INF 311

Introduction to computer science

Lecture 10: Introduction to algorithms

Exhaustive & greedy search algorithms
Dynamic programming

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Examen final 2008

Lundi **7 Juillet** de 9h a 11h

- Note finale (HC): 1/3 Pale machine + **2/3** Pale papier
- Le polycopie INF311+transparents sont autorises
- Sujet en Francais *or in English* (FR/EN)
- Les EV2s ont le droit a 30 minutes supplementaires
- Plusieurs parties independantes

Examen final 2008

- (re?)Lire le polycopie:
  Chapitres 1 a 11 (130 pages)
- Regarder les annales

INF 311: Introduction à l'informatique, niveau débutant

Le poly est disponible en pdf

Les pages des travaux dirigés

La pale de juillet 2006 et son corrigé .

http://www.enseignement.polytechnique.fr/informatique/INF311/

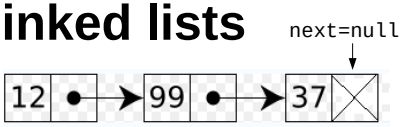
Agenda

A few algorithms and paradigms:

- I/ **Exhaustive search**
- II/ **Greedy algorithm** (set cover problems)
- III/ **Dynamic programming** (knapsack)

+...*Merging two lists*...

Linked lists




```
public class List
{
int container;
List next;  // a reference to a cell of a list

// Constructor  List(head, tail)
// Build a cell so that
//        the reference to the next cell is the tail
List(int element, List tail)
   {
   this.container=element;
   this.next=tail;
   }

}
```


Merging ordered linked lists

- Two *linked lists* u and v of increasing integers
- Build a *new linked list* in increasing order...
- ...using **only cells** of u and v (no cell creation, new)

For example:

```
U           | 3-->6-->8-->null
V           | 2-->4-->5-->7-->9-->null
Merge(U,V) | 2-->3-->4-->5-->6-->7-->8-->9-->null
```


Linked lists

```
class List
{
int container;
List next;

// Constructor  List(head, tail)
List(int element, List tail)
   {
   this.container=element;
   this.next=tail;
   }

List insert(int el)   // insert element at the head of the list
{
return new List(el,this);
}

void Display()
{
List u=this;

while(u!=null)
   {
   System.out.print(u.container+"-->");
   u=u.next;
   }
System.out.println("null");
}
```

```
U    | 3-->6-->8-->null
V    | 2-->4-->5-->7-->9-->null
```



```
class MergeList
{
//
// Merge two ordered lists
//
static List mergeRec(List u, List v)
{
if (u==null) return v;
if (v==null) return u;

if (u.container < v.container)
   {
   // Recycle cells/ no new
   u.next=mergeRec(u.next,v);
   return u;
   }
else
   {
   // Recycle cells/no new
   v.next=mergeRec(u,v.next);
   return v;
   }

}
```

```
public static void main(String [] args)
{
List u=new List(8,null);
u=u.insert(6);u=u.insert(3);
u.Display();

List v=new List(9,null);
v=v.insert(7);v=v.insert(5);
v=v.insert(4);v=v.insert(2);
v.Display();

List w=mergeRec(u,v);
w.Display();
}
```

```
static List sortRec(List u)
{
int i,l=u.length(), lr;
List l1, l2, split, psplit; // references to cells

if (l<=1)
   return u;
else
   {
   l1=u;

   psplit=split=u;
   i=0;lr=l/2;


   while (i<lr)
      {i++;
      psplit=split;
      split=split.next;}

   l2=split; // terminates with a null
   psplit.next=null;

   return mergeRec( sortRec(l1), sortRec(l2) );
   }
}
```

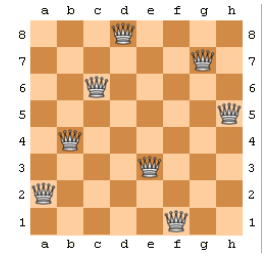
Sort in O(n log n) time:
- Split list in two halves
- Recursively apply sorting
- Merge ordered lists


```
public static void main(String [] args)
{

List u=new List(3,null);
u=u.insert(2);
u=u.insert(9);
u=u.insert(6);u=u.insert(1);
u=u.insert(15);u=u.insert(17);
u=u.insert(23);u=u.insert(21);
u=u.insert(19);u=u.insert(20);

u.Display();

List sortu=sortRec(u);
System.out.println("Sorted linked list:");
sortu.Display();
}
```

20-->19-->21-->23-->17-->15-->1-->6-->9-->2-->3-->null
Sorted linked list:
1-->2-->3-->6-->9-->15-->17-->19-->20-->21-->23-->null

Exhaustive search (Brute force search)

The Eight Queens puzzle:



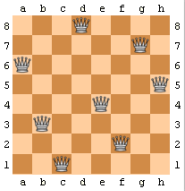
Max Bezzel (1848, chess player)
Find safe positions of 8 queens on a 8x8 chessboard

- 92 distinct solutions
- 12 non-naive distinct solutions (rotation/symmetry)
- Good exercise for *designing* algorithms
- Generalize to n-queens

Exhaustive search & Backtracking

Brute force (naive) algorithm:
Check all *64x63x...x57/8! = 283,274,583,552* ?! solutions...

