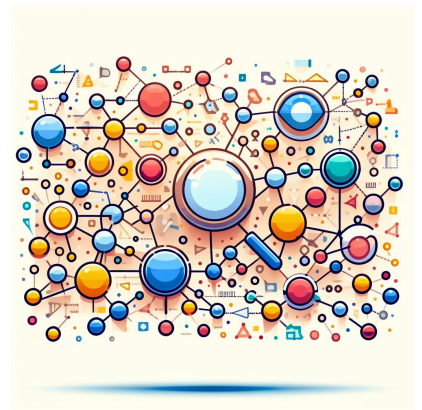


# Master Thesis

## Improving Graph Indices for Nearest Neighbor Search

### Context

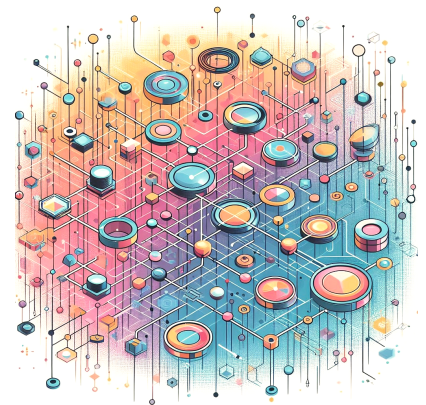
Nearest neighbor search is a fundamental algorithmic primitive that is employed extensively across several fields including computer vision, information retrieval (recommender systems or web search), and machine learning (retrieval-augmented generation for LLMs). Given a large pointset  $P \subset \mathbb{R}^d$ , we want to quickly retrieve the point  $p \in P$  with minimal distance to a given query point  $q \in \mathbb{R}^d$ . In low-dimensional space ( $d < 4$ ), the problem is well-understood and solved by standard data structures such as  $k$ - $d$  trees. With high dimensionality however ( $d > 50$ ) exact search effectively requires a linear scan in theory and practice. Therefore, one is primarily interested in approximate search. The current state-of-the-art techniques use so-called navigable search graphs on the pointset  $P$ . Popular examples are DiskANN and HNSW. The vertices are the points  $P$  and edges connect points such that a simple greedy search quickly converges to the solution. In each step, the greedy search expands to those neighbors of the current vertex which are closest to the query-point by distance.



### Topic

The goal of this work is to develop improved search procedures as well as optimize the search graph in a post-processing step. Some initial ideas are as follows.

- Construct a hierarchical search graph with ranks assigned to vertices. Develop a greedy search that preferably explores downward edges in the hierarchy and only backtracks or explores upward edges when it gets stuck.
- Optimize the search graph navigability by simulating queries at construction time, and inserting edges that would further speed up the search.



### Requirements

- Interest in algorithms and data structures
- Firm programming skills in modern C++

### Literature

- Full Delaunay Hierarchies <https://epubs.siam.org/doi/abs/10.1137/1.9781611972900.5>
- DiskANN [https://suhasjs.github.io/files/diskann\\_neurips19.pdf](https://suhasjs.github.io/files/diskann_neurips19.pdf)
- HNSW <https://arxiv.org/abs/1603.09320>