# Pervasive System for Searching the Appropriate Road: A Mobile Physician on Road Network Case Study

Hanen Faiez and Jalel Akaichi

BESTMOD-Higher Institute of Management of Tunis Rue de la Liberté - Cité
Bouchoucha. 41, 2000 Bardo, Tunisia

**Abstract.** Saving a patients live in an emergency state especially if he is far from medical institutions, is considered to be the primary concern of the physician. With a mobile physician, patients health state may vary to be in a critical situation that requires immediate medical intervention. Having chosen the medical institution as destination, the doctor must react immediately and reach his patient as rapidly as possible. The purpose of this paper is therefore to propose a new pervasive assistance system for finding the most suitable road without obstacles that may appear on the road. Our approach is provided by a new algorithm based on *The largest empty circle* geometric technique. Thanks to our approach the doctor can protect his patient from complications which pose a threat on his life since it successfully facilitate finding the appropriate route by which he can go in minimum of time.

**Keywords:** Mobile Physician, Delaunay triangulation (DT), Voronoi diagram (VD), the largest empty circle problem

## 1 Introduction

During the last decade, the introduction of telecommunication technologies in many fields has attracted the attention of a big number of researchers who have proved the usability of their use in the health care field. The use of mobile technologies and telecommunications in most of daily life activities has spurred the emergence of a new set of health concepts [1] which is mainly based on pervasive and mobile equipments [2] which tend to support and assist remote patients by offering them the comfort of being served at any time. These applications are called *"pervasive healthcare applications"* [3, 4, 2]. These latter open up new possibilities and new opportunities to support and ensure patient's treatment, offering increased accessibility to health care providers and overcoming all temporal and spatial difficulties between patient and physician. Monitoring patients is a task that takes a lot of time, what if patients are geographically dispersed or if they confront an emergency state that bears no delay. Physician must save patient's life as it is his basic responsibility and his most honorable task. To achieve this, the doctor must reach him as quickly as possible. So, he may ask himself the following question: By which road should i go quickly without having any problem that can delay me to join my patient? The answer to his question is in the context of determining of the *most appropriate road* that will be described in detail in a later stage. In reality, the main problem is that following a request sent to the mobile doctor from his patient he must react quickly to attain him. However, he may encounter problems on the road makes him blocked during a certain time interval. Probably, during this time the patient may lose his life. So, for the purpose of saving time, the goal of this paper is to propose a solution based on the *"Largest Empty Circle"* trigonometric method which handles time problems. The remainder of this paper is organized as follows: In the next section, we present related works. Subsequently, we present our approach modeled by a new pervasive system for determining the most appropriate road. In Section 4, we describe the experimentation. In the last section we conclude and we include interesting and practical directions for future works that we opened the door with this paper.

## 2 State of the art

During the last decade, the adoption of mobile technologies in all aspects of life is a so answered phenomenon. In general, mobile technology [6] has radically changed the way people communicate, perform tasks, and do exercises and daily life activities. The medical field is one of the areas that receive and benefits a lot of this technology. As a matter of fact, several are the factors which stimulate adoption of the mobile solution, namely the increase in chronic diseases, increased demand from the patients to inquire about their health state, treatment sessions etc. Thus, allowing the patient to contact directly his doctor via the mobile phone is going to solve certainly several problems of displacement and loss of time. In general, care demands sent by patients are increasing every day, every minute and every second. The medical staff is then called to respond with structured and adapted means to unscheduled health care demands. However, it is possible that the doctor is out of working hours, which will undoubtedly influence negatively the health care management. This reason was the factor that stimulated increased use of mobile technologies for medical purposes. In this context, *"pervasive health care systems"* come to solve these problems. In fact this kind of systems, can take advantages of *"Telemedicine phenomenon"* [5]. In reality, handheld devices will be able to understand sufficiently the current situation of user to provide him with services, resources or information that he needs in a well-defined context.

### 2.1 Telemedicine

These last years, the Telemedicine is one of the most widespread phenomena in the medical field. It can be defined as a set of possible medical practices facilitated by telecommunication technologies which tend to exchange medical information in order to make health care from a distance. One of the most answered technologies in such a case is the mobile phone [6]. At the best of our knowledge, mobile devices like PDAs tablets and mobile phones allows both of doctors and patients to communicate about symptoms and treatment options in real-time while remaining in contact with their doctors and caregivers. With telemedicine phenomenon, the patient has an access to his doctor in real-time which guarantees the comfort of being followed even if he is not stable geographically. So, patient can focus on finding the best care giver; unfettered by time and geography constraints. And doctor can focus on providing the best possible treatment options in minimum time.

