Empirical Examination of a Collaborative Web Application

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The collaborative web application (WeBWoRK), trace, and dataset described in these slides are publicly available.

http://www.cs.rochester.edu/u/stewart/collaborative.html

Motivation

- *"Benchmarks shape a field for better or worse; they are how we determine the value of change."*

  -- David Patterson, 1994

- Web applications benefit from systems research

- Systems research benefits from good benchmarks
  - SPECweb for static web content
  - TPC benchmarks for databases
  - RUBiS for multi-tier services

Benchmarks for Emerging Applications

- Benchmarks must evolve
  - Previous work: Static content benchmarks did capture dynamic content workloads

    [Amza-WWC-2002, Cecchet-Middleware-2003]

  - Open question: do dynamic content workloads capture web 2.0 workloads?

    [Nagpurkar-IISWC-2008, Lim-ISCA-2008]

- This study investigates an emerging web application
  - Do existing benchmarks capture its workload properties?
  - Are systems research solutions affected by this new workload?

Collaborative Web Applications

- Multi-tier web applications comprise a handful of scripts supplied by their developers

- Facebook, Google Docs, and SalesForce are different:

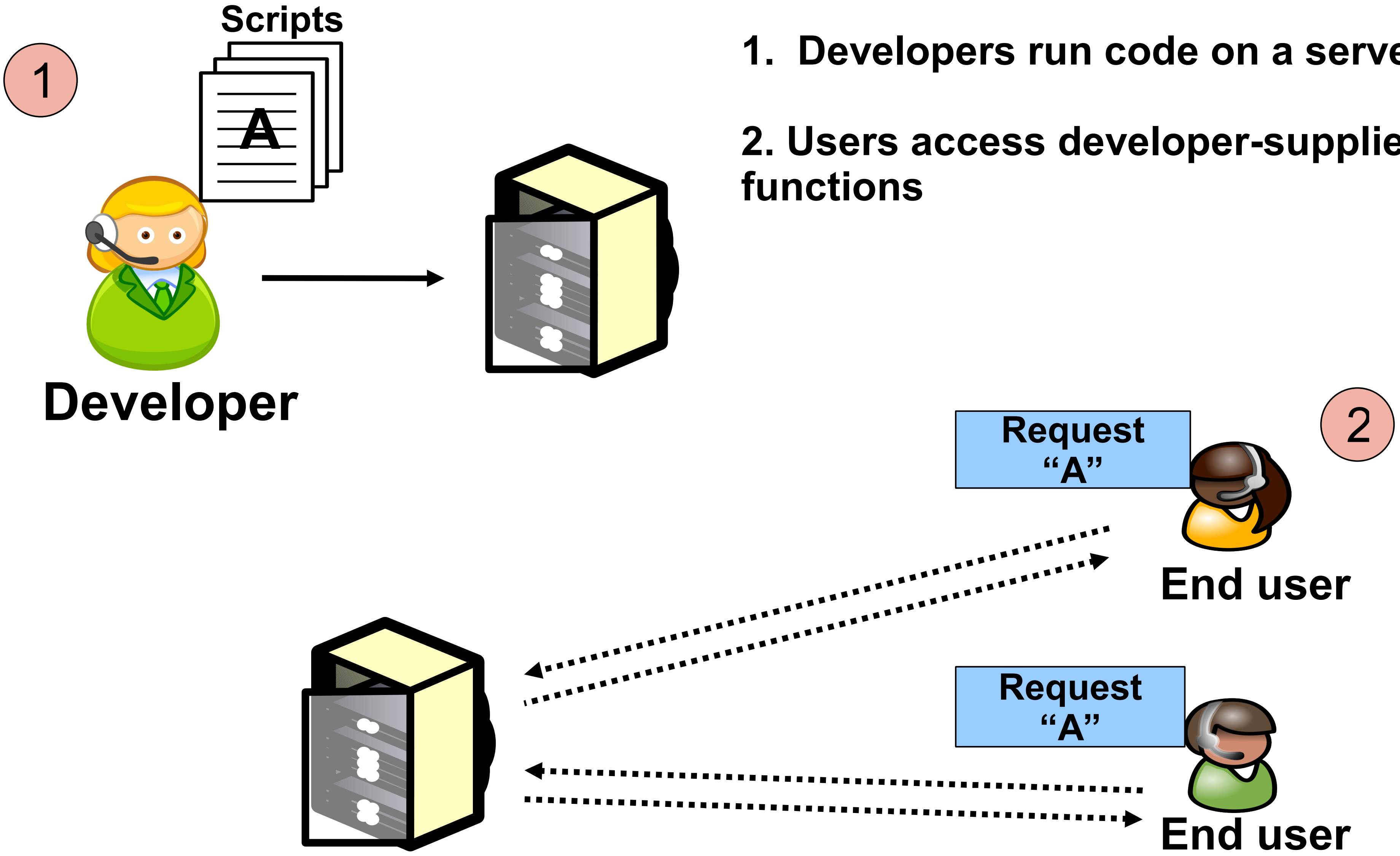
  They allow users to contribute content and scripts

