A Position Estimation Method of the Control Rod Guide Tube with Matched Filters

Jae C. Lee, Jun H. Seop, Yu R. Choi, Jae H. Kim
Korea Atomic Energy Research Institute, 150. Duckjin dong,Yusong gu, Taejon, jclee2@kaeri.re.kr

1. Introduction

The risk that PWR guide tube support pins will crack has increased the necessity for the development of inspection methods and equipment. A special remote-controlled manipulator has been widely used to inspect the guide tube support pins. In real situations, the manipulator is lowered into the internals pool and all the movements are monitored and controlled from a desk at the side of the pool. Because the diameter of the split pins is as small as 25mm, locating the ultrasonic transducer to the pins by a manual operation is a somewhat tedious task. To overcome this problem, a rail was placed on the bottom of the pool before the internals of the reactor vessel were lifted and lowered on to their stand.[1]

In this paper, we presented one method to eliminate this troublesome job by using a vision sensor already being used to monitor the manipulator's movements. There were some successful researches in designing controls for many dynamic systems in the case of their current position and where the desired trajectories are well defined.[2][3] But a current position estimation of a robot and/or environmental objects is another problem that must be solved.[4] A Matched filter algorithm is employed as a method for an automatic detection of the guide tube's and support pin's relative position to that of the robot. First, we construct two raw images corresponding to the guide tube and the support pin respectively. These are simply binary-valued image files that contain the shapes of each object. Next, we performed a 2-D FFT(fast fourier transform) on them. The transformed data files are the matched-filters to detect the presence of a guide tube and/or support pins and to estimate the positions of them. The cross-correlation between the matched-filter and real input image can be calculated by the method of multiplying them followed by an inverse FFT. If the resulting value is greater than the pre-determined threshold value, we can conclude that there is at least one object which we are looking for in that input image. In addition to the presence of the guide tube and pins, the cross correlation value will have a maximum at the exact position of the object. As a result, we can perform the inspection without any troublesome jobs such as a guide rail installation.

We studied this algorithm for applying it to the control rod guide tubes inspection robot and tried an inspection without on operator's intervention.

2. Matched-filters for Object Detection

Our algorithm is presented in fig. 1.

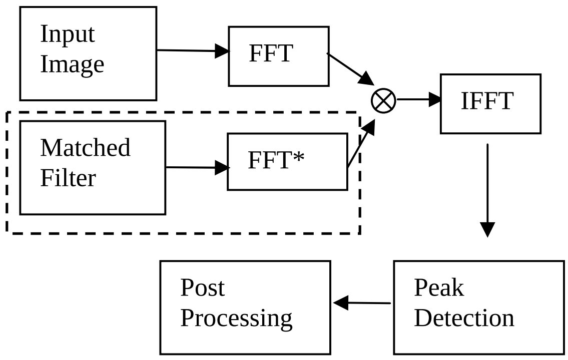
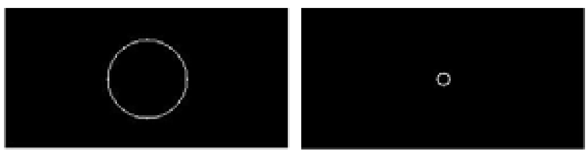


Fig.1. Block diagram of the proposed algorithm.

The upper part of the block diagram is general a matched filter algorithm. The operations in the dotted box are only needed for initializing process and * means the complex conjugation. All the remaining operations must be done with every video frame. The size of our image is 128 by 256 pixels and today's normal desktop computers (Pentium-4 operated at 2.0Ghz and we used the Cooley FFT algorithm) can execute the operations at the rate of 10frames/sec. Original computer generated matched-filters are shown in fig. 2. The black background regions have value '0' and the white object regions have a value '1'. The radius and thickness of the circles are equal to them in the camera input image. We stored the data files that were 2-D FFT transformed and conjugated from fig. 2.



(a) (b)

Fig. 2. Matched-filters for (a) guide tube and (b) support pin

An image captured from the camera mounted on the robot is shown in fig 3. We convert this image to a binary valued form as shown in fig.4. We did this operation for sharpening the correlation peak profile and reducing the noise influence.

