ISTC-CC Presentation by Georgia Tech (8/27/15)

Karsten Schwan (site director), ***Calton Pu*** (presenter), with L. Liu, S. Yalamanchili, G. Eisenhauer, A. Gavrilovska, M. Wolf
Georgia Tech

http://www.istc-cc.cmu.edu/

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Highlights of ISTC-CC (Georgia Tech)

- First part: yearly update on various projects
  - Karsten Schwan, Ling Liu, Calton Pu, Sudha Yalamanchili, Greg Eisenhauer, Ada Gavrilovska, Matt Wolf
  - Many students at PhD, MS, and undergraduate levels
- Second part: some details on automated management work (linking into Project Pulse)
- Highlights on work funded by ISTC-CC, or conforming to Intel open IP policy
  - Significant funding amplification from many industry collaborators and government funding agencies such as NSF and DoE

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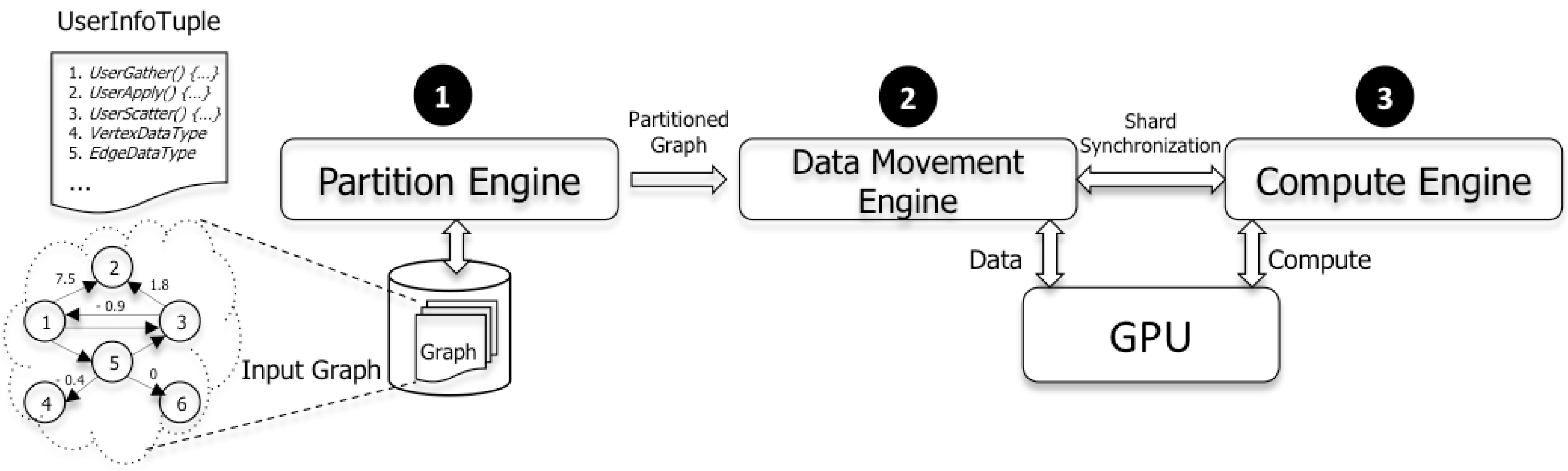
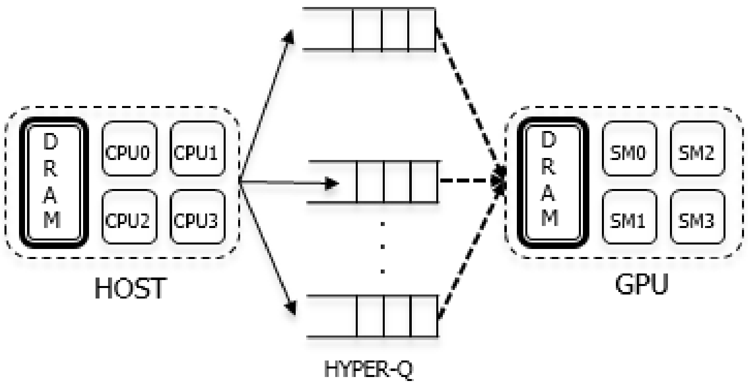
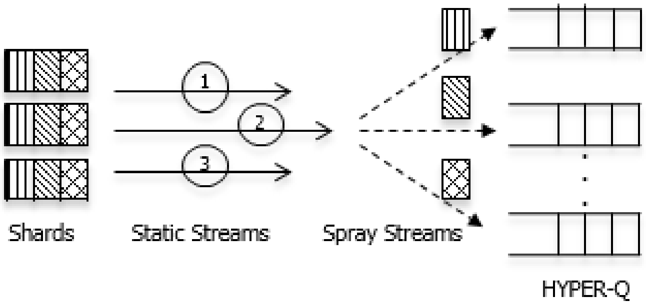
GraphReduce Architecture (Schwan)



