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Development of Parallel and Fan-Shaped Beam Mixed-Projection Optical Tomography

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Abstract: Parallel and fan shaped beam are two common projections that had been used widely in optical tomography system. These projections never have been merged before in the process of tomography area. In this paper, some enhancement has been made by combining these two modalities in order to solve the ambiguity that arises in the parallel beam projection. *Copyright © 2012 IFSA.*

Keywords: Parallel beam, Fan beam, Optical tomography.

1. Introduction

The general principle of optical tomography is a set of light sources and the photo detectors are used in attaining the parallel views of the pipeline. This type of tomography is popular for medical and process tomography. Recent researches focused more on medical side rather than the process. This is proved by a lot of journal's publication from year 2005 until 2010 that are mainly discussing about medical tomography. There are two types of tomography: "hard field" and "soft field". Optical tomography is a "hard field" type of tomography as they are sensitive to the parameters measured in all positions of the measurement volume thus making the data easily collected as the sensitivity uniformly sensed all positions. "Soft field" is vice versa where the parameter sensitivity relies on the position of the sensors in the measurement volume [1]. In optical, a beam of light is projected through some medium from one boundary point and this light will be sensed at another frontier point through the use of optical sensors. At the receiving point, the level of voltage will be measured and any decreasing value is proportional to the existing of an object in the pipe or vessel. It means the optical tomography detects the attenuation of the signal [2].

In the area of process tomography, two popular types of projection are defined, which are parallel beam and fan beam mode. Researchers tend to use fan beam [3-9] rather than parallel beam [10-13] due to the capability of covering wide range of area compared to parallel beam. The other factor is fan beam only need a small amount of sensors compared to parallel beam. Hence this will contribute to cost saving while developing the optical tomography system. On the other side, parallel beam has been chosen because of its faster processing time compared to fan beam since all received data at the receiver side, are sent simultaneously from the transmitter. The parallel beam projection produce a straight line view [14] resulted an ambiguous image since it projection is not enough to cover for overall area in the pipe.

Based on these advantages and disadvantages of both projections, an improvement had been explored and implemented. In this paper, the implementation of mixed-projection between these two beams had been done. This combination is a unique process as the fan beam can be applied together although the sensor jig is designed to enable the parallel beam projection only. But with a little modification in the sensor jig and the controlling process, the fan beam projection is possible to be implemented in the sensor jig that is designed for parallel beam projection. Through this technique, the problem faces by parallel beam had been overcome by fan beam while large spaces memory consumed by fan beam can be reduced through only selected activation of the transmitters. This mixed-projection technique had produced a better quality images. Some researchers also formulate a unique technique by combining the fan beam technique with Genetic Algorithm (GA) [15]. The reviews for the techniques of projection that are commonly used by the researcher in the optical tomography area can be referred in [16].

In this concept of light, the factor of diffraction and scattering is ignored by making a switching process for each view of light for both types of projection. Optical tomography is a type of light attenuation concept and this is suitable for solid gas application. An example of application; agriculture for grain and rice transportation, animal feed pellets and food (e.g. flour, sugar, tea, and coffee).

2. Mixed-Projection Optical Tomography: A Unique Concept

In mixed-projection optical tomography, the fan beam and parallel beam projections will be processed in sequence. The collected data of voltage sensors from both projections will be pooled together to produce a tomogram image. In this study, the focus is mainly to boost the image quality rather than processing timing. The design of the jig will enable both projections to be applied in the same sensor jig. The researcher before this only applied parallel beam in the design as its sensor jig cannot tolerate with fan beam projection. This is because the jig that they design has a collimator where the purpose is to make the light is in a straight line therefore only the right receiver will get the right signal. In our design, the collimator is eliminated, therefore the signal is illuminated in the angle that same as the infrared sensor which is 32 degree. The receiver side also does not have any collimator; therefore the acceptance angle will act as photo detector's angle which is in our case is 34 degree. Fig. 1(a) shows the previous sensor jig by Goh that can only enable the parallel beam projection. While Fig. 1 (b) shows the modification of the jig in our research that enable both projection to be applied together in the same sensor jig.

