Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Localization of Implanted Devices Combining TDOA, Particle Filter and Map Mapping with Intestine Modeling]

Date Submitted: [11 November 2019]

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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 Intestine Modeling

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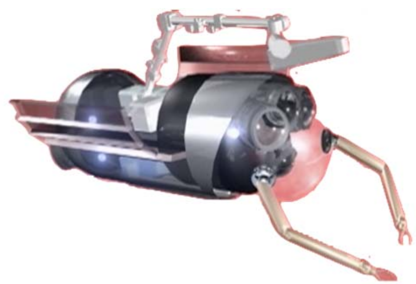
Chapter1　Background and Purpose

1.1 Background

Medical implanted device

- Pacemaker
  - Real-time monitoring of cardiac electrical signals
  - If necessary, send electrical stimulation to treat
- Capsule endoscopy
  - Unlike conventional endoscopes, it can reach the small intestine area
  - Capture internal video from the built-in camera

- Micro sensing robot
  - Move around the body while running independently
  - Remove abnormal part of the inner body



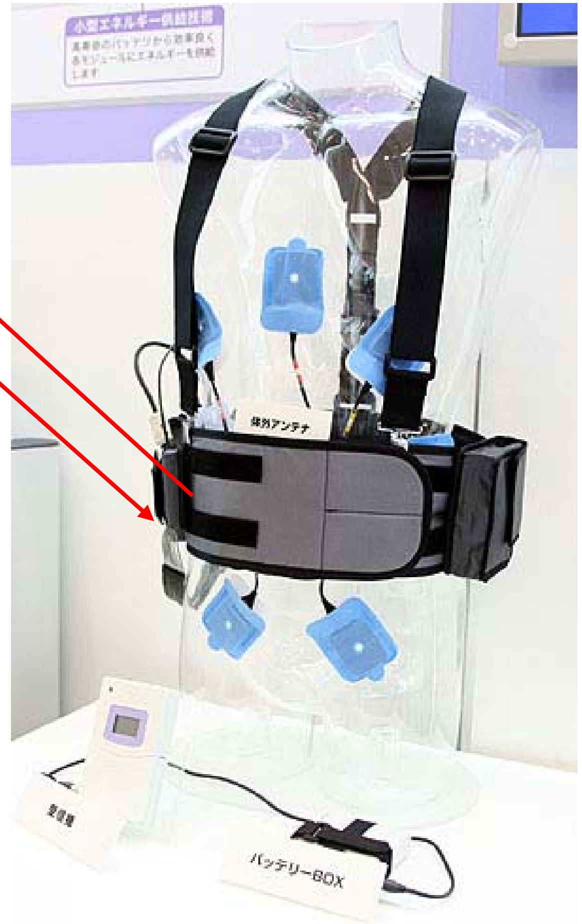
1.2 Aim of This Study

Medical implanted device
(e.g. Capsule endoscopy)

Adding location information

・Improve treatment efficiency
・Identify of abnormal sites in the body
・ Remote control of implant devices

Aim to improve the accuracy of localization of implanted device moving in the small intestine.



※OLYMPUS CAPSULE ENDOSCOPY

1.3 Localization method of implanted devices

- Particle Filter

  Merit It can handle nonlinear and non-Gaussian state space models.

  Demerit The amount of calculation increases in the order of O (M) in proportion to the number of particles.

