

CSC373 Worksheet 2 Solution

July 25, 2020

1) $[a_{11} = [12, 16]]$

i	1	2	3	4	5	6	7	8	9	10	11
s_i	1	3	0	5	3	5	6	8	8	2	12
f_i	4	5	6	7	9	9	10	11	12	14	16

A red arrow points from $s_{11} = 12$ to $f_8 = 11$. A blue arrow labeled k points up to $s_{11} = 12$.

3) $[a_{11} = [12, 16], a_2 = [8, 11], a_4 = [5, 7]]$

i	1	2	3	4	5	6	7	8	9	10	11
s_i	1	3	0	5	3	5	6	8	8	2	12
f_i	4	5	6	7	9	9	10	11	12	14	16

A red arrow points from $s_4 = 5$ to $f_2 = 5$. A blue arrow labeled k points up to $s_4 = 5$.

2) $[a_{11} = [12, 16], a_2 = [8, 11]]$

i	1	2	3	4	5	6	7	8	9	10	11
s_i	1	3	0	5	3	5	6	8	8	2	12
f_i	4	5	6	7	9	9	10	11	12	14	16

A red arrow points from $s_8 = 8$ to $f_7 = 10$. A blue arrow labeled k points up to $s_8 = 8$.

3) $[a_{11} = [12, 16], a_2 = [8, 11], a_4 = [5, 7], a_1 = [1, 4]]$

i	1	2	3	4	5	6	7	8	9	10	11
s_i	1	3	0	5	3	5	6	8	8	2	12
f_i	4	5	6	7	9	9	10	11	12	14	16

A blue arrow labeled k points up to $s_1 = 1$.

1.

This approach is a greedy algorithm because algorithm

- 1) Has the greedy choice: selecting the last activity to start that is compatible with all previously selected activities
- 2) Has the greedy choice that is always part of optimal solution:

Claim:

Consider any nonempty subproblem S_k . Let a_m be an activity in S_k with the last activity to start that is compatible with all previously selected activities. Then a_m is included in some maximum-size subset of mutually compatible activities of S_k

Proof. Let A_k be a maximum-size subset of mutually compatible activities in S_k , and let a_j be the activity in A_k with the last activity to start that is compatible with all previously selected activities.

If $a_j = a_m$, we are done, since we have shown that a_m is the maximum-size subset of mutually compatible activities of S_k .

If $a_j \neq a_m$, let the set $A'_k = A_k = \{a_j\} \cup \{a_m\}$ be A_k but substituting a_m for a_j . The activities in A'_k are disjoint, which follow because the activities in A_k are disjoint, a_j is the first activity in A_k to finish, and $s_j \leq s_m$.

Since $|A'_k| = |A_k|$, we conclude that A'_k is a maximum-size subset of mutually compatible activities of S_k , and it includes a_m . \square

Notes:

- Greedy Algorithm
 - Always makes the choice that looks best at the moment
 - * Locally optimal solution leads to globally optimal solution
- Activity-selection Problem (Greedy algorithm using dynamic programming)
 - Goal: Selecting maximum size set of mutually compatible activities

Example:

i	1	2	3	4	5	6	7	8	9	10	11
s_i	1	3	0	5	3	5	6	8	8	2	12
f_i	4	5	6	7	9	9	10	11	12	14	16

- Suppose a set exists $S = \{a_1 = [s_1, f_1), a_2 = [s_2, f_2), \dots, a_n = [s_n, f_n)\}$
 - * a_i represents an i^{th} activity
 - * s_i represents starting time
 - * f_i represents finishing time
 - * $0 \leq s_i < f_i < \infty$
 - * a_1, \dots, a_n sorted in monotonically increasing order of finish time

i.e.

$$f_1 \leq f_2 \leq f_3 \leq \dots \leq f_{n-1} \leq f_n$$

- * a_i and a_j are **compatible**, if intervals $[s_i, f_i)$ and $[s_j, f_j)$ don't overlap

i.e

$$s_i \geq f_j \text{ and } s_j \geq f_i$$

- Steps
 1. Think about dynamic programming solution
 - * Construct optimal solution using two subproblems

S_{ij} : activities that start after activity a_i finishes and before activity a_j starts

i.e.

$$S_{19} = \{a_4 = [5, 7), a_6 = [5, 9), a_7 = [6, 10)\}$$

A_{ij} : maximum set of mutually compatible activities in S_{ij} (including a_k)

- $A_{ik} = A_{ij} \cap S_{ik}$
- $A_{kj} = A_{ij} \cap S_{kj}$
- $A_{ij} = A_{ik} \cup \{a_k\} \cup A_{kj}$
- So, $|A_{ij}| = |A_{ik}| + |A_{kj}| + 1$

- * Verify that optimal solution A_{ij} must include optimal solution to the two subproblems for S_{kj}

Let A'_{kj} be another mutually compatible activities in S_{kj} where $|A'_{kj}| > |A_{kj}|$.