### 2.2 Pervasive healthcare systems

In fact, a good health rescue system is mainly based on a good emergency state's management. This means that these systems are based on a good management of emergency services (EMS) [7] and particularly the management of emergency vehicles (EMV) [7]. The two main components of this latter are: The vehicle fleet management and route guidance. Managing emergency vehicles tends to reduce the waiting time interval that summarizes the reception of a call or an event until the arrival of emergency vehicle on the site. Before presenting our new approach, we present the most famous pervasive healthcare systems found in the literature which take into account aspect of route guidance.

A first system for routing emergency calls called *GST system* has been proposed in [7] which is integrated into an emergency service vehicle (ESV) and has as principle the construction of a chain of immediate, fast and efficient answers to comer incidents. Since the GST rescue system guide the ESV as quickly as possible to the incident point while ensuring a fast route, and facilitating interaction between emergency vehicles and other road users circulating in the same area. Nevertheless, this system suffers from a major drawback, is the high computational cost due mainly to the use of Dijkstra's algorithm as a routing algorithm. A second system called *Advanced Spatial Technological System For Emergency Situations* has been described in detail in [8]. The main objectives behind the use of this system are: to reduce the time required for the arrival of the ESV to the place of the accident, to reduce the overall time required to transfer the patient to a health care center, and to provide high quality care to the patient in the ESV. This system seems to be one of the best real systems but it suffers from a major drawback due the high cost of storing information in the server related to the network traffic like speed limits, direction and traffic parameters. A third system called *Cooperative Freight and Fleet Applications System* has been described in [9], aims to provide a high level of safety and efficiency of transport. This system is designed to meet users needs and it provides effective supervision and guidance of the ESV with managing the traffic flow in sensitive areas. The major problem with this system is that there are many restrictions related to areas 'Parking' which returns this system very difficult to set up. A fourth system called *SPH* has been proposed in [10] aims to the development of a psychological automatic detection system which in turn helps to ensure good emergency medicine and good health care environment in which users are still followed and surrounded by experts in a remote way. Finally, authors in [11] have proposed a system for mobile health care emergency monitoring based on Smartphone which includes a privacy preserving emergency call. This system gives good results and the access to emergency data is controlled.

## 3 Motivating Scenario

Suppose the doctor is in the following context: moves from a place to another one in a village or in a town connected by a road network, in order to take care of his patients which are geographically dispersed. In point of fact, the patient's health state may vary in time and may be in a critical situation that requires immediate medical intervention. The doctor must join his patient after determining the point of interest (we want to say with point of interest: either the location of the patient or the appropriate medical institution that he has to go). To the best of our knowledge, systems that we described in the previous section, can provide several information on the road such as direction, bottling, other users of the road but does not give an indication about zones or roads containing obstacles. So our idea is the following: the doctor equipped with his mobile device, receives a request from his patient to inform him that he is in an emergency state. Then, the physician is called to seek a road without obstacles by which it can pass. Our proposed system framework described in figure 1 is discussed in the following subsection.

### 3.1 The new pervasive assistance system overview

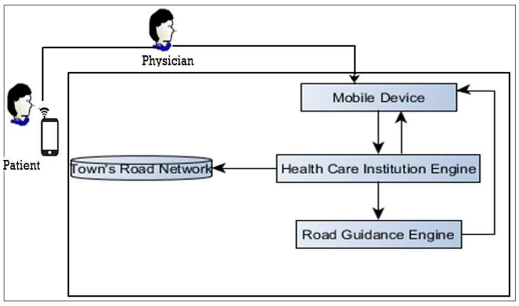

**Fig. 1.** System Overview

Figure 1 depicts the general architecture of our pervasive assistance system to run the scenario described above related to the mobile physician. According to the scenario, the doctor is in a given location from which he queries our system via his "Mobile equipment"(a PDA tablet for example) following a call from his patient . The second component is the "HealthCare Institutions Engine" which takes as an input a town's road network map to extract from it health care institutions existing to display them thereafter in the form of points of interest to the doctor. Finally, once the physician select an institution, a road guidance engine takes this latter as input and triggers the search of the area without obstacles. This engine is able to guide him to the right road.

