SEARCH PROBLEM

PROGRAMMING TECHNIQUES

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INTRODUCTION

- This problem is very popular
- Inputs of the problem are the information needed and output is *optimized solution* satisfying *constraint condition*
- Two methods of searching are linear and binary
- Search problem includes:
  - Search space/solution space
  - Constraint condition
- Solution space may include:
  - Explicit: only choose and check
  - Implicit: must create to continue processing

INTRODUCTION

- The process of choosing solutions includes following steps:
  - Step 0: create candidate solution (if not)
  - Step 1: check if candidate solution satisfies constrain condition or not
  - Step 2: Among the candidate solutions satisfying constrain condition, there are some standards to choose the best one
- Example: Find the even biggest number in array *a* with *n* whole distinct numbers ($n > 0$)
  - Search space: *n* elements
  - Constraint condition: even number
  - Standard: biggest

LINEAR SEARCH (IN 1D ARRAY)

- Problem 1: Let *a* be an array of *n* integers. Write a function finding a value of the biggest element

```
int FindMaxValue(int a[], int n){
  int res = a[0];
  for(int i = 1; i < n; i++){
    if(a[i] > res) res = a[i];
  }
  return res;
}
```

  - Cost: Loop array *a* = O(*n*)
  - Search space: *n* elements
  - Standard: biggest

LINEAR SEARCH (IN 1D ARRAY)

- Problem 2: Let *a* be an array of *n* integers and number *x*. Write a function finding the first position of appearance of *x*

1	int Find(int a[], int n, int x){	int Find(int a[], int n, int x){
2	int i = 0;	int i = 0;
3	while((**i < n**) && (a[i] != x))	**a[n] = x;**
4	i++;	while(a[i] != x) i++;
5	if(i < n) return i;	if(i < n) return i;
6	return -1;	return -1;
7	}	}

  - Cost: the luckiest is loop 1 time-looping. The average is *n*/2-looping and the worst is *n*-looping ⊏ O(n)
  - Search space: {0, *n* – 1}
  - Constrain condition: value equal to *x*
  - Standard: the element with the smallest index

LINEAR SEARCH (IN 1D ARRAY)

- Problem 3: Let *a* be an array of *n* integers. Write a function finding the position of the smallest square number

```
bool iSquare(int number){
  int i = (int)sqrt((float)number);
  return (i*i == number);
}
int IdxOfMinSquareNumber(int a[], int n){
  int idx = -1, lc = 0;
  for(int i = 0; i < n; i++){
    if(iSquare(a[i]) && (idx==-1 || a[i]<lc){
      lc = a[i];
      idx = i;
    }
  }
  return idx;
}
```

  - Cost: loop *n* elements ⊏ O(*n*)
  - Search space: {0, *n* – 1}
  - Constrain condition: square number
  - Standard: the smallest element

LINEAR SEARCH (IN 1D ARRAY)

- Problem 4: Let *a* be an array of *n* positive integers. Write a function finding the position of the biggest prime number

```
bool iSPrime(int number){
  if(number < 2) return false;
  int n = (int)sqrt(number);
  for(int i = 2; i <= n; i++)
    if(number % i == 0) return false;
  return true;
}
```

```
int idxOfMaxPrime(int a[], int n){
  int idx = -1, lc = 0;
  for(int i = 0; i < n; i++){
    if(iSPrime(a[i]) && a[i] > lc){
      lc = a[i]; idx = i;
    }
  }return idx;}
```

  - Cost: loop *n* elements = O(*n*)
  - Search space: {0, *n* – 1}
  - Constrain condition: prime number
  - Standard: the biggest

LINEAR SEARCH (IN 1D STRUCTURAL ARRAY)

- Problem 5: Let *sp* be an array of *n* products. Each product has: Code, product name and price. Write a function finding the highest price in the list

```c
#define MAX 100
struct PRODUCT
{
  int id;
  char name[MAX + 1];
  float price;
};
float findMaxPrice(PRODUCT sp[], int n){
  float maxPrice = 0;
  for(int i = 0; i < n; i++)
    if(maxPrice < sp[i].Price)
      maxPrice = sp[i].Price;
  return maxPrice;
}
```

  - Cost: loop *n* elements = O(*n*)
  - Search space: {0, *n* – 1}
  - Standard: the highest price

LINEAR SEARCH
(IN 1D STRUCTURAL ARRAY)

