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Submission Title: [IG DEP Localization of Implanted Devices Combining TDOA, Particle Filter and Map Mapping with WBAN]

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Abstract: [A important use case of dependable body area network(WBAN) for implanted devices is introduce to perform accurate localization of implantable devices such as implanted capsule endoscope in small intestine in presence of strong absorption inside a body..]

Purpose: [information]

Localization of Implanted Devices Combining TDOA, Particle Filter and Map Mapping with WBAN

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1. Background

★Medical implanted devices
(e.g. capsule endoscopy)

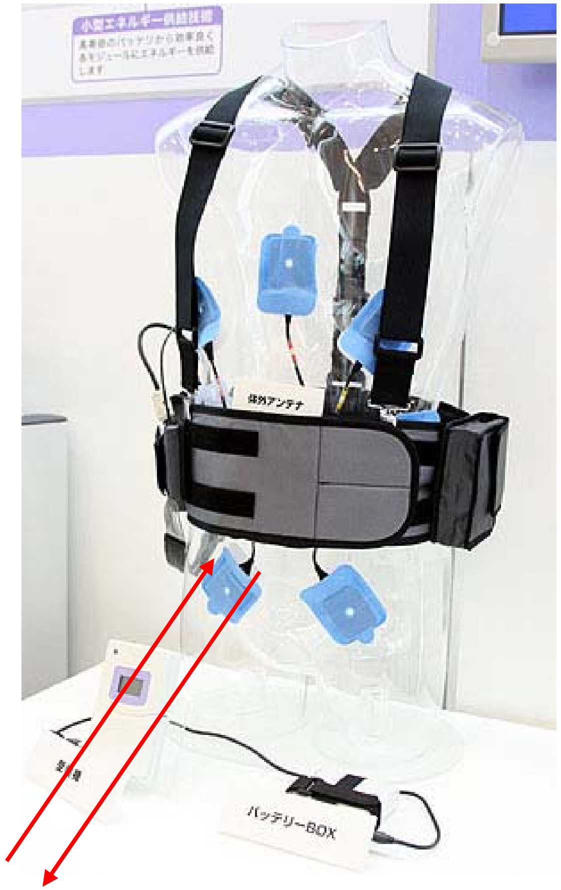
- It can reach the small intestine area unlike the conventional endoscopy
- Photograph the inside of the small intestine from the built-in camera

Adding location information

- Improvement of treatment efficiency
- Identification of abnormality in the body
- Control an implanted device remotely

Aiming at improving the accuracy of localization of the implanted device that moving in the small intestine

On body



In body

2. Localization Methods

Flowchart of localization

◆Flowchart of localization method

The basic principle is the same as car navigation.
Position information by TDOA is regarded as GPS position information, and images of the small intestine is regarded as a road map.

Start Localization

Create 2-dimensional map of small intestine using MRI or CT images

- Localization method combining particle filter and SLAM technology
- Localization method by TDOA using radio waves which emitted from implanted devices

- Correct using map matching method
- Image recognition for curve parts

Finish Localization

2. Localization Methods

Localization methods

In this research, two position estimation methods are combined.

- ・TDOA
- ・Particle Filter

⇒ Map matching with 2-dimensional map of small intestine

※TDOA (Time Difference of Arrival)

