Dispatch of mobile sensors in the presence of Obstacles Using Modified Dijkstra Algorithm

Shalini Kumari H A, Shivanna K,
Department of Computer Science and Engineering,
Shridevi Institute of Engineering and Technology, Tumkur,

Abstract

A hybrid wireless sensor network consists of both static sensor and mobile sensor nodes. Static sensors monitor the environment and report events occurring in the sensing field. Mobile sensors are then dispatched to visit these event locations to conduct more advanced analysis. The sensing field may contain obstacles. A big challenge is how to dispatch the mobile sensor to the event location without colliding with any obstacles and mobile sensor should reach the event location in a shortest path. Therefore the objective of the paper is to dispatch the mobile sensor to the event location in a shortest collision-free path. This paper gives a modified dijkstra's algorithm to dispatch mobile sensor from its position to the event location. Our solution proposes a simple way to dispatch the mobile sensor to the event location in the presence of obstacle with modified dijkstra's algorithm. This paper contributes in defining a more general and easiest dispatch solution in the presence of obstacles.

Index terms– Modified Dijkstra's Algorithm, Collision-Free Path, Mobile Sensor, Hybrid WSN, Global Positioning System, Dispatch, Static WSN.

I. Introduction

A Wireless Sensor Network is a collection of spatially deployed wireless sensors by which to monitor various changes of environmental conditions such as temperature, sound, vibration, pressure, motion, pollutants in a collaborative manner without relying on any underlying infrastructure support [1]. The development of WSN was originally motivated by military applications such as battlefield surveillance. However wireless sensor networks are now used in many civilian application areas, including environment and habitat monitoring, healthcare applications, home automation and traffic control. In addition to one or more sensors each node in a sensor network is typically equipped with a radio transceiver or other wireless communication devices, a small microcontroller and an energy source, usually battery. The envisaged size of a single sensor node can vary from shoebox-sized nodes to devices the size of grain of dust although functioning motes' of genuine microscopy dimensions have yet to be created. The cost of sensor nodes is similarly, ranging from hundreds of dollars to a few cents, depending on the size of the sensor network and the complexity required of individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and bandwidth [2].Sensors typically have very limited power, memory and processing resources. Therefore interactions between sensors are limited to short distances and low data-rates. Sensor node energy efficiency and sensor network data-transfer reliability are the primary design parameters. A WSN is usually deployed with static sensor nodes to perform monitoring missions in the region of interest. However due to the dynamic changes of events, a pure static WSN will face more severe problems [3]. By introducing mobility to some or all nodes i.e., by deploying mobile sensor nodes in a WSN, its capability can be enhanced. Hybrid Sensor Networks with static and mobile nodes open a new frontier of research in Wireless Sensor Networks (WSNs).Static sensors support environmental sensing and network communication. They serve as the backbone to identify where suspicious events may appear and report such events to mobile sensors. These Mobile sensors are more resource-rich in sensing [5] and computing capabilities and can move to particular locations to conduct more complicated missions such as providing in-depth analysis, repairing the network etc [3]. Once static sensors collect the sensed information about the event, mobile sensors are then dispatched to visit these event locations to conduct more in depth analysis about the events. Applications of wireless sensor networks have been studied in [4], [5].Mobile sensors have *less moving energy* and all the event locations should be visited, not even single location should not be left un-visited, because that may cause harmful effect to the sensor network. Therefore balancing energy consumption is very important in case of mobile sensors, so that all the event locations can be served. Dispatching mobile sensors to the event locations in an energy balanced way is discussed in [6]. The sensing field may contain obstacle but the mobile sensor should be dispatched without colliding with any obstacle, and it should reach event location with minimum distance or shortest path. The paper [18] gives dispatch solution in the presence of obstacles with traditional dijkstra's algorithm. In this paper we *focus* on the problem of dispatching mobile sensor to the event location in shortest collision-free path with modified dijkstra's algorithm. A mobile sensor of radius *r* (non-negative integer) has a collision-free motion among obstacles if its center always keeps at a distance of *r* and preventing the mobile sensor from moving into these expanded areas. This expanded area is treated as *configuration-space (C-space)*[18]. The shortest path of the center consists of a set of circular arcs of circles called *vertex circles (v-circles)*[18] of radius *r* centered at obstacles, and common tangents of the arcs. In this the tangent points and v-circles are determined by the value of the radius *r*.

After finding the C-space and v-circles of all the obstacles we need to find shortest path from mobile sensor to the target location. Paper [18] used dijkstra's algorithm to find the shortest path. But it has a drawback. To overcome that problem we adopted modified dijkstra's algorithm. The rest of the paper is organized as follows: Section 2 reviews related work. Section 3 proposes a method to compute shortest collision free path for a mobile sensor. Section 4 proposes modified dijkstra's algorithm. Conclusions and future research topics are drawn in Section 5.

