Coded Pulse Transmission and Correlation for Robust Ultrasound Ranging from a Long-Cane Platform

Punit Kumar
HOD,Mechanical Engineering
Department, JB Institute of Technology, Dehradun

ABSTRACT:
The objective of this research was to increase the independence and safety of the sight impaired by developing an enhanced travel aid in the form of a sensor embedded long cane to reduce the risk of injury from walking into suspended or overhanging objects while providing the sight impaired community with a familiar and well accepted tool.

Prior research at the Electromechanical Systems Laboratory had established a theoretical framework for ultrasound-based ranging and spatial obstacle localization from the moving reference frame of a long-cane. A prototype was implemented using analog threshold detection techniques.
This research focused on a new approach. A coded pulse was transmitted and correlation techniques were used to identify echoes and determine time of flight. Compared to the prior effort this new approach was more sensitive, had greater noise immunity, and provide greater spatial resolution for obstacle detection.

The first step in the coded pulse approach was to generate a transmit pulse with an embedded binary code that is highly distinguishable. A transmit pulse generated by phase modulating a 40 kHz carrier signal with a 13-bit Barker code word, with each bit consisting of 4 cycles of the 40 kHz carrier was used.

Digitized representative echoes were used as reference vectors for correlation to account for the effect of the impulse responses of the transducers, the air, and the reflection, on the transmitted pulse.

In a detection cycle, the coded pulse was transmitted; the A/D converters took 2600 samples at the 150 kHz sampling rate to capture any echoes from objects between 1 and 4 meters in front of the cane. The receiver data was cross-correlated with the stored echo image to find echoes in the received signal.

The correlation peak positions from the upper receiver were then compared to the peak positions from the lower receiver and if they collaborated within the synthetic aperture, the range and height were calculated annunciation was made by a synthesized voice.

The new obstacle detection system described above was designed and a prototype was constructed and embedded into the shaft of an 18 mm diameter body of a long cane.
Introduction

INTRODUCTION

The objective of this research was to investigate ultrasonic ranging techniques to enhancethe performance of the sensor embedded long-cane travel aid for the sight impaired. Thelong cane, as the most widely used and accepted travel aid of the sight impaired, leavesits users at risk of sustaining head and upper body injury from collision with protrudingor suspended obstacles [1].

The long-cane can feel the nature of a path and detect holes,curbs, steps, and obstacles on the ground, however, as Figure 1 shows, suspended orprotruding obstacles above waist height cannot be detected with a traditional long-cane.

Hanging plants, tree branches, and guy wires are just a few of the common obstacles thatcan injure the user of a long cane. This limitation can be corrected by embedding anelectronic collision warning system into the body of a long cane to detect such obstacles,while maintaining the platform that is well accepted by the sight impaired community.

Embedding an ultrasonic sensor system into a long-cane will reduce the risk of injuryfrom walking into suspended or overhanging objects while providing the sight impairedcommunity with a familiar and well accepted tool. Prior research efforts have shown thefeasibility of this solution [2].

The challenge was to achieve the robustness and reliabilitynecessary to be of practical use.
The significance of this research is illustrated by the size of the population that stands tobenefit.

According to the American Foundation for the Blind [1] there are approximately10 to 11 million blind and visually impaired people in North America and every sevenminutes, someone in America will become blind or visually impaired [3]. In 1994-95, 8.1million people were estimated to have a functional limitation in seeing and there wereapproximately 1.3 million Americans who reported legal blindness (a rate of 5 per 1,000).

There are 130,000 users of the long-white cane in North America alone. With theincrease of the elderly population and Macular Degeneration, this figure is expected todouble by 2015. The long-white cane is the most popular and accepted travel aid for thevisually impaired community.

According to the estimates of the World HealthOrganization [3], there are some 180 million people worldwide today with visualdisability and between 40 and 45 million persons are blind and cannot walk aboutunaided.The significance of this research is illustrated by the size of the population that stands tobenefit. According to the American Foundation for the Blind [1] there are approximately10 to 11 million blind and visually impaired people in North America and every sevenminutes, someone in America will become blind or visually impaired [3].

In 1994-95, 8.1million people were estimated to have a functional limitation in seeing and there wereapproximately 1.3 million Americans who reported legal blindness (a rate of 5 per 1,000).

There are 130,000 users of the long-white cane in North America alone. With theincrease of the elderly population and Macular Degeneration, this figure is expected todouble by 2015.

The long-white cane is the most popular and accepted travel aid for thevisually impaired community.

According to the estimates of the World HealthOrganization [3], there are some 180 million people worldwide today with visualdisability and between 40 and 45 million persons are blind and cannot walk aboutunaided.

