УДК 629.05

ACCURACY IMPROVEMENT OF LOCATION-BASED DECISIONS FOR DETECTION OF CLOSELY MOVING OBJECTS

Kashuba S.V., Lysenko O.I.
Institute of Telecommunication Systems,
National Technical University of Ukraine "Kyiv Polytechnic Institute"
E-mail: kashubasv@gmail.com

Підвищення точності виявлення близько розташованих рухомих об'єктів

Служби, що використовують інформацію про взаємне розташування рухомих об'єктів в оточуючому середовищі, є прикладом високої інтеграції між телекомунікаційними та обчислювальними системами. Оперативне виявлення фактів близького розташування рухомих пристроїв вимагає визначення та передачі позиції з певною періодичністю. Метод оцінки можливого положення між рознесеними в часі вимірами позицій дозволяє збільшити інтервал надсилання координат об'єктів або підвищити точність прийняття рішень.

Location-based services (LBS) are an example of high integration between mobile communication systems and information technology domain. These services are aimed to use location information (spatial position) of mobile devices and additional knowledge about environment to provide special applications to customers. There are three main domains of use for LBS: military and government industries, emergency services, and the commercial sector [1]. Location oriented technologies have perspective use area in context of personal devices progress and ubiquitous interactive applications. Also Internet of Things concept and vehicle automatic control researches introduces another niche for LBS where positioning information originated and consumed by automatic devices.

Moving devices frequently use global positioning system (GPS) modules to define current coordinates. Less precise position data also can be defined from mobile network base station signals or wireless hot-spots. Many navigation applications effectively use this information. But the core concept of LBS systems are transmission of position information to data center or another mobile device and it processing in near real-time way to make application specific decisions.

Survey of different sources shows plenty of possible use cases of LBS such as person/vehicle tracking, emergency services, local advertisement, fleet management or points of interest advisory. These applications have corresponding mathematical problems such as:

- find all objects within defined shape;
- find object closest to position or another object;
- where will be objects after time T (with some probability);
- detect if two objects become closer then defined distance;

One of the current problems in LBS is accuracy estimation and improvement. There are two main reasons of position inaccuracy. First is precision limit of device locality information. It can vary from 3-5 meters for GPS receiver, to hundreds meters in urban areas and only up to 3-kilometer accuracy in rural areas with so-called Cell-ID technology [1]. Second is positioning data outdating.

In order to make certain decisions depend on the movement of an object, we would have to know the position at all times, i.e., on a continuous basis. However GPS and telecommunications technologies only allows us to sample an object's position, i.e., to obtain the position at discrete instances of time such as every few seconds. Also it means that devices have to continuously send updates of their position via a wireless communication link. Frequent updating may be expensive in terms of internet traffic cost, battery usage and performance overhead. Alternatively, if position updates are infrequent, then the answer to position queries is outdated, i.e. imprecise; this in turn may involve a penalty cost in terms of incorrect decision-making [2]. Position uncertainty depends both on update period and maximum object speed.

Let consider one of the possible LBS scenario. Two moving objects with maximum speed v_{m1} and v_{m2} periodically send current location coordinates (position samples). Service has to detect if these two objects can be on distance less than defined threshold D. For sake of simplicity we will not consider any error connected to the position and time of measurements. This assumption can be justified when GPS is used as a measuring device application position information accuracy requirements are weak comparing with GPS precision.

The most naive solution of this problem is to measure geometrical distance between last position samples of tracked objects. Such approach can be adopted in systems where decision accuracy is not critical and computation performance is a limitation factor (e. g. friend finder application example from [1]). However such decision making mechanism is not sufficient in case of more strict requirements and fast moving objects. Fig.1a depicts example of false negative decision with this simple approach. Dashed lines represent real traces of two moving objects, dots $P_{Object}(t_i)$ are position samples in time points t_i. As we can see measured distance d_2 can be much bigger than real distance between objects at some intermediate point of time $t_1 < t_x < t_2$. Quality of result can be improved with more frequent position samples, but in practice it is restricted by communication limitations denoted above.