- The term *collaborative web application* reflects joint development between application designers and users
  - Benefit from the creativity of a large user base
  - Synonymous terms: web platform, utility

Traditional Web Application

1. Developers run code on a server

2. Users access developer-supplied functions

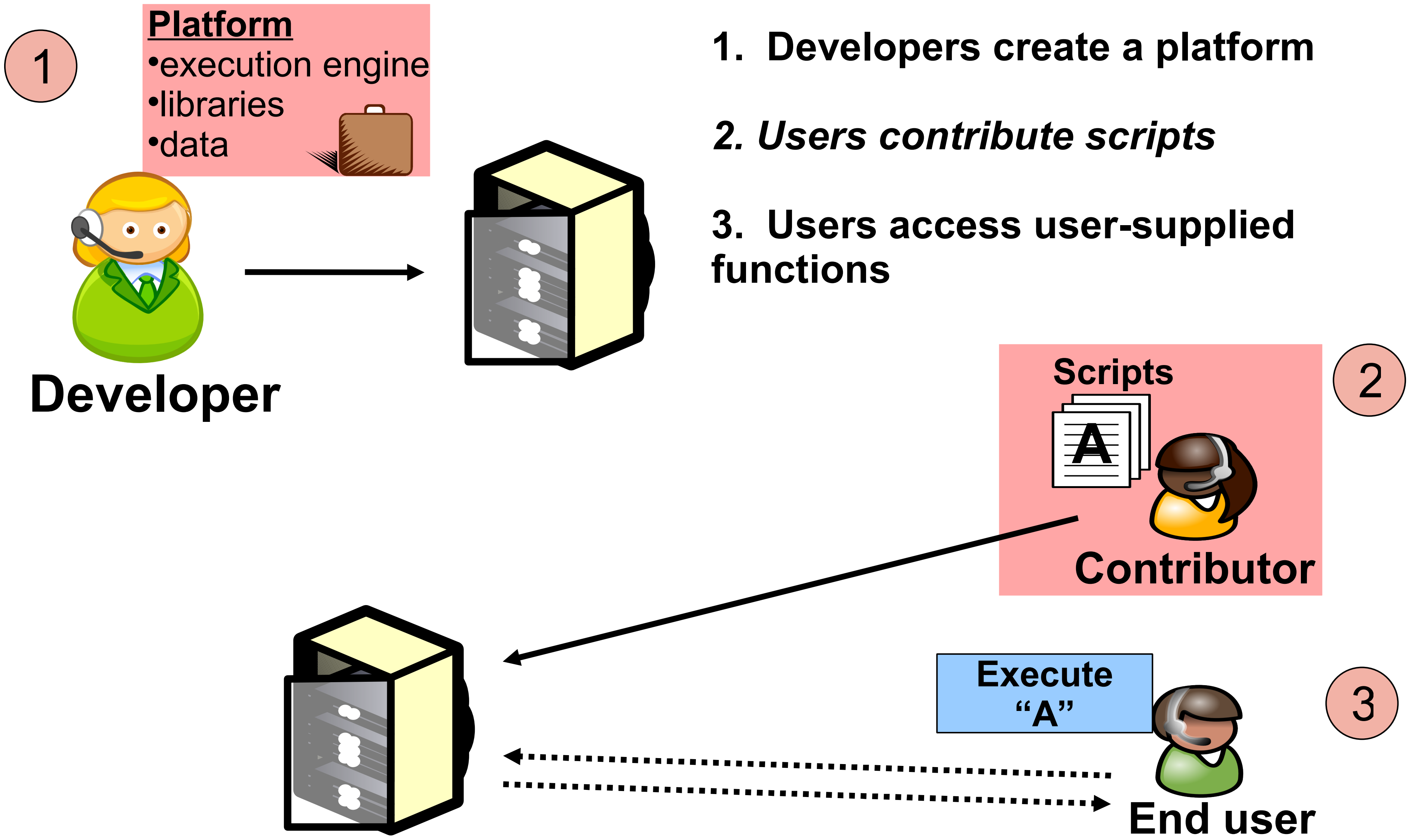


Collaborative Web Applications

1. **Developers create a platform**

*2. **Users contribute scripts***

3. **Users access user-supplied functions**



Evaluation of a Collaborative Web Application

- We deployed a real collaborative web application with a real dataset and real trace
  - *Do existing benchmarks represent collaborative web applications?*

    Compare with traditional benchmarks
  - *Are research solutions affected by this emerging application?*

    Reevaluate previous research with a collaborative web application

Study the characteristics of collaborative web applications

Public release of real application, dataset, and trace

Outline

1. Motivation

2. WeBWoRK: A Real Collaborative Web Application
   - Introduction and Design
   - Real Trace and Dataset
   - Similar Emerging Applications

3. Comparison with Existing Benchmarks
4. Reevaluation of Past Research
5. Conclusion

Introducing WeBWoRK

- WeBWoRK is a web-based homework checker
  - Developed at the University of Rochester
  - Services 50,000 students at 80 universities worldwide
  - **Teachers** contribute problems
  - **Students** access problems and check answers

- Design Goals
