Lecture Notes in Bioengineering

Moumita Mukherjee · J. K. Mandal ·
Siddhartha Bhattacharyya ·
Christian Huck · Satarupa Biswas *Editors*

Advances in Medical Physics and Healthcare Engineering

Proceedings of AMPHE 2020

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Lecture Notes in Bioengineering

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Preface

Healthcare technology is a marriage between medical science and technology to offer humanity better health. With increasing life expectancy, there is a constant demand and scope of improvement in the healthcare industry around the world. With this idea, the Department of Physics, Adamas University, in collaboration with the School of Engineering and Technology, has organised the 1st International Conference—Advances in Medical Physics and Healthcare Technology—AMPHE 2020, to create a platform for global professional development in terms of scientific research for the healthcare providing community. The theme of the conference being interdisciplinary in nature has created considerable interest amongst students, researchers, and faculty members from biomedical engineering, biotechnology, medical physics, life sciences, material science, and also from electrical, electronics, and mechanical engineering backgrounds nurturing applications in biomedical domain. The conference had special sessions along with regular technical sessions to discuss emerging trends of applications in healthcare technology. AMPHE 2020 has been conducted in technical co-sponsorship with IEEE—Kolkata Section and IEEE—ED section.

Original contributions from the academicians, researchers, consultants as well as practising engineers associated with advances and recent trends in medical physics and healthcare engineering are presented in the conference. All the submitted papers have gone through the peer-review process by the technical program committee, and accepted papers (acceptance rate: 60%) are considered for publication in the proceedings. The tracks for invited talks and contributory papers are:

Electron devices, systems, and circuits for health care
Biomedical sensors and transducers
Biomedical signal processing, radar signal and data processing, speech, image, and video processing, information theory and coding, antennas and propagation, sensor networks, big data analytics
Spectroscopy, medical imaging, and image processing techniques
Biomaterials, tissue engineering, and drug delivery systems
Biophysical modelling and simulation
Bio-robotics and biomechanics

Machine learning, machine intelligence, IoT, IoHT, and AI in diagnostic and therapeutic systems
Neural and rehabilitation engineering
VLSI, nano-technology, nano-science, and nano-medicine
Medical physics and electronics, materials
Control systems, robotics, automation and vision
Modelling/simulation of devices
Communication, networking, biotelemetry
Photonics, optical technology in bio-engineering
Bio-informatics, bio-engineering
Innovative intelligent systems and applications.

The conference committee wish to acknowledge Springer Nature, for their support to publish the full-refereed proceedings in the Lecture Notes in Bioengineering. Special thanks to Editor Shri Aninda Bose for his technical support and guidance to organise the conference and in publication.

Kolkata, India

Prof. (Dr.) Moumita Mukherjee
Convener, IEEE AMPHE 2020

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About the Editors

Dr. Moumita Mukherjee is an alumnus of Presidency College (Kolkata) and Calcutta University. Dr. Mukherjee received M.Sc. (Physics) degree with specialization in Electronics and Communication, M.Tech. degree in Biomedical Engineering and Ph.D. (Tech.) degree in Radio Physics and Electronics (2009), University of Calcutta, India. She has worked as DRDO-Scientist under DRDO, Ministry of Defence, Government of India, till 2015. She obtained 'Visiting Scientist' position from Newcastle University, UK (2009–2011). She obtained PDF position from Technical University, Darmstadt, Germany (2010). Dr. Mukherjee is Visiting/Adjunct Professor and a member of Board of Studies of the Joint Academic program on Biomedical Instrumentation under Calcutta University and the West Bengal University of Health Sciences. In continuation of her position at DRDO, she joined Adamas University in 2015 and presently working as Professor—Department of Physics (Pure & Applied Science)—and Dean (Research & Development). She has guided more than 30 postgraduate thesis under Calcutta University & West Bengal University of Health Sciences, West Bengal University of Technology (WBUT) and Adamas University. She is presently guiding/completed 11 (Eleven) Ph.D. theses under Adamas University and WBUT as Supervisor/Jt. Supervisor. Her research interest is focused on THz electronics, semiconductor devices based on wide-band-gap semiconductors, graphene electronics, photosensors, nano-biosensors and medical electronics & instruments, and biomedical imaging. She has published more than 150 peer-reviewed research papers on THz electronics, semiconductor devices, biomedical electronics & instrumentation and photonics in reputed international refereed journals including IEEE, SPIE, Elsevier, Springer and reviewed conference proceedings with more than 850 citations globally with h-index 16. She is Principal Investigator of five industry funded research projects and one Government of India reserach project of worth ~ 65 Lakhs. She is a reviewer of a number of international peer-reviewed journals and editorial board member of international journals. She has worked as Volume Editor of ISBN numbered books published from UK and India. She has delivered a number of invited talks and presented several research articles in IEEE International Conferences in India and abroad.

Dr. Mukherjee has received National Merit Scholarship award from Government of India and was enlisted in 'Marques Who's Who in Science and Engineering' and 'Marques Who's Who in the World.' She has received 'IEEE best paper award' three times in 2009, 2010 and 2019, prestigious 'Best Scientist Award,' 'Bharat Gaurav Award' in 2015, Best paper award in Science and Technology Congress, India, in 2012, Best paper award in International Conference MICRO 2019.