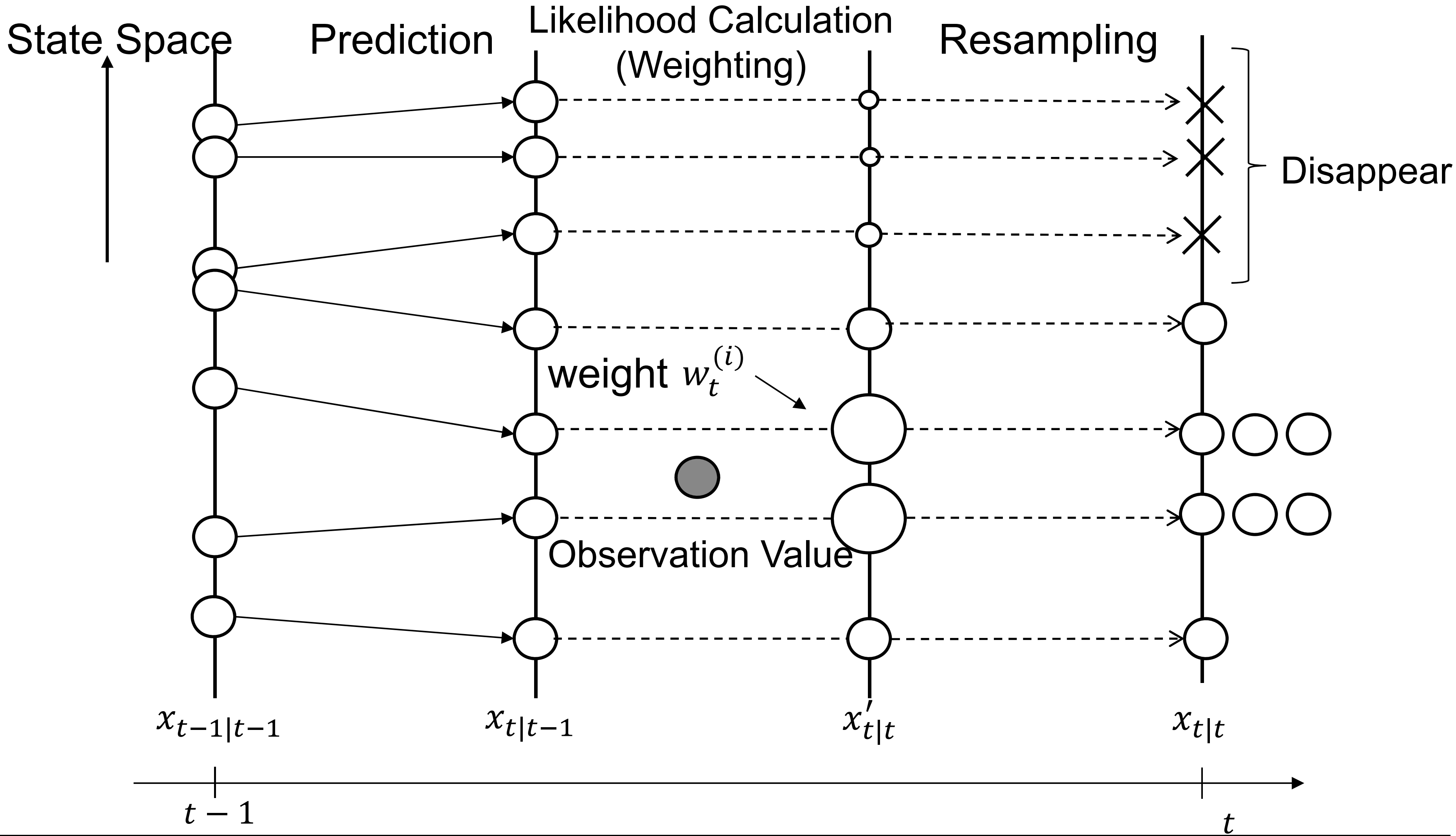
Localization method using signal reception time difference
Synchronization between anchor node and sensor node is unnecessary.

※Particle Filter

Express probability distribution as a collection of particles
A method for estimating states from observed data in nonlinear models

2. Localization Methods

Particle filter(PF)



