Determination of Positional Accuracy and Error Modeling for moving Objects Tracking

A. Anitha, M. Anoop, S. SherinLiba

Abstract- ***Position refers to the spatial location of an entity. That is the determination of the site or place of any process localization. A positioning system is a mechanism for determining the location of an object in space. Technologies for this task exist ranging from worldwide coverage with meter accuracy to workspace coverage with sub-millimeter accuracy. The statistical positional accuracy of a moving object being tracked any2D positioning system. This paper describes the measurement technique based on determining 1D cross-track errors from a nominal path, and then using this data set to determine the overall 2D positional error statistics. This method evaluates vehicle tracking in a city and people tracking in a city using Radio triangulation principle. Rayleigh-Gamma model is proposed to describe the radial positional errors used to perform error modeling. It is shown that this model has a good match with outdoor field measurements.***

Keywords: Cross-Track, Radio Triangulation, Positioning System.

I. INTRODUCTION

In this design and testing of a radio positioning system, accuracy evaluation is important since positional accuracy is one of the key requirements for a variety of applications and services. Location information is considered to add many potential applications to telecommunications systems, such as fraud protection, location-aware network access, person/asset tracking etc. The measurement of positional errors of a moving object can be difficult, as by definition an error is determined by comparing the estimated position of the mobile unit with some more accurate reference position.

As it is often the case that the positioning system under test is the most accurate positioning system available in its operating environment, typically the procedure is to measure the positional errors at fixed stationary points in the coverage area, with the position of the fixed points determined by some independent surveying method.Such techniques, while simple in concept, are very time consuming, and do not actually measure the true performance of a moving mobile device. The problem with inertial reference systems is that the errors integrate over time, so that frequent recalibration at known reference points is necessary to maintain adequate accuracy.

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This proposed system is a measure of accuracy in a positioning system while tracking a moving mobile unit in its normal operating environment. The method estimates the 2D positional errors based on 1Dcross-track positional errors. This technique does not need any additional equipment apart from the positioning system with data logging capability for recording the estimated tracked position of the mobile unit as a function of time, and an accurate map of the area in which tracking occurs. In particular, no extra more accurate reference positioning system or surveying is required. To test this method, positional error modeling and the cross-track errors measurement approach are tested through field measurements for actual positioning systems.

II. LITERATURE SURVEY

A. El-Rabbany describe GPS is a satellite-based radio navigation system. Users anywhere on the surface of the earth with a GPS receiver can determine their geographic position in latitude, longitude and elevation [9]. It was intended to help locate and identify troops and equipment as well as provide guidance signals for tactical weapons such as missiles and smart bombs. Each GPS satellite transmits radio signals that can be used to compute a position or a location. Obviously with such a sophisticated system, many things can cause errors in the positional computation and limit the accuracy of measurement. These errors include clock errors, ephemeris errors, satellite configuration, atmospheric interference, and multipath.

M. Modsching, R. Kramer and K.T. Hagen, examines the actual accuracy of positioning for various GPS receivers in areas of the city [5]. These measurements are based on a comparison between a dense network of reference points of known locations and the estimated positions provided by the GPS receivers. The error of GPS localization is largely determined by the interaction of the current constellation of GPS satellites and the built-up in the immediate proximity. The measured position data is compared with a dense network of reference points provided by the land surveying office to assess the accuracy. The design and the execution of several field studies executed to capture the localization error of commercially available GPS receivers targeting the consumer.

G.H. Elkaim, M. Lizarragaand L. Pedersen compare three commercially available, off-the-self units instituting terms of both position and attitude. The position truth measure is from a DGPS receiver and the attitude truth [8]. Compare two low cost GPS/INS navigation sensors. These are compared under three test conditions: static, road and flight. A few things became readily apparent.

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High quality GPS is in and of itself insufficient for guidance for autonomous vehicles, as the occasional position jumps will make control very challenging. Overall, this system performs well, and pointed to viable solutions for position and navigation for autonomous vehicles.

