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Subhas Chandra Mukhopadhyay
S. M. Namal Arosha Senanayake
P. W. C. Prasad *Editors*

Innovative Technologies in Intelligent Systems and Industrial Applications

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Preface

Hybrid intelligent systems that encompass humans and specialists in the loop lead the way to novel decision fusion methods, allowing systems to predict the behavior of complex adaptive systems. From a cognitive science perspective, natural intelligent systems operate on both symbolic and sub-symbolic levels. These hybrid systems enable more robust reasoning processes; induction, deduction, abduction, and reasoning by analogy. Neuro-symbolic systems, neuro-fuzzy systems, hybrid connectionist-symbolic models, and fuzzy expert systems are the main ingredients making hybrid intelligent systems versatile today.

The convergence of 5G and cloud opens doors to novel applications, transforming industries and enhancing user experiences. Thus, 5G and beyond and cloud computing are two transformative technologies that are shaping the future of communication and computation. In this era of digital transformation, the sky's the limit with cloud-based software, AI, and 5G! The convergence of 5G connectivity, artificial intelligence (AI), and the cloud is reshaping industries under the Industry Revolution 4.0 and Smart Society 5.0 leading to Smart Citizens. After a year of experimentation in 2023, 2024 is poised for the launch of new AI-enhanced products. Contact centre AI, for instance, enables agents to synthesize network issues, locate records, and respond to customer requests in real time. Shifting toward Software-as-a-Service (SaaS) allows customers to use cloud-based apps over the internet.

The application of big data and the innovation of computational algorithms are promoting real-time AI-enabled system development. Thus, with the cooperation of machine intelligence, human–machine fusion has led to unprecedented volumes of *Innovative Technologies in Intelligent Systems and Industrial Applications*. These achievements are based on adapting human intelligence and machine intelligence to each other, supporting each other, promoting each other, and materializing cooperative and collaborative evolution and optimization of decision-making intelligence.

The synergy of AI, cloud computing, and cybersecurity is reshaping how organizations defend against threats, automate responses, and safeguard sensitive data. Vast datasets enhance cyberthreat detection in AI-enabled cloud environments. AI-driven analytics provide scalable and efficient solutions for early warnings and incident response automation in the cloud. Advances in computational power and scalability promise a safer online landscape through AI-driven security.

AI-driven embedded systems are revolutionizing conventional processes by harnessing intelligent automation and predictive capabilities. They empower devices to make informed decisions locally, even in critical real-time scenarios. Unlike traditional AI systems that rely on cloud-based processing, embedded AI operates directly within the hardware it serves. AI-driven embedded systems enhance automation, adaptability, and efficiency. They leverage data and patterns for informed decision-making. These systems can be found in devices ranging from handheld remote controls to home appliances, vehicles, and industrial assembly lines.

The true potential of intelligent systems lies in their ability to empower and create a more inclusive world. As technology continues to evolve, more innovative solutions that enhance the lives of physically and mentally challenging people and senior citizens have dramatically increased recently. Among products and services in the current market, enhanced independence and communication by developing voice assistants and smart home automation, assistive technologies using speech recognition and screen readers, mobility solutions by introducing novel autonomous vehicles and navigation apps, customized prosthetics and orthotics by applying different AI designs and gait analysis tools, predictive health monitoring by integrating wearable devices and predictive analytics, and inclusive design and accessibility by fusing inclusive product design and captioning and subtitling.

This book addresses novel solutions leading to smart citizens based on time critical issues impacting the world and our livelihood on the earth. It contains chapters from authors presented during the International Conference on Innovative Technologies in Intelligent Systems and Industrial Applications (CITISIA) 2023, which was held in Sydney Australia, November 14–16, 2023. This book allows readers to enhance and to adapt novel solutions for the development of customized products and services based on societal needs. In the current context, the book addresses Industry Revolution 4.0 and Smart Society 5.0 impacting technological evolution and transformations in the years to come. Chapters are categorized by main topics so that readers are guided to their areas of interest:

Topic 1: Explores novel algorithms and information systems for real world applications.
Topic 2: Introduces hybrid data security models for a smart society.
Topic 3: Analyses synergy of AI, 5G, and clouds for smart systems.
Topic 4: Discusses advanced system modeling for industry revolution.
Topic 5: Explores IoT and cybersecurity for smart devices.
Topic 6: Introduces recent advances for intelligent digital innovations.