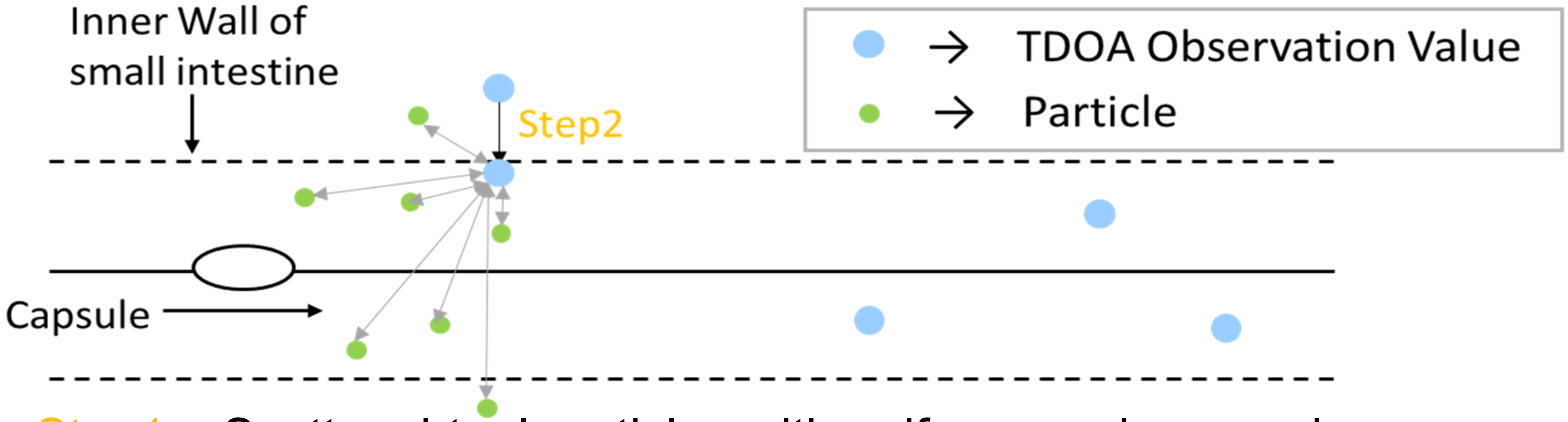
2. Localization Methods

How to combine TDOA and PF in previous research

Step1. Scatter virtual particles with uniform random number
Step2. Perform TDOA positioning by radio waves which emitted from capsule
Step3. Calculate the likelihood of virtual particles and TDOA observations
Step4. Resample based on likelihood
Step5. Calculate the average position of virtual particles after resampling
Step6. Return to Step3 using resampled virtual particles

2. Localization Methods

New method of combining TDOA and PF (Proposal1)



Step1. Scatter virtual particles with uniform random number
Step2. Perform TDOA positioning by radio waves which emitted by capsule

If TDOA observation value is outside small intestine, it is corrected
by map matching method on the inner wall of the small intestine

Step3. Calculate the likelihood of virtual particles and TDOA observations
Step4. Resample based on likelihood
Step5. Calculate the average position of virtual particles after resampling
Step6. Return to Step3 using resampled virtual particles

2. Localization Methods

The method of combining TDOA and PF (Proposal2)

Step1. Scatter virtual particles with uniform random number

Step2. Perform TDOA positioning by radio waves which emitted from capsule

Step3. The average position of the virtual particle group and the TDOA observed value are weighted by 2: 1 and averaged position is taken as a new observation value of TDOA and likelihood calculation

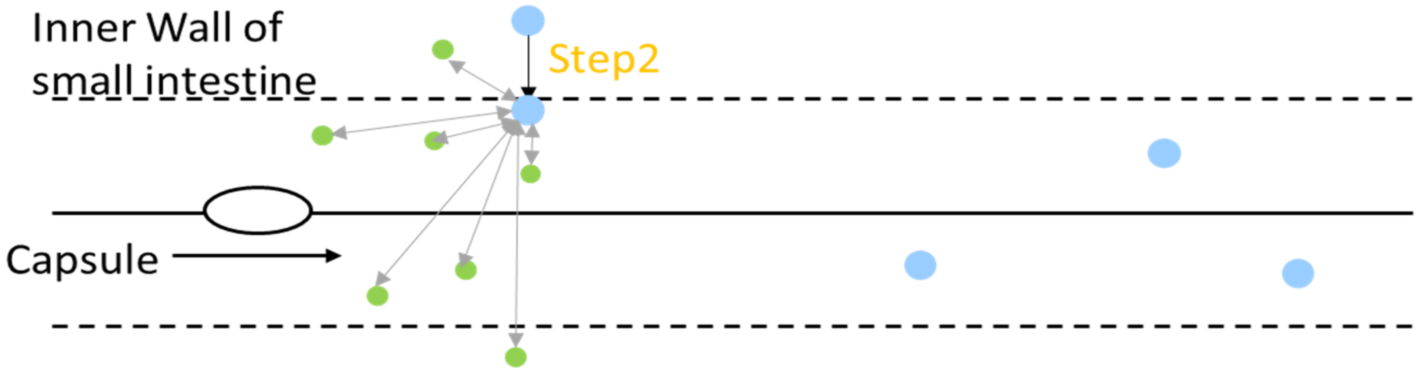
Step4. Resample based on likelihood

Step5. Calculate the average position of virtual particles after resampling

Step6. Return to Step4 using resampled virtual particles

2. Localization Methods

New method of combining TDOA/PF (Proposal3)



Step1. Scatter virtual particles with uniform random number

Step2. Perform TDOA positioning by radio waves which emitted by capsule

→ Map matching on the inner wall of the small intestine

Step3. The average position of the virtual particle group and the TDOA observed value are weighted by 2: 1 and averaged position is taken as a new observation value of TDOA and likelihood calculation

