# Response to Reviewers’ Comments

We would like to thank the editor and four reviewers for their valuable comments and suggestions. The comments and suggestions have significantly helped improve the quality of this manuscript. All the reviewer’s comments are fully addressed in the new manuscript. Especially, we have combined two submitted files (the main manuscript and the supplemental material) into a single one for the purpose of completeness. We also emphasize the novelty and contribution of this work in the introduction. In the experiment section, we add a comparison between the proposed approach and other existing methods to demonstrate the effectiveness of our approach. We have also revised the manuscript to improve its clarity and conciseness. The revisions are highlighted by the orange color texts in the revised manuscript. The following paragraphs detail our responses to each reviewer’s comments.

# Reviewer #1

**The topics is interesting, but I have some problems to discuss with the authors.**

1. **What is the novelty of the paper? Please specify in the paper.**

**Response:**

The authors would like to thank the reviewer for this important comment. The previous version of the paper has obscured the novelty and contribution of our work. In the revised version, we have added certain sentences to emphasize on the contribution and new features of the proposed distributed Bayesian filter. Here, we’d like to include a paragraph for your convenience.

“*In this work, we propose a novel measurement dissemination-based distributed Bayesian filtering approach for target localization using networked UGVs. We make the following contributions in this paper: (a) Different from existing works that assume full connectivity of the communication topology, each UGV only needs to broadcast the sensor measurements to its neighbors via single hopping and then implements individual Bayesian filter locally using its own measurements and the ones transmitted from neighbors. (b) We introduce the Latest-In-and-Full-Out (LIFO) protocol to reduce the communication burden, with the transmission data scaling linearly with the UGV number. (c) The proposed LIFO-based DBF has the following properties: (c.1) For a fixed and undirected network, LIFO guarantees the global dissemination of measurements over the network in a non-intermittent manner. (c.2) The corresponding DBF ensures the consistency of estimated target position, i.e., the estimate converges in probability to the true value when the number of measurements tends to infinity.*”

1. **Whether the length of paper could be shorten or not? In this case, a part of supplementary material could be added in the paper considering the supplementary material could not be read by readers.**

**Response:**

The authors would like to thank the reviewer for the suggestion. We have incorporated the supplementary material into the paper as the section V as the reviewer suggested.

1. **Whether the definition of several typical sensors on page 2 can be reduced or not?**

**Response:**

Thank you for the suggestion. We have trimmed unnecessary sentences in the definition of these typical sensors while maintaining the core parts. Please refer to section II.A for the updated version.

1. **Please specify the measurement issue existed in the measurement for networked unmanned vehicles.**

**Response:**

Don’t understand what the problem is.

# Reviewer #2

**The paper is well written and its objective is clearly presented. However, the originality of the paper needs to be further clarified.**

**Response:**

The authors would like to thank the reviewer for this important comment. The previous version of the paper has obscured the novelty and contribution of our work. In the revised version, we have added certain sentences to emphasize on the contribution and new features of the proposed distributed Bayesian filter. Here, we’d like to include a paragraph for your convenience.

“*In this work, we propose a novel measurement dissemination-based distributed Bayesian filtering approach for target localization using networked UGVs. We make the following contributions in this paper: (a) Different from existing works that assume full connectivity of the communication topology, each UGV only needs to broadcast the sensor measurements to its neighbors via single hopping and then implements individual Bayesian filter locally using its own measurements and the ones transmitted from neighbors. (b) We introduce the Latest-In-and-Full-Out (LIFO) protocol to reduce the communication burden, with the transmission data scaling linearly with the UGV number. (c) The proposed LIFO-based DBF has the following properties: (c.1) For a fixed and undirected network, LIFO guarantees the global dissemination of measurements over the network in a non-intermittent manner. (c.2) The corresponding DBF ensures the consistency of estimated target position, i.e., the estimate converges in probability to the true value when the number of measurements tends to infinity.*”

1. **Please do not use abbreviation in title.**

**Response:**

Thank you for this critical comment. We have changed our title to remove the abbreviation. The new title is “*Measurement Dissemination-based Distributed Bayesian Filter using the Latest-In-and-Full-Out Exchange Protocol for Networked Unmanned Vehicles*”.

1. **Please give the Index terms after abstract part.**

**Response:**

Thank you for this important comment. We have added the following Index terms after the abstract part: “*Bayesian filter, Multi-robot systems, Nonlinear filter, Unmanned vehicles*.”

1. **In the section V, experiment is not demonstrated clearly, especially how the method the authors proposed is verified.**

**Response:**

We appreciate the reviewer for this comment. In the previous version of the paper, we did not clearly present the procedure of the experiment. Our analysis of the experiment results was also insufficient. In the revised version of the paper, we provide more complete description of the experiment and add a new experiment result that compares our approach (LIFO-DBF) with two other methods (the centralized filter and the consensus-based filter). Please refer to section VI for the updated experiment section. Especially, we have added the following sentences to illustrate the effectiveness of the proposed approach:

“*Similar to previous simulations, we compare our method with CbDF and CF. All three approaches achieve accurate position estimation. However, they differ in the uncertainty reduction, as shown in Figure 9f. The CF has the fastest entropy reduction and the LIFO-DBF achieves comparable performance, while the CbDF shows the slowest entropy reduction*.”

