A Supercomputer for Everyone:
Cloud computing for clinical radiation therapy

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What is a super computer?

Performance definition constantly changing.

1984: $15M / GFLOP
2011: $1.80 / GFLOP
First a definition

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My arbitrary definition:

A performance machine that requires at least one order of magnitude more effort than usual to convince your institution to buy it.
• Proton plan checks with Monte Carlo (Geant4) take $\approx 240$ CPU hours at Harvard/MGH in 2011.

• MC treatment planning and future applications will be even more CPU hungry.
Cloud computing can potentially address the increasing demand for computing resources in radiation therapy.
Definition of cloud computing

- On-demand, pay-as-you-go, scalable computing resources
  - CPU time, RAM, storage, software, bandwidth, etc
  - Get as much as you need (likely)
- Several levels
  - Infrastructure as a service (IAAS), e.g. raw server
  - Platform as a service (PAAS), e.g. turn-key web server
  - Software as a service (SAAS), e.g. Gmail
**Cloud computing background**

- Current paradigm started ~2006
- Major internet companies tackled problem of managing massive and shifting computational resources internally
- Internal solutions became external products
- Enabled by commodity hardware, open source software (OS, VM, etc), and ubiquitous high speed networks
Cloud computing background

- Offered by several major internet companies
  - Google, Amazon, Microsoft, IBM, etc
- As well as many smaller providers
  - Rackspace, GoGrid, etc.
- Amazon appears to be current leader with Amazon Web Services (AWS).
What can cloud computing do?

- On-demand, scalable computing clusters
  - No up-front money invested
  - “Throw away” your cluster when your done
    - Pay for only what you use (by the hour [or minute?])
- Use exactly your software setup
  - No waiting for your sysadmin to install packages x,y,z
- Hardware maintenance and upgrades are transparent to you
- Potentially big performance
Could a cloud cluster really be a super computer?
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As of Nov. 2010 a 7040 core Amazon EC2 cluster ranked 231 on the TOP 500 super computer list with 41.82 Tflops (Linpack).

About $1400/hr

http://www.top500.org/system/details/10661
How does cloud computing work?

- Massive infrastructure
- Virtual machines on commodity hardware
- Transparency to end-user through API's
Pricing

- Amazon EC2: ~ $0.10 per 3 GHz core / hour
- Amazon S3 (file storage): $0.14 per GB / month
- Many options → Complicated pricing
- Online costs calculators available
Our work

- Our interest: particle therapy planning and secondary dose problems that require very long Monte Carlo calculations.
- Started developing distributed “virtual cluster” framework in 2009
- Proof of concept radiation therapy calculations using Amazon's service
- Improvements in performance and capabilities
- AWS in Education grant from Amazon
The idea

The Cloud Calculation Process

Upload calculation parameters → Select virtual cluster size → Calculation performed in cloud → Results returned to client
The idea

Step 2: Split dose calculation job, instantiate virtual nodes, and launch calculation

Virtual Master Node

Virtual Calculation Node 1

Virtual Calculation Node 2

... Virtual Calculation Node N

Cloud storage

Step 1: Send plan information

Clinical client

Step 4: Dose distributions retrieved

Step 3: Combine results and send to cloud storage

The Cloud

The Clinic
Our framework was built to run Fluka (Monte Carlo) on Amazon's EC2 and S3 using:

- Python
- Boto (Python AWS library)
- SSH

Proof of concept calculations:
- Depth-dose curves for photons, e-, protons
- Simple proton plans with voxel phantoms
Performance

Job time on Amazon EC2 (1.4x10^7 protons)

- 75 MeV Protons (dashed line with green circles)
- 200 MeV Protons (solid line with green triangles)

Time (minutes) vs Nodes
Platform as a Service

- PaaS is a cloud offering a pre-installed set of services
- PiCloud is an example
- Runs Python code on AWS (easily in parallel)
- Ran toy track-repeating code to produce Bragg peaks with PiCloud
- Google App Engine is another example
Cloud vs Local vs HPC vs Grid

- **Local**
  - In-house maintenance and upgrades
  - Acquisition costs (~ $1000/node)

- **HPC**
  - Little user control
  - Limited resources
  - Access issues

- **Grid**
  - Little user control
  - Fewer resources
  - Access issues
Cloud vs GPU

- GPU programming is highly specialized
  - (i.e. It's a BIG pain)

- CPU clouds don't need special porting.
  - Your current software will run as is.
Cloud vs GPU

- GPU programming is highly specialized
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- CPU clouds don't need special porting.
  - Your current software will run as is.
- But clouds are about ♥♥♥LOVE♥♥♥
- You can have GPU clouds as well!
- These are complimentary technologies.
Cloud Issues

- Not appropriate for all applications
- Licensing costs for proprietary software on clusters
- Vendor lock-in
  - Some industry initiatives on this
  - OpenStack vs standardizing on Amazon API
- Data privacy / security
  - Primarily a regulatory rather than technological hurdle
  - Several country and region specific services or sub-services exist that may address some geographic data issues.
Current / Future work

• Working on
  • Performance enhancements
  • Data integrity issues
  • Web interface
  • Multiple MC engines (Geant4 underway)
  • Multiple vendors

• Future
  • GPU and GPU + CPU clouds
Conclusion

- Cloud computing is greatly lowering the barrier to super computing scale resources
- Potential for particle therapy is great
  - New applications demand more resources
  - More resources enable new innovation
- I may need to revise my definition of a super computer
Visit our cloud computing page

http://cs.unm.edu/~compmed/PTG/cloud.html

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