R. Schubert, E. Richter and G. Wanielik estimates of a vehicle's dynamic state is one of the most fundamental data fusion tasks for intelligent traffic applications [7s]. This method surveys numerous models and compares their performance using tracking tasks which GPS and odometry data. Especially for advanced driver assistance systems such as Collision Avoidance/Collision Mitigation, Adaptive Cruise Control, and Stop-and Go Assistant in order to increase the stability and accuracy of the estimation. This model increases the performance of a vehicular tracking system. Further tracking systems, it is beneficial to combine the strengths of different models and simultaneously avoid their weakness.

III. PROPOSED SYSTEM

The proposed accuracy measurement method is based on measuring crosstrack errors, and then processing the data to obtain the required positional error statistics.

A. Concept Description:

A mobile device is moving relative to fixed base stations which "surround" the mobile location. Signals emanating from the mobile device are received by base stations located within radio range, and data related to the characteristics of the received signal are used to estimate the position, which will have errors. Now assume that the path of the mobile device is known, either as part of the testing procedure, or because the path is restricted.

From the above description, provided there is an accurate map of the location area, and the mobile moves along a defined path, the cross-track errors can be determined, either by a manual plotting procedure, or by an appropriate computer program. The key idea in performing this conversion is recognizing that overall the statistics in the cross-track and along-track directions should be quite similar.Crosstrack correction is intended to guide the plan to an optimal path, as opposed to simply pointing towards the desired waypoint. For the measurements, the path should include many changes in direction, so the local along-track reference used for an individual measurement is not in any way related to a fixed geographical direction. More specifically, Geometric Dilution Of Precision (GDOP) analysis shows that in general the error contours ofequal probability are in the form of ellipses, but with base stations deployed symmetrically about the mobile position the contour becomes a circle, with identical cross-track and along-track error statistics. In practice, this equality will not be true at each location, but would be expected to be approximately true when averaged over a large number of points on a path that has frequent changes of direction. Another situation that can result in estimation errors is where there is a rapid change in velocity. In such cases where raw data filtering is employed, the filtering can result in a long-track over or under shooting, which is not detected by the proposed cross-track method. Another case of interest is associated with a mobile device located on the body of a person, which can result local bias position errors due to signal blockage by the body.

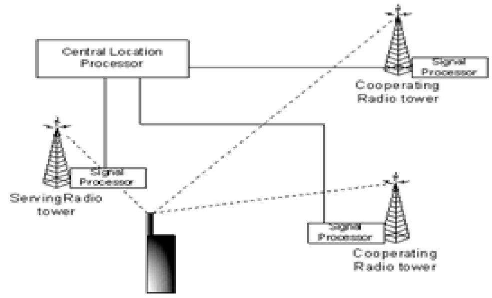

Figure 1: Network based location

B. Statistical Analysis

The statistical analysis of the cross-track data is now described,

This one-sided (magnitude only) cross-track error PDF is defined as where x denotes the crosstrack error, 1 so the (assumed) symmetrical two-sided error PDF is given by,

$$p_{xt}(x) = \frac{1}{2}\widehat{p_{xt}}(|x|) \qquad (-\infty \le x \le \infty)$$

The along-track errors are assumed to have the same statistics, and also the cross-track and along-track errors are assumed to be statistically independent, so the joint 2D probability is,

$$p(x,y)dxdy = p_{xt}(x)dxp_{xt}(y)dy$$

This 2D probability distribution in Cartesian coordinates is now converted to polar coordinates in the form

$$q(r,\theta), rd\theta\, dr \equiv p(x,y)dx\, dy$$

$$= p_{xt}(\mathrm{r}\cos\theta)\, p_{xt}(\mathrm{r}\sin\theta)\, d\theta\, r\, dr$$

Using this property and integrating out the variable, the required distribution can be described as a function of the radial positional error (r), and is given by

$q(r) = r\, f(r)$Where,

$$\mathrm{F(r)} = 8\int_0^{\frac{\pi}{4}} p_{xt}(\mathrm{r}\ \cos\theta)\, p_{xt}(\mathrm{r}\ \sin\theta)\, d\theta$$

Thus, the given PDF of the measured cross-track data, the function $f(r)$ can be computed numerically, and then the required radial error PDF $q(r)$ is produced. Alternatively, if there are analytical expressions for the crosstrack errors, analytical expressions of the PDF can be derived. Two important analytical cases are considered in the following section.