  - Support a broad range of problem sets
  - Reduce the burden of teachers in grading
  - Ensure each student does their own work

WeBWoRK Design

- A problem is encoded in script
  - Written in Problem Generation (PG) Language
    - a variant of PERL
  - WeBWoRK is a platform that executes teacher-supplied scripts
- PG Scripts include:
  - A function that displays the problem
  - A function that checks answers
  - Number randomization to prevent copying
    - Same core problem (e.g., algebraic equations), but each student receives a unique version

      Student A receives: $5x = 35$

      Student B receives: $4x = 24$

Real Dataset and Trace

- Real traces of end-user behavior are especially important in collaborative web applications
  - Trace collected over 3 years at the University of Rochester
  - Dataset of 3,000 teacher-supplied problems

- Redeployed on local machines in the CS department
  - 2GHz Intel XEON processor
  - 2GB memory
  - Linux 2.6.10 with request context tracking [ASPLOS-2008]
  - All benchmarks run on this platform

Outline

1. Motivation
2. WeBWoRK: A Real Collaborative Web Application
3. Comparison with Existing Benchmarks
   - Traditional benchmarks
   - Clustering and Regularity
   - Inter-property Correlations
4. Reevaluation of Past Research
5. Conclusion

Traditional Benchmarks

RUBiS

- Implements core functions of an auction website
- J2EE-based multi-component
- Realistic nonstationary workload [USENIX-2008]

TPC-C

- Terminal operators issuing order-entry transactions
- Database centric, several transaction types

