据模型和抽象定义,使用类似 Dijkstra 算法的思想来计算从查询点到目标对象间的最短距离,进而完成 C*k*NN 的查询.

Mouratids 等人[53]探讨了移动对象的 C*k*NN 监测问题,给出了一种增量监测算法 IMA(incremental monitoring algorithm).该算法在移动对象发生更新时,从前面的时间戳结果中增量获得查询结果用来重复评估当前的查询,使得重复查询产生的开销降低.但是位置更新的自然离散性使两个连续更新之间查询对象的 *k*NN 是未知的,造成 IMA 算法在两个连续更新的时间戳之间无法返回有效结果.

Huang 等人[54]提出了一种路网中移动对象 C*k*NN 的监测算法,该算法大体上可分为剪枝阶段和提炼阶段两个部分.方法中,由于剪枝策略中设置的剪枝距离过大,不能有效地去除一些不合格的对象,导致了提炼阶段的性能不佳.Demiryurek 等人[55]提出 ER-C*k*NN(Euclidian restriction based C*k*NN)查询处理方法,用于解决移动查询对象在动态变化的移动空间网络数据中的 CNN 查询.Liao 等人[56]给出了一种路网有向图模型,并且引入单向网络距离度量和双向网络距离度量方式,提出了单向网络扩展(UNE)算法和双向网络扩展(BNE)算法的 C*k*NN 查询处理方法.

Chen 等人[57]提出了 *k*-PNN(*k*-path nearest neighbor)问题,就是已知用户的当前位置和用户的目标位置,在当前位置到目标位置的最短路径上为用户提供满足其要求的最近邻对象列表,因为用户的当前位置是随时变化的,所以到目标位置的最短路径也是动态的.为了解决这一问题,文献[57]中提出了一种包括查找、验证和监视等 3 个阶段的 BNE(best-first network expansion)算法.

Li 等人[58−60]研究了解决路网中移动对象的 C*k*NN 查询的方法,处理速度不确定时移动对象的 *k*NN 查询问题.Shen 等人[61]提出了 V-Tree 索引结构,并基于这一索引结构处理路网上的移动对象的 *k*NN 查询.文献[61,62]中,利用 V-Tree 索引结构有效地降低了移动对象位置变化时索引更新的代价,在查询时可以有效过滤掉无关的节点,提高了移动对象的 *k*NN 查询性能,是目前最为高效的移动对象 *k*NN 查询方法.

3.2 聚集最近邻查询技术

聚集最近邻的定义是:已知一组数据点集合 P 和查询点集合 Q,从数据点集合 P 中查找到达查询点集合 Q 的聚集距离最小的点 p.比如几个朋友位于不同的地方,计划找一个到他们所在地方距离和最小的餐厅聚会.ANN 查询的关键就是如何减少不必要的距离计算和聚集距离计算.目前,主要的方法有利用欧式距离剪枝的改进的 IER 方法、利用平均距离作为剪枝下限的 TA(the threshold algorithm)算法和基于 Voronoi 的迭代扩展方法.

Yiu 等人[63]为了有效地解决 ANN 问题分别提出了 IER(incremental Euclidean restriction)算法、改进的 IER 算法、TA 算法和 CE(concurrent expansion)算法.其中的 IER 算法是利用欧式距离进行剪枝,利用改进的 A*算法查找 ANN 对象点,而 TA 算法和 CE 算法就是基于路网上的平均距离阈值作为剪枝条件,直接扩展查询实现的,CE 算法是对 TA 算法的改进.

文献[64]也在改进的 IER 框架基础上,采用欧式距离作为剪枝策略,提出了一种单源的多目标 A*算法处理 ANN 查询问题,并在验证阶段进行了改进.

Zhu 等人[65,66]提出利用 Voronoi 图的相邻性和预处理技术来解决 ANN 查询问题,文中将查询分为查找阶段和剪枝阶段.在查找阶段,分别从每个查询点开始寻找下一个最近邻目标对象,直至某个目标对象被所有查询点都扩展到,从而获得一个 ANN 候选集合;剪枝阶段就是去除 ANN 候选集合中不可能为 ANN 结果的目标对象,直到该候选集合中只有一个目标对象.文献[67]中又提出了一种基于 Voronoi 图的解决 *k*ANN 问题的方法,该方法首先通过 R 树索引查找出每一个查询点的 1NN,接着,按照某种策略不断计算某个查询 q 的下一个最近邻,然后检测这个最近邻对象点是否被所有的查询点扩展到:如果是,那么它就是所求的 1ANN;如果不是,那么更新它的当前聚集距离,再继续查找其他查询点的下一个最近邻.依此类推,最终可以找到所求的 *k*ANN 对象点.

还有的学者研究了连续的 ANN 查询问题.Qin 等人[68]提出了增量的 BUA(bidirectional updating algorithm)算法解决连续 ANN 查询问题,也就是从移动的数据点集中查找到多个查询点的聚合距离最小的 top- k 个数据点.Moumtidis 等人[69]研究了动态路网中的 ANN 查询.文献[69]中提出了 IMA 算法和 GMA 算法,IMA 算法存储最短路径扩展树并提出了 affecting edges 的概念,通过对目标节点更新、查询点更新和边权值更新这 3 种情况

分别讨论,并分别提出了相应的处理方法.在 GMA 算法中提出了 sequence 的概念,对处于同一 sequence 中的查询点利用 IMA 算法并行处理.

4 总结与展望

本文对路网环境下的最近邻查询技术进行了分类,从索引技术和查询方法两方面介绍了路网环境下的最近邻查询技术,并从网络规模、*k* 值的大小和对象分布密度 3 个因素探讨了最近邻查询技术之间的区别.目前的研究已经取得了阶段性的成果,但是还存在值得进一步研究的问题.

(1) 路网动态更新.路网数据是动态变化的:一是路网中的节点、路段和兴趣点是动态变化的;其次,路网中道路的权值是动态变化的;另外,查询点和查询对象都可能是动态变化的.在上述情况下,如何适应路网数据的动态更新、高效完成最近邻查询处理,是路网环境下最近邻查询技术需要面临的重大挑战.

(2) 考虑用户的个性化查询.随着基于位置服务的广泛应用,用户往往会有很多个性化的位置查询需求,这些查询大多都是以最近邻查询为基础的,比如带有时间约束或者包含关键字的最近邻查询问题.

(3) 可伸缩性.不同区域的路网规模不同、对象分布密度不同,而且同一区域路网的规模和对象分布密度也在不断增长,查询方法的可伸缩性就显得非常重要.目前,最近邻技术可伸缩性还有待进一步提高.

(4) 实验评测.文献[25]对路网环境下的主流技术进行了实验比较,但是评测还可以考虑更多的技术,同时也需要考虑各种技术在路网更新的情况下的适应性.

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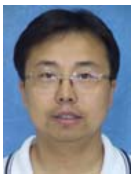

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