- TDOA Localization method

  Merit No need to synchronize time between nodes

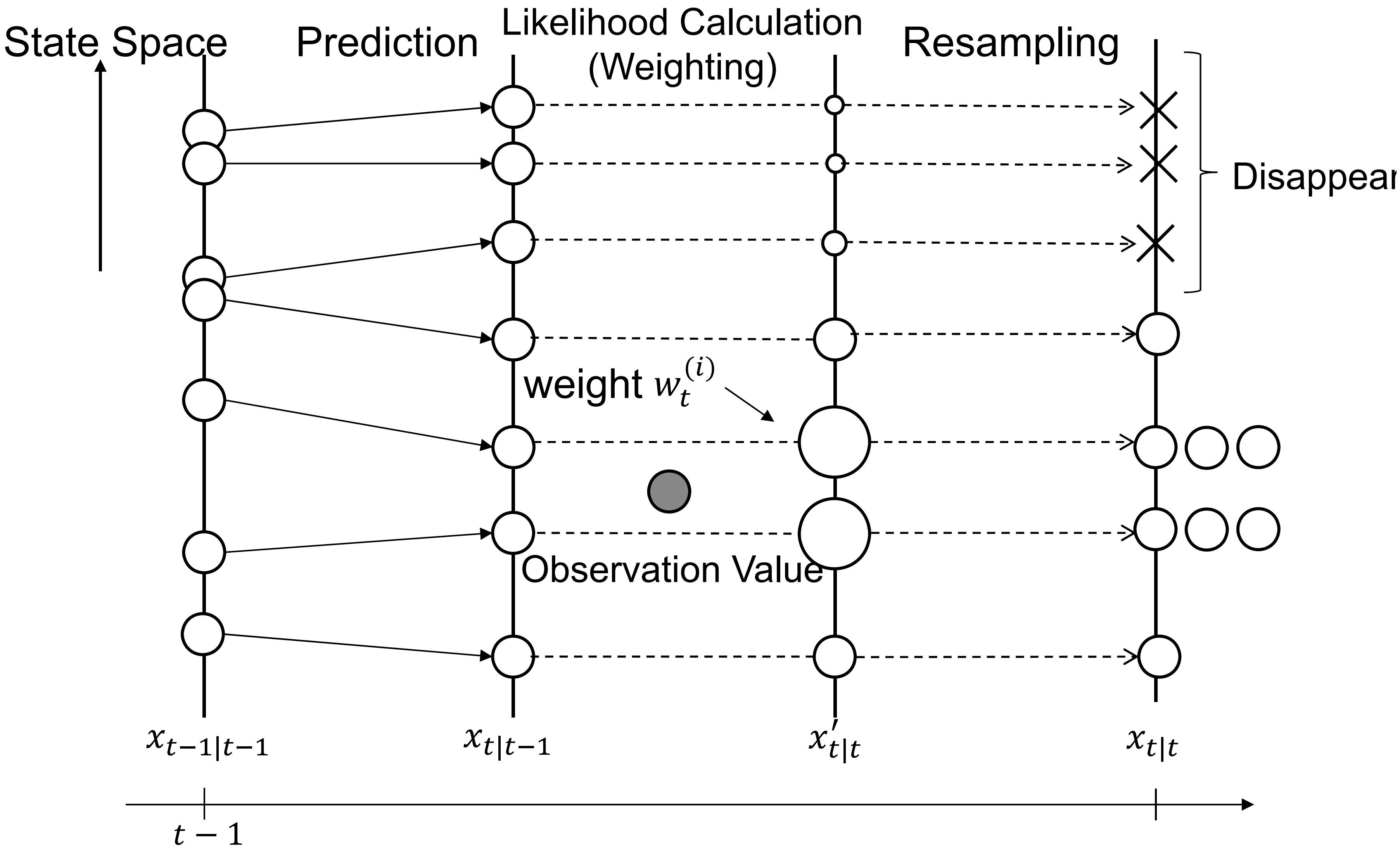
  Demerit The use of the arrival time difference may cause an error in time detection.

- Use of acquired images from MRI and CT (Map matching)

  Merit Since the position of the device can be determined from the imag the estimation accuracy is high.

  Demerit Real-time image acquisition is difficult and does not follow.

1.4 Particle Filter



Chapter2 Proposal method

2.1 Flowchart of localization

◆Localization image

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

- Localization method combining particle filter and TDOA
- Correction by map-matching method

When the implant device finished moving within a limited area in the small intestine

