Design Analysis of the Footsteps Identification through the Recognition of Home Occupant Walking Habits

Eko Polosoro*, Jazi Eko istiyanto, Agfianto Eko Putra*****

* Department of Computer Systems, Faculty of Information Technology, Budi Luhur University
** Department of Computer Science and Electronics, Faculty of Mathematics and Natural Sciences, Gadjah Mada University
*** Department of Computer Science and Electronics, Faculty of Mathematics and Natural Sciences, Gadjah Mada University

Keywords:
footsteps,
classification,
digital fourier transform,
power spectral density.

ABSTRACT

Human activities will produce different types of sounds and vibrations. The sounds and vibrations generated by human activities can be used for various purposes, among others, to identify or to know the position of their presence in a room.
In this paper proposed the method for identifying humans by their footsteps. The Identification is done by recognizing sounds and vibrations generated by human footsteps.
We also developed algorithm to clasify the detection of the human footsteps recognition, starting from the analysis of sounds and vibrations detection using geophone and microphone. The analysis was necessary to classify sounds and vibrations of footsteps with the sounds and vibrations of the surrounding environment.
From this research it is expected to know the traits of human footsteps, henceforth they can be used as identification of a person as the voice of utterance. That is due to the fact that the noise and vibration generated from footsteps are influenced by the weight, distance, shape of the sole of the foot, footsteps rhythm, gait and other factors.
The differences in footsteps can be known from the power spectral density of sounds and vibrations generated by footsteps. Every footstep of the human has a certain density of frequency, either from density of sounds or vibrations generated.

Corresponding Author:
First Author,
Department of Computer Systems, Faculty of Information Technology, Budi Luhur University,
Jl.Raya Ciledug, Jakarta, Indonesia [1)].
Office Phone. : +62215853753, Hp: +6281807578400 [1)]
E-mail : eko,polosoro@budiluhur.ac.id [1)]

1. INTRODUCTION

The sound signal and the like is a topic that still draws attention and still be the object in current research. The rapid development of research in the field of signal processing can be seen by considering the issues in some leading journals. Application of digital signal processing, however, has various problems. One of the topics in signal processing is for the recognition of human footsteps that generate sounds and vibrations. Footsteps have different characters from one person to another. The difference can be seen in digital quantization.

In this paper, the recognition of footsteps was delivered by doing voice detection and vibration generated by footsteps. By researching the footsteps it is expected to obtain unique values, so that one person’s footsteps can be differentiated from others.

If the steps have significant differences then it will be a lot of things can be done with the recognition of footsteps. Thus, the character of footsteps could be used as one of forensics indicators, for identification like human fingerprints. The recognition of the character of the human footsteps in this research is to identify a person's footsteps in a limited scope, namely: broad limitation of space, type of flooring and footwear.

2. RELATED WORKS

Many studies on sensing footsteps, with a variety of methods and also with different approaches. Well, here are some reviews of research related to foot steps, among others:

Shoji, Y et al [1] in their paper present that the feature extraction of a footstep is investigated. If a footstep is discriminable, the application to various fields can be considered. Shoji et al. focus on the recognizing a certain kind of footstep waveforms under the restricted condition. The propose a new methodology using the feature parameter such as the peak frequency set by the melcepstrum analysis, the walking intervals and the similarity of spectrum envelope. It is shown for personal identification that the performance of the proposed method is effective.

In their work, Iyengar, S.G. et al [2] present a copula-based framework for integrating signals of different but statistically correlated modalities for binary hypothesis testing problems. Specifically, Iyengar, S.G. et al consider the problem of detecting the presence of a human using footstep signals from seismic and acoustic sensors. An approach based on canonical correlation analysis and copula theory is employed to establish a likelihood ratio test. Experimental results based on real data are presented.

Itai, A. and Yasukawa, H. [3] in their paper purpose that the characteristics of a footstep are determined by the gait, the footwear and the floor. Accurate footstep analysis would be useful in various applications, home security service, surveillance and understanding of human action since the gait expresses personality, age and gender. The feasibility of personal identification has been confirmed by using the feature parameter of footsteps, however, the recognition rate of this method decreases as the number of subjects increases. In their paper Itai, A. and Yasukawa, H. applies psycho-acoustics parameter to feature extraction. Results show that the parameter proposed herein yields effective and practical personal identification.

Yukang Guo and Hazas, M. [4] at their paper present while a number of acoustic localisation systems have been proposed over the last few decades, these have typically either relied on expensive dedicated microphone arrays and workstation-class processing, or have been developed to detect a very specific type of sound in a particular scenario. However, as people live and work indoors, they generate a wide variety of sounds as they interact and move about. These human-generated sounds can be used to infer the positions of people, without requiring them to wear trackable tags.