Dr. Mukherjee is a member of IEEE (USA), IEEE-ED society (USA), and a life member of Biomedical Society of India, Indian Science News Association and Indian Science Congress.

Prof. J. K. Mandal M.Tech. (Computer Science, University of Calcutta), Ph.D. (Engg., Jadavpur University) in the field of Data Compression and Error Correction Techniques, and is Professor in Computer Science and Engineering, University of Kalyani, India. He is Former Dean Faculty of Engineering, Technology and Management 2008–2012 (two consecutive terms) and has 29 years of teaching and research experiences.

He served as Professor, Computer Applications, Kalyani Government Engineering College for two years. He served as Associate and Assistant Professor at the University of North Bengal for sixteen years. He is a life member of Computer Society of India since 1992 and a life member of Cryptology Research Society of India. He is a member of AIRCC. He is Honorary Chairman of CSI Kolkata Chapter 2016–2017. He is working in the field of network security, steganography, remote sensing & GIS application, image processing, wireless and sensor networks. He is Domain Expert of Uttar Banga Krishi Viswavidyalaya, Bidhan Chandra Krishi Viswavidyalaya, for planning and integration of public domain networks. He is Chief Editor, Advanced Computing: An International Journal, Associate Editor (Guest), Microsystem Technologies, Springer, Chief Editor, CSI Journal of Computing and Editor of Proceedings of ETCS 2012, NIDS-98 and ERC-95 of CSI. Seventeen Scholars awarded Ph.D., one submitted till January 2017, and eight scholars are pursuing their Ph.D. degree. He published five books from LAP—Lambert Academic Publishing, Germany, and one book from IGI Global publishers, Indexed by Thomson Reuters. Total number of publications is 359 including 146 publications in various international journals. He edited fifteen volumes as Volume Editor from Science Direct, Springer, CSI etc., organizing various international conferences of Springer and Science Direct. He is Director, IQAC, University of Kalyani, and Chairman, Center for Information Resource Management (CIRM), Kalyani University. He has successfully executed five research projects funded by AICTE, Ministry of IT Government of West Bengal.

Dr. Siddhartha Bhattacharyya (LFOSI, LFISRD, FIETE, FIEI, SMIEEE, SMIETI, SMACM, LMCRSI, LMCSI, LMISTE, LMIUPRAI, LMCEGR, LMICCI, LMALI, MIET, MIRSS, MIAENG, MCSTA, MIAASSE, MIDES, MISSIP, MSDIWC) is currently serving as Professor in the Department of Computer Science and Engineering of Christ University, Bangalore. He is a co-author of five books and co-editor of 54 books and has more than 280 research publications in international journals and conference proceedings to his credit. He has got two PCTs to his

credit. He is Associate Editor of Applied Soft Computing, IEEE Access, Evolutionary Intelligence and IET Quantum Communications. He is Founding Editor-in-Chief of International Journal of Hybrid Intelligence, Inderscience. He is serving as Book Series Editor of IGI Global, De Gruyter, CRC Press, John Wiley & Sons, Elsevier and Springer. His research interests include hybrid intelligence, pattern recognition, multimedia data processing, social networks and quantum computing.

Christian Huck obtained his doctorate in chemistry in 1998 from the University in Innsbruck, Austria, where he continued to work as Assistant Professor until the habilitation in 2006. In 2013, he received a call as Full Professor at the University of Stuttgart, Germany, and in 2015, another call back to the University of Innsbruck, where he is currently Vice-Head of the Institute of Analytical Chemistry and Radiochemistry and Head of the spectroscopy unit. From 2014 until 2017, he was Visiting Professor at Kwansei-Gakuin University in Sanda, Japan, in the laboratory of Professor Yukihiro Ozaki. Christian has published more than 300 peer-reviewed manuscripts resulting in an h-index of 49 based on more than 8500 citations. Besides several numerous awards, he was also the receiver of 2018 Tomas Hirschfeld Award. In his research, he is mainly focusing on vibrational spectroscopic technologies (NIR, MIR, Raman) for life and material science. Currently, he is Editor-in-Chief for Spectrochimica Acta A (Elsevier) and NIR news (Sage).

Dr. Satarupa Biswas is Assistant Professor in the Department of Physics at Adamas University since February 2019. She completed her doctoral studies from Indian Institute of Technology Kharagpur on Retinal prosthesis. She earned her B.Tech. and M.Tech. degrees, both in Biomedical Engineering, from West Bengal University of Technology and Jadavpur University, respectively. Her area of specialization includes neural rehabilitation, microdevice fabrication, simulation of medical devices, electrophysiology and biomedical instrumentation. She has authored 15 articles in reputed peer-reviewed international journals and national and international conferences. She is a reviewer for IET Micro & Nano Letters. She has received certification in Neural Networks and Deep Learning, Healthcare Innovations, Healthcare Organizations and Health Systems, and Fundamental Neuroscience for Neuroimaging. She is a member of IEEE Kolkata section. As an executive committee member of IEEE EMBS student club of IIT Kharagpur section, she actively participated in organizing various academic events and activities.