Topic 7: Analyses innovative entrepreneurship solutions.
Topic 8: Advances in hybrid intelligent systems.

Sydney, Australia
Malacca, Malaysia
Bathurst, Australia

Subhas Chandra Mukhopadhyay
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Currently he is working as a Professor of Mechanical/Electronics Engineering and Discipline Leader of the Mechatronics Degree Programme of the School of Engineering, Macquarie University, Sydney, Australia. He has over 30 years of teaching and research experience.

His fields of interest include Smart Sensors and Sensing Technology, Wireless Sensor Networks, Internet of Things, Electromagnetics, Control Engineering, Magnetic Bearing, Fault Current Limiter, Electrical Machines and numerical field calculation, etc.

He has authored/co-authored over 500 papers in different international journals, conferences, and book chapters. He has edited eighteen conference proceedings. He has also edited 25 special issues of international journals as lead guest editor and 35 books with Springer-Verlag.

He was awarded numerous awards throughout his career and attracted over AUD 6.2 M on different research projects.

He has delivered 359 seminars including keynote, tutorial, invited and special seminars.

He is a Fellow of IEEE (USA), a Fellow of IET (UK), and a Fellow of IETE (India). He is a Topical Editor of

IEEE Sensors Journal and an Associate Editor of IEEE Transactions on Instrumentation. He has organized many international conferences either as General Chair or Technical Programme Chair. He is the Founding Chair of the IEEE Sensors Council New South Wales Chapter.

Dr. S. M. Namal Arosha Senanayake Senior Member of IEEE is the founder and leader of IntelliHealth Solutions (Technology Licensing) and he has a well balanced portfolio on research, education (teaching), and service (administration). Currently, Dr. Arosha is working at Multimedia University, Malaysia where he launched novel research directions on Hybrid Augmented Intelligent Robotics (HAIR) jointly with pharmaceutical experts at Taylor's University, and clinical experts at Sydney University. He is also engaged as a visiting and adjunct professor/academic at different institutions in Australia, Japan, Malaysia, and Indonesia.

Having served as an assistant lecturer, lecturer, and senior lecturer at two different universities in his motherland Sri Lanka, he was invited to serve as a senior research fellow at Chalmers University of Technology, Sweden.

Dr. Arosha joined Monash University Sunway Campus as a senior lecturer in 2002 where he was considered an active researcher. He succeeded in getting the largest eScience fund from the Ministry of Science Technology and Innovation under the title Bio-Inspired Robotic Devices for Sportsman Screening Services (BIRDSSS). Based on research outcomes, he was awarded Pro-Vice Chancellor's award for excellence in research within three consecutive years; 2008, 2009, and 2010. In 2011, Dr. Arosha joined as an associate professor in artificial intelligence at the University of Brunei Darussalam. He was the recipient of the UK-South East Asia Knowledge Partnership—Collaborative Development Award, 2013. In 2021, he jointly with team members from Japan, Malaysia, and Vietnam was the recipient of research excellence award by the National Institute of Information and Communications Technology (NICT), Japan for the best project among six leading projects sponsored by the NICT during 2017–2020. He has been appointed as a liaison officer and visiting professor under the Advanced Global Program (AGP) at Gifu University, Japan since 2018.

As a Senior Member of IEEE, Dr. Arosha actively engaged with IEEE during the last two decades. He served as a chairman of IEEE Robotics and Automation Society Chapter, the director of IEEE Asia-Pacific Robotics and Automation Council, and a student branch counselor. He also serves as an associate editor of four international journals, a reviewer of 13 different IEEE Transactions, Elsevier, Springer, Taylor & Francis, Acta Press, etc. Dr. Arosha authored a book with the title Bio-Interfacing Devices. He was an editor for 10 proceedings. He was an external examiner for Ph.D. and Master's by research candidates at well-known universities in the Asia Pacific region.