SC 2015, GraphReduce: Processing Large-Scale Graphs on Accelerator-Based Systems

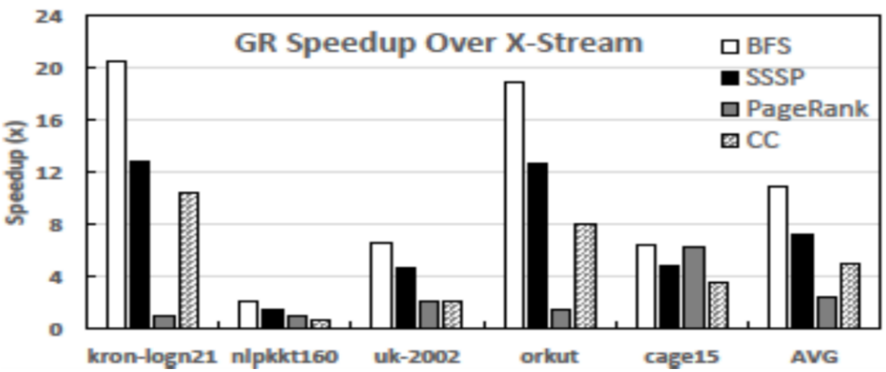
Optimizations on GraphReduce

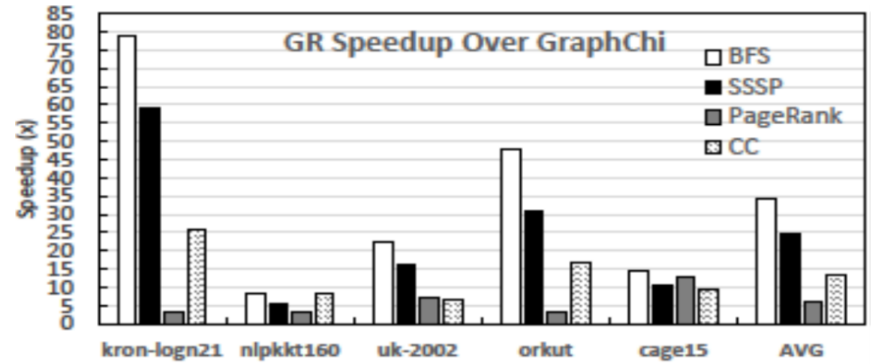




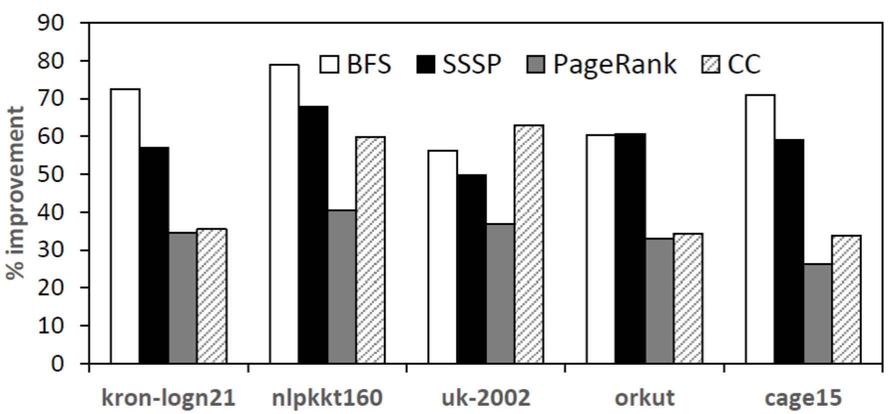
- Asynchronous execution and Spray (deep-copy) operation
- Dynamic frontier management
- Dynamic phase fusion and elimination

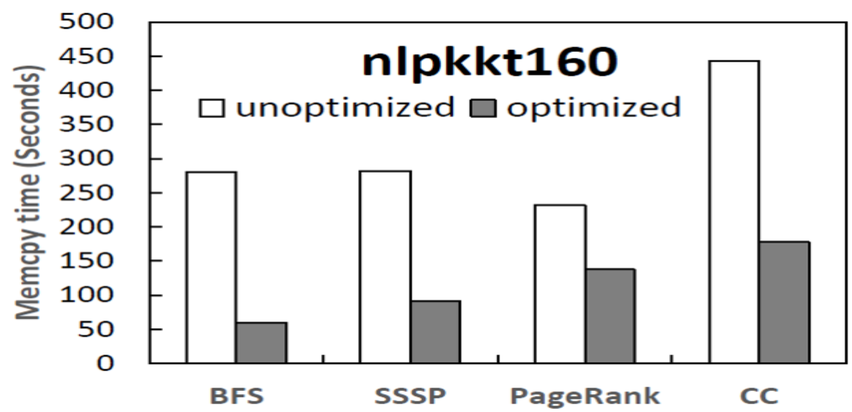
Gains by GraphReduce





GraphReduce's speedup over Graphchi and X-Stream for out-of-memory graph inputs





Benefits of GraphReduce optimizations over memcpy time

Understanding Issue Correlations: A Case Study of the Hadoop System

Scalable distributed systems are complex [Yuan et al., OSDI'14]

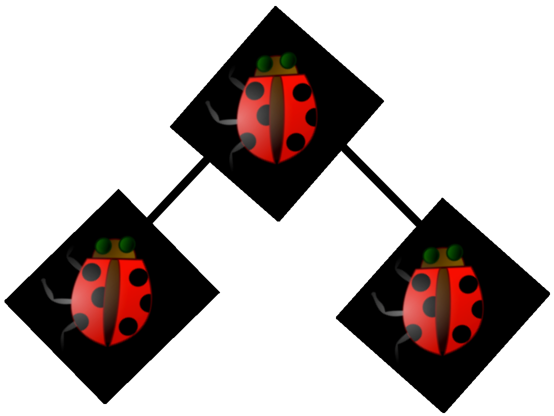
Complicated System + Error-prone + Hard to Debug

⇩ Issue Study

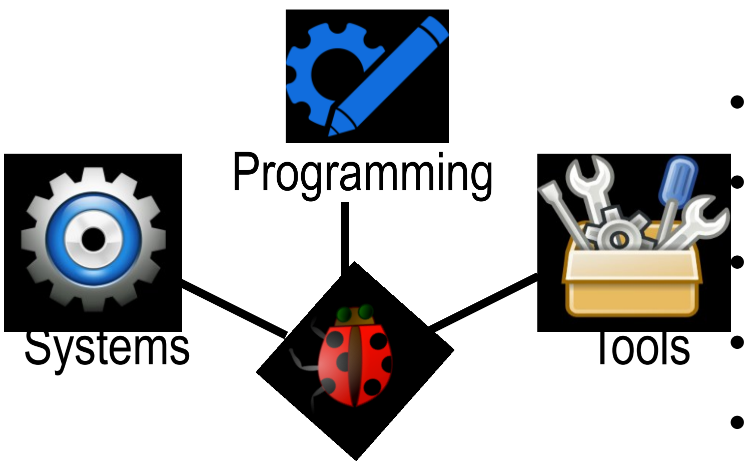
Issue Pattern → Better Software & Debugging Tools

