

score: 400

500

3-2 Greedy Algorithms

(How to justify your greed?)

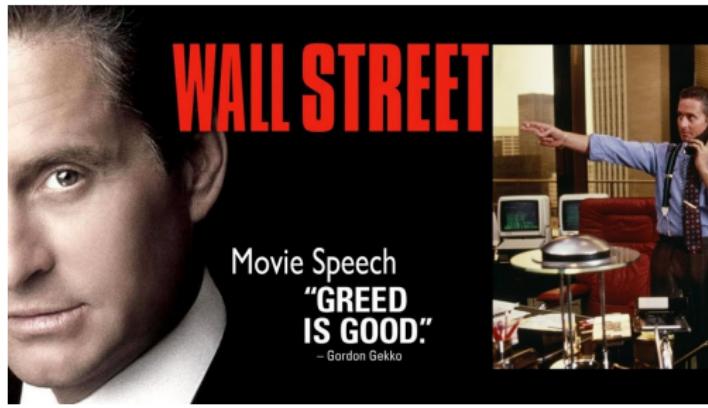
Hengfeng Wei

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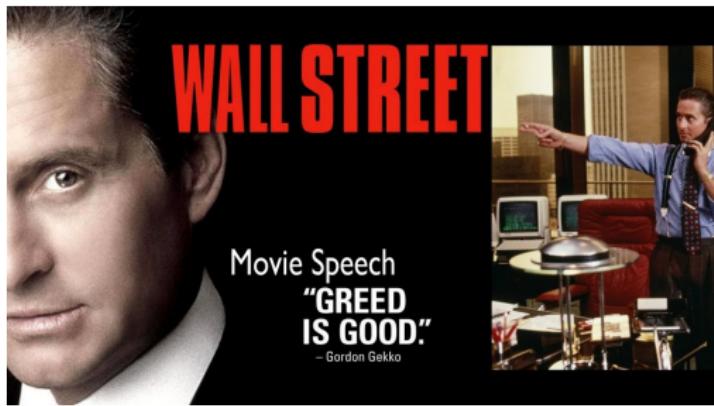
September 29, 2018



"GREED IS GOOD."



“GREED IS GOOD.”



“BUT”

*“Greedy algorithms without **proofs** are considered wrong.”*

Proof: Inductive Exchange Argument

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Theorem (Greedy-Choice Property)

There is an optimal solution that makes the greedy choice.

Theorem (Optimal Substructure Property)

A problem exhibits optimal substructure if an optimal solution to the problem contains within it optimal solutions to subproblems.

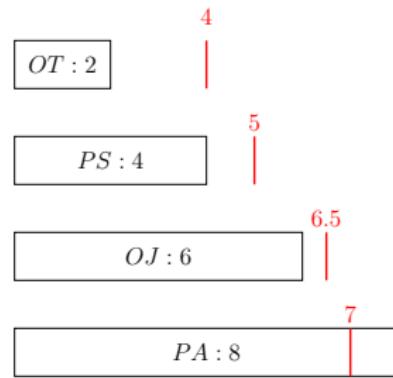
Live with Your Deadlines (Additional Problem)

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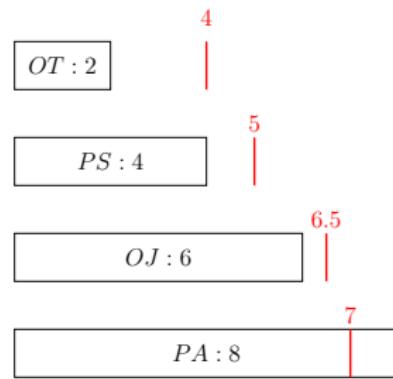
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$HW_i : (Length : t_i, \ Deadline : d_i)$



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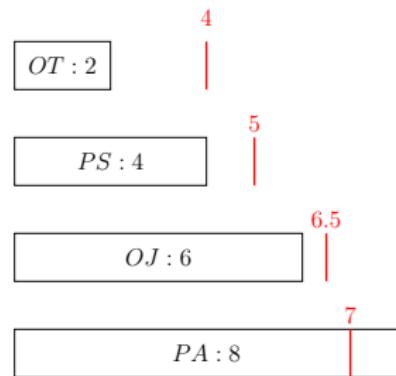


Finish time : $f_i = s_i + t_i$

Lateness : $l_i = f_i - d_i \quad (0 \text{ if } f_i \leq d_i)$

Live with Your Deadlines (Additional Problem)

$$HW_i : (Length : t_i, \text{Deadline} : d_i)$$



$$\text{Finish time} : f_i = s_i + t_i$$

$$\text{Lateness} : l_i = f_i - d_i \quad (0 \text{ if } f_i \leq d_i)$$

$$\min (L \triangleq \max_i l_i)$$

What are your greedy strategies?