Finish Localization

2.2 Localization method

Localization method in this research

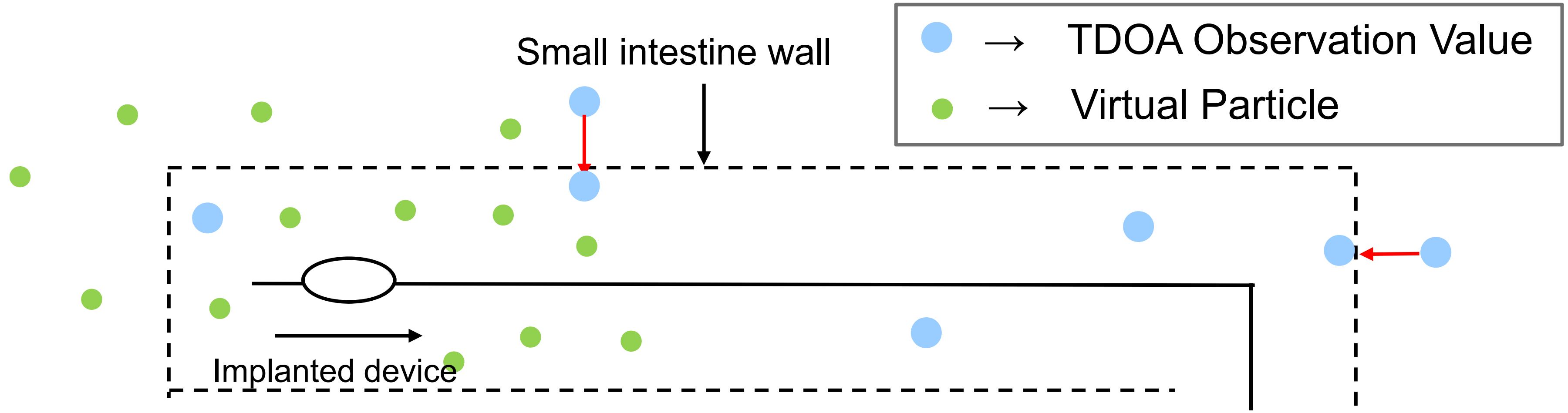
- Particle Filter
- TDOA

⇒ Use a small intestine image to correct points outside the small intestine wall.

Ratio of effect in TDOA + particle filter combination

	Ratio (TDOA)	Ratio (Particle Filter)
Particle Filter	0%	100%
TDOA	100%	0%
TDOA＋Particle Filter	50%	50%

2.3 How to combine TDOA and Particle Filter



1Step

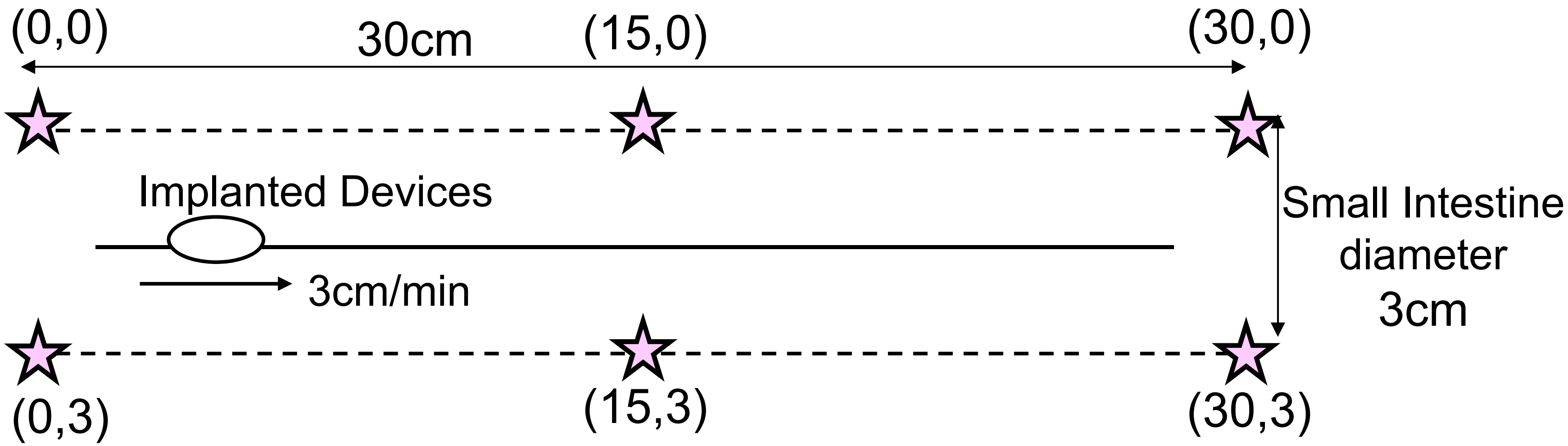
1. Scatter virtual particles with uniform random number
   Perform TDOA positioning by radio waves which emitted from capsule

(2. Map matching on the inner wall of the small intestine)

3. Weighted and averaged position of virtual particle group average position and TDOA observation value likelihood calculation as new observation value of TDOA
4. Resampling according to likelihood
5. Calculate the average position of virtual particles after resampling

Chapter3 Performance evaluation

3.1 Assumed 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.

3.2 Simulation Overview

Localization method

TDOA
Particle Filter(PF)
TDOA + Particle Filter

Mapmatching	Legend
Yes	Method1 (x1,y1)
No	Method2 (x2,y2)