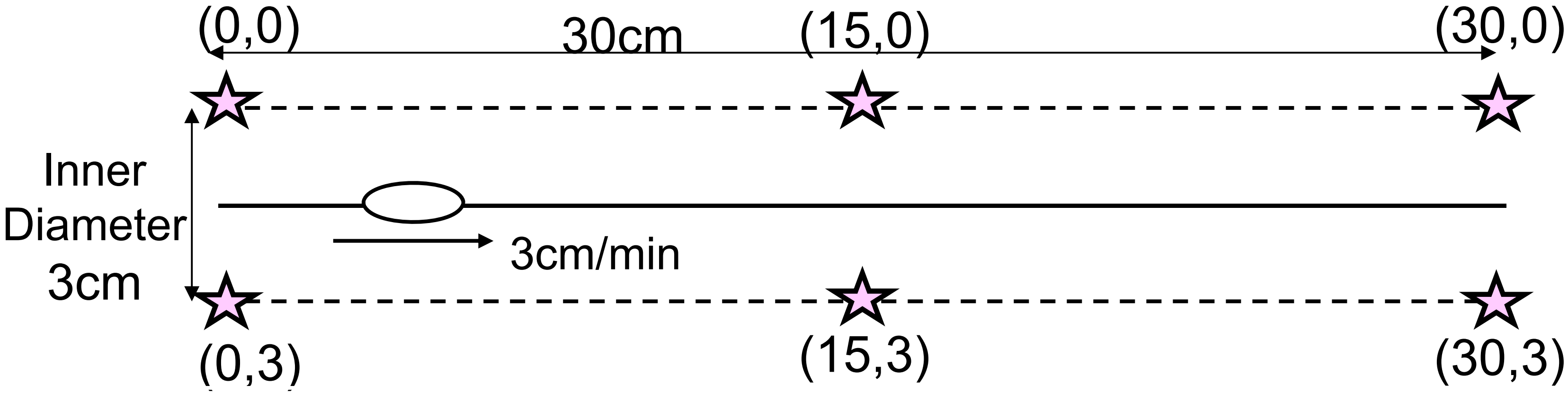
Step4. Resample based on likelihood

Step5. Calculate the average position of virtual particles after resampling

Step6. Return to Step4 using resampled virtual particles

3. Simulation

Simulation Environment



Conditions

・ The inner diameter of the small intestine is assumed to be 3 cm, and the width of the small intestine is assumed to be 30 cm.

・ The movement range of the small intestine is known from the image of the small intestine acquired in advance.

・ Capsule moves on straight line at constant speed.

・ There is no fluctuation in the movement of the capsule.

3. Simulation

Simulation Parameters

Table1. Simulation Parameters

The location of sensor nodes	Node1(0,0) Node2(15,0) Node3(30,0) Node4(0, 3) Node5(15,3) Node6(30,3)
Observation Noise	Average 4, Standard Deviation 2 (Normal Random Number)
System Noise	Average 2, Standard Deviation $\sqrt{2}$ (Normal Random Number)
The number of particles	100
The number of steps	1080
Moving speed of capsule	3[cm/min]
The initial position of capsule	(0 , 1.5)

3. Simulation

Simulation Result(1/2)