- Problem 6: Let *sp* be an array of *n* products. Each product has: Code, product name and price. Write a function finding the product name with lowest price in the list

```
float findProduct(PRODUCT sp[], int n, char* strQuery, char* strProductName){
  strcpy(strProductName, “”);
  int idx = -1; float minP = 0;
  for(int i = 0; i < n; i++)
    if(strstr(sp[i].Name, strQuery) != NULL && (idx == -1 || minP > sp[i].Price)){
      idx = i; minP = sp[i].Price;
    }
  if(idx != -1) strcpy(strProductName, sp[idx].Name);
}
```

  - Cost: loop *n* elements ⊏ O(*n*)
  - Search space: {0, *n* – 1}
  - Constrain condition: exist product name needed
  - Standard: the highest price

LINEAR SEARCH (IN STRUCTURAL VECTOR)

- Problem 7: Let *plist* be an array of *n* songs. Each song includes: name, singer, genre and points. Write a function choosing the songs with the highest point

```
struct SONG
{
  string name;
  string Artist;
  string Genre;
  float Rating;
};
```

```
vector<SONG> FindBestSong(vectot<SONG>& pList){
  vector<SONG> res; float bestR = 0;
  for(int i = 0; i < pList.size(); i++)
    if(bestR < pList[i].Rating)
      bestR = pList[i].Rating;
  for(i = 0; i < pList.size(); i++)
    if(bestR == pList[i].Rating)
      res.push_back(pList[i]);
  return res;
}
```

Note: string in struct
Following declarations are valid
SONG s;
Or
SONG* s = new SONG();

- Cost: loop *n* elements = O(*n*)
- Search space: {0, *n* – 1}
- Standard: the highest price

LINEAR SEARCH (IN LINKED LIST)

- Problem 8: Let a linked list of products. Each product includes: code, name and price. Write a function finding the highest price in the linked list

```
struct PRODUCT
{
  int id;
  char name[4];
  float price;
  PRODUCT* next;
};
```

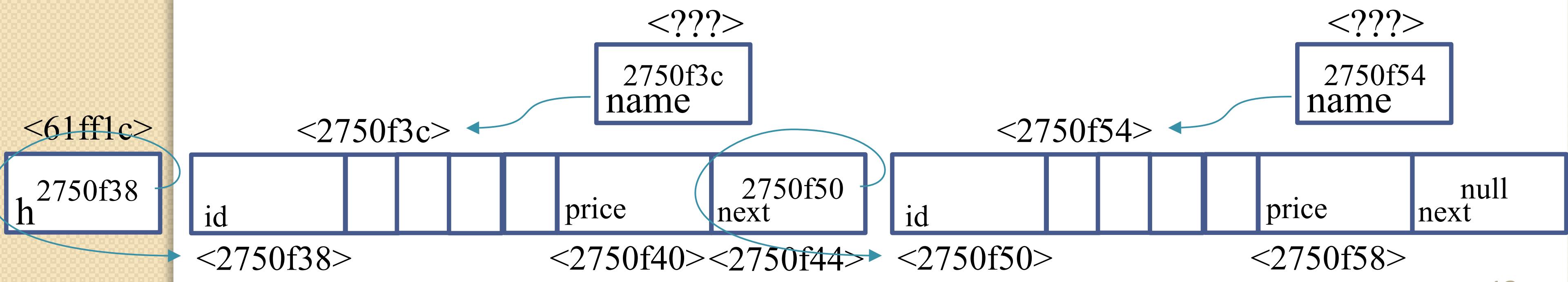
```
float findMaxPrice(PRODUCT* sp){
  PRODUCT* p = sp; float maxPrice = 0;
  while(p){
    if(maxPrice < sp->price)
      maxPrice = sp->price;
    p = p->next;
  }
  return maxPrice;
}
```

  - Cost: loop *n* elements = O(*n*)
  - Search space: {0, *n* – 1}
  - Standard: the highest price

LINEAR SEARCH (IN LINKED LIST)

- Problem 8: review the structure PRODUCT

1	struct PRODUCT	8	void main()
2	{	9	{
3	int id;	10	PRODUCT* h = new PRODUCT;
4	char name[4];	11	h->next = new PRODUCT;
5	float price;	12	h->next->next = NULL;
6	PRODUCT* next;	13	//cout<<…
7	};	14	};



LINEAR SEARCH (IN LINKED LIST)

