Finding upper bound for tightening of individual constraints in flexible manufacturing systems

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Introduction

This research focuses on analyzing schedules created for an industrial printer. The schedule, along with model constraint is reduced to a graph, in a way such that all constraints like times between operations and due times are represented as edges.

Objective

To determine the maximum amount by which each constraint can individually be changed to make a given schedule infeasible. Results obtained can be used for goals like risk analysis and adapting a scheduling solution to a changing environment.

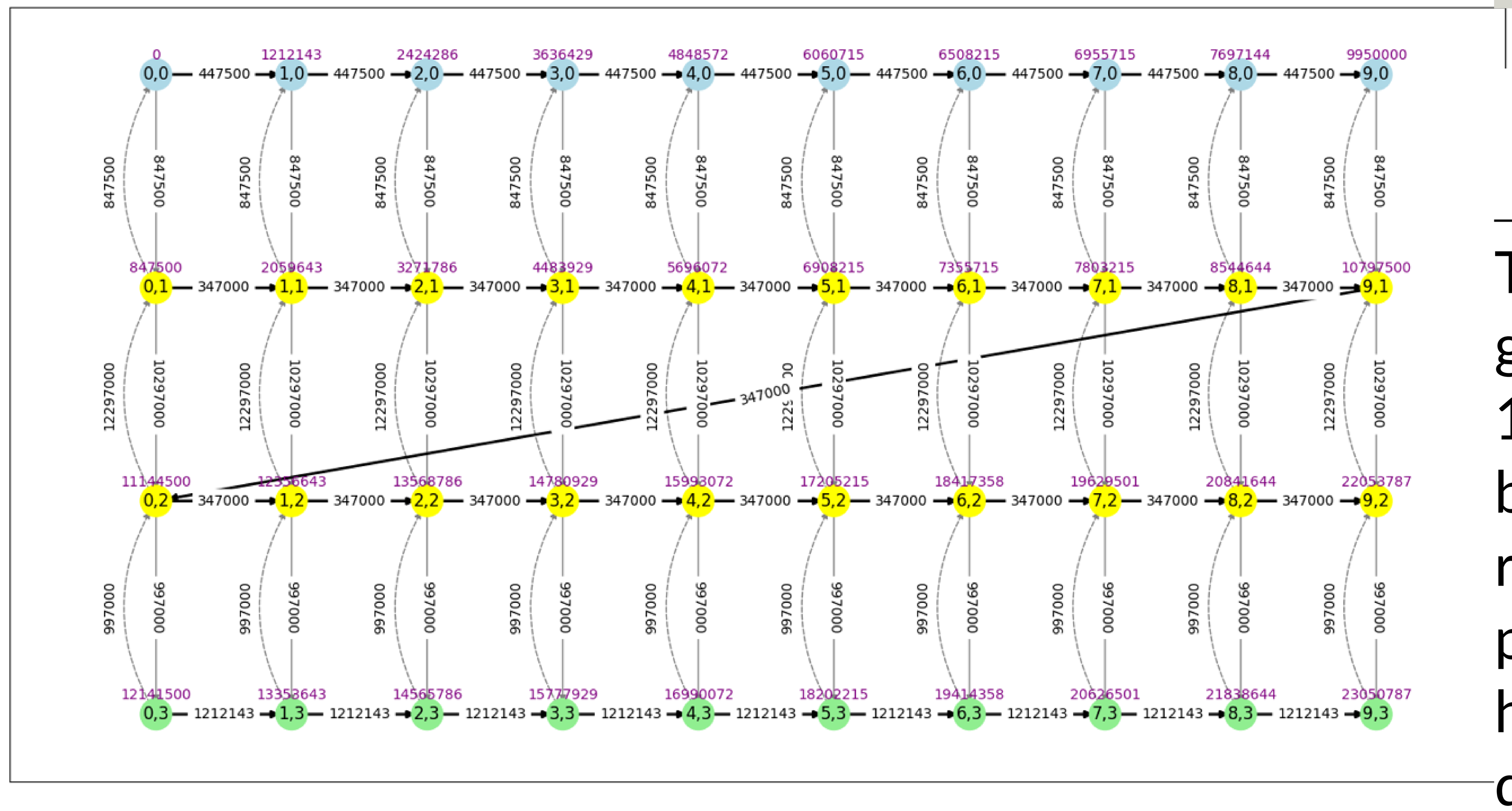

Figure 1. Example graph of a simple schedule

Solutions

Using the knowledge that a positive cycle in the graph indicates an infeasible schedules, the solution makes use of a slight modification of Bellman-Ford to find the cycle with highest total weight containing the edge of a constraint. The absolute value of the total cycle is returned.