II. Related Work

Mobile sensors have been intensively researched to improve a WSN's topology. In [7], static sensors detecting events will ask mobile sensors to move to their locations to conduct more in-depth analysis. The mobile sensor that has a shorter moving distance and more energy, and whose leaving will generate a smaller uncovered hole, is invited. The work in [6] addresses how to dispatch mobile sensors to the event locations in an energy balanced way, where dispatch problem is considered for *a single round*. In that we mainly considered centralized dispatch algorithm, in that they discussed two cases based on the values of number of event locations and the number of mobile sensors. One mobile sensor will be dispatched to one event location (when, mobile sensors >= event locations), one mobile sensor will be dispatched to one cluster of event locations (when, mobile sensors < event locations) But they made an assumption that the sensing field does not contain any obstacles. The assumption that was made in the previous paper is relaxed in this paper. The event location or cluster of event locations is considered as target. The studies [8], [9] also address the sensor dispatch problem, but they do not consider energy balancing, dispatching mobile sensor in the presence of obstacles and only optimize energy consumption in *one round*. There are several works treating the shortest path of a disc. These approaches use the concept of *configuration space (C-space)*. So that the disc can be processed as a point. *Chew [10] extended the idea of the visibility graph to a* path graph (called tangent graph in [11], [l2]), which registers circular arcs on the boundary of the configuration obstacles (C-obstacle) and common tangents of the circular arcs. Hershberger and Guibas [13] further developed this idea to a non rotating convex body, and pruned the path graph so that the logarithmic factor is removed. Storer and Reif also showed the usefulness of their algorithm for a disc. The Voronoi diagram [14] is obviously one answer because a point on the Voronoi graph is collision-free for a disc if its shortest distance to the obstacles is larger than the radius of the disc. However, it does not take care of the issue of shortest paths. The work in [1] addresses modified dijkstra's algorithm for route selection in car navigation system. Where it shows how the data structure that represents routes can be modified to assist Dijkstra's algorithm to find subjectively optimal driving route. Selecting the shortest path is not a hard problem, but the shortest path is not always what the user wants; what the user really wants to have is the most comfortable route for him or her to drive. Therefore the paper [1] gives solution to select the most comfortable route that the user wants. The path length and number of turns are the major factors in path planning of transportation and navigation systems. Most researches only take the issue of shortest distance into account, and the impact of turns are rarely mentioned, that is, the shortest path may not be the fastest. The work in [2] proposes two algorithms: the Least-Turn Path Algorithm and the Minimum-Cost Path Algorithm to balance both the path length and turns. Where the authors introduced modified dijkstra's algorithm for the proposed minimum-cost path algorithm.

The work in [3] also addresses car navigation problem such as finding the efficient route by the user. Where the paper proposes a new shortest path algorithm. The suggested algorithm is a modified version of dijkstra's, which states that search space is restricted by the use of a rectangle or a static and dynamic hexagon.

III Computing the Shortest Collision Free Path

Sensors are aware of their own locations, which can be achieved by Global Positioning System (GPS). In Hybrid Wireless Sensor Network, once static sensor identifies the event, Mobile sensor will be dispatched to the event location to collect in detail information about the event. The work in [6] gives the solution to the dispatch problem. The authors constructed a weighted complete bipartite graph G = (SUL, SXL). Each mobile sensor and event location is converted into a vertex. Edges only connect vertices between S and L. For each s_i belong to S and each l_j belongs to L, its weight is defined as w $(s_i,l_j) = e_{move}*$

d(s_i,l_j). Where e_{move} is the energy required to move unit distance and d (s_i,l_j) is the distance between s_i and l_j.

Algorithm to find M (matching between mobile sensor to event location) is as follows:

1. For each location l_j, associate with it a *preference listP_j*, which contains all mobile sensors ranked by their weights in correspondence with l_i in an ascending order. In case of tie, sensors IDs are used to break the tie. Construct a *queue Q* containing all locations in L.
   Create a bound B_j for each location l_j belongs to L to restrict the mobile sensors that l_j can match with. Initially, set B_j =w (s_i, l_j) such that s_i is the β^{th} element in l_j's preference list P_j, where β is a *system parameter*.
2. *Dequeue* an event location, say, l_j from Q.
   Select the first *candidate mobile sensor*, say, s_i from P_j, and try to match s_i with l_j. If s_i is also unmatched, we add the match (s_i, l_j) into *M* and remove s_i from P_j. Otherwise, s_i must have matched with another location, say, l_o. Then, l_j and l_o will compete by their bounds B_j and B_o. Location l_j wins the competition if one of these conditions is true:

a. $B_j > B_o$ Since l_j has raised to a higher bound, we match s_i with l_j.
b. $B_j = B_o$ and w (s_i, l_j) < w (s_i, l_O) since moving s_i to l_j is more energy efficient, match s_i with l_j.
c. $B_j = B_o$, s_i is the only candidate of l_j, and lo has more than one candidate: In this case, if s_i is not matched with l_j, l_j has to increase its bound B_j. However, l_o may not increase its bound B_o if s_i is not matched with l_o. Thus, we match s_i with l_j.
   If l_j wins the competition, were place the pair (s_i, l_o) in *M* by (s_i, l_j), remove si from P_j, enqueue l_o into Q, and go to step 7. Otherwise, remove si from P_j (since l_j will not consider s_i any more) and go to step 6.

3. If l_j still has candidates in P_j (under bound B_j), go to step 5 directly. Otherwise, increase l_j's bound to B_j = w (s_k, l_j) such that s_k is the β^{th} element in the current P_j and then go to step 5. (Note that since P_j is sorted in an ascending order and the first mobile sensor s_i is always removed from P_j after step 5, obtain a new larger bound B_j =w (s_k, l_j) > w (s_i, l_j)
4. If Q is empty, the algorithm terminates; otherwise, go to step 4. In [6], authors have calculated the distance between the mobile sensor and the event location without the presence of obstacles. In this paper we are showing the method to calculate the distance in the presence of obstacles and reaching the target in shortest path. We making use of the above mentioned algorithm to dispatch the mobile sensor.

A. Proposed Schema

Once the static sensor identifies the event location, mobile sensor will be dispatched to the event location. While moving mobile sensor towards the event location, it should not collide with any obstacles in the network. Sensor nodes are battery oriented, energy minimization is very important in WSN and mobile sensors have less moving energy it should reach the event location in a minimum distance. The path that allows mobile sensor to move without colliding with any obstacle is called as

Collision Free Path.

Our goal is to find the shortest collision-free path from Mobile Sensor s_i's current position to event location's position (x_j, y_j) which is treated as the destination or target, considering the existence of obstacles. Specifically, the movement of s_i should not collide with any obstacle. Several studies have addressed this issue [15], [16], [17]. Here, we propose a modified approach of that in [16]. Work in [18] addresses how to dispatching mobile sensor to event location in the presence of obstacles. The authors used dijkstra's algorithm to find the shortest path from mobile sensor to the event location, which is treated as target. But this method is having a drawback. The goal of the paper is to overcome this drawback. To overcome this drawback modified dijkstra's algorithm is proposed.

A. Modified Dijkstra's Algorithm

The classical Dijkstra's Algorithm is used to solve shortest path planning problem from one start point to other destination points in connected-graph, and only lengths of paths from start point to all other destination points are provided, but those middle points, which the final path from start point to each destination point passes through, is not provided, this is treated as the drawback in the classical Dijkstra's algorithm.

So, this paper uses modified Dijkstra Algorithm solve dispatch problem in the presence of obstacles. There are two aspects of Dijkstra Algorithm, which are mainly modified. One aspect, which was modified, is the finishing condition of the algorithm. In modified Dijkstra Algorithm, when algorithm obtains a path from start point to a certain point, algorithm compares the point with the destination point V_d, if it is the very V_d, algorithm can stop, otherwise, must continue. The other aspect, which was also modified, is the array, which array is named Dist, and it is used to store lengths of paths from start point to other destination points in Dijkstra Algorithm. In modified Dijkstra Algorithm, element structure of array Dist was extended as below:

```
typedef shuct DistRecorddouble
{
```

Value; //record length of path from V_S to current point
int Prior; //record No of prior point of current point in final path
} DIST;

Having that Dist array, when the destination point V_d is searched during executing algorithm, we may use the information of the Prior field of Dist to make tracks forward for the start point. Finally, all vertices that the final path from Vs to V_d passes through can be obtained, thereby, the final path can he protracted.Executing the above modified Dijkstra Algorithm, we can get a series of control points of path, and store control points into an array. In order to get smooth moving path, we can use those control points as interpolation points to do spline approximation to path. As far as interpolation problem is cconsidered, it has been solved very well today.

IV. Conclusion and Future Work

In this paper, we presented a method to find shortest and collision-free path for a mobile sensor to reach to event location which will be treated as target. This method is the easiest, simple and efficient way to find the path for a mobile sensor. To dispatch the mobile sensor to the event location use proposed Modified Dijkstra's Algorithm. This algorithm overcomes the drawback of the previously proposed algorithm.

