DISPLACEMENT MEASUREMENT OF INNER SURFACE IN WATER BY ULTRASONIC SPECKLE TECHNIQUES BASED ON GENETIC ALGORITHM

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Summary In this paper, we addressed the in-plane displacement measurement of an inner objective surface by introducing genetic algorithm as well as combining it with correlation algorithm. The applied genetic algorithm in our research was proved to have the advantages of higher accuracy, less computational time and avoiding misjudgement of correlation coefficient main peak when compared with full field coarse-fine sub pixel searching method.

INTRODUCTION

The distributions, characteristics and changes of ultrasonic speckles contain the information of the deformation of backscattered surface and the changes of structure, similar to laser speckles characteristics [1,2]. Moreover, ultrasonic speckles can be informed universally, no matter in air, liquid or solid, which makes possible the utilization of ultrasonic speckle correlation method into displacement measurements of an inner object surface in water.

The methods in digital image correlation-matching have been, to date, developed into numerous ways, such as full field coarse-fine sub pixel correlation searching method, cross sub pixel searching method, hill-climbing sub pixel searching method [3,4,5]. Comparing among these, full field coarse-fine method has the highest accuracy while costs the most computational time. Cross and hill-climbing methods, conversely, take less time with lower accuracy because of confusion between the main peak and other randomly distributed small peaks of correlation coefficient during the searching. Fortunately, with the help of global optimum and a good convergence, genetic algorithm can improve accuracy, reduce calculation and avoid misjudgement of main peak during correlation-match [6,7]. Under the condition of big ultrasonic speckle size and high background sound pressure, a genetic sub pixel searching method, which is the combination of genetic algorithm and correlation algorithm, was proposed in the experiment of displacement measurement of an inner objective surface in water with ultrasonic speckle techniques. The results showed that the genetic method has higher accuracy and less computational workload than full field coarse-fine method, which is in a good agreement with the theoretical prediction.

EXPERIMENTS

The experimental system used in the experiment to measure the displacement of inner surface is showed in Fig.1. The specimen in water is made of Plexiglas with smooth outer surface. The inner surface was painted by 40 meshes aluminium powder to become rough surface so that the ultrasound can backscatter to form speckles. Specimen can also be made from metal with burnished outer surface. Self-transmitting and self-receiving immersion ultrasound probe R was connected to the two-dimension translation stage T_2 which was controlled by a computer. R was perpendicularly placed and focused on the inner surface. The translation stage T_2 was applied to move the probe R, which was stimulated by pulse generator to emit ultrasound wave and received speckle signals at the same time. The signals were stored by the software of digital storage oscilloscope. In initial situation, R scanned in a small square are in the (O-XY) plane with 0.4mm as the step according to the transverse size of speckles. A total of 30×30 speckle signals were collected. The power spectral density of central frequency 5MHz of each point speckle signal was taken as characteristic value to compose the before-moving data array. Put R to the original location, moved the specimen with known displacements along with X direction and Y direction respectively by manual precision translation stage T_1. The measurements were then repeated by using the same way in the same square area, and after-moving data array was obtained.

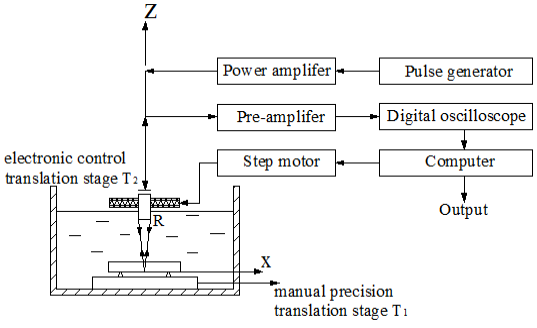

Fig.1 Experimental system

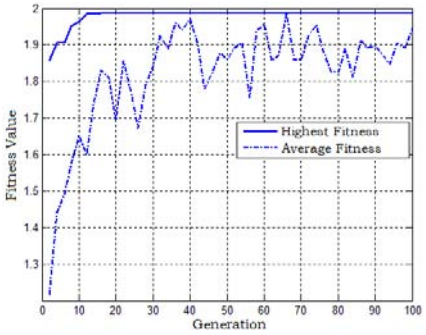

Fig.2. Variation of highest fitness and average fitness

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APPLICATION OF GENETIC ALGORITHM

Process of genetic method

Similar to traditional correlation methods, displacements can be obtained according to the correlation coefficient between the sample subset from before-moving data array f(x,y) and the objective subset from after-moving data array g(x',y'). The aim is to find the objective subset which has the largest correlation coefficient with the sample subset. Then the distance between the central point P(x,y) of the sample subset and the central point P'(x',y') of the objective subset is the displacement, where $x' = x + u$, $y' = y + v$, u and v are the displacement along with X and Y directions respectively. The specific steps are following.

a) Form the sample subset.

b) Solution initialization and encoding. Take the displacement u, v as the genes to form the solution (u,v). Instead of binary encoding and Gray encoding, real encoding is used in this experiment. The initial population is consisted of 40 solutions within the range [0 2].

c) Fitness calculation. Each solution can make an objective subset which needs to calculate the correlation coefficient C with sample subset. The range of C is [-1 1] when C is standard covariance correlation coefficient. In order to avoid negative number, the fitness function is F=1+C.

d) Selection operations. The roulette wheel method combined with optimal reservation strategy is used in this paper.

e) Crossover operations. Taking crossover operation on two chosen solutions ensures that the searching can be done in the full field and the solutions with have high fitness would not disappear in the next population. The single-point crossover is applied in this experiment.

f) Mutation operations. Replacing one of the genes in chosen solutions to form new solutions is mutation operation which improves the ability of local searching. Uniform mutation operation is applied in this experiment.

g) Termination decision. The maximum generation is 100 in this experiment. Therefore the searching will be terminated if the generation is 100; otherwise, turn to step c).

The variation of highest fitness in each population and average fitness (see Fig.2) showed that the genetic algorithm can well converge to the best solution quickly.

Results and improvement analysis

In this experiment, full field coarse-fine sub pixel correlation searching method was applied, with 30×30 data array interpolated with 1/4 interval and 3×3 data array interpolate with 1/10 interval in coarse and fine searching, respectively. Namely, a total of 46465 times correlation coefficient calculation needs to be performed in this method. Comparably, the only 4000 times calculation in genetic method which is just related with the number of solutions and generations, is much less than the workload in full field method and therefore reduces the required time to a great extent. The results can be accurate to 0.001 because of the two interpolations. However, the more interpolations do not necessarily mean the higher accuracy. Consequently, it is not surprise to observe the smaller error in genetic method which has only one interpolation and the results can be accurate to 0.0001 due to the floating calculation. Comparing with these two methods concerning obtaining the displacements from three experiments, the genetic method shows less the longest duration time 8.35 seconds as to 24.744 seconds in full field coarse-fine method; moreover, the maximum error (1.98%) in genetic one is also lower than that in full field coarse-fine method (5.27%).

CONCLUSION

The genetic algorithm combined with correlation method was applied in this research to measure the displacement of an inner objective surface in water with ultrasonic techniques. This algorithm improved accuracy and reduced much computational time, which will be helpful to the researches of displacement and deformation measurements in future.

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