# Response to Decision Letter

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 reviewers’ comments are fully addressed in the new manuscript. The revisions are highlighted by the texts in orange color in the revised manuscript. The following paragraphs summarize our responses to reviewer’s comments. A more detailed response is uploaded along with the revised manuscript.

**Novelty and contribution of the paper**

**Response:** The previous version of the paper obscures the novelty and contribution of our work. In the revised version, we have emphasized the contribution and features of the proposed distributed Bayesian filter. The contributions include (a) Different from existing works that assume full connectivity of the communication topology, in our work, 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: For a fixed and undirected network, LIFO guarantees the global dissemination of measurements over the network in a non-intermittent manner. 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.

**Experiment procedure and results**

**Response:** 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 paper, we provide more complete description of the experiment and add a new experiment result that compares our approach (LIFO-DBF) with two other commonly used methods (the centralized filter and the consensus-based filter). Please refer to section VI for the updated experiment section.

**Combining the manuscript with the supplementary material. Remove unnecessary contents.**

**Response:** We have added the supplementary material to the paper (section V) as the reviewer suggested. We have also 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.

**Remove abbreviation in title.**

**Response:**

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*”.

**Index terms after abstract part.**

**Response:**

We have added the following Index terms after the abstract part: “*Bayesian filter, Distributed estimation, Networked vehicles, Nonlinear filter, Unmanned vehicles.*”

**Measurement issue existed in the measurement for networked unmanned vehicles.**

**Response:** the measurement issues mainly come from the sensors and the communication network of networked unmanned vehicles. For the sensors, the measurement noise, biasness, and measurement quantization can affect the performance of sensors. For the communication network, the common issues include the asynchrony of the clock, the transmission delay, the changing network, and the packet loss.

**The application of distributed Bayesian filter in real world.**

**Response:**

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 the 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.

**Future work**

**Response:**

We have added contents to delineate our future work in section VII. First, we plan to extend the current LIFO-DBF to deal with some common issues in the measurement for networked unmanned vehicles, such as the asynchronous clock, communication delay, dynamically changing network, and packet loss. Besides, we will 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 so that multiple robots can actively localize and track targets, which can be applied to search and rescue and the navigation of autonomous vehicles.

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 reviewers’ comments are fully addressed in the new manuscript. The revisions are highlighted by the texts in orange color in the revised manuscript. The following paragraphs summarize our responses to reviewer’s comments. A more detailed response is uploaded along with the revised manuscript.

**Novelty and contribution of the paper**

**Response:** The previous version of the paper obscures the novelty and contribution of our work. In the revised version, we have emphasized the contribution and 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. The main contributions of this paper include: (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: For a fixed and undirected network, LIFO guarantees the global dissemination of measurements over the network in a non-intermittent manner. 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.*”

**Experiment procedure and results**

**Response:** 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 paper, we provide more complete description of the experiment and add a new experiment result that compares our approach (LIFO-DBF) with two other commonly used methods (the centralized filter and the consensus-based filter). Please refer to section VI for the updated experiment section.

We have added the following sentences to explain the experiment procedure:

*“Each robot is equipped with an onboard sonar sensor to measure the target (a small cardboard box) position.”*

*“The robots locally run the LIFO-DBF to estimate the target position. Each robot’s probability map is constructed on an evenly spaced grid with 0:1m interval on each axis. In the experiment, robots move to different locations to measure the target position. We manually measure the robot positions where the sensor measurements are obtained to reduce the effects of localization error.”*

We have added the following sentences to illustrate the effectiveness of the proposed approach in the revised paper:

*“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*. *These experiment results validate the consistency of LIFO-DBF and demonstrate its effectiveness for distributed filtering.”*

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**Measurement issue existed in the measurement for networked unmanned vehicles.**

**Response:** the measurement issues mainly come from the sensors and the communication network of networked unmanned vehicles. For the sensors, the measurement noise, biasness, and measurement quantization can affect the performance of sensors. For the communication network, the common issues include the asynchrony of the clock, the transmission delay, the changing network, and the packet loss. In the revised paper, we have mentioned some of these issues to be considered in our future work:

*“We plan to extend the current LIFO-DBF to deal with some common issues in the measurement for networked unmanned vehicles, including the asynchronous clock, communication delay, dynamically changing network, and packet loss.”*

**The application of distributed Bayesian filter in real world.**

**Response:**

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 the 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*.*”*

*“Second, 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. 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.”*

**Future work**

**Response:**

We have added 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, we plan to extend the current LIFO-DBF to deal with some common issues in the measurement for networked unmanned vehicles, including the asynchronous clock, communication delay, dynamically changing network, and packet loss. Second, LIFO-DBF provides a general framework for distributed nonlinear filtering. In our future work, we will 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.”*