DEVELOPMENT OF AN ULTRASONIC SYSTEM FOR OBJECT RECOGNITION

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ABSTRACT

The use of ultrasonic signals for recognition of persons has been usually used for its effectiveness and accuracy. Two are the methods usually employed for this purpose: The phase-shit analysis and the time delay related with the echo-impulse technique. In this work, we present preliminary results related with the obtaining of three-dimensional images of different shapes, as well as the development of the method to obtain images of persons. The system of pattern recognition is a combination of hardware and software. The goal is to find the system with lower computing time and more accurately.

RESUMEN

El uso de señales ultrasónicas para reconocimiento de personas ha sido ampliamente utilizado por su efectividad y precisión. Dos son las metodologías más utilizadas: El análisis de la variación de fase y la técnica de eco-impulso. En este trabajo se presentan resultados preliminares relacionados con obtención de imágenes tridimensionales de diferentes formas, así como el desarrollo de un método para obtener imágenes de personas. El sistema de reconocimiento es una combinación de hardware y software. El objetivo es encontrar el sistema con menor coste de tiempo computacional y mayor precisión.

BACKGROUND

Ultrasound plays a remarkable role in human life. From non-destructive testing to medical diagnosis. The unique physical peculiarity of ultrasound provides it processing many advantages. Associating with the unique physical peculiarities of ultrasound, it is an advanced method to do object recognition. Compared with others techniques of object recognition, it works in a larger detection range and depth with accuracy defected position. With the properties of low cost technique and harmless to the human body, ultrasonic system has becoming a most widely used technique with highly growth speed [1].

TECHNIQUES

Echo-Impulse Method

This method base on counting the propagating time of the ultrasound signal. The transducer emits the signal then the signal would be received after reflected by the object. In the figure1, the signal emitted by the transducer A is reflected at the “reference rigid surface” and come back to the transducer B. The total time since the signal is emitted until is received is tA=t1+t2. The signal that has been used in this method is the pulse signal. Based on this time difference it is possible to reproduce the shape of different objects[2] (Figure 1). In figure, signal is emitted and received by the same transducer. In our experiment we not use a single transducer emits and receives, so that the sender and recipient are two different elements.

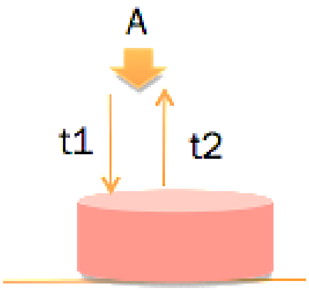


Figure 1. Basis of the echo-impulse technique

Phase Shift Analysis Method

In order to improve the view of the object under study it was used the technique of phase shift. The system configuration was practically the same as for the study of flight time, but the information to be analyzed corresponded to the phase change with respect to a reference phase value.
Practice made this technique was not used because it did not provide improvements. However, it could be interesting for small items with less than the wavelength size.

SIGNAL PROCESSING

Hilbert Transform

Hilbert transform is a useful tool in the field of digital signal processing. It can be used to detect the envelop of the ultrasonic signal and obtain the peak point of the envelop. The result of Hilbert transform working in a real function x(t) is the output of x(t) passing a linear time invariant system.

There are some relationships in the real part, imaginary part, amplitude-frequency response and phase-frequency response of a real signal x(t) or x(n) after Fourier transform. Assume the Hilbert transform of the function x (t) is $\hat{x}(t)$.

Hilbert transform can be write as

$$\hat{x}(t) = H[x(t)] = \frac{1}{\pi}\int_{-\infty}^{\infty}\frac{x(\tau)}{t-\tau}d\tau$$

There is a type of signal could be expressed as

$$x(t) = a(t)\cos(\Omega_o t + \varphi(t))$$

a(t)is a signal with low frequency and $\phi(t)$ is the phase function.

The Hilbert transform of this signal is

$$\hat{x}(t) = a(t)\sin(\Omega_o t + \varphi(t))$$

The envelop of the signal is

$$|a(t)| = \sqrt{x(t) + \hat{x}^2(t)}$$

Ema And Lema

Ema and Lema are functions to smoothen the obtained signal. The quality of detected image would be improved after applying these functions.