Indian Sign Language Recognition Using Combined Feature Extraction

R. Itkarkar Rajeshri, Anil Kumar V. Nandi, and Vaishali B. Mungurwadi

Abstract This research paper aims for the recognition of Indian sign language (ISL). Sign language is a language commonly used by deaf and dumb people to communicate with each other and rest of the world. There is an extensive research carried out for American sign language (ASL), but due to the lack of standard dataset, research for Indian sign language recognition is hampered a lot. This research work focuses on the use of a combined feature extraction technique so as to improve the accuracy and reduce complexity. Histogram of orientation gradient (HOG) and Gabor features are combined and classified using support vector machine (SVM) and K-Nearest neighbor (KNN) with accuracy of 83.92% and 84.92%, respectively.

Keywords Indian sign language (ISL) · HOG · Gabor · SVM

1 Introduction

Vision-based hand gesture recognition is appealing more nowadays as it provides the most natural way to interact for human-machine interaction. The vision base method is widely adopted for research due to low computational complexity. This paper work presents research carried out for the recognition of Indian sign language (ISL). ISL is one of the sign languages which is more complex than American Sign Language as it consists of complex signs (most signs are two hand signs). The typical processes performed for sign language recognition are preprocessing, feature extraction, and classification. Preprocessing consists of converting a color image into gray. Feature extraction is a technique where features such as shape, geometric features, statistical features, texture features, etc. for an image can be extracted. The shape of the hand can be used to identify the gesture termed as shape identification. The contour of the hand identifies the shape. Extracting the contour of hand gives more information in shape detection. Classification techniques such linear classifiers KNN, SVM, and

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neural network can be applied for recognition. This paper focuses on creation of own database with use of a simple web camera, feature extraction by combining Histogram of orientation gradient (HOG) and Gabor features and classified using support vector machine (SVM) and K-Nearest neighbor (KNN). Gabor filters are used in image processing due to its mathematical and biological properties (Guptaa et al. 2012). The feature dimension generated depends on the selection of parameters for the Gabor filter. The Gabor filter is designed by selecting parameters such as orientation, bandwidth, and frequency. The HOG features give the spatial distribution of local intensity gradients. These features well describe the hand gestures as they describe the edge features. Thus the shape feature of the hand gestures can be extracted by using HOG.

2 Related Work

Hand gesture recognition is one form of interaction between human and computer to achieve typical application. A real-time hand gesture recognition system implemented (Kishore and Rajesh Kumar 2012) with an accuracy of 96% using a combination of color and texture features and fuzzy logic for classification (Nandy et al. 2010). Indian sign language recognition was implemented by evaluating mean feature of histogram gradient and Euclidean distance for recognition and used for controlling a humanoid robot. Gabor is a linear filter that gives best localization characteristics by changing, bandwidth, frequency, and orientation (Huang et al. 2010). In (Zhao et al. 2010) extracted HOG features were converted into low-dimensional subspace using PCA-LDA. It was classified using the nearest neighbor classifier to achieve a recognizing accuracy of 91% in real-time. While in (Teoh and Branunl 2015) the authors used both HOG and Gabor for vehicle detection with three different classifiers SVM, Multi perceptron neural network, and distance classifier. They obtained best performance with HOG and SVM with less processing time. The authors in (Sheenu et al. 2015) have used HOG method followed by sequential minimal optimization with a recognition rate of 93.12%.

3 Methodology

The methodology proposed is a novel method for ISL recognition, where the Gabor features and HOG features combined to form a feature vector. The obtained feature vector is of a higher dimension, and hence PCA is used further to reduce the dimension and then applied to the classifier for recognition. The classifier used is SVM and KNN. Figure 1 shows the proposed methodology for ISL recognition.

