

1. Examples

This document is an example of how to use L^AT_EX 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 pseudocode.

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 $1, 2, \dots, n$ such that $f(1) \leq f(2) \leq \dots \leq f(n)$.

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, \dots, 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, \dots, j_ℓ . 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.

- 1 Sort jobs by finish times so that $f(1) \leq f(2) \leq \dots \leq f(n)$.
- 2 Maintain a set A which is initially empty.
- 3 **for** $i = 1$ **to** n **do**
- 4 If the job i is compatible with A , then include i to A .
- end**
- 5 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. \square

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 $O(n)$.