Operation Manual V1.0

Data set for UWB Cooperative Navigation and Positioning of UAV Cluster

Content

1 Introduction

This document primarily introduces how to use the dataset, as well as the precautions that should be taken during the process. The document is structured according to the organization of the dataset files and is divided into four parts: measurement environment, source data, technical verification, and code. Additionally, you will need to read the following content:

Paper： Data set for UWB Cooperative Navigation and Positioning of UAV Cluster

Code： https://github.com/ZhangCunle

2 Measurement Environment

The measurement environment consists of two parts: the outdoor environment Environment0 and the indoor environment Environment1.

The folder Environment0 contains an Anchors.mat file, which specifies the list of reference base station nodes (A1-A8) and their corresponding positions in the selected environment. Each reference base station node position is represented by x-axis, y-axis, and z-axis coordinates, with units in meters. Additionally, it includes an Environment0.png file, as shown in Figure 2-1, which illustrates specific information about the measurement environment, such as the actual site dimensions, equipment placement, and the basic formation of the drones. Moreover, the files outdoor-straight.png and outdoor-climb.png are used to depict the trajectories of formation flight, corresponding to the straight flight path and climbing flight path, respectively, as shown in Figure 2-2.

Figure 2-1. Specific information of Measurement Environment 0.

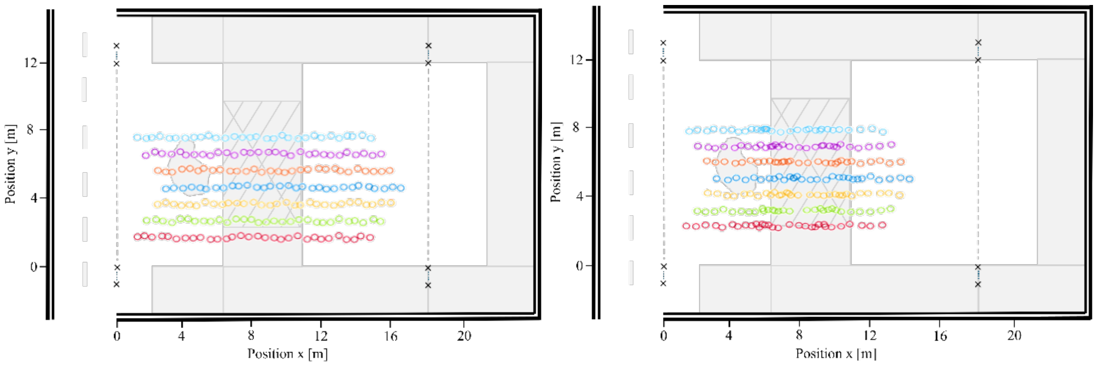

Figure 2-2. Schematic diagram of straight and climb flight trajectories.

The most important component is a “Flying_path” folder, which contains two types of swarm formation simulation flight paths: “Flying_straight” and “Flying_climb.” Each type of flight path includes 7 UAV nodes, named Position_UAV1.mat, ⋯, Position_UAV7.mat. The flight path of each drone consists of 30 trajectory points, with each point's position value given for the x-axis, y-axis, and z-axis, in meters.

The “Environment1” folder contains an “Anchors.mat” file, which specifies the list of reference base station nodes (A1-A8) and their corresponding positions in the selected environment. Each reference base station node position is represented by x, y, and z coordinates, with units in meters. It also includes an “Environment1.png” file, as shown in Figure 2-3, which illustrates specific information about the measurement environment, such as the actual site dimensions, equipment placement, and the basic formation of the drones. Additionally, the “indoor-circle.png” and “indoor-disperse.png” files are used to depict the trajectory patterns for formation flight, corresponding to the straight flight path and climbing flight path, respectively, as shown in Figure 2-4. Most importantly, there is a “Flying_path” folder, which stores the simulated flight paths for two types of swarm formations, “Flying_circle” and “Flying_disperse.” Each type of flight path includes 7 drone nodes, named Position_UAV1.mat, ⋯, Position_UAV7.mat. The flight path of each drone consists of 30 trajectory points, with each point's position value given for the x-axis, y-axis, and z-axis, in meters.

