A Utility-Centered Approach to Designing Dependable Internet Services

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Motivation

- Tradable properties ("ilities") in system design: functionality, usability, maintainability, performance, portability, security, availability, development cost, …
- Examples of multiway tradeoffs:
  - Inktomi: data quality ↔ performance+availability+cost
  - Akamai: security+manageability ↔ performance+availability+cost
  - Yahoo: cost+portability ↔ performance+functionality
- Key observation: tradeoffs improve service by providing a better match between service properties and app requirements
- Small systems: right mix is a matter of optimization
  Giant scale: indispensable to the very possibility of building sys

Issues

- Making the right tradeoffs is mostly ***art***
- 75% of system deployments fail or don't meet requirements (Yankee Group, 1998)
- Deployment costs exceed expectations (Forrester Research: 25% of Fortune 1000 reported 10-49% higher costs)
- To make it ***engineering***, we need three things:
  1. A straightforward model for the design space
  2. Simple, but comprehensive vocabulary for describing properties and the outcome of making tradeoffs
  3. Step-by-step process for trading properties among each other to maximize usefulness of system

Proposed Process

1. Identify set of relevant axes that span design space in req spec
   ("spanning set" → any interesting tradeoff can be expressed in terms of the axes)
2. State system utility functions w.r.t. each axis
3. Identify major design areas;
   choose representative design for each; then
   - find their coordinates in design space
   - compute overall utility by combining individual utilities
4. Choose design area that maximizes utility; repeat w/in scope of chosen area

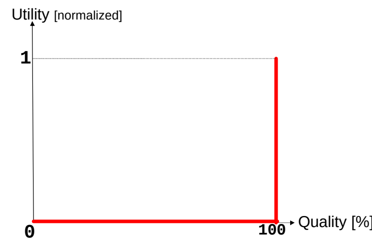
→ iterative process, with successive refining

Bank of America (`http://www.bofa.com`)

- System model: service takes inputs and must return outputs within specified amount of time
- Spanning set for design space:
  - **Q**uality of data: consistency with real account
  - **A**vailability: % of requests that are completed as required
  - **P**erformance: Throughput and latency for reads/writes
  - **S**ecurity: ITSEC levels
  - **C**ost of ownership: $ amount/year (including initial cost, amortized over expected lifetime of system)

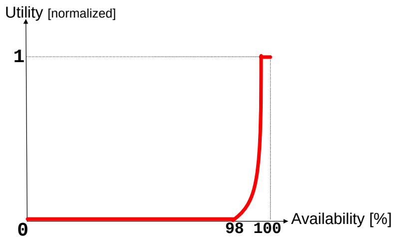
`bofa.com` : Quality of Data (Fidelity)

- Utility = how useful is a given level of quality

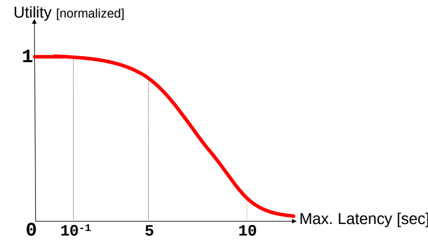


bofa.com : Availability

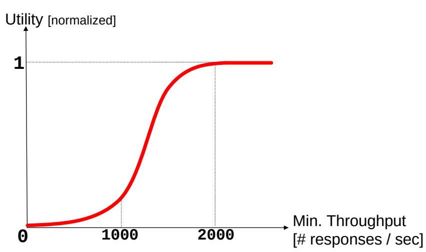
- Can choose salient points, then interpolate



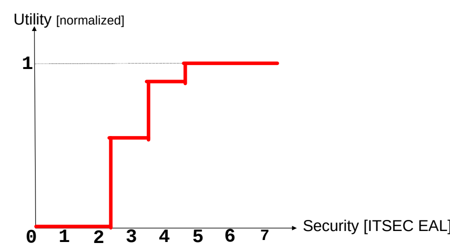
bofa.com : Performance/Latency



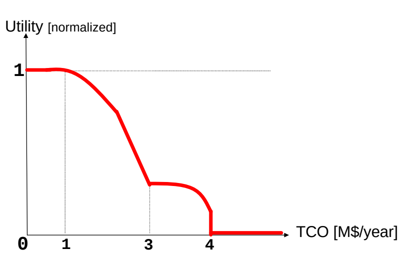
bofa.com : Performance/Throughput



bofa.com : Security



bofa.com : Cost



Proposed Process Overview

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Design Space Navigation: Phase 1

- Region #1: distributed DB, geographically distributed app servers, distributed web servers, caches everywhere
- Region #2: centralized DB, app server, web servers; no web caches

Type	Quality	Availability	Performance *Latency*	Performance *Throughput*	Security	Total Cost of Ownership	Overall *multiply*
#1	1.0	0.9 - 1.0	0.9 - 1.0	0.9 – 1.0	0	0.5-0.7	0
#2	1.0	0.2 - 0.4	0.8 - 0.9	0.6 - 0.8	0 - 1.0	0.7-0.9	0 - 0.26

→ choose Area #2

Design Space Navigation: Phase 2

- Design #1 (w/in Region #1): Sun Solaris 8, Oracle 8i, BEA WebLogic 7.0, Netscape-Enterprise 3.6
- Design #2 (w/in Region #2): RedHat Linux 7.2, proprietary DBMS, proprietary app server, Apache 2.0

Type	Quality	Availability	Performance *Latency*	Performance *Throughput*	Security	Total Cost of Ownership	Overall
#1	1.0	0.2 – 0.4	0.8	0.8	0.5 – 1.0	0.7 - 0.8	0.05 – 0.21
#2	1.0	0.3 - 0.4	0.9	0.8	0 – 0.5	0.8 - 0.9	0 – 0.13

→ choose #1 (much further refinement possible, config, etc.)

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→ iterate until confidence band gets sufficiently narrow

Alternate View

- Design space = multidimensional hyperspace spanned by the axes described earlier and utility as an extra axis
- Candidate designs = "discrete manifold" in this space
- process of making tradeoffs is analogous to navigating this manifold
- Search for a global max with no cliffs around it (i.e., a smooth plateau) to ensure robustness
- Can break design up into orthogonal subsystems that only concern themselves with subspaces (thus, only some of the axes) → makes it easier to design and develop

Benefits: Art vs. Engineering

- Make requirements and tradeoffs more explicit (thus, easier to evaluate <u>and</u> to change later)
- Closer match between requirements and delivered system
- <u>Use for dynamic adaptation</u> (blur design points into regions; at design time you choose region, at runtime you navigate w/in region to choose point)

Difficulties

- Stating utility functions can be a major effort
- Some properties are hard to quantify (<u>note</u>: we only need to to compare them, not measure on some absolute scale)
- Utility-centered design process may require hierarchical decomposition of axes (typically application-specific) → hierarchical utility composition
- Utility units must be uniform across all axes, to enable comparison
- The comparison must include the ability to say "how much better" one point is than another
- Unlike engineering, where you have struts, bolts, panels, etc. we are far from having standardized components in software engineering

More...

http://RR.stanford.edu