Easy to check that a **configuration** is not safe
(*check horizontal/vertical/diagonal lines*)



→ Two queens cannot be on the same line...

Therefore, *incrementally place queen* i (0...7)
on the i-th row, on the first **free** column

If there is no more free columns left, then **backtrack...**

Exhaustive search & Backtracking

Incrementally place queen i (0...7) on the first **free** column
If there is no more free columns left, then **backtrack:**

Consider the previous queen position and increment its column position, etc., etc., etc.

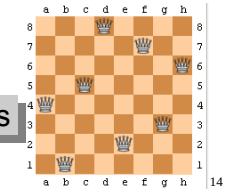
... until we find a solution
(=reach a successful location for queen indexed 7)

`queen`: 1D Array that specifies the column position
Queen i is located at position `(i,queen[i])`
(with i ranging from 0 to 7)

`search`: Static function that returns a/all solution(s).


```
// Are queen (i1,j1) and queen (i2,j2) safe ?
static boolean WrongPos(int i1, int j1, int i2, int j2)
{ // same row?, same col?, same diag?
return (i1==i2 ||
      j1==j2 ||
      Math.abs(i1-i2) == Math.abs(j1-j2));
}

// Place safely queen i at column j?
static boolean FreeMove(int i, int j)
{
boolean result=true;

for(int k=0;k<i;k++)
   result=result&&!WrongPos(i,j,k,queen[k]);

return result;
}
```

Check for the queens placed so far on the chessboard



Static functions to check for collisions


```
static boolean search(int row)
{
boolean result=false;

if (row==n)
   {// Terminal case
    DisplayChessboard();
    nbsol++;
   }
   else
   {// Exhaustive search
   int j=0;

      while(!result && j<n)
      {
         if (FreeMove(row,j))
         {
            queen[row]=j;
            result=search(row+1); // RECURSION/BACKTRACK
         }
         j++; // explore all columns
      }
    }
   return result;
```

Increment the number of found solutions (static class variable)


```
static final int n=8;
static int [] queen=new int[n];
static int nbsol;

static void DisplayChessboard()
{
int i,j;

System.out.println("");

for(i=0;i<n;i++)
   {
      for(j=0;j<n;j++)
      {
         if (queen[i]!=j) System.out.print("0");
            else System.out.print("1");
      }
      System.out.println("");
   }
}
```

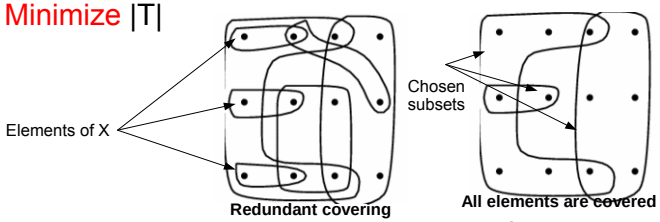
```
00100000
10000000
00000010
00010000
00000100

00000001
00100000
10000000
00000100
01000000
00001000
00000010
00010000

00000001
00010000
10000000
00100000
00000100
01000000
00000010
00001000
Total number of solution:92
```

```
public static void main(String [] arguments)
{
nbsol=0;
search(0); // Call exhaustive search procedure
System.out.println("Total number of solutions:"+nbsol);
}
```

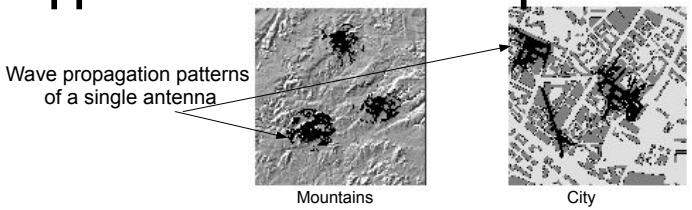
Optimization: Set Cover Problem (SCP)

- Given a graph:
– A **finite set** X = {1, …, n}
– A **collection of subsets** of S: S_1, S_2, …, S_m

