Automating Service Quality with TOMCAD

Raihan Al-Ekram, University of Waterloo
Richard C. Holt, University of Waterloo
Chris Hobbs, Nortel Networks
Susan Elliott Sim, University of California, Irvine

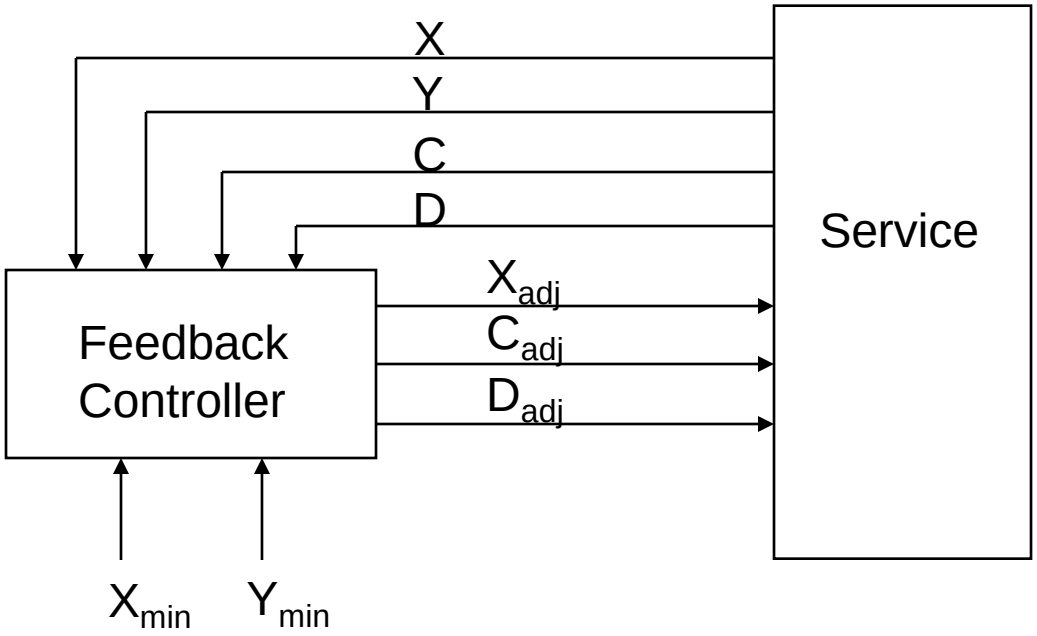
Workshop on Automating Service Quality
November 6, 2007

Raihan Al-Ekram

Contributions

- **T**rade**O**ff **M**odel with **C**apacity **A**nd **D**emand
- Modeling tradeoff: properties and constraints
- Tradeoff between any two qualities of a service is actually a 4-way tradeoff
- Tradeoff to Automate QoS