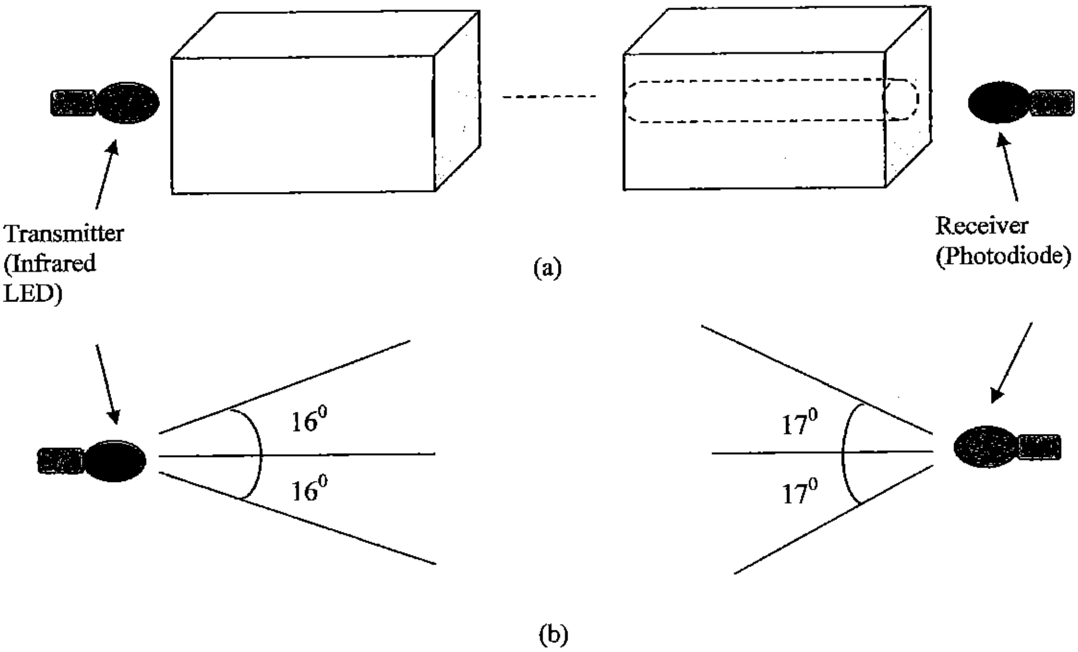


Fig. 1. Arrangment of sensor jig (a) with collimator; (b) without collimator.

The uniqeness of our approach is although there is no collimator for parallel beam mode, the adjacent receivers still do not detect the signal from the other transmitters. This is because the switching techniques will be used. Using switch mode technique, every transmitter and receiver pair will correspond in dissimilar time and it gives the opportunity for the receiver to get 'clean' signal from the transmitter because it acquires the signal at the time the transmitter confer to them. Differ from the old method of parallel projection where every transmitter is activated in the same time, and it makes the reflection and scattering occurred and thus give difficulty in differentiating the true signal. Besides that, this arrangment enable fan beam mode to be applied in this system as the signal from transmitter can be widely accepted by receivers in the opposite arrangment. Therefore, the combination of parallel beam and fan beam mode can be done without difficulty.

3. The Measurement Section

Measurement section is the core in any tomography system therefore a careful setup in this section is a must. The first stage is to design the sensor jig and a scratch drawing from Microsoft Visio is required. Fig. 2 shows the scratch drawing in Visual Basic before the drawing using Solid Works is prepared.

There are 8 sides for the projection and the number of side is depending on the sensor arrangement. The arrangement must not prevent sensors from detecting their associated transmitters, resulting in a bigger sensor jig to make sure all light is in a straight way thus creating the dimension between side A and E become 241.42 mm. In this drawing also the pipe diameter as measured is 99.6 mm.

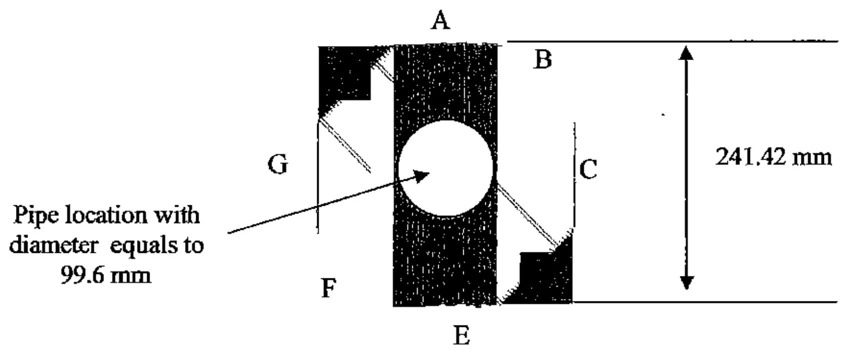


Fig. 2. A scratch from Microsoft Visio.