One function that used called Ema write formulas as here:

$$Ema = \frac{1}{\tau}\int_{t_0}^{t_0+\tau}[x(t)]dt$$

Another one named Lema

$$Lema = \frac{\int_{t=-\infty}^{t_0}[x(t)]e^{-\frac{t_0-t}{\tau}}dt}{\int_{t=-\infty}^{t_0}e^{-\frac{t_0-t}{\tau}}dt}$$

IMPLEMENTATION

This project can be separated into two parts. The first part is about experiments. Two important parameters are chosen to observe the influence to the detected images. The experiments start with detecting cuboid then gradually increase the complexity of the object. The second part is involving treating the data obtained in the experiment. In this section, we mainly start from two directions. One direction is using Hilbert transform to instead of Energy function. Another function is adding new functions to smooth the original signal. The steps of the project can be seen in Figure 2.

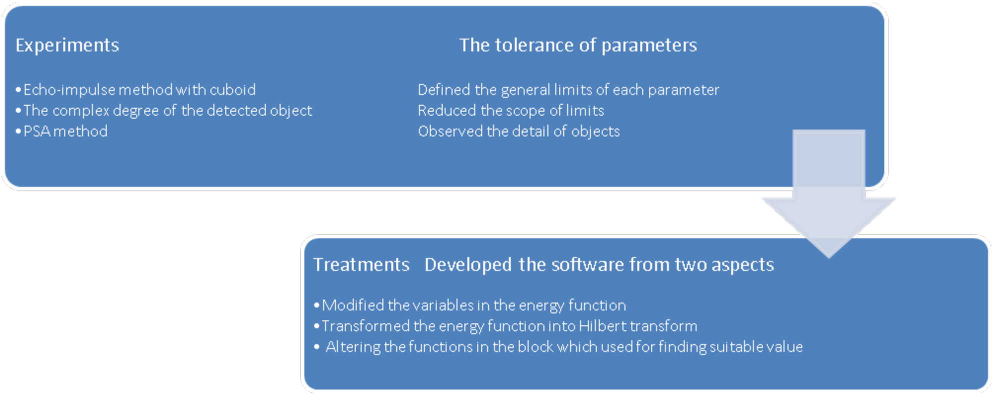


Figure 2. Steps of the Project

HARDWARE STRUCTURE

The hardware structure includes the parts of preparing work and the set-up of the software. The sequences to open the machines should be strictly followed when preparing work. The first machine that should open is the generator. It works to generate the signals that used in the experiment. The type of the signal is choosing in software named 3DREAMSUltra (Three Dimensional e-Acoustic Measurement System Ultra). The frequency and amplitude also set in this software. Then connecting the generator with oscilloscope to observe the signal whether satisfies the quality. The other wire linking to generator is connected with the emit transducer.

The second one is the Cartesian Robot. It plays the most important role in the experiment because it is the part used to detecting the object. This machine also is controlled by software named 3DREAMSUltra. Cartesian Robot is composed with transducers and a movement system. The set up of the transducers had been defined in the past experimenters. In the Echo-Impulse method, only one transducer is used in the experiment. This transducer is not only responsible for emitting signal but also handling received signal.

In the PSA method, there are two transducers working in the experiments. One used as the emitter and the other one is responsible for the received signal. The movement system can take the transducers to scan the whole place after the map is generated by 3DREAMSUltra. The limit of the movement system need to be noticed when the map of movement has been created. The limits alone to the semi-axis OX and OY could be fixed in the software. It means that the input value should less than limiting value when setting the movement map. But the semi-axis OZ cannot be defined before the experiment. Pressing the STOP button in the Cartesian Robot would be the only way to stop the move in this direction if the transducers working more than its scope.

The last machine that has to open is the computer. Then 3DREAMSUltra can be set then processing data through Matlab.

RESULTS

Ten groups of images have been obtained after conducting all experiments and develop the software. Group one to group five works with Echo-impulse method. Group six to group ten have been obtained by PSA method. The first and sixth groups are showing the images of single cuboid. A shape of two half-cylinders with curved surface upward behind a cube is the detected object of the second and seventh groups. The complexity of detected object is gradually increasing in each part. In the first three groups of each part, there are 40 images in each group. The images are changing with the two parameters. In the last two groups of each part, the numbers of images are decreasing to 20. The result of this performance is the reducing of the detecting value in one parameter.

In the third and eighth, the parts are the same with last groups but the angle of the half-cylinders has been modified which take the flat surface upward. In the fourth and group ninth, the results describe the pictures of the object that used in groups third and eighth adding a cylinder above the cube. The last two groups in each part are showing the object used in groups third and eighth with a half- cylinder above the cube.

Acceptable Range Of Two Parameters

The performance of detection is different with the technique, which used in the collecting data. Therefore the results are separated to discuss when defining the acceptable range in the project. After this step, the improvement has been demonstrated in the developed software.