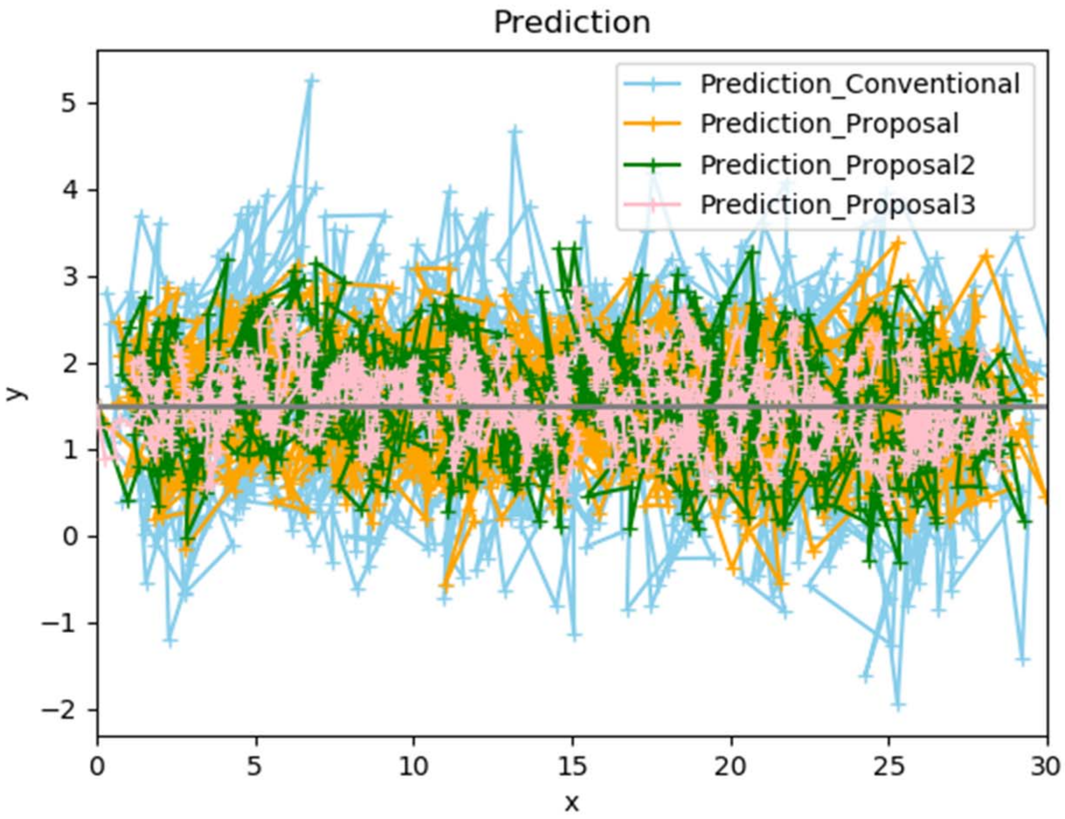


Fig.1 Transition of predicted value

Fig.1 shows the transition of the predicted value around y = 1.5 of the straight line in which capsule moves.

The proposed method has a smaller deviation from the center line of the capsule movement than the conventional method.

→Evaluation using variance value

3. Simulation

Simulation Result(2/2)

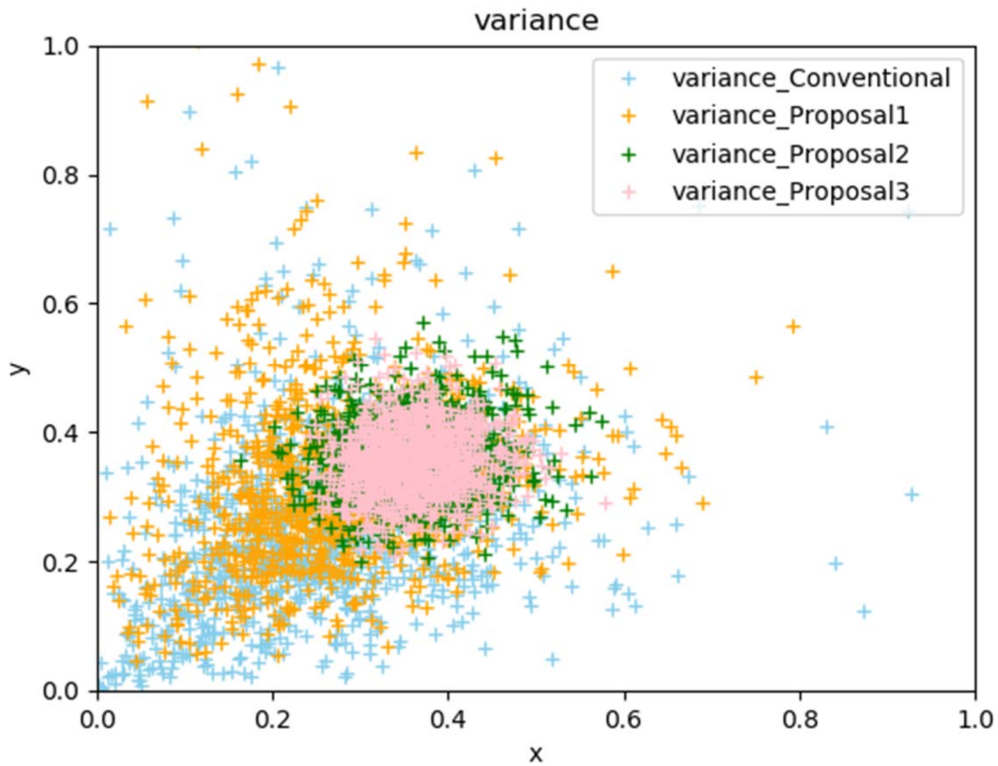


Fig.2 Variance of predicted value

Proposal 1
By limiting TDOA observation value to the range of the small intestine, the range in which particles are scattered is limited to perform likelihood calculation based on TDOA, and the dispersion becomes smaller.

Proposal2, Proposal3
The variance was reduced by averaging the dispersive values in the independent distribution.

4. Conclusion & Future Work

Conclusion

Considered the improvement of the position estimation accuracy by changing the combination of multiple localization methods.

Future Work

・ Change the number of sensor nodes to use

→Among TDOA observation points, if there are at least three observation points, it is possible to estimate the position. Thus, three observation points are combined to select an effective TDOA observation point.

・ Give the fluctuation to the small intestine map

→ Because the small intestine is moved by peristaltic movement, it is difficult to create the accurate map.

Thank you for your attention