For the sensor jig, the dimension depends on the size of sensors, pipe and the projection which is planned for. As mention before, dual projection will be implemented in this study; therefore collimator will be avoided in this design. In this design, each transmitter and receiver will be arranged alternately. The minimum distance between each sensor is 1mm as shown in Fig. 3. The distance will be 5 mm if it is measured from the centre of the sensor to the other centre of adjacent sensor. Fig. 4 shows the overall dimension for the sensors.

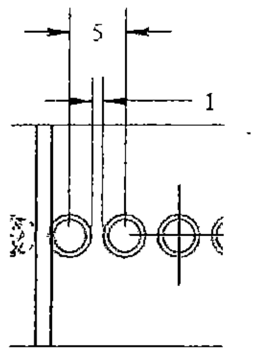


Fig. 3. Distance between each sensor.

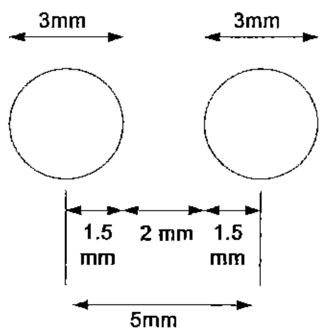


Fig. 4. The inner dimension for the sensor jig.

Fig. 5 (a) and (b) shows the dimension for the sensor and within the sensor jig. In order to ease the process of inserting the sensor into the sensor jig, we need to design the sensor jig as shown in Fig. 5 (b).

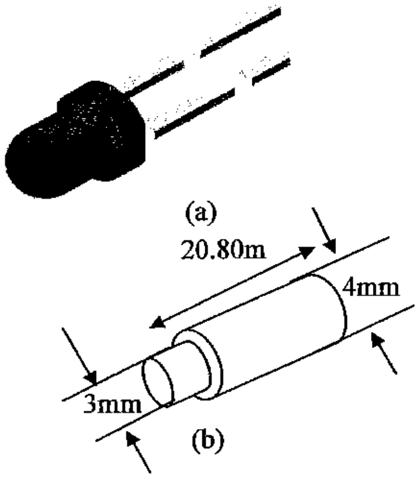


Fig. 5. (a) Dimension for the sensor; (b) dimension inside the sensor jig for each sensor.

The sensor is self locating because the sensor jig is designed to have two sections. The first section will be 3 mm diameter of sensor, and the second section is 4mm diameter from the lead to the division which is higher than 3 mm. As a result, there is no need to carefully insert the sensors into the jig and this will eliminate any wrong placement of sensors. After finalizing the design, we can see from the inner part as shown in Fig. 6, the 3 mm part of the sensor can be spotted; consequently fitting the need for fan beam mode projection.

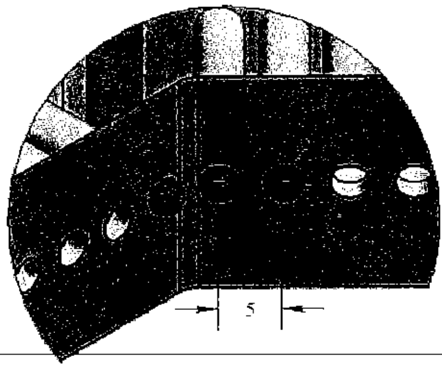


Fig. 6. Sensor is inserted in the hole of sensor jig.

Fig. 7 shows the overall dimension for the sensor jig. There are 8 sides and each of the side has 20 holes, 10 for transmitters and 10 for receivers that was arranged alternately. The final part of the sensor jig is as shown in Fig. 8 after each of miniature part was built with the first and third layer is PVC and the second layer is Aluminum. Researcher purposely used PVC to reduce the overall weight of this design as it is lighter than aluminum. Acrylic pipe is used in this design and the pipe is cut into two, where first part is glued with the top side, and the other one is glued with the bottom side. This research has the sensor jig built into an existing flow conveyer system in the lab.

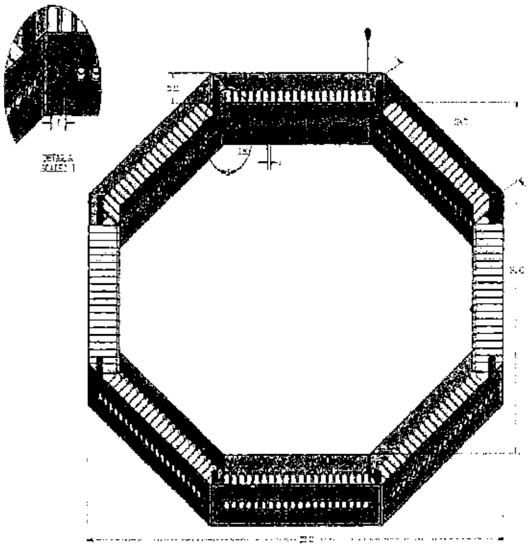
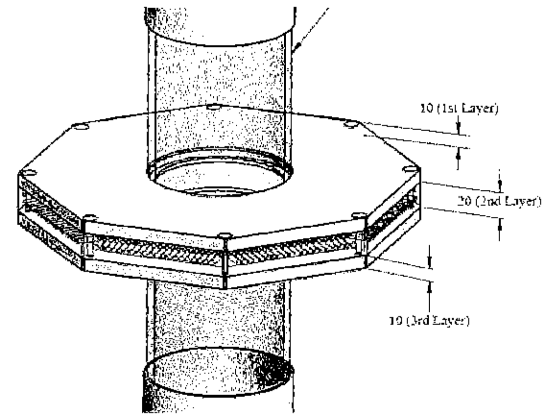