## 4 Finding the appropriate road

Further to an emergency situation, the doctor away all other considerations and pressures must join the patient as soon as possible. Here, we are speaking of several factors that may be an obstacle that prevents the doctor to pass. This is referred to several problems citing the example of: accidents on the road, road conditions, traffic congestion, temporary limitations and other problems that could delay the doctor to attain his patient which can risk losing him his life. So, we are going to implement an algorithm that will permit the physician to choose the right path. In this way, our mobile doctor does not risk wasting time to follow a path that may contain obstacles. To do that, we will rely the The largest empty circle problem technique [13].

### 4.1 The principle of the Largest empty circle problem

**DT and Voronoi Diagram**

In mathematics and more specifically in computational geometry for P sites, we call Delaunay triangle a triangle which has as vertices three sites. The assembly of these Delaunay triangles form for P sites form a triangulation of P sites called *Delaunay triangulation* [12]. A *Voronoi Diagram* [12] is a special decomposition of space. Let S be a set of n sites in the euclidean space with the dimension d. For each site p of S, the Voronoi cell V(p) of p is the set of points in space which are closest to p than all other sites S. The Voronoi diagram V(S) is the decomposition of the space formed by the cells of Voronoi sites(figure 2). Once the DT(P) has been calculated, it is quite simple to dualize it to Vor(P). The *duality* between the Voronoi diagram and Delaunay triangulation is such that each triangle in DT(P) corresponds to a vertex in Vor(P). Note that, triangles which are neighbors in DT(P) have automatically their vertices connected by an edge in the Vor(P) dual space. In this context and according to the Delaunay triangulation properties [13], the DT allows us to model a road network composed of a set of points in space connected by roads. The idea is to apply the principle of the Voronoi Diagrams to resolve the problem of road obstacles the sense that determine the most appropriate road without obstacles through it the physician can go. Based on the Voronoi diagram, we will subdivide the map that contains the sites, roads that bind them and obstacles. We call an obstacle, anything that prevents the rapid passage of the doctor to the point of interest.

The largest empty circle technique which is already based on both trigonometric technical described above will certainly solve the problem of loss of time and its principle is as follows : For a region of the plane, find the largest circle containing no obstacle. An obstacle is a subset of the plane, so the main idea is to find for a finite set S of points in the plane, the largest circle that no containing any point of S and whose the center is in the convex hull of S.

### Method

Before determining the largest empty circle for a set of points of interest already containing a set of obstacles, the first step is to build the Voronoi diagram (Vor(P)) and the Convex Hull (CH(P)) for this set. using the Voronoi diagram algorithm [12].

### Computing the DT(P), Vor(P) and CH(P)

- **The Delaunay Triangulation**
  The author in [12] has described an incremental algorithm for the computation of the Delaunay triangulation. To begin, we choose a very large encompassing triangle and we add to it points of P. While adding a point p, we check the current triangulation and we locate the triangle T that contains p. Then, we draw edges between P and each vertex of the triangle T. By doing this, we can introduce new triangles. Figure 2 shows an example. Now, once Delaunay triangulations are found, we can dualize it to represent the Voronoi diagram.

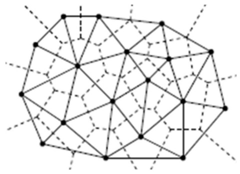

**Fig. 2.** The Delaunay triangulation (solid lines) and the Voronoi diagram (broken lines).

[12]

- **The Voronoi Diagram**
  As it was mentioned above, and according the dualization principle; triangles that are adjacent in DT(P) have their vertices connected by an edge in Vor(P). The coordinates of the Voronoi vertex which corresponds to a triangle T$\in$ DT(P)can be found by searching the center of the circumscribed circle of T. Knowing that, the circum circle of a triangle is centered at the intersection of all the mediators of this later. So to find Vor(P) from DT(P), we must seek all circumscribed circles of all triangles in DT(P). Once all the

vertices have been found, they are connected to each other with an edge. For each triangle T∈ DT(P) and its corresponding point p∈ Vor(P), we retrieve all of T's T′. For each t $\in T'$, we take its corresponding point $p' \in$ Vor(P) and draw an edge between p and p′. Finally, the resulting set of edges describes the Voronoi partition.(See figure 3)