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Novel Algorithms and Information Systems for Real World Applications

Threshold-Based Algorithm for Fall Detection Through an Inertial Sensor Fixed at the Head

Alejandro Vistorte, Adriana Companioni, Fidel Hernández, and Carlos Travieso

Abstract This work was focused on developing a low-cost, effective and reliable algorithm to be applied on fall detection through the analysis of data provided by an Inertial Measurement Unit attached at the head. In order to achieve this goal, trends of the acceleration vector variance were analyzed for the case of fall and no fall conditions, and such a feature, together with the time at which this feature remained above certain threshold, were the key points used for assessing whether a fall had happened or not. A public dataset, which included different types of falls and daily activities, was used for algorithm validation. The algorithm parameters (thresholds) were adjusted to achieve the highest Recall value. Accordingly, values of Precision, Recall, Specificity and Accuracy equal to 92.8%, 98.7%, 90.4%, and 95.0%, respectively, were obtained.

Keywords Fall detection · IMU · Thresholds · Variance

1 Introduction

Currently, the world is witnessing an increase of the elder population. This situation is turning to a significant challenge for the countries focused on warranting health and social services prepared to deal with such demographic change. Elder people are particularly prone to reduce motor capability and then to fall.

Different technologies have been implemented in order to detect falls. These systems allow for a quick ad intervention of fallen people and can be classified into three categories: vision-based, environmental, and wearable devices [1]. The latter are chosen very often for the specialists due to the advances achieved in the area of the Microelectromechanical System technology, which has led to the integration

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of accelerometers, gyroscopes and magnetometers into tiny chips (Inertial Measurement Sensor, IMU) that represent a more economical, low consumption and invasive alternative [1, 2]. These devices can be attached on different parts of the body, so they can be used comfortably as the devices are protected and their steady functioning is assured. Some results have proved that in certain scenarios, the use of IMU-based wearable devices in the head can be more suitable than attaching the device to more traditional parts, such as the wrist, the hip, the chest, etc. [3]. This approach, together with the use of two important methods for fall detection, those based on the use of magnitude vector thresholds and pattern recognition techniques, is a very active area of research work [4]. This paper is aimed to contribute to the efforts that are done in this context.

Several works, addressing the fall detection procedure by using IMUs attached at the head, have been performed. Ching et al. [5] presented a system for head acceleration and orientation monitoring in order to detect a fall with precision equal to 95.4%. In [6], the same authors implemented a Madgwick filter for improving orientation effectiveness and attained a sensibility equal to 96.7% and a specificity equal to 98.3%. However, the dataset built for these two research works can't be considered as diverse as required since just a given group of kind of falls and daily life activities were included. The same is for the work done by Kangas [7]; in this case the dataset included only two volunteers.

In other research works pattern recognition techniques are applied. For example, in [8], both the *k*-Nearest Neighbor and Decision Trees algorithms were applied and achieving sensibilities equal to 92.9% and 91.1%, respectively. In [9], the application of Support Vector Machine y Artificial Neural Network were proposed to be used for fall detection; in such cases the precisions obtained equaled 94.2% and 96.1%, respectively. These methods require a high computational cost for being implemented.

In general, the results achieved by proposed techniques addressing the fall detection task through IMUs attached to the head cannot be considered as reliable (have been validated through a low data diversity) or require a significant computation cost for being implemented (this issue impose constraints to the microcontroller-based implementation). The goal of this research work is to develop an effective and more reliable algorithm for detecting falls through an IMU attached to the head. The algorithm will be validated by using a wide diverse dataset and will not require a high computational cost.

This paper is organized as follows: General issues about the inertial sensors are presented on Sect. 2. In Sect. 3, some characteristics of the dataset used in this research work for algorithm validation are exposed. The algorithm and the metrics computed for its validation are presented in Sect. 4. Results are exposed in Sect. 5 and then, some conclusions are presented.

2 Inertial Measurement Units

An IMU is an electronic device usually comprised by accelerometers, gyroscopes, magnetometers, as well as a microcontroller in order to process gathered signals and send the information to an external agent, for example, a computer [10].

