ASTRO-K: Finding Top-k Sufficiently Distinct Indoor-Outdoor Paths

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***Abstract*—CAPRIO is an indoor-outdoor pedestrian path recommendation system that optimizes for shortest distance. Its path-finding algorithm, *ASTRO*, takes into account a set of user-provided congestion constraints and as such can recommend paths that can reduce the risk of COVID-19 exposure. In this paper, we extend *ASTRO* to consider the changes on congestion when providing path recommendations for overlapping requests. Our new algorithm, called *ASTRO-K*, can provide K alternative paths that satisfy the congestion constraints of all the path requests within a short time-window. Our experimental evaluation is conducted using two real-world datasets and shows that *ASTRO-K* can reduce the total average congestion of the recommended paths up to 4.5X with the trade-off of up to 7% increased total path time.**

***Index Terms*—Top-k Paths, Constraint-based Path Finding, Indoor-Outdoor Graphs, Congestion, COVID-19**

I. Introduction

The COVID-19 pandemic has shown us that there is a clear need for pedestrian path finding systems which can recommend paths that reduce the exposure to viral infection diseases. The exposure to viral airborne diseases is higher in crowded and congested spaces, and hence avoiding them reduces the risk of contracting a virus.

In our previous work, we proposed a solution to this problem of "physical distancing" with *ASTRO* [1], a constraint-based path-finding algorithm which factors in the predicted congestion of a space when constructing a path. *ASTRO* was implemented as the core path finding algorithm in CAPRIO [2]–[4], our indoor-outdoor pedestrian path recommendation system that suggests the shortest distance path for a given departure and arrival time between two locations.

By offering only one path per request, *ASTRO* may inadvertently contribute towards congestion problems by funneling people into a single area.

In this paper, we introduce *ASTRO-K*, an extension of *ASTRO* which computes the top-k sufficiently distinct constraint-satisfying paths for overlapping requests. Overlapping requests have similar departure and arrival time between the same two locations as shown in Figure 1. This provides CAPRIO with more paths to choose from for overlapping requests submitted within a short time-window and thus reduces the probability of inadvertently contributing towards congestion. Our hypothesis is that, *by only recommending paths which are sufficiently distinct, we are able to promote physical distancing and decrease the recommendations' contribution to congestion.*

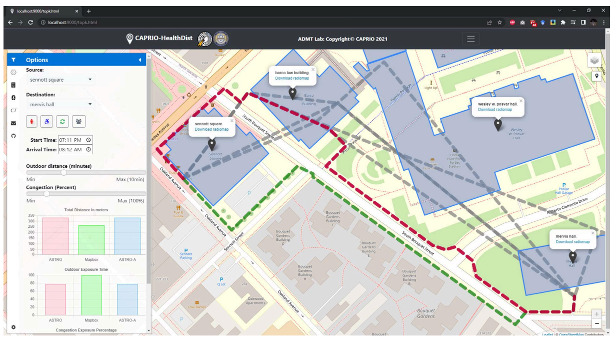

Fig. 1: CAPRIO with top-5 alternative paths produced by our *ASTRO-K*.

We evaluate *ASTRO-K* experimentally using two datasets modeling the campus of the University of Pittsburgh and the University of Cyprus. Our experiments show that *ASTRO-K* can reduce the average congestion by increasing K. Specifically, the average congestion of the recommended paths is reduced by 4.5X for the PITT dataset with $K = 6$ and 2.6X for the UCY dataset with $K = 3$. This reduction in the average congestion comes with the cost for the shortest distance. We observe an increase of total path time up to 7%. Clearly, these initial results are promising and support our hypothesis above.

Our main contributions are summarized as follows:

- We introduce *ASTRO-K*, an integration of the *ASTRO* and *ESX* [5] algorithms, which to our knowledge is the first algorithm for finding top-k sufficiently distinct constraint-satisfying paths.
- We conduct a preliminary experimental evaluation and show that *ASTRO-K* can reduce the total average congestion produced by the recommendations.

The rest of the paper is structured as follows. In the next section, we formalize the problem and provide the necessary background on *ASTRO* and *ESX* algorithms. In Section III, we present *ASTRO-K* and in Sections IV and V the experimental methodology and its evaluation respectively. In Section VI, we discuss related work.

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