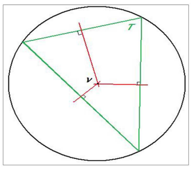

**Fig. 3.** The circum circle for a triangle T
[13]

- **The convex Hull**
  By definition, the boundary of the exterior face of the Delaunay triangulation is the boundary of the convex hull of the set of point. After determining DT(P) and Vor(P), we need to calculate CH(P) to proceed the research of the largest empty circle(LEC). To do this, a simple algorithm to compute CH(P) is described by the authors in [14]. An example is shown in figure 4

### 4.2 Finding The Largest Empty Circle

In the matter of fact, the LEC is always centered at either a vertex of the Voronoi diagram for P or on an intersection between a Voronoi edge and the convex hull of P. The following algorithm summarizes all the steps:

*Algorithm 1: LEC algorithm*

```
Input: G: Road networks map, P: Set of point in the map
Output: LEC: The largest empty circle
Method:
1: Compute the Voronoi diagram VD (P)and the Convex hull CH(P);
3: for each Voronoi vertex v do
       if v is inside CH then
         Compute radius of the circle centered on v and update max;
       end
   end
4: for each Voronoi edge e do
         Compute p = intersection between e and H and Compute
         radius of the circle centered on p and update max;
   end
LEC   max;
5: return LEC;
```

After constructing the Voronoi diagram and the convex hull of the set of points P, we proceed searching both of the Voronoi vertices and the intersections between Voronoi edges and Convex hull edges to find all candidates circles and leave the one with the largest radius.

- **Checking Interior Voronoi Vertices**
  This step consists in finding the summits Voronoi which are inside the convex Hull. To do this a naive approach based on the following principle can be used: for each Voronoi vertex, we walk counterclockwise around CH(P) while checking if the vertices are situated to the left of the edge. If this condition is checked and the vertices is to the left of all edges in CH(P), so this vertex is inside and added to the list of LEC candidate centers.
- **Finding Convex Hull and Voronoi Edge Intersections**
  Also in this step another naive approach is followed to find the intersection between Voronoi edges and the Convex Hull edges. The idea is: for each Voronoi edge we check the two end points compared with the CH(P). If one is inside and the other is outside, this edge must intersect CH(P) at a point. This procedure is performed for all Voronoi edges to successfully find all intersections of Vor(P) and CH(P)(see figure 4).

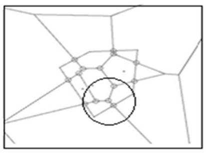

**Fig. 4.** All candidate centers.
[13]

- **Locating the Largest Empty Circle**
  Finally, after determining all possible points on which the LEC may be centered, the next step is to decide which of these candidates can be the center of the *Largest Empty Circle* (LEC). So, to find this latter, we can use properties of the duality between DT(P) and Vor(P). However, while drawing a circle around a candidate point, the idea is to ensure that this circle contains no points of P. A vertex is the intersection of three edges Voronoi. Indeed, according to the dual relationship between Vor(P) and CH(P), each Voronoi vertex corresponds to a Delaunay triangle and is connected to the vertices corresponding to the neighbors of this triangle. As we see in figure 4, each Voronoi vertex p is incident to at most three Voronoi cells, the three points in the data set P closest to p than other points are those three points which lie in the Voronoi cells to which p is adjacent. So by the same principle, those three points are the vertices of the dual triangle of p in DT(P). Thus,

by simply dualizing p ∈ Vor(P)to T ∈ DT(P), we easily find p's three nearest neighbors. Once they have been found, we choose the closest neighbor and draw a circle about p knowing that the radius is equals the distance between this neighbor and p.

