Maintaining low congestion potential among moving entities using minimal query frequency *

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Abstract

Consider a collection of entities moving continuously with bounded speed, but otherwise unpredictably, in some low-dimensional space. Two such entities encroach upon one another at a fixed time if their separation is less than some specified threshold. Encroachment, of concern in many settings such as collision avoidance, may be unavoidable. However, the associated difficulties are compounded if there is uncertainty about the precise location of entities, giving rise to potential encroachment and, more generally, potential congestion within the full collection.

We consider a model in which individual entities can be queried for their current location (at some fixed cost) and the uncertainty regions associated with an entity grows in proportion to the time since that entity was last queried. The goal is to maintain low potential congestion, measured in terms of the (dynamic) intersection graph of uncertainty regions, using the lowest possible query cost. Previous work [EKLS2013, EKLS2014, EKLS2016, BEK2019], in the same uncertainty model, addressed the problem of minimizing the congestion potential *of point entities* using location queries of some bounded frequency. It was shown that it is possible to design a query scheme that is $O(1)$-competitive, in terms of worst-case congestion potential, with other query schemes (even those that correctly guess the trajectories of all entities), subject to the same bound on query frequency.

In this talk we outline recent results that address a more general problem with the dual optimization objective: minimizing the query frequency, measured in terms of the minimum spacing between queries (query granularity), over any fixed time interval, while guaranteeing a fixed bound on congestion potential *of entities with positive extent.* This complementary objective necessitates quite different algorithms and analyses. Nevertheless, our results parallel those of the earlier papers, specifically tight competitive bounds on required query frequency, with a few surprising differences.

Applied to collision avoidance, our results show that it is possible to maintain, at all times, a certificate for each entity e_i that identifies some pre-specified number of other entities that could potentially encroach upon e_i (those warranting more careful local monitoring), using competitively-optimal query frequency An additional application, considered in earlier work, concerns entities that are mobile transmission sources, with associated broadcast ranges, where the goal is to minimize the number of broadcast channels so as to eliminate potential transmission interference. In this case, using competitively-optimal frequency, our query strategy maintains a fixed bound on the number of broadcast channels, an objective that seems to be at least as well motivated as optimizing the number of channels for a fixed query frequency (the objective in earlier work).

[EKLS2013] W. Evans, D. Kirkpatrick, M. Löffler, and F. Staals. Competitive query strategies for minimizing the ply of the potential locations of moving points. *29th Annual Symposium on Computational Geometry*, SoCG '13, pages 155-164, 2013.

[EKLS2014] W. Evans, D. Kirkpatrick, M. Löffler, and F. Staals. Query strategies for minimizing the ply of the potential locations of entities moving with different speeds. *Abstr. 30th European Workshop on Computational Geometry*, 2014.

[EKLS2016] W. Evans, D. Kirkpatrick, M. Löffler, and F. Staals. Minimizing co-location potential of moving entities. *SIAM Journal on Computing*, 45, 1870-1893, 2016.

[BEK2019] D. Busto, W. Evans and D. Kirkpatrick. Minimizing Interference Potential Among Moving Entities. *Proc. ACM-SIAM Symposium on Discrete Algorithms*, SODA'19, pages 2400-2418, 2019.

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