Tian-miao WANG, Yi-cheng ZHANG, Jian-hong LIANG, Yang CHEN, Chao-lei WANG, 2020. Multi-UAV collaborative system with a feature fast matching algorithm. *Front Inform Technol Electron Eng,* 21(12):1695-1712. https://doi.org/10.1631/FITEE.2000047

Multi-UAV collaborative system with a feature fast matching algorithm

Key words: Multiple UAVs; Collaboration; Simultaneous localization and mapping (SLAM); Feature description and matching

Corresponding author: Yi-cheng ZHANG
E-mail: zycet@126.com
ORCID: https://orcid.org/0000-0003-3643-9384

Motivation

1. A single UAV faces great limitations when performing practical missions. Thus, the collaboration of multiple UAVs is increasingly demanded.

2. Under most circumstances, UAV collaboration relies on the Global Navigation Satellite System (GNSS). Nevertheless there are several obvious limitations and disadvantages.

Main idea

1. We propose an innovative feature point description and matching algorithm named “fast matching feature” (FMF). It reduces the matching time complexity for large-scale data from $O(\log N)$ to $O(1)$.

2. Based on FMF, we describe a real-time monocular simultaneous localization and mapping (SLAM) system with a new distributed structure for a multi-UAV collaboration task.

Method

The FMF is based on the speeded up robust feature (SURF) feature vectors and the principal ideas of Hash and principal component analysis (PCA).

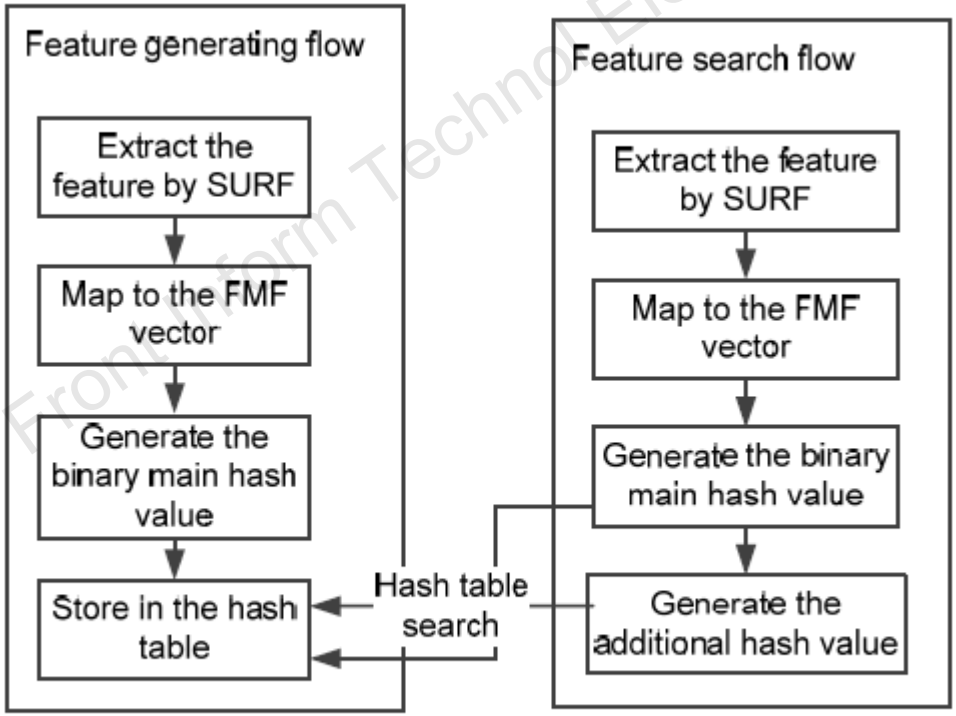

Fig. 4 FMF algorithm process flow

Method

In this SLAM framework, each vehicle transmits the feature vector extracted from the image to the independent back-end module of each vehicle. Every vehicle completes the building and update of its own map, and realizes the localization in its own map. This position relationship is referred to as vehicle-to-map for simplification.

