

UWB Asynchronous Location Algorithm Based On Variable and Adaptive Step Size

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Abstract—In this paper, a new fast convergence adaptive algorithm with variable step size is proposed for UWB asynchronous location. This new proposed algorithm is derived on the distance between the targets and measurement point, which adjusts adaptively the step size with the change of gradient descent. Numerical experiment shows that algorithm is stable in the effective rectangular area and the positioning error may be up to millimetres order of magnitude. Meanwhile the proposed algorithm decreases a computation as well as minimizes the processing delaying compared with the fixed step size, furthermore, the proposed algorithm overcomes the fluctuating that closed to the targets. Results of simulation show that the proposed method has better location accuracy, high convergence speed and low computation than the related decentralized approaches described previous.

Keywords—UWB, Asynchronous position, Variable Step Size, Adaptive Step Size, Fluctuating

I. INTRODUCTION

Ultra-Wideband (UWB) communication system has become ubiquitous and gained widespread popularity as the high multi-path resolution capacity, low power, high speed data and large bandwidth of a UWB signal. UWB asynchronous position is proposed in this paper is different from the traditional algorithm, but still provides the high accurate ranging and localization. A simple asynchronous UWB position location algorithm based on single round-trip [1]、NLOS ranging error mitigation in a distributed positioning algorithm for indoor UWB ad-hoc networks [2] has been proposed in.

Estimating the target location from traditional asynchronous algorithm is not an easy task since it is dealing with a set of nonlinear equations relating to the target location. All kinds of methods are by exhaustive search, which is computationally intensive and suffers from the initialization and convergence problems. UWB positions Algorithm devote to finding out the optimizing algorithm depend on the method of least square. As the optimization algorithm in UWB positioning characteristics of the target function, resulting in close to the complexity and convergence is slow approaching a lesser. This paper takes positioning equation that used 3 references points in examples to analysis its characteristics and develops a new

positioning algorithm which can adjust the step size with the change of gradient descent under the distance between the targets and measurement. The results demonstrated that optimizing algorithm has better performance.

II. OPTIMIZING ALGORITHM ON LOCATION EQUATION

Asynchronous measurement in UWB positioning model has been proposed in [3][4]. Where assume that the measurement position number can be expressed as follows:

$$i=1, 2, \dots, L \quad (1)$$

The measurement on coordinate positioning can be expressed as follows:

$$c_i = (c_{1i}, c_{2i}, c_{3i})^T \quad (2)$$

The measured point on coordinate positioning is

$$x = (x_1, x_2, x_3)^T \quad (3)$$

l_i is the measuring distance. Where, the location equation can be expressed as follows:

$$\begin{aligned} (x - c_i)^T (x - c_i) - l_i^2 &= (x_1 - c_{1i})^2 + \dots \\ (x_2 - c_{2i})^2 + (x_3 - c_{3i})^2 - l_i^2 &= 0 \end{aligned} \quad (4)$$

And the optimizing algorithm for target function can be expressed as follows:

$$f(x) = \sum_{i=1}^L [(x - c_i)^T (x - c_i) - l_i^2]^2 \quad (5)$$

Under the location model assumptions, an algorithm for searching after the minimum can be expressed as follows:

$$\min_{x \in E^3} f(x) = f(x) = \sum_{i=1}^L \left[(x - c_i)^T (x - c_i) - l_i^2 \right]^2 \quad (6)$$

Where $x \in E^3$ is target's estimated location, take a descended gradient method [7] to solve this nonlinear least-square problem in a Negative gradient manner, the iterative method can be proved as follows:

$$x^{k+1} = x^k - \alpha^k \nabla f(x^k) \quad (7)$$

Where α^k is the iterative step size, $-\nabla f(x^k)$ is a Negative gradient. By Eq. (7) let 1, 2, 3..., k is the ordered sequence that computes the targets location estimates in each cycle consisting of k iterations. At each cycle the initialize value is the last final value. As the iteration point is gradually to the target function until the Eq. (8)

$$\|X^{(k)} - X^{(k+f)}\| \leq \varepsilon \quad (8)$$

stop to iteration. We can prove the step size α_k play key factors in the estimation accuracy. So the fixed step size is proposed [5] in next part to solve the location equation.

III. THE FIXED STEP SIZE OPTIMIZED ALGORITHM

The fixe step size is used as Eq. (7), it means the step size is fixed at each cycle. The simulation can indicated that the convergence and high accuracy location can be got as long as using a smaller step size and the iteration without any restriction. Contrary to use the large step size for maximum convergence speed and low computational complexity. It is clear that using different step size for the same target function lead to different results, especially On the Locating Accuracy and computation. Where, this algorithm is performed for the case of the Fig.1. Assume that the location of a target is (0, 0), A rectangular regions of the area is (0, 0) to (60, 60). As shown in Fig.2. Meanwhile, the table1 demonstrated the fixed step size lie in some disadvantages when closed to the target point. Iterations and absolute error have been shown in table1, which based on different targets with the fixed step size.

