Fast Obstacle Spatial Query on Navigation Mesh

by

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Contents

Abstract . . . . **iv**

1 Introduction **1**
- 1.1 Overview 1
- 1.2 Major Challenges 2
- 1.3 Major Objectives 2
- 1.4 Thesis Organisation 2

2 Literature Review **3**
- 2.1 Overview 3
- 2.2 AI Search 3
- 2.3 Spatial Index 3
- 2.4 Obstacle k-Nearest Neighbor 3
- 2.5 Pathfinding on Navigation Mesh 3
- 2.6 Related Spatial Queries 3

3 Proposed Algorithms **4**
- 3.1 Overview 4
- 3.2 Interval Heuristic 4
- 3.3 Target Heuristic 4
- 3.4 Summary 4

4 Empirical Analysis **5**
- 4.1 Overview 5
- 4.2 Benchmark 5
- 4.3 Competitors 5
- 4.4 Experiment 1: lower bounds on performance 5
- 4.5 Experiment 2: computing more nearest neighbor 5
- 4.6 Experiment 3: changing number of targets 5

5 Conclusion and Future Work **6**
- 5.1 Research Contributions 6
- 5.2 Future Works 6

Bibliography **7**

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Abstract

Obstacle k-Nearest Neighbours problem is the k-Nearest Neighbour problem in a two-dimensional Euclidean plane with obstacles (*OkNN*). Existing and state of the art algorithms for OkNN are based on incremental visibility graphs and as such suffer from a well known disadvantage: costly and online visibility checking with quadratic worst-case running times. In this research we develop a new OkNN algorithm which avoids these disadvantages by representing the traversable space as a collection of convex polygons; i.e. a Navigation Mesh. We then adapt an recent and optimal navigation mesh algorithm, *Polyanya*, from the single-source single-target setting to the the multi-target case. We also give two new and online heuristics for OkNN. In a range of empirical comparisons we show that our approach can be orders of magnitude faster than competing methods that rely on visibility graphs.

Keywords: Obstacle Nearest Neighbor, kNN, Navigation Mesh, Spatial Search, Obstacle Distance, Obstacle Navigation

Chapter 1

Introduction

1.1 Overview

Obstacle k-Nearest Neighbour (OkNN) is a common type of spatial analysis query which can be described as follows: given a set of target points and a collection of polygonal obstacles, all in two dimensions, find the k closest targets to an a priori unknown query point q. Such problems appear in a myriad of practical contexts. For example, in an industrial warehouse setting a machine operator may be interested to know the k closest storage locations where a specific inventory item can be found. In competitive computer games meanwhile, agent AIs often rely on nearest-neighbour information to make strategic decisions such as during navigation, combat or resource gathering.

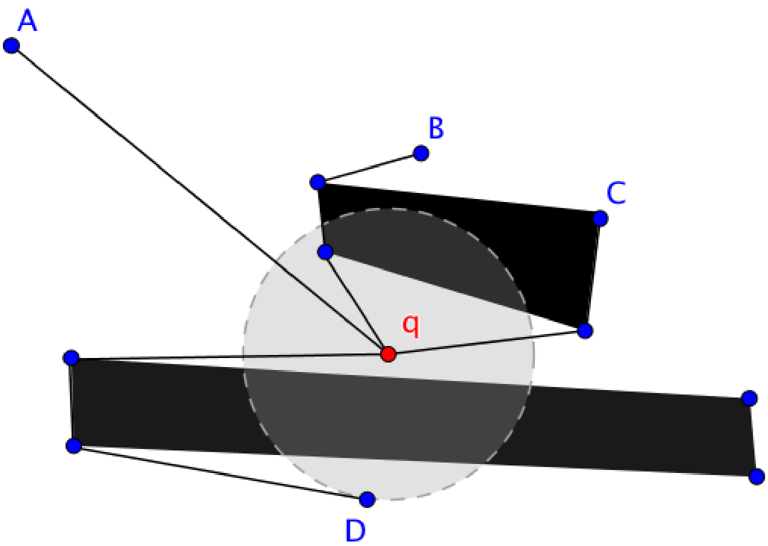

Figure 1.1: We aim to find the nearest neighbour of point q from among the set of target points A, B, C, D. Black lines indicate the Euclidean shortest paths from q. Notice D is the nearest neighbor of q under the Euclidean metric but also the furthest neighbor of q when obstacles are considered.