SOCC'15

Our Findings

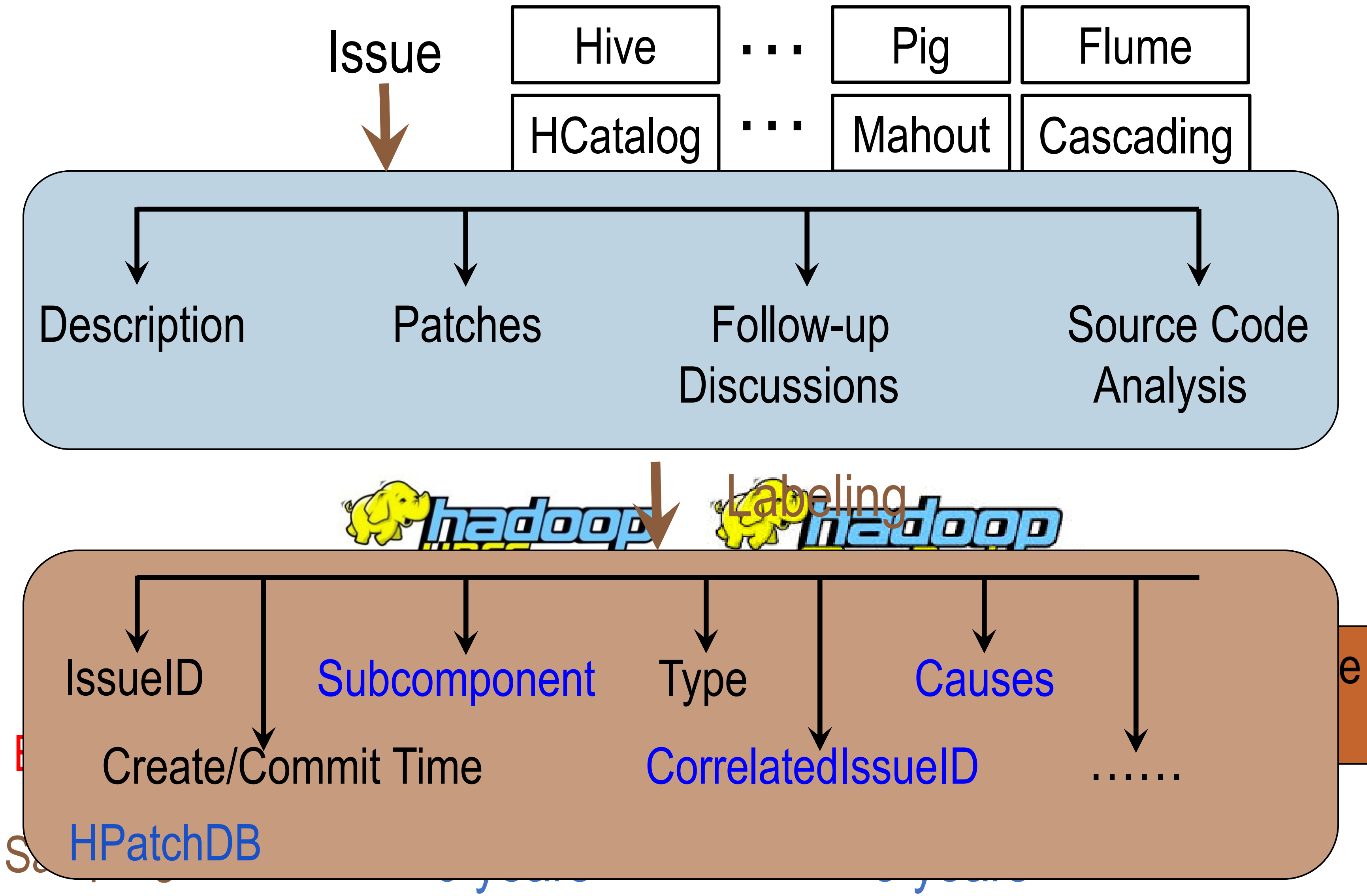


- Half of the issues are independent
- The issue correlations are not complex as we expected
- One third of the issues have similar causes
- ......

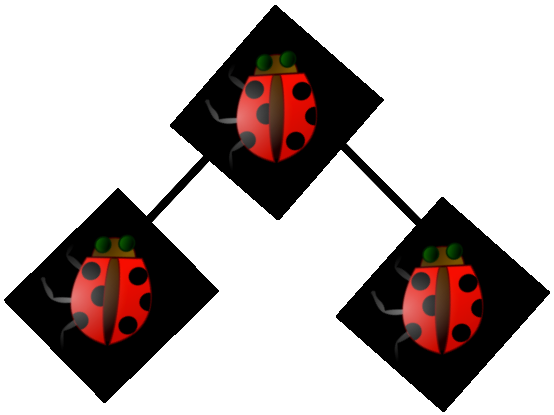


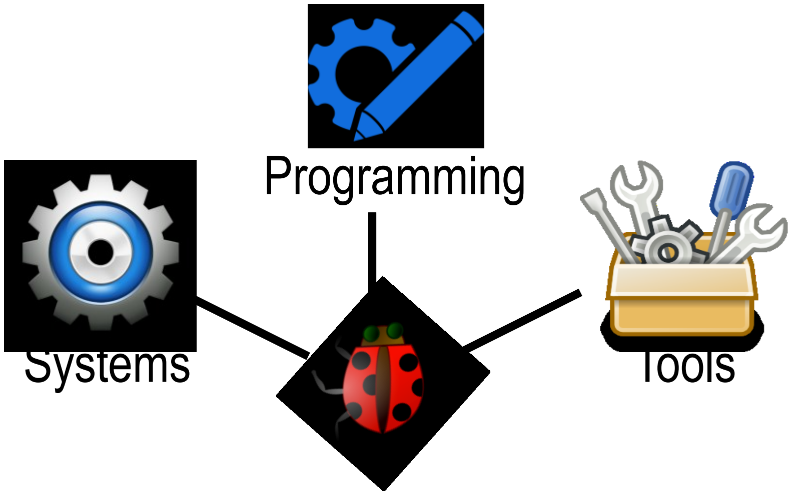
- For memory issues, GC is still the No. 1 concern
- The statement "99.99% of data reliability" is challenged
- One third of programming issues relate to interfaces
- The logging system is error-prone
- ......

Methodology Used in Our Study



Insights from Analyzing Issues





1 **Correlations Between Issues**

Issues are independent; 33% of issues have similar causes, etc.

2 **Correlations With System Characteristics**

Systems, programming, tools

Big Data Systems Research (L. Liu)

- Optimizations for Fast Iterative Graph Computations
  - GraphLego:
    - Resource Aware Graph Parallel Abstractions (Graph Cube and Slice, Strip, Dice) [ACM HPDC 2015]
  - GraphTwist:
    - Approximation with utility-aware pruning [VLDB2015]
    - Edge pruning by slices: removing some insignificant edges
    - Vertex pruning by cuts: removing some insignificant vertices
  - GraphMap:
    - Workload aware Distributed Graph Processing Framework [IEEE SC2015]

Shared Memory Optimization in Virt. Cloud

- Shared Memory Management Mechanisms
  - MemPipe:
    - Shared memory channels for improving communication efficiency between co-resident VMs
    - Incremental shared memory management
  - MemFlex
    - Shared memory based ballooning (inflate and deflate)
    - Shared memory based optimization for memory page fault.
  - MemMon
    - Memory working-set monitoring and estimate.

Poster by Qi Zhang (L. Liu)

Optimizing Performance and Productivity on Heterogeneous Processors

Sudhakar Yalamanchili
School of Electrical and Computer Engineering
Georgia Institute of Technology

Collaborators: H. Wu, M. Gupta, C. Kersey, H. Kim, I. Saeed, J. Young, H. Wu, and LogicBlox Inc.

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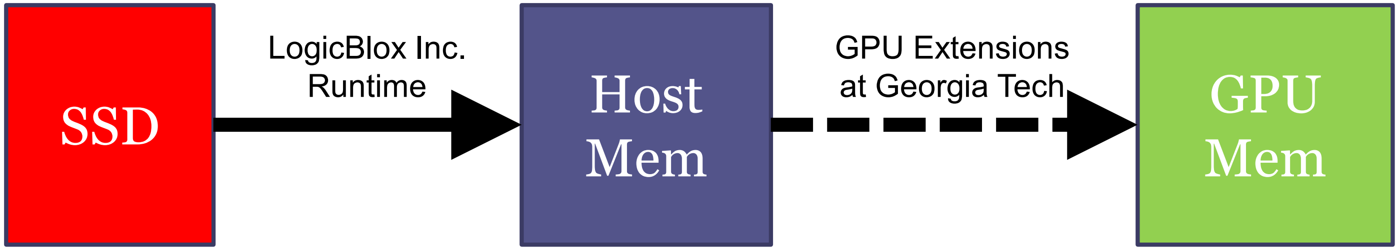
Accelerating Relational Processing

Haicheng Wu and S. Yalamanchili

- Finding cliques
  - triangle(x,y,z)<-E(x,y),E(y,z),E(x,z), x<y<z.
  - 4cl(x,y,z,w)<-E(x,y),E(x,z),E(x,w),E(y,z),E(y,w),E(z,w), x<y<z<w.