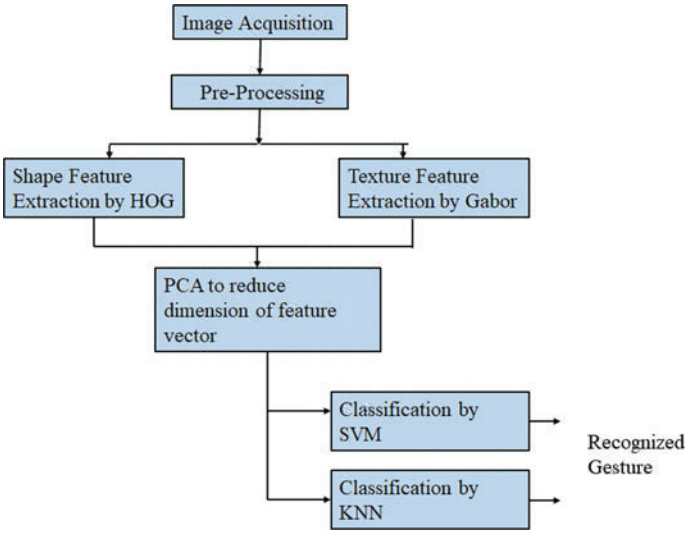

Fig. 1 Proposed methodology for ISL recognition

3.1 Feature Extraction by HOG

The HOG features are widely used for object detection. The image is divided into small square cells, the histogram of oriented gradients is computed for each cell, normalizes the result using a block-wise pattern, and return descriptors for each cell. Histogram of Oriented Gradient descriptor assumes that the local object appearance and shape within an image can be described by the distribution of intensity gradients or edge directions. The implementation of these descriptors can be achieved by dividing the image into small connected regions called cells, and for each cell computing a histogram of gradient directions i.e. edge orientations for the pixels within the cell. The combination of these histograms then represents the descriptor (Savaris and von Wagenheim 2010). The shape features are evaluated by applying color normalization on the input image, then evaluate the horizontal and vertical gradients, next is the formation of spatial blocks and then calculate orientation binwise and then forming a feature vector. The gradient magnitude and its orientation are calculated as in Eqs. (1) and (2) respectively, where gx and gy are horizontal and vertical gradients.

$$G = \sqrt{gx^2 + gy^2} \tag{1}$$

$$\theta = \tan^{-1} \frac{gy}{gx} \tag{2}$$

3.2 Feature Extraction by Gabor Filter

Gabor filter is a linear filter used for object edge detection. Gabor transform has strong frequency and orientation selectivity so that the edge features can be extracted. Gabor gives the best resolution in time and frequency domain and hence recognized as a very useful tool in computer vision and image processing (Huang et al. 2010). The parameters such as bandwidth, frequency, and orientation are changed to achieve best local features as Gabor is a linear filter. The features are extracted by convolution of the Gaussian kernel with the input image. A 2-D Gabor filter kernel over the image (x, y) is defined as per Eq. 3

$$G(x, y, \theta, \lambda, \varphi, \sigma, \gamma) = \exp -\frac{1}{2}\left\{\frac{x'^2}{\sigma x'^2} + \frac{y'^2}{\sigma y'^2}\right\} \cos\left(\frac{2\pi}{\lambda x'} + \varphi\right) \tag{3}$$

where $x' = x\sin\theta + y\cos\theta$ and $y' = x\cos\theta - y\sin\theta$, $G(x, y, \theta, \lambda, \varphi, \sigma, \gamma)$ kernel is a function of various parameters θ, λ, φ, σ, γ of the wavelet. θ is the orientation of the Gabor function, varied between 0 and 360. λ is the wavelength of the cosine factor of the Gabor kernel referred to as the wavelength of the filter. φ, it is the phase shift of the Gabor function in degrees which specifies the elasticity of the Gabor function. The features are extracted by convolution of the image with Gabor kernel represented as in Eq. 4

$$G(x, y, \theta, \lambda, \varphi, \sigma, \gamma)(x, y) = I(x, y) * G(x, y, \theta, \lambda, \varphi, \sigma, \gamma) \tag{4}$$

where $I(x, y)$ is the image.

The HOG features and Gabor features are finally combined together to form feature vector. The features are concatenated and the length of the feature vector.

4 Results

4.1 Results of HOG and Gabor

For implementation, Matlab is used. The final HOG vector Obtained is a vector of 2 $\times$ 2 $\times$ 9 vector i.e. 36 $\times$ 1. Here as the block overlap is of 2 there are 9 matrices of 2 $\times$ 2 size. Thus 8 $\times$ 8 cell finally reduced to 2 $\times$ 2 of 2 block overlap. Therefore 9 bins contain gradients of each cell. The final feature vector evaluated is the combination of both HOG and Gabor. This combination provides a perfect feature matrix which represents signs of Indian sign language. The HOG extraction method applied to a grayscale resized image of 130 $\times$ 130 resolution results in a feature vector of size 2700 $\times$ 1. The cell size selected 8, the block size is 2, and bin size is 3 for HOG extraction. The Gabor coefficients obtained after convolution of the Gaussian kernel