- **Problem**:
– Find a subset T of {1, …, m} such that $U_{j \text{ in } T} S_j = X$
– Minimize |T|



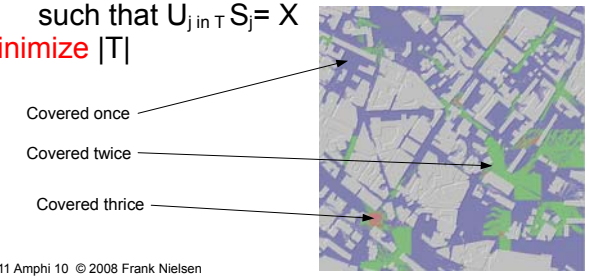
Applications of set cover problems



- Choose base stations for quality of service (cell phone network, etc)
- Discretize terrain using a regular grid (set X)
- Each position of antenna -> subset of covered grid areas (S)
- Minimize the number of chosen antennas (X)

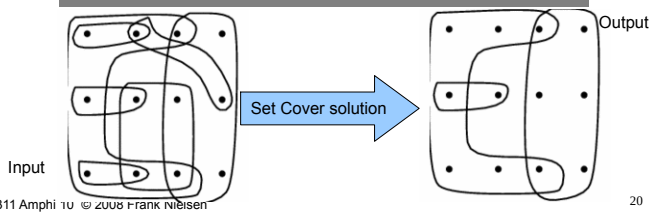
- Given a graph:
– A **finite set** X = {1, …, n} (=regular grid elements)
– A **collection of subsets** of S (=antenna patterns)
S_1, S_2, …, S_m

- **Problem**:
– Find a subset T of {1, …, m} (=subset of antennas) such that $U_{j \text{ in } T} S_j = X$
– Minimize |T|



A greedy algorithm (algorithme glouton)

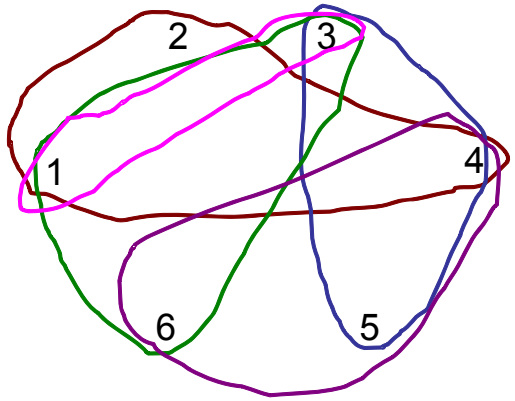
```
GREEDY-SET-COVER(X,S)
1 M ← X     // all elements must be covered
2 C ← Ø     //  chosen subsets
3 while M ≠ Ø do
4       select an Q Є S that maximizes |Q ∩ M|
5          M ← M – Q
6          C ← C U {Q}
7 return C
```



Visualizing a « range set »

Elements:
X = {1, …, 6}

Subsets:
S_1 = {1,2,4}
S_2 = {3,4,5}
S_3 = {1,3,6}
S_4 = {2,3,5}
S_5 = {4,5,6}
S_6 = {1,3}



Data-structure for the set cover problem

X = {1, …, 6}

S_1 = {1,2,4}
S_2 = {3,4,5}
S_3 = {1,3,6}
S_4 = {2,3,5}
S_5 = {4,5,6}
S_6 = {1,3}

M=6 SUBSETS

1	2	3	4	5	6	
1	1	0	1	0	0	S_1
0	0	1	1	1	0	S_2
1	0	1	0	0	1	S_3
0	1	1	0	1	0	S_4
0	0	0	1	1	1	S_5
1	0	1	0	0	0	S_6

N=6 ELEMENTS

Incidence matrix: boolean matrix


```
class SetCover
{
int nbelements;
int nbsubsets;
boolean [][] incidenceMatrix;

//Constructor
SetCover(int nn, int mm)
{
this.nbelements=nn; this.nbsubsets=mm;

incidenceMatrix=new boolean[nbsubsets][nbelements];

for(int i=0;i<nbsubsets;i++)
   for(int j=0;j<nbelements;j++)
      incidenceMatrix[i][j]=false;
}

void SetSubsets(int [] [] array) // Set incidence matrix
{for(int j=0;j<array.length;j++)
   {for(int i=0;i<array[j].length;i++)
         incidenceMatrix[j][array[j][i]]=true;
   }
}

}
```



```
void Display()
{
for(int i=0;i<nbsubsets;i++){

   for(int j=0;j<nbelements;j++)
      if (incidenceMatrix[i][j]) System.out.print("1");
         else System.out.print("0");
         System.out.println("");
         }
}
```

```
public static void main(String [] args)
{
int [][] subsets={{0,1,3},{2,3,4}, {0,2,5},{1,2,4},{3,4,5},{0,2}};

SetCover setcover=new SetCover(6,6);
setcover.SetSubsets(subsets);

System.out.println("Set cover problem:");
setcover.Display();
}
```

```
Set cover problem:
110100
001110
101001
011010
000111
101000
```

