

Project: Disk as a load-dependent server

Theoretically, the disk seek time is proportional to the square root of the distance the I/O head travels from its current position to some destination position: $T_{seek} = T_{max} \sqrt{x / x_{max}}$. A more accurate seek time model is the following exponential model:

$$T(x) = \begin{cases} t + c(x-1)^r & , \quad 1 \leq x \leq x^* \\ \frac{cr(x-x^*)}{(x^*-1)^{1-r}} + t + c(x^*-1)^r & , \quad x \geq x^* \end{cases}$$

Quantum Atlas III parameters: xmax=8057 cyl,
C=9.1GB, N=7200 rpm, x*=1686, t=1.5455ms,
c=0.3197 ms, r=0.3868

All operating systems provide optimizing algorithms that minimize the movement of the I/O mechanism. The simplest such algorithm is the shortest seek time first (SSTF) where the I/O mechanism always serves the request that is closest to the current position of the I/O head. If we have only one request in the disk queue then there is no chance to optimize the movement of the mechanism and the mechanism moves in a way that makes the average distance equal to the 1/3 of the maximum distance. However, if the disk queue contains $n > 1$ service requests, then it is possible to optimize (i.e. to minimize movements of the I/O mechanism). The optimization algorithm is activated before each seek operation. This means that in the case of high load disk performance is better than in the case of low load. In other words, disk is a load-dependent server.

In this homework we want to study *the average seek time* for Quantum Atlas III as a function of the disk queue length. This is a strictly decreasing function $Sd(Q)$, where Q is the number of jobs in the disk queue. Write a simulator program for computing $Sd(Q)$ as follows:

1. Make an array dq of Q components that represents the disk queue.
2. Initialize dq with Q uniformly distributed random numbers that represent cylinders where the I/O head has to move.
3. Generate an initial position of the I/O mechanism as a random value X .
4. In each simulation step move the head to the closest position. After the head moves to the position $dq[k]$ the new position will be $X = dq[k]$, and the component $dq[k]$ has to be replaced by a new random value. Compute the seek distance and the seek time.
5. Compute the average seek distance and the average seek time for at least 10000 disk accesses.
6. Plot the average seek distance and the average seek time for $Q=1, 2, \dots, 20$.

Extra credit questions:

1. Compute analytically the average seek distance and the average seek time for $Q=2$.
2. Create a real queue where jobs arrive with random interarrival times. The queue length will be a variable value. Compute $Sd(Q)$ under these conditions that are more realistic than the conditions in the simplistic simulator.
3. $Sd(Q)$ is a decreasing function. Try to find some simple analytic approximation of this function that has some predictive power (polynomials are generally not suitable as predictive models, because outside of the measured range they behave in unacceptable way).
4. Compare this analysis for Quantum Atlas III with the theoretical case $T_{seek} = T_{max} \sqrt{x / x_{max}}$. Analyze and discuss the differences.