Capsule Endoscopy Position Estimation Method Using RF Phase

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***Abstract*— This study proposes a method for estimating the position and rotation of the motorized capsule endoscope in real-time. We used the RF phase generated by the capsule endoscope to locate the lesion accurately. The antenna uses a signal in the 900Mhz band, and the position and rotation are estimated through the phase difference of 8 antennas. We acquired samples from the 9 points inside the antenna array and interpolated the data at intervals of 1cm to acquire a local-specific phase pattern map. As a result, the mean error between the estimated data and measured data was less than 2cm for the x and y axes, respectively, and less than 15° for the degree.**

***Keywords*— RF; Capsule endospcope; Localiztion**

I. INTRODUCTION

Capsule endoscopy is used to photograph the stomach, small and large intestine. It is less painful than a general endoscope and easy to observe the small intestine. The capsule endoscope currently in practical use is a model that has no way to move itself, moves only through the movement of the digestive system, and is discharged through bowel movements. For this reason, it has a long shooting time, it is impossible to stop and shoot at a specific location, and it is difficult to accurately determine the location of the lesion. So, motorized capsule endoscope is under development. Accordingly, methods of determining the position and rotation of the capsule endoscope are also being studied. Among them, Received Signal Strength Indication(RSSI)-based localization of capsule endoscope has a problem with a weak received signal and a high degree of distortion due to internal and external influences[1][2]. While, in phase-based localization, if the capsule endoscopy phase signal reaches the antenna array, the difference can be acquired easily, and the signal is also relatively stable.

II. METHOLOGY

A. Antenna array placement.

Since RF has a wavelength of 30cm in the 900MHz band, 8 antennas are arranged at a distance of 30cm in the direction facing each other, as in fig1, and phase difference data which has an interval of 45 degrees between one antenna and the next antenna is obtained in a counterclockwise direction. The acquired data were $3 \times 3 \times 8$ data, and measured by rotating the capsule endoscope module by 45 degrees at a total of 9 points with an interval of 7.5cm from the center and the center.

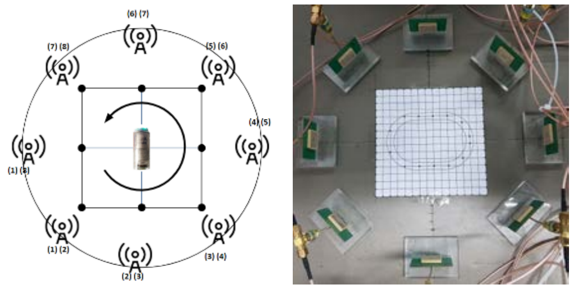

Fig. 1. Antenna array placement

B. Acquisition of the location-specific patterns.

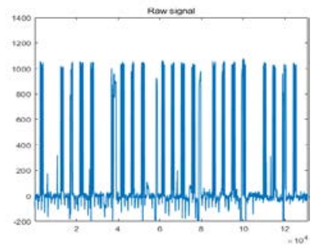

Fig. 2. a. Raw signal

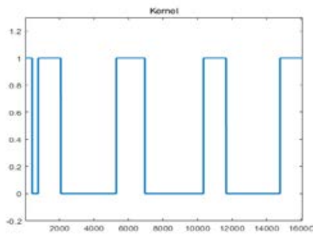

Fig. 2. b. Kernel

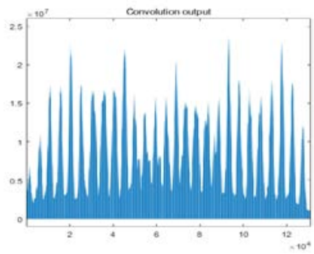

Fig. 2. c. Convolution

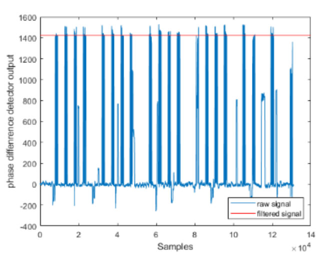

Fig. 2. d. Filtered phase signal

We acquired raw data containing phase difference signal(fig.2.a) from pairs of antenna. And convolution the acquired raw data with the kernel (fig.2.b) to obtain a phase difference signal separating the base signal from the raw data. As a result of calculating the median of the signals acquired by 100 samples at each point, and comparing it with the phase difference signal, a stable phase difference signal was obtained as shown in the red line in fig.2.d.