SPECweb

- Included in the paper

Experimental Setup

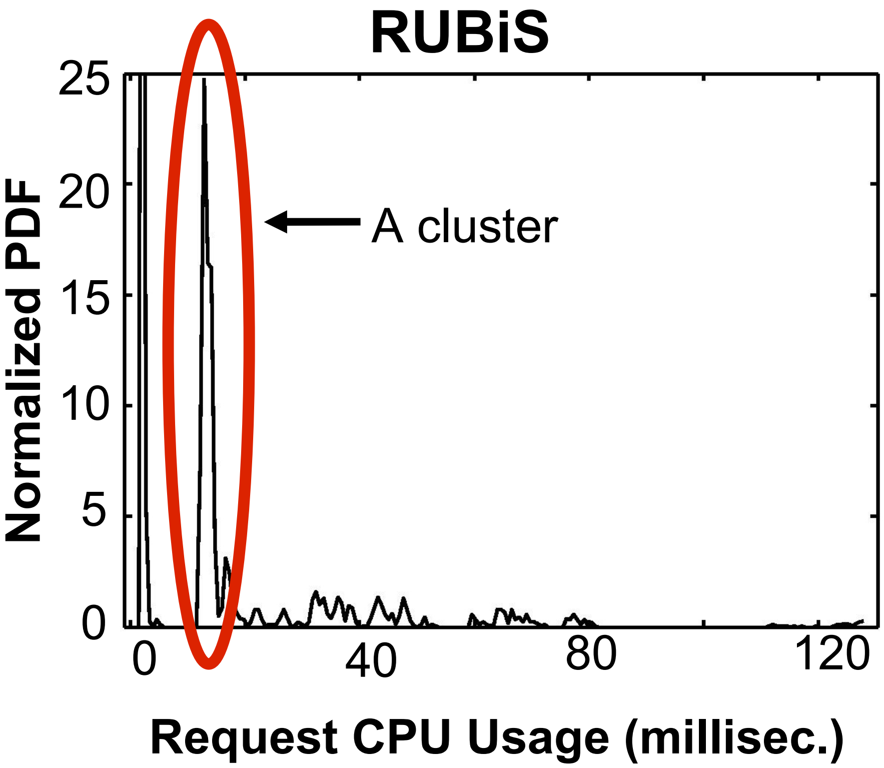
- We analyze request-level characteristics
  - A request is common unit of work
  - Request-level properties are important in research solutions

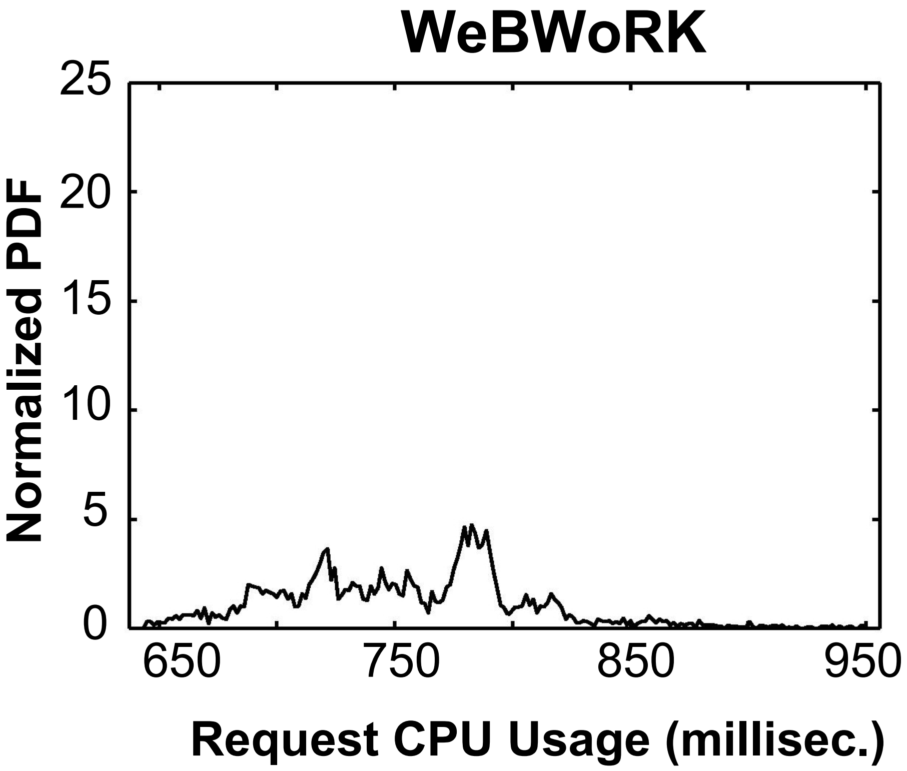
    [pai-asplos-1998][urgoankar-osdi-2002][barham-osdi-2004][elinkety-eurosys-2007][stewart-eurosys-2007][lim-isca-2008][soundararajan-usenix-2008][stewart-usenix-2008] and many others

