1. Examples

This document is an example of how to use LaTeX for writing homework solutions. Read the text, commented out by % signs, to get some explanations.

a) This part includes a theorem with a proof and uses mathematical expressions.

Theorem 1.

$$\sum_{i=1}^{n} i = \frac{n(n+1)}{2} \tag{1}$$

Proof. The proof is by induction.

Base case: Prove that the formula is true when $n = 1$. The LHS is $\sum_{i=1}^{1} i = 1$, while the RHS is $\frac{1(1+1)}{2} = 1$. Hence, the base case holds.

Induction step: For each $k \geq 1$, assume that (1) is true for $n = k$. We show that it is true for $n = k + 1$.

$$\sum_{i=1}^{k+1} i = \sum_{i=1}^{k} i + (k+1) = \frac{k(k+1)}{2} + (k+1) = \frac{k(k+1) + 2(k+1)}{2} = \frac{(k+1)(k+2)}{2},$$

where the second equality follows from induction hypothesis that $\sum_{i=1}^{k} i = \frac{k(k+1)}{2}$. The formula (1) is true for $n = k + 1$, which proves the theorem. $\square$

b) This part has a figure that displays a picture from an external file.

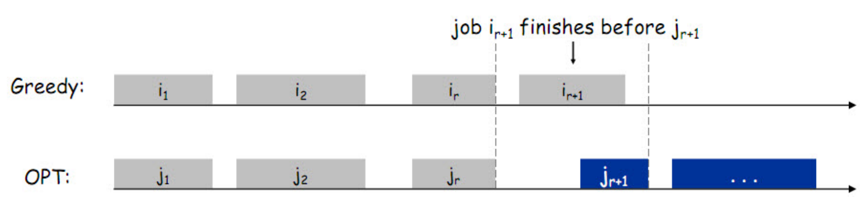

Figure 1: Comparing two sets of jobs

c) This part has an example of writing algorithm psuedocode.

Assume that there are n jobs and the i^{th} job has a start time $s(i)$ and a finish time $f(i)$. These jobs are sorted with respect to their finish time. For simplicity, we assume that the sorted jobs are numbered 1,2,..., n such that $f(1) \leq f(2) \leq \cdots \leq f(n)$.

A set of jobs is *compatible* with a job j if none of the jobs in the set overlaps with j. The algorithm maintains A, a set of selected jobs, which is initially empty. Our intuitive approach is to grow A by choosing a compatible job with the earliest finish time at each step.

Let $i_1, ..., i_k$ be the set of jobs in A in the order they were added to A. Similarly, let the set of jobs in B, which selects jobs in some method other than greedy approach, be denoted by $j_1, ..., j_\ell$. One interesting consequence is that the greedy rule *stays ahead*: $f(i_m) \leq f(j_m)$ for $1 \leq m \leq \min(k, \ell)$.

Algorithm 1: Earliest-Finish-Time(L).

input : a list L of n jobs.
output: a maximum set of mutually compatible jobs.

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Sort jobs by finish times so that f(1) ≤ f(2) ≤ ··· ≤ f(n).
Maintain a set A which is initially empty.
for i = 1 to n do
    If the job i is compatible with A, then include i to A.
end
Output A.
```

Claim 2. *For all indices* $m \leq \min(k, \ell)$, $f(i_m) \leq f(j_m)$.

Proof. We prove by induction on the index m. For $m = 1$, the statement is true because the greedy approach selects the job with the earliest finish time. For $m > 1$, we will assume the statement is true for $m = t-1$ and prove it for $m = t$. The t^{th} job in B must start after $f(j_{t-1})$ since this job is compatible with B. It means $f(j_{t-1}) \leq s(j_t)$. By combining the induction hypothesis $f(i_{t-1}) \leq f_j(t-1)$, it also means $f(i_{t-1}) \leq s(j_t)$. So this job is compatible with A too. As the greedy algorithm selects a job with earliest finish time, $f(i_t)$ is not larger than $f(j_t)$. This completes the induction step; therefore, the statement is true. □

Proof of Correctness Assume for contradiction that the greedy approach returns a non-optimal solution A while an optimal set $\mathcal{O}$ has more jobs. Assume that $|A| = k$ and $|\mathcal{O}| = \ell$ with $\ell > k$. By Claim 2, we have $f(i_k) \leq f(j_k)$. Let us focus on the $(k+1)^{\text{th}}$ job x in $\mathcal{O}$. The job x starts after the job j_k ends and hence after the job i_k ends. But the greedy algorithm stops with i_k while x is compatible with A – a contradiction.

Implementation Once the input jobs are sorted, an array is enough for the set A. When a new job is checked for compatibility with A, it is enough to compare its start time with the last added job x's finish time rather than all the jobs' finish times in A – the resource becomes free after $f(x)$ and the input jobs are sorted.

Time and Space Complexity It takes $\Theta(n \log n)$ time to sort the input jobs of size n. Creating an array of size n takes $O(n)$ time. For each job, it takes $O(1)$ time to check whether a job is compatible with the set A, and the array can be updated in constant time if we maintain an end-of-the-array pointer. These operations must be repeated for each job, so the `For` loop takes $O(n)$ time. Hence, the total running time is $O(n \log n)$.

It takes $O(n)$ space to store the input. An in-place sorting takes $O(n)$ space. Finally, the set A can be implemented by an array of size n. Thus, the space complexity is $O(n)$.