Fig. 7. Overall dimension for the sensor jig.



(a)

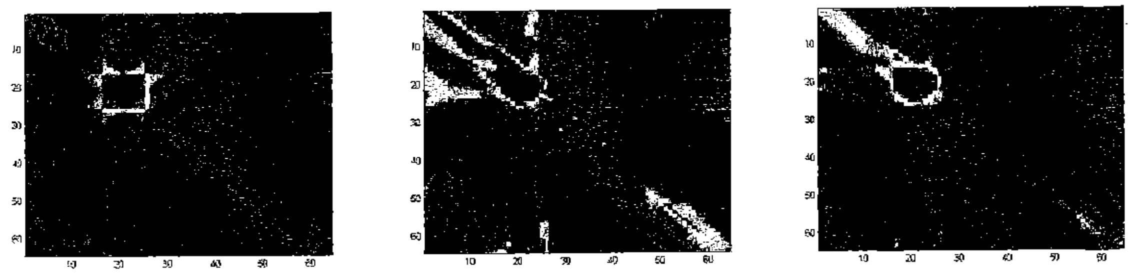
(b)

Fig. 8. The complete sensor jig (a) sensor jig without circuit; (b) sensor jig with circuit.

There are 80 data for parallel views and 160 data for fan beam views and the total sensor pairs are 80. Therefore for parallel beam, 80 data measurement will be processed. For fan beam, in each side of projection as shown in Fig. 2, only two transmitters will be switch 'ON', and 20 receivers will respond to that signals. Therefore, there are 160 measurement will be process. Following to the combination of quantity, there are 240 measurements will be considered in this process.

4. Experiments and Discussion

The performance of the output for parallel and fan beam projection are compared. These two methods were tested using a phantom with a single object resulting in the tomogram shown in Fig. 9 (a) and (b), while 9(c) is the combination between parallel and fan beam projection.



(a) (b) (c)

Fig. 9. The tomogram image (a) parallel beam (b) fan beam (c) Combination between parallel and fan beam.

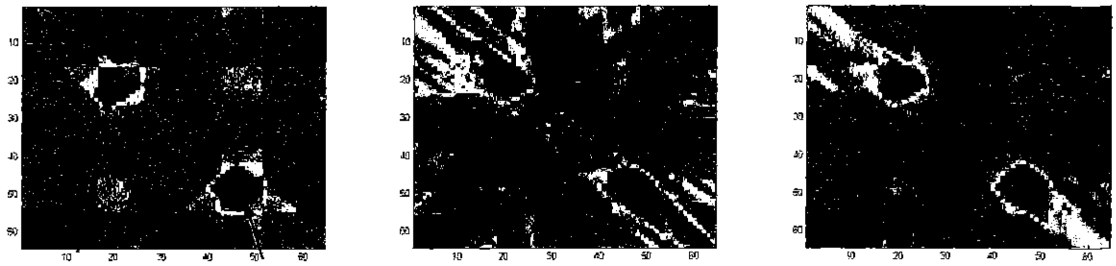
There are clear merits that by applying both parallel and fan beam mode the coverage of the system is better. As shown in Fig. 9 (a), it shows that in parallel mode, the image is in a rectangular shape instead of cylindrical shape. While in Fig. 9 (b), the image has improved in terms of shape but the noticeable image smearing spoils the tomogram. The shape and the noise improve significantly as shown in Fig. 9 (c) in attendance of the combination between fan beam and parallel beam. The noise is defined when the colour of the background is same as the colour of the object. The image diameter of the shape after the combination can be calculated using the data from the contour mode in MATLAB which is 17 units while the right side is 25 units as shown in Fig. 10. Therefore, the distance is equal to eight pixels where eight pixels multiply with 1.56 mm is equivalent to 12.48 mm. The diameter of the object is 13 mm and the error percent is 4 % for the single image.