1.1. Present State of Knowledge in Electronic Travel AidsResearch efforts aimed at developing Electronic Travel Aids (ETAs) to enhance themobility of the visually impaired can be traced back to the early 1960s.

A wide range ofETAs have been developed that can be used alone or in conjunction with primary aids suchas guide dogs or long-canes [4].

Only the most significant examples are presented here.Most ETA's can be grouped into one of two categories: environmental sensors or clearpath indicators [4]. Environmental sensors attempt to compensate for lost vision byproviding spatial information to functioning senses such as hearing or touch.

This'alternate vision' using functioning senses is to enable the visually impaired to performlike sighted people. Clear path indicators acknowledge that many blind persons can travelindependently without using any electronic aid and therefore only provide limitedinformation to supplement and interact with their already highly developed mobilityskills.

1.1.1. Environmental Sensors

Environmental sensors use the sight impaired user's functioning senses (auditory ortactile) to create a virtual mental image of the space ahead.

The problem is the signalsproduced are complex and difficult to interpret, and interfere with the direct sensing ofthe environment. A typical example is the *Sonicguide*developed by *Leslie Kay* [4] whichwas a head mounted device resembling a pair of glasses with a sensing range up to 5meters within a field of view of approximately 50° .

The device sensed the reflectedfraction of the emitted ultrasonic beams and transposed the ultrasonic frequency into theaudible spectrum.

The resulting signal heard through an earphone was a complex soundpattern containing information about the distance, direction and the surfacecharacteristics (hard or soft, rough or smooth, etc.) of the obstacles from which theultrasonic energy was reflected [6].

Comparisons in a real world setting between blindpedestrians using the Sonicguide along with the long cane and those who used long caneonly demonstrated a measurable improvement by the Sonicguide users in terms oforientation, reduction of bodily contacts with obstacles and continuousness of walking.However, evaluations from psychologists, mobility teachers and blind people have shownthat the signal produced by the Sonicguide was difficult to interpret, required specialtraining to apply effectively, and masked direct environmental cues [7].

Jorgensen patented a hand held echo location system [8] which delayed the received echo toimprove perception. He utilized a hand held ultrasonic emitter, which could be pointed inany direction and a microphone to receive the echoes. The echo signal was stretched overtime to make them interpretable and then converted to an audible frequency signal the usercould hear. Together with the attenuated initial burst, this stretched echo enabled the user toconstruct a mental picture of the obstacles in the direction pointed in. While technicallysuccessful, this had the disadvantage of disrupting the ordinary hearing of the user. Also thecost was potentially high.

Similarly, Ifukube et al [9] designed and built an echo location device modeled after thatof the bat.

The device was located on a pair of eyeglasses and used down swept FM soundsfrom 70 to 40 kHz, emulating the location method used by most bats. The signals werepicked up by a two channel receiver, processed into 8192 sampling points, and thenconverted into an audible signal.

Testing has demonstrated that a user can perceive fineobjects (a few millimeters in size) at a range of 1 meter. However, this device also obstructsthe user's normal hearing of the environment.

1.1.2. Clear Path Indicators

Clear path indicators provide a simple "go" or "no-go" warning signal indicatingwhether or not it is safe to proceed along the path of travel. This class of mobility aid isgenerally used in conjunction with other primary aids such as the long cane or a guidedog. A true clear path indicator only provides the minimum information necessary toindicate an obstruction.

Typical examples of this type of aid are the Nottingham ObstacleDetector (NOD), the Mowat Sensor, the Sonic Pathfinder, and the Laser Cane.

The *Nottingham Obstacle Detector* (NOD) is a pocket-sized, flashlight (torch) shaped,hand-held unit that radiates ultrasonic pulses in a narrow beam about 2 meters ahead ofthe user [10]. Eight musical notes were used to indicate the distance to the nearestobstacle within this range. No special training was needed to use the device.

However, itwas found that the tones tended to drift resulting in possible misinterpretations and thedevice required active scanning by the user. The tones were also difficult to distinguish ina noisy environment and the unit provided no information as to the height or size of anobstacle.

Hoydal and Zelano's work [11] appears to be relevant in spirit to the NottinghamObstacle Detector.

They directly applied a Polaroid ultrasonic ranging system [12], andused an audible signal with a frequency inversely proportional to the distance of thetarget as output.

Tests were conducted on two blind individuals who confirmed thegeneral sensing capability of the device under normal environmental conditions.However, since the "flashlight-like" device is mounted in a PVC tube that must be handheld, its use interferes with the use of a long-cane which may limit its acceptance by theblind community.

The *Mowat Sensor* was a hand-held ultrasonic device that was based on the "singaround"principle [13].