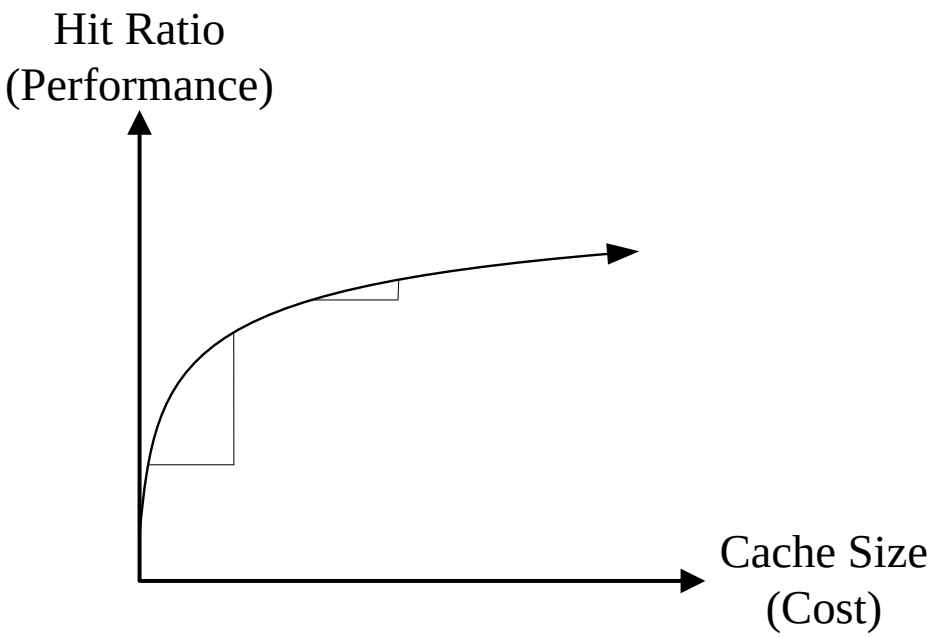
Automating Service Quality



Tradeoffs in Services

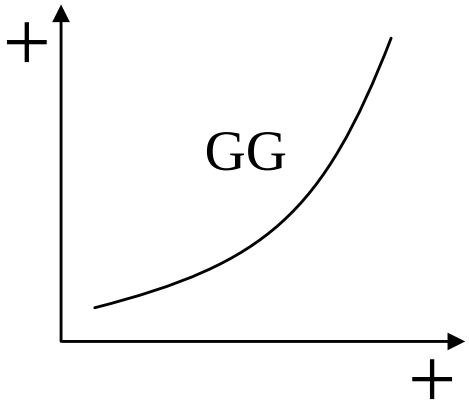
- Definition
  - Compromise between different qualities
  - Sacrifice some of one and get more of another
- Desired Service Qualities
  - Performance, Reliability, Availability, Scalability, Consistency, Security etc.
  - Not possible to maximize all of them
- Examples
  - Lazy Replication: Availability vs. Consistency
  - Web Caching: Performance vs. Consistency
  - RPC: Security vs. Performance