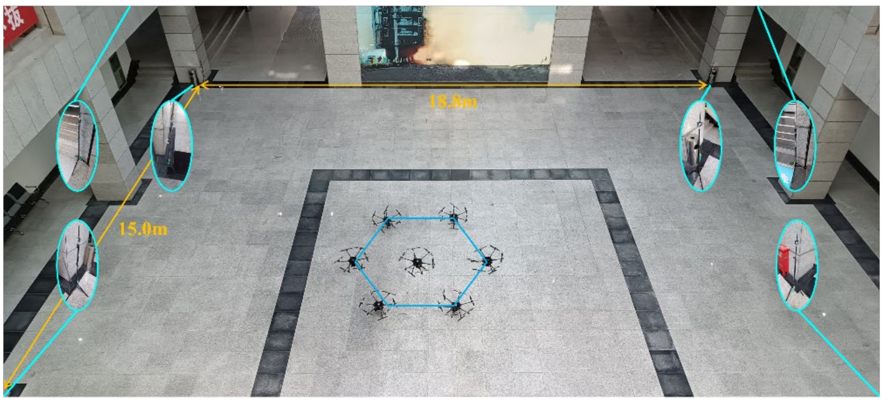

Figure 2-3. Specific information of Measurement Environment 1.

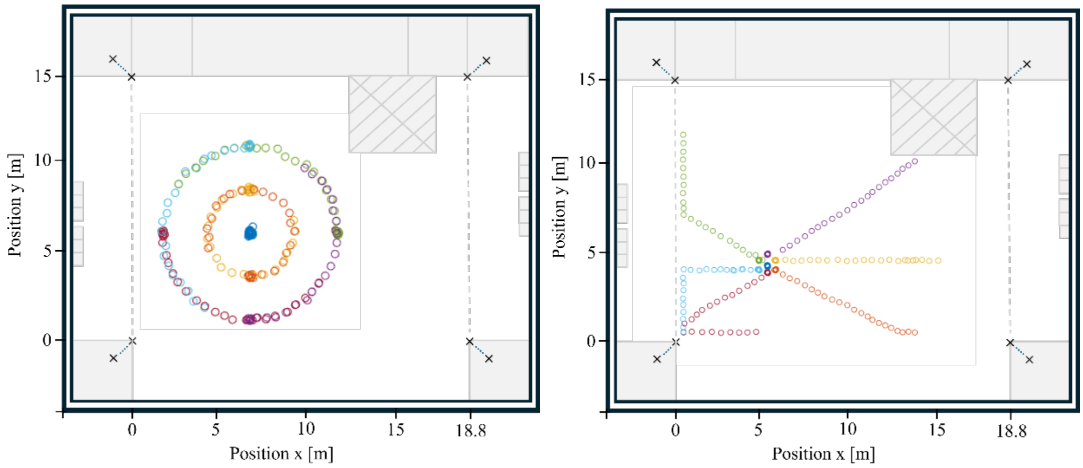

Figure 2-4. Schematic diagram of circle and disperse flight trajectories.

3 Original Data

The “Raw_data” folder contains all the measurement values collected in a specific environment. This folder houses two environmental folders, “Environment0” and “Environment1”. Each environmental folder includes folders for two different types of swarm formation flights (for “Environment0”, these are “Flying_straight” and “Flying_climb”; for “Environment1”, these are “Flying_disperse” and “Flying_circle”). Each formation flight type folder corresponds to the trajectory points of the simulated flight path, with a total of 30 sets of measurement data. All measurement values are categorized and stored in sequence from 1 to 30. Each set of trajectory points is measured across four communication channels, and each subfolder contains 4 sub-files.

Taking “Flying_straight” as an example, it first contains a subfolder named “Original_data,” which includes 4 measurement files. Each measurement file records the raw measurement data frame information from a specific environment without any processing. The file names are defined using the format “data_hex_orgin_chi.mat,” where “chi” represents the system measurement channel number. For instance, “data_hex_orgin_ch2.mat” is the raw measurement data for communication channel 2, containing 30 data frames, which represent the actual measurement data for 30 sets of trajectory points. The specific structure of a single data frame can be found in the paper.

The next subfolder is “Distance_Anchor_Label,” which also contains 4 measurement files. These files store the measured distances from each of the seven UAV nodes to the eight reference base station nodes in the corresponding environment. A single set of measurement distances is represented by an 8×7×30 matrix, indicating the distance measurement matrices for 30 sets of trajectory points. The file names are defined using the format “Dis_anchor_label_chi.mat.” For example, “Dis_anchor_label_ch2.mat” is the distance measurement matrix between the UAV nodes and the base station nodes for communication channel 2, and the distance matrix for the 4th set of trajectory points is shown in Figure 3-1.

val(:,:,4) =

810	806	735	747	693	883	619
1504	1604	1526	1674	1540	1820	1590
1551	1563	1661	1580	1742	1636	1784
910	807	973	749	964	686	997
732	785	630	807	577	844	504
1545	1757	1575	1728	1594	1545	1653
1713	1719	1384	1668	1458	1709	1500
821	699	858	627	904	548	940

Figure 3-1. Distance measurement matrix for the 4th set of trajectory points during communication channel 2.