Evaluation index

Localization value of implanted device at each step
(x-direction dispersion and
y-direction dispersion)

Parameter

- The number of particles
- Particle dispersion
- Ratio of effect in TDOA and particle filter

3.3 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	Standard deviation $\sigma = 5$ (Normal Random Number)
The number of steps	1080
Moving speed of capsule	3[cm/min]
The initial position of capsule	(0, 1.5)
Initial particle dispersion	Standard deviation $\sigma = 2$ (Normal Random Number)
Maximum weighted average ratio	10
Initial weighted average ratio	5 : 5

3.4 Change in the number of particles

When the number of particles is changed from 100 to 500

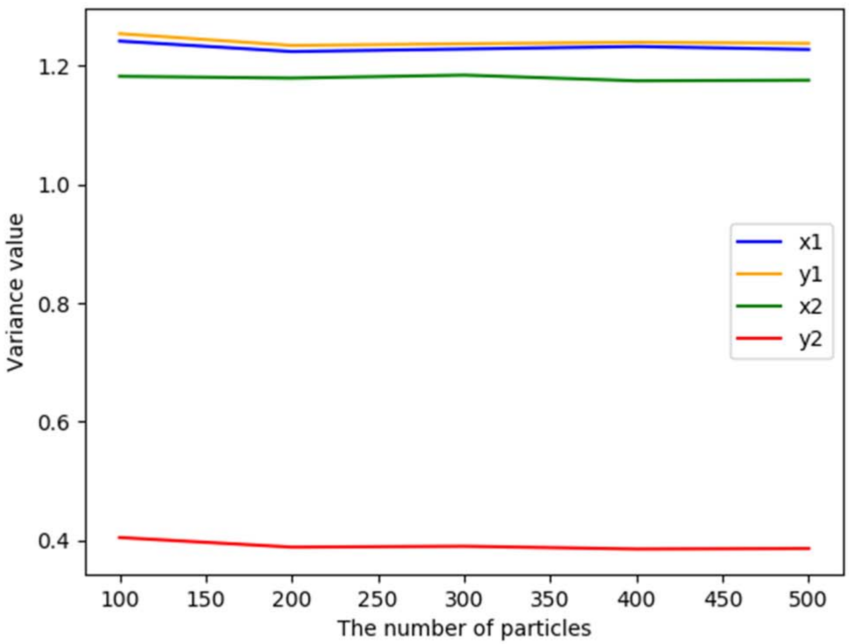


Fig.1 The number of particles (TDOA + Particle Filter)

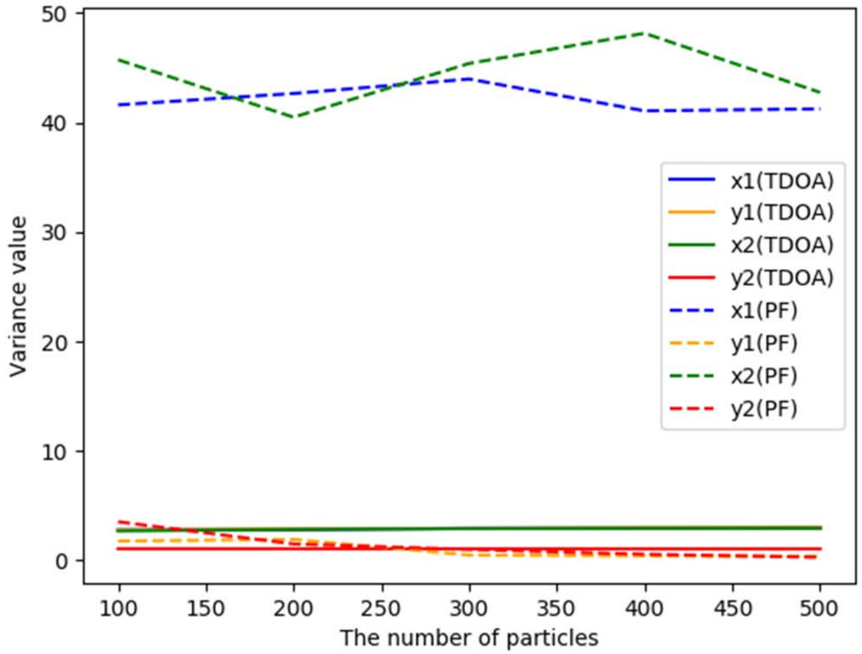


Fig.2 The number pf particles (TDOA / PF)

The dispersion value is smaller when TDOA and particle filter are combined.
When map matching is performed, the effect is remarkable in the y direction.