The accelerometer is an electronic sensor that measures acceleration forces in order to determine space position and monitor movement [11, 12]. Among the main accelerometer types are the piezoelectric, piezoresistive and capacitive accelerometers; the latter are the most used accelerometers for wearable device applications. Capacitive accelerometers use the change of the electric capacitance for determining the object acceleration; when the sensor is under velocity variation, the distance between the capacitor plates vary as well. The problem of using capacitive accelerometers is the fact that the gravity acceleration is measured as well, then the discrimination between gravity and linear acceleration from the acceleration signals turns into a very difficult task.

The gyroscopes are devices based on the Coriolis effect and used in order to measure angular velocity [11]. The magnetometers measure the magnetic field at some point in the space [13].

Since inertial sensors can be used for monitoring human activities and movement disorders symptoms, such as Parkinson disease, they are widely applied on medical assistance and rehabilitation areas. They can also be used in order to control gait patterns and to detect falls [10].

3 Materials and Methods

3.1 Dataset Used in This Work

In order to validate the proposed algorithm, the dataset Simulated Falls and Daily Living Activities Dataset provided in [14] was used. This dataset, comprised by data gathered from IMU attached to different body parts (the head is included) of 17 volunteers with ages ranging from 19 to 27 years, can be considered as a high diverse dataset. The dataset included information from 36 different movements, divided into 20 kinds of falls and 16 daily life activities. Each activity was repeated 5 times by each participant, resulting in 3060 instances.

Although this dataset registered signals from IMU's accelerometers, gyroscopes and magnetometers, in this research work only accelerometers signals were used. The signals were gathered through a XsensMTw kit. The sampling frequency was 25 Hz.

3.2 Proposed Algorithm and Validation

The algorithm developed in order to detect falls was based on the computation of the acceleration magnitude vector variance in a window and the analysis of its behavior in a given time interval. The length of the window was set to be 3 secs because the analysis of the datasets signals revealed that the action of a fall over the acceleration signals does not last more than such a time. Then this size window is enough long to cover any occurrence of this kind of transient event.

The acceleration magnitude vector was computed as follows:

$$A = \sqrt{(Acc\_X)^2 + (Acc\_Y)^2 + (Acc\_Z)^2} \quad (1)$$

where:

Acc_X: "x" axis acceleration.

Acc_Y: "y" axis acceleration.

Acc_Z: "z" axis acceleration.

The algorithm proposed in this research work initially computes the variance of the acceleration magnitude vector within a 3 s length sliding window that moves over the signal. If the variance in the current window is higher than certain threshold, at this stage, ThV1, some high stress event, like a fall, is assumed to have occurred and the algorithm pass to a new state (see Fig. 1). Then, the time at which the variance remains higher than ThV1 is registered. If this time is lower than certain threshold, ThT1, a fall is assessed to have occurred; otherwise, the algorithm returns to the initial conditions.

Since there are some kinds of falls, such as syncopes, that do not produce high variance events in the acceleration signals, if the variance is lower than ThV1, the algorithm asks if the variance is higher than a second threshold, named as ThV2, which is lower than ThV1, but high enough as to distinguish between some daily life activities and a syncope occurrence (see Fig. 2). Then, if the variance is lower than ThV1 and higher than ThV2, similar to the previous algorithm branch, the time at which the variance remains higher than ThV2 is monitored. If this time is lower than certain threshold, ThT2, a fall is assessed to have occurred; otherwise, the algorithm returns to the initial conditions.

The four thresholds are determined by working with the dataset signals and computing the algorithm performance for different values of such thresholds. The values, by which the best performance is achieved, will be chosen.

The performance is assessed by the following metrics based on the confusion matrix [15]:

- Precision

$$P(\%) = \frac{TP}{TP + FP} \cdot 100 \quad (2)$$

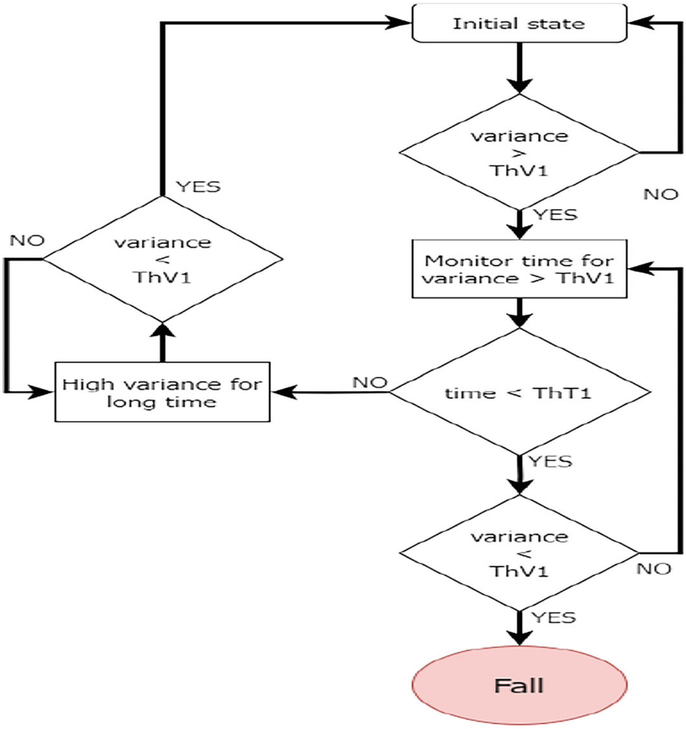

Fig. 1 Branch of the proposed algorithm corresponding to variance values higher than ThV1

- Recall

$$R\ (\%) = \frac{TP}{TP + FN} \cdot 100 \tag{3}$$

- Specificity

$$S\ (\%) = \frac{TN}{TN + FP} \cdot 100 \tag{4}$$

- Accuracy

$$Ac\ (\%) = \frac{TP + TN}{TP + TN + FP + FN} \cdot 100 \tag{5}$$

In this research work, the thresholds were selected in such a way that the algorithm performs as more sensitive to a fall occurrence as possible, that is, the Recall yields the highest value.

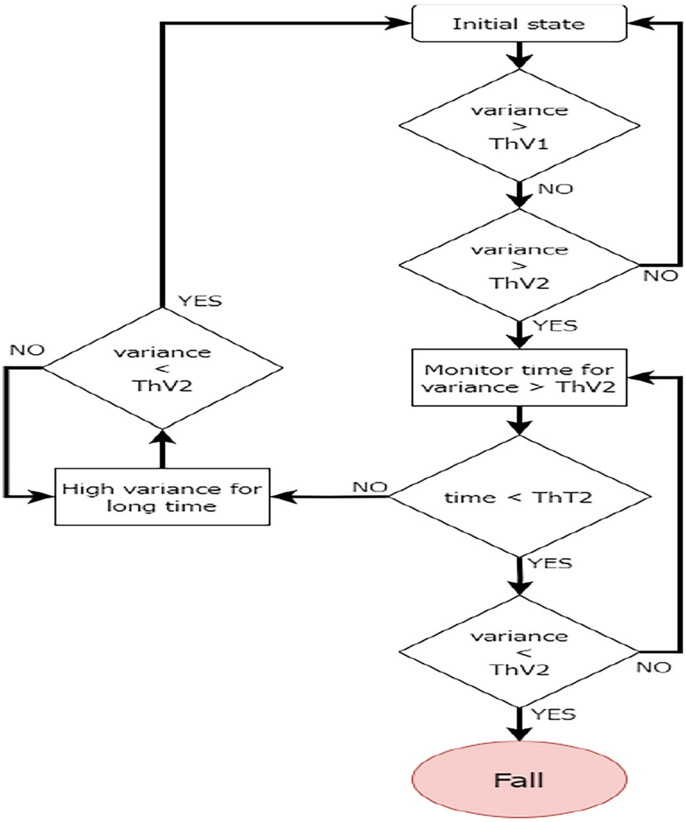

Fig. 2 Branch of the proposed algorithm corresponding to variance values lower than ThV1

4 Results

The thresholds that led to best algorithm performance are presented in Table 1.

For the threshold values presented on Table 1, the achieved Confusion Matrix is shown in Table 2.

The Confusion Matrix shows the effect of prioritizing the detection of a fall if it is produced. It can be noticed that when a fall has happened a significant low number of False Negatives occur; as a matter of fact, this False Negatives number is significantly lower than the case of a fall has not happened.

The metrics computed from the Confusion Matrix are presented in Table 3.