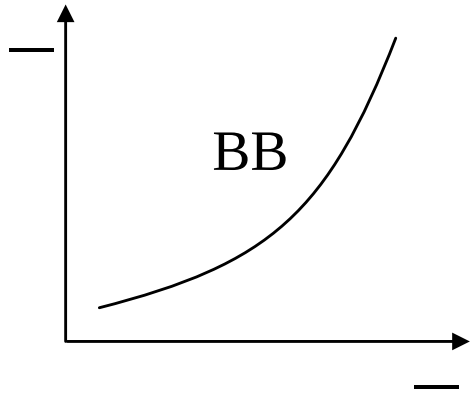
Tradeoff Example

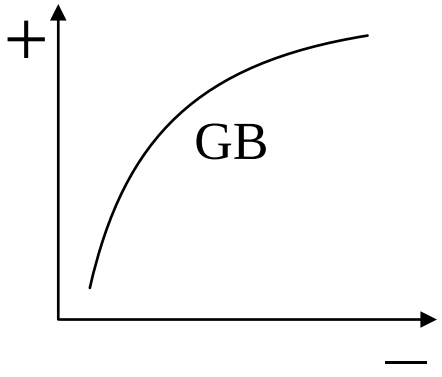


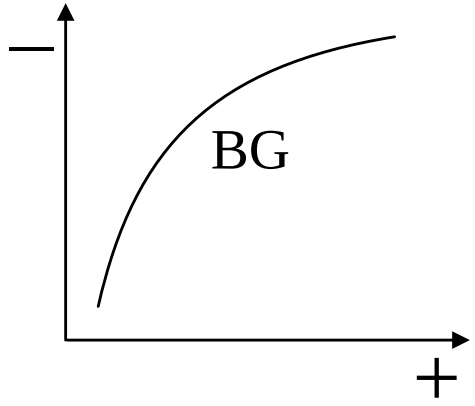
Tradeoff in Memory Caching

Tradeoff Property: Morality

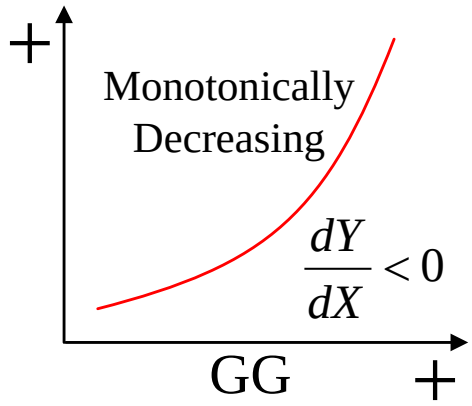


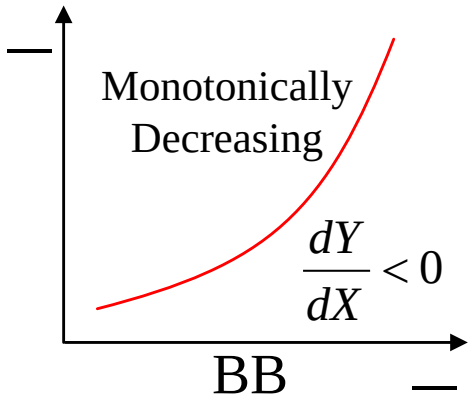


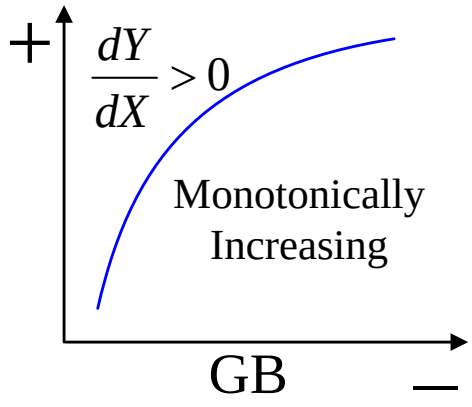


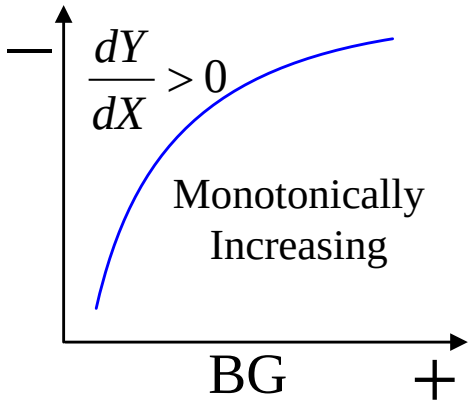


Tradeoff Property: Monotonicity









Tradeoff Constraint

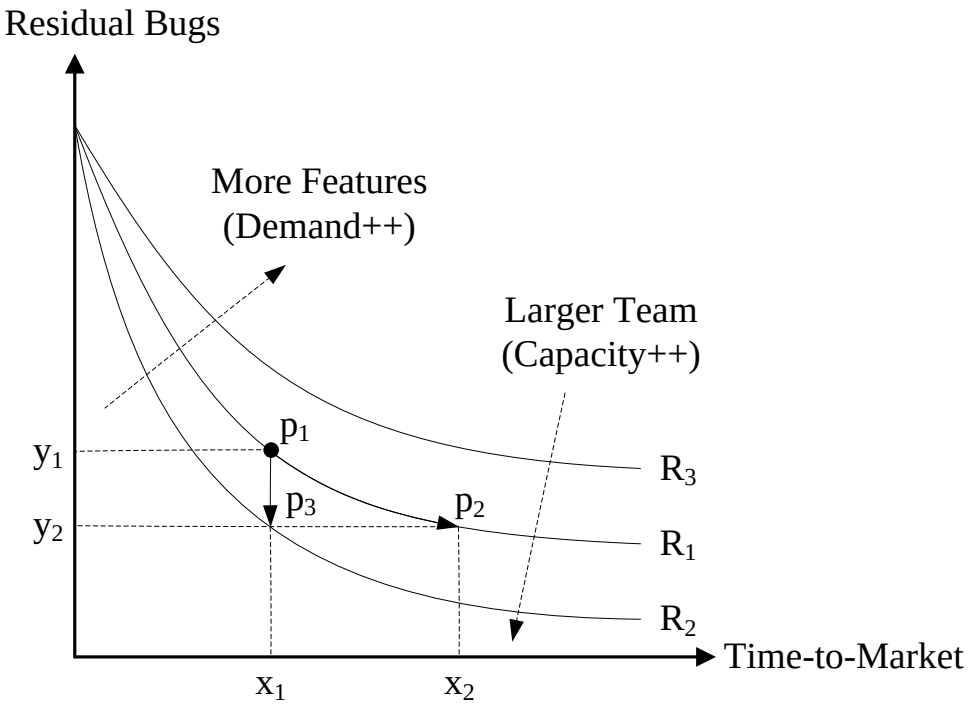
- GG, BB → Monotonically Decreasing

$$Y = f(X) \quad and \quad \frac{dY}{dX} < 0$$

- GB, BG → Monotonically Increasing

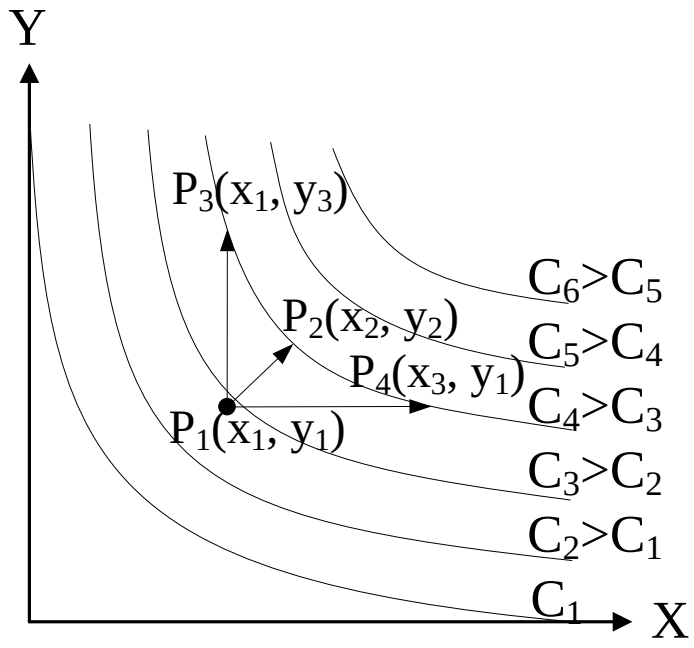
$$Y = f(X) \quad and \quad \frac{dY}{dX} > 0$$