In their paper, Yukang Guo and Hazas, M. take a practical yet general approach to localising a number of human-generated sounds. Drawing from signal processing literature, we identify methods for resource-constrained devices in a sensor network to detect, classify and locate acoustic events such as speech, footsteps and objects being placed onto tables. Yukang Guo and Hazas, M. evaluate the classification and time-of-arrival estimation algorithms using a data set of human-generated sounds we captured with sensor nodes in a controlled setting. And they are show that despite the variety and complexity of the sounds, their localisation is feasible for sensor networks, with typical accuracies of a half metre or better. We specifically discuss the processing and networking considerations, and explore the performance trade-offs which can be made to further conserve resources.

Schumer, S. [5] in her paper concluded that a method of combining multiple seismic geophone signals to reduce noise and improve SNR was demonstrated in this paper. It has been shown that applying this method will lower false alarm rates and improve classification capabilities. Additionally, localization characteristics can be determined on a multi-axis fused signal to model expected behavior of a human target when traversing a seismic sensor’s field of detection. This method may have benefits when detecting other targets and has the potential to be expanded into multiple modalities.

2. RESEARCH METHOD

Digital signal processing is related to the representation of signals using symbols or the systematic processing. The purpose of the processing is to estimate the parameters of the signal characteristics or to change the signals form to some desirable ways. The classic formula of numerical analysis: as they were designed for interpolation, integration, and differentiation, is a digital signal processing algorithms Naturally.

In this study we focus on the sound and vibration generated by footsteps with a detection method simultaneously with the geophone and microphone to detect the frequency range under 250 Hz. This is because geophone has sensitivity below 250Hz (BLASMATE III), whereas for the microphone, we will use a special microphone with sensitivities at low frequency; that is the microphone used on instruments of music. The recognition of the character voice of footsteps using DFT method is to determine the power of spectral density.

In this paper the detection system is designed as shown in Figure 1. In Figure 1 the sensing of human activity is shown, then the analysis is conducted. From the analysis of human activity then further analysis is conducted related to environmental sensing results. This is done to know original voice signal and vibrations generated by footsteps. Some environmental factors that can affect the sound and vibration are generated by the environment, such as sounds and vibrations of motor vehicles, air conditioning, household appliances or office etc.

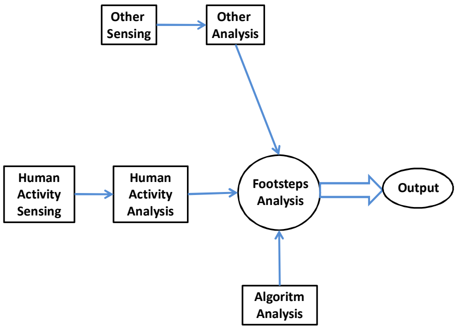

Figure 1. Detection system design

Then analysis is conducted to classify sounds or vibrations that are shown in Figure 2. Signal classification algorithm is required to classify the type of signal which is detected by the microphone or geophone. We can obtain the signal of footsteps detected as a result of the classification. Then from the recognition of footsteps it would be able to distinguish between a person's footsteps and other people's. If there is an unrecognized foot step during analysis phase, it will be classified as anomaly. The footsteps that are classified as anomalies can have many possibilities. The cause of this anomaly can be: one's psychological condition, a new resident, guest, intruder-owned or may be due to a worn out/ broken detector.

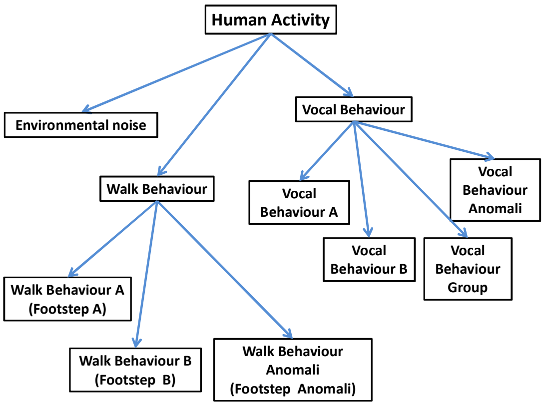

Figure 2. Signal classification algorithm

In Figure 3. the system configuration is shown. In this configuration the signal received by the geophone and the microphone will be forwarded to the computer by a sensor peripheral interface through the shield and the Arduino Mega. This peripheral interface not only has a function as an intermediary but also as a controller of the geophone and microphone. The interface peripheral, the geophone and microphone are connected to the computer wireless.