Table 1 Threshold values to be used by the algorithm

Threshold	ThV1 (m^2/s^4)	ThT1 (s)	ThV2 (m^2/s^4)	ThT2 (s)
Value	4.45	6.00	0.60	3.75

Table 2 Confusion matrix

		Assigned class	
		Fall	Normal activity
Real class	Fall	1678	22
	Normal activity	131	1229

Table 3 Performance achieved by the algorithm (highest Recall value)

Metric	*P* (%)	*R* (%)	*S* (%)	*Ac* (%)
Value	92.8	98.7	90.4	95.0

Results given in Table 3 are reliable since the used dataset was wide and diverse. To verify whether the amount of processed data was high enough as to consider that the achieved results were robust, the metrics trend, computed for different number of data, was analyzed. The four trends are shown in Fig. 3. This figure reveals that the metrics values become stable (around the values presented in Table 3) from the analysis of 2500 data.

A comparison of the findings achieved in this research work, which addresses the fall detection task through an inertial sensor attached to the head, with those obtained in other works is presented in Table 4. This table reveals that the achieved results are in the range of the results obtained in the rest of the research works.

It should be remembered that this work was focused to reach the highest Recall value. Accordingly, this research work exhibits the highest Recall value among the previous performed works. Values of the other metrics are also included in Table 3. One can notice that the highest values were achieved by the research works that used a low number of kinds of falls. For example, in [6] high values of metrics

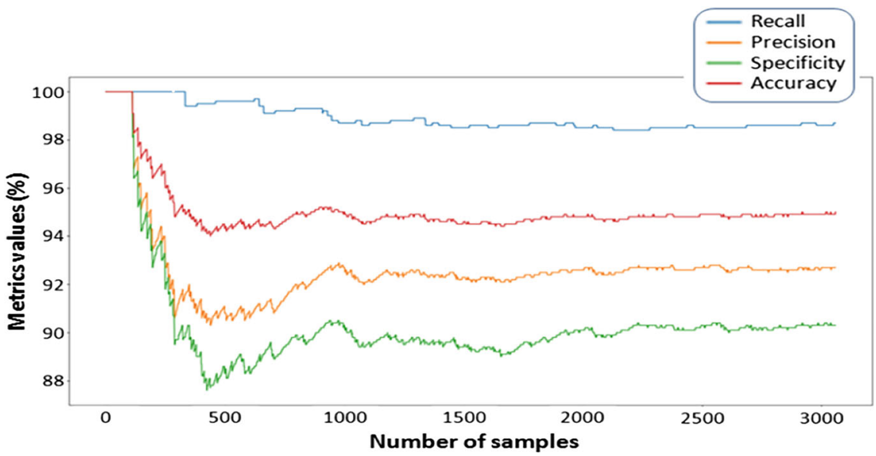

Fig. 3 Trend of the computed metrics for the increasing number of processed data

Table 4 Comparison of the performance achieved in this research work other works

Research work	Algorithm	IMU	Dataset	P (%)	R (%)	S (%)	Ac (%)
Burwinkel [3]	Livio AI firmware	2	8 falls 8 ADL 10 participants 320 samples	–	92.1	98.8	96.0
Lin [6]	Based on thresholds	1	3 falls 2 ADL 15 participants 2220 samples	96.4	96.7	98.3	97.7
Ntanasis [8]	Decision trees	1	20 falls 16 ADL 14 participants 2520 samples	–	91.1	95.8	96.5
Ntanasis [8]	k-NN	1	20 falls 16 ADL 14 participants 2520 samples	–	92.8	94.8	93.7
Lin [5]	Based on thresholds	1	4 falls 5 ADL 5 participants 570 samples	–	–	–	95.4
Özdemir [9]	Artificial neural network	1	20 falls 16 ADL 14 participants 2520 samples	94.2	–	–	–
Özdemir [9]	Support Vector Machine (SVM)	1	20 falls 16 ADL 14 participants 2520 samples	96.1	–	–	–
Algorithm proposed in this work	Based on thresholds for variance and time	1	20 falls 16 ADL 17 participants 3060 samples	92.8	98.7	904	95.0

were obtained, however in that work only 3 kinds of falls were processed. The work presented here used a dataset that involved 20 kinds of falls including the syncope, detection of which is a very difficult task to be accomplished.