The device detected the closest object in a four-meter range andindicated the distance by vibrating, the higher the vibration frequency, the shorter thedistance. Vibration of the device body in the range of 10-40 Hz was used to indicate thetarget's distance. Similar to the NOD, this device was simple to use, and the cost wasrelatively low.

However, blind users in evaluations did not favor the use of vibration asan indicator of distance, since it caused bodily fatigue.

The *Sonic Pathfinder* is a further development of the NOD, this ultrasonic aid is mountedon a spectacle frame and could sample the environment about 2.4 meters ahead of theuser within an arc of 120° [13].

Similar to NOD, descending notes of the major musicalscale were used as an audible indication of the decreasing distance to the target as theuser approached. The aid was easy to use, required no special training, and, since it wasplaced at the eye height, it provided much better head protection than the NOD or theMowat sensor.

Like other aid devices mentioned above, the Sonic Pathfinder must beused in conjunction with the long cane, due to the simple nature of its output signals.

The *Laser Cane* resembled the form of a long cane with a thick upper section into whichthree laser sensors were mounted. The laser cane used the triangulation principle to scanobstacles within three areas ahead of the users: obstacles lying on the travel path ahead,those above chest height, and discontinuities in the road surface (e.g. step downs).

Like aconventional long cane, the tip of the laser cane scanned in an arc across the travel path insynchronism with the forward motion of the user.

Three audible signals of 200, 1,600 and2,600 Hz were used to identify and display potential dangers within the three areasrespectively [4].

Evaluation by blind pedestrians showed that although the signals weresimple in nature, a relatively long period of learning under the supervision of professionalinstructors was required to handle the cane effectively.

This long training period as wellthe very high price (more than $2,000 apiece) and the special maintenance and servicerequired has prohibited the laser cane from gaining popularity.

The above cited efforts have not produced a widely accepted and functional travel aid forthe sight impaired community.

These early devices lacked good functionality, interferedwith the use of the reliable, traditional long cane, produce tones or beeps that distractedfrom listening to the environment, or were prohibitively costly.

Research efforts at theUniversity of Massachusetts Electro-Mechanical Systems Laboratory has been aimed atovercoming these deficiencies by creating a system that was easy to use, did not maskaudible environmental cues, complemented the use of the traditional long cane, and wasaffordable. Prior research has made considerable progress in embedding a sensor systemthat detected obstacles not normally detected by the long-cane into a long-cane.

The focus of this research is the investigation of coded-pulse and correlation techniques forultrasonic ranging to improve the robustness of the embedded obstacle detection system.False alarms must be minimized while still providing a high level of obstacle detection.Not only must obstacles be detected, their threat must be assessed in terms of thedetecting capabilities of the long-cane.

INTELLECTUAL CONTRIBUTION AND CONCLUSIONS

7.1 Intellectual Contributions

In this research digital signal processing techniques were applied to develop a method forusing encoded ultrasound waves and correlation to improve TOF measurements from theplatform of a long-cane.

A filtering algorithm or "*Synthetic Aperture*" was derived to filter correlation peaks anddiscriminate between obstacles in area of interest and those that do not pose a threat. The"*Synthetic Aperture*" algorithm accomplishes this task with a low computational loadingof the microcontroller.

A low power, miniaturized electronic circuit to implement the algorithm from a longcaneplatform was developed.A physical cane housing for the detection system with the *look and feel* of a long-canewas designed to enhance the acceptance of the sensor embedded technology by the sightimpaired community.

7.2 Conclusions

Through the efforts of this research significant improvements have been made to theSensor Embedded Long-Cane in both the mechanical form and the computationaldetection algorithms areas.

A filtering algorithm or "Synthetic Aperture" for thediscrimination of obstacles by position and the elimination of false positives wassuccessfully derived, implemented and tested and a new prototype Sensor EmbeddedLong-Cane having the look and feel of a standard long cane was developed.

References

1. S.jindal ,B.p. Nandwana,N.S. rathore ,v.Vashishtha ,Experimental investigation of the effect of compression ratio and injection pressure in a direct injection diesel engine running on jatropha methyl ester ,applied thermal engg. Vol. 30 ,pp 442-448,2010

2. Biodiesel from Jatropha Oil as an Alternative Fuel for DieselEngineKaziMostafijurRahman, Mohammad Mashud, Md. Roknuzzaman and Asadullah Al Galib Department of Mechanical Engineering,Khulna University of Engineering and Technology (KUET)Khulna-9203, Bangladesh.