C. Statistical Error Models

The method assumes a statistical model for the PDF of the radial errors, then uses this model to generate some cross-track errors, and finally used to reconstruct the radial distribution. This reconstructed distribution can then be compared with the original distribution, which ideally should be the same. However, the reconstruction process involves two important assumptions, namely:

1. The cross-track and along-track errors are statistically independent.
2. The cross-track and along-track errors have the same statistical distribution, which is an even function.

These assumptions may not be exactly true in either measured or simulated data. In the case of the simulated data the model/reconstruction results can be checked, but this is not possible with the measured data.

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D. Gaussian Statistical Error Analysis

The positional error statistics of a radio tracking system are directly related to the ranging error statistics. If the range or pseudo range measurement errors are due to receiver noise, then the noise statistics will be Gaussian, which translates into a Rayleigh distribution for 2D positional errors. In the Line-Of-Sight (LOS) case, ranging errors due to multipath propagation also can be approximated by a Gaussian model. In the case where the measurement errors are dominated by multipath effects in a NLOS environment, the measurement errors will not be Gaussian.

If the number of such base stations is moderately large (say five or more), the Central Limit Theorem (CLT) can be invoked, and the positional error statistics can again be approximated by a Gaussian model—the higher the number of base stations the better the approximation becomes. Assumed that the cross-track and along-track statistics are the same, both Gaussian and statistically independent, then the joint probability is,

$$p_g(r,\theta)r\,d\theta dr = \frac{r}{2\pi\sigma^2} exp(-\frac{r^2}{2\sigma^2})\,d\theta dr$$

Where σ is a parameter can be used to match the model to measured data. Integrating out the θ component gives,

$$p_{rayleigh}(r) = \frac{r}{\sigma^2}\ exp(-\frac{r^2}{2\sigma^2})$$

This is recognized as a Rayleigh distribution, and is due to the assumed symmetry and the properties of the Gaussian distribution. The positional error statistics are presented in terms of the Complementary CDF (or CCDF), as the CCDF allows low probability, large errors to be readily observable on a logarithmic plot.

$$C_g(r) = \ 1 - \int_0^r \frac{z}{\sigma^2} \exp\left(-\frac{z^2}{2\sigma^2}\right) dz = \exp\,(-\frac{r^2}{2\sigma^2})$$

In this case two random variables are required, and the simulated cross-track error data can be generated by

$$x = \left|\sigma\sqrt{-2\ln\,(U(1))}\sin\,(U(2\pi))\right|$$

Where $U(a)$ is a uniform random variable in the range $[0, a]$.

E. Exponential Statistical Error Analysis

The assumption that cross-track errors are Gaussian is appropriate for scenarios where the range measurements are corrupted with Gaussian noise, or where multipath propagation exists, but the number of base stations within radio range is large. In this case, the error distribution is non-Gaussian, with typically the "tail" of the distribution much larger than the Gaussian case. In such cases, an alternative model for the cross-track errors is a Laplace distribution with a PDF

Given by

$$p_{xt}(x) = \frac{1}{2a} e^{-|x|/a}$$

$$(-\infty \le x \le \infty)$$

Where a is a parameter which defines the rate of exponential decay of the cross-track error. The probability distribution in polar coordinates is given by

$$q(r,\theta)d\theta r\ dr = \frac{r}{2a}\exp\left[-\frac{r}{a}(|\cos\theta| + |\sin\theta|)\right] d\theta\ dr$$

Applying the eight-way symmetry property as explained is given by,

$$f(r) = \frac{8}{2a}\int_0^{\frac{\pi}{4}} \exp\,[-\frac{r}{a}(\cos\theta + \sin\theta)]\ d\theta$$

$$=\frac{4}{a}\int_0^{\pi/4} \exp\,[-\frac{r}{a}(\cos\theta + \sin\theta)]d\theta$$

$$=\frac{4}{a}\int_{\pi/4}^{\pi/2} \exp\,[-\frac{\sqrt{2r}}{a}\sin\emptyset]d\theta$$

