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Determining Region of Confidence for the Purpose of Localization in Wireless Sensor Network

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Abstract

Localization of a sensor node and target tracking have become an extremely important issue for many applications over WSN. To detect a sensor node is easy if there is no error found between the sensor and reference node. But in real life there is a high possibility that error exists. There are various techniques to determine the position of sensor node but here we are not concern about the techniques. Here we mainly emphasize on calculation of the error percentage between experimental and theoretical distance. The BTS works here as reference node. Here, we have worked with three BTSs in 2D environment. When the BTS wants to measure the distance of the targeted sensor node it increases its range of circumference. After increasing the range of the three BTS they intersect and create a common overlapping area. Our work is to estimate this area.

Declaration

We hereby declare that, this project was done under CSE497 and has not been submitted elsewhere for requirement of any degree or diploma or for any purpose except for publication.

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Letter of Acceptance

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Abbreviation and Acronyms

WSN = Wireless Sensor Network

ROC= Region of Confidence

ROCRSSI= Ring Overlapping based on Comparison of Received Signal Strength Indicator

CPE = Convex Position Estimation

APIT = Approximate Point In Triangulation

AHLoS = Ad-Hoc Localization System

GPS = Global Positioning System

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Chapter 1

Introduction

1.1 Wireless Sensor Network and Localization

Wireless Sensor Networks (WSNs) distinguish themselves from other traditional wireless or wired networks through sensor and actuator based interaction with the environment. In these WSN application, tracking the position of nodes is one of the extremely important issue. That's why sensor node localization with an acceptable accuracy is a basic and important problem for location aware applications of Wireless Sensor Networks (WSNs). Different localization techniques have been used to provide location information of each deployed sensor node in a sensor network. The goal in WSN is to obtain maximum localization accuracy with minimum computations. Several methods can be used to compute the position of a node.

1.2 Region of Confidence

In WSN Region of confidence is the possible area where the unknown node can be located. The three beacon nodes have been used here as reference nodes. Error can be occurred when distance is estimated from the beacon node to dump node because of many environment variables. When the three access points want to detect the dumb node intersection points of them create an overlapping area from the beacon node which is called region of confidence. Only location falling estimates within the ROC has been considered for further processing. The accuracy of such estimation, however varies with the transmission medium and surrounding environment, and usually relies on complex hardware [25]. In this paper we want to represent some methods for calculating that possible area and minimize the possible area of the unknown sensor node to determine it's accurate position.

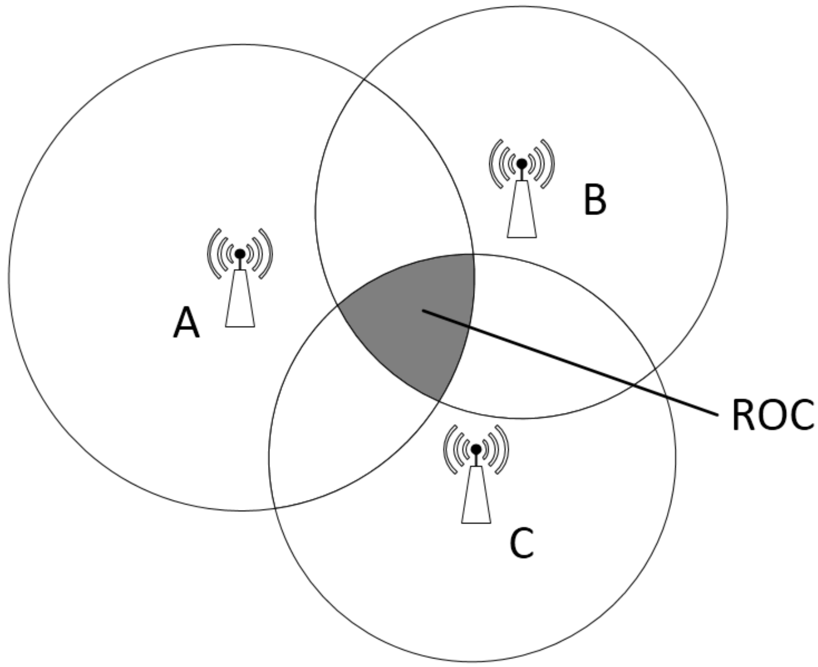

Figure 1.1: Region of Confidence

1.3 Objective of Research

We have taken here three beacon nodes as access points. From these access points, we want to detect the dump node. We assume theoretically the dump node's possible position will be in ROC .The main objective of our thesis is, in a static environment determine the possible ROC and percentage error of distance between experimental and theoretical distance.

1.4 Significance of Research

To determine the area of region of confidence is mainly beneficial for tracking or localization. Localization plays an important role now-a-days. Localization determines the physical coordinates of a group of sensor nodes in a wireless sensor network (WSN) .Investigation and absolute position measurement are also important issues. Localization is also used in nuclear, biological and chemical detection, battlefield surveillance, army operations, industry sectors, exploration of opposing forces and terrain etc. There are many techniques to detect the sensor node. In range free localization system we need to determine the area in which the sensor node might be located. To localize the sensor node there can be used DV-Hop algorithm, Centroid algorithm, ROCRSSI algorithm which only can determine the position of the sensor node. But we also need to measure the possible area in which the sensor node can be located.

In this paper we actually proposed to measure the possible area where the sensor node can be located. In previous work there have many solution to determine only the sensor node. But the significance of the paper is to determine the area where the sensor node might be located.

Chapter 2

Related Work

2.1 Background

In wireless sensor network certain applications require that the sensor nodes should be aware of their position relative to the sensor network. The location or position estimation of sensor nodes simply termed as localization. The term localization has earlier been used in robotics where it is used to refer to determination of location of a mobile robot in some coordinate system. Under certain circumstances, the nodes should not only by aware of their position but also the direction or orientation relative to the network [1].

In a sensor network, the nodes may be categorized as:

Dumb Node (D): The dump node does not know its position and which would eventually find its location and position from the output of the localization algorithm under investigation. Dumb nodes are also known as free or unknown nodes [2].

Settled Node (S): It is a node which was initially a dumb node but managed to find its position using the localization algorithm [2].

Beacon Node (B): A beacon node is a node that knows its position from the very start and always knows its position afterwards also without the use of localization algorithm. It has a mechanism other than the localization algorithm to find its position [2].

Localization is estimated through communication between localized node and unlocalized node for determining their geometrical placement or position. Location is determined by means of distance and angle between nodes.

There are many concepts used in localization such as the following.

- **Lateration:** It occurs when distance between nodes is measured to estimate location.
- **Angulation:** It occurs when angle between nodes is measured to estimate location.
- **Trilateration:** Location of node is estimated through distance measurement from three nodes. In this concept, intersection of three circles is calculated, which gives a single point which is a position of unlocalized node.
- **Multilateration:** In this concept, more than three nodes are used in location estimation.
- **Triangulation:** In this mechanism, at least two angles of an unlocalized node from two localized nodes are measured to estimate its position. Trigonometric laws, law of sines and cosines are used to estimate node position [3].

Localization schemes are classified as anchor based or anchor free, centralized or distributed, GPS based or GPS free, fine grained or coarse grained, stationary or mobile sensor nodes, and range based or range free. We will briefly discuss all of these methods.

2.1.1 Anchor Based and Anchor Free

In anchor-based mechanisms, the positions of few nodes are known. Unlocalized nodes are localized by these known nodes positions. Accuracy is highly depending on the number of anchor nodes. Anchor-free algorithms estimate relative positions of nodes instead of computing absolute node positions [3].

2.1.2 Centralized and Distributed

In centralized schemes, all information is passed to one central point or node which is usually called “sink node or base station”. Sink node computes position of nodes and forwards information to respected nodes. Computation cost of centralized based algorithm is decreased, and it takes less energy as compared with computation at individual node. In distributed schemes, sensors calculate and estimate their positions individually and directly communicate with anchor nodes. There is no clustering in distributed schemes, and every node estimates its own position [4-7].

2.1.3 GPS Based and GPS Free

GPS-based schemes are very costly because GPS receiver has to be put on every node. Localization accuracy is very high as well. GPS-free algorithms do not use GPS, and they calculate the distance between the nodes relative to local network and are less costly as compared with GPS-based schemes [8][9]. Some nodes need to be localized through GPS which are called anchor or beacon nodes that initiate the localization process [3].

2.1.4 Coarse Grained and Fine Grained

Fine-grained localization schemes result when localization methods use features of received signal strength, while coarse-grained localization schemes result without using received signal strength.

2.1.5 Stationary and Mobile Sensor Nodes

Localization algorithms are also designed according to field of sensor nodes in which they are deployed. Some nodes are static in nature and are fixed at one place, and the majority applications use static nodes. That is why many localization algorithms are designed for static nodes. Few applications use mobile sensor nodes, for which few mechanisms are designed [10].

2.1.6 Distance Estimation Techniques

- ANGLE OF ARRIVAL method allows each sensor to evaluate the relative angles between received radio signals
- TIME OF ARRIVAL method tries to estimate distances between two nodes using time based measures
- TIME DIFFERENT OF ARRIVAL is a method for determining the distance between a mobile station and nearby synchronized base station
- THE RECEIVED SIGNAL STRENGTH INDICATOR techniques are used to translate signal strength into distance.

2.2 Prior Works Related to ROC

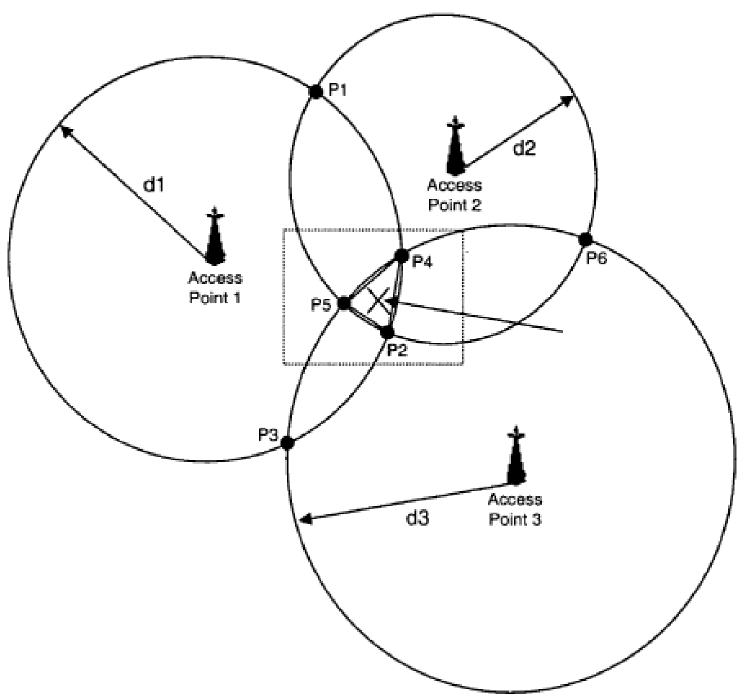

Figure 2.1: Possible Overlapping Area

With the development of pervasive computing and location-aware systems and services, there has been an increased interest in location estimation techniques.

Figure 2.1, the three circles have six intersection points, P1, P2, P3, P4, P5 and P6. The triangulation algorithm examines areas formed by the intersection points to obtain a location estimate for the object. Specially, the triangle formed by P2, P4 and P5 has the smallest area among all possible triangles formed by these intersection points, and the centroid X of the triangle (P2, P4, P5) is the best location estimate of the object. SELFLOC algorithm is advantageous to provide a method for more accurate processing of collected signals to estimate locations of stationary and mobile objects with improved accuracy. The method of the present invention it filers raw values of the run-time radio signal measurements to reject distorted inputs. The method of the present invention also forms a region of confidence (ROC) using conventional location estimation algorithms. An interested object is bound within the ROC with a high probability. Only location estimates falling within the ROC are considered for further processing toward a final location estimate. The present invention uses location estimation algorithms, such as triangulation, K-nearest neighbor averaging, and smallest M-polygon, to determine the center of the ROC. It should be understood that other location estimation algorithms could be used as well.

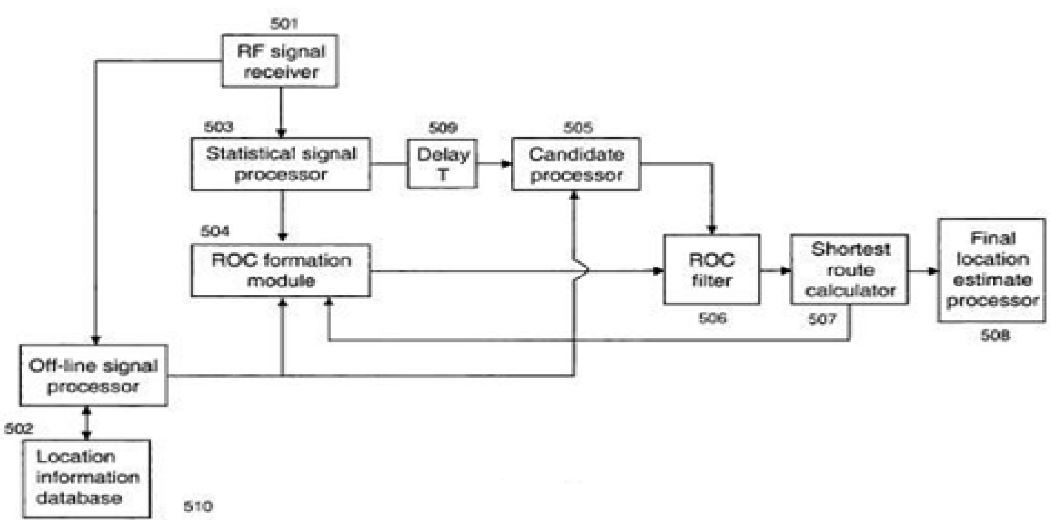

Figure 2.1: Flow Chart to Determine ROC

Whenever the T ROC expires, the shortest route calculator 507 informs the ROC formation module 504, and a new ROC is generated. In one embodiment, when the total distance of the shortest route exceeds radius of the ROC, it is possible that the object has moved out of the current ROC, and a new ROC is generated. In another embodiment, T ROC is a configurable parameter and the ROC is regenerated periodically whenever the T ROC expires. A shortest route (or shortest path) calculator 507 receives signals from the ROC fitter 506, and calculates a shortest route connecting all location estimate candidates output by the ROC filter 506. (From block diagram figure 2.2) [13].

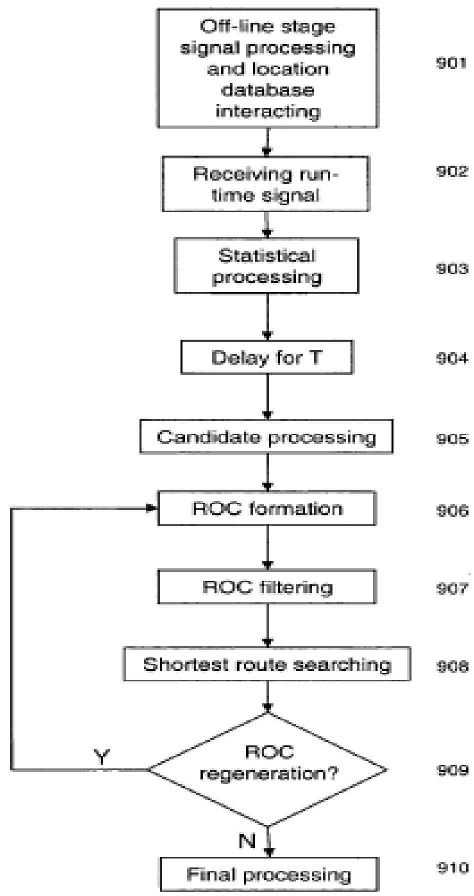

Figure 2.1: Flow Chart of a Method for Location Estimation

Here, Fig. 2.3 shows a flowchart of a method for location estimate according to embodiments of the present invention. At step 901, the off-line stage signal processing is carried out and the indoor Wireless environment is calibrated by creating and storing the signal metric and associated positions in new entries in the location information database or by updating the existing entries with new values. Run-time signals are received at step 902 and statistically processed to remove distorted RF signals at step 903. In accordance with certain embodiments, the statistically processed run-time RF signals may be provided with a time delay T at step 904. Location estimate candidates are calculated at step 905 and a ROC is formed at step 906. At step 907, location estimate candidates out of the ROC are filtered to improve the accuracy of the location estimation. At step 908, the shortest route connecting all location estimate candidates output by the ROC filter 506 is searched to further reduce errors. If it is time for ROC regeneration, the process goes back to step 906. Otherwise, the process proceeds to step 910 to produce the final location estimates [13].

