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Urban navigation beyond shortest route: The case of safe paths

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ABSTRACT

Advancements in mobile technology and computing have fostered the collection of a large number of civic datasets that capture the pulse of urban life. Furthermore, the open government and data initiative has led many local authorities to make these datasets publicly available, hoping to drive innovation that will further improve the quality of life for the city-dwellers. In this paper, we develop a novel application that utilizes crime data to provide safe urban navigation. Specifically, using crime data from Chicago and Philadelphia we develop a risk model for their street urban network, which allows us to estimate the relative probability of a crime on any road segment. Given such model we define two variants of the SafePaths problem where the goal is to find a short and low-risk path between a source and a destination location. Since both the length and the risk of the path are equally important but cannot be combined into a single objective, we approach the urban-navigation problem as a biobjective shortest path problem. Our algorithms aim to output a small set of paths that provide tradeoffs between distance and safety. Our experiments demonstrate the efficacy of our algorithms and their practical applicability.

1. Introduction

A recent United Nations report states that more than 50% of the world's population currently lives in cities. This percentage is projected to increase to 70% by 2050 [9]. One of the main reasons for these levels of urbanization is the long-lived thought of cities as the paramount instrument for innovation and wealth creation. Nevertheless, there are side effects attached to this phenomenon. Cities have become the main source of crimes, diseases and pollution, significantly deteriorating the quality of life of their dwellers.

During the last years, local authorities have collected a large number of civic datasets that capture various aspects of urban life. These datasets include information for street constructions, crimes, bicycle routes, etc. The open government and data initiative from President Obama's administration [7] has further led many local authorities to systematically collect, organize and publicize such datasets. Besides the transparency of federal and local government operations, this initiative seeks the development of innovative services that will impact people's lives, from the people themselves.

In this paper, we take steps towards this direction. In particular, we focus on one of the major aforementioned problems present in almost every megacity today: crimes and public safety. We develop a novel application aiming to identify *safe* and *short* paths for people to take when they navigate the city. For this purpose, we take into consideration both the spatial constraints imposed by the structure of the city's road network as well as the criminal activity in the city. Ideally, prioritizing the safety of dwellers, one would like to provide the user with the safest path from origin s to destination t. However, such a

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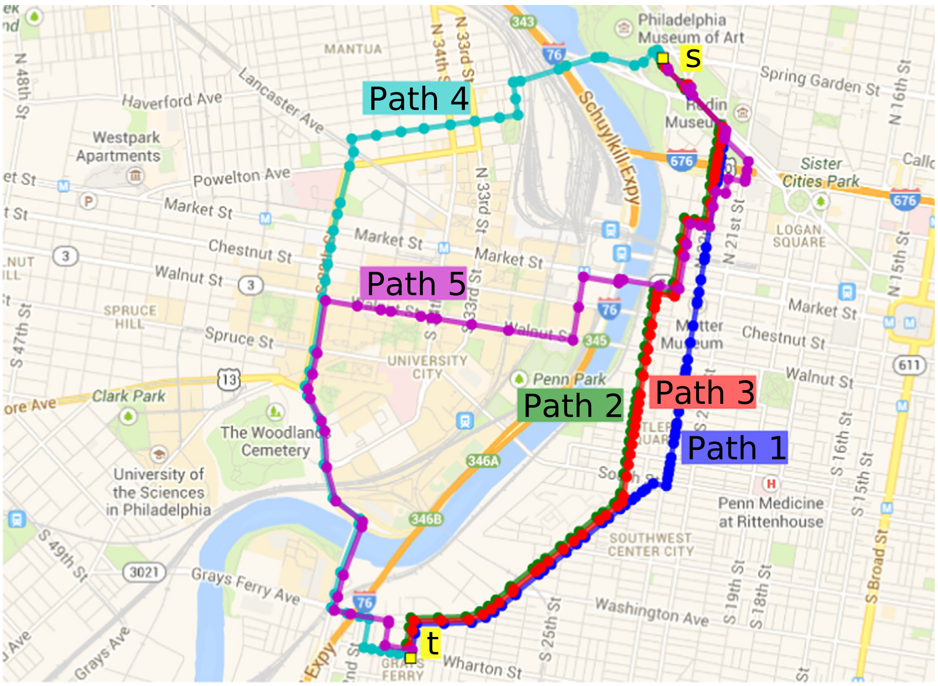
path may incur a significant penalty in the total distance that needs to be traveled. Conversely, the shortest path between s and t may be risky. Therefore, we approach the problem of safe urban navigation as a bicriteria optimization problem where the goal is to provide users with a small collection of paths, each offering a different tradeoff between distance and safety. Possibly, none of the available walking options might be satisfying to the user, who might consider that the safest path is still too risky, for instance, and in light of this information decide to use alternative means of transportation (e.g., taxi).

As an example, consider the scenario illustrated by Fig. 1: a city dweller is at the Philadelphia Museum of Art (s) and wants to return to her home on Wharton Street (t). Her shortest way to home is given by Path 1. However, according to the crime model we develop in Section 2, the itinerary indicated as Path 5 constitutes her safest option, which is also about 1.5 times longer than Path 1. Instead, our art lover may prefer one of the intermediate routes (Paths 2–4) that offer various tradeoffs between distance and risk.

Our approach in a nutshell: Our approach includes a modeling and an algorithmic component. As part of the former, we develop a framework for the crime risk on street urban networks. We focus on the US cities of Chicago and Philadelphia. After exporting their street networks from OpenStreetMap (OSM) into a graph format we use publicly available crime datasets to assign a risk score to each edge (i.e. street segment).

As part of the algorithmic component, we define the SafePaths problem as a biobjective shortest path problem where the goal is to output a *collection of paths* that offer different tradeoffs between their length and the associated risk. Of course the space of all possible paths can be extremely large and showing all such paths to the users may be overwhelming. Thus, our goal is to select a *small* subset of paths that gives a good summary of the solution space and the available tradeoffs. We study two variants of this generic problem that differ on their definition of the risk of a path. In the first variant, the risk of the path is defined as the total probability of a crime happening along all its segments. In the second variant, the risk of the path is defined as the maximum risk to which the user is exposed on any segment. The key challenge in designing algorithms for these problems stems from the fact that they aim to explore and summarize a possibly exponential solution space. The algorithms we present can report a representative set of paths in a matter of seconds. Moreover, we enhance these algorithms with early-stopping criteria which, in practice, lead to 4-fold reduction of the running time with minimal sacrifices in the information content they provide to the user.

Scope of our work: While we focus and study a specific aspect of public safety, one that is related to criminal



	Path 1	Path 2	Path 3	Path 4	Path 5
Length ℓ (m)	3955	4027	4060	4922	5988
Risk r ($\times 10^{-3}$)	2.32	2.02	2.01	1.71	1.70

Fig. 1. An illustrative example of safe urban navigation. The routes depicted as Paths 1–5 offer various compromises between distance and risk for traveling between s and t.