Fig. 3. An original image captured from the camera on the robot

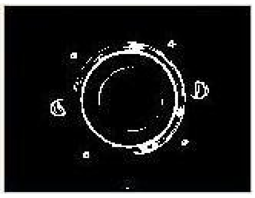


Fig. 4. Binary-valued image converted from fig.3

Next, we transformed the image shown in fig.3 using a 2-D FFT and multiplied it by the matched-filter (generated by the dashed box in fig.1.) on an element by element basis. Then, we transformed that data using a 2-D IFFT(inverse FFT) and showed the resulting image in fig. 5.

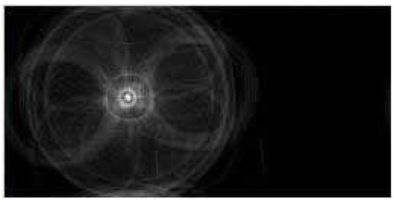


Fig. 5. Image after inverse FFT(guide tube)

Small white point near the center of the circle indicates the position of the guide tube's center. Difference in size between fig.4 and fig.5 is the result from the zero padding algorithm adopted for applying the FFT which assumes the size of the row and column as 2's powers. The dimensions of fig.3 and fig.4 are 120 by 160 and that of fig.5 is 128 by 256.

Post processing is the process to eliminate the guide tube's image from fig. 4. We do this for a more exact estimation of the support pin's position. Without this post processing, the correlation peaks corresponding to the support pins appeared in some unacceptable positions. To eliminate the guide tube as much as possible we used two parameters, the center position obtained from fig. 5 and the radius used for generating fig. 2(a). Resulting image is shown in fig. 6. Support pin's image shown in fig. 6 is slightly different from that of fig. 4 because another input image is used for eliminating the guide tube in a real time based operation.

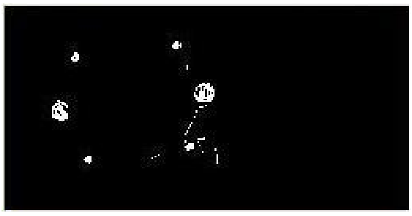


Fig. 6 Image after eliminating guide tube

Finally, algorithm in fig.1 is used again with fig.6 as an input image and fig.2 (b) as a matched-filter. The resulting image is shown in fig. 7.

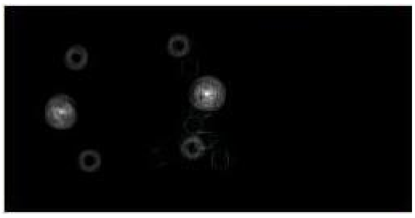


Fig. 7. Image after inverse FFT(support pins)

From the finally obtained two images, fig. 5 and fig.7, we can estimate the following parameters.

(1) Center position of the guide tube
(2) Center positions of the support pins
(3) Heading orientation of the robot from the line connecting two support pins.

3. Conclusion

We proposed a method for inspecting the guide tube support pins with matched-filters. We experimented with this method for our mock-up and inspection robot. We can inspect the guide tube support pins without auxiliary structures such as a rail and manual operations such as initial position alignments. And our method shows reasonably good results for partially occluded (about 45%) images.

REFERENCES

[1] J. Gustafsson, Inspecting Guide Tube Support Pins in Swedish PWRS, Nuclear Engineering International, 1985.

[2] D. Gu, Wavelet Neural Network based Predictive Control for Mobile Robots, IEEE, p.3544, 2000. Documentation from Internet

[3] R. M. Sanner, Structurally Dynamic Wavelet Networks for the Adaptive Control of Uncertain Robotic Systems, Lab. Documentation from Internet. Proc. Of the 34 Conf. On Decision and Control, New Orland LA, p.2460, 1995

[4] J. C. Lee A Fast Position Estimation Method for a Control Rod Guide Tube Inspection Robot with a Single Camera, Proc. Of the Korean Nuclear Society Autumn Meeting Youngpyong, p. 643, Oct. 2004,