- Patterns in the per-request CPU usage

- Correlations between CPU usage and system calls for each request

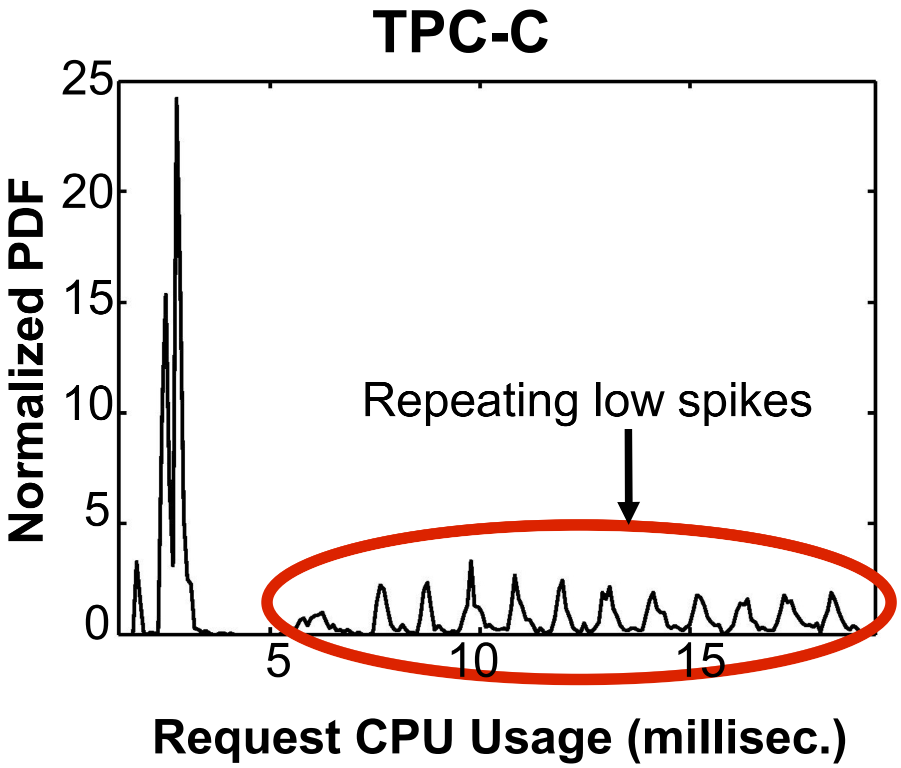
Resource Consumption Clusters

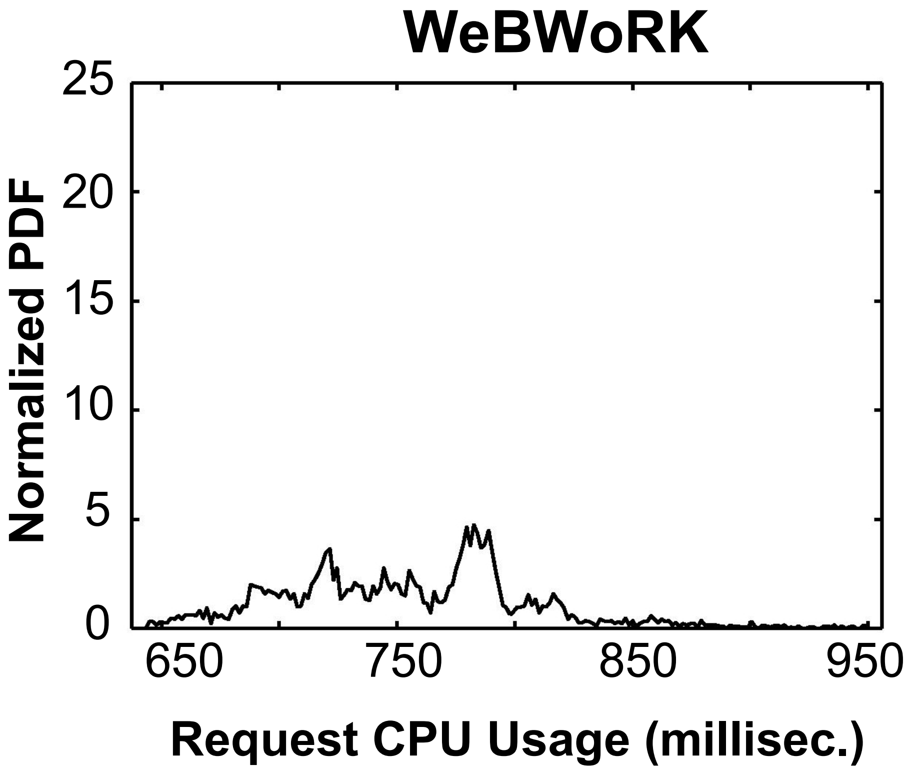




- In RUBiS, clusters with similar CPU usage are obvious
- In WeBWoRK, no clear cluster boundaries

