A Review On Various Techniques Used For Material Identification Using Acoustic Signal Processing

Vishal Agarwal, Shubham Kapse, Kishori Shimple, Dr.Javed Shaikh

Abstract: Since the dawn of robots, researchers have always attempted to give robots the ability to interact with the surroundings objects similar to humans. But to interact with physical objects one must know the material of that object. As the material changes the precaution needed to handle that object also changes. We cannot handle wood and glass in similar fashion. Over the years a lot of research has been done in this field to achieve better performance. In this review paper, we have studied and discussed all previous work done on this topic. This paper contains basic review of previous work as well as their merits and demerits. Finally, a tabular comparison has been given toward the end of the paper in order to conclude the discussion.

Key words: Signal processing, Absorption coefficient, Material identification

1 INTRODUCTION

Future intelligent robots are envisioned to be endowed with perceptive capabilities to see, touch and hear what is happening in the ambient world, which would enable robots to perform various tasks with material based object recognition being among the most common ones. The ability to recognize materials plays an important role in how we interpret our surroundings and interact with the environment. Human beings have the remarkable ability to represent object knowledge using multiple modalities, including vision, touch, and proprioception. More than 40 years of research state that the foundations of object categorization are given from exploratory behaviors and sensations during human infancy [1][2]. Research in psychology has shown that multiple modalities are required to capture object properties such as strength, roughness, and stiffness [3]. In contrast, most object recognition systems used in robotics today use almost exclusively computer vision techniques and thus rely on a single modality. Computer vision is an effective tool for recognizing object but information retrieved from image is insufficient in identifying material of that object. Such systems suffer from several limitations. For example, using vision alone robot cannot distinguish between glass, plastic or metal utensils. As material changes handling parameters also change thus making material identification one of the most important ability for robots. Material identification implies giving robotic system an ability to identify the material of the object they are handling.

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This ability comes in handy when system need to perform functions without human interactions. Such systems can easily understand difference between plastic toy gun and real metal gun. To date lot of work is done in identifying materials, specifically metals by using various techniques like analyzing electric properties of material such as resistance or capacitance or by analyzing magnetic properties, thermal and IR testing. However, to restrict the scope of this study we focused specifically on identification using Acoustic techniques.

2 TECHNIQUES FOR MATERIAL IDENTIFICATION

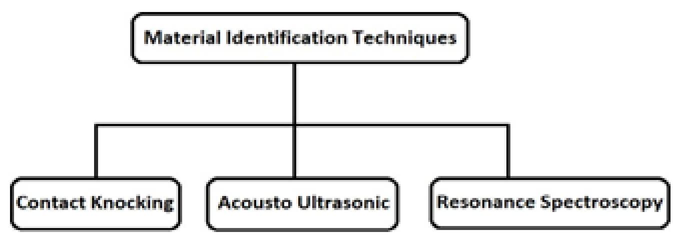

Fig. 1 *Flowchart showing existing techniques*

A. Contact knocking:

Contact knocking is a destructive test method, in which the test object is gently tapped to generate the sound. Generated sound is recorded and its frequency components are identified using fast Fourier transform algorithm. Also some other features of sound like timbre and tune are observed. Contact knocking works on the principle that sound is a molecular oscillation of kinetic energy moving through a medium in form of a mechanical wave [4]. When an object is hit, the energy of impact causes deformations to propagate through the object, causing its outer surface to vibrate and emit the sound wave [5]. This sound signal exposes theintrinsic properties of object such as elasticity and internal friction [6]. The elasticity of the object is directly related to the speed of sound wave in object and therefore influences the frequency of the sound. The internal friction determines how generated sound decays over time [6][7]. Therefore, material composition can be deduced by analyzing these acoustic properties.

B. Acousto ultrasonic:

Acousto ultrasonic is a non-destructive test method. Here ultrasonic signal is incident on test material and by analyzing reflected signal, absorption coefficient for different material type is calculated and compared to ideal case. Basically Acousto-ultrasonic deals with acoustic impedance. The acoustic impedance of an object is defined as a product of density and acoustic velocity propagated in the object. Depending on physical composition of the material, every material has different acoustic impedance. Therefore, the difference in acoustic impedance between measured object gives the sorting a key for material identification. Since the method contains transmission and reception of sound, combining this method with time of flight technique, shape can also be identified [8].

C. Resonance Spectroscopy:

Acoustic resonance spectroscopy is non-destructive test method, used to identify liquids and their compositions. It works on the principle that when forced vibration is generated due to impact of an external excitation, that system starts to vibrate but that vibration is maximum when the vibration frequency matches the natural frequency of the system. This phenomenon is called as resonance. This technique uses this acoustic property of liquids and try to find the natural frequency of the test material, which helps to identify the liquids since natural frequency is dependent oncomposition of liquids. Every liquid has unique natural frequency and also it gets altered by dissolving impurities in the liquid.

3 DISCUSSION

This section deals with survey of various previous papers on material identification using acoustic signal processing. Table I gives clear idea of various successful papers written on various methods. From application point of view, we see that Acousto-ultrasonic method provides much accurate and reliable results [9]. It is non-destructive as well as capable of identifying shape of symmetric objects [8]. We also see that contact knocking provides good results but it involves an additional task of knocking the object which takes time. Resonance spectroscopy gave satisfying results in liquid identification, but there was no work in solids so its scope is unpredictable.

