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Design of UWB/IMU fusion positioning system based on topological constraints

Haiyan Yao[a] , Qiang Guo[a,*], Xufeng Zhang[a], Yi Liu [a], Penghao Luo[b]
[a]Hangzhou Electric Power Equipment Manufacturing Co., Ltd. Yuhang Qunli Complete ElectricalManufacturing Branch
[b]Hangzhou Dianzi University; 13340967515@163.com
[*] Corresponding Author; E-mail: ackypaper@163.com.

Abstract

Complex indoor scene localization has problems such as signal occlusion and multi-path effect, this paper analyses the topology formed by the motion trajectory of IMU and the coordinates of the UWB base station, and based on this topological constraints, it implements the judgement of line-of-sight/non-line-of-sight UWB measurements, and selects line-of-sight measurements to participate in localization computation. The heuristic extended Kalman filter algorithm (H-EKF) is used to establish the error model of IMU/UWB dual sensors, and the UWB and IMU are tightly coupled for fusion processing, and the Kalman filter information is corrected according to the results of the selection of range values to make full use of the useful information of multiple moments, improve the fusion accuracy, and achieve the alleviation of the non-visual range error.

Introduction

Single UWB or IMU positioning techniques have certain limitations in complex environments[1], such as UWB signals are susceptible to environmental interference and IMU data are prone to accumulated errors. Therefore, fusion of UWB and IMU to achieve complementary advantages has become an important way to improve positioning accuracy and stability

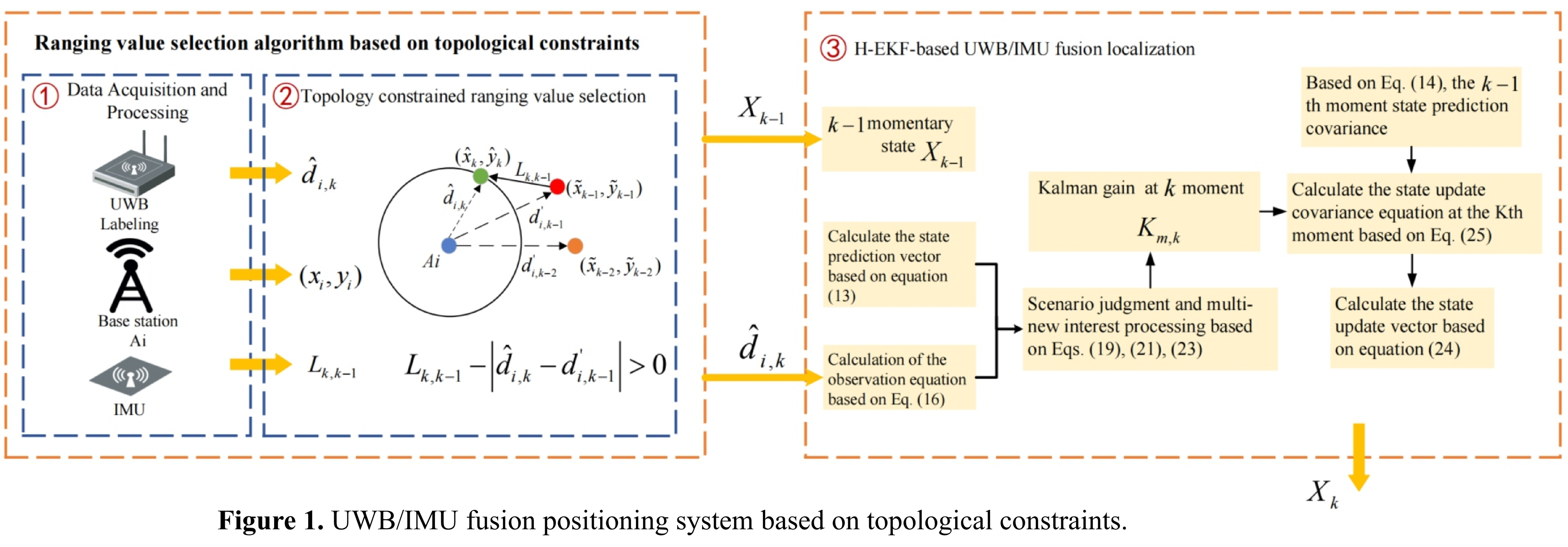

Figure 1. UWB/IMU fusion positioning system based on topological constraints.