One possibility is to approximate the sine function by a quadratic function, but the simplest approach is to replace the sine function by its average over the range of the integral; such an approximation was found to have minimal effect on the accuracy of the result. Applying this simplification and carrying out the integration result in

$$\hat{q}(r) = \frac{\pi}{a} rexp[-\frac{4r}{\pi a}]$$

The normalization constant is

$$\int_0^\infty \hat{q}(r)\,dr\ = \frac{\pi^3}{16}$$

The exponential model radial error PDF as

$$q_e(r) = \left[\frac{4}{\pi a}\right] rexp\left[-\frac{4r}{\pi a}\right] = \frac{r}{\beta^2} exp\left[-\frac{r}{\beta}\right]$$

The associated CCDF is

$$C_\varepsilon(r) = 1 - \int_0^r q_\varepsilon(z)dz) = (1 + \frac{r}{\beta})\ exp\left[-\frac{r}{\beta}\right]$$

When the CCDF is plotted using a logarithmic scale, the asymptotic curve is linear with the position error, in contrast to the quadratic function for the Gaussian model. Furthermore, increasing the number of data samples does not significantly improve the match, so measured crosstrack errors that have approximately exponential characteristics will result in some imprecision in CDF estimation, particularly for large positional errors.

IV. MEASURED DATA PROCESSING

This section describes the general procedures for gathering raw cross-track data and subsequent data processing for real positioning systems. For an outdoor system, tracking a vehicle on a road, the positioning system accuracy is typically 10-30 m, which implies that the vehicle must be driven along the predefined track to an accuracy of 2 m.

This means that the vehicle should stay in the center of a lane, typically the one next to the curb, to achieve the required accuracy.

The second step in the data processing is to compare the measured track positions with some type of map.

The third step in the data processing is to plot the measured tracking data as an overlay onto the reference map.

The fourth step in the processing is the generation of a histogram from the measured data, and hence the PDF of the cross-track data.

To at least partially overcome these difficulties in estimating the PDF, an alternative data processing technique is suggested.

Instead of using the histogram method, the raw cross-track data are sorted in ascending order. The above procedure allows a good estimate of the radial error CDF to be determined, even if there are large quantization errors and a limited number of samples. The case is considered, outdoor case with a coverage area of a city.

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When radio waves propagate out of a mobile station, it reaches different radio receiving towers at different time. The signal will take t1 time to reach the tower A, and its circular path. In the same way it would reach the tower B in time t2 and tower C in time t3.

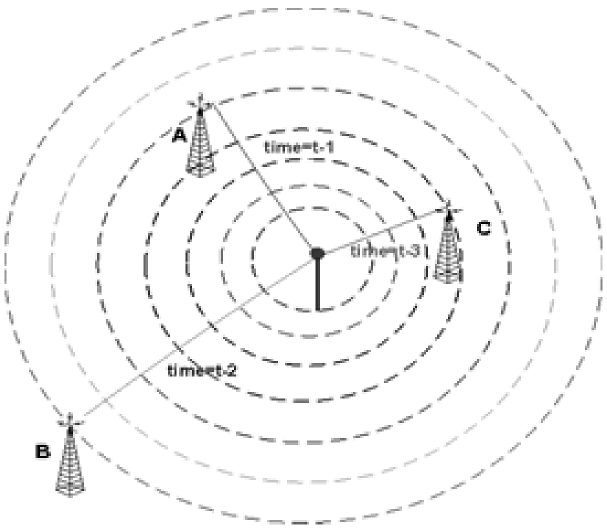

Figure 2: Radio triangulation principle

In the second diagram it is shown that if the tower receives a signal at time t1, one can find the distance of the mobile station to the tower by using distance = ct1, where c is the velocity of radio waves. By taking these three towers as the centre and drawing three arcs (with calculated distance as radius) would intersect at one point. This point is the location of the mobile station. In fact, the second diagram inverse of the first one with lines mapped to circles and vice versa.

