Easy to use software
  • Low entry cost and high productive
• Insatiable demand
  • Cycles, storage, support
• Distributed acquisition/deployment
  • Duplicative, non-shared infrastructure
• Distributed cost structures
  • Power, space, staff, staff, hardware
• Long-term sustainability
  • Decades rather than months/years
LEAD: Adaptive Weather Prediction

- Dynamic adaptive, on-demand system
- Changes in response to weather
- Responds to user inputs
- Steers remote observing technologies

Source: LEAD Team
So Many Choices ...
Scientific Workflow Reliability

- Many workflows with deadlines
- Severe weather events
- Disaster response, ...
- Complex workflow sensitivity
  - Faults are the norm
    - Distributed systems
    - Services and resources
  - Largely unsuccessful
- Research solutions
  - Data consolidation
  - Retry/over-provisioning
Rethinking Software

- Programming in the large
  - Issues do not scale linearly
- Eventual consistency wins
  - CAP theorem
- Component failure
  - Failure as a first class object
- Systemic resilience
  - Upgrade during operation
  - Never go down
Windows Azure Fabric Controller

Out-of-band communication – hardware control

In-band communication – software control

Load-balancers
Switches

Highly-available Fabric Controller

Node can be a VM or a physical machine

WS08 Hypervisor
WS08
Control VM
Control Agent
Service Roles
VM
VM
VM
The Data Explosion

The Challenge

*Enable Discovery.*

Deliver the capability to mine, search and analyze this data in near real time

The Response

A massive private sector build-out of data centers

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**Experiments**

**Simulations**

**Archives**

**Literature**

**Consumer**

*Petabytes*

Doubling every 2 years
Social Implications of the Data Deluge

- Hypothesis-driven
  - “I have an idea, let me verify it.”
- Exploratory
  - “What correlations can I glean?”

- Different tools and techniques
  - Rapid exploration of alternatives
  - Testing a single idea
The Data “Pipeline”: Creating Invisibility

Data Gathering
“Raw” data includes sensor output, data downloaded from agency or collaboration web sites, papers (especially for ancillary data)

Discovery and Browsing
“Raw” data browsing for discovery (do I have enough data in the right places?), cleaning (does the data look obviously wrong?), and light weight science via browsing

Science Exploration
“Science variables” and data summaries for early science exploration and hypothesis testing. Similar to discovery and browsing, but with science variables computed via gap filling, units conversions, or simple equation.

Domain-Specific Analyses
“Science variables” combined with models, other specialized code, or statistics for deep science understanding.

Scientific Output
Scientific results via packages such as MatLab or R2. Special rendering package such as ArcGIS.

Paper preparation.

Source: Catherine Van Ingen, MSR
DryadLINQ: From LINQ to Dryad

- LINQ: .NET Language Integrated Query
  - Declarative SQL-like programming with C# and Visual Studio
  - Easy expression of data parallelism

```
var logentries =
    from line in logs
    where !line.StartsWith("#")
    select new LogEntry(line);
```

Source: Yuan Yu et al
Free Storage: Like Free Puppies

- Storage is cheap (<$1K/TB)
- Storage management is not
  - opX > 100 capX
  - Goal: opX << capX
Windows Azure Storage Service

- SQL Azure also
- SQL in the cloud
HPC and Clouds: Twins Separated At Birth

- Similar technology issues
  - Node and system architectures
  - Communication fabrics
  - Storage systems and analytics
  - Physical plant and operations
  - Reliability and resilience
- Differing culture and sociology
  - Programming models
  - Design and operations
  - Management and philosophy
Exascale Exponentials

Danger, danger

\[ \lim_{\text{Perf} \to \infty} \text{User(Perf)} = 0 \]

Technical Computing + Clouds

Exascale User Base Desktop/mobile
Technical Computing: Creating Invisibility

- Petascale/Exascale/...
- National infrastructure
- University infrastructure
- Laboratory clusters
- Mobile/desktop computing
- Data, data, data
High Performance: Not The Only Story

- High value does not imply high utilization
  - Rapid response is often more important
- Relaxing utilization enables new opportunities
  - High utilization is unnecessary
- Remember Little’s Law
  \[ n = XR \]
Expectations and Needs Vary Widely

- Three groups with differing needs
  - Heroes (Einstein)
  - Mainstream (Joe)
  - Entry/Novice (Elvis)
- Each with differing needs
- Parallel heroes
  
  "Neurosurgery? No problem! Hand me that whiskey bottle and a screwdriver."

- Mainstream
  - Typical user or scientist
- Entry/novice
  - Casual developer or new researcher
Economic Divergence/Optimization

- $/teraﬂop-year
  - Declining rapidly
- $/terabyte-year
  - Also declining rapidly
- $/developer-year
  - Rising (even for Elvis)
- Applications
  - Outlive systems by many years
  - Are rising in complexity
Research Empowerment

• Very few users love technology itself
  • Clusters and parallel programming
  • Distributed services, grids or clouds
  • Data models and databases

• Desktop/mobile acceleration
  • Seamlessly accessible
  • Standard metaphors/tools
  • Intentional not imperative
Simplify, Simplify: Thoreau Was Right

- High level toolboxes
  - Domain-specific capabilities
- Scripting languages
  - Rapid exploration
- Declarative specification
  - Intent, not mechanism
- User-centric design
  - Human optimized
Windows Azure: Client Plus Cloud

- Applications
- Windows Azure
- .NET Services
- SQL Azure
- Live Services

Windows Azure

- Windows Server
- Windows Vista/XP/7
- Windows Mobile
- Others

www.azure.com
Client to Cloud: Accelerating Desktop Tools

- Seamless integration
  - Local and remote data access
  - Computation acceleration and scheduling
  - Collaboration and sharing

Azure table access via Excel plugin
Some Observations ...

• Co-locate when possible
  • (Usually) higher reliability
  • (Usually) lower cost
  • Lower access latency
• Robust trumps experimental
  • Infrastructure stability

• Success is sustainability

• Human productivity dominates
  • Not resource utilization
  • Declarative beats imperative
  • Focus on the goal
  • Domain-specific benefits
  • Leverages user expertise

• Success is invisibility
Convergence: It’s Happening Now