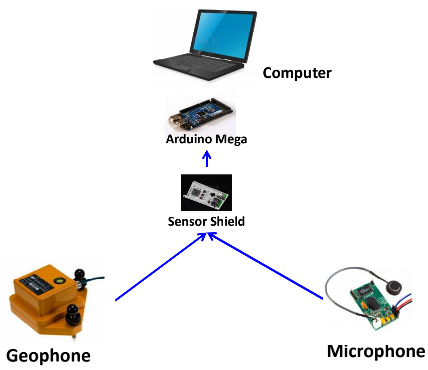

Figure 3. System configuration

The detection system of Algorithm Design either geophone or microphone is shown in Figure 4. It is shown that the detection is started with initialization node, that is the interface for geophone and microphone. This initialization is performed on the sensor shield and Arduino Mega, then the address is configured. After the setting is completed then the geophone and microphone are ready to detect the sounds and vibrations generated by the footsteps. After doing the data acquisition (sounds and vibrations detection) we used DFT as the algorithm to figure out the power spectral density of each detected footstep.

The reverse of the DFT is calculated simply by applying the Fourier transform again, and reversing the resulting buffer (to be precise, because of our normalization, should also divide the resulting samples by N). By reversing, that mean reading the buffer from back to front.

The components of the DFT are complex numbers, and they have a modulus and a phase. The modulus of V[k], sqrt (V[k]*V*[k]), describes the intensity of the particular frequency corresponding to k (more precisely, because of our normalization, should divide the modulus by sqrt(N)). The phase of a given component describes the phase shift of this component at what angle it starts its oscillations.

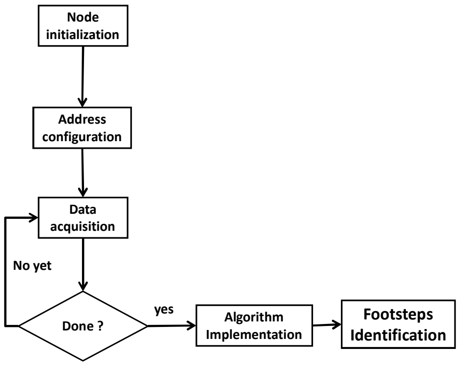

Figure 4. Detection system design both geophone and microphone

3. CONCLUSION

The differences of footsteps can be known by the power spectral density of sound and vibration generated by footsteps. Every footstep of the human has a certain density of frequency, of generated sounds or vibrations. The difference between one's footstep and others' will be more accurately distinguishable by detecting footsteps simultaneously, that is by using geophone and microphone.

Geophone and microphone have sensing with each characteristics, so that by doing the simultaneous detection, the accuracy of foot step identification can be more believable obtained. This was intensified by the power spectral density that is processed using DFT.

ACKNOWLEDGEMENTS

We wish to thanks A.Harjoko and E.Winarko for discussions and suggestions on this work.

REFERENCES

[1] Y. Shoji, A. Itai and H. Yasukawa *"A study on footstep detection for personal recognition. "Nonlinear Signal and Image Processing, 2005. NSIP 2005. Abstracts. IEEE-Eurasip Digital Object Identifier*: 10.1109/NSIP.2005.1502271. Publication Year: 2005.

[2] S.G. Iyengar, P.K. Varshney and T. Damarla, "*On the Detection of Footsteps Based on Acoustic and Seismic Sensing."* Signals, Systems and Computers, 2007. ACSSC 2007. Conference Record of the Forty-First Asilomar Conference on Digital Object Identifier: 10.1109/ACSSC.2007.4487641. Publication Year: 2007 , Page(s): 2248 – 2252.

[3] A. Itai, H. Yasukawa, "*Footstep Recognition with Psyco-acoustics Parameter*." Circuits and Systems, 2006. APCCAS 2006. IEEE Asia Pacific Conference on Digital Object Identifier: 10.1109/APCCAS.2006.342254. Publication Year: 2006 , Page(s): 992 – 995.

[4] Y. Guo and M. Hazas, "Localising speech, footsteps and other sounds using resource-constrained devices." Information Processing in Sensor Networks (IPSN), 2011 10th International Conference on Publication Year: 2011 , Page(s): 330 – 341.

[5] S. Schumer, "*Analysis of human footsteps utilizing multi-axial seismic fusion*". Acoustics, Speech and Signal Processing (ICASSP), 2011 IEEE International Conference on Digital Object Identifier: 10.1109/ICASSP.2011.5946499 Publication Year: 2011 , Page(s): 697- 700

BIBLIOGRAPHY OF AUTHORS

Eko Polosoro Drs., M.Eng., M.M.
Contact Address : Sekip Utara Kotak Pos BLS 21
Office Phone/Fax : +62 21 585 3753 / +62 274 546194
Office E-Mail : eko.polosoro@budiluhur.ac.id
Alternate E-mail : eko.polosoro@gmail.com
Department : Computer Systems
Teaching and Supervision Expertise: S2
Status : Active

Education Background :

- Master, Opto-electrotechnics and Laser Application, University of Indonesia, Indonesia, 1995.
  Thesis : Voice Recognition Methode by Implementation of The DFT for Determining The Power Spectral Density.
- Undergraduate, Physics, Gadjah Mada University, Indonesia, September 1980 - 1987.
  Thesis : Observation Services On ROM-BIOS Systems.

