Improved RANSAC Algorithm in Infusion Stabilization

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Abstract—With the popularity of the Internet of Things technology applications in various fields and the continuous improvement of technical level, the intelligence level of China's medical equipment industry is also growing. For example, the infusion monitoring system in the application of intravenous fluids. After collecting the infusion weight by sensors, and uploaded to the host machine to achieve real-time monitoring of the infusion. However, these systems had brought some challenges, such as system of real-time, precision and so on. In this paper, we introduce an infusion stabilization system. The system first obtains the weight of the stability of infusion liquid by weighing sensor, then using the RANSAC algorithm to fit the infusion data characteristic curve. Last, by fitting the model to filter jitter generated in the process of infusion, and around the filter of fitting model to get stable and accurate infusion data. Through the characteristics of transfusion data model, the patient's behavior characteristics were analyzed by system. Through a large number of experiments to prove that such a system has strong robustness.

Keywords-RANSAC; infusion jitter; infusion monitoring; real-time; Intelligent Medical

I. INTRODUCTION

Intravenous infusion is an important therapeutic means in clinical medicine and an important part of medical surveillance, and is widely used in medical work in various hospitals; according to the statistics inpatient infusion rate was 70% to 80%. It is not only an important route of administration, but also is the important way to replenish body fluids, nutrition to patients [1]. In the course of intravenous infusion, someone must accompany, in case the bulge of the accident. In particular, the need for almost 24 hours after infusion of the patient's care, it is so physically and mentally exhausted caregivers. Sleepiness occurs when a caregiver, prone to accidents. When infusion is completed, if no escort bedside or health care dressing or pull the needle is not timely, there will be back to the blood and so on. To this end, accompanied by the patient and family members of patients require continuous observing the infusion situation. It's so easily leading to cross-infection, and patients may also get a bad rest, affecting the quality of treatment and rehabilitation of patients. Meanwhile, the nurses also need to constantly ward rounds, increasing workloads, and sometimes produce medical disputes [2].

In recent years, with the development of the medical profession, medical information management has became an important symbol of modern hospital, especially in the field of medical monitoring proposed diversification, informatization, personalized medical equipment needs. The progress and development of modern science and technology, provides the medical monitoring technology innovation condition and new development space. However, the development of medical monitoring technology and equipment cannot meet the requirements of the hospital, the patient, family and personal health aspects raised [3]. For example, in the infusion monitoring system, although there are infusion monitoring system has been in use to solve some practical problems, there are some limitations, especially with the rapid development of network technology, wireless communication technology today, infusion monitoring needs to a more efficient and safe direction. Therefore, this paper puts forward a kind of based on RANSAC algorithm to remove the jitter in the infusion process in order to improve the accuracy and security of the infusion monitoring. The remainder of the article is organized as follows. First, in Section II, describes the infusion process jitter problems. In Section III, elaborates the RANSAC algorithm and how to choose the key parameters. Then, in Section IV, an improved RANSAC algorithm is proposed. In Section V, the RANSAC algorithm is assessed. Finally, Section VI gives the conclusions of the paper.

II. INFUSION JITTER PROBLEMS

Infusion monitors time to send the liquid weight packets to machine, which for infusion state judge has played a very important role. Because of the importance of accurate weight of the liquid packets, the infusion process to jitter is particularly important [4]. We'll be the liquid weight d Projection become d_1, d_2,..., d_n planar point set, and fitting a linear curve by the least squares method. In the process of infusion, the patient will inevitably be some specific behavior actions, and these actions will certainly lead to the infusion process jitter, causing noise, making the infusion data inaccurate [5]. According to these characteristics the behavior of the patient, the jitter will be classified into two categories: slight jitter and larger jitter.

A Slight jitter

Infusion process, patient to drink, eat, shaking hands, etc. to a lesser extent the action occurs. In Fig .1, we can see a straight line obviously, and in a straight line (virtual) surrounding a number of discrete points, such that the jitter caused by noise.