Family of Curves



Tradeoff in Software Testing

Tradeoff and Capacity



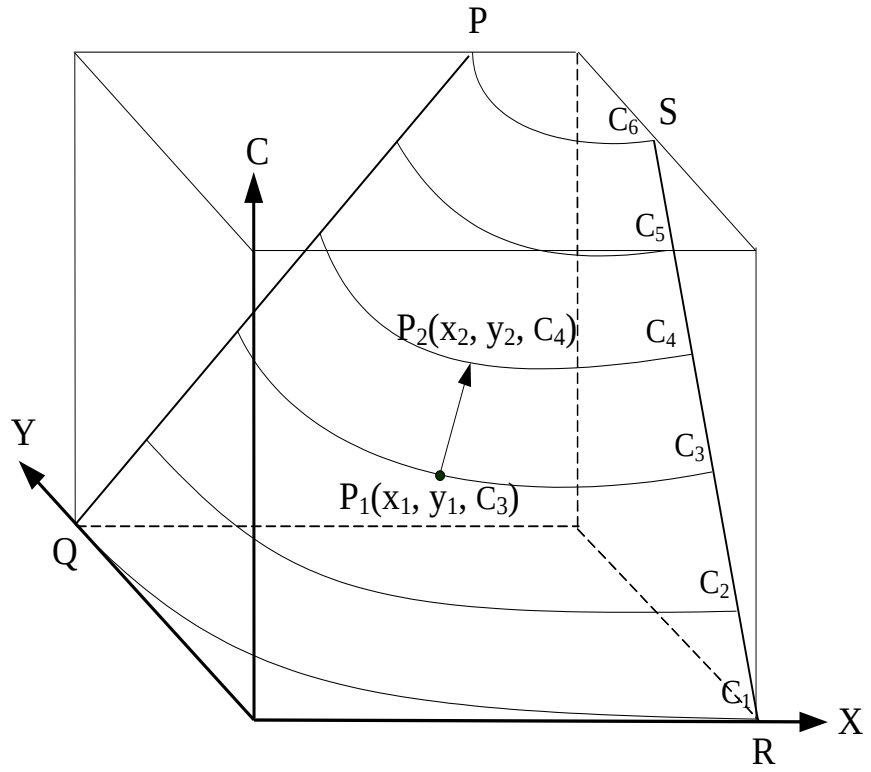
For any two GG properties X, Y and Capacity C

$$C = f(X, Y)$$

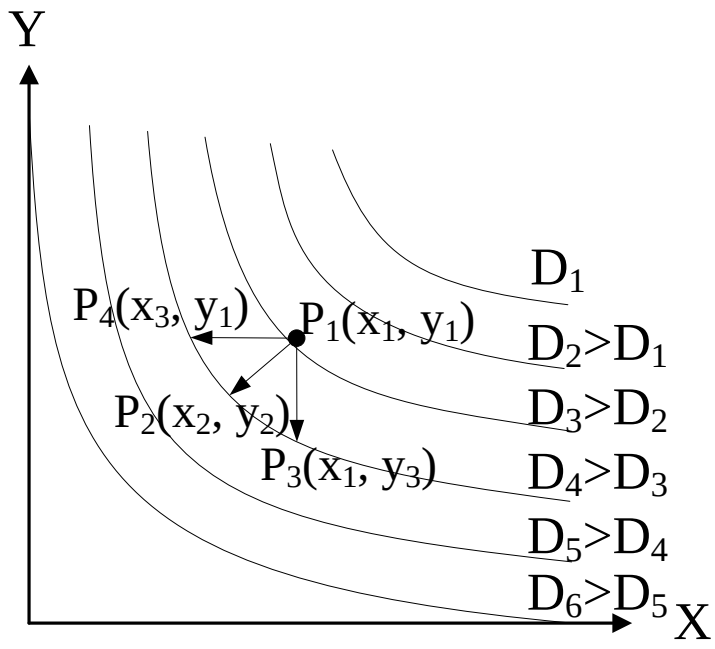
$$\frac{\partial X}{\partial C} > 0 \; and \; \frac{\partial Y}{\partial C} > 0$$