Greedy algorithm

```
   static boolean [] GreedySCP(SetCover problem)
   {
   boolean [] result=new boolean[problem.nbsubsets];
   int cover=0; int select;

   for(int i=0;i<problem.nbsubsets;i++)  // initially no subsets
         result[i]=false;

   while(cover!=problem.nbelements)
   {
   // Choose largest not-yet covered subset
   select=problem.LargestSubset();
   result[select]=true;

   // Update covered matrix
   cover+=problem.Cover(select);

   // Update incidence matrix
   problem.Update(select);

   System.out.println("Selected "+select+" Number of covered
elements="+cover);
   problem.Display();
   }

   return result;
   }
```


Methods of class SetCover

```
// Number of covered element by subset i
int Cover(int i)
{
int nbEl=0;

for(int j=0;j<nbelements;j++)
      if (incidenceMatrix[i][j]) ++nbEl;

return nbEl;
}

// Report the current largest subset
int LargestSubset()
{
int i, nbel, max, select;

max=-1;select=-1;

for(i=0;i<nbsubsets;i++)
   {
   nbel=Cover(i);
   if (nbel>max) {max=nbel; select=i;}
   }

return select;
}
```


Methods of class SetCover

```
// Update the incidence matrix
void Update(int sel)
{
int i,j;

for(i=0;i<nbsubsets;i++)
{
  if (i!=sel) //use sel below so don't modify it
     {
     for(j=0;j<nbelements;j++)
       if (incidenceMatrix[sel][j])
          incidenceMatrix[i][j]=false;
     }
}
// Remove the chosen subset as well
for(j=0;j<nbelements;j++)
     incidenceMatrix[sel][j]=false;
}
```



```
public static void main(String [] args)
{
int [] [] subsets ={{0,1,3},{2,3,4},
                    {0,2,5},{1,2,4},
                    {3,4,5},{0,2}};
SetCover setcover=new SetCover(6,6);

setcover.SetSubsets(subsets);

System.out.println("Set cover problem:");
setcover.Display();

boolean [] solution=GreedySCP(setcover);

System.out.print("Solution:");
for(int i=0;i<setcover.nbsubsets;i++)
if (solution[i]) System.out.print(" "+i);
System.out.println("");
}
```

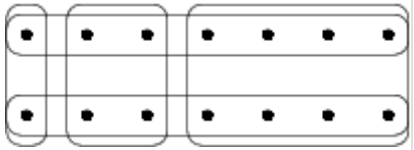
```
Set cover problem:
110100
001110
101001
011010
000111
101000
Selected 0 Number of covered elements=3
000000
001010
001001
001010
000011
001000
Selected 1 Number of covered elements=5
000000
000000
000001
000000
000001
000000
Selected 2 Number of covered elements=6
000000
000000
000000
000000
000000
000000
Solution: 0 1 2
```

Optimization bounds for greedy algorithm

CoptT<= Cgreedy <= ApproximationFactor x Copt

Upper bound:
Approximation factor is at most H(n)<=log(n)

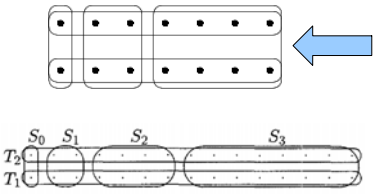
2 sets is optimal solution
but greedy chooses 3 sets here



Lower bound:
Approximation factor can be as big as Omega(log(n))

Difficult to approximate: cannot beat (1-eps)Opt unless P=NP


```
int [] [] subsets={{0,1,2,3,4,5,6},{7,8,9,10,11,12,13},
                   {0,7},{1,2,8,9},{3,4,5,6,10,11,12,13}};
   SetCover setcover=new SetCover(14,5);
```



Etc...