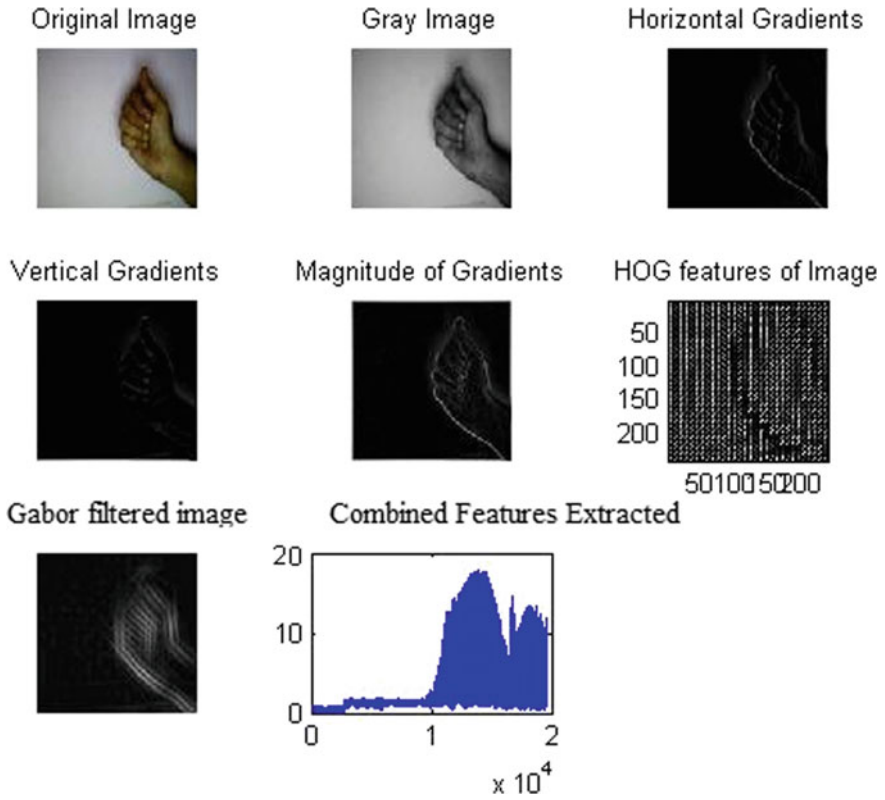

Fig. 2 Results of combined features of HOG and Gabor gestures for sign "0"

with the sign image are of size 16,900 × 1. Figures 2 and 3 shows the results for sign "0" and "*A*".

The performance of the classifier algorithm is stated by evaluating the accuracy from confusion matrix. The confusion matrix is as shown in Table 1 is for SVM and Table 2 is for KNN. The average accuracy obtained with SVM 83.92% and with KNN is 84.92% for $K = 3$. As there is very less research carried on ISL and no method used based on combined recognition comparison with existing work cannot be obtained.

5 Conclusion

The combined feature extraction by HOG and Gabor technique is obtained to increase the accuracy and reduce complexity of the system, though average accuracy obtained is just 83.92 and 84.92%. Gabor though is a robust technique accuracy decreases as filter output depends on many parameters. The recognition for ISL is a challenging

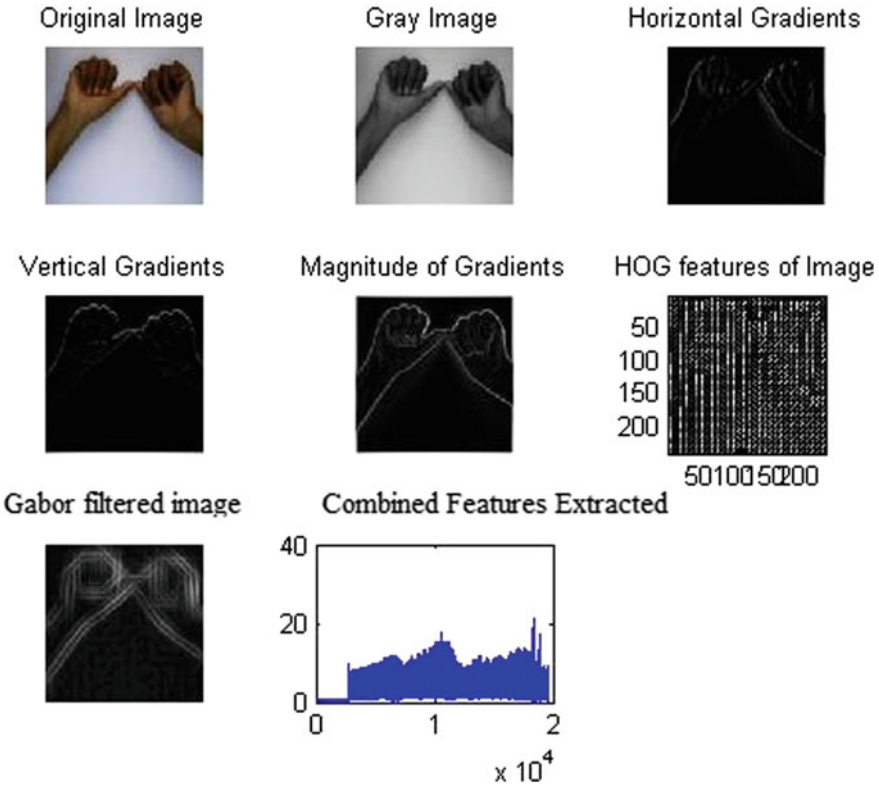

Fig. 3 Results of combined features of HOG and Gabor gestures for Sign "*A*"

Table 1 Confusion matrix by combined hog and Gabor features with SVM

Sign	*A*	*B*	*C*	*D*	1	2	3	4
A	**71**	0	0	0	0	0	0	0
B	0	**50**	0	0	0	0	0	0
C	0	0	**80**	0	0	5	0	0
D	0	0	0	**75**	0	0	0	25
1	0	0	0	0	**100**	0	0	0
2	0	0	0	0	0	**100**	0	0
3	0	0	0	0	0	0	**100**	0
4	0	0	0	0	0	0	0	**95**

Table 2 Confusion matrix by combined hog and Gabor features with KNN

Sign	*A*	*B*	*C*	*D*	1	2	3	4
A	**71**	0	0	0	0	0	0	0
B	0	**75**	5	0	0	0	20	0
C	0	0	**65**	0	15	5	0	0
D	0	0	0	**75**	0	0	0	25
1	0	0	0	0	**100**	0	0	0
2	0	0	0	0	0	**100**	0	0
3	0	0	0	0	0	2	**98**	0
4	0	0	0	0	0	0	0	**95**

task as the signs in ISL are complex. Further, the technique can be extended to recognize sentences and generate audio output for the recognized gestures.