In our work we have treated mobile sensors to be in circular shape. But they may also be in different shapes. As a future research, we extend our work to find shortest, collision-free path for a mobile sensor which is in any shape.

REFERENCES

[1.] IanF.Akyildiz,WeilianSu,YogeshSankarasubramanian, and Erdal Cayirci Georgia Institute of Technology "A Survey on Sensor Networks" IEEE Communication Magazine August 2002.

[2.] Yong Wang, Garhan Attebury and Byrav Ramamurthy "A Survey Of Security Issues In Wireless Sensor Networks" IEEE Communications surveys, The Electrinoc Magazine of Original Peer-Reviewed Survey Articles, Volume 8, No. 2, 2006.

[3.] Y.C. Wang and Y.C. Tseng, "Intentional Mobility in Wireless Sensor Networks," Wireless Networks: Research, Technology and Applications, Nova Science Publishers, 2009.

[4.] M.A. Batalin, M. Rahimi, Y. Yu, D. Liu, A. Kansal, G.S. Sukhatme, W.J. Kaiser, M. Hansen, G.J. Pottie, M. Srivastava, and D. Estrin, "Call and Response: Experiments in Sampling the Environment," Proc. ACM Int'l Conf. Embedded Networked Sensor Systems, pp. 25-38, 2004.

[5.] Y.C. Tseng, Y.C. Wang, K.Y. Cheng, and Y.Y. Hsieh, "iMouse: An Integrated Mobile Surveillance and Wireless Sensor System," Computer, vol. 40, no. 6, pp. 60-66, June 2007.

[6.] Y.C. Wang, W.C. Peng, and Y.C. Tseng, "Energy-balanced Dispatch of Mobile Sensors in a Hybrid Wireless Sensor Network," IEEE Trans. On parallel and distributed systems, vol. 21, no. 12, December. 2010.

[7.] A. Verma, H. Sawant, and J. Tan, "Selection and Navigation of Mobile Sensor Nodes Using a Sensor Network," Pervasive and Mobile Computing, vol. 2, no. 1, pp. 65-84, 2006.

[8.] Y.C. Wang and Y.C. Tseng, "Distributed Deployment Schemes for Mobile Wireless Sensor Networks to Ensure Multilevel Coverage," IEEE Trans. Parallel and Distributed Systems, vol. 19, no. 9, pp. 1280-1294, Sept. 2008.

[9.] Y.C. Wang, C.C. Hu, and Y.C. Tseng, "Efficient Placement and Dispatch of Sensors in a Wireless Sensor Network," IEEE Trans. Mobile Computing, vol. 7, no. 2, pp. 262-274, Feb. 2008.

[10.] L. P. Chew, "Planning the shortest path for a disc in O (n2 log N) time," in Proc. ACM Symp. Computational Geometry, 1985, pp. 214-219.

[11.] Y. H. Liu and S. Arimoto, "Proposal of tangent graph and extended tangent graph for path planning of mobile robots," in Proc. IEEE Inr. Con$ Robot. Automat., 1991, pp. 312-317.

[12.] "Path planning using tangent graph for mobile robots among polygonal and curved obstacles," Int. J. Robot. Res., MIT Press, vol. 11, no. 5, pp. 376-382, 1992.

[13.] J. Hershberger and L. Guibas, "An O(n2) shortest path algorithm for a non-rotating convex body,'' J. Algorithms, vol. 9, pp. 1846, 1988.

[14.] 0.Takahashi and R.J. Schiling, "Motion planning in a plane using generalized Voronoi diagrams," IEEE Trans. Robot. Automat., vol. 6, no. 2, pp. 143-150, 1989.

[15.] Yasushi Kambayashi , Hidemi Yamachi, Yasuhiro Tsujimura, Hisashi Yamamoto "Dijkstra Beats Genetic Algorithm: Integrating Uncomfortable Intersection-Turns to Subjectively Optimal Route Selection", ICCC2009 IEEE 7th International Conference on Computational Cybernetics, November 26-29, 2009.

[16.] Gene Eu Jan, Ming Che Lee, S. G. Hsieh, Yung-Yuan Chen, "Transportation Network Navigation with Turn Penalties", IEEE/ASME International Conference on Advanced Intelligent Mechatronics Suntec Convention and Exhibition Center, Singapore, July 14-17, 2009.

[17.] Sara nazari, M. Reza Meybodi, M.ali salehiGh, Sara taghipour, " An Advanced Algorithm for Finding Shortest Path in Car Navigation System", First International Conference on Intelligent Networks and Intelligent Systems,2008.

[18.] Shalini Kumari H A, Aparna R, "Finding the Shortest Collision-free Path for a Mobile Sensor in Hybrid Wireless Sensor Networks", International Conference, ICN-2011, Sep. 2011.