2.3 Relevant Algorithms to Identify the Location of Unknown Node

In localization system there are various types of algorithms are proposed to estimate the sensor nodes. The related algorithms to identify the location of unknown node are shortly described below.

2.3.1 Centroid Localization Algorithm

Centroid algorithm is put forward by outdoor positioning algorithm of network connectivity in the University of Southern California [12]. The core of the algorithm is that the anchor nodes broadcast a beacon signal to the network every once in a while. The signal itself and location information contained in “received from different when the unknown anchor node beacon signals exceeds a preset threshold or received after a certain period of time, the node will determine its position for the anchor nodes of polygon centroid”, “literature of centroid algorithm is improved, the density of the proposed adaptive method, the best plans in areas of low anchor node density increase of anchor nodes, in order to improve the positioning accuracy”. Fully advantages of the algorithm are based on network connectivity, without coordination between the unknown node and anchor node. This implementation is relatively simple, where shortcoming is positioning accuracy which is not high. A disadvantage of the centroid localization algorithm is that the localization accuracy depends on the density of the anchor node excessively.

2.3.2 DV-Hop Algorithm

DV-Hop algorithm is one of the range-free localization algorithms in wireless sensor networks. DV-Hop algorithm is based on hop count which was proposed by Dragos Niculescu [11].

DV-Hop algorithm positioning process is divided into three steps:

1st Step:
Beacon nodes broadcast their locations to the neighbors of information packets, containing the jump number field is initialized to 0. Each receiving node maintains minimum hop count value which ignores a beacon node from the same large number of hops of a packet. Then hop count plus one, and forwarded to the neighbors. Through this process, all nodes in the network get the minimal hop count to every anchor node.

2nd Step:
In this step the unknown node average hop distance is estimated. Beacon nodes by saving the coordinates of the other beacon nodes and the minimum number of hops using the equation (1) in the network calculate the average hop distance:

$$c_i = \sum_{i \neq j} \frac{\sqrt{(x_i - x_j)^2 - (y_i - y_j)^2}}{\sum_{i \neq j} hop_{ij}} \tag{1}$$

(x_i, y_i) and $(x_j, y_j)$are the coordinates of anchor node i and j, respectively. hop_{ij} is the jump section number between anchor node i and j ($i \neq j$), we can calculate the coordinates of the nodes to be located. Then, the beacon node will calculate the average distance per hop fields with a packet with a lifetime of broadcasting to the network. The unknown nodes receive the hop size information and save the first one. Meanwhile they forward the hop size to the neighbors. This strategy ensures that the most recent beacon node from the node receives the value of the average distance per hop. Unknown node receives the average hop distance, according to the recorded number of hops to each beacon node calculate the hop distance.

3rd step:

In this step, when unknown nodes get three or more distance information from anchor nodes, the trilateral measuring method or the maximum likelihood estimation method is used to calculate their locations."

The DV-hop algorithm is simple, less communication overhead, computation amount is less, the cost is low; but to achieve good positioning accuracy, it needs to decorate the large number of anchor nodes [12].

2.3.3 Bulusu's Algorithm

Bulusu's Algorithm has been designed for the localization of nodes in sensor networks. This single-hop, range-free localization algorithm due to Bulusu, Heidmann and Estrin assumes an idealized radio model where all sensor nodes possess the same transmission power so that their transmission range is identical [4]. It is further assumed that all sensor nodes transmit in an idealized spherical fashion. Each node transmits periodic beacon signals every T seconds containing its position information. The neighbor beacon nodes are synchronized in time such that their beacon signals do not overlap in time, and in any time interval T, each beacon node transmits exactly one beacon signal. However, beacon nodes have an overlapping region of transmission. Each dumb node j keeps a count of the number of beacon signals received from a particular beacon node i in some fixed time interval t. Knowing the time period T after which a beacon signal is transmitted by the beacon node i, the dumb node j can also compute the total number of beacon signals transmitted by the beacon node i in time interval t. Using both these parameters, the dumb node j can compute a connectivity metric for a particular beacon node. The connectivity metric is given by the percentage of beacon signals received by the dumb node j which were transmitted by the beacon node i. According to experimental results obtained by Bulusu, Heidmann and Estrin [20], the localization error falls within 30 percent of the separation distance between two adjacent beacon nodes. One major advantage of Bulusu's algorithm and all other proximity based and range-free algorithms is that no additional hardware is required to measure timing information so as to calculate distance between beacon node and dumb node. Without this additional hardware, size of the node remains tiny, and energy, which is a scarce resource in sensor network has been also conserved. Disadvantage of Bulusu's algorithm is that it requires a high density of beacon nodes in the sensor field so that each dumb node has at least three neighbor beacon nodes. Furthermore, the algorithm works only for single-hop sensor networks and is not suitable for sensor network which are multi hop in nature [13].

2.3.4 Amorphorous Algorithm

Amorphous algorithm is easy to implement but it will produce large error in the process of localization. In order to solve the problem, an improved localization algorithm has been proposed.

The proposed algorithm is clarified in two aspects:

(1) Modify the minimum hop from the unknown node to the beacon node by setting the received signal strength threshold;

(2) BP algorithm is introduced to optimize the threshold and reduce the localization error The improved algorithm introduces the received signal strength threshold to modify the minimum hop from the unknown node to the beacon node. Then, BP algorithm has been introduced to optimize the threshold and reduce the localization error [14] [15]. It assumes that the average network connectivity of local is known and uses Equation (1) to compute network average hop distance. Among them, r is the communication radius, n local is the average network connectivity. The average distance of each hop estimated distance multiplied with minimum hop count is calculated to be positioning of nodes, and anchor nodes also need to work out at least three distances, using maximum likelihood estimation to estimate its position.

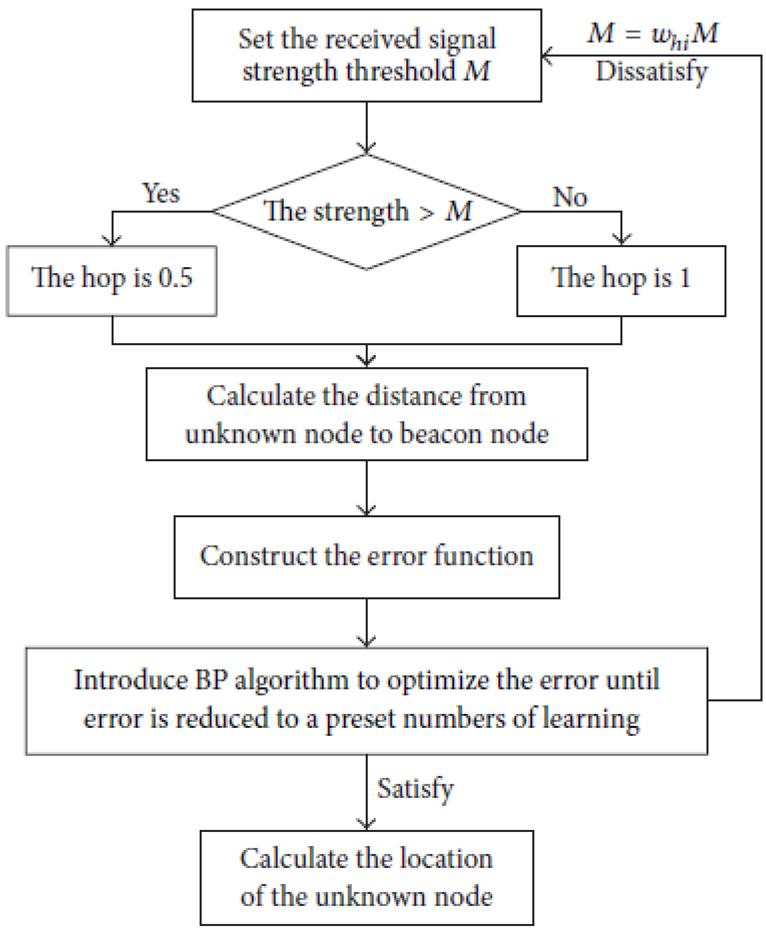

Figure 2.2: The Flow Chart of the Improved Algorithm

In essence, the Amorphous algorithm is an enhanced version of DV-Hop algorithm, the gradient correction method and the distance of each hop algorithm calculation, and the introduction of a number of anchor nodes estimate refinement. The algorithm needs to predict the average connectivity of network and need higher node densities.

2.3.5 Convex Position Estimation

Convex Position Estimation (CPE) algorithm was proposed by Doherty, Pister and Ghaoui [16]. It treats the problem of sensor node localization as an optimization problem and applies linear programming to arrive at the solution for the localization problem.

A convex set is a set of points such that any two points in the set can be connected with a path comprising of points contained within the set. The set of all the nodes in a sensor network forms a convex set as a path between any two nodes comprises of only nodes which are within the set of the sensor nodes. There is a path P between nodes M and N if either of M and N communicates with the other or both M and N communicate with each other. The path comprises of nodes M and N and all other intermediate nodes which participate in communication between them.

Given: Positions of beacon nodes

Find: Positions of dumb nodes

Subject to: Connectivity constraints of the beacon and dumb nodes

2.3.6 Approximate Point In Triangulation (APIT)

In this section, we describe our novel area-based Range-free localization scheme, which is called APIT. APIT requires a heterogeneous network of sensing devices where a small percentage of these devices (percentages vary depending on network and node density) are equipped with high-powered transmitters and location information obtained via GPS.

The first step of APIT algorithmic is to determine a plurality of triangular region that contains unknown node, the intersection of these triangular areas is a polygon; then to determine the smaller area including unknown node and calculating the position of the centroid of the polygon, that is, the position of unknown node.

The APIT algorithm can be broken down into four steps:

1) Gather Information**:** Information of the anchor.
node near the unknown node, such as the position, identification number, signal strength degree;
2) APIT Testing**:** Testing whether the unknown node is internal of the triangle that combined with different anchor nodes.
3) Calculate Overlapping Areas**:** Calculate the overlapping area of the all triangles that contain unknown nodes;
4) Computing Unknown Node Position**:** Calculate the centroid of the overlapping area and the position of the unknown node.

These steps are performed at individual nodes in a purely distributed fashion. Before providing a detailed description of each of these steps, we first present the basic pseudo code for our algorithm.

2.3.7 Bounding Box Algorithm

This algorithm uses discrete communication model, and uses a square as communication area, which take *r* as communication radius and 2*r* as side length, as shown in Figure 2.5**.**
P is unknown node in Figure 2.5. Considering P as the center, within the area of r radius, there are A, B and C anchor nodes. To make these squares which take point of A, B, C as the center respectively and 2*r* as side length.

Then take the centroid of rectangular region of three squares' intersections as the estimated location of node P. If the P as the center, within the area of *r* radius, there are *k* as anchor nodes, the rectangular region centroid of *k* squares' intersection can be the position of the unknown node.

The size and position of intersection region can be obtained by Equation (2).

$$
\begin{aligned}
y_1 &\quad \max\ y_i - r; \\
y_2 &\quad \min\ y_i + r; \\
x_1 &\quad \max\ x_i - r; \\
x_2 &\quad \min\ x_i + r;
\end{aligned}
\tag{2}
$$

that (x_i, y_i) is the coordinates of the ith anchor nodes, $i = 1, 2, k$.

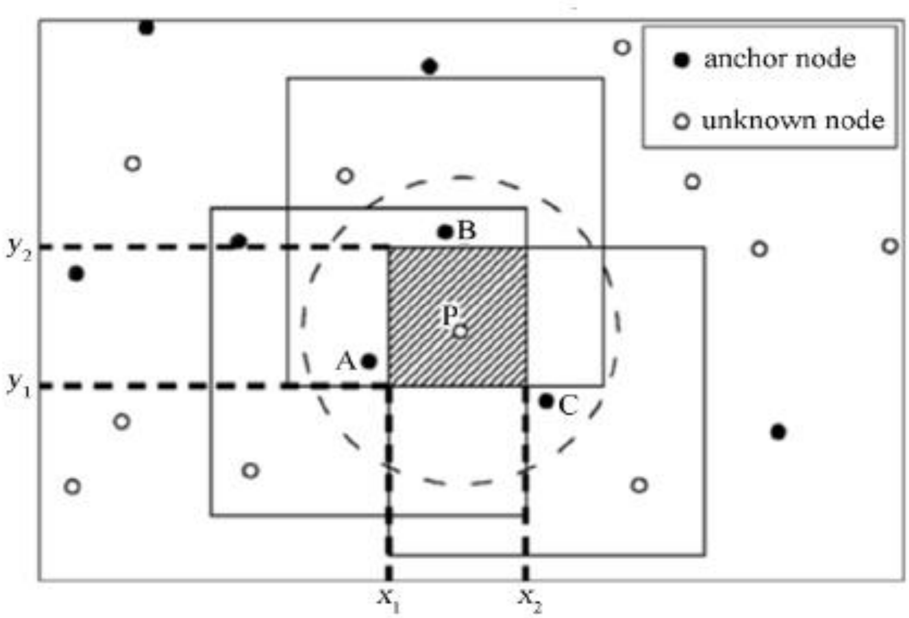

Figure 2.3: Bounding Box Algorithm

2.3.8 Geometric Algorithm for RSS Based Mobile Positioning

This paper describes a simple and efficient geometric algorithm using received signal strength measurements extracted from at least three base stations. This method is compared with standard Least Squares method. The simulation results show, that geometric algorithm gives more accurately location estimation than LS algorithm in multipath propagation.

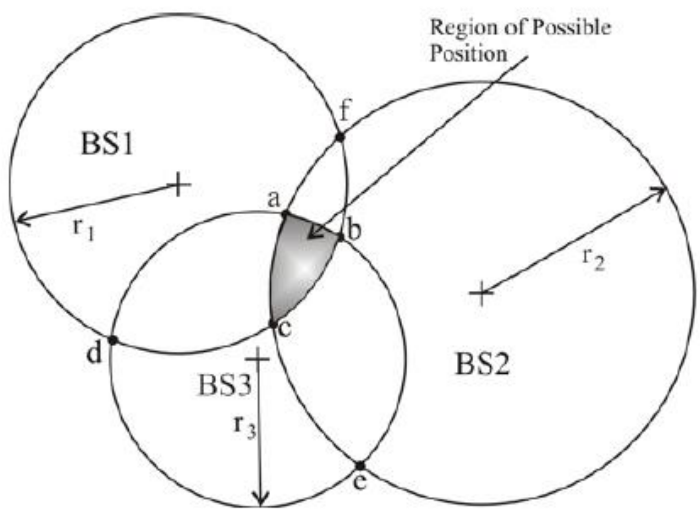

Figure 2.4: Geometric Algorithm

2.3.9 Iterative and Collaborative Multilateration

In this case where a dumb node is at a distance of one hop from at least three non-collinear beacon nodes, the dumb node can perform multilateration to determine its position.

Once a dumb node has estimated its position with the help of beacon nodes, it can be used as a beacon node by other dumb nodes to estimate their positions. This basic scheme of position estimation is the basis of iterative location estimation [19]. The algorithm is essentially a two-step process. As proposed by Savarese, Rabaey and Beutel and Savarese, Rabaey and Langendoen, all the dumb nodes compute a rough estimate of their positions in the first phase using an algorithm called Hop-Terrain [23]. This is referred to as start-up phase. In the second phase, called the refinement phase, the computed position estimates are refined using an iterative process in which the immediate neighbor nodes of a dumb node take part in the process.