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Creating Sleep-Health Awareness and Developing of a Sleep-Apnea Screening Tool for People of Developing/Under-Developed Countries

Jyoti S. Bali, Anilkumar V. Nandi, P. S. Hiremath, Prabha C. Nissimagoudar, and Poornima G. Patil

Abstract The socio-economic development of a nation depends on the health of the citizens, who contribute towards it. Sleep-health is an essential indicator of the well-being of a person. There are many ailments related to heart and brain reported that are caused by problems of lack of sleep, interrupted sleep, and unhygienic sleep conditions. Several sleep-related disorders are affecting people of various age groups, which reduce the quality of life as well as the physical and mental health of the affected person drastically. Awareness about the problem among medical experts and the general public is poor in countries of lower economy, like India. The Polysomnography (PSG), a gold-standard and a popular test is used to detect sleep-related disorders. PSG requires a sophisticated Sleep-Lab facility and proves costly and hence not affordable by lower sections of society. Under the proposed work, the focus is on the need for creating awareness on the up-keeping of sleep-health and developing a convenient screening tool for sleep apnea. The development issues of an intelligent and cost-efficient screening tool as an alternative to PSG and the feasibility of using the tool at smaller clinical setups are discussed.

Keywords Sleep-health · Sleep-related disorders · Quality of life · Polysomnography(PSG) · Sleep lab facility · Cost-efficient screening tool

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1 Introduction

Sleep apnea is a type of breathing disorder resulting in interruptions in breathing or causing shallow breathing during night sleep. The disorder can occur in three different forms, namely, Obstructive Sleep Apnea (OSA), Central Sleep apnea (CSA), and Mixed Sleep Apnea (MSA), among which OSA is the most prevalent. In all these three forms of sleep apnea, the interrupted breathing activity leads to the problem of oxygen deficiency leading to chronic cardiac-related ailments, namely stroke, hypertension, atrial fibrillation, etc. Only a close relative of the patient can identify the problem as it occurs during night sleep. In most cases, the problem goes unnoticed in the preliminary stage. Earlier detection of sleep apnea can save a patient from severe life risk. The delay of diagnosis can prove fatal (Campbell et al. 2017; Thomas et al. 2017; Elgendi et al. 2014). The awareness toward sleep apnea is very poor across the globe. Even in developed countries like the US, only 15–20% of the affected population is screened for sleep apnea as per a survey report. The problem occurs among people of all economic sections and age groups. The health care cost towards the treatment of heart-related ailments is very high, many times not affordable by some sections of society. The need for creating awareness about sleep disorder is very critical. Even the medical experts do not insist cardiac patients to undergo sleep test, as it can provide information on the root cause as sleep apnea many times. Even the experts in the medical community fail to educate people about sleep health, and the need for screening in case of heart-related problems (Campbell et al. 2017; Thomas et al. 2017; Elgendi et al. 2014; Bali and Nandi 2016, 2017a, b; Stuart 2010; https://www.resmed.com).

2 Sleep Apnea Diagnosis and Treatment Methods

Polysomnography (PSG) is a well-established gold-standard test, conducted overnight on the patient to detect the presence of sleep-related disorders. PSG test is conducted in a sophisticated sleep lab facility with instrumentation systems, and monitoring equipment, under the supervision of a trained technician. PSG test involves monitoring of several physiological parameters gathered from the set of electrodes put on the patient's body during the entire sleep time. The test proves to be very cumbersome and expensive involving complex analysis and is available at tertiary level health care facilities. The facility is not affordable by poorer sections of society in countries of the lower economy. The affected people are advised to visit the sleep lab facility, only after undergoing heart stroke or any other heart-related ailment. There are several standard guidelines released from various internationally renowned organizations, namely, American Academy of Sleep Medicine (AASM), Indian Society for Sleep Research (ISSR), All India Institute of Medical Sciences (AIIMS), New Delhi, and other international bodies. They provide guidelines for therapists and experts responsible for creating awareness and promoting research in

the area of sleep and sleep medicine. There are different home-based portable monitoring devices used as screening tools that simplify the diagnosis of OSA before the affected person is referred for Polysomnography (PSG) test by an expert. The devices can be used for sleep evaluation program that provides access to sleep lab facility, PSG test, and specialists. CPAP method provides an effective treatment for diagnosed OSA (Bali and Nandi 2017a, b; Stuart 2010; https://www.resmed.com).

The sleep apnea detection methodologies have evolved over years, from study of various physiological parameters in single or as a combination. Some of the important physiological parameters used are, namely, breathing pattern, nasal airflow, EEG, ECG, Saturated Oxygen (SaO_2) and limb movements gathered from the human being through sophisticated instrumentation systems. EEG provides information on the mental activity of the brain from the fully active state, engaged in cognitive efforts to sleepiness. The effect of sleep apnea causes the shifting of EEG from the delta wave to theta and alpha waves. EEG needs pre-processing to free it from artifacts before analysis. Saturated blood oxygen (SpO_2) is measured by a pulse oximetry sensor, and the sleep apnea event is accompanied by a reduction in SpO_2 level. The analysis of ECG and SpO_2 in combination can provide information on the de-saturated oxygen level as well the Heart rate variability parameters caused by sleep apnea events. The physiological parameters used for sleep apnea study along with the respective features are listed in Table 1.