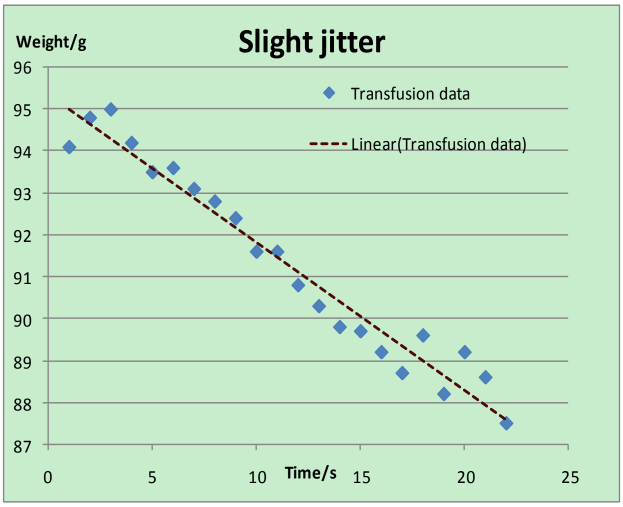

Figure 1. Slight jitter

B. Larger jitter

During the infusion, assuming that the patient in the process of covering quilt pressed the infusion tube, which resulted in increased liquid weight instantly. Shown in Fig .2, at a certain point, the liquid weight suddenly increases.

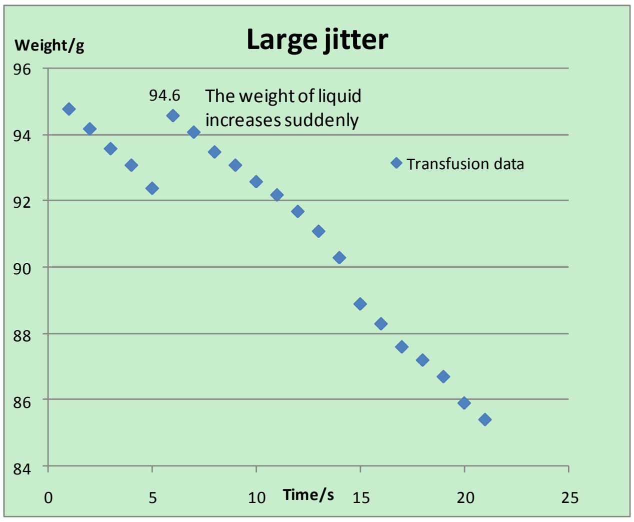

Figure 2. Larger jitter

When each infusion data no jitter interference, high precision for least squares algorithm [6]. But once one or some of the data points jitter severely during infusion process, the data is passed to the target host computer might appear substantial error, here called the gross error, and least-squares fitting algorithm for gross error data is not anti-poor robustness, and these gross errors data will also significantly affect the accuracy of the infusion in the final [7].

Infusion de-jitter problem is from the sampled data points $d_1, d_2, \ldots, d_n$ fitting the data model, and then use RANSAC algorithm removed the error data from the fitting model and determine the behavioral characteristics of patients according to the characteristics of infusion data so that nurses take appropriate measures in accordance with the actual situation.

III. INFUSION DE-JITTER ALGORITHM

A. Infusion de-jitter based on RANSAC algorithm

RANSAC algorithm is based on the mathematical model of multiple data points to estimate the parameters a robust algorithm, data processing gross error has been widely used. It is through the multiple random sampling of data, each time removing as little as possible but sufficiently random data to determine the plurality of model parameters. Then, according to the model have been determined for all data and the pre-determined threshold value to judge. Within the error threshold range for this model, called the inliers, outside the margin of error, called outliers. Because the inliers data point to determine the model close to the real model, most of the data will fall within the error threshold value; while outliers are abnormal data disorganized, identified by their model, only a few data falls within the error threshold value, large part of the data fall outside the error range [8,9].