- Problem 9: Let a linked list of students. Each student includes: code, name, faculty and GPA. Write a function counting a number of students with GPA in [min, max]

```c
#define DEPT 50
#define NAME 100
struct STUDENT{
  int ID;
  char strDept[DEPT+1];
  char strName[NAME+1];
  float GPA;
  STUDENT* next;
};
float count(STUDENT* s, char* strDept, float min, float max){
  STUDENT* t = s; int c = 0;
  while(t){
    if(strcmp(t->strDept, strDept) ==0 )
      if(t->GPA>=min && t->GPA<=max) c++;
    t = t->next;
  }
  return c;
}
```

  - Cost: loop *n* elements □ O(*n*)
  - Constrain condition: exist the faculty name needed
  - Search space: {0, *n* – 1}
  - Standard: in [min, max]

LINEAR SEARCH (IN HIERARCHICAL STRUCTURE)

- Problem 10: Counting a number of files with the size bigger or equal to minSize in the given directory

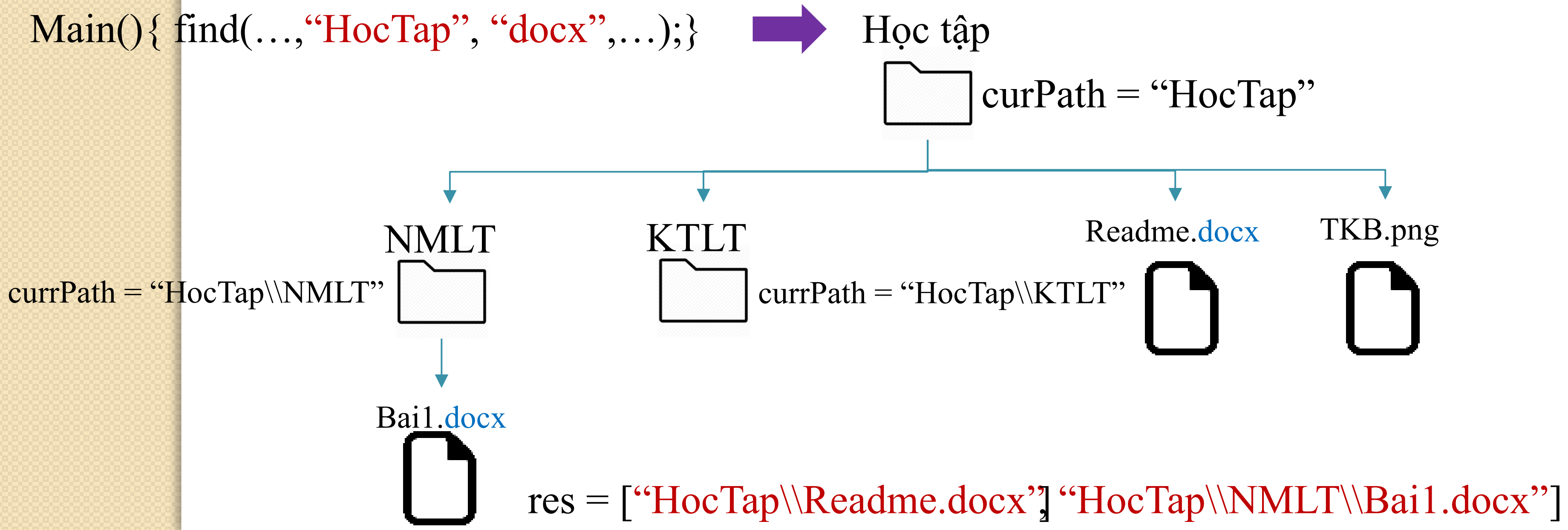
```
struct File{
  string Name;
  int Size;
}
struct Folder{
  string Name;
  vector<Folder> Folders;
  vector<File> Files;
};
```

```
int count(const Folder& f, int minSize){
  int i, c = 0, nFiles = f.Files.size(), nFolders = f.Folders.size();
  for(i = 0; i < nFiles; i++)
    if(f.Files[i].Size >= minSize)
      c++;
  for(i = 0; i < nFolders; i++)
    c+=count(f.Folders[i], minSize);
  return c;
}
```

  - Cost: loop *n* files = O(*n*)
  - Search space: multi-branch tree
  - Standard: bigger or equal to minSize

LINEAR SEARCH
(IN HIERARCHICAL STRUCTURE)

- Problem 11: Search all the files with the name containing a given string strPat. Result is a list of names (including file paths) of the files just found
  - Cost: loop *n* files = O(n)
  - Search space: multi-branch tree
  - Standard: file with the name needed