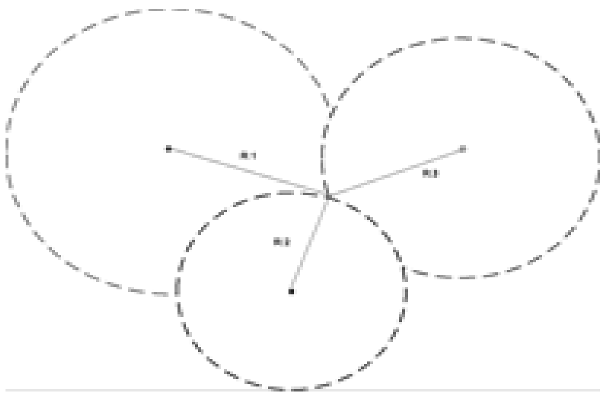

Figure 3: Position determination based on radio triangulation

Time difference of arrival has been the preferred technology of choice for high accuracy location systems since the advent of radar. The global positioning system is a TDOA based system as most of the systems proposed for the Location and Monitoring Service (LMS) band recently allocated by the FCC. TDOA systems operate by placing location receivers at multiple sites geographically dispersed in a wide area; each of the sites has an accurate timing source. When a signal is transmitted from a mobile device, the signal propagates at approximately 1,000 feet per microsecond to the entire antenna sites where the signal reception is time stamped. The differences in time stamps are then combined to produce intersecting hyperbolic lines from which the location is estimated.

A. *Advantage*

- A significant advantage of the technique is that no additional equipment is required to perform the accuracy testing.
- Positional error modeling was also performed and a hybrid Rayleigh-Gamma model was proposed to model the radial positional errors.
- It was shown that the proposed error model is a good fit to the measured data from outdoor field measurements using different positioning systems.

V. EXPERIMENT RESULT

The first practical case considered is data from a tracking system which provides vehicle tracking and data services within a city, typically covering thousands of square kilometers. The system used for the measurements described below is located in Kanyakumari in TamilNadu, with 14 base stations covering a geographical area of approximately 1684km^2. The system operates at about 400MHz with a bandwidth of 2MHz. The nominal accuracy of the system is 30m. For a typical location the number of base stations in radio range of the vehicle is four to six. One of the main applications of the system is in stolen-vehicle recovery, where its ability to resist radio jamming gives it an advantage over GPS-based technology.

If the vehicle moving in location nagercoil means the base stations are numbered 15,16,11,14 base stations are applied in the radio triangulation principle and get the accurate particular moving location.

A. *Calculation*

Therefore

Using the trigonometric identities

$$\tan\alpha = \sin\alpha / \cos\alpha \text{ and}$$

$$\sin(\alpha+\beta) = \sin\alpha\cos\beta + \cos\alpha\sin\beta,$$

This is equivalent to:

From this, it is easy to determine the distance of the unknown point from observation point, its north/south and east/west offsets from the observation point, and finally its full coordinates.

Figure 4: Tracking location

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The measured data were obtained by driving a vehicle on roads, and recording the track positional data. The vehicle path is about 20 km in length, and the sample period is 5 seconds. These data are then plotted on a road map of the city to obtain the raw cross-track errors.

Table1: Comparison of cross track error in Gaussian and Exponential Methods

Time(sec)	Gaussian(m)	Exponential (m)
20	0.5	0.53
40	0.48	0.48
60	0.4	0.41
80	0.35	0.35
100	0.29	0.24
120	0.24	0.12
140	0.16	0
160	0	0

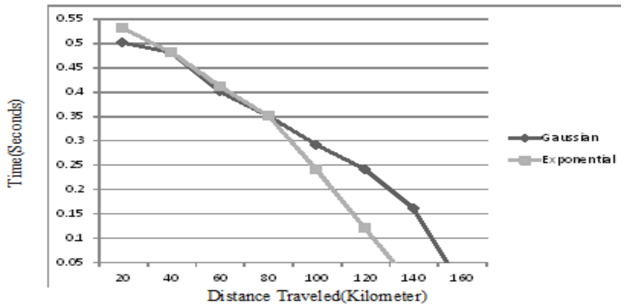

Figure 5:Comparison between the Gaussian and Exponential Errors in position tracking

VI. CONCLUSION

In this paper, a measurement technique for determining the accuracy of 2D positioning systems is presented. The method is based on the measurement of cross-track errors relative to a track as defined on a map.The method was validated using simulated tracking, which shows that the reconstructed statistics are close to the true statistics for typical applications.The method was also demonstrated with field measurements from a vehicle-tracking system. While the technique was

Developed to test radiolocation systems, the general concept can be used to determine the performance of any type of positioning technology when tracking moving objects. A significant advantage of the technique is that no additional equipment is required to perform the accuracy testing. Positional error modeling was also performed and a hybrid Rayleigh-Gamma model was proposed to model the radial positional errors.

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