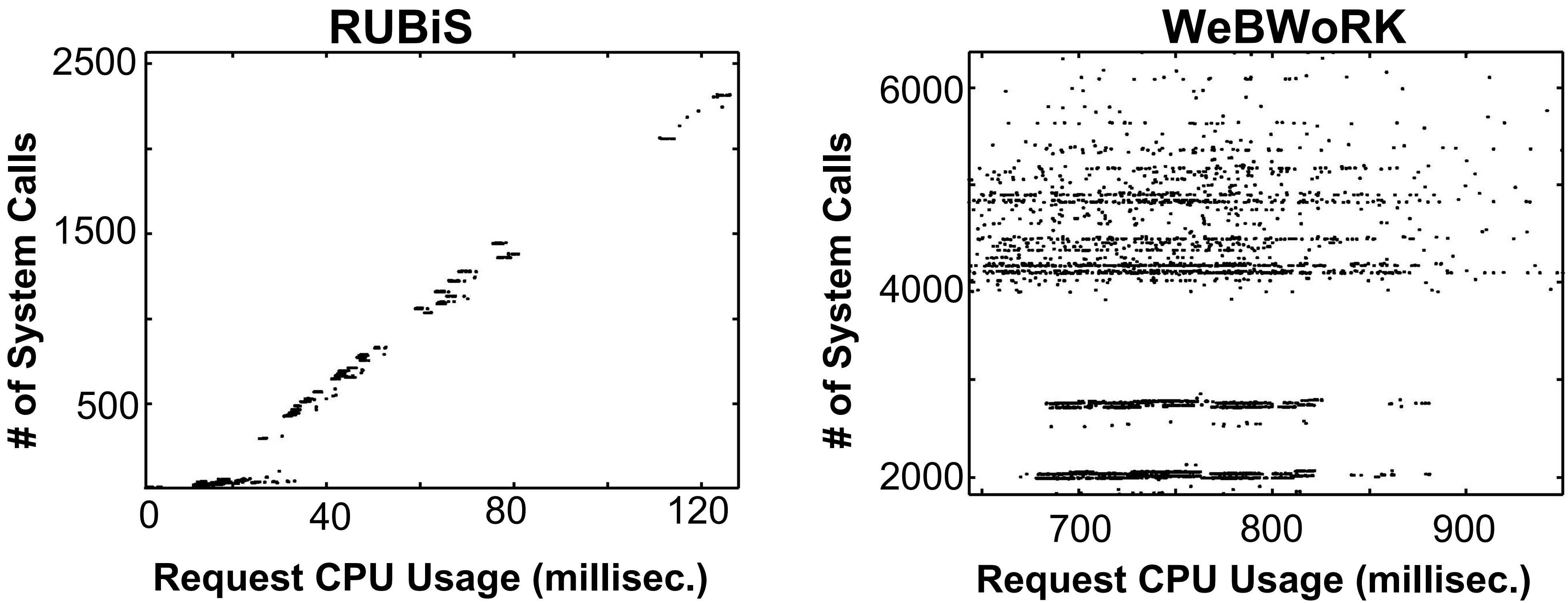
Regular Execution Patterns





- In TPC-C, we observe a regular pattern in the CPU usage
  - Caused by a request type that depends on a random integer
- In WeBWoRK, there is no clear pattern in the CPU usage

Inter-property Correlation



- In RUBiS, there is a strong correlation between system calls and CPU usage
- In WeBWoRK, there is no correlation at all

Summary of Comparison with Traditional Benchmarks

- Request-level characteristics in WeBWoRK are different
  - *Less clustered; more diverse CPU usage*
  - *Do not follow easily identifiable patterns*
  - *There is no correlation between properties*
- These results makes sense:
  - Resource consumption depends heavily on user contributions
  - Large number of independent users injects randomness
- *Do these results matter?*

Outline

1. Motivation
2. WeBWoRK: A Real Collaborative Web Application
3. Comparison with Existing Benchmarks
4. Reevaluation of Past Research
   - Magpie-style Request Classification [OSDI-2004, ASPLOS-2008]
   - Request Mix Performance Models [Eurosys-2007, USENIX-2008]
5. Conclusion

Request Mix Performance Models

[stewart-eurosys-2007, stewart-usenix-2008]

- *Motivation:* System management--- *i.e.*, server consolidation and platform selection--- affects the bottom line of almost every firm in every industry

- *Goal:* Build performance models that can guide management for production web applications

- *Insight:* Requests of the same "type" have similar resource requirements.

Performance models parameterized by the mix and volume of request types

Application to WeBWoRK

- Request mix model of CPU utilization

$$U = B_{\cdot} + \sum B_j \cdot N_j \longleftarrow$$

Intuition: Aggregate CPU usage is a linear combination of the average usage per type