3. Emission Characteristics of Jatropha - Dimethyl Ether Fuel Blends on A DI Diesel Engine M. Loganathan , A. Anbarasu& A. Velmuruga

4. Biodiesel production: a review1 FangruiMaa, Milford A. Hannab,*a Department of Food Science and Technology, University of Nebraska, Lincoln, NE, USA b Industrial Agricultural Products Center, University of Nebraska, 211 L.W. Chase Hall, Lincoln, NE 68583-0730, USA Received 24 March 1998; revised 16 December 1998; accepted 2 February 1999

5. Extraction of biodiesel from Jatropha oil and performance study of diesel engine with biodiesel fuels *Ayush Kumar Raghuvanshi, **C P Singh *Mechanical Engineering Department of JSSATE Noida **Mechanical Engineering Department of JSSATE Noida

6. Experimental investigations on jatropha biodiesel and additive in diesel engineY.V.Hanumantha Rao1, Ram Sudheer Voleti1 , A.V.Sitarama Raju2 and P.Nageswara Reddy31Dept of Mechanical Engg., KoneruLakshmaiah College of Engg., Green Fields, Guntur-522502, AP, India.2Dept. of Mechanical Engg., Jawaharalal Nehru Technol. Univ. College of Engg, Kakinada-533003, Andra Pradesh.3Balaji Institute of Technolgy& Science, Narasampet-506331, Warangal Dt, Andhra Pradesh.

7. Engine Performance Test of Cottonseed Oil Biodiesel Xiaohu Fan1, Xi Wang*,2, Feng Chen1, Daniel P. Geller3 and Peter J. Wan1

8. Experimental analysis on engine performance and emission Carateristics using Biodiesel Obtained form Non edible oil.A.M. Liaquat, H.H. Masjuki,M.A. kalam

9. Combustion characteristics of a turbocharged DI compression ignition engine fueled with petroleum diesel fuels and biodiesel pyre 1982

10. Blazek J.Computational fluid dynamics—principles and applications.1sted..Oxford, UK:Elsevier;2001.

11. Garg HP,Prakash J.Solar energy fundamentals and applications.1sted.. New Delhi:TataMcGraw-Hill;2000.

12. Duffie J A, Beckman W A.Solar engineering of thermal processes.2nded..New York:Wiley;1980.

13. PatankarSV.Numericalheattransferandfluidflow.1sted..USA:Hemi-

14. sphere PublishingCorporation;1980.

15. Tannehill JC, Andeson DA, Pletcher RH. Computational fluid mechanics and heat transfer.2nded..London: Taylor &Francis;1997.

16. Versteeg H K, Malalasekera W.An introduction to computational fluid dynamics. 2nded..England: Pearson Education Limited;2007.

17. Kumar A, Bhagoria J L, Sarviya R M. Heat transfer and friction correlations for artificially roughened solar air heater duct with discrete W-shaped ribs. Energy Conversion and Management2009;50:2106–17.

18. Mittal M K, Varun R P, Singal S K. Effective efficiency of solar air heaters having different types of roughness elements on absorber plate. Energy 2007;32:739–45.

19. Prasad B N, Saini J S. Optimal thermo hydraulic performance of artificially roughened solar air heaters. SolarEnergy1991;47(2):91–6.

20. Prasad B N, Saini J S. Effect of artificial roughness on heat transfer and friction factor in a solar air heater. Solar Energy1988;41(6):555–60.

21. Aharwal KR, Gandhi BK, SainiJS. Experimental investigation on heat-transfer enhancement to a gap in an inclined continuous rib arrangement in a rectangular duct of solar air heater. Renew Energy2008;33:585–96.

22. Muluwork KB.Investigations on fluid flow and heat transfer in roughened absorber solar heaters. PhD thesis. IIT Roorkee, India;2000.

23. PrasadK, Mullick SC.Heat transfer characteristics of a solar air heater used for dryingpurposes.AppliedEnergy1983;13:83–93.

24. Gupta D,SolankiSC,SainiJS.Heatandfluidflowinrectangularsolarair

25. heaterductshavingtransverseribroughnessonabsorberplates.Solar

Energy 1993;51(1):31–7.

26. Verma SK, Prasad BN.Investigation for the optimal thermo hydraulic performance of artificially roughened solar air heaters.RenewalEnergy2000;20(1):19–36.

27. KarwaR. Experimental studies of augmented heat transfer and friction in asymmetrically heated rectangular ducts with ribs on heated wall in transverse, inclined, v-continuous and v discrete pattern. International communications in Heat and MassTransfer2003;30(2):241–50.

28. Vijay Singh Bisht, Anil Kumar Patil, Anirudh Gupta, Review and performance evaluation of roughened solar air heaters, Renewable and Sustainable Energy Reviews,Volume 81, Part 1, 2018