Data Structures and Algorithms

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Session: Running Time of Program: Empirical and Analytical Method

Running Time of Programs

- Consider algorithms for searching for an element e in a sequence S
- Running time is function of ?
  - Input Size
  - Position of e
- Empirically finding running time?

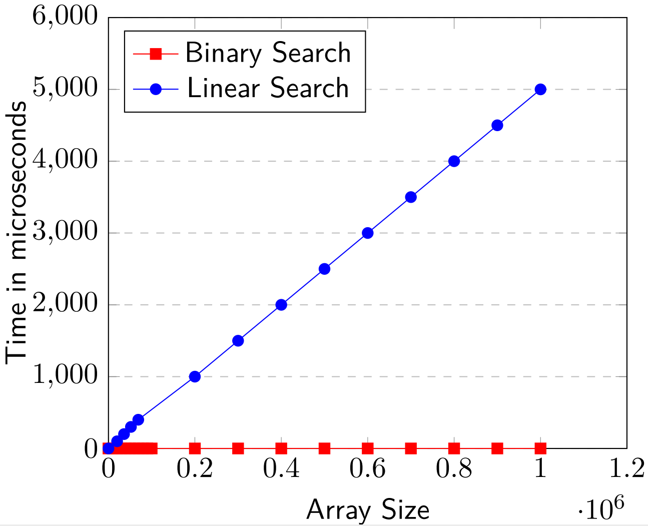
Running Time of Programs

- Consider algorithms for searching for an element e in a sequence S
- Running time is function of ?
  - Input Size
  - Position of e
- Empirically finding running time?
  - Run the program (with properly designed running time experiments) multiple times with a large number of different inputs (Sequence S, element e to search for)
  - Time each run and compute average times across runs

Empirical Analysis of Running Time

- No background processes
- Comparable data types (structures)
- Single threaded / no wasted steps
- To normalize w.r.t OS/Kernel related background processes
  - Average across multiple runs for each program
  - Use virtual machines with guaranteed resources

Results of Experiments (Execution time comparison)



Question

How will plot(s) of time vs position of element e being searched for look like (for fixed size of S) ?

Issues with Empirical Analysis

- Primary Issue: Reasoning about the outcome should precede the experimentation
- Too time consuming
- Affected by several hidden factors (the hardware, the compiler, etc.)
- Might ignore the essential behaviour of the algorithm while focusing on unnecessary details
- Analysis on paper provides the foundational understanding of a system

Caveat: Such analysis always requires a model of the system under study

Model for Algorithm Analysis

- Sequential instructions and Infinite memory
- All basic instructions take one unit of time - addition, subtraction, multiplication, division, bit operations, comparison, assignment, etc.
- The above assumptions hold equally well for integer and floating point data types
- Ignores disk read times, memory hierarchies, paging, context switching, etc.

Analysis of Linear Search Algorithm A: Successful Search

$Assignment : 1$

$Comparison : 1*(n+1)$

for($i = 0;$ $i < size;$ $i++$) { $Increment : 1$

$if(S[i] == num)$ {

$Array Access : 1$
$Comparison : 1$

found $=$ $true;$ $Assignment : 1$

$break;$ $Assignment : 1$

}

}

Search Algorithm A: Time for Successful Search

- Total time $T_s(n)$, when element is at index $n = 0...N-1$ (successful search)
- $1 + 2 * (n + 1) + 1 + 1 * n + 1 * (n + 1)$
- $T_s(n) = 4n + 5$

Analysis of Search Algorithm A: Unsuccessful Search

$Assignment : 1$

$Comparison : 1*(n+1)$

for($i = 0;$ $i < size;$ $i++$) { $Increment : 1$

$if(S[i] == num)$ {

$ArrayAccess \ : \ 1$
$Comparison \ : \ 1$
$*N$

found = $true;$
$break;$
}

}

Search Algorithm A: Time for Unsuccessful Search

- Total time for unsuccessful search
- $1 + 2 * N + 1 * N + 1 * (N + 1)$
- $T_u(N) = 4N + 2$

Question

How would you compute the average number of instructions executed by program A?

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Here averaging is across all possible values of the position of ‘num’ while holding the length of the list as a constant

Thank you