Easy to build generic examples where greedy does not behave well with O(log n) approximation ratio

```
Set cover problem:
11111110000000
00000001111111
10000001000000
01100000110000
00011110001111
Selected 4 Number of covered elements=8
11100000000000
00000001110000
10000001000000
01100000110000
00000000000000
Selected 3 Number of covered elements=12
10000000000000
00000001000000
10000001000000
00000000000000
00000000000000
Selected 2 Number of covered elements=14
00000000000000
00000000000000
00000000000000
00000000000000
00000000000000
Solution: 2 3 4
```


Knapsack problem (sac a dos)

(First version)

Given:

- A set of n Objects `O1, ..., On` with corresponding weights `W1, ..., Wn`
- And a bag (knapsack) of capacity `W`

Find:

All the ways of choosing objects to **fully** fill the bag

Filling the knapsack

Need to enumerate all possibilities:
n objects => 2^n choices
(2, 4, 8, 16, 32, 64, ...)

How to program this?
n **is** a variable
(cannot fix the number of nest loops)

Need to enumerate all combinations:

= **Exhaustive search**

n=4
2^4=16

```
1 1 1 1
1 1 1 0
1 1 0 1
1 1 0 0
1 0 1 1
1 0 1 0
1 0 0 1
1 0 0 0
0 1 1 1
0 1 1 0
0 1 0 1
0 1 0 0
0 0 1 1
0 0 1 0
0 0 0 1
0 0 0 0
```

Enumerating: A recursive approach

```
static void Display(boolean [] tab)
{
for(int i=0;i<tab.length;i++)
   if (tab[i]) System.out.print("1 ");
      else
      System.out.print("0 ");

System.out.println("");
}

static void Enumerate(boolean [] selection, int pos)
{
if (pos==selection.length-1)
      Display(selection);
   else
   {
   pos++;
   selection[pos]=true;
   Enumerate(selection,pos);
   selection[pos]=false;
   Enumerate(selection,pos);
   }
}
```

```
public static void main(String[] args)
{
int n=4;
int i;
boolean [] select=new boolean[n];
for(i=0;i<n;i++)
   select[i]=false;

Enumerate(select,-1);
}
```


Fully filling the knapsack

```
final static int n=10; // 10 objects
static int [] weight={2,3,5,7,9,11,4,13,23,27};

static void SolveKnapSack(boolean [] chosen, int goal, int
i, int total)
{
numbercall++; // keep track of total number of calls

if ((i>=chosen.length)&&(total!=goal)) return;

if (total==goal)
   {  Display(chosen, goal);
         numbersol++; // total number of solutions
      }
else
   {
   chosen[i]=true;// add item first
   SolveKnapSack(chosen,goal,i+1,total+weight[i]);
   chosen[i]=false;  // and then remove it
   SolveKnapSack(chosen,goal,i+1,total);
   }
}
```



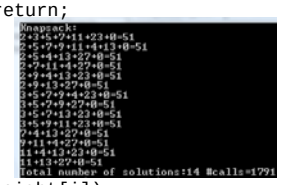
```
final static int n=10; // 10 objects
static int [] weight={2,3,5,7,9,11,4,13,23,27};

public static void main(String [] args)
{
int totalweight=51;
numbersol=0;
numbercall=0;

System.out.println("Knapsack:");
boolean [] chosen=new boolean[n];

SolveKnapSack(chosen, totalweight, 0, 0);
System.out.println("Total number of
 solutions:"+numbersol);
System.out.println(" #calls="+numbercall);
}
```

```
Knapsack:
2+3+5+7+11+23+0=51
2+5+7+9+11+4+13+0=51
2+5+4+13+27+0=51
2+7+11+4+27+0=51
2+9+4+13+23+0=51
2+9+13+27+0=51
3+5+7+9+4+23+0=51
3+5+7+9+27+0=51
3+5+7+13+23+0=51
3+5+9+11+23+0=51
7+4+13+27+0=51
9+11+4+27+0=51
11+4+13+23+0=51
11+13+27+0=51
Total number of solutions:14
 #calls=2029
```

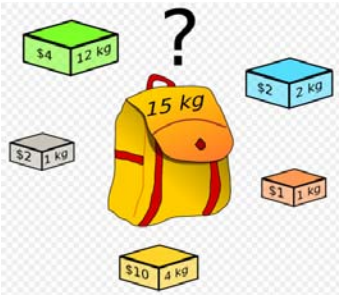

Exhaustive search: Branch & bound

```
static void SolveKnapSack(boolean [] chosen, int goal, int i,
int total)
{
numbercall++;

if (total>goal) return; // cut

if ((i>=chosen.length)&&(total!=goal)) return;

if (total==goal)
   {  Display(chosen, goal);
         numbersol++;
      }
else
   {
   chosen[i]=true;// add item first
   SolveKnapSack(chosen,goal,i+1,total+weight[i]);
   chosen[i]=false;  // and then remove it
   SolveKnapSack(chosen,goal,i+1,total);
   }

}
```