Multi-predicate Join

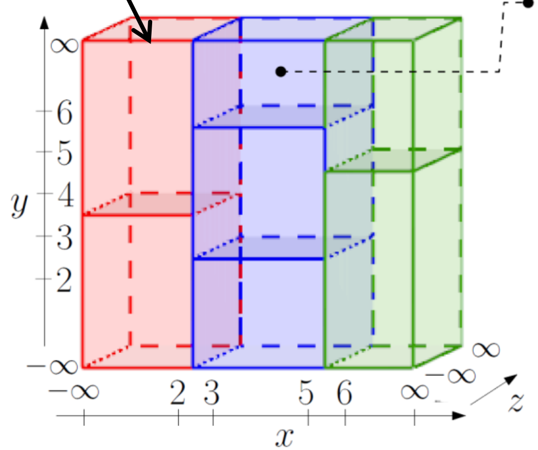


- Relational computations over out of core data sets
- Implementation of multi-predicate join for graph processing using GPUs
  - 3-clique and 4 clique problems

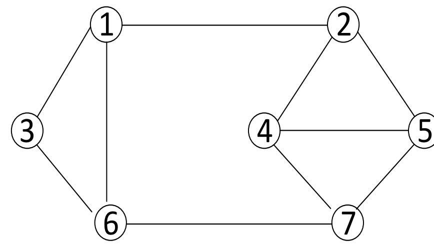
H. Wu, D. Zinn, M. Aref, and S. Yalamanchili, "Multipredicate Join Algorithms for Accelerating Relational Graph Processing on GPUs," *Proceedings of ADMS*, September 2014

Out-of-Core Data Management

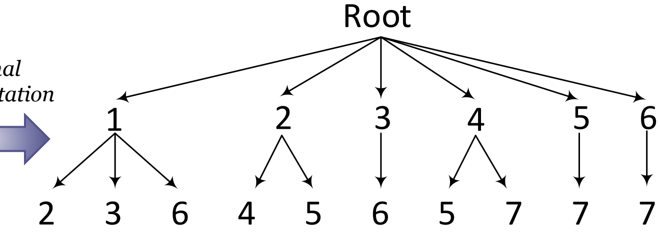
Data partitions (boxes) to fit in memory (worst-case optimal)



Box [3⩽x⩽5,6⩽y<∞,-∞<z<∞]

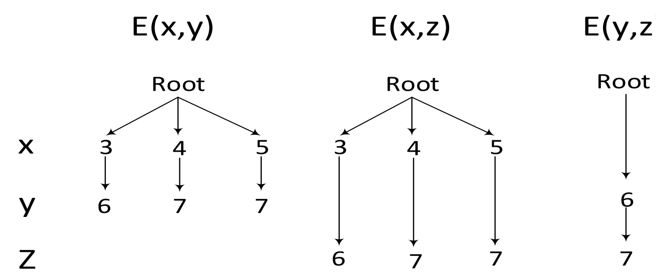


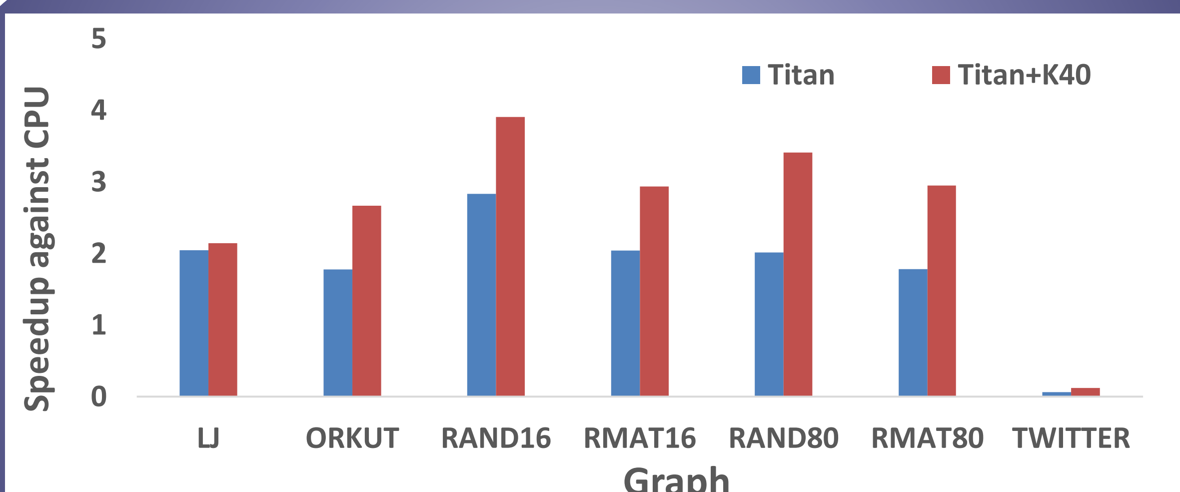
Internal Representation



Trie representation of edges

triangle(x,y,z)<-E(x,y),E(y,z),E(x,z), x<y<z



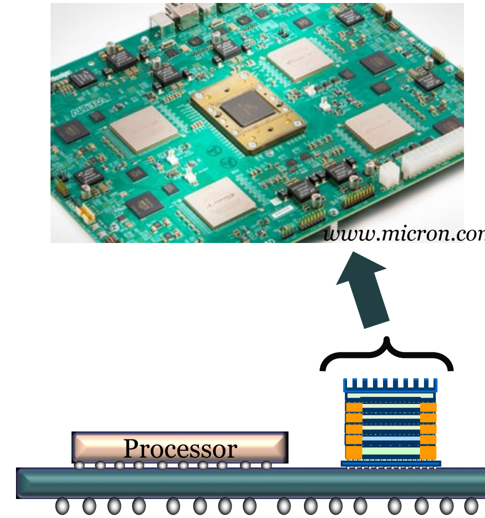


- Large, out of core graphs
- Baseline is CPU boxed multi-predicate join
- SSD and PCIe are not the bottlenecks

Near Memory Data Intensive Computing

Kim (CS), Mukhopadhyay (ECE), Yalamanchili (ECE)
Collaborative Discussions with Intel Labs (N. Carter)

- Move Analytics Primitives (RA) into the memory system
  - Custom low power GPU(Harmonica)
  - Progress on Base compiler for in-memory GPU



A. Gavrilovska (CS), K. Schwan (CS), Yalamanchili (ECE)

- Technology Assessment
  - Collaboration with Lexis Nexis
  - Assess the impact of In-memory acceleration for HPCC

HPCC SYSTEMS®

LexisNexis®

HPCC Engineering Summit

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Leveraging eBoxes and Compilers