5 Conclusions

In this work, an algorithm for fall detection was developed. It was based on the time analysis of the variance of acceleration signals gathered by an IMU attached to the head. The work was addressed to the detection of a fall whenever it occurs, that is why the best performance was achieved for the case of the Recall, which was equal to 98.7%. This algorithm has a low computational cost, which makes it suitable to be implemented in microcontroller platforms and did not constitute an obstacle to achieve results in the range of those obtained by more complex algorithms.

The algorithm was validated by means of a dataset comprised by a large number of kinds of falls, activities of daily living and participants. Then, it can be said that the obtained results are more robust and reliable than the results presented by previous research works that used less diverse datasets.

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Least Squares Optimization with Incorporations from Haar Wavelet

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Abstract This study explores the fusion of Least Squares Optimization and Haar Wavelet analysis using twenty years of climate data. Regression analysis was conducted on monthly rainfall and diurnal temperature variation data from the Climate Research Unit. Statistical methods were applied utilizing MS Excel, MINITAB 14, and MATLAB software. The research examines the background of Least Squares Optimization and its integration with Haar Wavelet analysis. It introduces a novel central tendency measure, contrasting it with traditional mean calculations and emphasizing its significance. Furthermore, the implementation of this new measure is demonstrated through a MATLAB program, detailed in the appendix. The study contributes to the understanding of optimization techniques alongside wavelet analysis, offering valuable insights into the analysis of intricate datasets such as climate data. By employing advanced statistical methodologies, this research enhances our ability to discern patterns and trends within complex environmental data, ultimately facilitating more informed decision-making in various fields reliant on climate information. This study aims to examine diverse techniques within Least Squares Optimization and explore their applications across varied domains. Additionally, it focuses on a comprehensive investigation into the Haar wavelet and its inherent properties. A central objective is to integrate the Haar wavelet methodology with Least Squares Optimization, with the goal of refining optimization processes through wavelet-based approaches. By conducting this investigation, the study endeavors to illuminate the potential advantages and consequences of incorporating the Haar wavelet within the framework of Least Squares Optimization, ultimately fostering the development of more efficient and resilient optimization strategies.

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1 Introduction

In this chapter, we delve into the foundational concepts surrounding Least Squares Optimization problems and their integration with Haar Wavelet analysis. Our primary aim is to elucidate the main objective of this study within this context. Traditionally, when faced with a limited number of data series, the common approach involves computing the mean and drawing regression lines. However, in this study, we endeavor to advance beyond conventional methodologies. Leveraging the capabilities of Haar Wavelet analysis, we embark on the development of a novel central tendency measure. This measure promises to offer enhanced insights into the underlying patterns and trends present within the data. By extending our analysis to incorporate this newly devised central tendency measure, we aim to broaden the scope of our investigation. Through the application of regression analysis on this refined metric, we aspire to uncover nuanced relationships and dependencies that may have previously eluded detection. Thus, our exploration encompasses both the theoretical underpinnings of our chosen methodologies and the practical implications they hold for our research objectives.

The objective of this study is to explore various techniques in Least Squares Optimization, delving into its applications across different domains. Additionally, the research aims to investigate the Haar wavelet and its properties thoroughly. A key focus lies in integrating the Haar wavelet methodology with Least Squares Optimization [1], aiming to enhance the optimization process through the utilization of wavelet-based approaches. Through this investigation, the study seeks to elucidate the potential benefits and implications of incorporating Haar wavelet within the framework of Least Squares Optimization, paving the way for more efficient and robust optimization strategies [2].

This report begins by elucidating various techniques pertinent to least square optimization, followed by an exploration of several applications within this domain. Subsequently, it delves into a comprehensive discussion on the Haar wavelet [3] and the Taming method, which will serve as primary methodologies in this study. Finally, it addresses the integration of the Haar wavelet with least square optimization, consolidating theoretical and practical aspects to enhance optimization methodologies.

2 Literature Review

The integration of Least Squares Optimization with Haar Wavelet analysis represents a significant advancement in the field of statistical analysis, particularly in the context of complex datasets such as climate data. This review focusing on the fusion of LSO and Haar Wavelet analysis applied to twenty years of climate data. The study aims to enhance our understanding of optimization techniques and wavelet analysis, shedding light on their integration for more efficient data analysis and decision-making processes.