Main(){ find(…,"HocTap", "docx",…);}

res = ["HocTap\\Readme.docx", "HocTap\\NMLT\\Bai1.docx"]

LINEAR SEARCH
(IN HIERARCHICAL STRUCTURE)

- Problem 11: Search all the files with the name contaning a given string strPat. Result is a list of names (including file paths) of the files just found

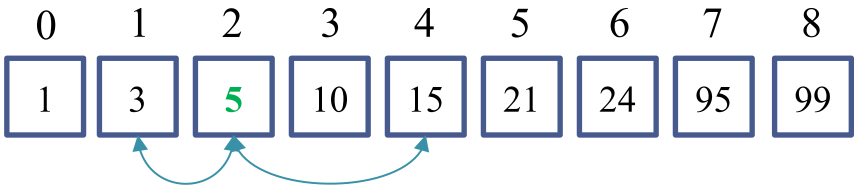
```
void find(const Folder& f, string strCurrentPath, string strPat, vector<string>& res){
  int i, nFiles = f.Files.size(), nFolders = f.Folders.size();
  string strFilePathName, strNewPath;
  for(i = 0; i < nFiles; i++)
    if(f.Files[i].Name.find(strPat, 0) != string::npos){
      strFilePathName = strCurrentPath + “\\” + f.Files[i].Name;
      res.push_back(strFilePathName);
    }
  for(i = 0; i < nFolders; i++)
    find(f.Folders[i], strCurrentPath + “\\” + f.Folders[i].Name, strPat, res);
}
```

- Cost: loop *n* files ⊏ O(*n*)
- Search space: multi-branch tree
- Standard: file with the name needed

BINARY SEARCH (IN 1D ARRAY)

- Problem 12: Let *a* be an array of *n* increasing integers. Write a function determining the position of the element having *x* value.
  - If $x > a[i] \Rightarrow x$ in $[i + 1, n – 1]$
  - If $x < a[i] \Rightarrow x$ in $[0, i – 1]$

```
void BinarySearch(int a[], int x, int n){
  int from = 0, to = n – 1, mid;
  while(from <= to){
    mid = (from + to)/2;
    if(a[mid] == x) return mid;
    else{
      if(a[mid] > x) to = mid – 1;
      else from = mid + 1;
    }} return -1;}
```



0	1	2	3	4	5	6	7	8
1	3	5	10	15	21	24	95	99

BINARY SEARCH
(IN 1D ARRAY)

- Problem 13: Let *a* be an array of *n* decreasing positive integers. Write a function determining the position of the biggest element smaller than *x* (for example *x* = 20)

```
int findMaxValue(int a[], int x, int n){
 if(n == 0) return 0;
 int from = 0, to = n – 1, mid;
 while(from < to){
  mid = (from + to)/2;
  if(a[mid] > x) from = mid + 1;
  else to = mid;
 }
 if(a[from] <= x) return a[from];
 return 0;
}
```

0	1	2	3	4	5	6	7
80	55	46	24	21	15	10	9

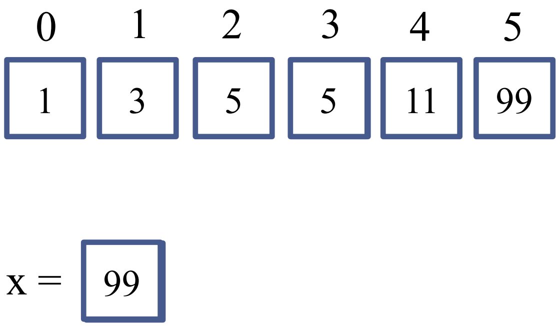
$> 20 > 20 < 20$

BINARY SEARCH (IN 1D ARRAY)

- Problem 14: Let *a* be an array of *n* increasing integers. Write a function inserting *x* into array, such that maintaining the increasing order

```
void BinaryInsert(vector<int>& a, int x){
  int from = 0, to = a.size() – 1, mid;
  while(from <= to){
    mid = (from + to)/2;
    if(a[mid] < x) from = mid + 1;
    else to = mid – 1;
  }
  a.insert(a.begin + from, x);
}
```

from = 4   to = 4   mid = 4



0	1	2	3	4	5
1	3	5	5	11	99

x = 99

BINARY SEARCH (IN 1D ARRAY)