Given the observed data set D, Remember m is a model fitted by number of data points(or rather for the parameters of the model), M are the set of all models (different parameters), and $b < |D|$ is the minimum of the required number of data points to fitting the model. Given error equation $e: D \times M \to R > 0$, if $e(d,m) \le t$, defined d is inliers data for m, and vice versa are outliers. According to the above description, the implementation process of RANSAC is described as follows:

1) Randomly select b data constitute a subset $S \in D$;
2) By $d \in S$ using the least squares method (or other methods) mathematical to estimate the model parameter, denoted m;

$$m = \arg\min_{m \in M} \sum_{d \in S} \| d, m \| \tag{1}$$

3) For each data point $d \in D$, use $e(d,m) \le t$ to Judge: if $e(d,m) \le t$, reserved d, otherwise removed. All data points to meet the conditions d forming a new collection S', and save it as S'_{last};
4) The process is repeated from 1 to 3, it is determined $|S'_{new}| \ge |S'_{last}|$, if true, then make $S'_{last} = S'_{new}$; If false, the new subset of the data will be removed. This process is repeated k times;
5) Given data set S'_{last}, Re-model fitting, get a new model:

$$m' = \arg\min_{m \in M} \sum_{d \in S'_{last}} \| d, m \| \tag{2}$$

B. RANSAC algorithm parameter selection

From the above algorithm description, we can know that the algorithm is necessary to set several parameters: the error threshold t, Fitting points b, Algorithm cycle parameters K.

1) Error threshold t: According to the characteristics of infusion data we know that it can be seen a linear equation, which the intercept greater than 0, and the slope is negative. According to the fitting equation and then calculate the distance from a data point to this line, we can agree on an error threshold . The distance greater than this threshold value are outliers.

2) Algorithm cycle parameters K: Assuming iteration of RANSAC algorithm to estimate the model parameters selected from at least need to focus on data b points as the sampling point, and the result of this calculation process of the model sample points are generated in the data points are useful. The probability of this event denoted as p, use this probability p to produce an acceptable results for algorithm. Note at a time from the data set in the data sampling point the probability of a $w = |D_{inliers}| / |D|$, usually the w values are unknown. The model parameter estimation requires at least b data points, so b points are the inliers of probability w^b, and at least one point for outlier probability is $1 - w^b$. That is in accordance with the probability $1 - w^b$ to estimate bad model parameters [10]. Further, $(1 - w^b)^k$ is no once by number of b inliers to estimate of the probability of the model parameters in the K times cycle, this probability is equivalent to $1 - p$, Namely:

$$1 - p = (1 - w^b)^k \tag{3}$$

Logarithm on both sides to get:

$$K = \frac{\log(1-p)}{\log(1-w^b)} \tag{4}$$

Derived this equation is based on assumption that the b points are selected independently. In other words, a point can be repeated selection in the same iterative process, but obviously this is not a very reasonable assumption, therefore deduced K Value is considered to select the number of iterations does not repeat points.

3) Fitting Points b: Theoretically two points can determine a straight line, but due to the initial point selection have a great influence on the algorithm, we can choose the initial points more than following data points in order to ensure the accuracy of the initial model. In fact, through the above cycle parameters K Calculations, we can know, if you want to high succeed rate, p = 0.99, when b is constant, the larger K, the grater p; When w is Constant, the larger b, required K Greater. Usually, w is Unknown, so choose b smaller is better.

IV. RANSAC IMPROVEMENTS

A. Initial point selection

At the beginning of infusion, since nurses will adjust the drip rate, check the patient's personal information in infusion bag. All these actions will result in the infusion of behavior jitter frequency increases. Therefore, the choice of the initial point RANSAC algorithm is particularly important. Whether you choose the points too much or too little can cause the speed of convergence to the optimal solution slowly. To overcome this problem, we propose to select as little as possible but sufficient amount of data to fit the original model, is expected to improve convergence. Fitting points b mentioned in 3.2, we choose n ($n > b$) initial point to fit the model $W = kt + G$, among them W is the live weight of liquid, G is liquid initial weight, k is drip rate. When the slope of the current model k_{new} is similar with the slope of the front of a model k_{old}, namely: $|k_{new} - k_{old}| \le t$, t is slope of the model set error threshold. We believe that the data is stable, then re-fitting points for change b to running algorithm.