Complexity: O(|E| * |V|^2)

Temporal optimization

A heuristic solution that approximates the result of the base one can be utilized. The variation only checks nodes of the same machine for the highest weight cycle. Hypothetically works better in graphs with more consistent values of constraints between machines.

Experiments and results

The experiment was carried out by running the algorithm and its optimization for 450 schedules with 100 jobs, and 450 schedules with 500 jobs, generated based on industry data benchmarks. The base algorithm had around a 90-time increase in average computational time with the increase in jobs, whereas the heuristic approach had around a 40-time increase. The downside of the heuristic approach was an overestimation of the feasibility bound by around a factor of 2.1 for the 500-job schedules.

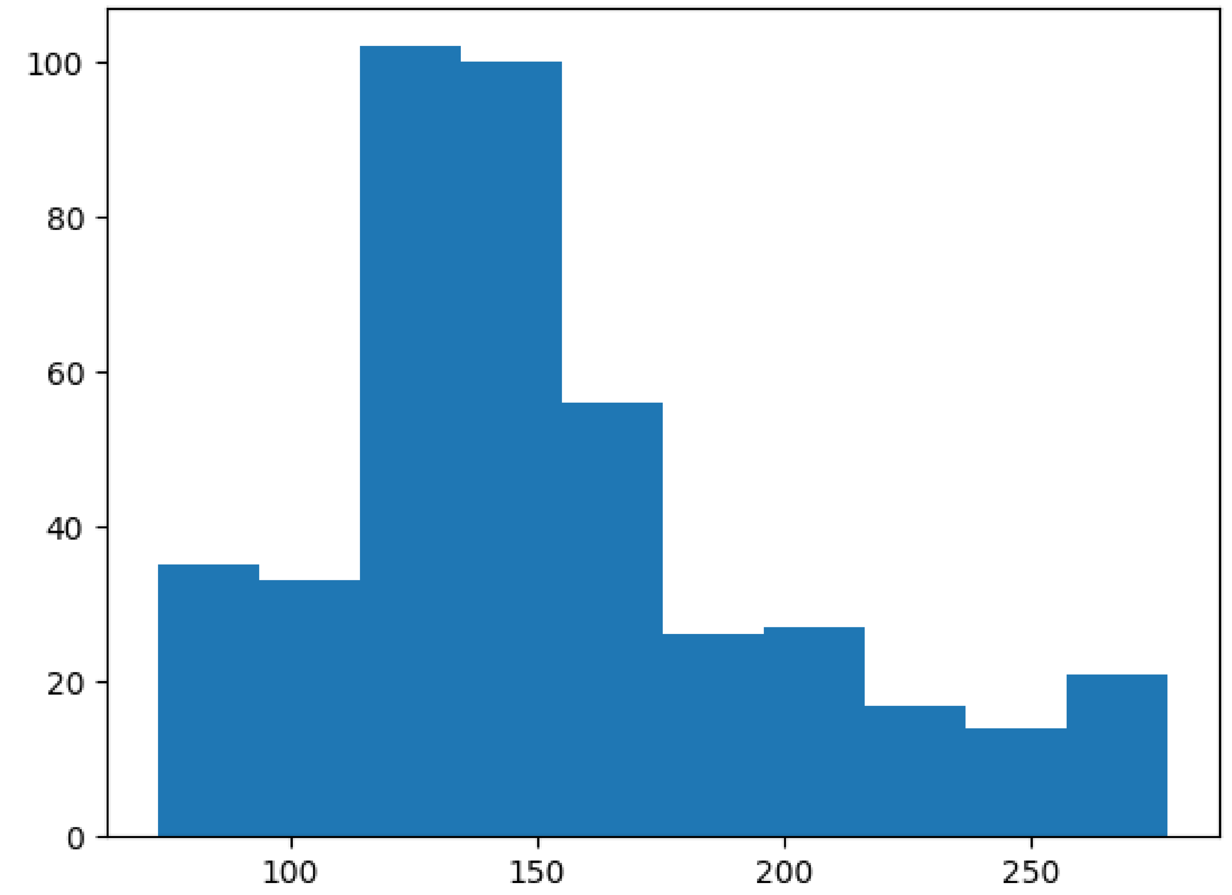

Figure 2. Distribution time taken by the optimal solution algorithm to calculate feasibility bounds for every node in the graph (in seconds)