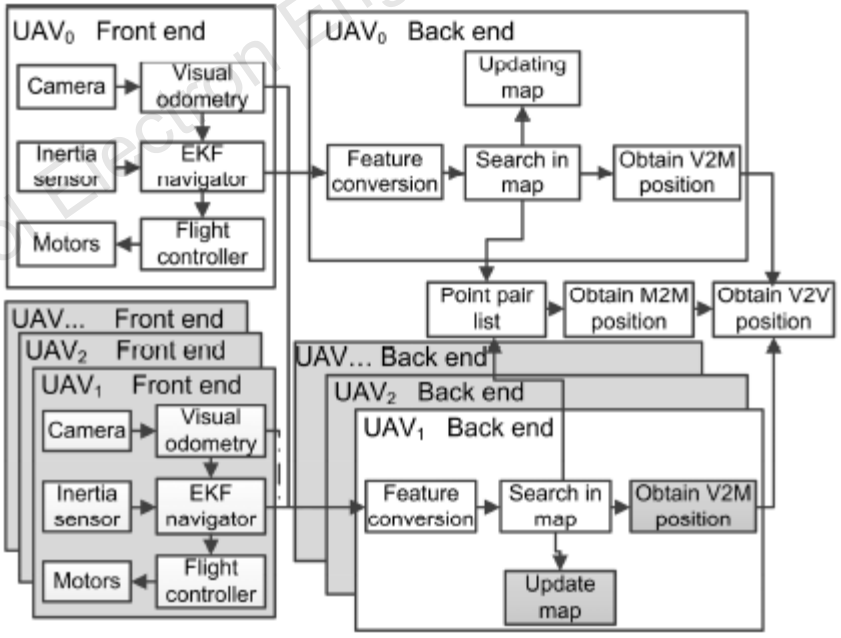

Fig. 13 Front- and back-end algorithm framework of multi-UAV SLAM

Major results

FMF vs. SURF on the MVS dataset

Table 1 Correct rates of different algorithms with different parameters

Algorithm		Correct rate
SURF		82.21%
FMF	N=0	55.67%
	N=4	63.32%
	N=6	67.89%
	N=8	72.79%

Table 2 Area under the curve (AUC) of different algorithms with different values of N

Algorithm		AUC
SURF		0.9009
FMF	N=0	0.7752
	N=4	0.8122
	N=6	0.8320
	N=8	0.8551

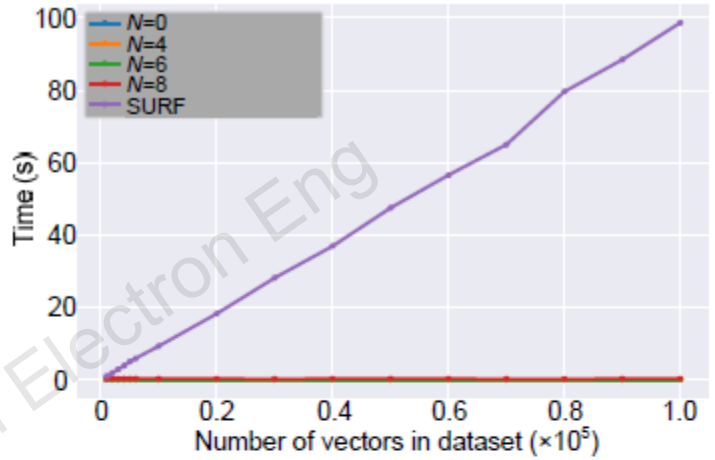

Fig. 9 Matching time of datasets with different scales
Curves of the FMF algorithm are overlapped

Fig. 10 Matching time of the FMF algorithm with different values of N on datasets with different scales