A similar algorithm has been proposed by Savvides, Han & Strivastava [19]. The authors call this algorithm as Ad-Hoc Localization System (AHLoS). The algorithm builds upon the idea of atomic multilateration. The case where a dumb node is at a distance of one hop from at least three non-collinear beacon nodes, the dumb node can perform multilateration to determine its position. This is termed as atomic multilateration. The iterative multilateration uses the atomic multilateration as its main primitive. The algorithm supports central, distributed or cluster-based processing. If the algorithm is deployed using distributed processing, first the dumb nodes with a distance of one hop from at least three beacon nodes estimate their position using atomic multilateration. These dumb nodes, after their positions have been estimated, are immediately available as beacon nodes and the other dumb nodes can then utilize their position information for their own position estimation using iterative multilateration.

If the algorithm uses centralized processing, the central node has the global knowledge of the sensor network. The network is represented by a graph G on which the algorithm operates. The graph has weighted edges to denote the separation between two adjacent nodes. At first, the positions of those dumb nodes which are at a distance of single hop from at least three beacon nodes are determined using atomic multilateration. With the central processing, the algorithm first determines positions of those dumb nodes that have connectivity with maximum number of beacon nodes. This results in better accuracy and faster convergence. As soon as a dumb node has settled i.e. it has estimated its position, it becomes a beacon node so that remaining dumb nodes can use it for multilateration. This iterative procedure repeats until the positions of all the dumb nodes have been estimated.

A drawback of the iterative multilateration is the propagation and accumulation of error which results from the use of settled nodes as beacon nodes. As the position estimates of these nodes are not as precise as beacon nodes, the multilateration involving these nodes may accumulate these errors.

It is also possible that the algorithm does not converge due to accumulation of error and the accumulated error increases with time if the algorithm keeps running. As a countermeasure, it has been suggested to add confidence weights to position estimates of settled nodes being used as beacon nodes and then solve a modified optimization problem [18]. With this approach, the algorithm converges for almost all cases of location estimation and also produces better position estimates. Furthermore, the convergence problem can also be avoided by using better and high precision ranging techniques.

For iterative multilateration to be possible, at least three beacon or settled nodes must be in the neighborhood of the dumb node for which position is to be estimated. However, this is not always the case. Not all the nodes in the sensor field have three neighbor nodes with known position estimates. Under such situation, it is not possible to find the position of a dumb node by mere atomic or iterative multilateration. Another technique called collaborative multilateration may be used for position estimation of such nodes [18][19]. Collaborative multilateration is a technique in which a dumb node uses multi-hop information from another neighbor dumb node and solves a joint set of location estimation functions to determine positions of both dumb nodes simultaneously. The solution obtained may or may not be unique. A unique solution to the problem of location estimation using collaborative multilateration is reached only when a participating node has at least three participating neighbors. A participating node is a sensor node which is either a beacon node or a dumb node with at least three participating neighbors.
Collaborative multilateration may be used as an enhancement to iterative multilateration. As a result of collaborative multilateration, the number of dumb nodes reduces and the number of settled nodes increases. These settled nodes can further be used in another round of iterative multilateration to determine locations of more nodes and to improve the accuracy of location estimates.

2.3.10 Comments about Localization Algorithms

Several localization algorithms focus on different aspects such as errors, number of beacons, number of settled nodes, or GPS usage, among other things. Usually, these algorithms try to reduce or completely remove the need for GPS receivers on beacon nodes. Other algorithms take advantage of certain network features, such as beacons with high-powered transmitters, a directed localization recursion, or a beacon infrastructure [23] [21] [22]. The choice of which algorithm to use depends on the resources available, the scenario, the requirements of the application, and the mean localization error acceptable to the nodes.

Chapter 3

Proposed Method

3.1 Methodology to Determine the ROC in Different Scenario

Our main purpose is to determine the overlapping area with the help of various formula and compare the percentage of error in distance in various situations. We also add here a new term to determine the ROC. This term will be shown in flowchart.

3.1.1 Formula which are used to determine the ROC

Heron's formula states that the area of triangle whose sides have lengths a, b, and c is

$$A = \sqrt{s(s-a)(s-b)(s-c)}$$

Where S is the semiperimeter of the traingle that is ,

$$s = \frac{a+b+c}{2}$$

Heron's formula can also be written as

$$A = \frac{1}{4}\sqrt{(a+b+c)(-a+b+c)(a-b+c)(a+b-c)}$$

$$A = \frac{1}{4}\sqrt{2(a^2b^2 + a^2c^2 + b^2c^2) - (a^4 + b^4 + c^4)}$$

$$A = \frac{1}{4}\sqrt{(a^2 + b^2 + c^2)^2 - 2(a^4 + b^4 + c^4)}$$

$$A = \frac{1}{4}\sqrt{4a^2b^2 - (a^2 + b^2 - c^2)^2}$$

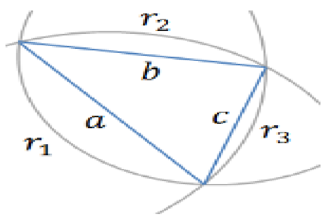

Figure 3.1: Inner Triangle of Overlapping Area and their Sides

The sides a, b and c of the inner triangle can be calculated as

$$a = \sqrt{(x_{i1} - x_{i2})^2 + (y_{i1} - y_{i2})^2}$$

In order to calculate segment area ,

$$A = r_1^2 \sin^{-1}\left(\frac{a}{2r_1}\right) - \frac{a}{4}\sqrt{4r_1^2 - a^2}$$

Now the combined lapping area is,

$$A_{seg} = \sum_{n=1}^{3} r_n^2 \sin^{-1}\left(\frac{a}{2r_n}\right) - \sum_{n=1}^{3} \frac{a_n}{4}\sqrt{4r_n^2 - {a_n}^2} + \sqrt{s(s-a)(s-b)(s-c)} \quad [24]$$

3.1.2 Flow chart to Determine ROC

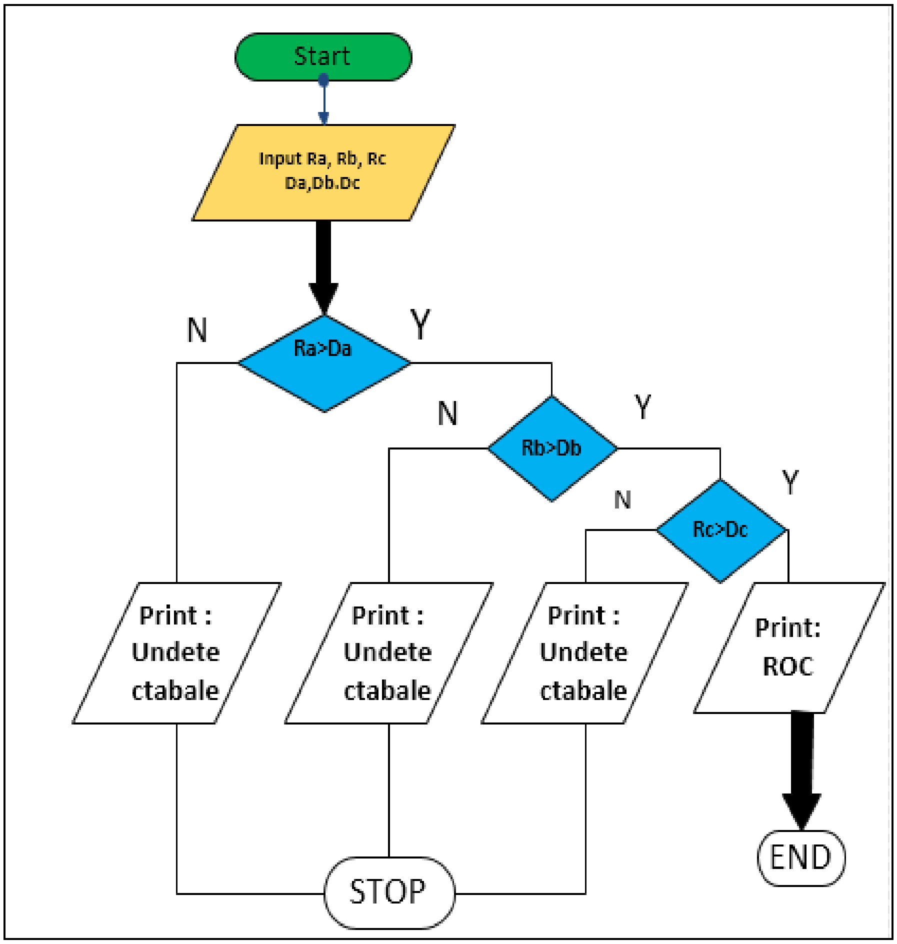

Figure 3.2: Flow Chart of Determining Negative Error

+ve error : When the experimental value is greater than theoretical value we get positive error.

-ve error : When the experimental value is less than theoretical value we get positive error.

Then percentage error of distance also gives negative percentage of error.

Here the flowchart explains that,

If the experimental value Ra, Rb and Rc both of them are greater than their theoretical distance (Da, Db, Dc) from sensor to beacon then we can get the ROC.

3.1.3 Simulation of Figure in Different Scenario

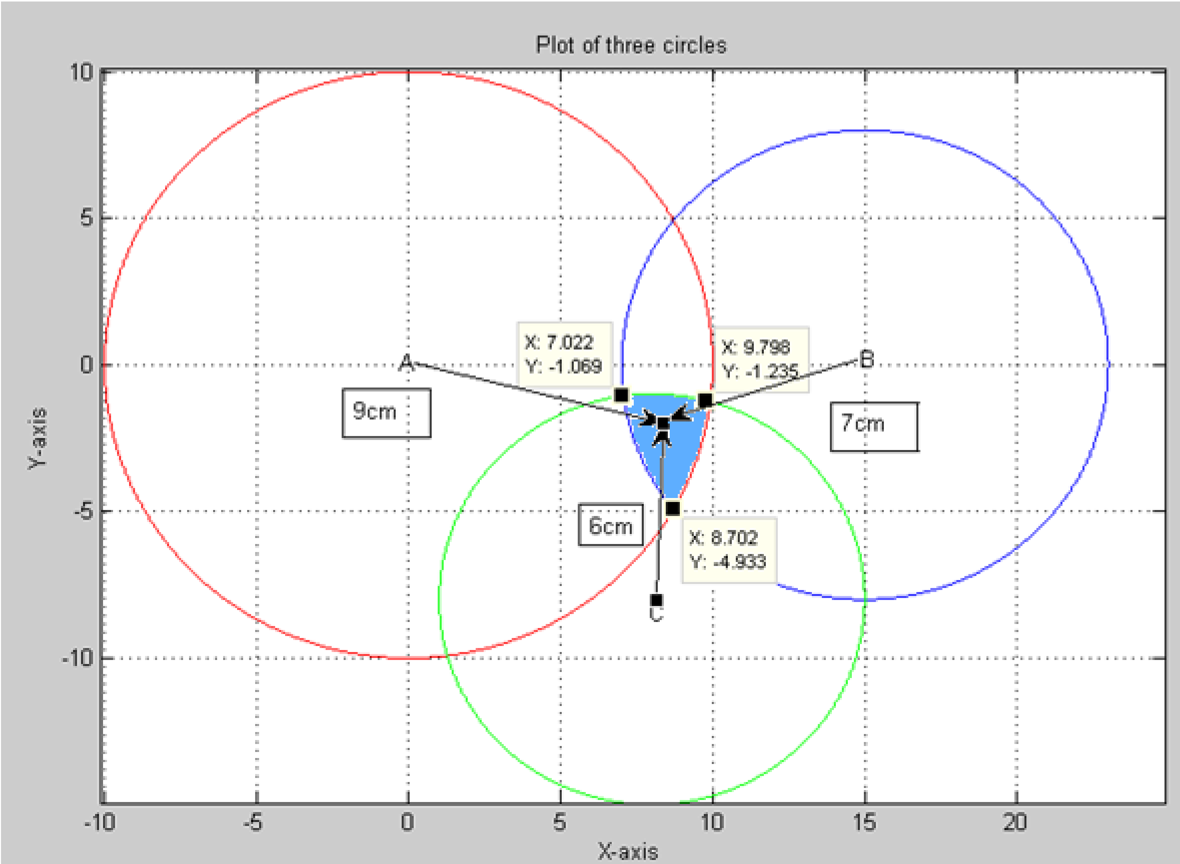

Figure 3.3: Positive Error of Percentage in Three Circles

Experimental distance (measured value getting from sensor to beacon):

A =10 cm , B=8 cm ,C=7 cm

Theoretical distance:

A =9 cm , B=7 cm ,C=6 cm

Error of 3 beacons: +ve error

Difference of error: little difference in A ,B and C (C> B >A)

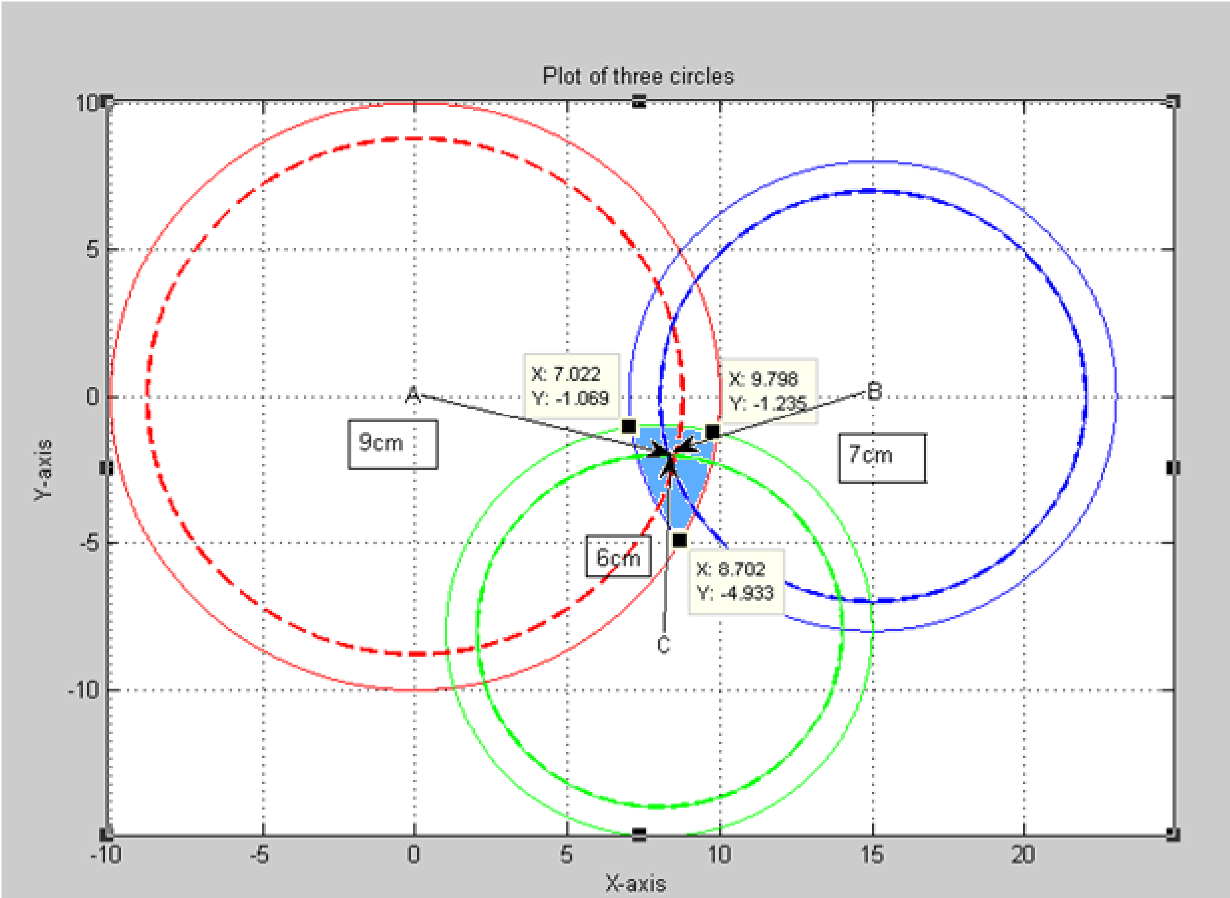

Figure 3.4: Positive Error of Percentage in Three Circles

Experimental distance (measured value getting from sensor to beacon):

A =10 cm, B=8 cm, C=7 cm

Theoretical distance:

A =9 cm , B=7 cm ,C=6 cm

Error of 3 beacons: +ve error

In this figure dot dot circles have drawn to show when in ideal environment the circles perfectly intersect the unknown node's position.