UWB/IMU fusion positioning based on H-EKF

$$\begin{bmatrix} x_k \\ y_k \\ v_{x,k} \\ v_{y,k} \end{bmatrix} = \begin{bmatrix} 1 & 0 & \Delta T & 0 \\ 0 & 1 & 0 & \Delta T \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_{k-1} \\ y_{k-1} \\ v_{x,k-1} \\ v_{y,k-1} \end{bmatrix} + \begin{bmatrix} \frac{1}{2}(\Delta T)^2 & 0 \\ 0 & \frac{1}{2}(\Delta T)^2 \\ \Delta T & 0 \\ 0 & \Delta T \end{bmatrix} \begin{bmatrix} a_{x,k-1} \\ a_{y,k-1} \end{bmatrix} + V_{k-1}$$

$$E_1(k) = \begin{bmatrix} e_1(k) \\ e_2(k) \\ \overline{e}_3(k) \end{bmatrix} \quad E_2(k) = \begin{bmatrix} \overline{e}_1(k) \\ \overline{e}_2(k) \\ e_3(k) \end{bmatrix} \quad \overline{e}_1(k) = \frac{e_1(k-1)+e_1(k-2)}{2}、\overline{e}_2(k) = \frac{e_2(k-1)+e_2(k-2)}{2} \quad \overline{e}_3(k) = \frac{e_3(k-1)+e_3(k-2)}{2}$$

$$E_3(k) = \begin{bmatrix} e(k) \\ e(k-1) \\ e(k-2) \end{bmatrix} = \begin{bmatrix} Z_k - [h(\hat{X}_{k/k-1}) + W_k] \\ Z_{k-1} - [h(\hat{X}_{k-1/k-2}) + W_{k-1}] \\ Z_{k-2} - [h(\hat{X}_{k-2/k-3}) + W_{k-2}] \end{bmatrix}$$

Experiments and Results

Scenario 1 is an indoor test scenario in an underground garage selected by the author, to solve for the location of the three UWB base stations, the underground garage scenario is shown in Figure 2.

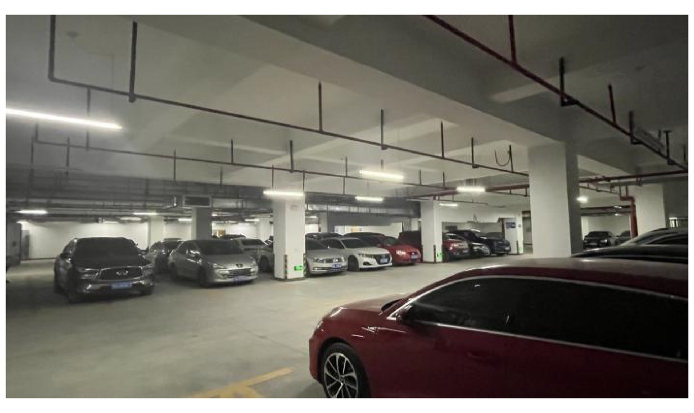

Figure 2. Measured Scene.

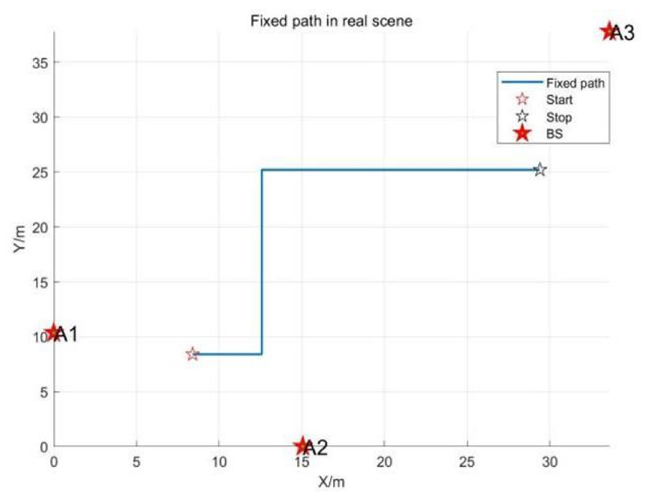

Figure 3. True Reference Path Diagram.

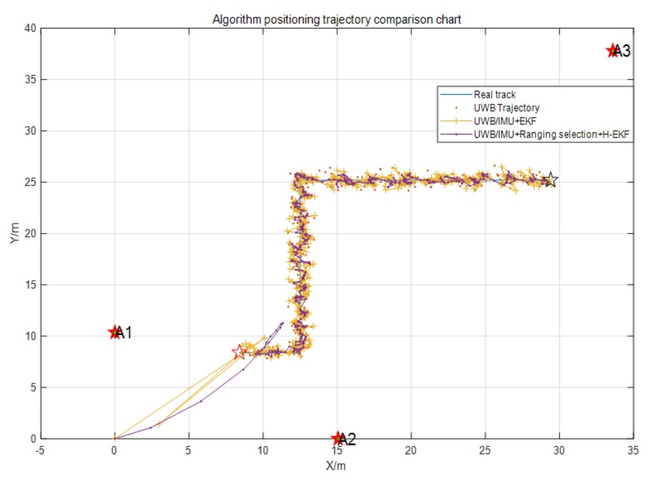

Figure 4. Comparison of algorithm positioning trajectories in scene 2.