Ada Gavrilovska
Georgia Tech

http://www.istc-cc.cmu.edu/

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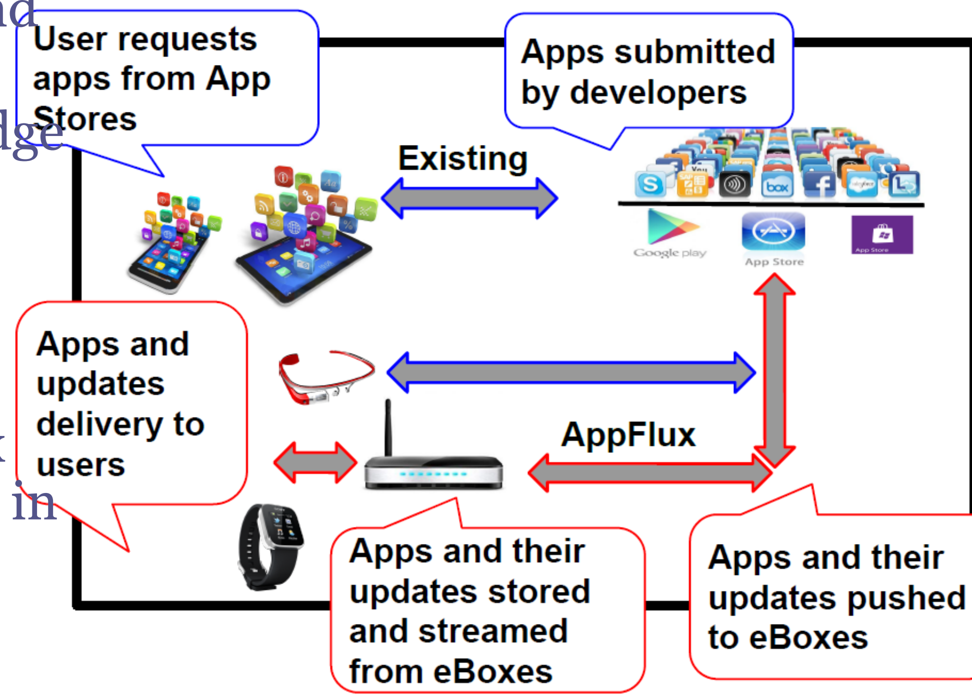
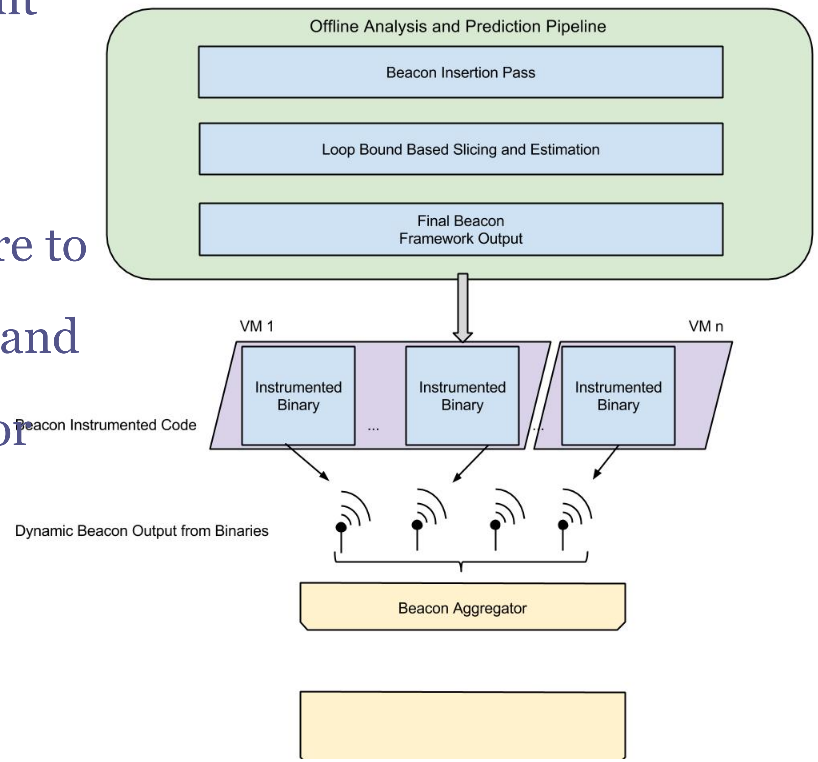
Enhancing the Edge via eBox-based Services

- Some results presented last year, also supported by ISTC-EC in the past and VMware
- Leverage high-density/low-power edge boxes – eBoxes
- Infrastructure for app streaming, caching, ephereral app delivery;
- Fully integrated in Android stack
- Outcome: 2x faster app delivery, 10x faster app descovery, 70% reduction in traffic; no performance impact
- AppFlux: Taming App Delivery @TRIOS'15 (Bhardwaj, Agarwal, Gavrilovska, Schwan); others in submission/preparation



Compiler-Assisted Resource Management

- Goal: dynamic resource allocation to concurrent workloads/workload components
- Problem: profile-based techniques limited effectiveness (input-dependent requirements, irregular applications…)
- Approach: LLVM-based compiler infrastructure to instrument binary with "**beacons**". Beacons generate information based on dynamic input and actual execution path taken. Intercepted by resource managers (e.g., VM manager, VCPU or thread scheduler, runtime-level scheduler…)
- Outcome: improved workload performance, reduced performance variability, improved resource use and management efficiency
- Compiler-assisted Load Balancing on Large Clusters @PACT'15 (Deodhar, Parikh, Gavrilovska, Pande); others in submission/preparation



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Automated Cloud Management through Experimental Measurements

Calton Pu
Professor and J.P. Imlay Chair in Software
Georgia Institute of Technology
Many PhD, MS, Undergraduate students and industry collaborators