Stop recursion if we already exceed the weight amount



Knapsack: Fundamental optimization problem



Given a bag capacity (15 kg),
maximize the **utility** (price) of selected objects

(NP-hard problem)

Knapsack optimization problem

Given $p_1, p_2, \ldots p_n$ ← weights

$a_1, a_2, \ldots, a_n$ ← utility

$Pmax$ ← Maximum weight (capacity of bag)

Optimize $\sum_{i \in I} a_i$

such that

$$\sum_{i \in I} p_i \leq Pmax$$

(Maybe there exists several solutions)

Knapsack: Example

$Pmax$ = 12 8 objects

weight	2	3	5	2	4	6	3	1
utility	5	8	14	6	13	17	10	4

Dynamic programming (Knapsack)

Dynamic programming computes a table...
... from which a solution can be retrieved.

Requires a relational equation to deduce solutions progressively.

Dynamic programming (Knapsack)

Let u(i,j) be the maximum utility by taking objects in {1, ...,i} with total weight <=j

- If i=1 then u(i,j)=0 for j<p1
  and u(i,j)=A1 for j>=P1
- If i>1
  u(i,j)=max(u(i-1,j) , u(i-1,j-Pi)+Ai)

Do not take object Oi

Take object Oi:
- gain Ai
- but leave room: Pi

weight	2	3	5	2	4	6	3	1
utility	5	8	14	6	13	17	10	4

Pmax= 12

u(i,j)=max(u(i-1,j) , u(i-1,j-Pi)+Ai)

$u_{i,j}$	0	1	2	3	4	5	6	7	8	9	10	11	12
$i=1$	0	0	5	5	5	5	5	5	5	5	5	5	5
$i=2$	0	0	5	8	8	13	13	13	13	13	13	13	13
$i=3$	0	0	5	8	8	14	14	19	22	22	27	27	27
$i=4$	0	0	6	8	11	14	14	20	22	25	28	28	33
$i=5$	0	0	6	8	13	14	19	21	24	27	28	33	35
$i=6$	0	0	6	8	13	14	19	21	24	27	30	33	36
$i=7$	0	0	6	10	13	16	19	23	24	29	31	34	37
$i=8$	0	4	6	10	14	17	20	23	27	29	33	35	38

Optimization result: Maximum utility, given Pmax

Reading *back:* Solution

2	3	5	2	4	6	3	1
5	8	14	6	13	17	10	4

$u_{i,j}$	0	1	2	3	4	5	6	7	8	9	10	11	12	
$i=1$	0	0	5	5	5	5	5	5	5	5	5	5	5	Choose (38=33+5, 2-2=0)
$i=2$	0	0	5	8	8	13	13	13	13	13	13	13	13	5=5 do not choose
$i=3$	0	0	5	8	8	14	14	19	22	22	27	27	27	5=5 do not choose
$i=4$	0	0	6	8	11	14	14	20	22	25	28	28	33	Choose (33=27+6,4-2=2)
$i=5$	0	0	6	8	13	14	19	21	24	27	28	33	35	Choose (27=14+13,8-4=4)
$i=6$	0	0	6	8	13	14	19	21	24	27	30	33	36	24=24, do not choose
$i=7$	0	0	6	10	13	16	19	23	24	29	31	34	37	Choose (14, 11-3=8)
$i=8$	0	4	6	10	14	17	20	23	27	29	33	35	38	Choose (4, 11)

Choose (Utility=0, Pmax=12)

From the table, chosen solution: O8, O7, O5, O4, O1


```
static int nbObjects=8;
static int [] weight={2,3,5,2,4,6,3,1};
static int [] utility={5,8,14,6,13,17,10,4};
static int weightmax=12;
static int [] [] array;

static void SolveDP()
{
int i,j;
array=new int[nbObjects][weightmax+1];

// initialize the first row
for(j=0;j<=weightmax;j++)
   if (j<weight[0]) array[0][j]=0;
         else array[0][j]=utility[0];
// for all other rows
for(i=1;i<nbObjects;i++)
   {
   for(j=0;j<=weightmax;j++)
      if (j-weight[i]<0) array[i][j]=array[i-1][j];
       else
         array[i][j]=max( array[i-1][j],
                     array[i-1][j-weight[i]]+utility[i]);
   }
}
```

