Managing Web server performance with AutoTune agents

by Y. Diao, J.L. Hellerstein, S. Parekh, J.P. Bigus

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Seoul National University
Computer Science and Engineering
DCSLAB
Sophal HONG
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Introduction

• Managing the performance of e-commerce sites is challenging
  o Site content changes frequently
  o Dynamically varying workloads
  o Some applications of control theory to computing systems include
    ▪ flow and congestion control, differentiated caching and web service, multimedia
      streaming, web server performance, e-mail server control

• To maintain good performance
  o System administrators must tune their information technology environment
  o Manual effort can be time consuming and error-prone, and requires highly
    skilled, making it costly
Introduction

• All applications provide a degree of autonomic behavior by providing algorithms
  o to automatically control some aspect of a computing system’s operation

• In this paper…
  o proposing an agent-based solution
    ▪ Automates the ongoing system tuning
    ▪ Automatically designs an appropriate tuning mechanism for the target system
Apache Web server and performance tuning

• Apache v1.3.x of the server on UNIX is structured as
  o One master process: monitors the health of the worker processes and manages their creation and destruction.
  o A pool of worker processes: responsible for communicating with Web clients and generating responses.
    ▪ One worker process can handle at most one connection at a time.
    ▪ Worker processes cycle through three states: idle, waiting, busy
Apache Web server and performance tuning

• The application-level tuning parameters in Apache Web server
  o MaxClients: The number of simultaneous requests that will be served
  o KeepAlive: Whether or not to allow persistent connections

• Administrator must operate indirectly by adjusting tuning parameters
  o Increasing MaxClients: Increasing both CPU and Memory utilizations
  o Decreasing keepAlive: Allows worker process to be more active.
    ▪ Directly results in higher CPU utilization
    ▪ Indirectly increases memory utilization (more clients can connect).
Results of manually tuning the Apache Web server

Suppose the desired
CPU level = 0.5
Memory = 0.6

Y-axis: measured values
X-axis: time (second)

Result:
MaxClients: 400
KeepAlive: 10
Effects of Dynamics Workloads

- A change of Web site contents also affect the CPU and memory usage per request and
- also require different MaxClients and KeepAlive setting.

- Need AutoTune agents: to automate the adjustment of the MaxClients and KeepAlive values
- Both at system start-up and on an ongoing basis in response to changing workload
Server self-tuning with AutoTune Agents

Solution:
- Multiple agents
  - Automate the entire methodology of controller design
  - Perform the on-line system control
- These agents are implemented using the ABLE (Agent Building and Learning Environment)
  - Java**based toolkit
  - ABLE: provides a comprehensive library of intelligent reasoning and learning components
Architecture of the AutoTune agent

- Modeling and design: performed in a “testing” (or nonproduction) mode
- Run-time control: active when the system is “live” (Production mode)
Modeling Agent

• Modeling agent: A good design for the feedback controller relies on a mathematical model of the target system.
• Quantifying the relationship between the tuning parameters and performance metrics

• $2 \times 2$ matrices $A$ and $B$
• Include modeling parameters
• Can be identified using the least squares method

\[
\begin{bmatrix}
CPU_{k+1} \\
MEM_{k+1}
\end{bmatrix} = A \cdot \begin{bmatrix}
CPU_k \\
MEM_k
\end{bmatrix} + B \cdot \begin{bmatrix}
KeepAlive_k \\
MaxClients_k
\end{bmatrix}
\]
Controller Design Agent

- To design the parameters
- Choosing the controller parameters based on minimizing the following quadratic cost function:

\[
J(K_p, K_i) = \sum_{k=1}^{\infty} \left[ e_{CPU,k} e_{MEM,k} v_{CPU,k} v_{MEM,k} \right] \cdot Q \cdot \left[ e_{CPU,k} \\
 e_{MEM,k} \\
v_{CPU,k} \\
v_{MEM,k} \right] + \left[ \text{KeepAlive}_k \ \text{MaxClients}_k \right] \cdot R \cdot \left[ \text{KeepAlive}_k \\
 \text{MaxClients}_k \right]
\]

\[
u_{CPU,k} = \sum_{j=1}^{k-1} e_{CPU,j}
\]

\[
R = \text{diag}(r_1, r_2)
\]

\[
Q = \text{diag}(q_1, q_2, q_3, q_4)
\]

- Q and R perform some scaling functions in addition to determining a trade-off between control error and control variability
Run-time Control Agent

• Implements a state feedback controller
  o To make control decisions based on feedback of errors

\[
\begin{bmatrix}
\text{KeepAlive}_k \\
\text{MaxClients}_k
\end{bmatrix} = K_P \cdot \begin{bmatrix}
e_{\text{CPU},k} \\
e_{\text{MEM},k}
\end{bmatrix} + K_I \cdot \sum_{j=1}^{k-1} \begin{bmatrix}
e_{\text{CPU},j} \\
e_{\text{MEM},j}
\end{bmatrix}
\]

o $K_P$: Proportional control gain for fast response
o $K_I$: Integral control gain for removing steadying-state error
Experimental Environment

• Sever machine: Linux 2.2.16, Apache HTTP server v1.3.19
• One or more client machines:
  o Workload generator: WAGON (Web trAffic Generator and beNchmark)
  o File access distribution: Web Stone

• Dynamic workload
  o Web pages generated through CGI (Common Gateway Interface)
  o The session following a Poisson distribution
  o A rate of 10 sessions per second
Experimental Assessment

• Results of automatically tuning the Apache Web server
Experimental Assessment

- Performance of the AutoTune controller for the Apache Web server under dynamic workload
Conclusions

• Proposing an agent-based solution
  o Automating the ongoing system tuning
  o Automatically designing an appropriate tuning mechanism for the target system

• Experiments showing
  o The feedback-driven controller to be robust and adaptable to situations other than the one for which it was designed