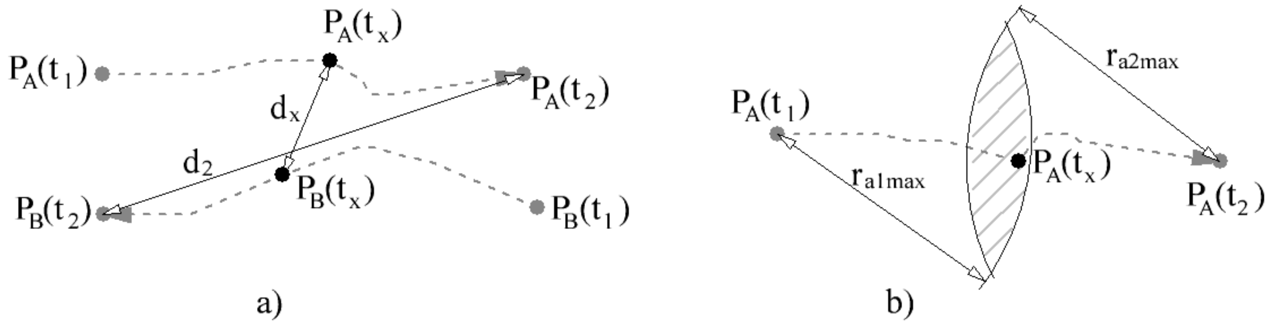

Fig.1 Difference of distance between real objects and position samples (a); possible position estimation using maximum velocity (b)

It is possible to limit the area of possible location at certain time moment even if we do not measure the positions in-between two consecutive sampling points. Such method is used in [3] to solve problem of the form "find the moving-object that were inside query rectangle A at some time between times of position samples B and C with a probability of at least Q". Maximum velocity of object is used to define spatial circle with center in first sample in which object can be after time period $\tau = t_x - t_1$. Intersection with another circle drawn from second sample point gives area (shaded shape on fig.1b) of object possible position at t_x.

We can apply this method to considered problem with two moving objects from fig.1a. Service which task is to detect facts of close moved objects periodically calculates possible areas of each object using technic described in previous paragraph and makes estimation of distance between them.

It is possible to make two claims about mutual position of objects based on possible location areas at intermediate time moment (fig.2):

1) real distance is guaranteed to be less than *D* if:

$$\forall P'_A \in S_A, \forall P'_B \in S_B \Rightarrow d(P'_A, P'_B) < D \quad (1)$$

where $d(P'_A, P'_B)$ is function of distance calculation between possible location points of two objects, S_A, S_B are areas of possible objects location;

2) real distance is guaranteed to be greater than D if:

$$\forall P'_A \in S_A, \forall P'_B \in S_B \Rightarrow d(P'_A, P'_B) > D \quad (2)$$

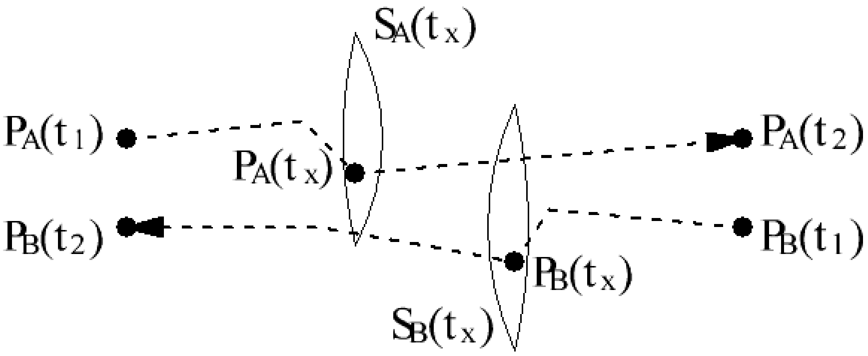

Fig.2 Illustration of possible location areas for two moving objects

Detection of closely moved objects with (1) and (2) can be performed only in discrete points of bordering circles according to required accuracy.

This method of distance estimation between two moving object can be used to reduce ratio of position data sampling or to improve accuracy of decisions such as detection of closely moved tracked vehicles or persons. One drawback of such approach is observed if speed of objects is low or equal to zero. In such cases possible location area between samples is very large compared to real object movement. The future work considers reducing impact of this issue.

References

1. J. Schiller, A. Voisard Location-Based Services. The Morgan Kaufmann Series in Data Management Systems / Elsevier Science – 2004, 255 p. (ISBN: 9780080491721, in San Francisco).
2. O. Wolfson, S. Chamberlain, S. Dao, L. Jiang, G Mendez Cost and imprecision in modeling the position of moving objects / Data Engineering, 1998. Proceedings, pp 588-596.
3. Dieter Pfoser, Christian S. Jensen Capturing the Uncertainty of Moving-Object Representations / Advances in Spatial Databases Lecture Notes in Computer Science Volume 1651, 1999, pp 111-131.