http://www.istc-cc.cmu.edu/

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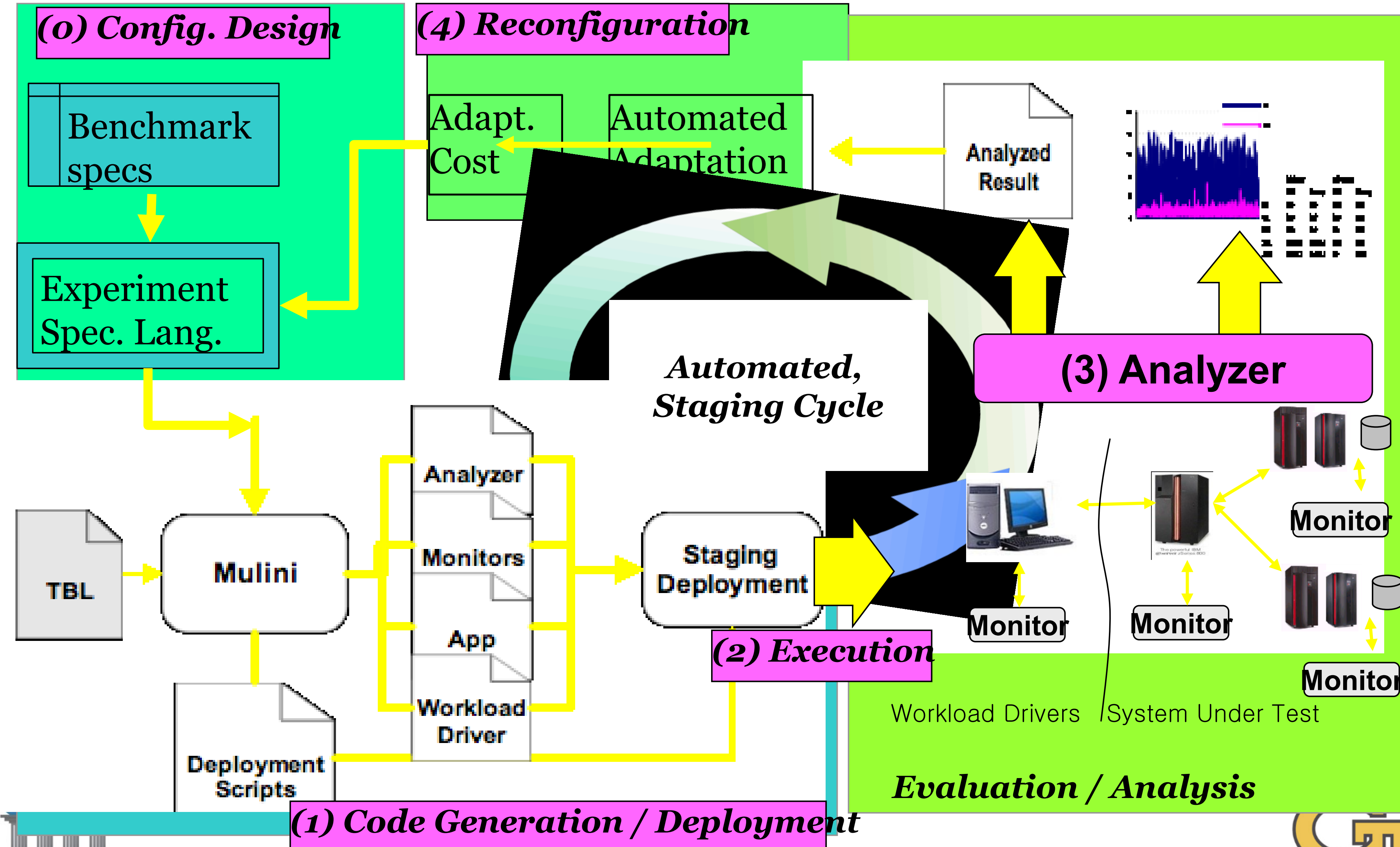
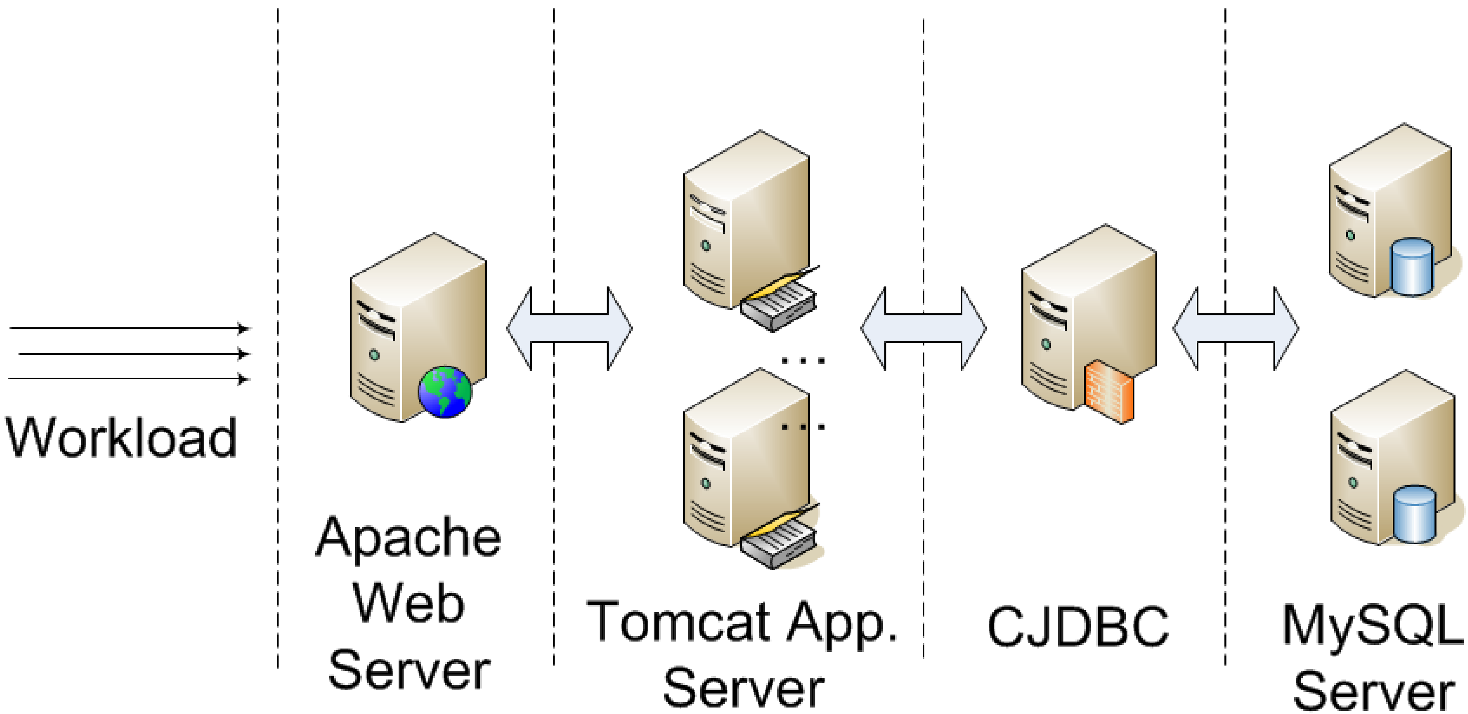
Elba: Automated Measurements



N-tier Benchmarks

Example Experiment: RUBBoS benchmark based on Slashdot

- Sample configuration (1/2/1/2)



Elba Experience

- Experimental studies analyzing performance data
  - Production-scale experiments on “real data centers”
  - Collaboration with many industry partners
  - Funding amplification from NSF
- Between 2013 and 2014: 13 papers
  - IEEE CLOUD, SCC, ICDCS, IRI, Big Data Congress, BigData, ACM TRIOS
  - More than 40 papers (2005 – 2014)

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Automating Experiments

- Transform and generate scripts to automatically create, manage and analyze experiments from user-friendly specification files
- Develop open tools for automated experiments
  - Support a wide variety of ***evolving*** clouds, benchmarks and performance monitors
  - Support flexible customization for many configuration parameters
- High resolution monitoring at low cost