The images of a cuboid with variety values of parameters are used to define the acceptable range of two parameters. According to the Table1 (Table 1 results of detecting cuboid with different parameters), the images are showing better performance when the range between 40mm to 90 mm and fixed the distance of each collecting points. In the height in 60mm, the images are clearer than the others. If the height has been fixed into 60mm, the limits of the object would become ambiguous when the distance of each collecting point is more than 8mm.

The scope of the variables is gradually decreasing. For the second and third sets of experiments, the shape still could be recognized till the distance between collecting points achieved 8mm. in the second set of experiments, the interfering signal not showing much damage in the image. But the changing of the ‘arm’ is hardly to be recognized. In the last of two object, the distance of acceptable range is reduce to 6mm because the affect of ‘head’.

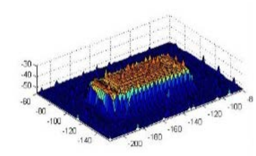
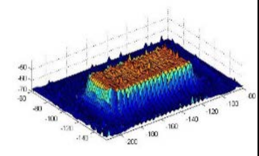
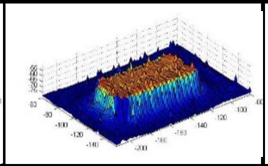
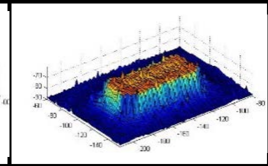
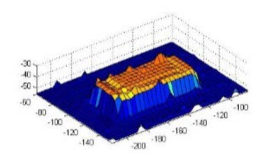
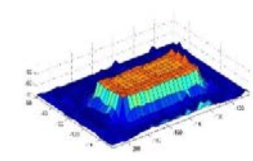
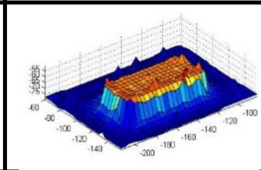
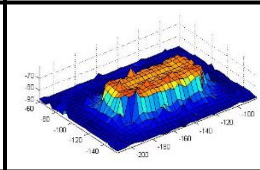
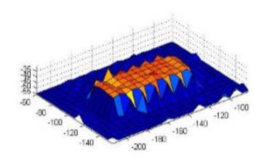
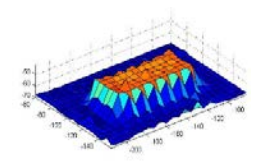
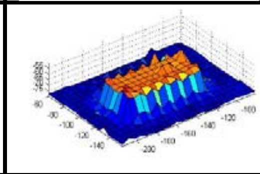
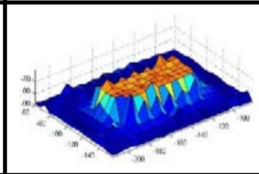
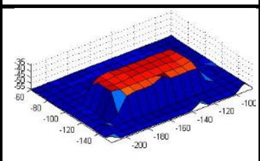
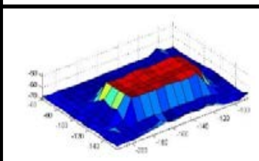
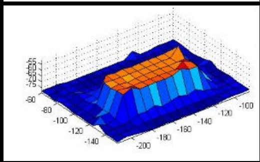
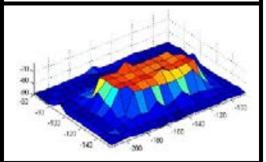
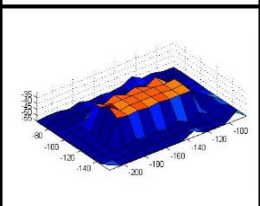
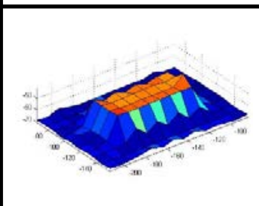
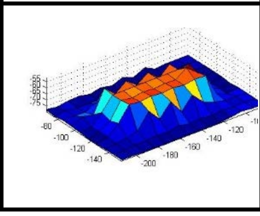
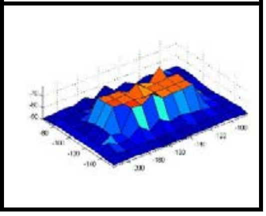
Height / Distance	20mm	40mm	60mm	90mm
2mm				
4mm				
6mm				
8mm				
10mm				

Table 1. Results of detecting cuboid with different parameters

Therefore, the acceptable values of height are from 90mm to 40mm. The acceptable value of the length is between 6mm to 4mm.

Fastest Method In Calculation

Hilbert transform with original function make a huge improvement in saving time after the time of each improve method has been calculated.

