Simple Searching

Slides

Sequential Searching

Unsorted List

- Each element is compared to locate the desired element one after another starting at the head of the list.
- Worst Case Order = $\mathbf{O}(N)$
  - † desired element is at the end of the list.
- Average Case Order = $\mathbf{O}(N/2) \in \mathbf{O}(N)$
  - † one half of the list must be scanned on the average.
- Assumes that the probability of each element in the list being searched for is equal.

Sequential Searching on a Sorted list

- Search stops when element is located or a larger element (ascending order) is encountered.
- Worst case and average case orders are the same as the unordered list.

```
Simple Searching
        • Internal (primary memory) searching

External => File Search
        • (Indexes, BTrees, files, etc.)
```

Probability Ordering

Unequal Access Probabilities

- Implemented when a small subset of the list elements are accessed more frequently than other elements.

Static Probabilities

- When the contents of the list are static the most frequently accessed elements are stored at the beginning of the list.
- Assumes that access probabilities are also static

Dynamic Probabilities

- For nonstatic lists or lists with dynamic probability element accesses, a dynamic element ordering scheme is required:
- Sequential Swap Scheme
  - † Move each element accessed to the start of the list if it is not within some **threshold** units of the head of the list.
- Bubble Scheme
  - † Swap each element accessed with the preceding element to allow elements to "bubble" to the head of the list.
- Access Count Scheme
  - † Maintain a counter for each element that is incremented anytime an element is accessed.
  - † Maintain a sorted list ordered on the access counts.

Sequential Search Code

Normal Sequential Search Function

```
const int MISSING = -1;

int SeqSearch (const Item A[], Item K,
               int size) {
   int i;

   for ( i = 0 ; i < size; i++ ) {
     if ( K == A[i] )
        return ( i );
   }
   return (MISSING);
}
```

- Coded inline to avoid function call overhead:

```
inline int SeqSearch2 (const Item A[], Item K,
                         int size) {
  int i;
  for ( i = 0; ((i < size) && !( K == A[i])); i++ )
    ;
  return ( ( i < size ) ? ( i ) : ( MISSING ) );
}
```

- Problem: two comparisons in the loop are inefficient
- Search sequentially down to 0 using 0 as limit test.

```
const int MISSING = -1;

int SeqSearch3 (const Item A[], Item K, int size) {
  int i;

  for ( i = size -1; (!(K == A[i]) && (i)); i--);

  if ( K == A[i] )
    return ( i );
  else
    return (MISSING);
}
```

Sequential Search continued

Sentinel Method

- Store the desired element at the end of the array:

```
const int MISSING = -1;

int SeqSearch4 (Item  A[], Item  K, int size) {

  int i;

  A[size] = K;
  for ( i = 0; !(K == A[i]); i++ )
    ;

  if ( i < size )
    return ( i );
  else
    return ( MISSING);
}
```

- Requires storage at the end of the array to always be available.
- Ensures that the loop will terminate.
- Array parameter must be passed by reference to allow the sentinel insertion.

Binary Search

Algorithm

```
IF desired element = middle element of list THEN
  found
ELSE
  IF desired element < middle element
  THEN set list to lower half & repeat process
  ELSE set list to upper half & repeat process
```

Recursive Binary Search Function

```
const int MISSING = -1;

int BinarySearch ( const Item A[], Item K, int L, int R) {

  int Midpoint = (L+R) / 2 ;   //compute midpoint

  if  ( L > R )      // If search interval is empty return -1
    return MISSING ;
  else if ( K == A[Midpoint] ) //successful search
    return Midpoint;
  else if ( A[Midpoint] < K  )  //search upper half
    return BinarySearch(A, K, Midpoint + 1, R);
  else                         //search lower half
    return BinarySearch(A, K, L, Midpoint - 1);
}
```

- Worst Case Order = **O**($\log_2 N$)
- Note: for small lists a sequential search will usually be faster due to the midpoint computation and comparsions.

Subtle Algorithm Adjustments

- Minor changes to highly efficient algorithms (e.g., binary search) can have a drastic negative effect on execution.
- Changing the indexes to longints can increase execution time by a factor of 3.
- Using real division and truncating for the midpoint computation may slow execution by more than 10 times.

Interpolation Search

Variation of Binary Searching

- Attempts to more accurately predict where the item may fall within the list. Similar to looking up telephone numbers
- Standard Binary Search Midpoint Computation:

```
Midpoint = (L+R) / 2;
```

- General Binary Search Midpoint Computation:

```
Midpoint = L + 1/2 * ( R - L);
```

- Interpolation replaces the 1/2 (in the above formula) with an estimate of where the desired element is located in the range, based on the available values (be careful of int arithmetic):

```
Interp = L +                // base loc +
         ((K - A[L]) /      // % of distance K is from
          (A[R] - A[L])) * // A[L] to A[R] *
         (R - L);           // length of search space
```

- Example:
- Assume 30K recs of SSNs in the range from 0 ... 600 00 0000
- Searching for 222 22 2222 yields an initial estimate of:

```
Interpolation = 0 + ((222222222 - 0) /
                     (600000000 - 0)) *
                     (30000 - 0);
              = 11111
```

- Worst Case Order approximately $= \mathbf{O}(\log \log N)$
- Can be assumed to be a constant of about 5 since ≅ (lg lg 10^9)
- Assumes the search values are evenly distributed over the search range, (! True for SSNs)
- Inefficient for searching small number of elements