Research Interest / Cluster/Group:

- Embedded Systems, Disgital Systems Optimization./ Digital Automation Systems.

Work Experience :

- Lecturer, February 1988 - Present, Budi Luhur University.

Society Membership :

- APTIKOM (Indonesian Association of Computer Science Universities), National, 2007.
- Chairman APTIKOM Chapter III DKI Jakarta 2011 – 2015.

Prof. Jazi Eko Istiyanto Ph.D, M.Sc., MIET., MIEEE
Contact Address : Sekip Utara Kotak Pos BLS 21
Office Phone/Fax : +62 274 546194 / +62 274 546194
Office E-Mail : jazi@ugm.ac.id
Alternate E-mail : jaziugm@gmail.com
Department : Computer Science & Electronics
Website : www.jazieko.com
Teaching and Supervision Expertise : S3
Status : Active

Education Background :

- Doctor, Electronic Systems Engineering, University of Essex, United Kingdom, October 1991 - May 1995.
  Thesis : The Application of Architectural Synthesis to the Reconfiguration of FPGA-based Special-Purpose Hardware
- Master, Computer Science, University of Essex, United Kingdom, October 1987 - September 1988.
  Thesis : The Design of a High-Speed Sorter
- Undergraduate, Physics, Gadjah Mada University, Indonesia, September 1980 - May 1986.
  Thesis : The Effect of Thermal Neutron Field on the Neutron Flux

Research Interest / Cluster/Group:

- Embedded Systems, Disgital Systems Optimization, Information security./ Computer System and Networks.

Award :

- Visiting Professor (1 Sept 2012- 31 Aug 2015), University of Essex, UK, 2012.

Work Experience :

- Lecturer, March 1988 - Present, Gadjah Mada University.

Society Membership :

- Institute of Electrical and Electronic Engineers (IEEE), International, 2012.
- Institution of Engineering and Technology (IET), International, 2012.
- IEEE Robotics and Automation Society, International, 2012.
- IEEE Computer Society, International, 2012.
- APTIKOM (Indonesian Association of Computer Science Universities), National, 2007.
- PII (Indonesian Association of Engineers), National, 1997.
- HFI (Indonesian Physical Society), National, 2011.

Dr. Agfianto Eko Putra M.Si
Contact Address : Sekip Utara Kotak Pos 21 Bulaksumur
Office Phone : +62274545185
Office Fax : +62274545185
Office E-Mail : agfi@ugm.ac.id
Alternate E-mail : agfi68@gmail.com
Department : Computer Science & Electronics
Website : agfi.staff.ugm.ac.id
Teaching and Supervision Expertise : S3
Status : Active

Education Background :

- Doctor, Physics, Gadjah Mada University, Indonesia, August 2007 - August 2010
  Thesis : Non-Stationary signal analysis based on Wavelet Signal Processing.
- Master, Physics, Gadjah Mada University, Indonesia,, August 1995 - August 1998
  Thesis : FIR Filter Implementation on Xilinx FPGA.
- Undergraduate, Physics, Gadjah Mada University, Indonesia, August 1986 - August 1992.
  Thesis : Penggabungan Algoritme Proyeksi Balik Tersaring dan Iterasi untuk rekontruksi Citra Tomografi.

Research Interest / Cluster/Group:

- Digital Signal Processing, Embedded Electronics, Satellite Systems./ Electronic and Instrumentation.

Work Experience :

- Technical Consultant, January 2007 - December 2008, Intesol Inc.Jakarta.
- Assistant Director for Electronics & Instrumentation, January 1996 - January 2000, Center of Informatioan and Technoly Services, Gadjah Mada University.
- Multimedia Expert, January 1995 - August 2000, Computer Center, Gadjah Mada University.
- Lecturer at Electronics & Instrumentation B.Sc. program, October 1994 - Present, Mathematics & Natural Sciences, GMU.

Trainner in Training :

- Applied Science Faculty, Science & Technology Institute (AKPRIND), Yogyakarta, Technical Assistance Content e-Learning, August 2008.
- LPPT, GMU, Pelatihan Maintenan Perbaikan Peralatan Laboratorium, July 2008
- MSG Engineering Faculty, Sanata Dharma University, Rekayasa Mikrokontroler dalam Industri, June 2005.
- Faculty of Mathematics & Natural Sciences, GMU, Pelatihan Success Skills, September 2004.