Major results

Simulated flight state of our SLAM framework

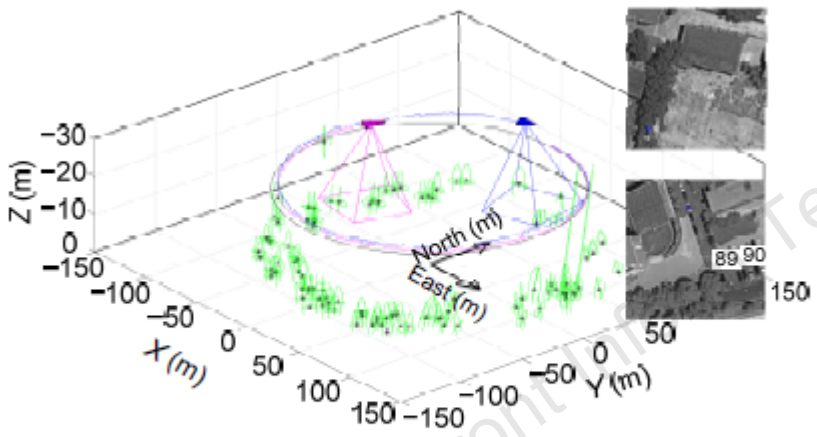

Fig. 16 Three-dimensional flight state of multi-UAV SLAM simulation (References to color refer to the online version of this figure)

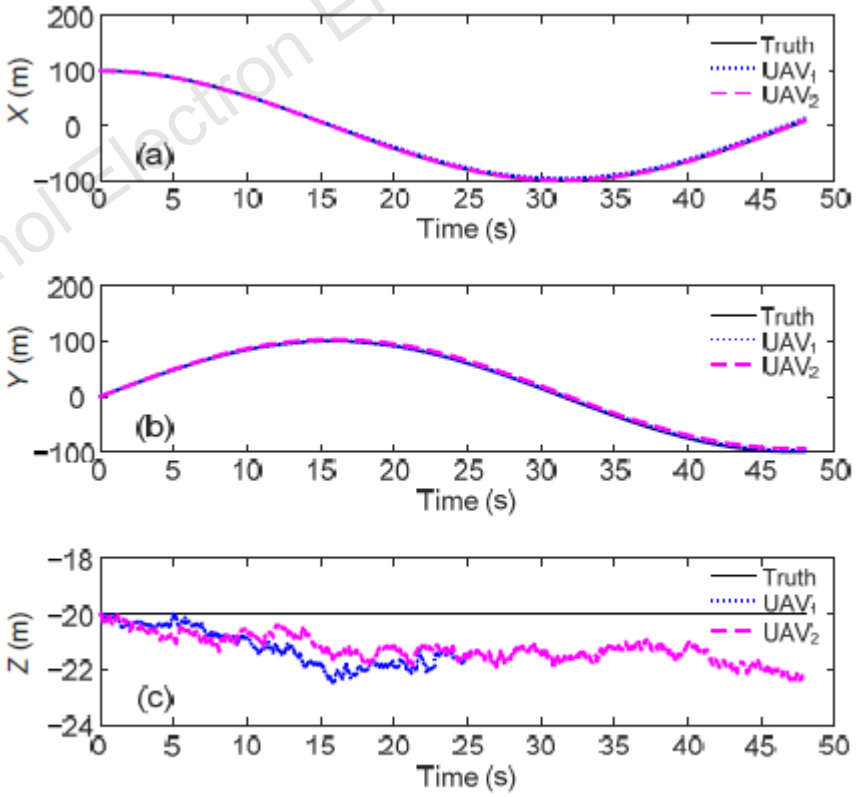

Fig. 17 Position curves of the vehicles: (a) X; (b) Y; (c) Z

Conclusions

1. The calculation costs of the feature vector transformation and Hash value generation are low, and the time complexity of matching is $O(1)$ (almost irrelevant to the data scale). Thus, the FMF algorithm is suitable for the large-data environment.

2. Even though the correct matching rate is lower than that of the SURF algorithm, considering that the RANSAC algorithm is applied to motion estimation, a lot of mismatches do not have marked influence on the overall function.

3. We have constructed an innovative multi-UAV SLAM framework based on FMF, and emphasized optimization of real-time multi-UAV collaboration without establishing a complete global map. Specifically, we have solved the problem of low computing efficiency as the data scale grows in the traditional SLAM algorithm. In addition, it is superior in terms of both low sensor cost and limited dependence on the environment. Finally, the simulation and real flight experiments have verified the feasibility of the FMF algorithm and this framework.