- Capacity ➔ Cost ➔ Bad
- CX/CY ➔ BG, Monotonically Increasing
- ➔ Tradeoff

Tradeoff and Capacity



Tradeoff and Demand



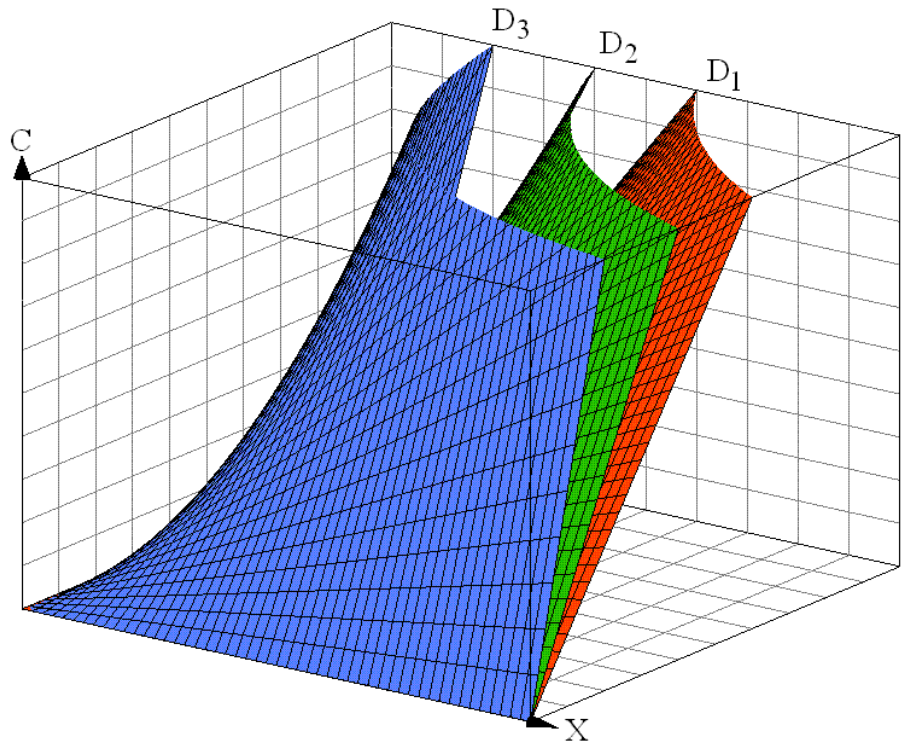
For any two GG properties X, Y and Demand D

$$D = f(X, Y)$$

$$\frac{\partial X}{\partial D} < 0 \; and \; \frac{\partial Y}{\partial D} < 0$$

- Demand ➔ Revenue ➔ Good
- DX/DY ➔ GG, Monotonically Decreasing
- ➔ Tradeoff

4-Way Tradeoff



$$f\ (X, Y, C, D) = 0 \quad where$$

$$\frac{\partial Y}{\partial X} < 0,\ \frac{\partial C}{\partial X} > 0,\ \frac{\partial C}{\partial Y} > 0,$$

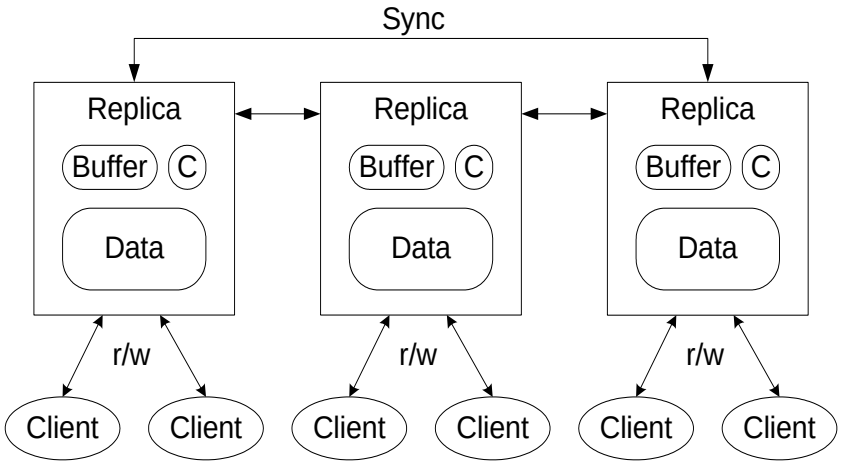
$$\frac{\partial D}{\partial X} < 0,\ \frac{\partial D}{\partial Y} < 0 \ \ and \ \ \frac{\partial C}{\partial D} > 0$$

Applying the Model

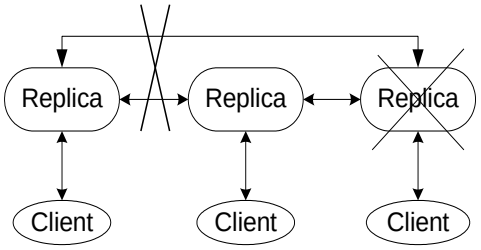
- Verify TOMCAD
- Analyze TACT Middleware

- **T**uneable **A**vailability and **C**onsistency **T**radeoff

Tradeoffs in TACT



- Replication Protocol
  - Client request
  - Update accumulation
  - Update propagation
  - Ordering
  - Conflict resolution



- Tradeoff: Consistency vs. Availability
  - Inconsistency ↑
  - Chances of repair ↑
  - Rejected operations ↓
  - Availability ↑