3.5 Change in the particle dispersion

When particle dispersion is changed from σ = 0 to σ = 20

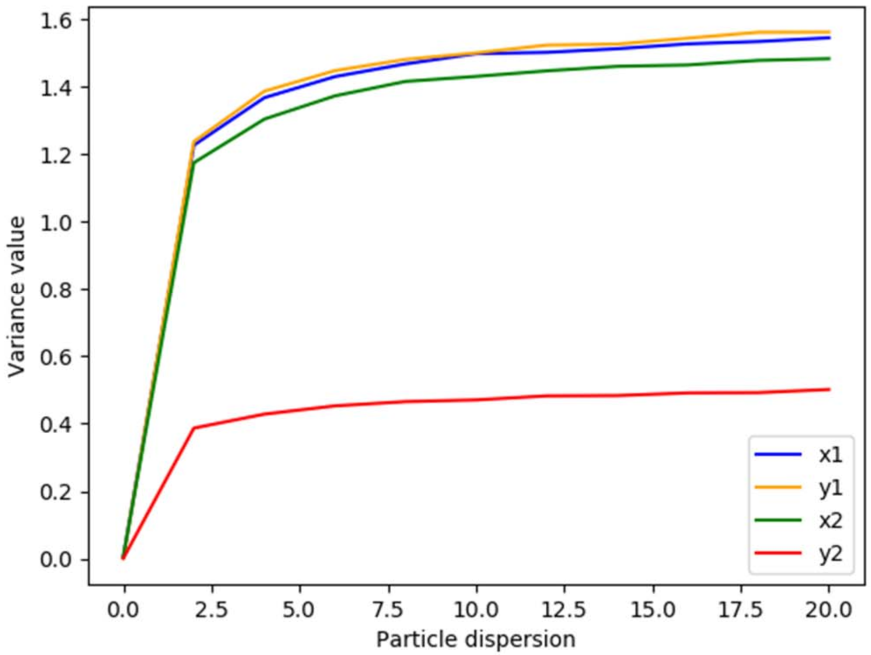


Fig.3 Particle dispersion (TDOA ＋ Particle Filter)

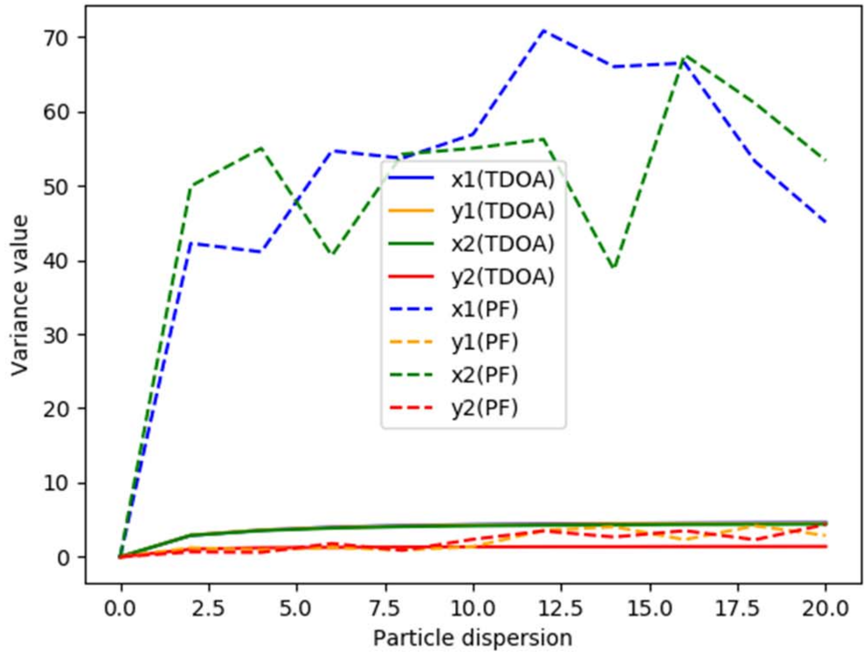


Fig.4 Particle dispersion (TDOA / PF)

The smaller the degree of particle dispersion, the higher the estimation accuracy.
The dispersion value is smaller when TDOA and particle filter are combined.