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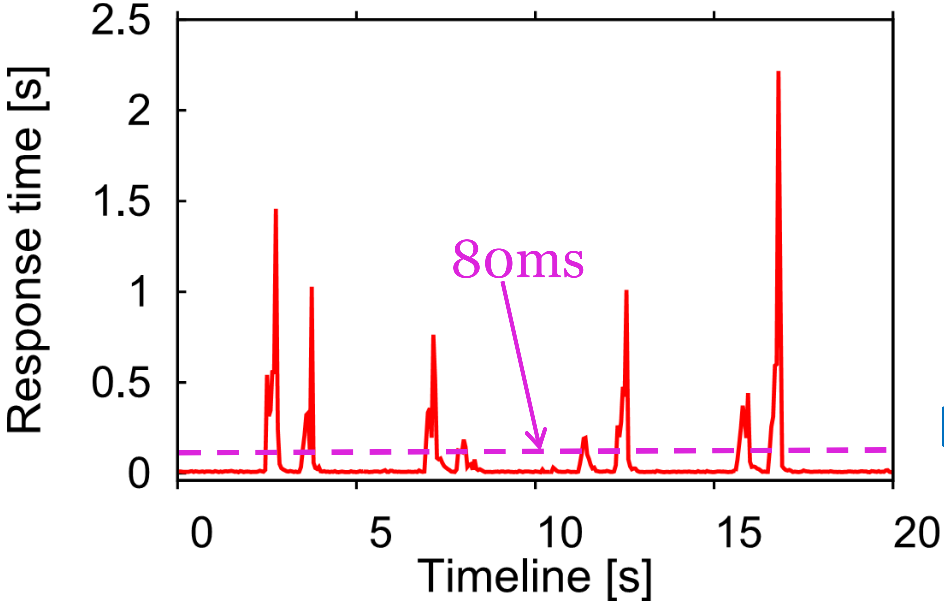
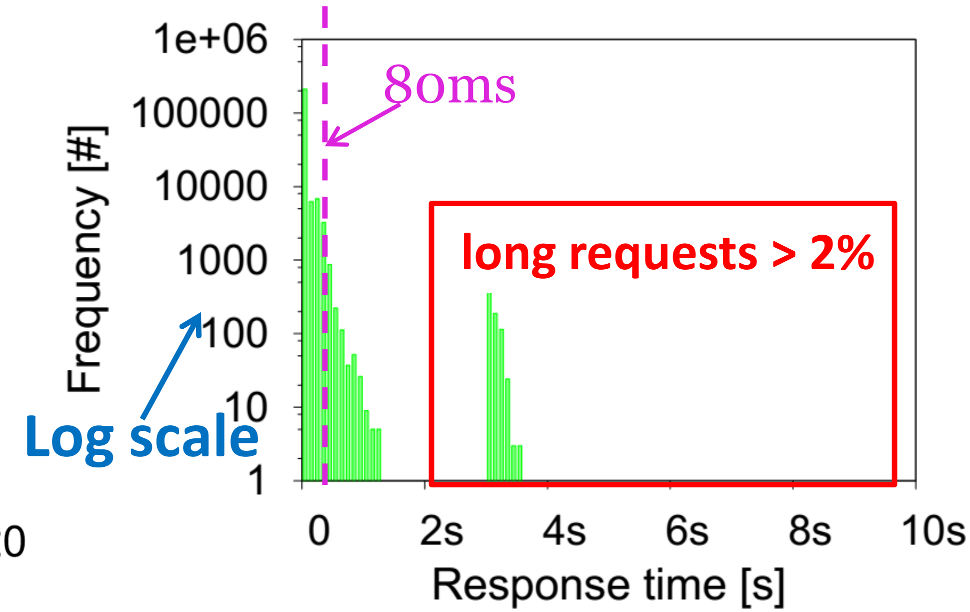
Example: Very Short Bottlenecks (TRIOS'13)

- High resolution monitoring at low cost:
  - See VSBs at tens of milliseconds
  - A few percent monitoring overhead

P-I-T Response time at 50ms resolution



Cumulative request response time distribution



Five Steps of Experimental Process

1. Input Experiment Metadata (XML)

User-provided configuration
Scripts and generator execution

2. Generate Experiment Scripts

Provision environment
Run benchmark
Setup, tear down infrastructure

3. Execute experiment on various clouds

Performance data extraction & load into database

4. Collect, extract, load experimental Data

5. Analyze Results (Excel and statistical tools)

Scale of Experiments

Figures for Fall 2014 and Spring 2015; taking into account diversity of work, including large-scale experimentation and infrastructure development activities

	Emulab	**PRObE**	**Local Cluster**
Experiments (mins)*	***91,728***	***4,641***	***2,925***
Nodes Used (#)	***6,048***	***1,092***	***4,516***
Experiments (#)	***14,112***	***714***	***450***

*Experimental workloads range from 3 - 7 mins, each lasting about 20 - 30 min

Step 2: Script Transformation Example

Code Template

```
source set_elba_env.sh
mkdir -p <xsl:value-of
select="//params[@name='RUBBOS_
TOP']/@value"/>
```

1 template line

XML Input

```
<xtbl name="Rubbos" version="0.1">
<params name="OUTPUT_HOME"
value="/opt/rubbos/output"/>
<params name="RUBBOS_TOP"
value="/mnt/rubbos"/>
</xtbl>
```

Intermediate Representations

```
<file>
<name id="Tomcat_deploy.sh" loc="/home/scripts"/>
source set_elba_env.sh
mkdir -p /mnt/rubbos
</file>
```

Occurs in 5 templates

Experiment-specific Scripts

```
#/home/scripts/TOMCAT_DEPLOY.sh
source set_elba_env.sh
mkdir -p /mnt/rubbos
```

And 3 script files

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Script Size of Experiment Runs

The following figures correspond to deploying a 16-node, (4 clients; 2W\4A\1M\4D), RUBBoS application benchmark in the Emulab cluster. Generated lines are an intermediate representation that enable application, DBMS, OS and user-specific customizations to be applied.

	Templates (XSLT Lines)	**Intermediate** (XML/XLST Lines)	**Final Scripts** (Shell Script Lines)
Core	**900**	**400**	**1500**
Deployment	**3300**	**2000**	**2200**
Benchmark	**1400**	**500**	**500**

Step 4: Extract/Load Monitor Results

- Challenge: many performance monitors, many configuration parameters, many output formats
- Automated Approach:
  - use script transformation techniques to annotate monitor output
  - generalize parser to consume schema (from the annotations) and parse the encapsulated data accordingly