(a) (b)

Fig. 10. The coordinate to calculate the diameter of the image after combination process (a) left side; (b) right side.

Fig. 11 shows the tomograms obtained with a two object phantom. Both types of experiment are done by using real hardware measurement. The object measurement is a plastic cylindrical rod in diameter of 13 mm for the small one, and the bigger one is 16 mm. The pipe diameter is 99.6 mm and 64 × 64 pixel is used in the tomogram, and the relation is one pixel which is equal to 1.56 mm.

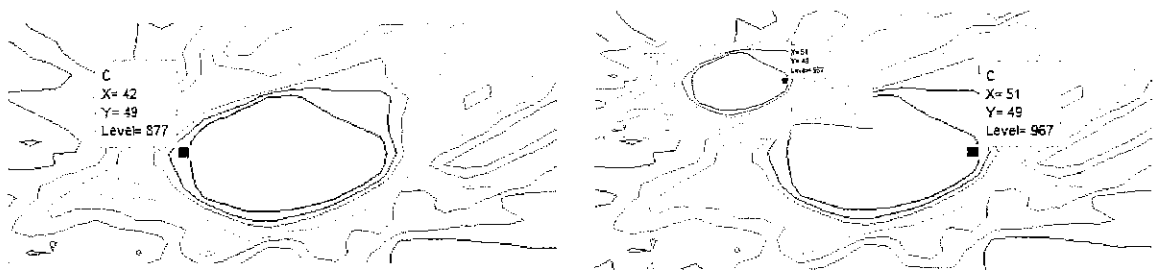
The above methods were repeated for the two object phantom and the resulting tomograms are shown in Fig. 11. For parallel beam mode in Fig. 11 (a), the image produced an accurate image only for one object which is the bigger one. For the smaller one, the object is inaccurate. For fan beam mode as shown in Fig. 11 (b), the noise appears at the background but the shape of the sphere still can be seen. The combination as shown in Fig. 11 (c) display the best image where it shows the improvement on the shape and noise.



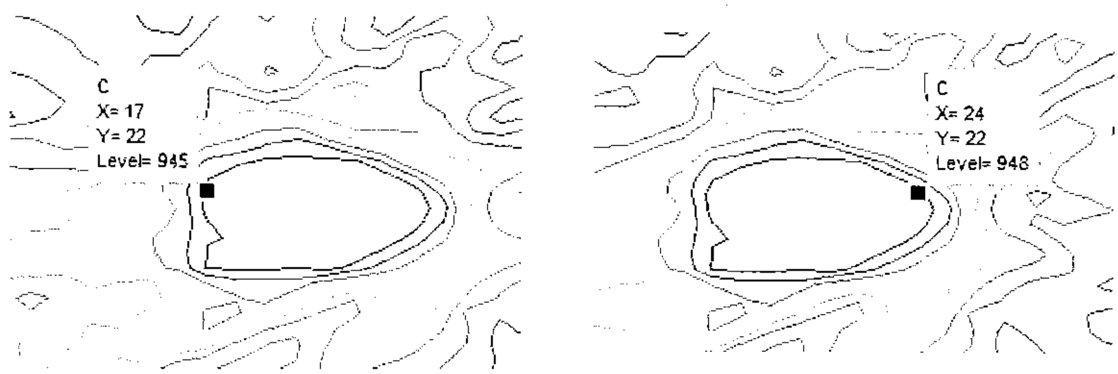
(a) (b) (c)

Fig. 11. Tomogram image for multi model using: (a) parallel beam; (b) fan beam; (c) combination of parallel and fan beam.

Fig. 12 shows the coordinate in a unit pixel to calculate the diameter of the sphere. For the big object the coordinate at the left side of the image is 42 and for the right side are 51 as in Fig. 12 (a). The differences are nine units. The diameter of the sphere image is 14.04 mm (9 multiply with 1.56 mm). The real diameter is 16 mm; therefore the image error is about 12 % while for the small image the error in the image is around 16 % by referring the coordinate in Fig. 12 (b).



(a)



(b)

Fig. 12. Coordinate of the object (a) Bigger object; (b) Small object.

5. Conclusion

Voltage loss has a linear relation with the obstacle diameter where the greater the obstacle diameter will result a higher voltage loss. The linear relation also can be seen in the graph of measuring time spend of the obstacle when they go through the sensing area where the greater the length of ball size, the longer time will be needed to go through the sensor area. Both experiments fulfill the linear characteristic of optical sensor that is needed for tomography application.

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