B. Repeat select fitting points

Infusion monitoring system requires a higher real-time. When the points were few options fitted model, will lead to model fitting accuracy is not enough, the speed of convergence to the optimal model is too slow, affect the system real-time; When choice more points to fitting model, although the system can meet the accuracy requirements, cannot meet the system real-time requirements. To weigh the data accuracy and system convergence rate, consider increasing the number of inliers in past N seconds in the selection of the current model. Assuming the number of points used to fit the current model for n_1, n_2, n_3, n_4, n_5, then, when fit under a model you can choose $n_4, n_5, n_6, ..., n_m$ to fit the next model. So not only because of the number of points is not enough to meet the resulting accuracy is too low, but also to ensure the system for real-time requirements [11].

C. Reduce the number of iterations

RANSAC calculate parameters of iterations is no upper limit, it is only a certain probability to get credible model, and is proportional to the probability and the number of iterations. If you set the upper limit of the number of iterations, the result may not be optimal results, and may even get the wrong results. If does not control the number of iterations the algorithm will definitely affect the efficiency of the algorithm, resulting in a larger delay, unable to meet the requirements of real-time for systems [12]. To address this problem, we propose that a continuous m ($m > 0$) models approximately equal (to determine the model slope differences), pause iterative algorithm until the slope of the current model with the next model differ by more than the error threshold slope t, then re-started running algorithms. Assuming that the slope of the model for three consecutive k_1, k_2, k_3. If the three slope pair wise comparison, the difference was within the error threshold, in other words: $|k_1 - k_2| \le t$, $|k_2 - k_3| \le t$, $|k_1 - k_3| \le t$, we believe that the data is stable, pause algorithm's iterative. When the slope of the model k_n and the slope of the next model k_{n+1} difference exceeds the error threshold, $|k_n - k_{n+1}| > t$, then we recovery algorithm.

V. PERFORMANCE EVALUATION

There are many parameters affect RANSAC algorithm. RANSAC parameters are vary under different scenarios. RANSAC algorithm for the application of this research is only for the infusion characteristics. In order to evaluate the performance of RANSAC, we compare the algorithm four kinds of models:

- Standard RANSAC algorithm.
- Fitting points optimized RANSAC algorithm.
- Iterations optimized RANSAC algorithm.
- Fitting points and iterations are optimized RANSAC algorithm.

The second of which includes two parts: First, select the initial point; second, fitting points repeat. Repeat selected point mainly to under the premise of increasing the fit points, not only can guarantee system real-time, but also improve the accuracy of data. A detailed description can refer to section IV. The third, mainly to enhance the efficiency of the algorithm and improve the system real-time.

In order to evaluate the system real-time, applied delay model. Time for the current data set t_1, the PC displays the current data time t_2, then the delay time of the system $T = t_2 - t_1$.

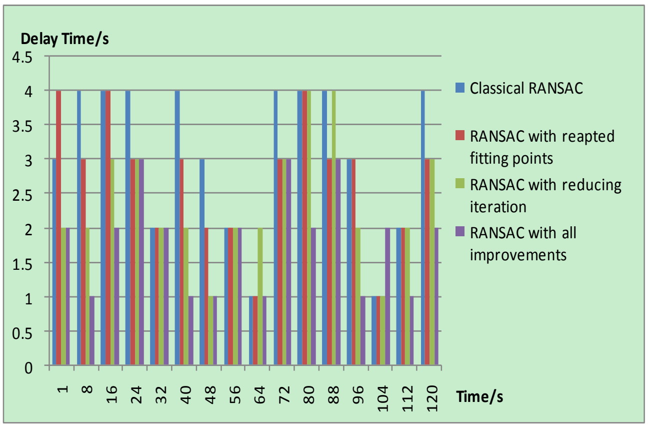

Figure 3. System delay

Fig .3 describes the system delay of the original algorithm and improved algorithm. Although traditional RANSAC has a good robustness, because of the convergence of defects, resulting in system real-time is not very good. In the repeated use of the RANSAC algorithm fitting points, the system delay is significantly reduced, but there is a problem that, due to the larger initial point selected at the system start time, the delay is relatively large. After reducing the number of iterations in the algorithm, system real-time is better than fit with a duplicate select points. After all improved points combined, system real-time has significantly improved [13,14].