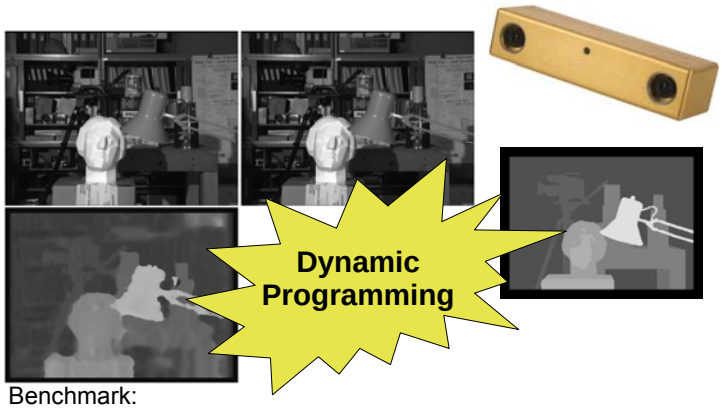
```
static void InterpretArray()
{
int i,u,w;
u=0;
w=weightmax;

for(i=nbObjects-1;i>=1;i--)
{
   if (array[i][w]!=array[i-1][w])
         {System.out.print((i+1)+" ");
         w=w-weight[i];
         u=u+utility[i];
         }
}

if (array[0][w]!=0);
   {System.out.println("1");
   w=w-weight[0];
   u=u+utility[0];
   }
System.out.println("Cross check:"+u+" remaining weight "+w);
}
```



```
public static void main(String[] args)
{
System.out.println("Solving knapsack using the dynamic
            programming paradigm.");
SolveDP();
Display();
System.out.println("Reading solution:");
InterpretArray();
}
```

```
Solving knapsack using the dynamic programming paradigm.
0   0   5   5   5   5   5   5   5   5   5   5
0   0   5   8   8   13  13  13  13  13  13  13
0   0   5   8   8   14  14  19  22  22  27  27  27
0   0   6   8   11  14  14  20  22  25  28  28  33
0   0   6   8   13  14  19  21  24  27  28  33  35
0   0   6   8   13  14  19  21  24  27  30  33  36
0   0   6   10  13  16  19  23  24  29  31  34  37
0   4   6   10  14  17  20  23  27  29  33  35  38
Reading solution:
3 2 5 4 1
Cross check:38 remaining weight 0
```


Dynamic programming: binocular stereo matching



Benchmark:
http://vision.middlebury.edu/~schar/stereo/web/results.php

Optimization: A brief summary

- Exhaustive search: recursion but O(2^n) complexity
- Can be improved by backtracking (cuts)
- Greedy algorithm: Polynomial O(n^3)
- but yields an approximation
- Dynamic programming yields an exact solution
  but requires O(weightxobjects) time
  (weights should not be too bigs)

Last but not least: Java applets!

Applets are special java programs...
...that can run into your favorite Internet browser

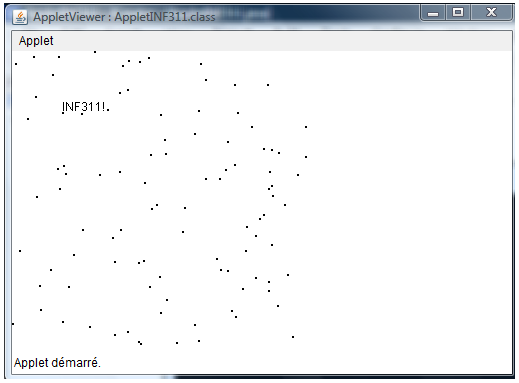
You need to:
(1) write a web page with <APPLET> </APPLET> tags
(2) write and compile the Java applet code (`javac`)

Advantages of applets are:
(1) to be accessible worldwide
(2) to provide graphics


```
import java.awt.*;
import java.applet.*;

class Point2D
{double x,y;
Point2D()
{this.x=300.0*Math.random();
this.y=300.0*Math.random();}}

public class AppletINF311 extends Applet {
final static int n=100;
static Point2D [] set;

   public void init() {
      int i;
      set=new Point2D[n];
      for(i=0;i<n;i++)
         set[i]=new Point2D();}

   public void paint(Graphics g) {int i;

      for(i=0;i<n;i++)
      {
      int xi, yi;
      xi=(int)set[i].x; yi=(int)set[i].y;
      g.drawRect(xi, yi,1,1);
      }
      g.drawString("INF311!", 50, 60 );
   }
}
```


Java applets

```
<APPLET
   code   = "AppletINF311.class"
   width  = "500"
   height = "300"
   >
</APPLET>
```



Java applets for online demos...