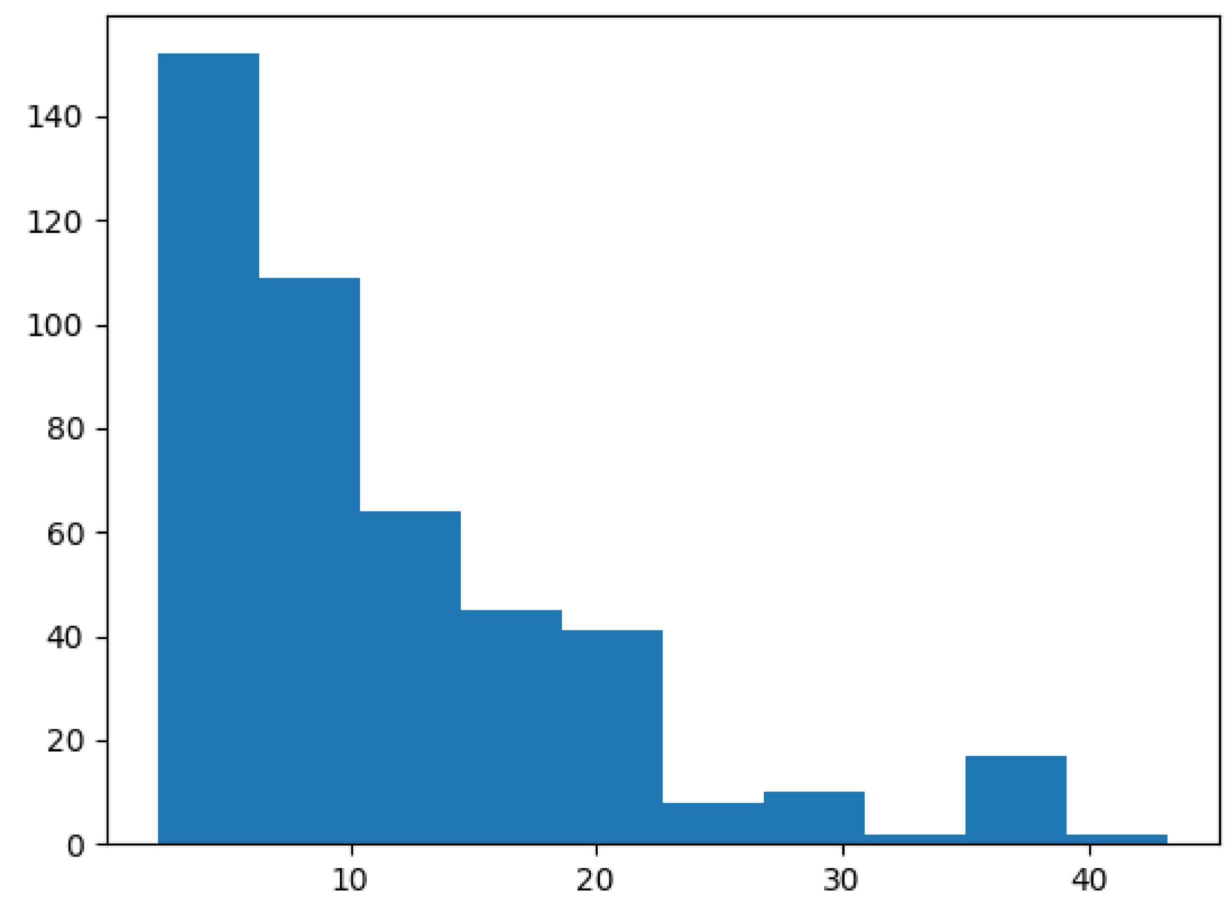

Figure 3. Distribution time taken by the heuristic solution algorithm to calculate feasibility bounds for every node in the graph (in seconds)

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