In the infusion process, how to ensure the accuracy of the infusion data is very important. In nearing completion of the infusion stage, precision infusion fluid is particularly important. We set the remaining amount of the infusion bag threshold 5ml when the infusion is completed. That is, when the infusion bag of liquid remaining amount is less than or equal to 5ml, the system will prompt the infusion is completed so that nurses can change the infusion bag. When prompted infusion is completed, if the actual margin greater than 5ml, even more will be wasted, but also increase the workload of nurses; On the other hand, if the actual margin is too small, even when empty bottles will endanger the patient's health, even life.

Based on this, the importance of infusion the accuracy of the results is self-evident. Accuracy of the model we proposed to evaluate the accuracy of the system results. Set the bottle of liquid actual margin of M_s, the weight of the host computer for display M_c, the error weight $M_w = |M_c - M_s|$.

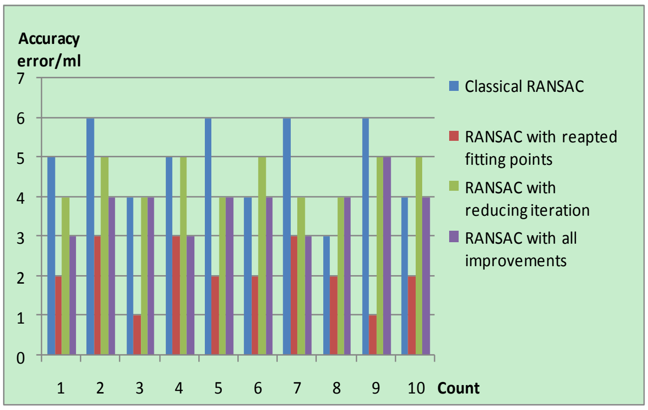

Figure 4. System accuracy error

Fig .4 describes the system accuracy error of original algorithm and the improved algorithm. Although traditional RANSAC is robust, the system is only able to basically meet the accuracy requirements. In the repeated use of the RANSAC algorithm fitting points, the accuracy of the system has increased significantly. After reducing the number of iterations in the algorithm, although the system accuracy has increased, but the effect is not obvious. And after all the improvements points combined algorithm to improve system accuracy is worse than using only repeat selection fitting points.

If in the infusion process, there has been a substantial jitter (such as patient tuck), then the model will certainly appear relatively large fluctuations, at this time, the method of repeating select fitting points inevitably do not apply. Because of the slope of the adjacent two models larger deviation, algorithm needs re-calculation, fitting the new model, while the model stable, then using repeat selection method of fitting points. So the infusion weight has a greater of actual bias, then you can appear some warning signs or voice prompts in the host computer, the nurse be told the patient infusion is abnormal, then the nurse to take appropriate measures in accordance with the actual situation.

VI. CONCLUSIONS

In this paper, we study how to effectively use the RANSAC algorithm to filter out the jitter generated during the infusion. Through a series of related work, we studied the characteristics of infusion data and the factors of jitter in infusion process. The results show that, RANSAC algorithm is suitable for transfusion to shake, because it has strong robustness. However, in terms of the convergence, it does not much better some other filtering methods. Given this result, we propose a series of improvements to improve the algorithm in real time and accuracy. Since the algorithm for the initial model has great dependence, in the select initial point, we used a learning strategy. After studying the infusion characteristics of data in the initial period of time, according to the start of model parameters to determine the number of initial fitting. While doing so will bring some initial delays in the system, for the convergence of the system and the precision will bring greatly improved in later. To further enhance the system real-time, we propose a method for fitting points repeat choice, not only can improve the system real-time, but also improve system accuracy. Then, from the perspective of efficiency of the algorithm, if a number of m models are approximately equal, then pending algorithm, improve the algorithm efficiency and the system in real time. Finally, we have simulated the implementation of RANSAC to evaluate their performance. The results show that, under the premise of guaranteed convergence rate, RANSAC improves the accuracy of the large extent of the infusion data, and according to the model can determine the abnormal infusion.