Tradeoffs in TACT

- Operating Model of TACT

$$\text{Capacity} = \frac{\text{Replicas . Demand . Consistency . Availability}}{\text{K (1–Consistency) + 1}}$$

$$C = \frac{NDXY}{K(1-X)+1}$$

Tradeoffs in TACT

- Consistency and Availability

$$\text{Capacity} = \frac{\text{Replicas} \cdot \text{Demand} \cdot \text{Consistency} \cdot \text{Availability}}{K\,(1-\text{Consistency}) + 1}$$

$$\frac{\partial Y}{\partial X} = -\frac{C(K+1)}{NDX^2} < 0$$

- GG
- Monotonically Decreasing
- ➔ Tradeoff

Tradeoffs in TACT

- Capacity and Consistency/Availability

$$\text{Capacity} = \frac{\text{Replicas} \cdot \text{Demand} \cdot \text{Consistency} \cdot \text{Availability}}{K\,(1 - \text{Consistency}) + 1}$$

$$\frac{\partial C}{\partial X} = \frac{NDY(K+1)}{[K(1-X)+1]^2} > 0$$

$$\frac{\partial C}{\partial Y} = \frac{NDX}{K(1-X)+1} > 0$$

- BG
- Monotonically Increasing
- ➔ Tradeoff

Tradeoffs in TACT

- Demand and Consistency/Availability

$$\text{Capacity} = \frac{\text{Replicas} \cdot \text{Demand} \cdot \text{Consistency} \cdot \text{Availability}}{K\,(1 - \text{Consistency}) + 1}$$

$$\frac{\partial D}{\partial X} = -\frac{C(K+1)}{NX^2Y} < 0$$

$$\frac{\partial D}{\partial Y} = -\frac{C[K(1-X)+1]}{NXY^2} < 0$$

- GG
- Monotonically Decreasing
- ➔ Tradeoff

Tradeoffs in TACT

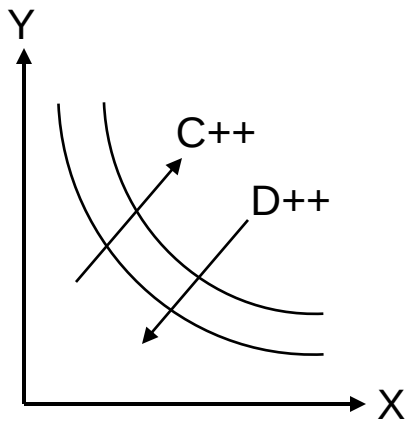
- Capacity and Demand

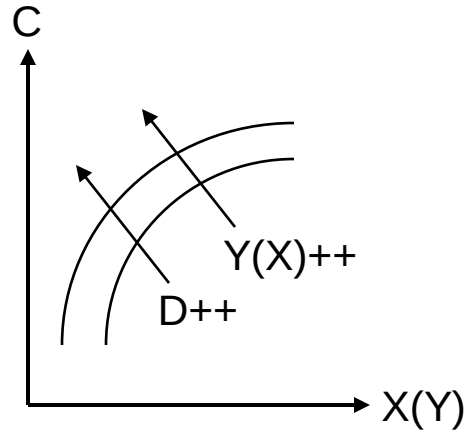
$$\text{Capacity} = \frac{\text{Replicas} \cdot \text{Demand} \cdot \text{Consistency} \cdot \text{Availability}}{K\,(1-\text{Consistency}) + 1}$$

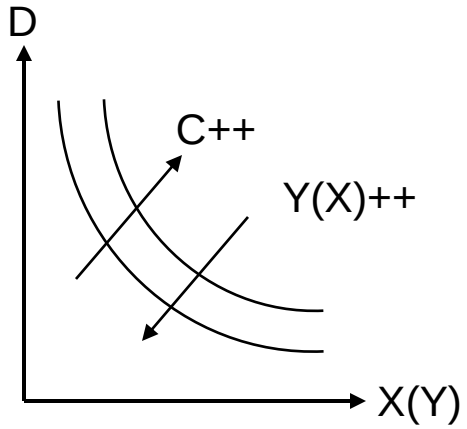
$$\frac{\partial C}{\partial D} = \frac{NXY}{K(1-X)+1} > 0$$

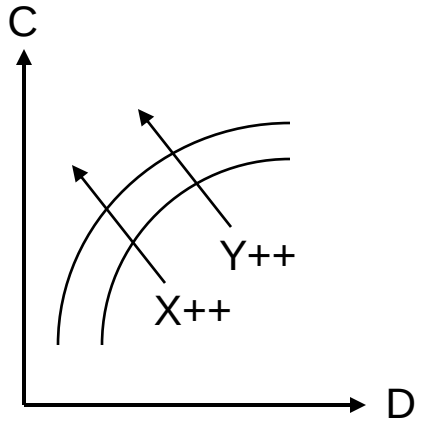
- BG
- Monotonically Increasing
- ➔ Tradeoff