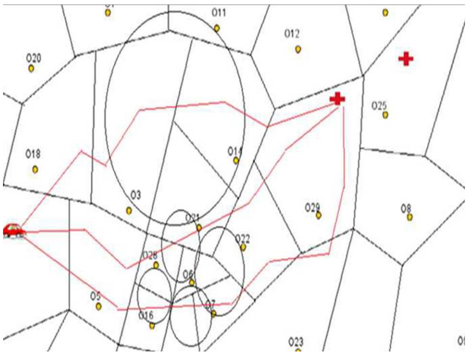

**Fig. 5.** The voronoi diagram and the LEC.

Now if we try to recap all steps cited above, the figure 5 shows an example to obtain the largest empty circle on a town's road network map. First of all, we draw the Voronoi Diagram and the convex Hull of the set of point P. Recall that, the set P consists of: all sites which are marked in red color (we denote by "Site" medical care institutions). Besides, there are obstacles in the form of points (marked in yellow color) such as accidents, road works and other miscellaneous problems and by green color we mark human obstacles. And by red colored path, we depict different road to the point of interest.

### 4.3 Finding the appropriate road

Candidate circles are circles which have a smaller radius than the LEC's radius. To put it simplistically, the area containing the candidate circle is full of obstacles that are presented by rallies of points that somehow prevent the passage of the doctor. Supposedly the obstacle is an accident, where cars and peoples around the obstacle represent an impediment to the passage of the doctor. So, the more points are close to each other, the greater the radius of a circle centered in the vicinity of this barrier is small. And, the more points are distant from each other, the more the circle is large and the more moving is easier as that it is the case with the largest empty circle that contains no obstacle. Actually, the possibility of a rapid movement is proportional to the radius of a circle. In the sense that, with a circle with a large radius the possibility that this circle contains multiple path and different roads is more important. It is at this level therefore appears the importance of Algorithm 2 to find the right way

*Algorithm 2: Finding the appropriate road algorithm*

```
Input: NR: Set of roads leading to the point of interest, G.
Output: SR: The selected road without obstacles.
Method:
1: LEC  LEC algorithm();
2: LSTCcand   Cercle_Cand();
3: for i = 1 n do
       if NR[i] Cross LEC then
              SRNR[i] ;
         else
              SRVerif(G,LSTCcand);
       end
   end
4: Return SR
```

After determining the point of interest, our algorithm proceeds to determine the right path to get there.The algorithm has as input the set of points on the town's road network map, including the points that can be an obstacle and the set of roads that lead the physician to the point of interest. The first step consists in drawing the Voronoi diagram DV (P) and the convex hull CH (P) on the set of points. Then, the second step is tracing the largest empty circle *LEC* as shown in Algorithm1 after tracing the set of candidate circles using the *Circle_Cand()* function. According to Algorithm2, Once the area without hindrance is determined and the list of candidates circle is ready, we proceed to check which is the road that cross *LEC* using the *Cross* function. This function takes as input routes to the point of interest and the largest empty circle and checks which route pass through LEC. Once it is found, this is the road that we are looking for(SR). Otherwise, the algorithm proceeds to execute the *Verif* function. As it's name indicates, it checks in which candidate circle lies the intersection. Similarly, the *Verif* function takes as input all roads leading to the point of interest and the list of candidates circles *LSTCcand*. Figure 5 shows the road which passes through the largest empty circle. This is the road that the doctor is looking for.

## 5 Performance analysis

As indicated in the figure 7, using the button "Show point of interest", the physician select the point of interest and click on the button "Show the largest empty circle". At this time, the area without obstacle modeled by the LEC is displayed to the doctor on his PDA tablet as shown in figure 6. Once the point is selected and the interesting area was displayed, the physician clicks on "Finding the appropriate route" button to display the road which cuts the area without obstacles to go through it.(See figure 7). In reality, we used a Pentium IV 3.0 GHZ CPU and 512 MByte under windows XP to test our system to validate