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REFERENCES

[1] Cataldo, A; Cannazza, G.; Giaquinto, N.; Trotta, Amerigo; Andria, G., "Microwave TDR for Real-Time Control of Intravenous Drip Infusions," Instrumentation and Measurement, IEEE Transactions on , vol.61, no.7, pp.1866,1873, July 2012.

[2] Cataldo, A; Cannazza, G.; De Benedetto, E.; Giaquinto, N.; Trotta, Amerigo, "Reproducibility analysis of a TDR-based monitoring system for intravenous drip infusions: Validation of a novel method for flow-rate measurement in IV infusion," Medical Measurements and Applications Proceedings (MeMeA), 2012 IEEE International Symposium on , vol., no., pp.1,5, 18-19 May 2012.

[3] Gurtov, A; Porambage, P.; Nikolaevskiy, I, "Secure lightweight protocols for medical device monitoring," Open Innovations Association FRUCT, Proceedings of 15th Conference of , vol., no., pp.46,51, 21-25 April 2014.

[4] Amano, H.; Ogawa, H.; Maki, H.; Tsukamoto, S.; Yonezawa, Y.; Caldwell, W.M., "A remote drip infusion monitoring system employing Bluetooth," Engineering in Medicine and Biology Society (EMBC), 2012 Annual International Conference of the IEEE , vol., no., pp.2029,2032, Aug. 28 2012-Sept. 1 2012.

[5] Jiang Ma; Yuqiao Wen; Jie Yin; Duoli Zhong; Kun Yang; Wei Zeng; Lingyan Du; Kang Huang, "A New Algorithm of Drop Speed Measuring of Infusion Monitoring Device," Computer Sciences and Applications (CSA), 2013 International Conference on , vol., no., pp.229,232, 14-15 Dec. 2013.

[6] Sharp, I; Kegen Yu, "Enhanced Least-Squares Positioning Algorithm for Indoor Positioning," Mobile Computing, IEEE Transactions on , vol.12, no.8, pp.1640,1650, Aug. 2013.

[7] Castillo, M. R M; Bretas, N. G.; London, J.B.A, "Parameter errors and gross errors detection, identification and correction," Power and Energy Society General Meeting, 2012 IEEE , vol., no., pp.1,12, 22-26 July 2012.

[8] Shuqiang Yang; Biao Li, "Outliers Elimination Based Ransac for Fundamental Matrix Estimation," Virtual Reality and Visualization (ICVRV), 2013 International Conference on , vol., no., pp.321,324, 14-15 Sept. 2013.

[9] Niedfeldt, P.C.; Beard, R.W., "Multiple target tracking using recursive RANSAC," American Control Conference (ACC), 2014 , vol., no., pp.3393,3398, 4-6 June 2014.

[10] Yue Wu; Wenping Ma; Maoguo Gong; Linzhi Su; Licheng Jiao, "A Novel Point-Matching Algorithm Based on Fast Sample Consensus for Image Registration," Geoscience and Remote Sensing Letters, IEEE , vol.12, no.1, pp.43,47, Jan. 2015.

[11] Chen, K., "Implicit dynamic system for online simultaneous linear equations solving," Electronics Letters , vol.49, no.2, pp.101,102, January 17 2013.

[12] Xu, Xiaoquan; Xia, Junying; Xiong, Jiulong; Xie, Xiu-fen, "Robust camera calibration with vanishing points," Image and Signal Processing (CISP), 2012 5th International Congress on , vol., no., pp.931,935, 16-18 Oct. 2012.

[13] Xu, M.; Lu, J., "Distributed RANSAC for the robust estimation of three-dimensional reconstruction," Computer Vision, IET , vol.6, no.4, pp.324,333, July 2012.

[14] Raguram, R.; Chum, O.; Pollefeys, M.; Matas, J.; Frahm, J., "USAC: A Universal Framework for Random Sample Consensus," Pattern Analysis and Machine Intelligence, IEEE Transactions on , vol.35, no.8, pp.2022,2038, Aug. 2013.