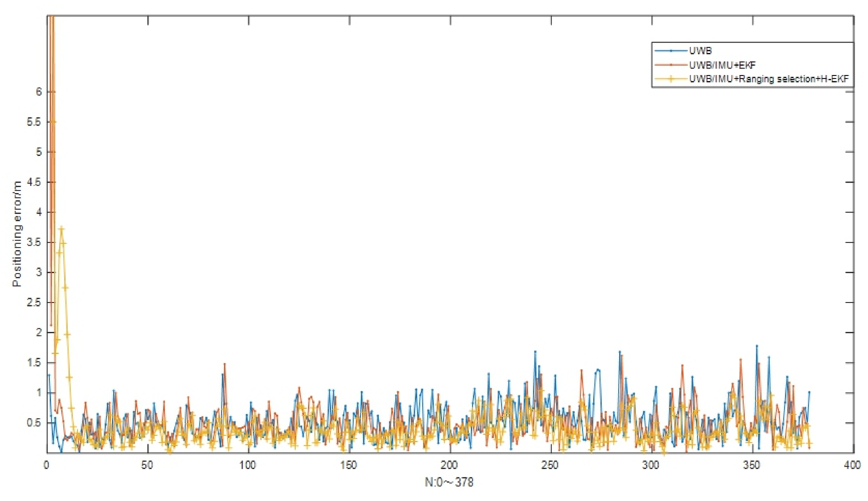

Figure 5. Positioning error distribution.

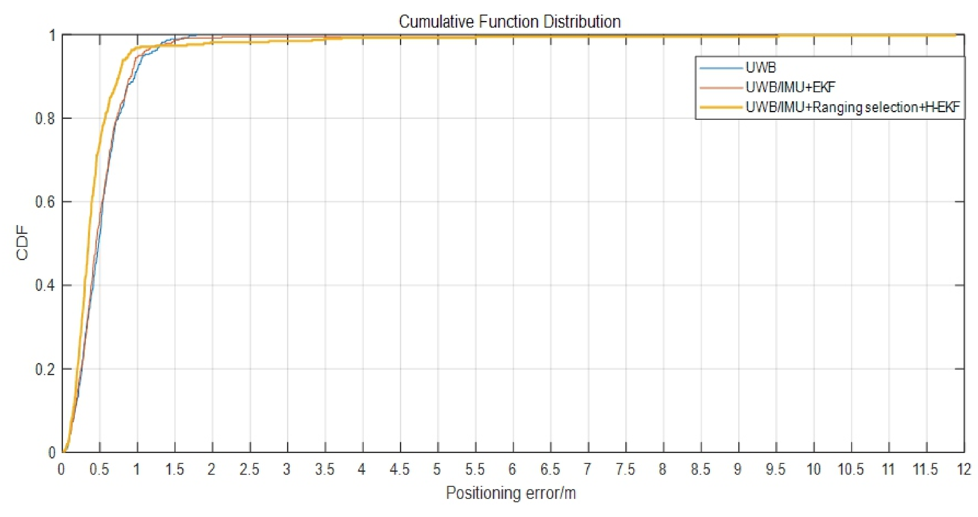

Figure 6 .Comparison of cumulative errordistribution .

Conclusions

- Facing the complex indoor scene, the thesis takes Kalman filtering as the basis, by analysing the topological constraint relationship formed between the IMU motion trajectory and the UWB base station, and obtains the ranging value selection method based on this relationship.
- The thesis adopts the heuristic extended Kalman filter algorithm (H-EKF) to tightly couple the UWB and IMU to achieve the optimal estimation of the system state.
- Comparison of data acquisition and algorithm results is carried out in two selected complex indoor scenes, and the experimental simulation results show that even in the case of UWB base station with its serious occlusion, the method proposed in the dissertation is able to effectively mitigate the non-line-of-sight error, and realise a more accurate localisation in complex indoor environments.

References

[1]Yang, B.; Li, J.; Shao, Z.; Zhang, H. Self-Supervised Deep Location and Ranging Error Correction for UWB Localization. IEEE Sensors Journal 2023, 23, 9549–9559.