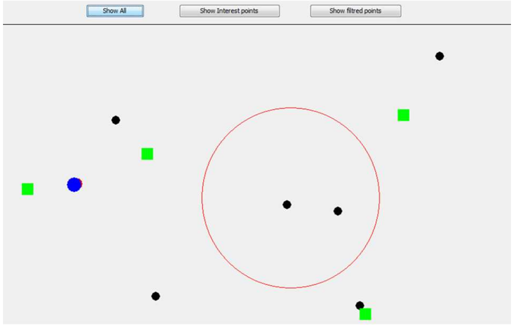

**Fig. 6.** The largest empty circle containing no obstacle.

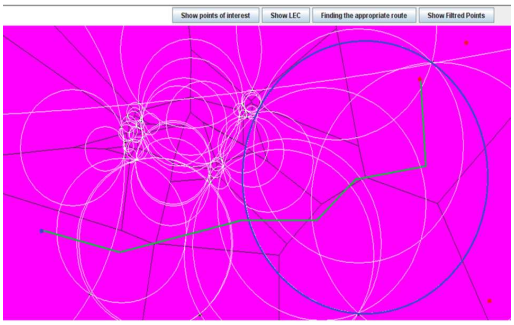

**Fig. 7.** User interface showing the most appropriate road.

results. Concerning the programming language, we used JAVA. To evaluate the performance of the proposed framework, we used two sets of points, one for the set of medical institutions, and the other for the set of obstacles. The experiments show that our algorithm gives good results in terms of accuracy in an acceptable time. Our approach gives accurate results; this is due to the fact that the user(the doctor) has the opportunity to have an idea about what happens on the road. Our algorithm certainly allows him to avoid going through a road that is full of obstacles in which he may be stuck and this is what can cause the death of a patient.

## 6 Conclusions, future works and challenges

In this paper, we have discussed works that has been carried out for medical assistance purpose. Subsequently, we presented health care assistance systems which take into account road information. Compared to what has been achieved, we proposed our approach modeled by a road guidance system. This latter is able to find the appropriate road without obstacle. Finally, our experiments have been showed that our algorithm can solve the wasting time problem since it is capable to give good results in an acceptable time. In reality, after several tests, we find that the execution time tends to 0; it is about 30 milliseconds. As future works, further improvements are possible for the proposed algorithm. We propose to add a technique that controls the traffic on the road which is able to identify congestion areas. Thus, we propose the integration of the high parallel computing capacity that characterizes the Graphics Processing Units(GPU's) to process the continuous change of the mobile obstacles.

## References

1. Varshney, U.: Pervasive healthcare and wireless health monitoring. Mobile Networks and Applications, vol.12, pp.113-127 (2007)
2. Ziefle, M., Rocker, C.: Acceptance of pervasive healthcare systems: A comparison of different implementation concepts. In: PervasiveHealth, pp. 1-6 (2010)
3. Zhenmin, z., Xiaoli, S., Faqun, J., Jintao, L., Jian, Y. : A user-centric pervasive computing services model for medical and health-care. In: GCC 07 Proceedings of the Sixth International Conference on Grid and Cooperative Computing, pp. 841-846. Washington, DC, USA (2007)
4. Tan, J.: E-Health Care Information Systems: An Introduction for Students and Professionals. Jossey-Bass, April (2012)
5. Sulaiman, R., Huang, X., Sharma, D.: E-health services with secure mobile agent. In: Proceedings of the 2009 Seventh Annual Communication Networks and Services Research Conference, CNSR 09, pp. 270-277. IEEE Computer Society,Washington, DC, USA (2009)
6. Malone ,B.: The rise of mobile health devices. Clinical Laboratory News, vol.39, May (2013)
7. Murro, A.: Architecture and interface specifications applications. In: Architecture workshop. Brussels, Belgium (2005)
8. Dimopoulou, E.G.: Implementation of an advanced spatial technological system for emergency situations. In: FIG Workshop on eGovernance, Knowledge Management and eLearning, pp. 187–200 (2006)
9. Nygren, N.: Cooperative freight and fleet applications. In: CVIS W2 open workshop, (2006)
10. Kung, H.Y., Hsu, C.Y., Lin ,M.H.: Sensor-based pervasive healthcare system: Design and implementation. J. High Speed Netw, vol.16, pp.35-49, Jan (2007)
11. Geetha,M., Revathi,R.: M-healthcare emergency monitoring in framework using smart phones. In:International Journal of P2P Network Trends and Technology, vol.3, July (2013)
12. Berg, M.d., Cheong, O., Kreveld, M.v., Overmars, M.: Computational Geometry: Algorithms and Applications,pp.367 (2000)
13. Berg, M.d., Cheong, O., Kreveld, M.v., Overmars, M.: Computational Geometry: Algorithms and Applications. Springer-Verlag TELOS, Santa Clara, CA, USA, 3rd ed (2008)
14. Barber, C. B., Dobkin, D. P., Huhdanpaa, H.: The quickhull algorithm for convex hulls.In: ACM TRANSACTIONS ON MATHEMATICAL SOFTWARE, vol. 22, pp.469-483 (1996)