

Lecture 4

Search Techniques and STL

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Abstract. This lecture is a part of competitive programming training lectures prepared for Eastern University, Dhaka. This lecture introduces useful search techniques like Binary Search, Ternary Search and Exponential Search. This lecture also describes the basic of STL (Standard Template Library).

1 Binary Search

1. Given a function f and an value p .

Condition: $f(x - 1) \leq f(x) \leq f(x + 1)$

* **Problem :** find minimum integer x such that $f(x) \geq p$

```
int BS(int x, int n){
    // Be careful about the limits of lo and hi
    int lo = 0;
    int hi = n - 1;

    while(hi - lo > 1){
        int mid = (lo + hi) / 2;
        if(f(mid) >= x) hi = mid;
        else lo = mid;
    }

    // Only 2 candidates lo and lo + 1 (= hi) to compare
    if(a[lo] >= x) return lo;
    else return hi;
}
```

* **Problem :** find minimum integer x such that $f(x) > p$

Need to perform a few small changes

```
if(f(mid) > x) hi = mid;
```

```
if(a[lo] > x) return lo;
else return hi;
```

* **Problem :** find maximum integer x such that $f(x) \leq p$

```
int BS(int x, int n){
    // Be careful about the limits of lo and hi
    int lo = 0;
    int hi = n - 1;

    while(hi - lo > 1){
        int mid = (lo + hi) / 2;
        if(f(mid) <= x) lo = mid;
        else hi = mid;
    }

    // Only 2 candidates lo and lo + 1 (= hi) to compare
    if(a[hi] <= x) return hi;
    else return lo;
}
```

* **Problem :** find maximum integer x such that $f(x) < p$
Need to perform a few small changes

```
if(f(mid) < x) lo = mid;
```

```
if(a[hi] < x) return hi;
else return lo;
```

2. Given a function f and an value p .

Condition: $f(x-1) \geq f(x) \geq f(x+1)$

* **Problem :** find maximum integer x such that $f(x) \geq p$

* **Problem :** find maximum integer x such that $f(x) > p$

* **Problem :** find minimum integer x such that $f(x) \leq p$

* **Problem :** find minimum integer x such that $f(x) < p$

Think yourself and figure out

3. Binary Search on floating point variables

– $while(hi - lo) > 1$ will not work

– Run a loop for around 100 steps, it should be enough.

2 Ternary Search

1. **Problem Statement :**

Given a function f and an value p .

– find x such that $f(x)$ is maximum

– find x such that $f(x)$ is minimum

2. **Condition :** convex

```

// finds x such that f(x) is maximum
int lo = 1;
int hi = n;
while(hi - lo > 2){
    int mid1 = lo + (hi - lo) / 3;
    int mid2 = hi - (hi - lo) / 3;
    if(f(mid1) > f(mid2)) hi = mid2;
    else lo = mid1;
}
while(lo < hi){
    if(f(lo) > f(lo + 1)) return lo;
    lo++;
}
return hi;

```

3 STL

1. __gcd
2. vector
3. sort
4. lower_bound
5. upper_bound