Obtained the Envelop / Smoothed the envelop	Energy function	Hilbert transform
	240s	60s
Ema	480s	180s
Lema	900s	900s

Table 2. Time consuming in each method

The calculation time would change according to the different type of computer and we do not want to compare absolute times. It should be notice that every method has been ran in same physical conditions to compare times with different techniques. It is obviously that when altering the Hilbert transform in to the project. The efficiency has been improved four times than before. From the images of two methods in Table3 (Table 3 Compared Energy function with Hilbert transform), it is clear that the quality of ultrasonic images is similar. Therefore if we want to use the system into a time saving environment, the software with Hilbert transform is the best choice.

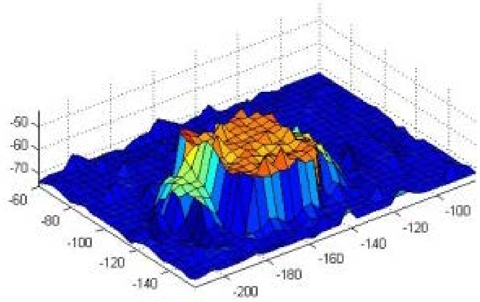
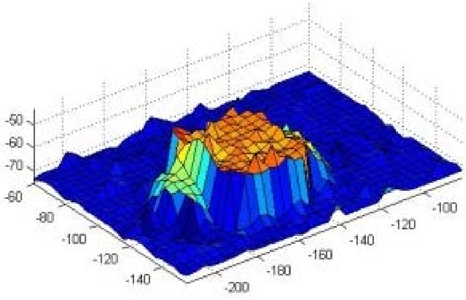
Energy function	Hilbert transform
	

Table 3. Compared Energy function with Hilbert transform

Best Quality Of Ultrasonic Image

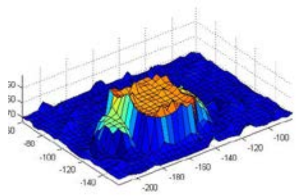
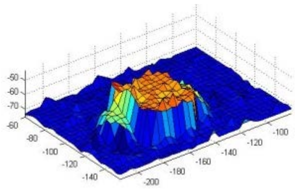
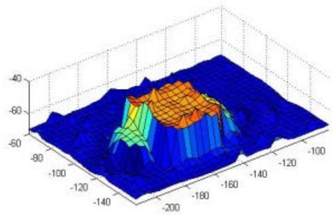
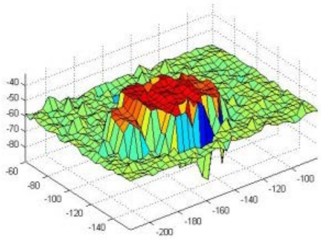
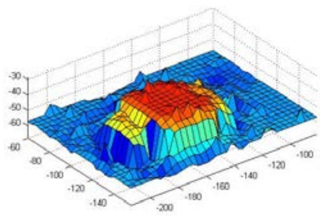
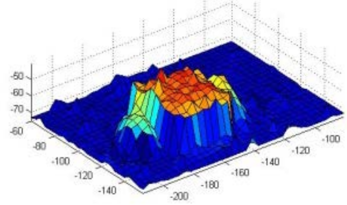
	Energy function	Hilbert transform
		
Smooth Ema function		
Smooth Lema function		

Table 4. Compared Energy function with Hilbert transform

Putting the images in the same conditions assure the accurate of compartment. Table 4 (Table 4 results of the ultrasonic images processing by each method) gives us a convenience way to draw the conclusion. There are two aspects of the quality need to be noticed. One is the clear degree of the edges. It is no doubt that the images produced by Energy transform and Ema function provides the greatest result in these images. It is the only one method clearly demonstrating the connecting areas of two blocks. Another part to test the improvement is the flat degree of surface. The image produced by the Lema function with the Energy function showing a clear edge of the object and a more flat surface in the surface. After considering with the combination of the time consuming and the quality of images, the improved energy function with Ema function are the suitable one for our system.

In case of the occasionally inside the experiments, other shapes of object also has been tested to confirm the result. Other images also demonstrate the same regular of each method. Therefore the software is steady and the characters of each method are occupied normal usability.

CONCLUSION

The purpose of this project is to define a structure of a detection system to improve the quality of detected image with the assistance of ultrasound. We design many experiment with different methods to correspond with the distinct requirements. At the end of this project, the results showing we successfully realize the goal. The system not only can produce the clearest ultrasonic image but also can reduce working time comparing to the original detected system. In the future, the extend of this project can aim to the part of user interface.

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