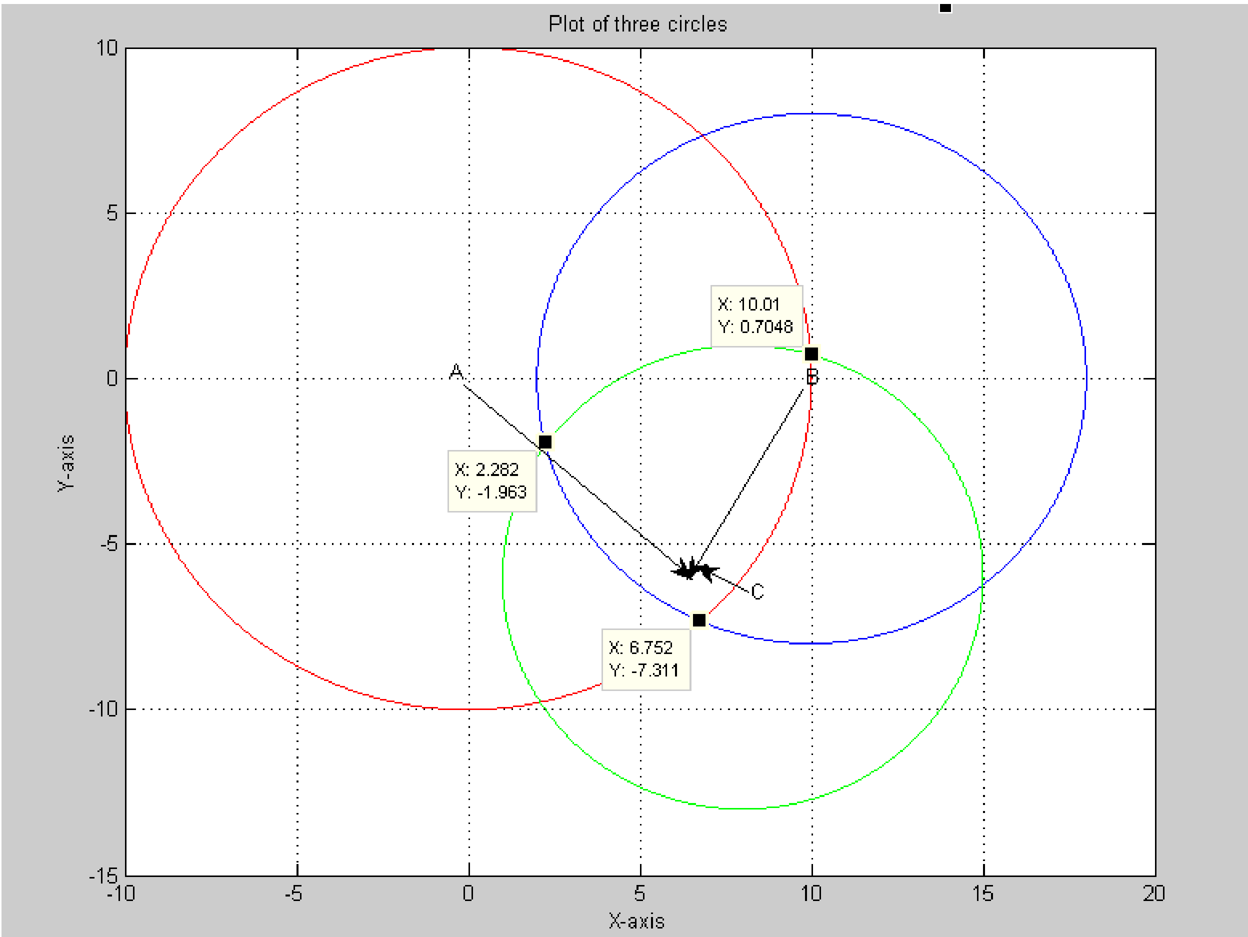

Figure 3.5: Positive Error of Percentage in Three Circles

Experimental distance (measured value getting from sensor to beacon):

A =10 cm, B=8 cm, C=7 cm

Theoretical distance:

9 cm, 7 cm, 2 cm

Extreme error: Beacon C

Difference of error: B>A

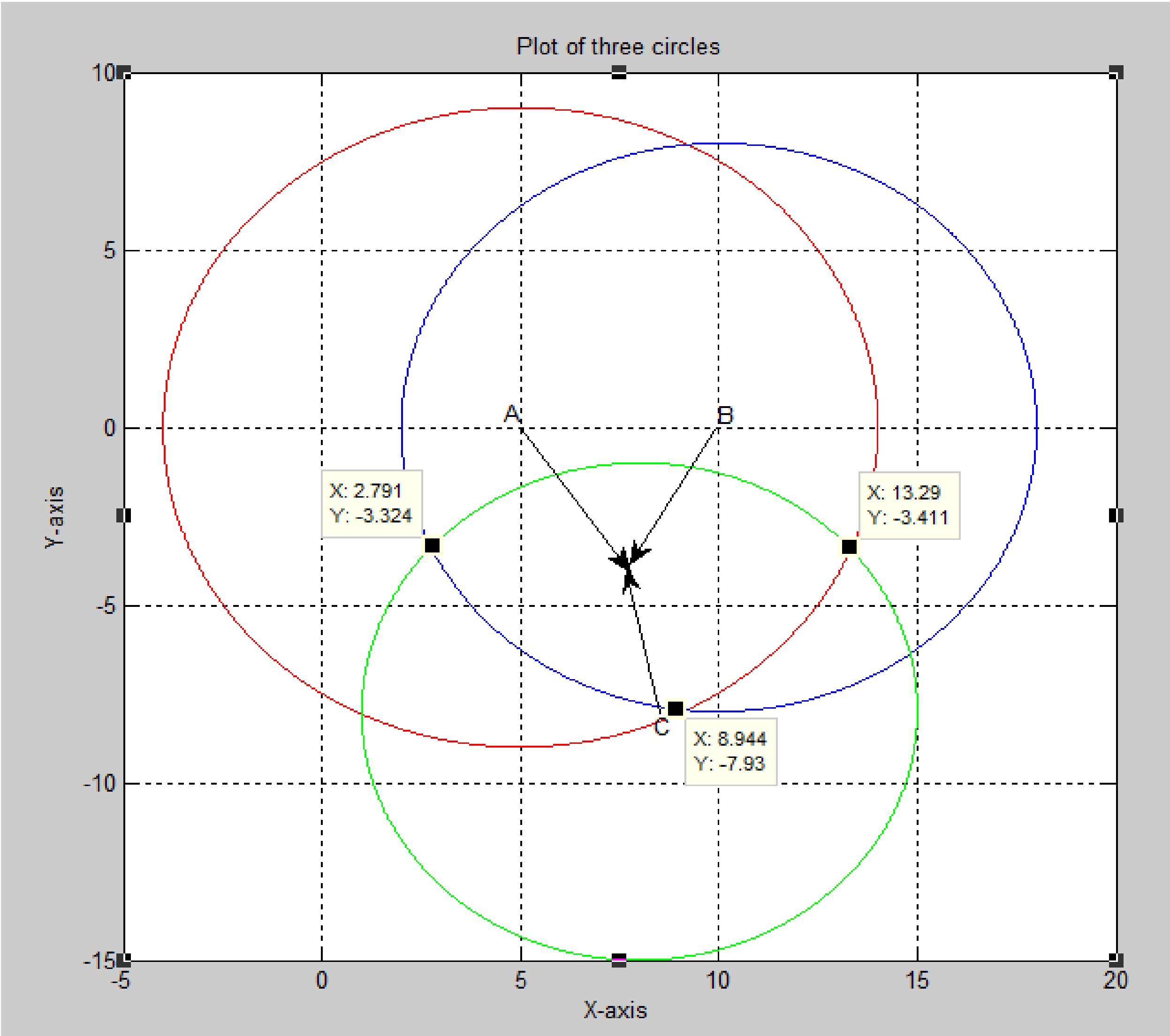

Figure 3.6: Positive Error of Percentage in Three Circles

Experimental distance (measured value getting from sensor to beacon):

A =9 cm, B=8 cm, C=7 cm

Theoretical distance:

5 cm, 4.5 cm, 4.5 cm

Difference of error: Almost same in Beacon A and B (A>B)

Theoretical Value and Experimental Value Same:

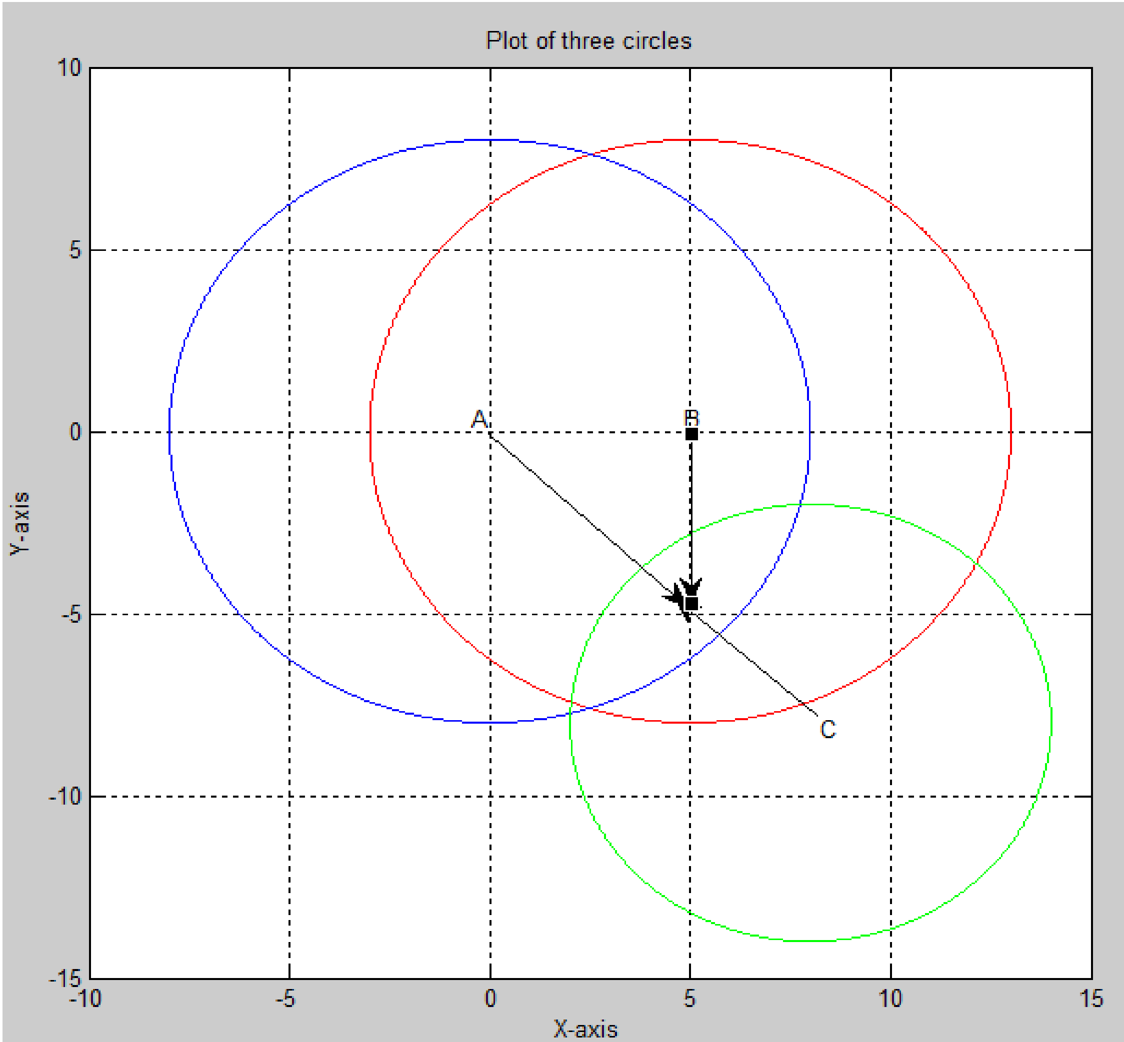

Figure 3.7: Positive Error of Percentage in Three Circles

Experimental distance (measured value getting from sensor to beacon):

A =8 cm, B=8 cm, C=6 cm

Theoretical distance:

7 cm, 7 cm, 4.5 cm

Difference of error: Almost same in Beacon A and B (A>B)

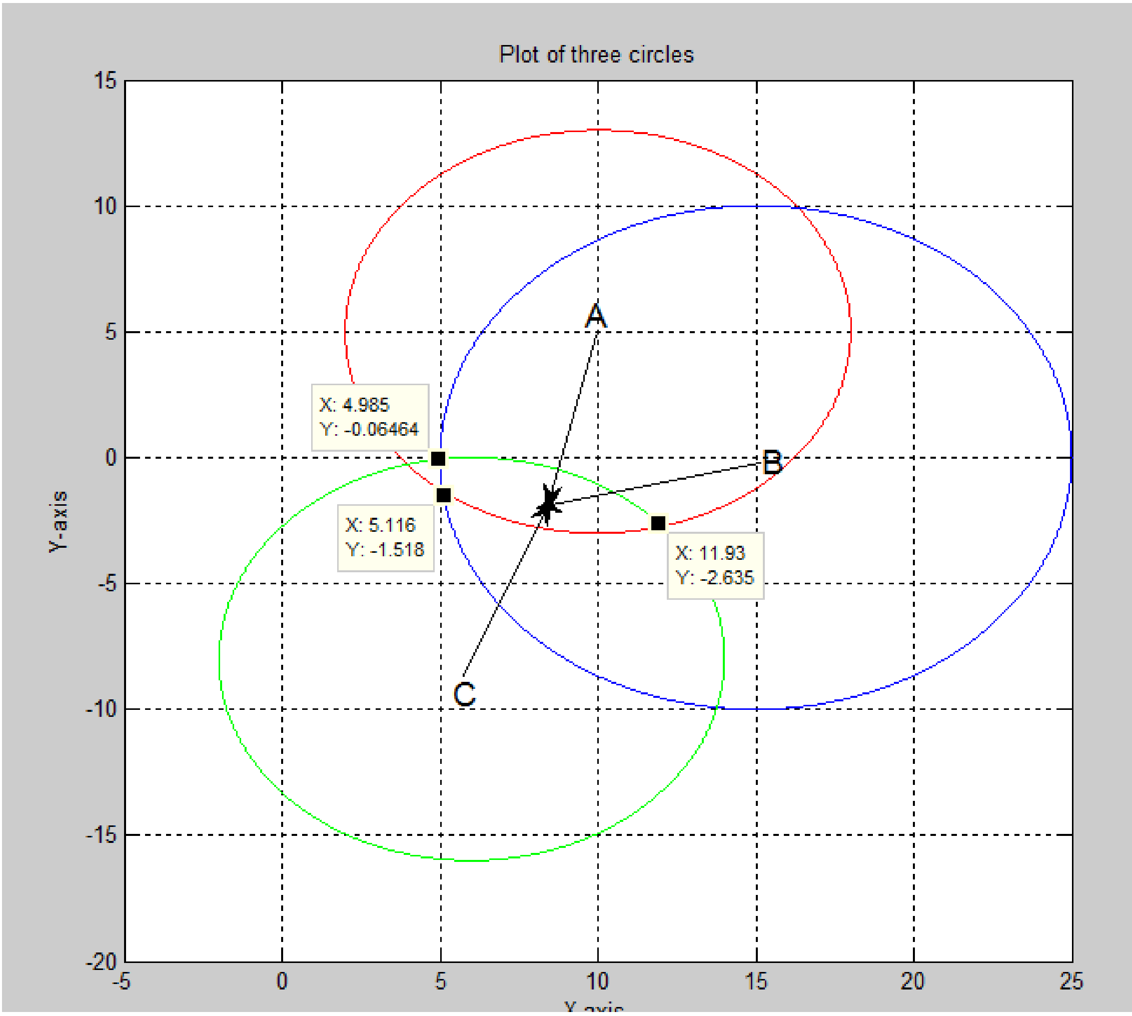

Figure 3.8: Positive Error of Percentage in Three Circles

Experimental distance (measured value getting from sensor to beacon):