3.6 Change in localization method ratio

In order to show which method is more effective by TDOA or particle filter, the effect of particle filter in the whole simulation is expressed as a ratio.

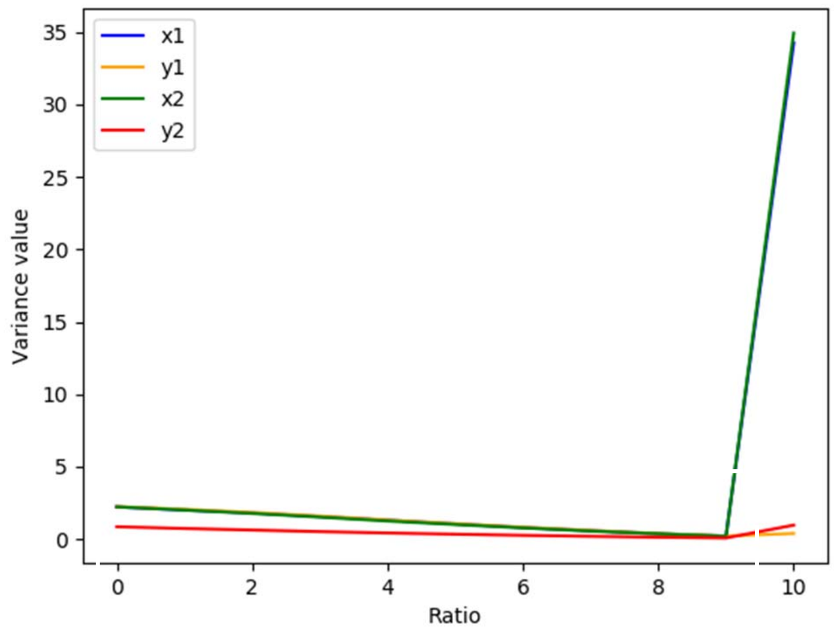


Fig.5 Localization method ratio (TDOA + Particle Filter)

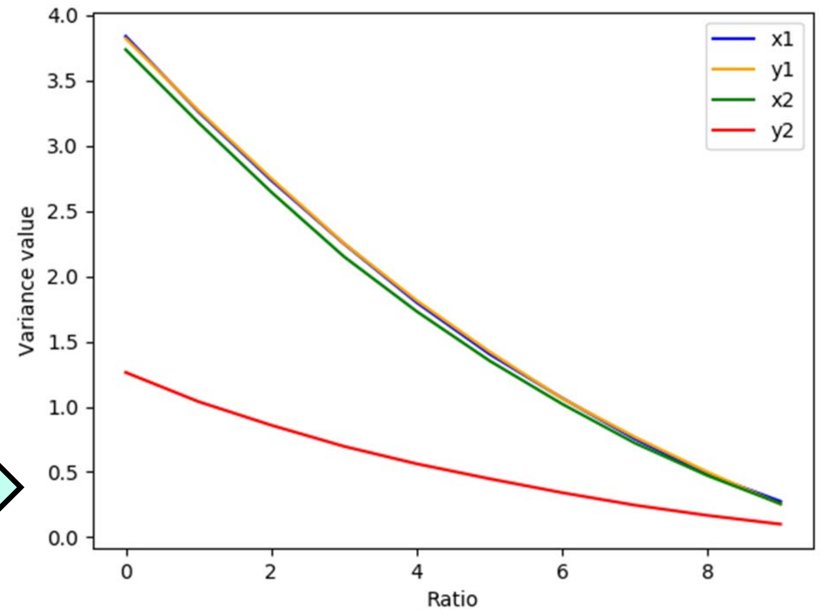


Fig.6 Localization method ratio (TDOA / PF)

The dispersion value is smaller when the effect of the particle filter is increased. By combining TDOA, higher accuracy is expected.

Chapter4 Conclusion & Future Works

4. Conclusion

Purpose

Improving the accuracy of position estimation for implantable devices moving inside the small intestine

⇒ A study on the combination of multiple location estimation methods

Proposal

Localization method combining TDOA, particle filter, and map matching

Evaluation results

Usefulness of position estimation method combining particle filter and TDOA.
Furthermore, the accuracy of localization is improved by adding map matching.

Future Works

- Localization considering the small intestine curve
- Localization in a model considering the peristaltic movement of small intestine
- Additional evaluation methods such as power consumption and calculation amount

Thank you for your attention!