As shown in Fig.1 from the starting point (30, 70/3) is to the location of target (0, 0) with fixed step size results demonstrated that a large step size with reduce computation but fluctuating near the location of target, and the smaller step size may avoid the problems of fluctuating with the large field of convergence but increasing computation. Observe that the stability region in Fig.2 as shown the starting point is to target is not directly followed the straight line. The convergence speed will be declined. So the next part the Variable Step Size algorithm is proposed to solve this problem.

IV. THE VARIABLE STEP SIZE WITH ADAPTIVE OPTIMIZED ALGORITHM

Variable step size Incremental sub-gradient Algorithm [6] has been proposed. But still need large computation and easily to overflow. We anticipate that algorithm will achieve the Locating Accuracy with low computational complexity. So this paper proposed variable step size with adaptive algorithm. In this section we will first analyse the influenced factor of Step size. Then presents the variable step size optimizing algorithm, the last part we proposed the variable step size with adaptive algorithm for UWB asynchronous position.

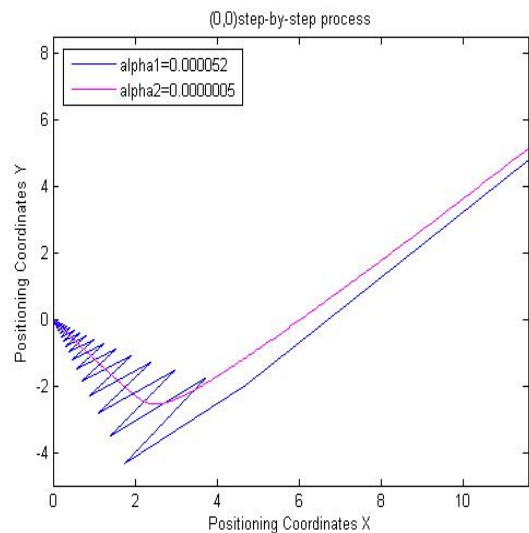


Figure 1. (0, 0) with different step size

Table 1. The fixed step size based on different targets

coordinate	iteration	X absolute error	Y absolute error
(0, 0)	6954	4.6e-3	4.2e-3
(0,40)	6525	3.6e-3	6.4e-3
(60,0)	6954	3.6e-3	-5.8e-3
(30,20)	5113	0.0e-0	8.3e-3
(15,15)	6704	3.7e-3	6.2e-3
(120,80)	7704	3.9e-3	6.2e-3

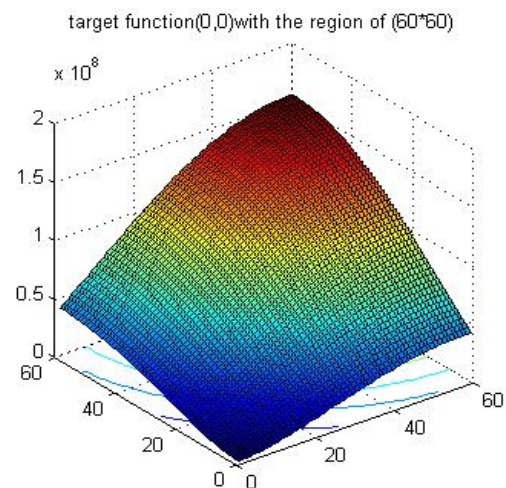


Figure 2.the gradient vector projections

A. The Step size based on the distance between Measurement and iteration point

We can obtain the distance between the target and measurement, meanwhile, compute the distance between Measurement and iteration point, so their different value is proper to update the step size as follow (9):

$$\alpha^k \propto (\mathbf{x}^k - \mathbf{c}_i)^T (\mathbf{x}^k - \mathbf{c}_i) - l_i^2 \quad (9)$$

The results indicated that using the different value to adjust the step size can avoided the fluctuating but still need large computation, so we should devote to find the optimized algorithm.

B. Optimized Algorithm with monotone variable step size

The method we design to estimate the target function is as follows:

$$f(\mathbf{x}^{k+1}) = f(\mathbf{x}^k + \alpha_k \mathbf{p}^k) = f(\mathbf{x}^k - \alpha_k \mathbf{f}'(\mathbf{x}^k)) < f(\mathbf{x}^k) \quad (10)$$

Where, as long as this in equation is right, the optimizing value could be got. We use three propositions to analyse the step size.

Propositions 1: given the initial value for α_k , make sure the Eq. (10).is right;

Propositions 2: if the Eq. (10) is not right, reduce the step size until its right;

Propositions 3: as long as Eq. (10) is right successively, increase the step size.

Simulation results indicate that the iterations has decreased sharply in many targets But rarely point would fluctuant when it is to the target point, which lead to a large iterations. As is shown in Fig.3 where is (30, 70/3) is to the location of target (0, 0), the performance is perfect. As is shown in Fig.4 where is (30, 70/3) is to the location of target (15, 15).