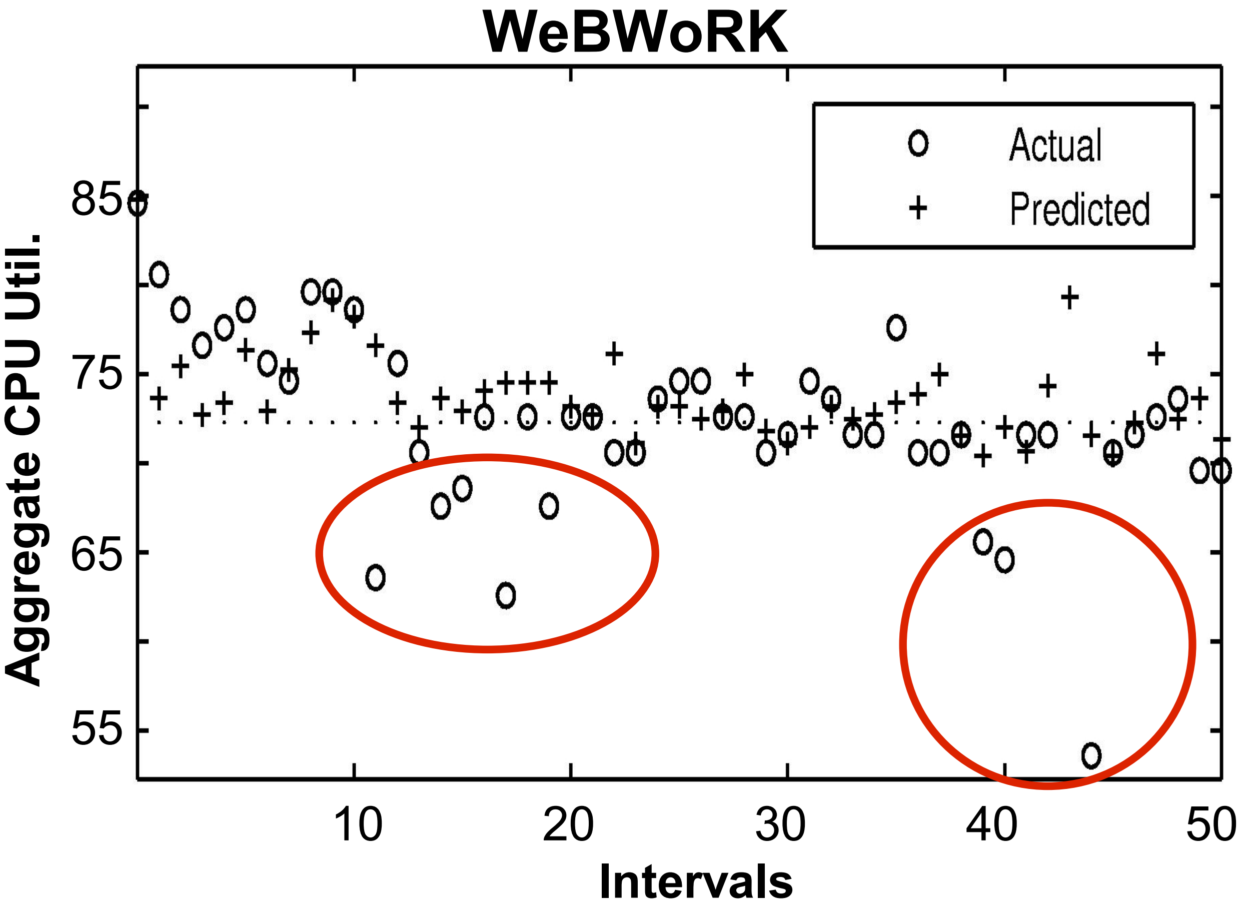
  - Relative frequency of request types varies (*i.e.*, the mix is nonstationary), which allows calibration from logs of request arrivals and CPU utilization

WeBWoRK comprises three request types

  - Submit problem, access problem, and submit solution
  - Calibrated with nonstationary 10-hour trace
  - Evaluated on the next 10-hours (prediction)

Results

- CPU utilization over time--- Each interval is 5 minutes
- Actual CPU utilization differs significantly from model based prediction
- Request mix models describe the variation in utilization for RUBiS--- not for WeBWoRK



	RUBiS	WeBWoRK
R^2	0.90	0.25

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5. Conclusion
   - Future Work
   - Take aways

Open Problems

- How do we deploy collaborative web applications?
  - Maximize overall performance
  - Differentiated services
- How do we deploy collaborative web applications on top of collaborative web applications?
  - Facebook on Amazon EC2?
- Challenges for system management
  - Performance modeling is more difficult
  - Dynamic control in constant flux
  - Integration with traditional applications--- fall back?

Take Away Points

- Collaborative web applications are not well represented by existing benchmarks
    - Request-level characteristics are more diverse and less regular

- Previous research should be revisited in the context of collaborative web applications

- Need for benchmark innovation
    - As a first cut, our WeBWoRK setup is available

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