論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Three-dimensional airborne ultrasonic position and velocity measurement based on echolocation
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出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第10039号, 授与年月日:2015年12月31日, 学位の種別:課程博士, 審査員:黒澤 実,山口 雅浩,杉野 暢彦,田原 麻梨江,蜂屋 弘之
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第10039号, Conferred date:2015/12/31, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	Information Processing 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of Engineering
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要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

This dissertation describes the methods for concurrently determining the position and velocity of a moving object in three dimensions using a definition of echolocation. The position is computed using a time-of-flight (TOF) technique based on a cross-correlation function, which requires less computational time when using one-bit technology. The velocity is subsequently calculated from the length of ultrasonic linear-period-modulated wave and the velocity measurements between the instantaneous position of a moving object and the position of the acoustical receivers.

Chapter 1: This chapter describes various technologies enabling position indication: laser, camera, millimeter wave, and ultrasonic. In general, ultrasonic considered a distance less than 5 m is very attractive when compared with others for the mobile-robot applications due to simple hardware, small size, and low cost.

Chapter 2: Many methods involving with the ultrasonic system for autonomous mobile robots are described in this chapter. The most important points for enabling autonomous mobile robots real-time signal processing are low computational time, reliability and low cost. Although the most of proposed ultrasonic systems can provide high accuracy of the position measurement, they may use the complex devices, which require a long computational time and a high price. In addition, they have only the ability of measuring the position without the knowledge of the velocity measurement. A system capable of concurrently measuring the 3D position and the velocity measurements is proposed. This method, in which an ultrasonic transmitter is a moving target, can be applied in a special work. Nevertheless, the development of simultaneously measuring the 3D position and the velocity under ultrasonic echolocation system with low computational cost is far from complete.

Chapter 3: One-bit modulation signal rather than a multi-bit signal sampled by means of oversampling can obtain a high SNR. By means of oversampling, very high resolution is obtained. The cross-correlation using one-bit modulated signal processing is compared with the cross correlation of multibit digital signal. This technique can be performed to reduce the circuit scale. To support a real-time application, FPGA cyclone V is useful to calculate recursive cross correlation of one-bit signals.

Chapter 4: LPM ultrasonic wave, a period of which is linearly swept with time, was proposed for Doppler effect compensation. This wave is directly generated by means of PT-R4 pioneer speaker from a sound source to a target. The loudspeaker of Pioneer model PT-R4 has a rectangular plane surface source. It can radiate ultrasonic wave from area X to +X and from area Z to +Z when the object appears in front of the loudspeaker in the +Y area. Moreover, a low-cost silicon MEMS microphone based on a development for hand-held telecommunication instruments is presented. It can extremely reduce the cost more than 100 times when relatively compared with the previous microphone of B&K and ACO.

Chapter 5: An ultrasonic three-dimensional system for moving object position and velocity estimation using a pair of LPM was proposed. The design method comprises of, one-bit signal processing, object-velocity-measurement and Newton Raphson method. We employed three microphones to detect the reflected echo from the moving object. Time-of-flight and the relative velocity were computed with low-cost time. Newton-Raphson played a vital role as object-position estimator. Finally, the Doppler velocity and object position from the earlier measurements were used to determine the object velocity on the basis of vector velocity theory.

Chapter 6: A three-dimensional position and velocity measurement based on an over-sampling signal processing method using an LPM ultrasonic signal was demonstrated. The velocity measurements were computed based on the three-dimensional velocity vector measurements. The object position was estimated using spherical coordinates (i.e., the distance from the sound source to the target, the angle of elevation, and the azimuth angle). Positions determined in the proposed system were evaluated by experiments using ultrasonic position measurements. The object position can be sensed by the sound beam propagated by a loudspeaker. Rotating the loudspeaker can expand the range of measurements to a wider area.

Chapter 7: The proposed system by redesigning the receiver arrangement uses cross-correlation one-bit signal processing technology, low-computation-cost Doppler-shift compensation, and low-cost devices. This is the development from the previous space measurement of one-bit signal processing to simultaneously measure position and velocity in three-dimensional space. Through Monte-Carlo computer simulation of 100 trials, the variances of estimated parameters can achieve the analytical CRLB for SNR as low as 0 dB. Accuracy of the proposed method was tested by the additional White Gaussian Noise. The results can provide accuracy less than 0.1 mm at a SNR of 0dB. Since the position-measurement model is a form of nonlinear systems, it is then improved into a linear model.

Chapter 8: In this chapter we describe Gaussian as well as non-Gaussian noise model, stationary as well as some nonstationary models. In the most case, we assume that the proposed method is proceeded under White Gaussian Noise. Thus, to evaluate the proposed method in other conditions, ultrasonic LPM signal including Colored Gaussian Noise, General Gaussian Noise, Laplacian PDF Noise, and Gaussian Mixture Noise is performed. Simulation results were observed that the rest method has robustness as low as SNR of -10 dB. The second method and the third method can just achieve robustness as low as SNR of 0 dB. In the case of accuracy comparisons, error from measurement of the rest method is approximately 0.2 mm. For the second method, measurement is deviated from the reference from 0.8 mm. The worst case expresses error from the reference around 1 mm that is the third method.

Chapter 9: This chapter talks again about many reasons why ultrasonic systems that are interesting when compared with others. Next, this thesis mentions on only time-domain analysis without any technique of frequency domain. It helps to reduce a computational-time cost for achieving real-time applications. Acoustical devices are demonstrated as a sound source and receivers. Then, the methods of position and velocity measurement are explained following to 1) the iterative method, 2) the direction of Arrival method, and 3) the linearization-based method. Finally, performance and comparison in different noisy signal are evaluated.