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Example 1: dstat

- **Some monitors can output simple, CSV-formatted data files**

```
"Dstat 0.6.9 CSV output"
"Author:","Dag Wieers <dag@wieers.com>",,,,"URL:","http://dag.wieers.com/home-made/dstat/"
"Host:","169",,,,"User:","root"
"Cmdline:","dstat -c -d -i -m -n -r -y --vm --no --output /tmp/169.254.100.3.csv 1",,,,"Date:","25 Feb 2012 19:14:49 EST"

"total cpu usage",,,,,,"dsk/total",,"interrupts",,,"memory usage",,,,"net/total",,"io/total",,"system",,"virtual memory",,,
"usr","sys","idl","wai","hiq","siq","read","writ","15","17","18","used","buff","cach","free","recv","send","read","writ","int"
0.731,0.794,97.731,0.536,0.066,0.144,370910.050,14976.328,1.031,18.487,1.806,219025408.0,23076864.0,249458688.0,3556507648.0,
0.0,0.0,100.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,4.0,219045888.0,23076864.0,249470976.0,3556474880.0,468.0,386.0,0.0,0.0,28.0,16.0,0
0.990,0.0,99.010,0.0,0.0,0.0,0.0,0.0,2.0,0.0,2.0,219045888.0,23076864.0,249470976.0,3556474880.0,60.0,0.0,0.0,0.0,26.0,16.0,0
10.309,59.794,23.711,5.155,1.031,0.0,2867200.0,139264.0,0.0,23.0,37.0,655368192.0,23093248.0,250908672.0,3118698496.0,3651.0,
5.0,44.0,50.0,0.0,1.0,0.0,245760.0,0.0,2.0,1.0,13.0,219578368.0,23093248.0,251027456.0,3554369536.0,618.0,570.0,2.0,0.0,532.0
0.0,0.0,100.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,1.0,219578368.0,23093248.0,251027456.0,3554369536.0,60.0,0.0,0.0,0.0,22.0,20.0,0.0,
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0.0,0.0,100.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,2.0,219578368.0,23093248.0,251027456.0,3554369536.0,120.0,0.0,0.0,0.0,19.0,14.0,0.0
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7.0,14.0,79.0,0.0,0.0,0.0,0.0,81920.0,0.0,4.0,55.0,220344320.0,23109632.0,251031552.0,3553583104.0,5386.0,6105.0,0.0,8.0,294.
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0.990,0.0,99.010,0.0,0.0,0.0,0.0,0.0,0.0,0.0,1.0,228540416.0,23130112.0,251039744.0,3545358336.0,0.0,0.0,0.0,0.0,18.0,11.0,0.
0.0,1.0,99.0,0.0,0.0,0.0,0.0,0.0,2.0,0.0,1.0,228540416.0,23130112.0,251039744.0,3545358336.0,60.0,0.0,0.0,0.0,23.0,16.0,0.0,0
```

Example 2: sar

- Other monitors can produce highly variable and difficult-to-parse output (syntax & semantics)

```
Linux 2.6.32-358.18.1.el6.x86_64 (elba2)    09/18/2013  _x86_64_    (4 CPU)

08:11:18 AM     CPU     %user     %nice   %system   %iowait    %steal     %idle
08:11:19 AM     all      1.01      0.00      0.25      0.50      0.00     98.24
08:11:19 AM       0      4.08      0.00      1.02      2.04      0.00     92.86
08:11:19 AM       1      0.00      0.00      0.00      0.00      0.00    100.00
08:11:19 AM       2      0.00      0.00      0.00      0.00      0.00    100.00
08:11:19 AM       3      0.00      0.00      0.99      0.00      0.00     99.01

08:11:18 AM    proc/s   cswch/s
08:11:19 AM      2.04   2068.37

08:11:18 AM  pswpin/s pswpout/s
08:11:19 AM      0.00      0.00

08:11:18 AM  pgpgin/s pgpgout/s   fault/s  majflt/s  pgfree/s pgscank/s pgscand/s pgsteal/s    %vmeff
08:11:19 AM      0.00     28.57    646.94      0.00    541.84      0.00      0.00      0.00      0.00

08:11:18 AM       tps      rtps      wtps   bread/s   bwrtn/s
08:11:19 AM     12.24      0.00     12.24      0.00    114.29

08:11:18 AM   frmpg/s   bufpg/s   campg/s
08:11:19 AM    -61.22      2.04      3.06

08:11:18 AM kbmemfree kbmemused  %memused kbbuffers  kbcached  kbcommit   %commit
08:11:19 AM   7179524    711684      9.02     36444    456152    254532      1.60

08:11:18 AM       DEV       tps  rd_sec/s  wr_sec/s  avgrq-sz  avgqu-sz     await     svctm     %util
08:11:19 AM    dev8-0      5.10      0.00     57.14     11.20      0.03      5.40      5.20      2.65
08:11:19 AM  dev253-0      7.14      0.00     57.14      8.00      0.03      4.14      3.71      2.65
08:11:19 AM  dev253-1      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
08:11:19 AM  dev253-2      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

08:11:18 AM     IFACE   rxpck/s   txpck/s    rxkB/s    txkB/s   rxcmp/s   txcmp/s  rxmcst/s
08:11:19 AM        lo      3.06      3.06      0.16      0.16      0.00      0.00      0.00
08:11:19 AM      eth0   1271.43   1173.47    679.75    854.51      0.00      0.00      0.00

08:11:18 AM     IFACE   rxerr/s   txerr/s    coll/s  rxdrop/s  txdrop/s  txcarr/s  rxfram/s  rxfifo/s  txfifo/s
```

Intel Science & Technology Center for Cloud Computing

Transforming Output of sar

XML Tree Parser

```
tree = XMLTree.parse(input_file)
root = tree.getroot()
node_list = list(root.iter())
for i in node_list:
        #controls when to start the next record
        if i.tag == record_ind:
            if ctr > 0:
                diff = value_str[len(last_str):len(new_str)-1]
                row_list.append(diff)
                value_str = value_str + '\n'
                last_str = value_str
            ctr = ctr + 1
        if len(i.attrib) ==0:
            #check for invisibile characters like tabs and line feeds
            test_list = [ord(s) for s in i.text if ord(s) == 9 or ord(s) == 10]
            if len(test_list)==0:
                    key_str = key_str + i.tag + ","
                    value_str = value_str + i.text + ","
        for k,v in i.attrib.iteritems():
            key_str = key_str + k + ","
            value_str = value_str + v + ","
        new_str = value_str
#output row_list to a file for database import
```

Parsing the following version of SAR output is reduced to parsing a XML tree

SAR Annotated Output


```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE sysstat PUBLIC "DTD v2.13 sysstat //EN"
"http://pagesperso-orange.fr/sebastien.godard/sysstat.dtd">
<sysstat>
    <sysdata-version>2.13</sysdata-version>
    <host nodename="node-5.111base.elba.marmot.pdl.cmu.local">
        <sysname>Linux</sysname>
        <release>2.6.43.8-1.fc15.x86_64</release>
        <machine>x86_64</machine>
        <number-of-cpus>2</number-of-cpus>
        <file-date>2015-07-18</file-date>
        <statistics>
            <timestamp date="2015-07-19" time="01:16:04" utc="1" interval="1">
                <cpu-load>
                    <cpu number="all" user="6.63" nice="0.00" system="3.06" iowait="0.00" steal="0.00" idle="90.31"/>
                    <cpu number="0" user="13.40" nice="0.00" system="5.15" iowait="0.00" steal="0.00" idle="81.44"/>
                    <cpu number="1" user="0.00" nice="0.00" system="1.01" iowait="0.00" steal="0.00" idle="98.99"/>
                </cpu-load>
                <process-and-context-switch per="second" proc="2.00" cswch="1588.00"/>
                <swap-pages per="second" pswpin="0.00" pswpout="0.00"/>
```

Georgia Tech Highlights for ISTC-CC

- Research on big data graph algorithm optimization
  - K. Schwan, L. Liu
- Research on program optimization for heterogeneous processors and memories
  - S. Yalamanchili, A. Gavrilovska
- Research on automating experiments on large scale benchmarks
  - C. Pu
- Many publications, some tool releases, more planned