Tradional kNN queries in the plane (i.e. no obstacles) is a well studied problem that can be handled by algorithms based on spatial index. A key ingredient to the success of these algorithms is the Euclidean metric which provides perfect distance information between any pair of points. When obstacles are introduced however the Euclidean metric becomes an often misleading lower-bound. Figure 1.1 shows such an example.

1.2 Major Challenges

Two popular algorithms for OkNN, which can deal with obstacles, are *local visibility graphs* [5] and *fast filter* [4]. Though different in details, both of these methods are similar in that they depend on the incremental and online construction of a graph of co-visible points, and use *Dijkstra* to compute shortest path. Algorithms of this type are simple to understand, provide optimality guarantees and the promise of fast performance. Such advantages make incremental visibility graphs attractive to researchers and, despite more than a decade since their introduction, they continue to appear as ingredients in a variety of kNN studies from the literature; e.g. [1–3]. However, incremental visibility graphs also suffer from a number of notable disadvantages including:

1. online visibility checks;
2. an incremental construction process that has up to quadratic space and time complexity for the worst case;
3. duplicated effort, since the graph is discarded each time the query point changes.

In section 2.4, we will introduce these two algorithms with detail, and discuss why they have such disadvantages.

1.3 Major Objectives

In this research, we develop a new method for computing *OkNN* which avoids same disadvantages in existing works. Our research extends an existing very fast point-to-point pathfinding algorithm *Polyanya* to multi-target case.

1.4 Thesis Organisation

The rest of the thesis is organised as follows:

- Chapter 2
- Chapter 3
- Chapter 4
- Chapter 5

Chapter 2

Literature Review

2.1 Overview

2.2 AI Search

2.3 Spatial Index

2.4 Obstacle k-Nearest Neighbor

2.5 Pathfinding on Navigation Mesh

2.6 Related Spatial Queries

Chapter 3

Proposed Algorithms

3.1 Overview

3.2 Interval Heuristic

3.3 Target Heuristic

3.4 Summary

Chapter 4

Empirical Analysis

4.1 Overview

4.2 Benchmark

4.3 Competitors

4.4 Experiment 1: lower bounds on performance

4.5 Experiment 2: computing more nearest neighbor

4.6 Experiment 3: changing number of targets

Chapter 5

Conclusion and Future Work

5.1 Research Contributions

5.2 Future Works

Bibliography

[1] Yunjun Gao, Qing Liu, Xiaoye Miao, and Jiacheng Yang. Reverse k-nearest neighbor search in the presence of obstacles. *Information Sciences*, 330:274–292, 2016.

[2] Yunjun Gao, Jiacheng Yang, Gang Chen, Baihua Zheng, and Chun Chen. On efficient obstructed reverse nearest neighbor query processing. In *Proceedings of the 19th ACM SIGSPATIAL international conference on advances in Geographic Information Systems*, pages 191–200. ACM, 2011.

[3] Yunjun Gao and Baihua Zheng. Continuous obstructed nearest neighbor queries in spatial databases. In *Proceedings of the 2009 ACM SIGMOD International Conference on Management of data*, pages 577–590. ACM, 2009.

[4] Chenyi Xia, David Hsu, and Anthony KH Tung. A fast filter for obstructed nearest neighbor queries. In *British National Conference on Databases*, pages 203–215. Springer, 2004.

[5] Jun Zhang, Dimitris Papadias, Kyriakos Mouratidis, and Manli Zhu. Spatial queries in the presence of obstacles. *Advances in Database Technology-EDBT 2004*, pages 567–568, 2004.