C. Missing data interpolation

We have acquired $3\times3\times8$ data for every 8 channels by rotating the capsule endoscope clockwise at 45° intervals. The 9 points are 7.5cm apart from the center of the antenna array, as in fig.1.a. Total 576 data were interpolated between 1cm for the x and y axes and 5° for the angles, to increase the separable coordinates and angles. Fig. 3. shows the phase signals of each 8 channels for the 0°. Each grid cell represents the degree of phase difference, and the phase difference is within 0 to 180 degrees.

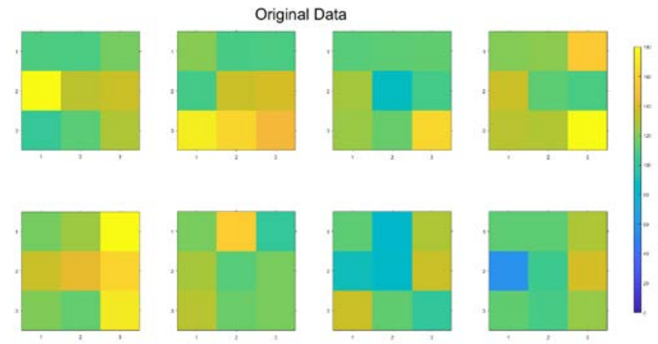

Fig. 3. a. Acquired actual data

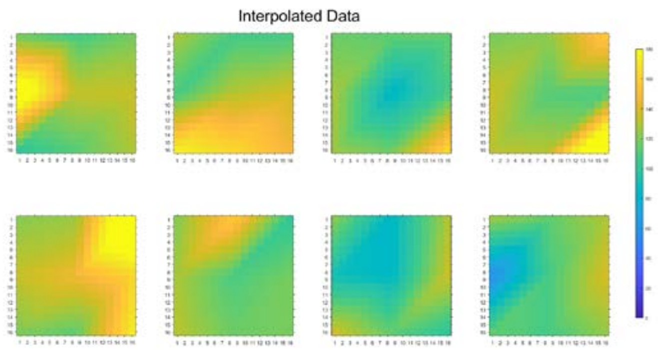

Fig. 3. b. interpolated data

III. Results

We have configured the local-specific phase difference pattern map through the above methods. By obtaining the signal from 10 random location points, we measured the error between the actual points and the estimated points through the map. In Fig. 4. a. The red circles are the actual points that we acquired the phase signal. And green squares are the estimated points from the phase signal. As a result, when comparing the mean error between the actual point and the estimated point through 10 randomly acquired x and y coordinates, it becomes 1.1cm and 1.5cm, respectively, as shown in Fig. 4. a.

Since, in the general case, the distinction between the data of 0° and 180° is very difficult. So, when the maximum discernable angle is 90°, the mean error for the degree is 11.5 °.

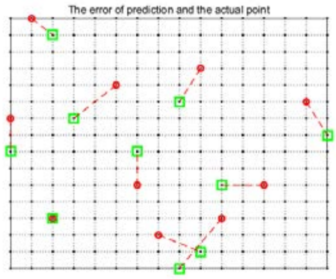

Fig. 4. a. Error of the prediction data

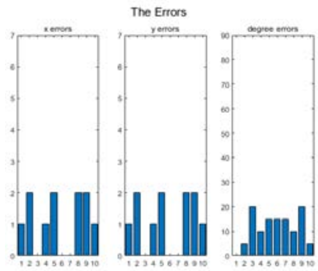

Fig. 5. b. The error of the acquired points

IV. Conclusion

As the error between the actual data and the predicted data appears to be large in a specific part, it can be expected that the sampling data for that part was insufficient.

In the future, we will use a new configuration of the antenna array for acquiring various data. And we will shorten the intervals of the sampling points and degree so that the interpolation can be better for the x and y axes and degree. Further, we will use the acquired test data for data interpolation to improve performance.

Acknowledgment

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