C. The Variable Step size with adaptive Optimized Algorithm

The algorithm has been found out to solve the problem of convergence and computation, but the only problems is fluctuating occasionally occur in a turning point, as the change of gradient reversed Where, there are three methods proposed in this paper. Firstly, monitoring the changes of descend gradient [7] has been proposed, once the gradient with no reversals in polarity, reduce the step size to eliminate the fluctuating; Secondly, select the mid-point to control the fluctuating in either iteration; thirdly, if the error increases suddenly, this will attribute to its large step size and beyond the convergence region, so reduce the step size and back to iterate. As follows in fig.4 (15, 15) variable and adaptive step size, the performance is perfect. In fig.5 (15, 15) is fluctuating point enlargement, it can be indicated that the improved algorithm is effective to reduce the fluctuating. As is shown in Table 2, computer based on simulation has been

carried out to validate the performance of proposed variable step size with adaptive optimizing algorithm for UWB asynchronous position.

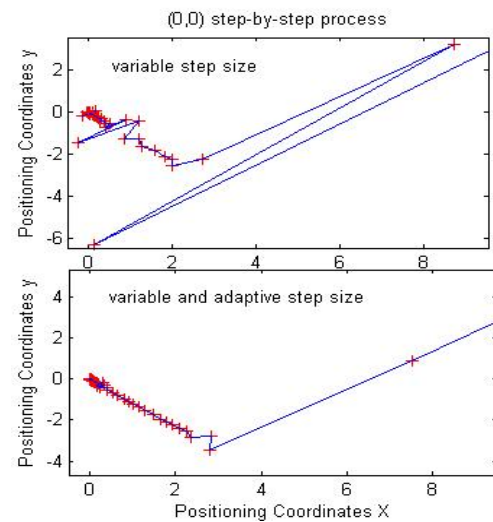


Figure 3. (0, 0) with Variable step size

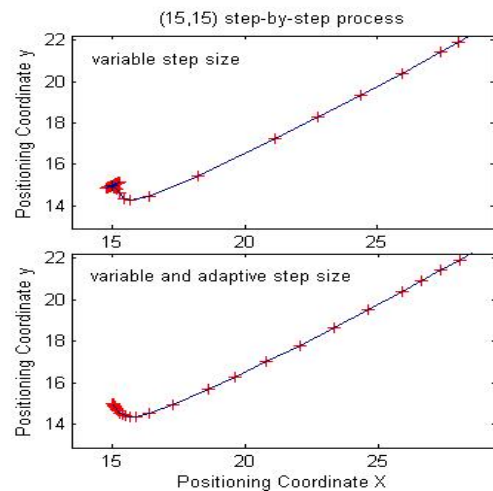


Figure 4. (15, 15) with Variable step size

Table 2. The variable and adaptive step size based on different targets

coordinate	iteration	X absolute error	Y absolute error
(0,0)	98	3.0e-5	4.0e-5
(0,40)	81	0.0e-0	0.0e-0
(60,0)	98	0.0e-0	0.0e-0
(30,20)	16	0.0e-0	0.0e-0
(15,15)	40	0.0e-0	0.0e-0
(120,80)	710	2.0e-4	3.0e-4

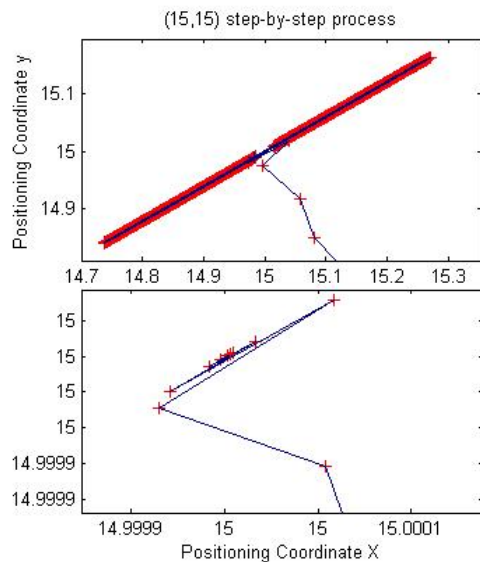


Figure 5. (15, 15) fluctuating point enlargement

Computer simulation results have been given to demonstrate the proposed method has better location accuracy than the related decentralized approaches described previously. Especially, Compared to the fixed step size, the computation decreased evidently. As is shown in Table2, the positioning error may be up to millimetres order of magnitude, it is understood that the performance of the variable step size with adaptive algorithm is working satisfactorily compared with the other algorithms mentioned.

V. CONCLUSIONS

In this paper, we proposed and evaluated an asynchronous UWB position location algorithm based on Variable and Adaptive Step Size. We have also presented a performance analysis to show that this optimizing algorithm can converge

to location. Computer simulation results have been given to demonstrate that the proposed method has better location accuracy, high convergence speed and low consumption than the related decentralized approaches described previous. Consequently, the proposed optimizing algorithm is useful for UWB asynchronous location.

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