Computing for the Future of the Planet

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Optimal Digital Infrastructure  
Sense and Optimise  
Predict React Automate  
Physical to Digital


2. Sense and Optimise – “Computing for Green”

3. Predict, React, Automate - “Guaranteed Computing”

4. Digital Alternatives to Physical Activities – “Physical to Digital”
Green Computing  Computing for Green  Guaranteed Computing  Physical to Digital
1 – Green Computing

- Data centre design
- Energy-proportional processing, networking, storage
- Direct use of renewable energy
- Use of surplus renewable energy
- Use of very remote renewable energy?
Energy-proportional processing

Figure 5.4: Average activity distribution of a sample of two Google clusters, each containing over 20,000 servers, over a period of 3 months (January-March 2013).
Energy-proportional storage (Facebook)

- **Hot storage: read a lot**
  - Replication(striping across data centres)
  - 3.5x stretch factor for resilience and performance
  - Data cools by 500x over 1st year
- **Warm storage: read a bit**
  - 2.5x stretch factor at lower performance
  - Migrate 1 month old data
- **Cold storage: read almost never**
  - Cheap drives by the million powered 1/15 of the time
  - 1.4x stretch
- **Very cold storage: read never?**
  - Optical (eg Blu-ray) thus little energy storage cost
Use of Renewable Energy

- Execute computing tasks where renewable energy is available
- Use renewable energy that cannot be used for another purpose
- Do we ship or replicate programs, data sets, or both?
- Will this change as photonic networks evolve?
Technology Perspective

• Technology trends
  • Better hardware performance and power scalability
  • “Internet of Things”

• Workload trends
  • “Big Data”
  • Increasing large data and batch computations

• The future
  • Energy proportional computing, networking, and storage?
  • How much of the world’s computing will use surplus energy?
  • Ultimate processing architecture: latency or energy driven?
  • Ultimate storage architecture: store everything for ever?
Green Computing  Computing for Green  Guaranteed Computing  Physical to Digital
2 – Computing for Green

• A sensor-based digital model of everything

• “Googling” Earth in space and time

• How do we do it?
  • coverage
  • fidelity
  • scalability
  • performance
  • usefulness
Future Street View – Heat Sensing?

- Dense Urban Area
  - Un-heated vacant housing
  - Poorly insulated housing with varying degrees of heat loss
  - Well insulated occupied housing with heat loss visible through the chimney pots
Indoor Location

- Active tag and receiver infrastructure
- 3D accuracy up to 15cm (95% confidence level)
- Max range up to 160m
BMW Car Plant, Germany
(Final Assembly Tool Assistance)

- Tracking tools on a complex production line
- Automatically programs tool with correct settings for each car
- Fewer manual processes, reducing errors
Multiple Airbus sites in Europe
(Process Tracking)

- Process monitoring across multiple factory sites in UK, France, Germany
- Provides central overview of process state
- Automatically updates planning system
Smartphone tracking

R. Harle et al

Knowledge of environment
Motion models

Fuse

Position

Accelerometers
Gyrosopes
Compass
Barometer
WiFi
Cellular
Bluetooth
NFC, RFID
Whitespace radio
Light
Temperature
etc
DeviceAnalyzer for Android

Global Personal Energy Meter - PEM

A. Rice et al

- Complete
  - all energy accounted for: sensed, embedded, shared, hypothecated

- Accurate / Bounded / Personalised
  - my actions relate to me only

- Sensible
  - incentives work correctly

- Assured
  - rules are understood
  - fidelity / error bounds
  - security / privacy
Privacy Dilemmas

- Privacy vs Sustainability
- Privacy vs Public Good
- Privacy vs Unexpected Consequences (eg Facebook)
- Privacy vs Wealth Creation
- Who is Big Brother anyway?
Framework for Big Data

- Collection
  - Transparency, Consent, Purpose, Access, Withdrawal, Accountability

- Governance
  - Who owns it
  - Who do we trust
  - How does business work
  - How does society work
Increasing societal dependence on computing and automation
- Complex systems
- Advances in machine learning and artificial intelligence

Technical challenges
- Correctness, bounding of errors
- Data archiving, code archiving, audit trails, transparency, repeatability, provenance
- Security, privacy
Provenance in Guaranteed Computing Systems

R. Sohan et al

• Complete history of a piece of data and its transformations
  • Can be applied at various levels

• A component of Guaranteed Computing Systems
  • Promulgate all changes to data
  • Invalidate backwards and compute forwards
  • Automatic or on-demand implementation

• Uses
  • Validation and Reproducibility
  • Audit and Compliance
  • System Optimisations
  • Reversible consent for exploratory use of Big Data?
Ongoing Projects

**IPAPI** – An Improved Provenance API

**HadoopProv** – A tool for augmenting “Big Data” programming

**OPUS** – Observational Provenance in User Space

**Resourceful** – System-call level Resource Accounting
Capture key-value record dependency for across entire work-flow

Low (<10%) temporal overhead

Enables forward and backward key-value trace

Uses: verification, validation, subset processing
OPUS: Observational Provenance In User-Space

- General purpose process-level provenance capture for POSIX
- Record all process I/O calls at library level
- Low use barrier, low overhead, always on
Relation Between Cat Colour and Popularity

Fluffy Cat
University of Cambridge
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Abstract

1. Introduction
Lorem ipsum dolor sit amet, consetetur sadipscing elitr. Aliquam ac diam, vel velit sint consectetur, lorem aenean congue, sed tellus. Sed et nunc euismod, vel tortor vel, ac tincidunt, sed tellus. Nulla a turpis sed diam, euismod diam, vel velit.

2. Methods
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3. Results
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4. Conclusion
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Dataset

How?
When?
Why?
4 – Wealth in Cyberspace?

- Can we construct a digital world in which we can conduct our lives?
  - On a ultra-cheap platform
  - Using miniscule power
  - Fed with sensor data from the real-world
  - Accessible to everyone and everything

- Opportunity for the “Developing World” to bypass intermediate steps
  - Create wealth with a smaller footprint
Mobile traffic in Rwanda

The chart above shows the maximum download throughput for both smart phones and feature phones on both Thursday and Friday. The red line represents smart phones, while the blue line represents feature phones. The y-axis represents Mbps, and the x-axis represents time, with Thursday on the right and Friday on the left.

The data indicates that the download throughput for smart phones is generally higher than for feature phones, with some fluctuations observed on both days.
Its happening!

- Coverage of cellular infrastructure is over 75%
- Auto-rickshaw: mGaadi, PoochO
- Amazon Mechanical Turk is a crowdsourcing marketplace for work
- MOOCs for education, eg: isaacphysics.org
- etc
Optimal Digital Infrastructure
Sense and Optimise
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Physical to Digital


https://www.cl.cam.ac.uk/research/dtg/www/research/