**“I love deadlines.
I like the
whooshing
sound they
make as they
fly by. ”**

Douglas Adams

Shortest Job First: $\min t_i$

Urgentest Job First: $\min(d_i - t_i)$

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$$t_1 = 1, d_1 = 100$$

$$t_2 = 10, d_2 = 10$$

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Urgentest Job First: $\min(d_i - t_i)$

$$t_1 = 1, d_1 = 2$$

$$t_2 = 10, d_2 = 10$$

Earliest Deadline First



Proof: Inductive Exchange Argument.

$$\mathcal{O} : J_1^*, J_2^*, \dots, J_n^*$$

$$\mathcal{G} : J_1, J_2, \dots, J_n, \quad (d_i \leq d_j, \forall i \leq j)$$

J_i : a job with the **earliest** deadline

$$d_{J_i} < d_{J_1^*}$$

$$d_{J_i} \leq d_{J_i^*}$$

J_1^*		J_i^*		J_i		
---------	--	---------	--	-------	--	--

J_i		J_i^*		J_1^*		
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$$l'_{J_i^*} = f'_{J_i^*} - d_{J_i^*} \leq f_{J_i} - d_{J_i^*} \leq f_{J_i} - d_{J_i} = l_{J_i}$$

Theorem

All schedules with no idle time and no inversions have the same maximum lateness.

Theorem (Optimal Substructure Property)

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$$L(s, S)$$

The optimal lateness obtainable from scheduling the jobs in S

which are available to start at the common start time s .

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$$L(s, S)$$

The optimal lateness obtainable from scheduling the jobs in S

which are available to start at the common start time s .

What is the first job to schedule?

$$L(s, S) = \min_{1 \leq i \leq n} \left(\max (L(0, \{J_i\}), L(t_i, J \setminus \{J_i\})) \right)$$

$$J = \{J_1, J_2, J_3\}$$

$$t_1 = 6, t_2 = 2, t_3 = 2$$

$$d_1 = 2, d_2 = 7, d_3 = 8$$

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$$\mathcal{O} : J_1, J_3, J_2$$

$$L(0, \{J_1, J_2, J_3\}) = 4$$

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$$\mathcal{O}' \not\subset \mathcal{O}$$

$$\exists \mathcal{O} \triangleq J_1, J_2, J_3 : \mathcal{O}' \subset \mathcal{O}$$

Theorem

The greedy solution has no idle time and no inversions.

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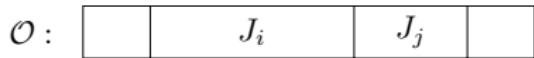
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Immediate Inversion

$$d_j < d_i$$



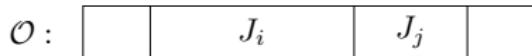
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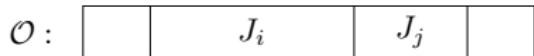
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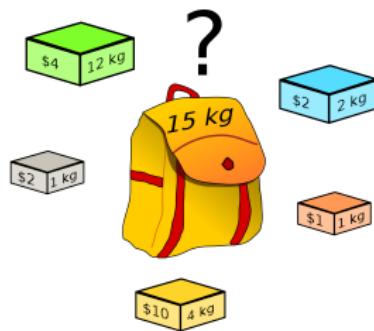


$$l'_i = f_j - d_i < f_j - d_j = l_j$$



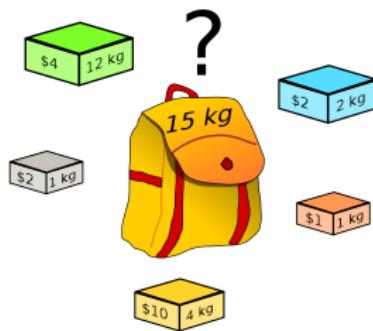
Fractional Knapsack Problem (Problem 16.2-1)

Prove that the fractional knapsack problem has the greedy-choice property.



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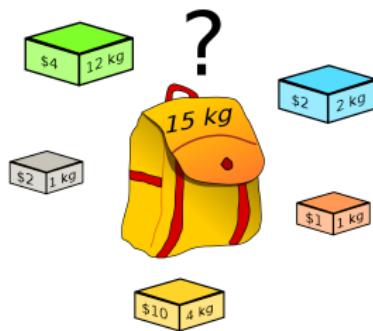
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\exists an optimal solution which contains the greedy choice.

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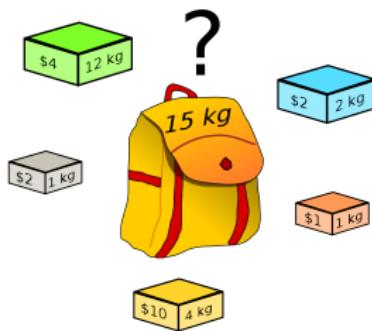


\exists an optimal solution which contains the greedy choice.

$$\frac{v_1}{w_1} \geq \frac{v_2}{w_2} \geq \dots \geq \frac{v_n}{w_n}$$

Fractional Knapsack Problem (Problem 16.2-1)

Prove that the fractional knapsack problem has the greedy-choice property.



\exists an optimal solution which contains the greedy choice.

$$\frac{v_1}{w_1} \geq \frac{v_2}{w_2} \geq \dots \geq \frac{v_n}{w_n}$$

As most item of $\frac{v_1}{w_1}$ as possible.

Change-Making Problem (Problem 16-1 (a))



Making change for v cents using the fewest number of coins.

