Goal?

- To characterize a workload by building an abstract model of it out of statistical experimental data.

OR

- To produce some quantitative and qualitative relations and invariants that characterizes the behavior of a workload.
Who’s Interested in the Results?

- Computer System Designers
- OS Designers
- DBMS Designers
- Compiler Developers
- Application Developers
- Managers.
- etc.

Example: Online Transaction Processing (OLTP) Workload

- Example
  - day-to-day operation of commercial and financial institutions.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Implication for System Designers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant code and data locality</td>
<td>Benefits from large on-chip cache.</td>
</tr>
<tr>
<td>On a multiprocessor setup, there are lots of read/write sharing</td>
<td>CPUs with large number of cores are preferable. Large-scale SMPs are preferable. Not easy to have good speed up on clusters.</td>
</tr>
<tr>
<td>Huge database working set size.</td>
<td>Large disk I/O bandwidth is needed (both the I/O controller and the disk devices must be very fast).</td>
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Simple Techniques

- Averaging
- Identifying Correlations
- Histograms
- Breakdowns
- Identifying Time-Variant Behavior
- More ...

Averaging: Basic Terminology

- **Mean** \( \bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i \)
- **Standard deviation**: \( s^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2 \)
- **Coefficient Of Variation**: \( s / \bar{x} \)
- **Mode** (for categorical variables): Most frequent value
- **Median**: 50-percentile
Example: IPC of Bioinf. Applications

![Graph showing IPC and μPC for various applications.]

Figure 2. IPC and μPC

Figure from: Y. Li et al, *Workload Characterization of Bioinformatics Applications*, appeared in MASCOTS’05

Identifying Correlations

- Showing how the value of a metric changes as a result of varying a workload parameter.

- Vary only a workload parameter not a system parameter
  - Example of workload parameter:
    - # of simultaneous Web requests, input data type and size, etc.
  - Example of system parameter:
    - # of processors, size of the cache, network bandwidth
Example: Multithreaded Java Servers

Figure from: Y. Luo et al., *Workload Characterization of Multithreaded Java Servers*, appeared in IISWC’05.

Histograms

- For a metric $P$
  - Divide the range of values into $K$ equal-sized buckets.
  - Count the frequency of elements in the system for each bucket.

- Useful only if the variance among the buckets is high.

- Usually captures the “important” cases.
Example: Reuse Distance

Figure from: Alexandra Federova et al., *Performance of Multithreaded Chip Multiprocessors And Implications For Operating System Design*, appeared in USENIX ’05.

Breakdown

- Quantifying all the sources for a workload metric.
- Used for guiding optimization effort to the most important factor.
Example: Instruction Breakdown

Figure from: Y. Li et al, *Workload Characterization of Bioinformatics Applications*, appeared in MASCOTS'05

Example: Cycle Breakdown

Figure from A. Ailamaki et al. *DBMSs On A Modern Processor: Where Does Time Go?*, appeared in VLDB'99.
Identifying Time-Variant Behavior

- Workloads often have time-variant behavior.

- Taking only average behavior may miss important performance-related characteristics
  - Examples: Peak Load, or Idle Periods

Example: WWW Traffic

*Figure 1. TCP bandwidth: total TCP bandwidth consumed by HTTP transfers for different content delivery systems. Each band is cumulative; this means that at noon on the first Wednesday, Akamai consumed approximately 10 Mbps, WWW consumed approximately 100 Mbps, P2P consumed approximately 200 Mbps, and non-HTTP TCP consumed approximately 300 Mbps, for a total of 610 Mbps.*

*Figure is from: S. Sariou et al., An Analysis of Internet Content Delivery Systems, appeared in OSDI’02.*
Example: Program Phases

Fast Fourier Transform (FFT)

More Advanced Techniques

- Clustering
- Principal Component Analysis (PCA)
- Markov Chains
Workload Characterization Criteria

- **Completeness**
  - No important aspect of the performance should be overlooked
    - Example: measuring only the average load without considering the peak load.

- **Platform Independence**
  - Look at the metrics that are inherent to the workload and therefore, measured consistently across different platforms and implementations.

- **Input Data Independence**
  - Identified characteristics must consistently appear across a wide range of input data.

- **Coverage**
  - Identified characteristics should be applicable to a class of programs or usage scenarios rather than only to a specific program or usage scenario.