The research begins by examining the foundational concepts of LSO, which serves as a fundamental technique for curve fitting and optimal solution determination in systems of linear equations [1]. Through the minimization of the sum of squared residuals, LSO enables the extraction of meaningful insights from empirical data, crucial for accurate modeling and prediction in various domains. The application of LSO extends across disciplines such as statistics, engineering, and economics, highlighting its versatility and importance in real-world applications.

Haar Wavelet analysis, on the other hand, offers a powerful alternative to Fourier series for signal processing and data approximation. By decomposing signals into localized wavelets, Haar Wavelet analysis facilitates the recognition of patterns and trends at different scales, making it particularly suitable for analyzing non-periodic and transient signals [3]. The simplicity and effectiveness of Haar Wavelet analysis makes it a valuable tool in data analysis and signal processing tasks.

The study introduces a novel central tendency measure derived from Haar Wavelet analysis, aiming to provide enhanced insights into complex datasets such as climate data. By contrasting traditional mean calculations with this new measure, the research demonstrates its significance in uncovering nuanced relationships and dependencies within the data. Through regression analysis [4] conducted on the refined metric, the study illustrates the practical implications of integrating Haar Wavelet analysis with LSO, offering valuable insights for data analysts and researchers. Furthermore, the research explores the application of the Haar Wavelet methodology within the framework of LSO, aiming to refine optimization processes through wavelet-based approaches.

Methodologically, the research employs statistical methods utilizing MS Excel, MINITAB 14, and MATLAB software for data analysis and regression modeling [5]. The integration of these tools enables a comprehensive exploration of LSO techniques alongside Haar Wavelet analysis, providing researchers with a robust framework for analyzing intricate datasets.

In conclusion, the study enhances our understanding of optimization techniques and wavelet analysis, particularly in the context of climate data analysis. By integrating Haar Wavelet analysis with LSO [6], the research offers valuable insights into data analysis methodologies, paving the way for more informed decision-making in fields reliant on climate information. The exploration of diverse techniques in LSO and the thorough investigation of Haar Wavelet properties underscore the importance of interdisciplinary approaches in tackling complex data analysis challenges [2].

3 Methodology and Mathematical Formulation

3.1 Least Square Optimization

The Method of Least Squares Optimization is a technique utilized in curve fitting and the determination of optimal solutions for systems of linear equations with infinite solutions. These problems commence with a set of data points (x1, y1), …, (xn, yn), and a predefined class of functions. The primary objective is to ascertain the function y = f(x) that offers the optimal fit to the given data points [1]. Thus, the Method of Least Squares Optimization serves as a powerful tool for extracting meaningful insights from empirical data, enabling identification of mathematical relationships that accurately represent real-world phenomena. Its application extends across various disciplines (i.e., statistics, engineering, and economics) where precise modeling of data is essential for making informed decisions and predictions,

3.2 Haar Wavelet

The best way to understand wavelet is to compare it with Fourier series which are best suited for approximation of periodic smooth functions. To approximate the characteristic functions, especially in application areas such as signal processing [7], wavelets provide a better tool. Wavelets are an alternative to the Fourier transform to represent a signal, using short wavelets instead of long waves. They are also the basis for many image impression algorithms [8]. The basic idea of wavelet analysis is to generate the basic building blocks of the decomposition of space expansions and translation function called single function scaling. In the wavelet analysis, and hierarchically decompose function, and the coefficients corresponding to a certain level to reflect the details of the task at this level [6]. In this section we consider the simplest wavelet, the Haar wavelets.

The corresponding scaling function is the basic unit step function (Fig. 1).

$$\varphi(\mathrm{x}) = \begin{cases} 1.0 \le x < 1 \\ 0, x < 0\, or\, x \ge 1 \end{cases} \tag{1}$$

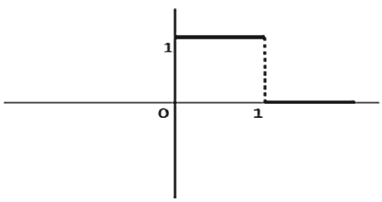

Fig. 1 Graph of the Haar sailing function