Change-Making Problem (Problem 16-1 (a))



25



10



5



1

Making change for v cents using the fewest number of coins.

$$\text{OPT} : v = 25 \times A^* + 10 \times B^* + 5 \times C^* + 1 \times D^*$$

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$$G : v = 25 \times A + 10 \times B + 5 \times C + 1 \times D$$

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(A^*, B^*, C^*, D^*) vs. (A, B, C, D)

$$\text{OPT} : v = 25 \times A^* + 10 \times B^* + 5 \times C^* + 1 \times D^*$$

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(A^*, B^*, C^*, D^*) vs. (A, B, C, D)

$$A^* = A$$

$$\text{OPT} : v = 25 \times A^* + 10 \times B^* + 5 \times C^* + 1 \times D^*$$

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Lemma (Properties of OPT)

- (I) $B^* \leq 2$
- (II) $C^* \leq 1$
- (III) $D^* \leq 4$
- (IV) $\neg(B^* = 2 \wedge C^* = 1)$

$$\text{OPT} : v = 25 \times A^* + 10 \times B^* + 5 \times C^* + 1 \times D^*$$

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Theorem

$$10 \times B^* + 5 \times C^* + 1 \times D^* \leq 24$$

$$5 \times C^* + 1 \times D^* \leq 9$$

$$1 \times D^* \leq 4$$

$$\text{OPT} : v = 25 \times A^* + 10 \times B^* + 5 \times C^* + 1 \times D^*$$

Lemma (Properties of OPT)

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$$10 \times B^* + 5 \times C^* + 1 \times D^* \leq 24$$

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$$1 \times D^* \leq 4$$

$$(A^*, B^*, C^*, D^*) = (A, B, C, D)$$

Change-Making Problem (Problem 16-1 (c))



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$$\{1, 3, 4\}, \quad v = 6$$

Change-Making Problem (Problem 16-1 (c))



$$\{1, 3, 4\}, \quad v = 6$$

G : 4, 1, 1 **vs.** OPT : 3, 3

Change-Making Problem (Problem 16-1 (c))



$$\{1, 3, 4\}, \quad v = 6$$

$$G : 4, 1, 1 \quad vs. \quad OPT : 3, 3$$

Why does the previous proof fail here?

Change-Making Problem (Problem 16-1 (b))

$$c^0, c^1, c^2, \dots, c^k, \quad c > 1, k \geq 1$$

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Change-Making Problem (Problem 16-1 (b))

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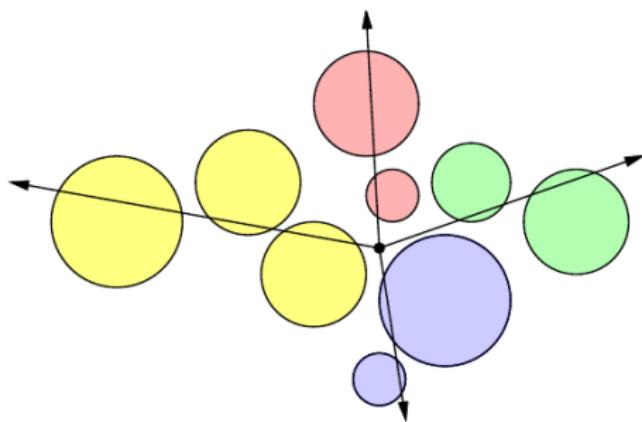
$$\text{G} : v = \sum_{i=0}^{i=k} c^i \color{blue}{a_i}$$

$$\color{red}{a_i^*} = \color{blue}{a_i}$$

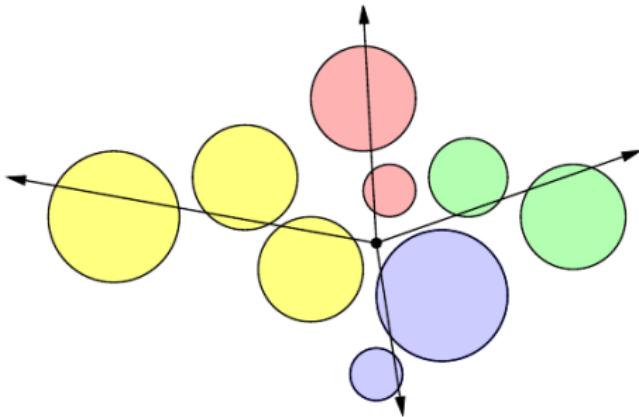
Canonical Coin Systems



Minimum Shots Problem (Additional Problem)



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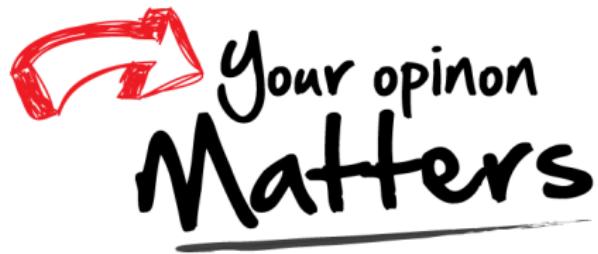


Assumption:

Possible to shoot a ray that does not intersect any balloons.







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