A =8 cm, B=10 cm, C= 8 cm

Theoretical distance:

7.8 cm, 4.5 cm, 7.5 cm

Difference of error in distance measurement: Little difference in C and A (C>A)

Extreme error: Beacon B

3.1.4 Analysis of Problem Field from Figures of Simulation

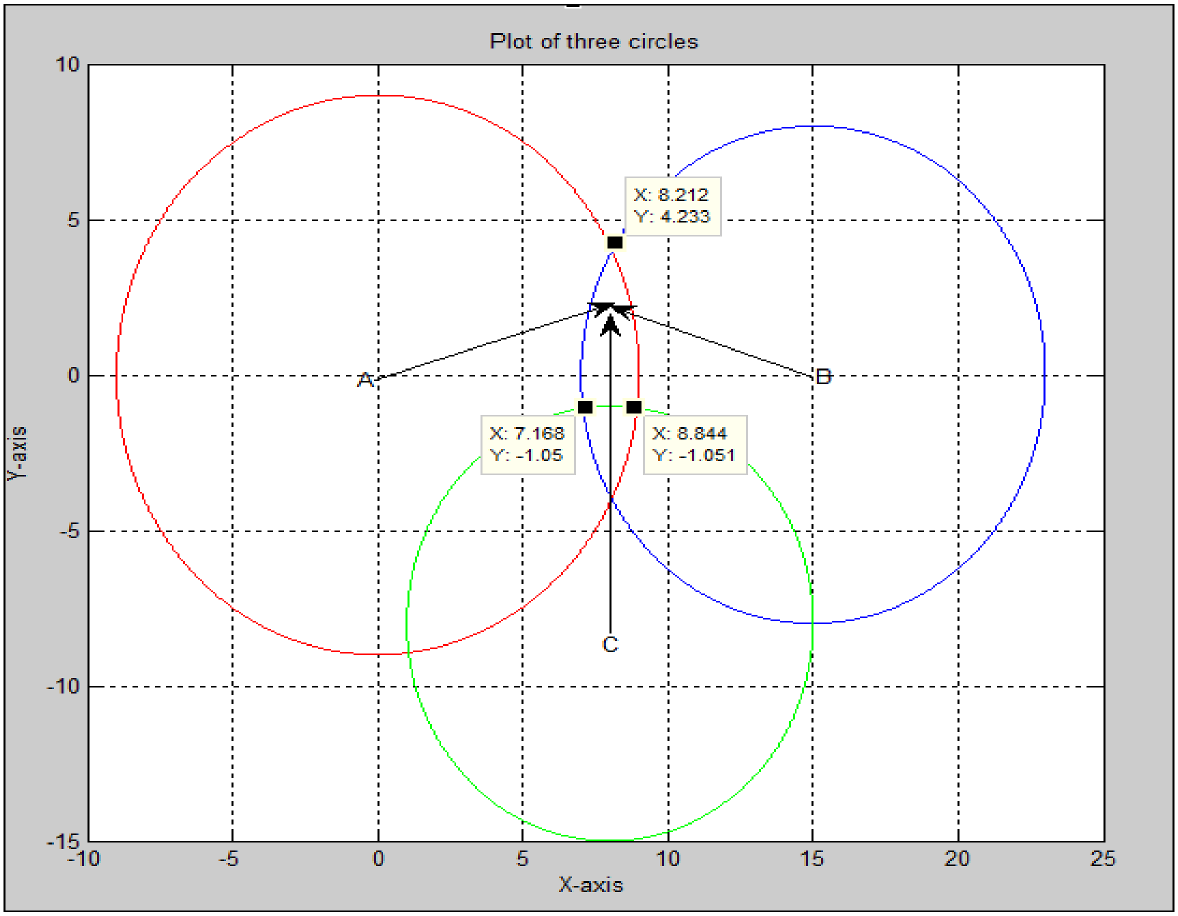

Figure 3.9: Negative vs Positive Error

Experimental distance (measured value getting from sensor to beacon):

A =9 cm, B=8 cm, C= 7 cm

Theoretical distance:

8.8 cm , 7.8 cm , 9 cm

Beacon's error : +ve error in A and B and -ve error in C

There is no exact overlapping area of 3 circles .

So it is undefined ROC.

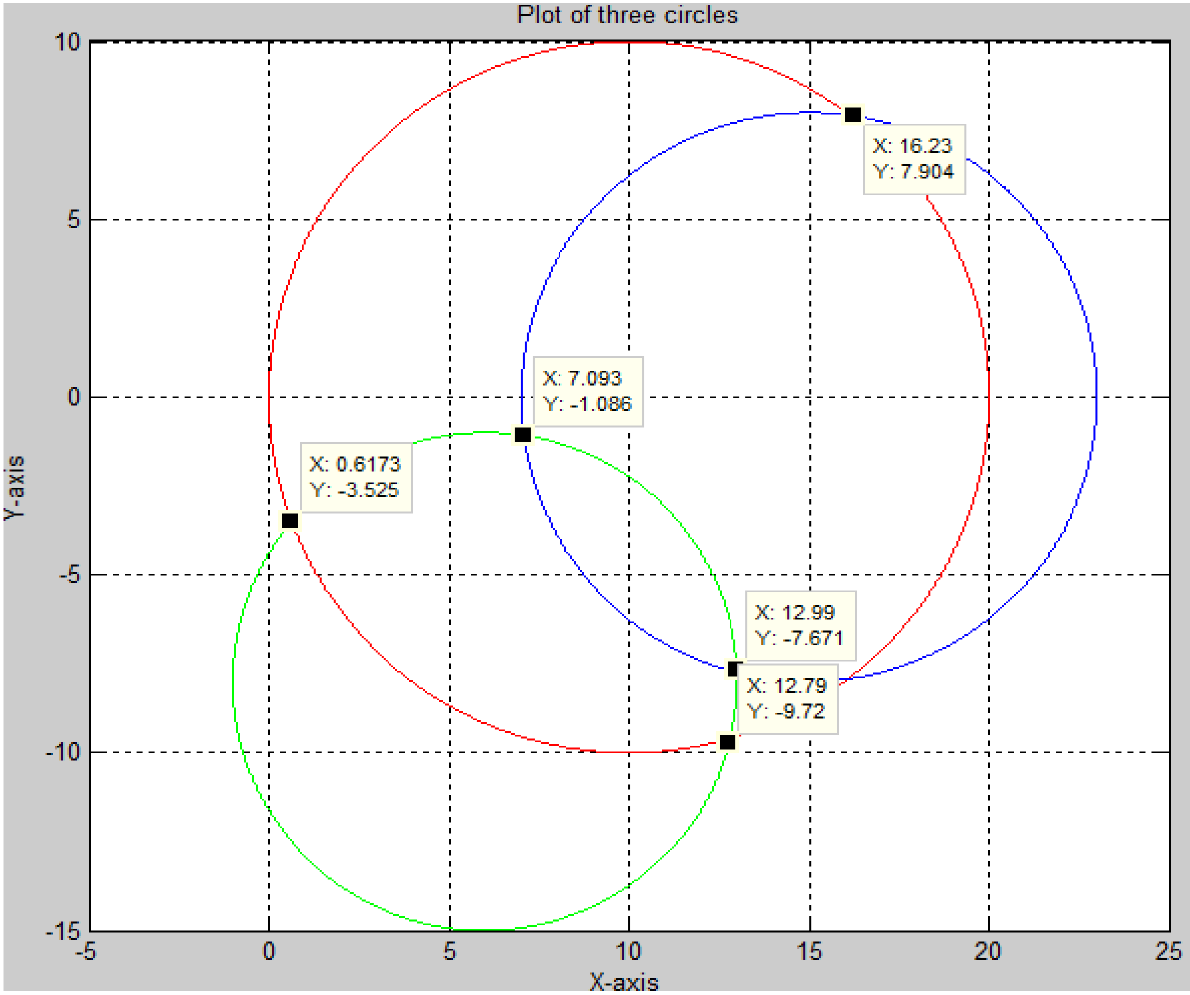

Figure 3.10: Undetermined Overlapping Area

Experimental distance (measured value getting from sensor to beacon):

A =10 cm, B=8 cm, C= 7 cm

Theoretical distance:

Not needed.

There is no exact overlapping area of 3 circles.

So it is undefined ROC.

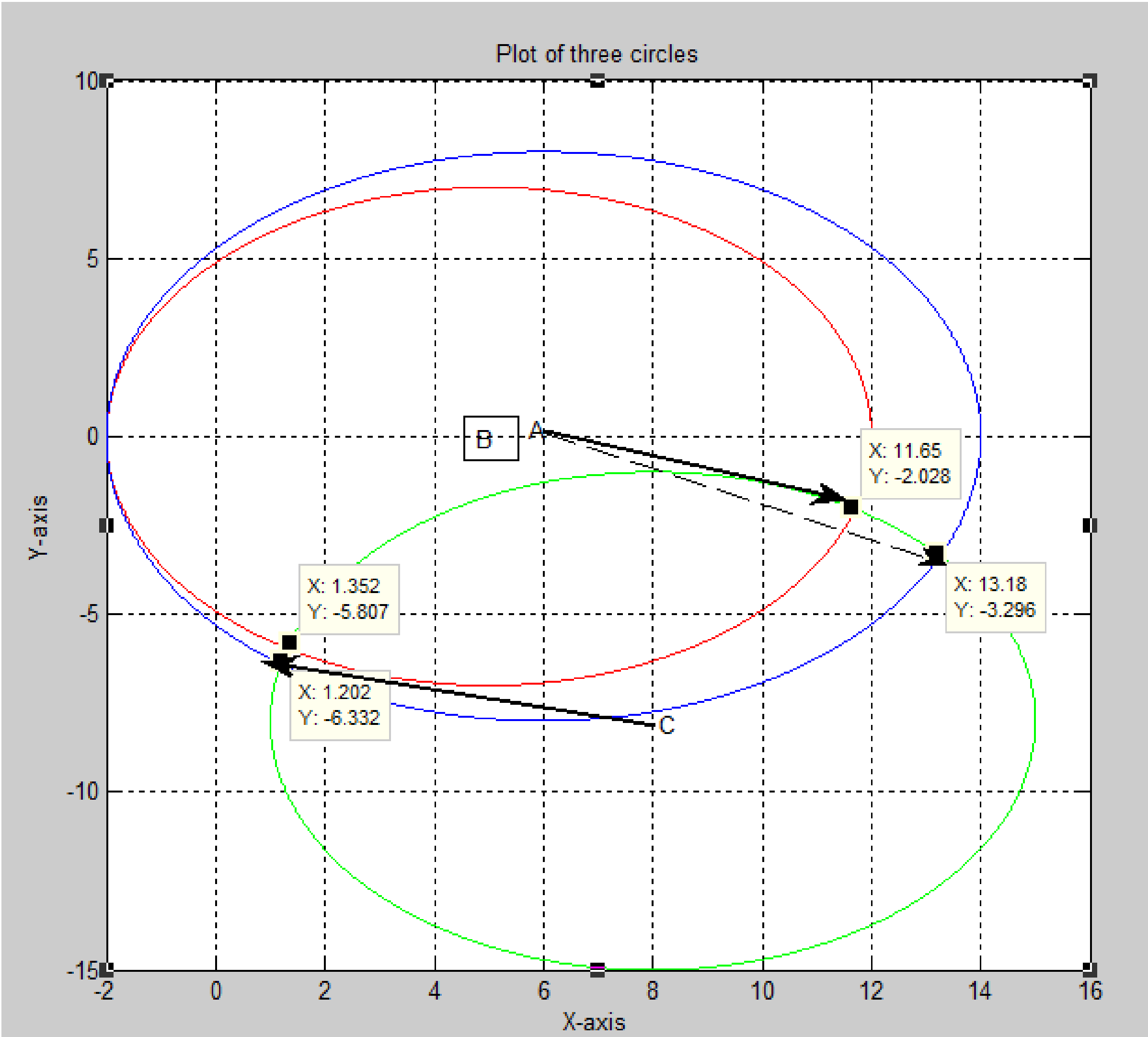

Figure 3.11: Undetermined Overlapping Area

Experimental distance (measured value getting from sensor to beacon):

A =7 cm, B=8 cm, C= 7cm

Theoretical distance:

A =7 cm, B=8 cm, C= 7cm

There is no exact overlapping area of 3 circles.

So it is undefined ROC.

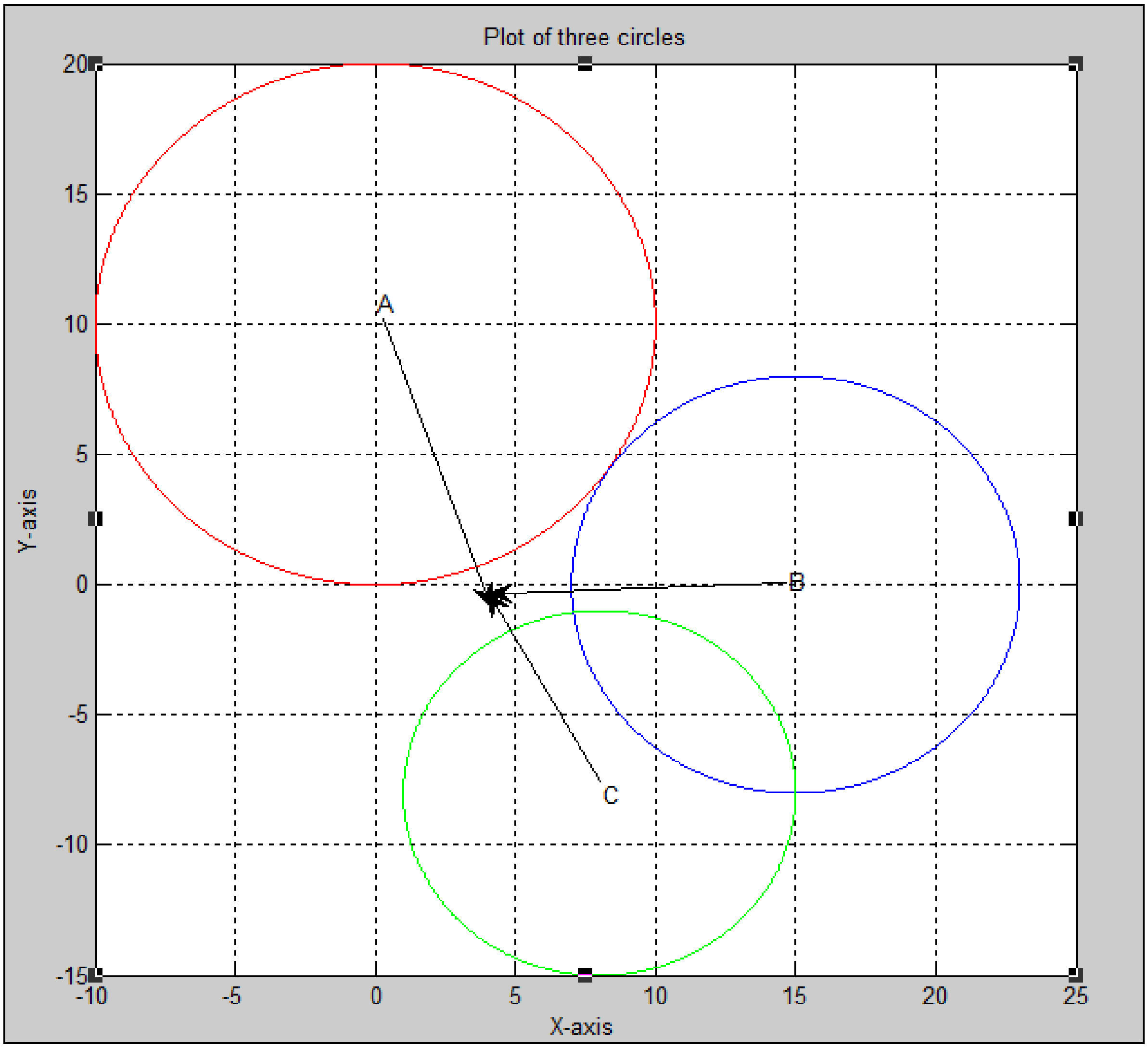

Figure 3.12: Negative Error Undefined ROC

No overlapping area

So it is undefined ROC.