Tradeoffs in TACT







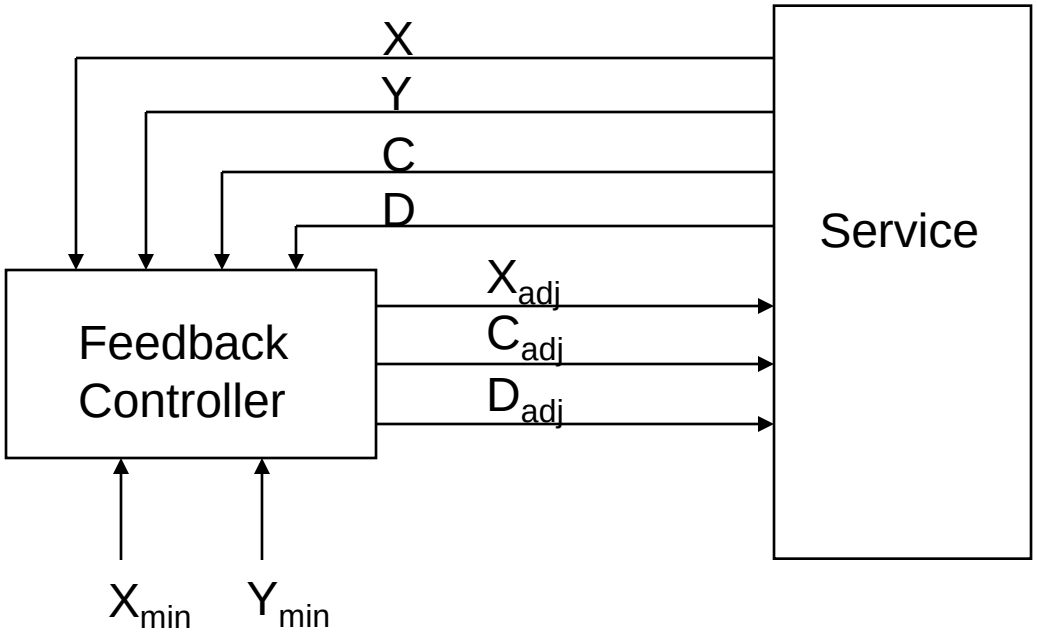


Automating Service Quality

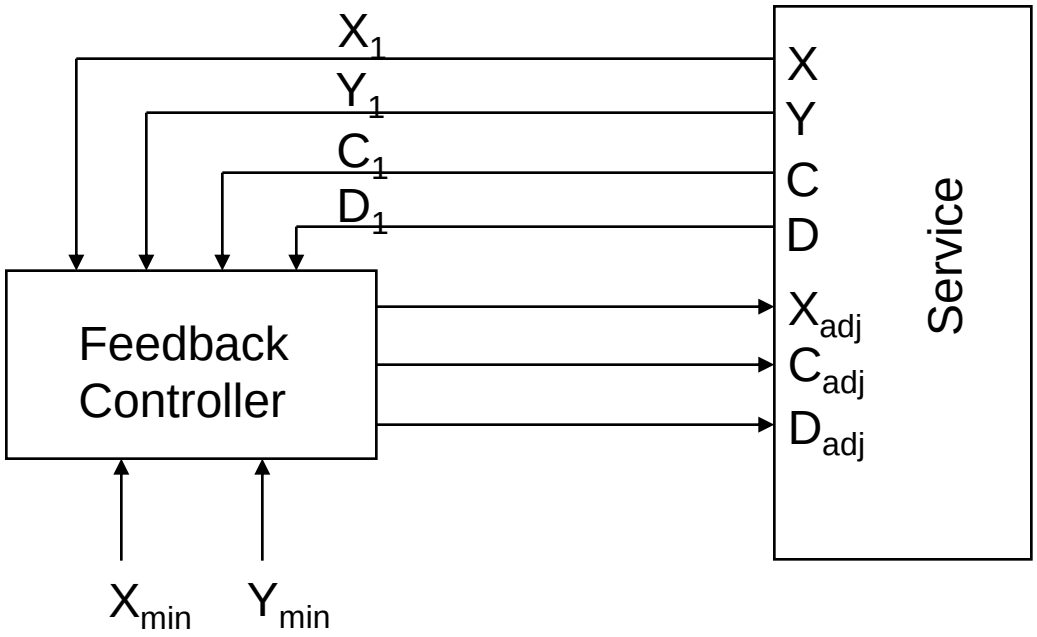
- System Parameters
  - Independent: Capacity C, Demand D, Consistency X
  - Dependent: Availability Y