Analysis of recording of the tracheal sound during sleep can provide information on estimated respiratory flow and changes in the breathing pattern caused by the occurrence of an apnea event. The analysis of ECG and SpO_2 in combination can provide information on the de-saturated oxygen level as well the Heart rate variability parameters. They are implemented using a combination of classifiers. Whenever the sleep apnea event occurs, the de-saturation of blood oxygen sensed by SpO_2 sensor level initiates the sympathetic nervous system by monitoring EEG to act in order to restore the blood oxygen level. The analysis of power spectral features of EEG and ECG in sleep conditions are used in detecting the OSA events during night sleep (Campbell et al. 2017; Thomas et al. 2017; Elgendi et al. 2014; Bali and Nandi 2016,

Table 1 Physiological parameters used for sleep apnea study

Physiological parameters	Feature extraction
EEG	Measure of the shift from Delta waves to Theta and Alpha waves
ECG	Cyclic variation patterns in heart rate and RR interval duration
SpO_2	Oxygen De-saturation level, spectral and non-linear features
Snoring	Estimation of Formant frequency
Body movement	Analysis of video of captured body movements in different angles
EEG + ECG	Power spectral features of EEG and ECG in sleep conditions
ECG + SpO_2	Heart rate variability parameters with De-saturated oxygen level
Tracheal sound	Estimation of Respiratory flow and changes in the breathing pattern
Airflow	Spectral features

2017a, b; Stuart 2010; https://www.resmed.com; https://www.usa.philips.com/healthcare/product/HC1109289).

3 Sleep Apnea Detection Systems for Home Use

Apart from Polysomnography (PSG) test, the home-testing devices can be of help in testing of a patient for sleep apnea conditions. AASM (2009) standard approves the use of such sleep monitoring devices as screening tools. Home sleep test (HST) devices are user-friendly to be used by experts for monitoring their patients at ease. With the advancement of technology in developing systems as per standard, dealing with Sleep apnea is not so difficult. There is a good demand for cost-effective portable recording systems as screening tools for sleep apnea before the patient is advised for costly and cumbersome PSG test. Thus sleep apnea patients and normal subjects can be clearly separated with a more convenient and cost-effective system. The various diagnostic devices used for Sleep apnea are, namely, Clinical PSG devices, ambulatory PSG devices. Among the HST Devices, Oximeter, Actigraphy Devices, and Sleep Screening Devices are popularly used. The physicians, expert in the area, need to use specialized software for analyzing as per their requirements. Some of the real-time monitors are equipped to gather and transmit data as well as do real-time analysis of apnea events that occur and alert the patient or the attendant immediately and give analysis as feedback (Elgendi et al. 2014; Bali and Nandi 2016, 2017a, b; Stuart 2010; https://www.resmed.com; https://www.usa.philips.com/healthcare/product/HC1109289). Table 2 provides a summary of real-time sleep apnea monitoring devices.

The studies are carried out by several researchers to suggest alternative means of sleep apnea detection in a home environment with a reduced number of physiological parameters required for analysis. There is no such proven screening device yet, and experts can use that at the primary and secondary clinical setups. The respiration function and heart function are inter-dependent. The changes in the heart function, caused by sleep disorder can be captured using the Electrocardiography (ECG), a well-established diagnostic modality. Similarly, during the sleep apnea condition, the physiological signals like EEG, blood oxygen, body position, temperature, EMG characteristics change and deviate from their normal characteristics. The medical experts in sleep lab facility observe such changes in characteristics of physiological signals and infer about the sleep apnea conditions. Several researchers have proposed to automate sleep apnea diagnostics with intelligent assistive technology. However, they have not reached the acceptable accuracy and efficiency. Hence there is a need for an efficient, cost-effective and portable facility that can be used at primary and secondary-level health-care facilities (Satija et al. 2018; Krishnan and Athavale 2018; Bali et al. 2018a, b, c; Lyon et al. 2018; Altay and Kremlev 2018; Liu et al. 2018; Dey et al. 2017; Bali et al. 2020; https://www.resmed.com; https://www.usa.philips.com/healthcare/product/HC1109289; https://physionet.org/

Table 2 Real-time sleep apnea monitoring devices

Parameters	System features
Multi-parameter input	ApneaLink™ Plus using respiratory action, pulse rate, oxygen saturation, and nasal airflow (off-line)
	The SleepStrip™ uses thermistors for oral and nasal airflow(Off-line)
	WM ARES, monitors heart rate, airflow, respiratory action, pulse rate, oxygen saturation (off-line)
	Alice Night One from Philips, Respironics, gathers data on airflow, snore, thorax effort, SpO_2, pulse rate, body position(on-line)
	Transmitter for body position, nasal airflow, abdomen/chest efforts, oxygen saturation (on-line)
Body movement	Body movement captured in 10 videos of 3 different angles with two SONY infrared camcorders
SpO_2 only	Wearable system using PPG signal from SpO_2 sensor (on-line)
	HealthGear, a blood oximeter for the blood oxygen level (on-line)
	Medical, Inc., 4100 Digital Pulse Oximeter, decision tree classifier, ADTree (on-line)
ECG only	Apnea MedAssist, with Android operating system based smartphone using single lead ECG sensor (on-line)

physiobank/database/slpdb/; https://sleepdata.org/datasets/shhs; https://www.physionet.org/physiobank/database/apnea-ecg/).