1. **Please explain how the distributed Bayesian filter can be used in real world.**

**Response:**

The authors would like to thank the reviewer for this important comment. We realize that, in spite that we showed the use of the distributed Bayesian filter for target localization in both the simulation and experiment, we did not discuss about some efficient numerical implementation alternatives to the histogram filter that we used in the paper. We also did not provide examples of the potential applications of this approach. So in the revised paper, we added several sentences in section VII. We include them here for your reference:

“*The LIFO-DBF is promising for a wide range of applications using multiple robots, such as the environment monitoring, precision farming, and vehicle localization and mapping*.”

“*LIFO-DBF provides a general framework for distributed nonlinear filtering. In our future work, we plan to develop computationally efficient implementation of LIFO-DBF by using particle filters and Unscented Kalman filters*.”

# Reviewer #3

**The proposed method is clearly elucidated with rigorous mathematics. Some experimental results are given. The following comments must be addressed before its final acceptance.**

1. **Please avoid abbreviations in the title.**

**Response:**

Thank you for this critical comment. We have changed our title to remove the abbreviation. The new title is “*Measurement Dissemination-based Distributed Bayesian Filter using the Latest-In-and-Full-Out Exchange Protocol for Networked Unmanned Vehicles*”.

1. **The novelty and contributions could be more explicit in the introduction section.**

**Response:**

The authors would like to thank the reviewer for this important comment. The previous version of the paper has obscured the novelty and contribution of our work. In the revised version, we have added certain sentences to emphasize on the contribution and new features of the proposed distributed Bayesian filter. Here, we’d like to include a paragraph for your convenience.

“*In this work, we propose a novel measurement dissemination-based distributed Bayesian filtering approach for target localization using networked UGVs. We make the following contributions in this paper: (a) Different from existing works that assume full connectivity of the communication topology, each UGV only needs to broadcast the sensor measurements to its neighbors via single hopping and then implements individual Bayesian filter locally using its own measurements and the ones transmitted from neighbors. (b) We introduce the Latest-In-and-Full-Out (LIFO) protocol to reduce the communication burden, with the transmission data scaling linearly with the UGV number. (c) The proposed LIFO-based DBF has the following properties: (c.1) For a fixed and undirected network, LIFO guarantees the global dissemination of measurements over the network in a non-intermittent manner. (c.2) The corresponding DBF ensures the consistency of estimated target position, i.e., the estimate converges in probability to the true value when the number of measurements tends to infinity.*”

1. **In my mind. the analysis results should be richer, in addition to the only Fig. 5. How about a comparison with other existing methods?**

**Response:**

We appreciate the reviewer for this important comment. In the previous version of the paper, the analysis of the experiment results was insufficient. In the revised version of the paper, as the reviewer suggested, we add a new experiment result that compares our approach (LIFO-DBF) with two other methods (the centralized filter and the consensus-based filter). Please refer to section VI for the updated experiment section. Especially, we have added the following sentences to illustrate the effectiveness of the proposed approach:

“*Similar to previous simulations, we compare our method with CbDF and CF. All three approaches achieve accurate position estimation. However, they differ in the uncertainty reduction, as shown in Figure 9f. The CF has the fastest entropy reduction and the LIFO-DBF achieves comparable performance, while the CbDF shows the slowest entropy reduction*.”

1. **A hint on likely future work is welcome.**

**Response:**

Thank you for this suggestion. We have added more contents to delineate our future work in section VII. Here we would like to include a paragraph for your convenience.

“*This work has opened up several directions for future work. First, when the communication network between UGVs is dynamically changing due to limited communication range or packet loss, current LIFO-DBF needs to be improved to ensure the consistency of estimation results. Second, LIFODBF provides a general framework for distributed nonlinear filtering. In our future work, we plan to develop computationally efficient implementation of LIFO-DBF by using particle filters and Unscented Kalman filters. Lastly, we will combine the distributed filtering with path planning approaches [34] so that multiple robots can actively localize and track targets, which can be applied to search and rescue and the navigation of autonomous vehicles*.”

# Reviewer #4

**This paper is well written. The reviewer suggests to further highlight the main contributions of this work.**

**Response**:

The authors would like to thank the reviewer’s support. Some revisions have been made to highlight the main contribution of the work. Here, we’d like to include a paragraph for your convenience.

“*In this work, we propose a novel measurement dissemination-based distributed Bayesian filtering approach for target localization using networked UGVs. We make the following contributions in this paper: (a) Different from existing works that assume full connectivity of the communication topology, each UGV only needs to broadcast the sensor measurements to its neighbors via single hopping and then implements individual Bayesian filter locally using its own measurements and the ones transmitted from neighbors. (b) We introduce the Latest-In-and-Full-Out (LIFO) protocol to reduce the communication burden, with the transmission data scaling linearly with the UGV number. (c) The proposed LIFO-based DBF has the following properties: (c.1) For a fixed and undirected network, LIFO guarantees the global dissemination of measurements over the network in a non-intermittent manner. (c.2) The corresponding DBF ensures the consistency of estimated target position, i.e., the estimate converges in probability to the true value when the number of measurements tends to infinity.*”