- QoS Guarantee
  - Consistency X_{min} , Availability Y_{min}

Automating Service Quality



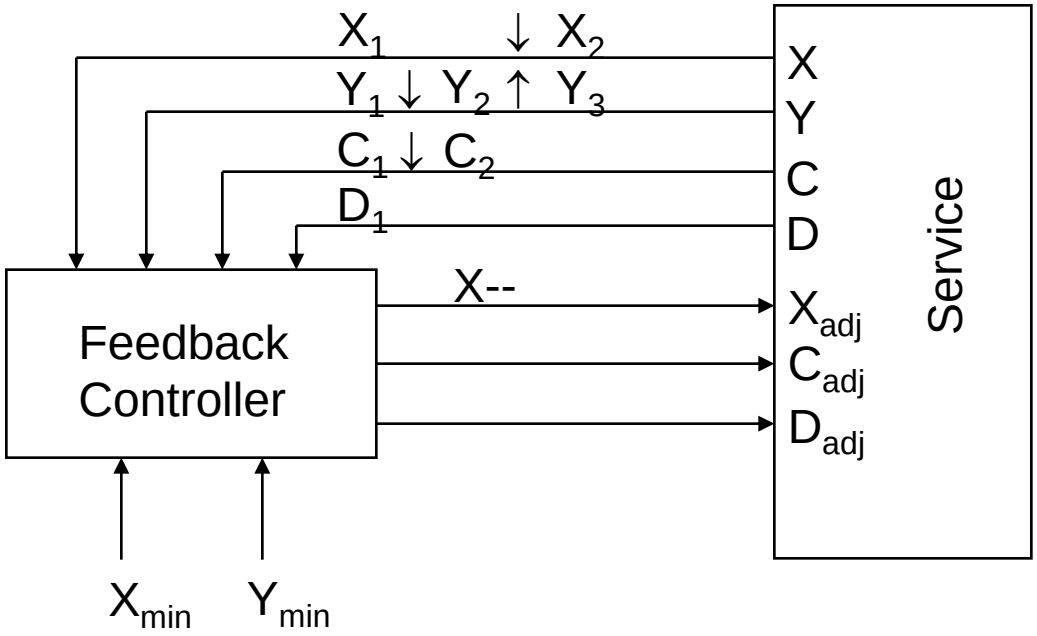
Automating Service Quality



Initial Values

- $X_1 > X_{min}$
- $Y_1 > Y_{min}$
- C_1, D_1

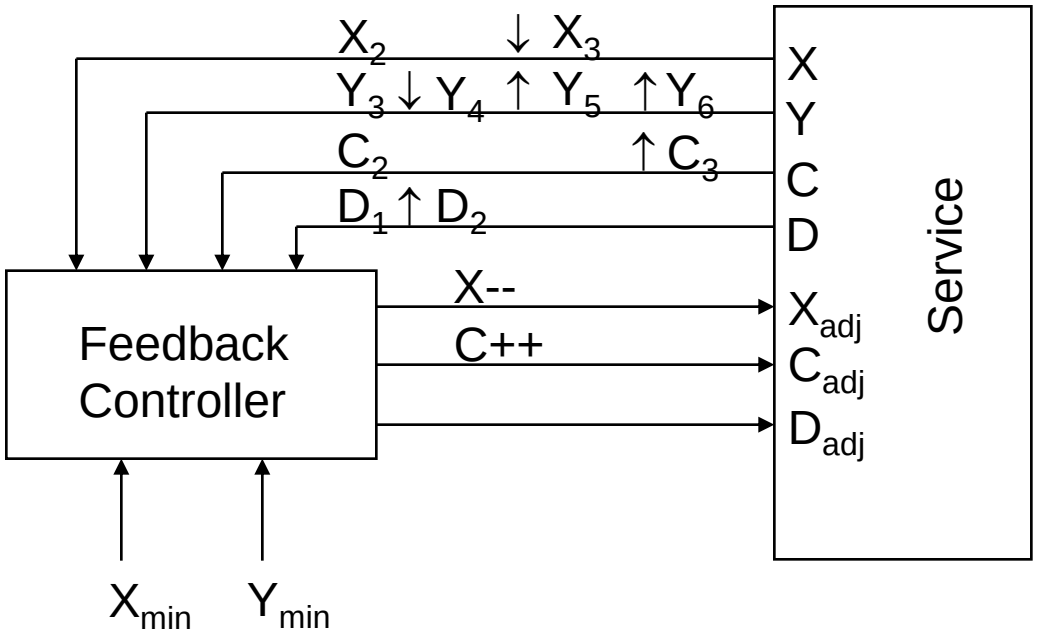
Automating Service Quality



A replica goes down

- Capacity ↓, $C_2 < C_1$
- CY Tradeoff
- Availability ↓, $Y_2 < Y_{min}$
- Send X-- in X_{adj}
- XY Tradeoff
- Consistency ↓, $X_2 > X_{min}$
- Availability ↑, $Y_3 = Y_{min}$

Automating Service Quality



Demand increases

- Demand ↑, $D_2 > D_1$
- DY Tradeoff
- Availability ↓, $Y_4 < Y_{min}$
- Send X-- in X_{adj}
- XY Tradeoff
- Consistency ↓, $X_3 = X_{min}$
- Availability ↑, $Y_5 < Y_{min}$
- Send C++ in C_{adj}
- CY Tradeoff
- Capacity ↑, $C_3 > C_2$
- Availability ↑, $Y_6 = Y_{min}$

Contributions

- **T**rade**O**ff **M**odel with **C**apacity **A**nd **D**emand
- Modeling tradeoff: properties and constraints
- Tradeoff between any two qualities of a service is actually a 4-way tradeoff
- Tradeoff to Automate QoS

Conclusion

- Modeling tradeoff: properties and constraints
- Tradeoff between any two qualities of a service is actually a 4-way tradeoff
- Tradeoff to Automate QoS