- Problem 15: Let *a* be an *unimodal* array with *n* integer elements. Write a function finding the biggest element

```
int BinarySearchMax(int a[], int n){
  int from = 0, to = n – 1, mid;
  while(from < to){
    mid = (from + to)/2;
    if(a[mid] < a[mid + 1]) from = mid + 1;
    else to = mid;
  }
  return a[from];
}
```

from = 0 to = 6 mid = 3

0	1	2	3	4	5	6
1	4	8	9	7	6	2

BINARY SEARCH (IN 1D STRUCTURAL ARRAY)

- Problem 16: Any library has the books with the names following the alphabetically increasing order. Write a function determining the position of the book needed

```
struct POSITION{
  int BookShelf, Level;
};
struct BOOK{
  string Title;
  string Authors;
  string Publisher;
  POSITION Position;
};
```

```
POSITION BinarySearch (vector<BOOK> &Lst, string strTitle){
  POSITION res; res.BookShelf = res.Level = -1; int n = Lst.size();
  if(n == 0) return res;
  int from = 0, to = n – 1, mid;
  while(from <= to){
    mid = (from + to)/2;
    if(Lst[mid].Title == strTitle) return Lst[mid].Position;
    else{
      if(Lst[mid].Title > strTitle) to = mid – 1;
      else from = mid + 1;
    }
  } return res;
}
```

BINARY SEARCH (IN 1D STRUCTURAL ARRAY)

- Problem 17: write a function determining the camera’s name with the highest price not exceeding *maxPrice*. The camera’s information includes name, manufacturer and price

```
struct CAMERA{
  char ProductName[50];
  char Manufacturer[50];
  float Price;
};
```

```
void findCam(CAMERA lst[], int n, float maxPrice, char* strName){
  strcpy(strName, “”);
  if(n == 0) return;
  int from = 0, to = n – 1, mid;
  while(from < to){
    mid = (from + to)/2;
    if(lst[mid].Price > maxPrice) to = mid – 1;
    else from = mid;
  }
  if(lst[from].Price<=maxPrice)strcpy(strName, lst[from].ProductName);
}
```

BINARY SEARCH (IN 1D STRUCTURAL ARRAY)

- Problem 18: Write a function adding a record into the contact, such that all records follow the rule of Name alphabetically increasing

```
struct CONTACT{
  string Name;
  string PhoneNumber;
  string EmailAddress;
};
```

```
void binaryInsert(vector<CONTACT>& lst, CONTACT newContact){
  int from = 0, to = lst.size() – 1, mid;
  while(from <= to){
    mid = (from + to)/2;
    if(lst[mid].Name < newContact.Name) from = mid + 1;
    else to = mid – 1;
  }
  lst.insert(lst.begin() + from, newContact);
}
```

BINARY SEARCH (IN 2D ARRAY)

- Problem 19: Let *a* be integer array (*m* ≗ *n*). Array *a* has the numbers left-to-right increasing in each row. Write a function checking if array *a* contains the element with *x* value or not (for example *x* = 14).

```
bool search2D(int** a, int m, int n, int x){
  int from, to, mid;
  for(int i = 0; i < m; i++){
    from = 0; to = n – 1;
    while(from <= to){
      mid = (from + to)/2;
      if(a[i][mid] == x) return true;
      else{
        if(a[i][mid] < x) from = mid + 1;
        else to = mid – 1;
      }}}
return false; }
```

4	7	9	21	⊏ loop $\log_2 4$
7	9	11	43	⊏ loop $\log_2 4$
8	9	44	67	⊏ loop $\log_2 4$
1	3	4	6	⊏ loop $\log_2 4$
2	4	6	7	⊏ loop $\log_2 4$
1	1	6	7	⊏ loop $\log_2 4$

$6\log_2 4$

BINARY SEARCH (IN 2D ARRAY)

- Problem 20: Let *a* be integer array (*m* ㅎ *n*). Array *a* has the numbers left-to-right increasing in each row, and numbers bottom-to-up increasing in each column. Write a function checking if array *a* contains the element with *x* value or not (for example *x* = 14)

```
bool search2D(int** a, int m, int n, int x){
  int i = 0, j = 0;
  while(i < m && j < n){
    if(a[i][j] == x) return true;
    else{
      if(a[i][j] < x) j++;
      else i++;
  }
  return false;
}
```

j

ㅈ

	0	1	2	3	4
i ㅇ 0	7	12	16	20	95
1	5	9	**14**	15	19
2	3	5	7	9	11
3	1	2	3	4	5

Loop cost O(m + n)