4 CONCLUSION

Material Identification is a challenging problem in the field of engineering. It has the wide range of application in industrial and household robots. It can also be used in waste separation and or mineral identification. In this paper different material identification using acoustic signal processing are discussed. On can use any of them as per their requirements and application. One can also work over to improve the efficiency of the discussed algorithms and improve performance.

TABLE I

LITERATURE SURVEY SUMMARY

Sr. No.	*Paper*	*Methodology*	*Results*	*Remark*
1	*"A simple identification method for object shapes and material using ultrasonic sensor array" By M. Baba et al. (2006) [8]*	*This paper develops a neural network based system on the basis of reflection ratio and reflected signal's ultrasonic pressure distribution*	*This system gave 100% accurate results for shape identification and almost 95% accurate result for material identification*	*This system was tested in range of 200 mm to 290 mm at operating frequency of 40 KHz*
2	*"Ultrasonic sensor for industrial inspection based on the acoustic impedance" By Juan José González España et al. (2015)[9]*	*This paper develops small and portable system using peniel method for material identification*	*This system gave 100% accurate results for material identification*	*This system identified material by being in contact with test object and worked on 125 KHz operating frequency*
3	*"Preliminary study of using acoustic signal for material identification in underwater application" By Sien Yan Kong et al. (2013)[10]*	*This paper develops underwater material identification with single transreciever by calculating reflection coefficient*	*This system gave near perfect to satisfactory result depending on the test materials*	*This system was tested at 25 KHz operating frequency and 20 cm test distance.*
4	*"Material characterization in situ using ultrasound measurements" By G. P. P. Gunarathne et al. (2000)[11]*	*This paper develops a curvature compensation algorithm to identify sludge deposited inside of the pipelines.*	*This system gave near perfect results.*	*This system identified sludge material in situ using acoustic impedance*
5	"Acoustic resonance spectroscopy based simple system for spectral characterization and classification of materials" By Munna	This paper identifies fluid materials based on their resonance frequency	This system successfully identified various solution of water, water + salt & water + sugar etc.	This system identifies material by being in contact to liquid

	Khan et al. (2018)[12]			
6	“From acoustic object recognition to object categorization by a humanoid robot” By Niko Sinapov et al.[13]	5 exploratory behaviors are tested on 36 objects and obtained natural sound is represented as a state diagram to classify objects	Gave 72.84 % result for object detection and 83.33 % in case of category detection.	5 exploratory behaviors like grasp, shake, drop, push, and tap were done. Robot formed a hierarchical taxonomy of interacting objects
7	“Classification of materials by acoustic signal processing in real time for NAO robot” By Edgar Lopez-Caudana et al. (2017)[14]	NAO robots use audio signal acquisition & its real time processing, FFT is used to check for the frequency & classify the objects.	The robot can successfully classify cardboard, aluminum, and plastic which falls under a specific ranges but fails for materials with most alike frequency range	The system was developed to classify waste products that are found at public places.
8	“Interactive object recognition using proprioceptive & auditory feedback” By Jivko Sinapov et al. [15]	5 exploratory works are performed on 50 different objects & then a self-organized map is used to convert high dimensional modalities in sequence on map.	The average accuracy for auditory behaviors was 51.6 % and for proprioception was 45.1 %	50 different objects using five exploratory behaviors (lift, shake, drop, crush, and push) were tested
9	"Knock-Knock: Acoustic Object Recognition using Stacked Denoising Autoencoders" By Shan Luo, Leqi Zhu, Kaspar Althoefer et al. [16]	A deep learning framework using acoustic data in which, stacked de-noising auto encoders are used to train a deep learning model which use marker pen for knocking	A high accuracy of 91.50% was achieved. A recognition rate of 82.00% was achieved when using a shallow classifier.	30 different objects were knocked 30 times with marker pen to obtain results with 91.50 % accuracy.
10	"Characterising the Sound Amplitude and Force Feedback for Various Materials in Tele- Haptic Operation" By Crankson Kwesi Mensa, Eu Kok Seng and Kian Meng Yap et al. (2016)[17]	An application is developed which is able to differentiate materials by using the Sound Spectrum Graph giving us a vivid difference in the sound and frequency levels for each material	Sound spectrum graph of wood and metal is analyzed and it is observed that wood shows peak of 36 dB to 40 dB whereas, metal shows peak of 40 dB to 48 dB.	This paper focuses on technology which enables telerobots to identify materials in the performance of its duties in rescue missions.
11	"Object Identification Using Knocking Sound Processing and Reaction Force from Disturbance Observer" By Watcharda Hamontree, Chowarit Mitsantisuk et al. (2015)[18]	In this paper, the combined method of force response and knocking sound is proposed. Object is knocked using robot, then the force response is observed by a disturbance observer	Then FFT of force response graph is done which gives us a phase plot which is analyzed to classify the different objects.	Sound signal comes with high noise thus force signal was combined to reduce error

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