Undefined ROC

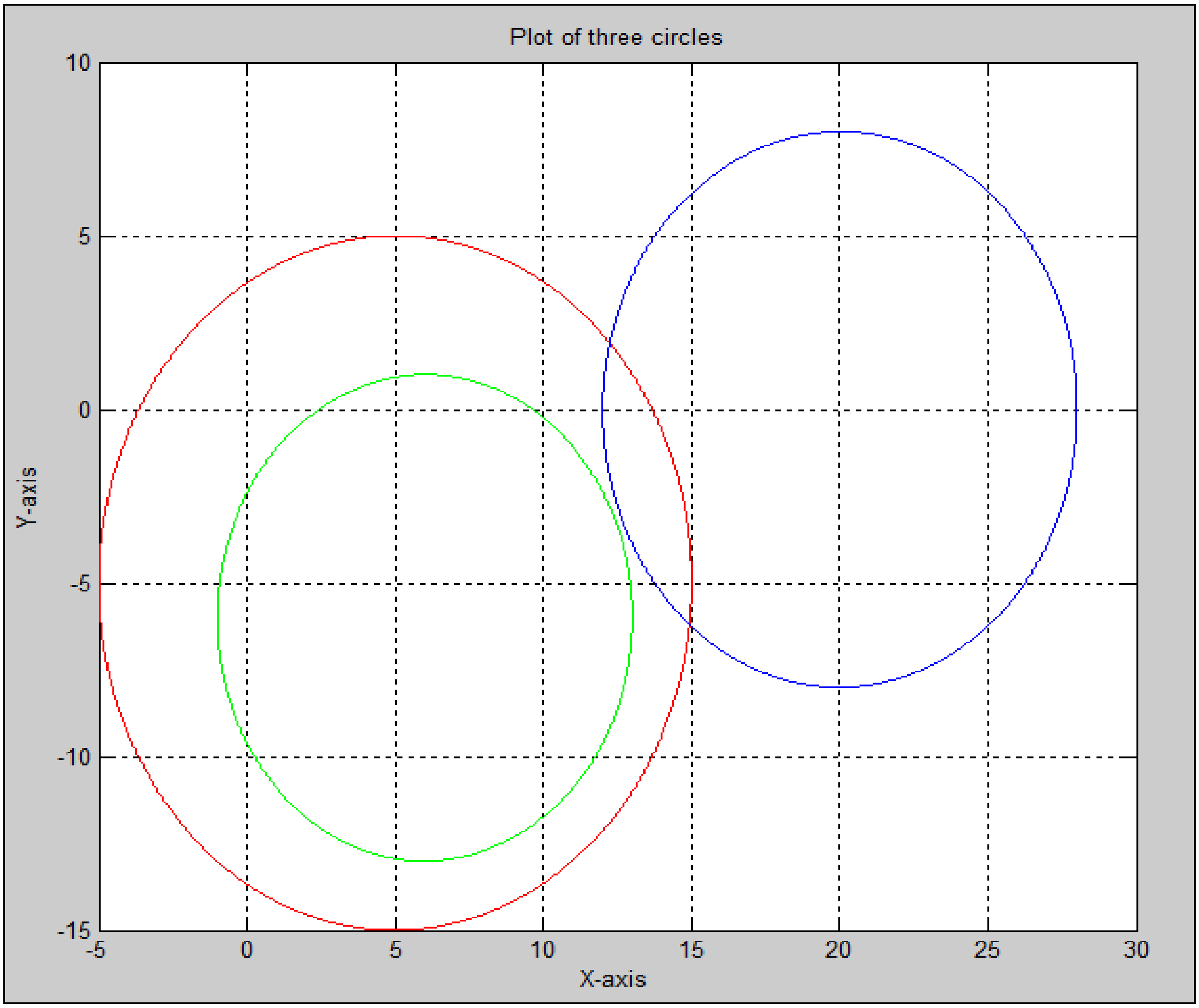

Figure 3.13: No Common Overlapping Area

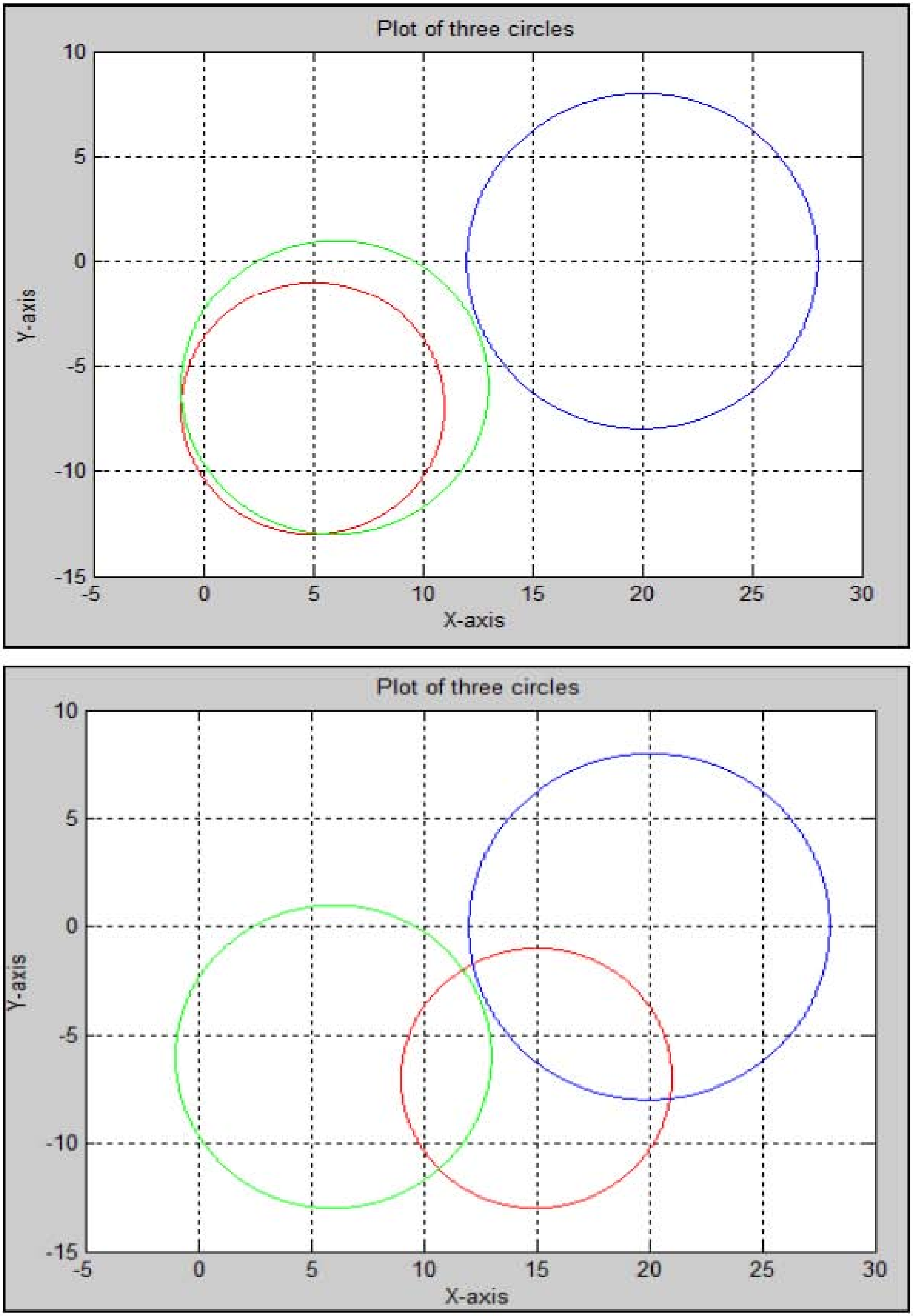

Figure 3.14: No Common Overlapping Area

3.1.5 Comparison among Different types of Scenerio

Here for the following figures

Red circle indicates reference node A,

Blue circle indicates reference node B,

Green circle indicates reference node C

In Mat-lab after running the code we get the overlapping area.