Design of optimized hardware and efficient algorithms is very important to develop a wearable device to gather the required physiological parameters. The system needs to be user-friendly, cost-effective with optimized battery life. The offline processing of captured information can be done for analysis and automated decision making on the condition of sleep disorder and advise timely medication. In the process, medical experts need to be trained on the use of smart screening tools for sleep apnea for earlier identification, to avoid life threats. There is a need for a cost-effective screening tool with a lesser number of sensors. In order to support the development of the screening tool, there is a need for developing reliable Indian data sets for sleep apnea testing and validation by domain experts. The need for government initiatives on creating awareness on the sleep apnea problem among common people is very crucial and is to be conducted through the government health-care facilities and Non-Government Organizations (NGO's). In this direction, ECG signal forms an important source of information for studying sleep apnea conditions (Campbell et al. 2017; Thomas et al. 2017; Elgendi et al. 2014; Bali and Nandi 2016, 2017a, b; Stuart 2010; Satija et al. 2018; Krishnan and Athavale 2018; Bali et al. 2018a; https://www.resmed.com; https://www.usa.philips.com/healthcare/product/HC1109289). ECG signal is a reliable diagnostic modality used for study and diagnosis of heart health. ECG signal can be analyzed using which the signatures due to sleep apnea disorder can be tracked. But the ECG signal needs to be pre-processed for separating it from the undesired inherent noise present in it as baseline wander

noise, motion artifact noise, and the power-line interference noise. Efficient analysis of the ECG signal to detect the deviations caused in its parameters due to sleep apnea effect needs to be ensured. There are several ECG signal preprocessing techniques developed over the years to improve the Signal to Noise Ratio (SNR) of the signal. The survey of automated ECG processing and analysis algorithms that evolved from derivative methods in time domain and transform domain has been carried out. The QRS detection process is a very critical step, for extraction of important parameters from the ECG signal. Several research studies are carried out to compare the various QRS detection methods with regard to the three assessment criteria, namely, robustness to noise, choice of parameters and the attained numerical efficiency for battery-enabled, portable applications involving large ECG databases (Satija et al. 2018; Krishnan and Athavale 2018; Bali et al. 2018a, b, c; Lyon et al. 2018; Altay and Kremlev 2018; Liu et al. 2018; Dey et al. 2017; Bali et al. 2020; https://physionet.org/physiobank/database/slpdb/; https://sleepdata.org/datasets/shhs; https://www.physionet.org/physiobank/database/apnea-ecg/).

The experimentation of working with sleep apnea problems requires a wide variety of ECG datasets of normal subjects as well sleep apnea affected subjects for study. The databases can be got from hospitals with Sleep lab facility or use benchmark databases from standard sources. The estimated performance measures of analysis algorithms depend on the datasets used. There are publicly available databases for study, namely, *The MIT-BIH Polysomnography Database,* Sleep Laboratory, Boston's Beth Israel Hospital for chronic OSA syndrome and the effect of CPAP treatment, Sleep Heart Health Study (SHHS) housing recordings of EEG, EOG, EMG, airflow, thoracic and abdominal excursions, ECG, body position, ECG Apnea database from physionet.org (PNDB) comprising of 70 night time ECG recordings. Once the ECG signal features are extracted, there is a need to analyze the significant features depicting sleep apnea conditions using an intelligent decision-making algorithm (Lyon et al. 2018; Altay and Kremlev 2018; Liu et al. 2018; Dey et al. 2017; Bali et al. 2020; https://physionet.org/physiobank/database/slpdb/; https://sleepdata.org/datasets/shhs; https://www.physionet.org/physiobank/database/apnea-ecg/). Hence the proposed work aims at throwing light on the available methods, technologies, devices for sleep apnea detection and monitoring. Also, the need for a useful screening tool that can be used by experts at smaller clinical setups is emphasized.

4 Conclusion

There is a critical need for creating awareness of sleep health, sleep hygiene, and the impact of sleep disorders on cardiac health among the people of the countries of the lower economy. The proposed tool can prove a boon to the people of developing and under-developed countries, where the health care facility is not easily affordable by lower-income groups of society. The local clinical setups can be equipped with the screening tool to make affected people be aware of the problem early and undergo preventive measures to avoid future damage to the health of the individual. Hence

there is a need for simplified and reliable screening tool that can be used by experts as a supplementary facility to PSG at the primary and secondary health care facilities, so that the detection can happen at an earlier time. Later the patient can be referred for a sleep lab test for detailed analysis and finalize the medication accordingly, thus improving the quality of life.

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