Then we could use A'_{kj} in a solution to subproblem of S_{ij}

Then we have $|A_{ik}| + |A'_{kj}| + 1 > |A_{jk}| + |A_{kj}| + 1 = |A_{ij}|$ mutually compatible activities

This contradicts assumption that A_{ij} is an optimal solution

- * Verify that optimal solution A_{ij} must include optimal solution to the two subproblems for S_{ik}

The same applies for activities in S_{ik}

2. Observe that only one choice - greedy choice, and that when we make the greedy choice, only one subproblem remains

- * Steps

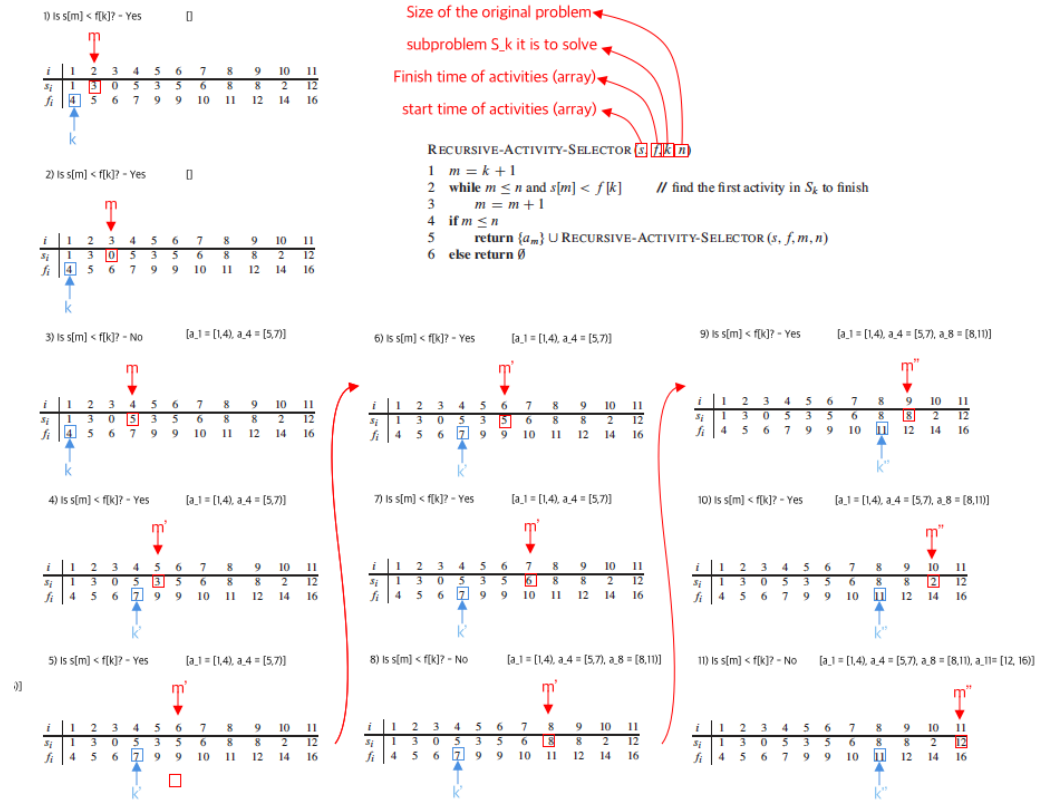
1. Make a greedy choice
 - Choose an activity that makes the most resource possible (intuition)
 - Choose an activity that finishes the earliest (intuition)
2. Solve a subproblem: Find activities that start after a_1 finishes
3. Verify that making greedy choices always arrive at optimal solution

Theorem 16.1 (Page 418):

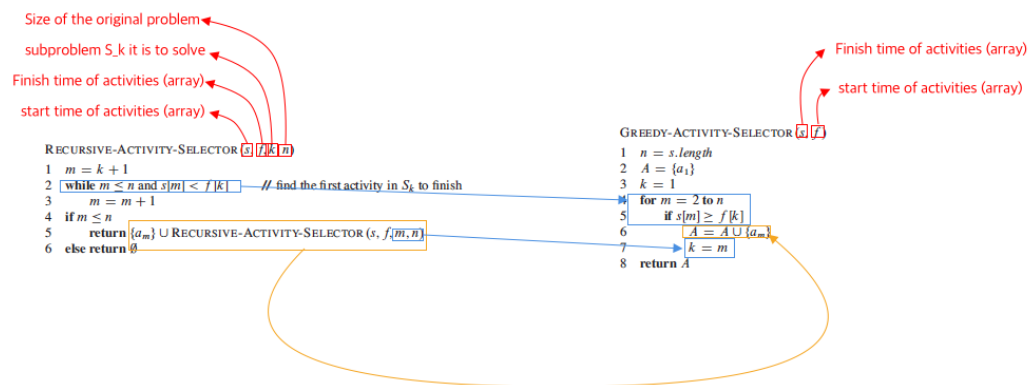
Consider any non-empty subproblem S_k , and let a_m be an activity in S_k with the earliest finish time. Then a_m is included in some maximum-size

subset of mutually compatible activities of S_k

3. Develop recursive greedy solution



4. Convert the recursive algorithm into iterative one



2. Notes:

- Greedy-choice property and optimal substructure to problem are the two key ingredients