<u>Scenario 1:</u> Beacon's Position & Theoretical Distance Constant

Experimental distance change

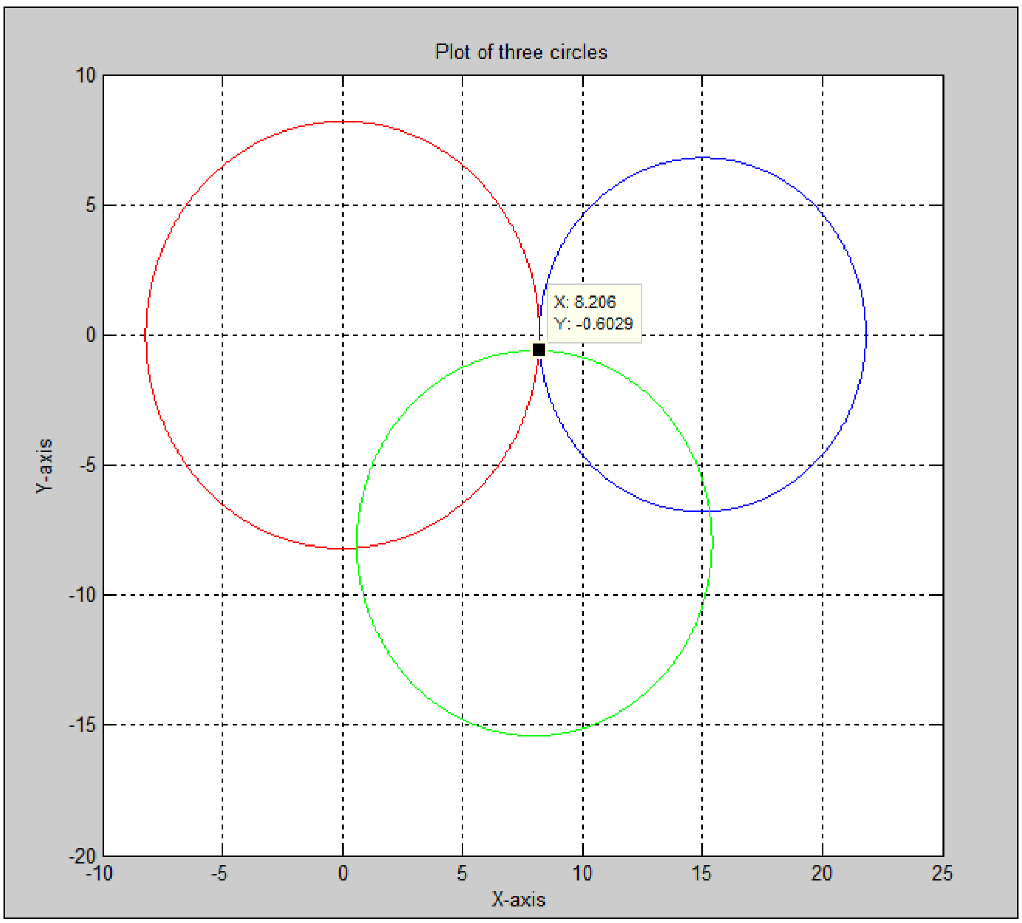

Figure 3.15 : Perfect Scenario for Intersection of Three Circles

Scenario 1(a): Compare with previous figure 3.15

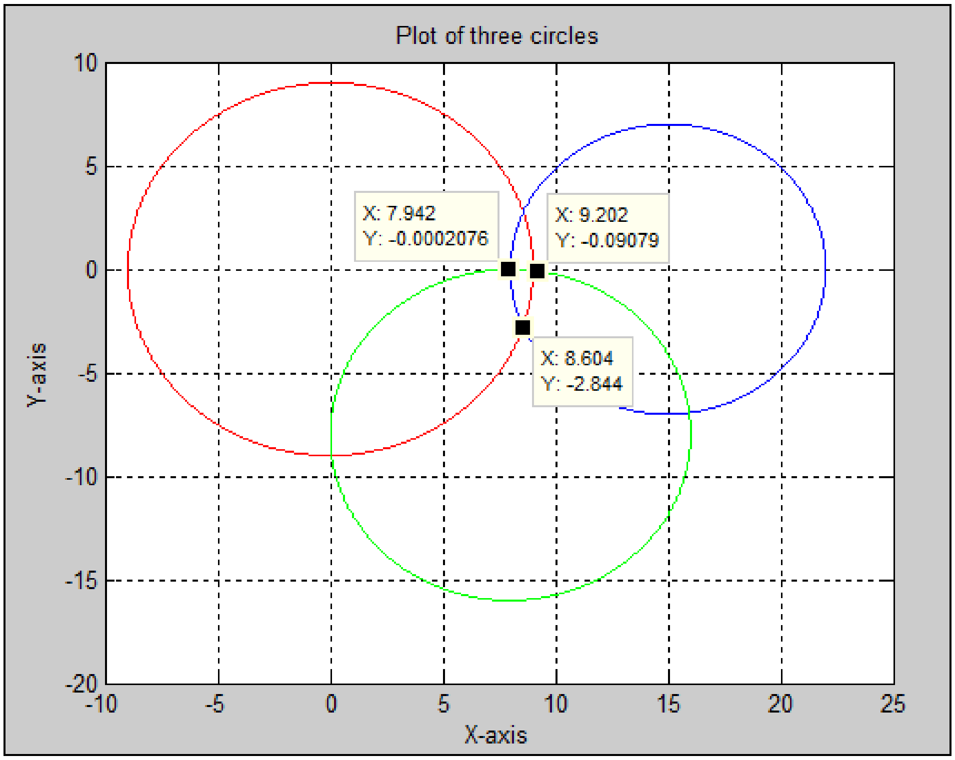

Figure 3.16 : Positive Error of Three Circles

Experimental distance: A>C>B

Error range: little error in B

Scenario 1(b): Compare with previous figure 3.15

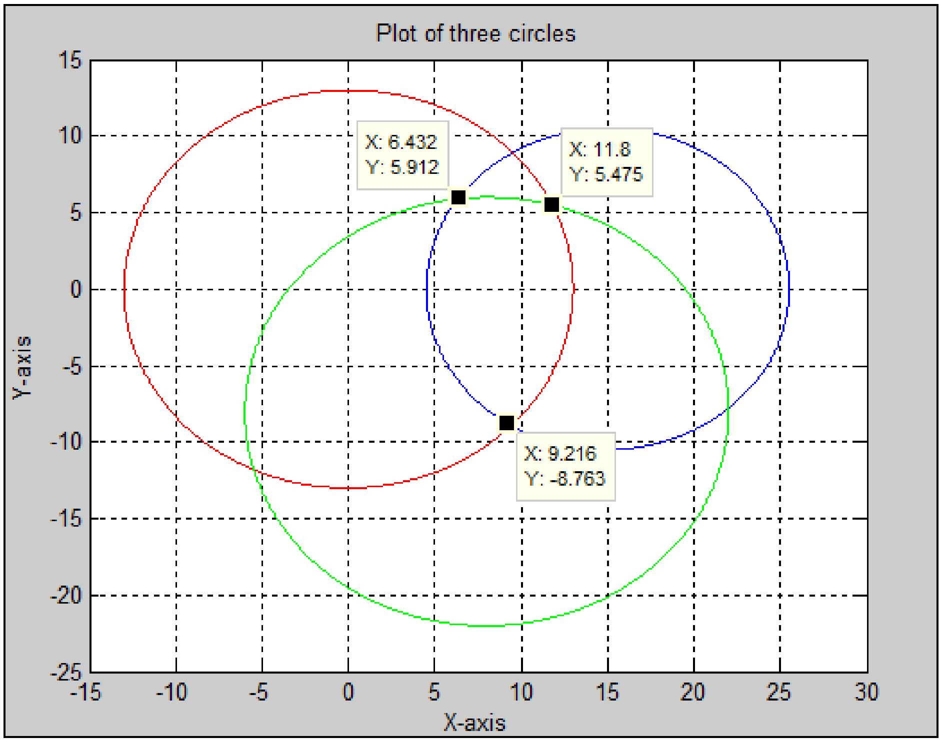

Figure 3.17 : Positive Error of Three Circles

Experimental distance: C>B>A

Error range: extreme error in C

<u>Scenario 2(a):</u> Beacon's Position Constant

Experimental distance change and theoretical distance change

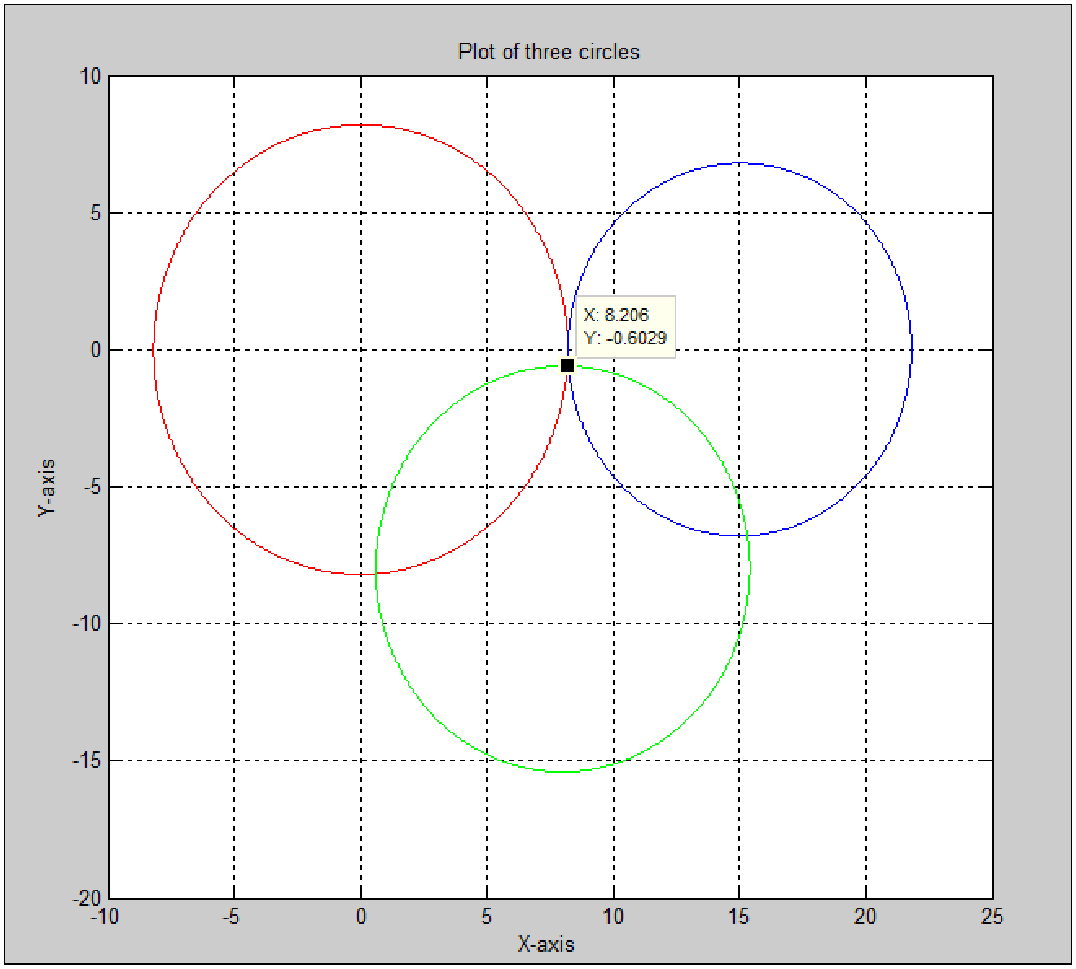

Figure 3.18 :Perfect Intersction of Three Circles

Theoritical distance: A>C>B

Scenario 2(b): Compare with previous figure

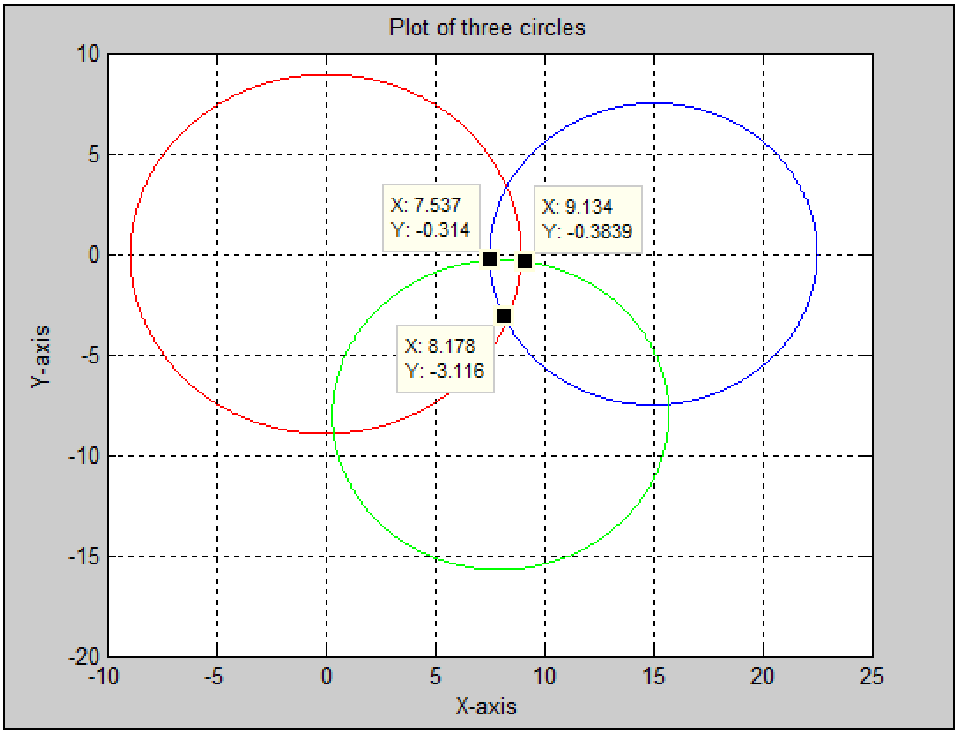

Figure 3.19 : Positive Error of Three Circles

Experimental distance: C>B>A

Error range: Almost same error in A,B and C

Scenario 2(c): Beacon's Position Constant

Experimental distance change and theoretical distance change

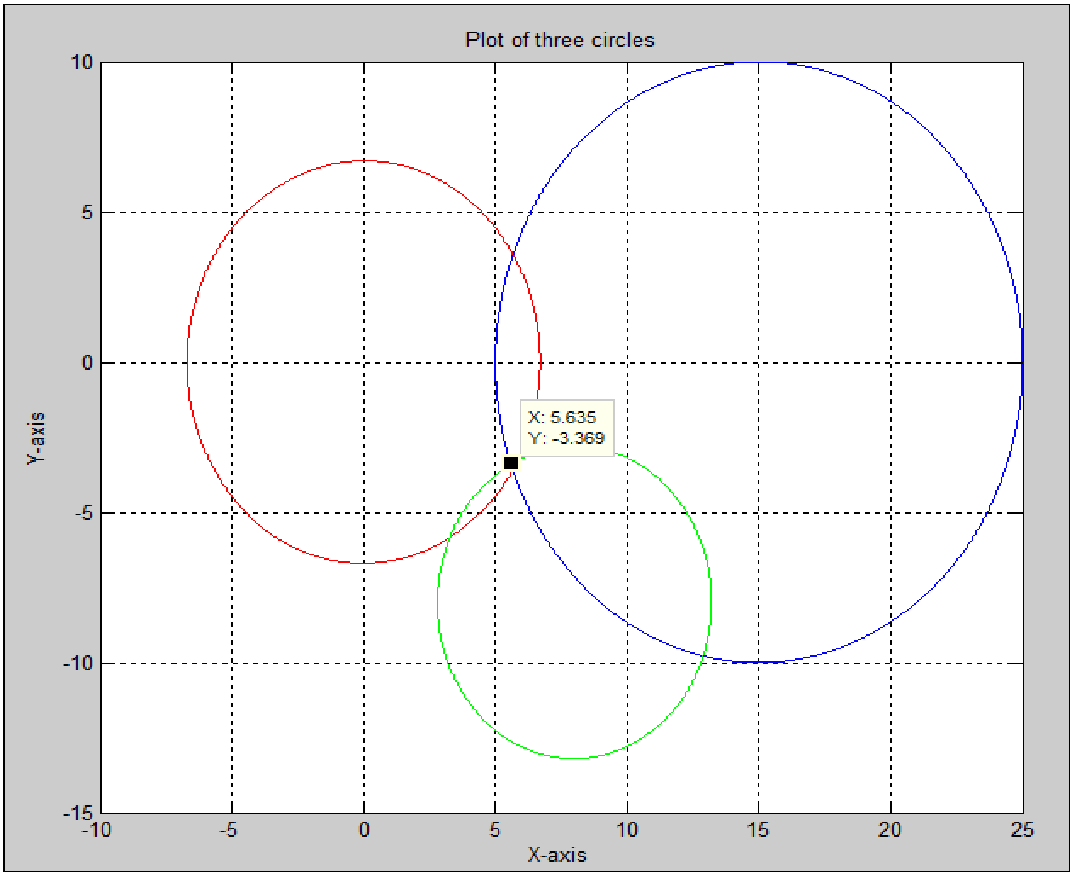

Figure 3.20:Perfect Intersction of Three Circles

Theoritical distance: B>A>C

Scenario 2(d): Beacon's Position Constant

Experimental distance change and theoretical distance change

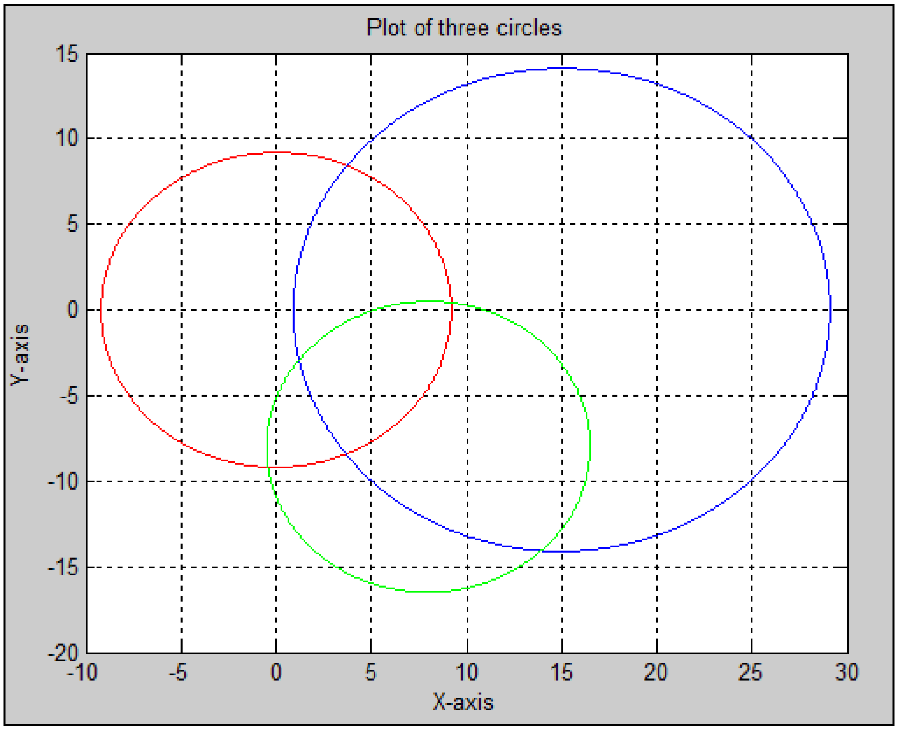

Figure 3.21 : Positive Error of Three Circles

Experimental distance: C>B>A

Error range: extreme error in C

<u>Scenario 2(e):</u> Theoretical distance constant

Experimental distance change and Beacon's position change

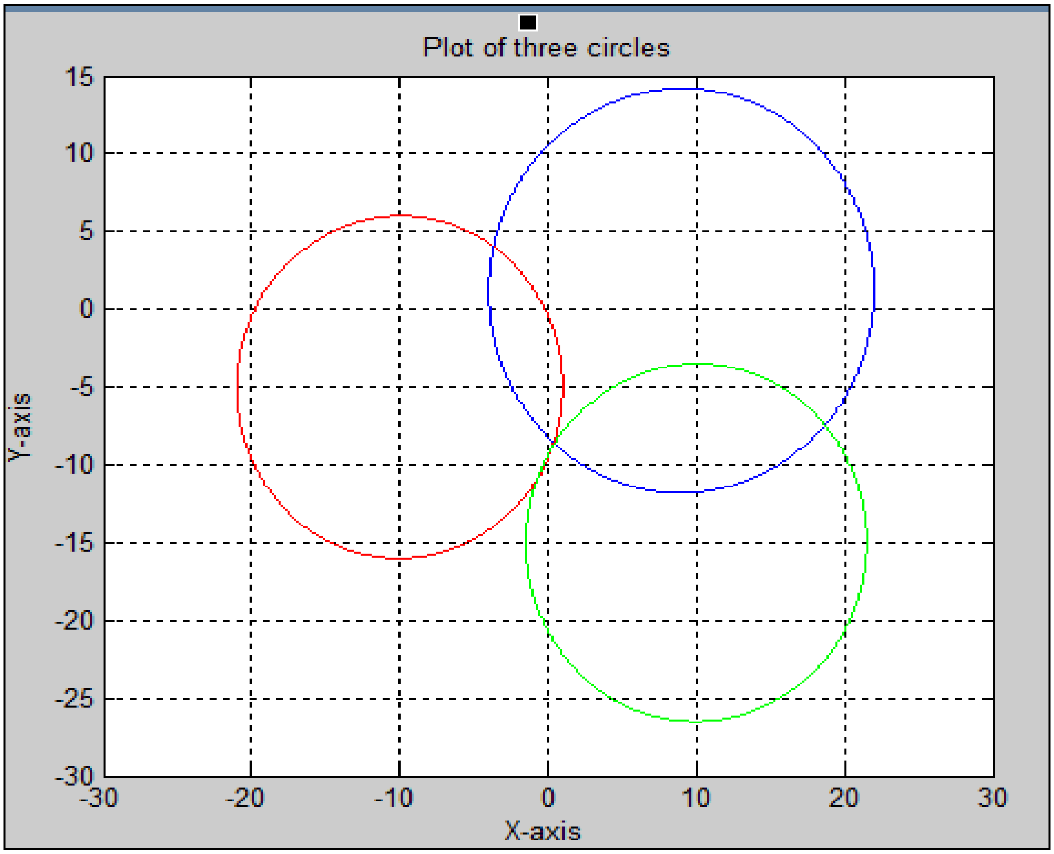

Figure 3.22 : Perfect Intersction of Three Circles

Theoritical distance:

A=11, B=13, C=11.5

<u>Scenario 2(f):</u> Theoretical distance constant

Experimental distance change and Beacon's position change compare

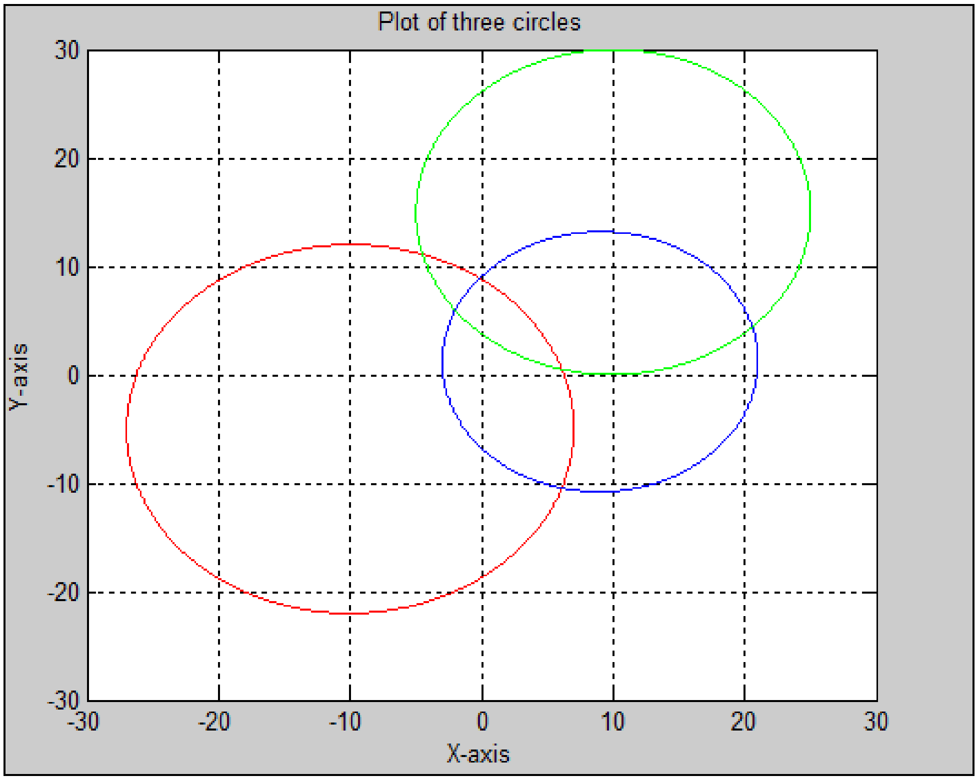

Figure 3.23 : Positive Error of Three Circles

Experimental distance: C>B>A

Error range: 10 to 30 %

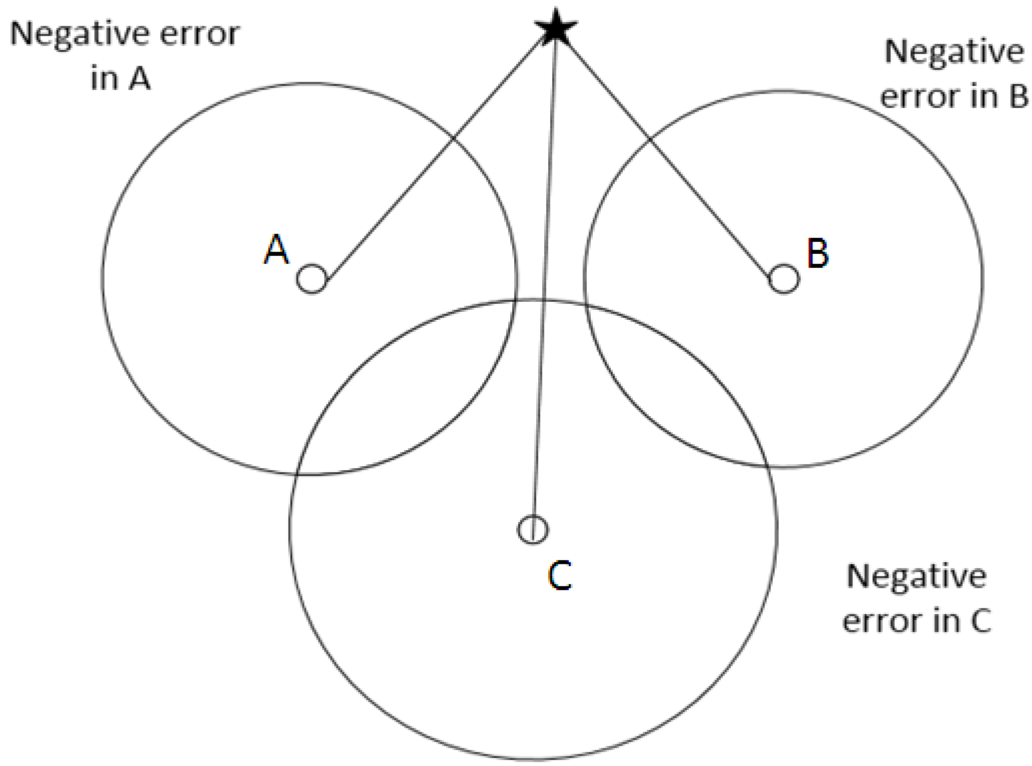

Figure 3.15: Undetectable ROC for Different Positions of Beacon

Error: –ve error in A, B, C.

As a result there is no ROC.

That's why it is undetectable.

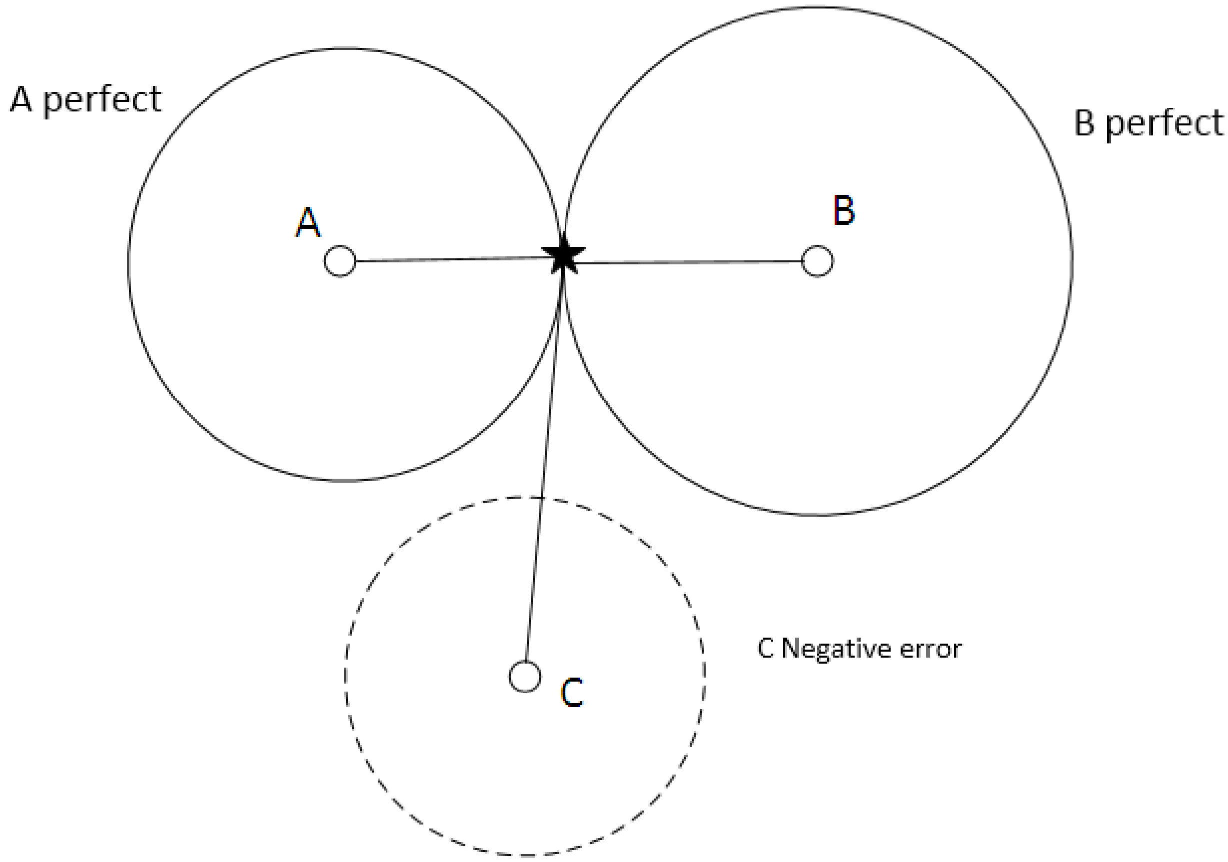

Figure 3.16: Undetectable ROC for Different Positions of Beacon

In this figure A and B is perfect

But –ve error in C.

So, there is no ROC.

It is also undetectable.

Chapter 4

Results and Analysis

4.1 Different Types of Situation for Getting Overlapping Area

Here we analysis different types of situation for various beacons' coordinate position. The first table gives us ROC for assumption of various experimental and perfect or actual distance.Then the other tables change their value for individual situation. Then we can compare the situation with the perfect scenario.

Table 4.1:

The Percentage Error in Distance for Different Positions and Overlapping Area

Figure No	Center's Coordinate Beacon			Radius Of Beacon			Actual Distance from Beacon's centre To Sensor			Percentage Error in distance			Has ROC	Overlapping Area ROC
	A	B	C	*Ra*	*Rb*	*Rc*	Da	Db	Dc	Ea	Eb	Ec		
1	0,0	15,0	8, -8	10	8	7	9	7	6	11.11	14.2	16.7	yes	6.836
2	0,0	10,0	8, -6	10	8	7	9	7	2	11.11	14.2	250	yes	43.67
3	5,0	10,0	8,-8	9	8	7	5	4.5	4.5	80	77.8	55.56	yes	49.415
4	5,0	0,0	8,-8	8	8	6	7	7	4	14.3	14.3	50	yes	16.36
5	10, 5	15,0	6,-8	8	10	8	7.8	4.5	7.5	2.6	122	6.67	yes	13.01
6	0,0	15,0	8,-8	9	8	7	8.8	7.8	9	2.27	2.56	-22.2	no	no
7	5,-5	15,0	6,-8	8	10	8	8	3.8	8	No error	163.2	No error	yes	10.36
8	10, 0	15,0	6,-8	10	8	7	N	N	N	∞	∞	∞	no	no
9	5,0	6,0	8,-8	7	8	7	7	8	14	No error	No error	-50	no	42.23
10	0,1 0	15,0	8,-8	10	8	7	N	N	N	∞	∞	∞	no	no

Here,

Percentage of error in distance:

((Experimental value – Theoretical value)/ Theoretical value)*100

Table: 4.2

Beacon's position & theoretical distance constant

Experimental distance change

Figure No#	Center's Coordinate of Beacon			Theoretical Distance			Experimental Distance			Percentage of error %			ROC
	A	B	C	A	B	C	Ra	Rb	Rc	Ea	Eb	Ec	
1	0,0	15,0	8,-8	8.1	6.8	7	9	7	8	11.11	2.9	14.3	1.83
2	--	--	--	--	--	--	10	11	12	23.46	61.76	71.43	51.67
3	--	--	--	--	--	--	13	10.5	14	60.49	54.41	100	96.81

In this table, beacon's position and theoretical distance is constant. But experimental distance is not constant. It is increasing. At a time percentage of error and ROC is also increasing.

Table 4.3

Beacon's position & theoretical distance constant

Experimental distance change but percentage of error almost same

Figure No#	Center's Coordinate of Beacon			Theoretical Distance			Experimental Distance (0.2 cm rate)			Percentage of error %			ROC
	A	B	C	A	B	C	Ra	Rb	Rc	Ea	Eb	Ec	
1	0,0	15,0	8,-8	8.1	6.8	7	8.94	7.5	7.7	10.4	10.3	10	2.79
2	--	--	--	--	--	--	9.78	8.2	8.4	20.7	20.6	20	11.02

In this table, beacon's position and theoretical distance is constant. Experimental distance is changing but percentage of error almost same. Although the percentage of error almost same, ROC is increasing.

Table: 4.4

Beacon's position constant

Experimental distance change and theoretical distance change

Figure No#	Center's Coordinate of Beacon			Theoretical Distance			Experimental Distance (0.2 cm rate)			Percentage of error %			ROC
	A	B	C	A	B	C	Ra	Rb	Rc	Ea	Eb	Ec	
1	0,0	15,0	8,-8	8.1	6.8	7	8.94	7.5	7.7	10.4	10.3	10	2.79
2	--	--	--	10	7.2	4.1	12.5	9.1	5.3	25	26.4	29.3	15.18
3	--	--	--	6.7	10	5.2	9.2	14.1	8.5	37.3	41	63.5	45.88
4				11	5.2	5.8	8.5	7.7	7.3	22.73	25	25.9	1.63

In this table, beacon's position is constant. Experimental distance and theoretical distance is changing. When experimental distance is greater than theoretical distance the percentage of error is increasing.

Table: 4.5:

Theoretical distance constant

Experimental distance change and Beacon's position change

Figure no#	Center's Coordinate of Beacon			Theoretical Distance			Experimental Distance (0.2 cm rate)			Percentage of error %			ROC
	A	B	C	A	B	C	Ra	Rb	Rc	Ea	Eb	Ec	
1	-10,-5	9,1.2	10,15	11	13	11.5	12.2	14.85	15	10.9	14.23	30.43	0
2	0,0	15,0	8,-8	--	--	--	15.4	17.8	14.2	40	36.9	23.48	281.87
3	15,-5	15, 10	5,10	--	--	--	11.7	18.7	12.18	6.3	43.8	5.9	62.76

In this table, theoretical distance constant is constant and experimental distance and Beacon's position is changing. When experimental distance and beacon position is changing at a time rate of error is also changing.

Table 4.6:

Theoretical distance change

Experimental distance change and Beacon's position change

Figure No#	Center's Coordinate of Beacon			theoretical distance			Experimental Distance			Percentage of error %			ROC
	A	B	C	A	B	C	Ra	Rb	Rc	Ea	Eb	Ec	
1	0,0	15,0	8, -8	8.2	6.8	7.2	10	8	7	21.95	17.64	-2.77	6.89
2	-10,-5	9,1.2	10,-15	11	13	11.5	13	15	13.5	18.18	15.38	17.39	22.17
3	15,-5	15,10	5,10	10	9	8	11	12	14	10	33.33	75	56.94

In this table, theoretical distance, experimental distance and beacon's position is changing. When everything is changing rate of error and ROC is also changing.

Chapter 5

Conclusion and Future Work

5.1 Conclusion

In our paper, we worked on localization technique. One of the techniques in localization is to determine unknown node. By determining the region of confidence we can now easily identify the possible area where the unknown node can be located. We also get change in error with respect to different beacon's position. Along with that we have also determined the percentage of error in distance measurement. While working on the calculation part of getting overlapping area we sometimes detect some undefined situation where there is no region of confidence. Because of some change in position or other changes there will be some situations which will not have the region of confidence.

5.2 Future Work

In our paper we have determined the region of confidence for sensor node in WSN. In future we want to reduce the region of confidence. Here work on 2D environment so that in future we want to develop our work in 3D environment. We also want to develop some algorithms that can help to simulate an optimized overlapping area for different percentage error in distance and also can give us an estimated value for various beacon's position. In our paper beacon node detect the unknown node in future we develop an algorithm by which we can get the unknown node's own position that means it can calculate detect it's own position

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