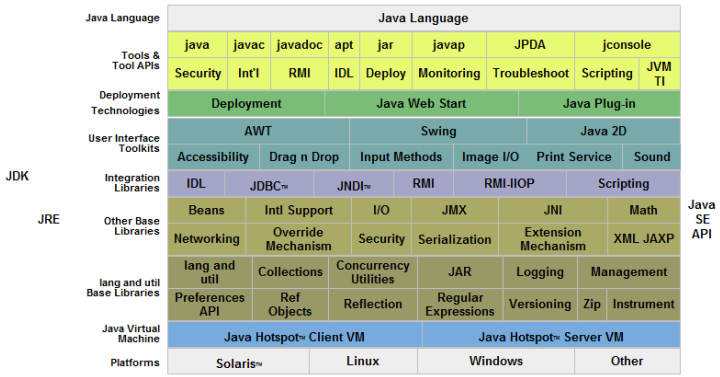
Hallucination (mirage)

Two technologies in use:
- Image segmentation
- Texture synthesis (hole filling)

Try it !!! http://www.sonycsl.co.jp/person/nielsen/ClickRemoval/

F. Nielsen, R. Nock ClickRemoval: interactive pinpoint image object removal. ACM Multimedia 2005

There is much more in Java!



JDK™ 6 Documentation

A glimpse at object inheritance

All objects inherit from the topmost object: `Object`
...meaning some methods are already **predefined**

java.lang
Class Object

`java.lang.Object`

`public class Object`

Class `Object` is the root of the class hierarchy. Every cl
the methods of this class.

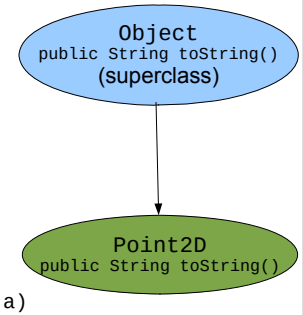
Method Summary

protected Object	clone() Creates and returns a copy of this object.
boolean	equals(Object obj) Indicates whether some other object is "equal to" this one.
protected void	finalize() Called by the garbage collector on an object when garbage collection determines that there are no more references to the object.
Class<?>	getClass() Returns the runtime class of this Object.
int	hashCode() Returns a hash code value for the object.
void	notify() Wakes up a single thread that is waiting on this object's monitor.
void	notifyAll() Wakes up all threads that are waiting on this object's monitor.
String	toString() Returns a string representation of the object.

Can overwrite the method `toString`

A glimpse at object inheritance

```
class Point2D
{double x,y;
// Constructor
Point2D(double xi, double yi)
{this.x=xi;this.y=yi;}
// Overrides default method
public String toString()
{return "["+x+" "+y+"]";}
}

class SuperClass
{
public static void main(String [] a)
{
  Point2D myPoint=new Point2D(Math.PI, Math.E);
  System.out.println("Point:"+myPoint);
}
}
```




```
Point:[3.141592653589793 2.718281828459045]
```


http://www.enseignement.polytechnique.fr/profs/informatique/Robert.Cori/Questionnaire/resultatSondage.html

Sondage sur l'enseignement INF 311 (débutants), Promotion X2006: l résultats (mer jui 4 13:14:23 CEST 2007)

Nombre de réponses: 241

Les renseignements que vous fournirez dans ce sondage seront très utiles pour l'amélioration des enseignements futurs.

Qui êtes-vous?

- Votre nom (facultatif)
- Filière d'entrée à l'X MP1 2 MP SI 58 PC 112 PSI 36 PT 8 TSI 2 UNIV 2 EV1 3 EV2 22
- Votre numéro de groupe de TD 1 20 2 16 3 19 4 13 5 20 6 21 7 21 8 22 9 19 10 18 11 24 12 21

Opinions générales sur le cours

- Intérêt de la matière enseignée Grand 59 Assez grand 140 Assez faible 44 Faible 6

Please answer the poll INF311
(in TD10)

Inspired by Rober Cori...

Merci et a bientot!

Année	Septembre	Octobre	Novembre	Décembre	Janvier	Février	Mars	Avril	Mai	Juin	Juillet	Août
1	Incorporation								INF 311: Introduction à l'informatique INF 321: Principes des langages de programmation			
2	INF 421: Programmation et Algorithmique		INF 421: Programmation et Algorithmique			INF 431: Algorithmes et Programmation: du séquentiel au distribué						
						INF444: Modex			INF444: Modex			
3		Programmes d'approfondissement (Master 1)							Stage de recherche (Master 1)			
4	Année professionalisante (Master 2)											

http://www.enseignement.polytechnique.fr/informatique/

- M1 Informatique, thematique Image
- Colloquium Nov. on visual computing.