- Summary of Steps for Greedy Algorithm

1. Determine the optimal structure of the problem
2. Develop a recursive solution.
3. Show that if we make the greedy choice, then only one subproblem remains
4. Prove that it is always safe to make the greedy choice
5. Develop a recursive algorithm that implements the greedy strategy
6. Convert the recursive algorithm to an iterative algorithm

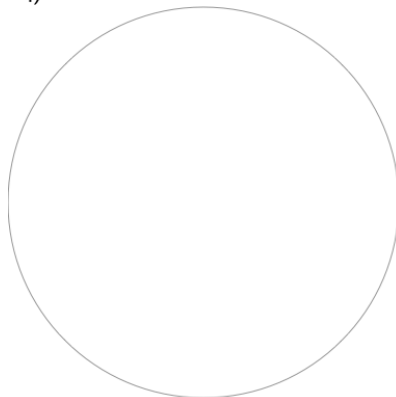
- Criteria for Greedy Algorithm

1. Greedy-choice property
 - Exists if we can assemble a globally optimal solution by making a locally optimal (greedy) choices
2. Optimal Substructure
 - Exists if an optimal solution to the problem contains within it optimal solutions to subproblems.

- Greedy vs Dynamic Programming

- 0-1 Knapsack Problem

1)



Capacity: 50 lbs
Current: 50lbs

item 1
weight: 10 lbs
worth: \$60
value: \$6/lbs

item 2
weight: 20 lbs
worth: \$100
value: \$5/lbs

item 3
weight: 30 lbs
worth: \$120
value: \$4/lbs

0-1 Knapsack Problem

2)

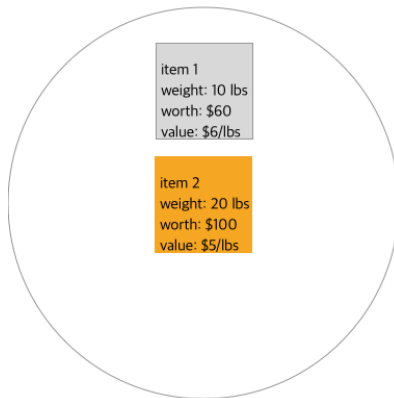


Capacity: 50 lbs
current: 40 lbs

item 2
weight: 20 lbs
worth: \$100
value: \$5/lbs

item 3
weight: 30 lbs
worth: \$120
value: \$4/lbs

3)



Capacity: 50 lbs
current: 20 lbs

item 3
weight: 30 lbs
worth: \$120
value: \$4/lbs

Uh oh. This is not greedy!

– Fractional Knapsack Problem

1)



Capacity: 50 lbs
Current: 50lbs

Fractional Knapsack Problem

item 1
weight: 10 lbs
worth: \$60
value: \$6/lbs

item 2
weight: 20 lbs
worth: \$100
value: \$5/lbs

item 3
weight: 30 lbs
worth: \$120
value: \$4/lbs

2)



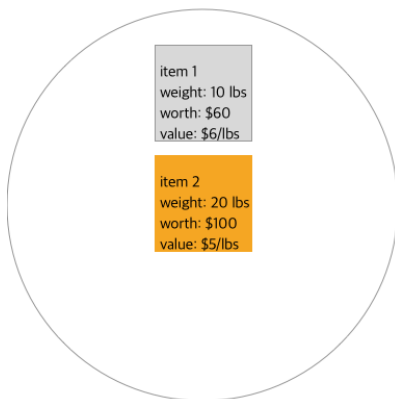
Capacity: 50 lbs
current: 40 lbs

item 1
weight: 10 lbs
worth: \$60
value: \$6/lbs

item 2
weight: 20 lbs
worth: \$100
value: \$5/lbs

item 3
weight: 30 lbs
worth: \$120
value: \$4/lbs

3)



Capacity: 50 lbs
current: 20 lbs

item 1
weight: 10 lbs
worth: \$60
value: \$6/lbs

item 2
weight: 20 lbs
worth: \$100
value: \$5/lbs

item 3
weight: 30 lbs
worth: \$120
value: \$4/lbs

item 2
weight: 20 lbs
worth: \$100
value: \$5/lbs

4)