The subsequent subfolder is "Distance_Label_Label," which contains the measured distances between the seven UAV nodes within the corresponding environment. Each set of measurement distances is represented by a $7 \times 7 \times 30$ matrix, indicating the distance measurement matrices for 30 sets of trajectory points. The filenames are defined using the format "Dis_label_label_chi.mat." For instance, "Dis_label_label_ch2.mat" is the distance measurement matrix between UAV nodes for communication channel 2, and the distance matrix for the 4th set of trajectory points is shown in Figure 3-2.

val(:,:,4) =

0	189.4997	126.6496	209.1154	158.8584	262.8459	189.5312
189.4997	0	278.6272	46.3344	305.2947	247.3605	314.0618
126.6496	278.6272	0	279.9673	66.6050	226.1708	130.1832
209.1154	46.3344	279.9673	0	303.5003	216.2307	309.3316
158.8584	305.2947	66.6050	303.5003	0	253.7805	67.6520
262.8459	247.3605	226.1708	216.2307	253.7805	0	278.4878
189.5312	314.0618	130.1832	309.3316	67.6520	278.4878	0

Figure 3-2. Distance measurement matrix for the 4th set of trajectory points during communication channel 2.

The final subfolder is "Position_Label," which stores the real-time positioning solutions for the seven UAV nodes during flight in the corresponding environment. Each set of positions is represented by a $7 \times 3 \times 30$ matrix, indicating the position matrices for 30 sets of trajectory points. The filenames are defined using the format "Position_label_chi.mat." For example, "Position_label_ch2.mat" is the position matrix for the UAV nodes during communication channel 2, and the position matrix for the 4th set of trajectory points is shown in Figure 3-3.

```
val(:,:,4) =

  414.9561  528.0384  384.0621
  313.5339  661.9706  296.3933
  399.8709  501.1413  506.8998
  277.6640  673.6065  323.3161
  359.2461  448.4367  509.7441
  272.1310  684.9726  539.1770
  305.6750  413.2833  488.0379
```

Figure 3-4. Position matrix of the 4th set of trajectory points during communication channel 2.

4 Technical Validation

The “Technical_validation” folder contains the technical validation results of the dataset, mainly including two parts: range error estimation and positioning error estimation. The “Range_error” subfolder contains range error estimates from two specific environments, with each environment folder respectively including LOS error estimates and NLOS error estimates, and presenting histograms of range error under different measurement channels. The “Position_error” subfolder contains positioning error estimates for two specific environments, with the positioning error estimation results for different swarm formation flight types in these two environments stored within.

Distance error analysis is conducted for both indoor and outdoor environments based on actual measurement conditions. Experiments are carried out separately for LOS and NLOS situations according to signal propagation characteristics. Taking the LOS scenario in an indoor environment as an example, the experiment set up seven test distances: 3.0 m, 6.0 m, 9.0 m, 12.0 m, 15.0 m, 18.0 m, and 21.0 m. Two UWB nodes were used for ranging, with one being a fixed node and the other a mobile node. A laser rangefinder was used to ensure the actual physical distance between the two nodes. By placing the mobile node at different distances, UWB ranging results at various distances were obtained. The difference between the measured distance and the physical distance was saved and analyzed as the ranging error. This process was executed sequentially in four system measurement channels. In the NLOS situation, a wooden cube with a side length of 1.0m was placed between the fixed node and the mobile node. The surface and inside of the cube contained irregular metal sheets, and the same measurement process as described above was carried out. The same approach was used for estimating the ranging error in outdoor environments. It should be noted that during the construction of the dataset, UWB ranging errors were not used to process the experimental data, with the aim of preserving the original flight ranging data. The dataset is also available for scholars engaged in error analysis.

5 Code

The “Code” folder contains all the code and functions for the entire process of data measurement and subsequent processing, divided into two parts according to the measurement environments “Environment0” and “Environment1”. Within the subfolders “Flying_straight” and “Flying_climb” under “Environment0”, each subfolder includes code for data frame reception, data preprocessing, data parsing, range error analysis, range error compensation, positioning solution calculation, positioning error analysis, and data saving.

Each code file contains detailed explanations and annotations. To use, simply run the “Main.m” file. The same applies to the “Environment1” folder.