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ALGORITHM FOR RECOGNIZING PEOPLE FALLING

ABSTRACT
for a master's degree

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INTRODUCTION

With the rapid development and urbanization of the world, urban population density is growing rapidly, especially in some densely populated places, such as subway stations and bus stops, which are very prone to congestion, falling, and stampede, which will bring relatively large safety hazards. On the other hand, according to the survey, with the aging of the population and the change of economic patterns, there is currently a large number of elderly people living alone, and the number is growing rapidly. In general, the physical condition of the elderly is poor, and once a fall occurs in the case of living alone, it is likely to be difficult to save themselves, resulting in irreversible consequences. In addition, there is also a large number of people with disabilities, and in the case of physical disabilities, it is generally difficult for people with disabilities to help themselves. Therefore, to sum up, if the fall status of the human body can be detected in the above occasions and scenarios, after the occurrence of the fall event is perceived, the emergency can be called for rescue through automatic alarm or automatic contact with emergency contact, which can greatly reduce the occurrence of accidents and avoid irreversible consequences.

GENERAL CHARACTERISTICS OF THE WORK

Relevance of the subject

1. Societal Safety Needs: With the aging population and changes in lifestyles, the incidence of falls is on the rise. Effective fall detection can promptly identify and respond to such incidents, reducing injuries and enhancing overall societal safety.

2. Technological Advancements: The rapid development of computer vision, deep learning, and sensor technologies provides new opportunities for research in fall detection algorithms. The application of these technologies can improve detection accuracy and real-time response, meeting modern safety monitoring demands.

3. Policy Support: This research aligns with paragraph 6 of the State Program for Innovative Development of the Republic of Belarus for 2021–2025, which emphasizes "ensuring the safety of man, society, and state," highlighting its importance in a policy context.

4. Academic Significance: The study of fall detection intersects with various fields, including computer science, artificial intelligence, healthcare, and elderly care, offering significant academic value and practical application potential.

By conducting in-depth research and innovation in fall detection algorithms, this work aims to contribute to improving the quality of life for the elderly and other high-risk groups.

The aim and tasks of the work

The aim of this work is to develop and enhance algorithms for recognizing individuals who are falling. To achieve this aim, the dissertation addresses the following tasks:

1. Review and analyze existing fall detection algorithms.
2. Develop new algorithms suitable for real-time fall recognition.
3. Implement machine learning techniques to improve accuracy and efficiency.
4. Conduct experiments to evaluate the performance of these proposed algorithms.
5. Analyze experimental results to further refine the algorithms.

Personal contribution of the author

In this dissertation, my personal contributions are primarily reflected in the following areas:

1. Scientific Substantiation: I conducted in-depth research to scientifically justify the developed algorithms, including specific methods and software tools for fall detection.

2. Experimental Design and Execution: I was responsible for setting up and conducting experiments to investigate the characteristics and performance of the proposed algorithms.

3. Performance Assessment: I evaluated the efficiency of the developed algorithms through rigorous testing and analysis, ensuring their effectiveness in real-world scenarios.

4. Data Processing and Analysis: I processed and analyzed the results obtained from the experiments, drawing meaningful conclusions to further refine the algorithms.

5. Collaboration with Supervisors: I engaged in discussions with my supervisor, regarding task setting and the interpretation of results, which ensured a comprehensive approach to the research.

Overall, my research demonstrates my contributions to the field of fall detection algorithms and highlights my role in advancing safety technology.

Testing and implementation of results

The main findings and contributions of my dissertation have undergone rigorous testing and evaluation through various channels:

1. Presentation at Conferences: I presented the key results and methodologies at several conferences and seminars, where I received valuable feedback from experts in the field. This helped to refine my approach and validate my findings.

2. Experimental Validation: I conducted comprehensive experiments to assess the performance of the developed fall detection algorithms. These experiments were designed to simulate real-world scenarios, ensuring that the algorithms are both effective and reliable.

3. Continuous Improvement: Based on the feedback and results obtained from testing, I am committed to ongoing refinement of the algorithms to improve their accuracy and efficiency further.

Through these efforts, I aim to ensure that my research not only contributes to academic knowledge but also has practical applications that enhance safety and well-being in society.

Author's publications

To date, I have published several papers in related conferences and journals, focusing on fall detection algorithms. These publications provide a theoretical foundation and background for this research.

Structure and size of the work

This thesis will consist of the following main sections:

1. Introduction: Overview of the research background and significance.

2. Literature Review: Review of related studies and existing technologies.

3. Methodology: Detailed description of the fine-tuning process and some experimental designs.

4. Experimental Results: Presentation and analysis of test results.

5. Discussion: The exploration of the implications of the results and future research directions.

6. Conclusion: Summary of research findings and future outlook.

SUMMARY OF THE WORK

This research develops two novel algorithms for real-time human fall detection to address safety risks in aging populations and high-density public spaces. The first algorithm leverages triaxial accelerometers embedded in wearable devices, analyzing acceleration patterns, zero-crossing points, and polarity changes to detect falls with 91.23% accuracy. It integrates Bluetooth Low Energy (BLE) and a WeChat Mini Program for alerts and emergency contact notifications. The second algorithm uses computer vision (MediaPipe for 33-body keypoint extraction) and a weighted K-Nearest Neighbors (KNN) classifier to analyze posture dynamics, achieving 95.2% accuracy. Both systems were rigorously tested: the wearable approach excelled in daily activities but faced challenges during high-motion tasks, while the vision-based solution demonstrated robustness in real-time video analysis. The work advances fall detection by balancing accuracy, cost-effectiveness, and deployability in real-world scenarios like elderly care and public safety.

CONCLUSION

This research aimed to develop and enhance algorithms for recognizing human falls, addressing the growing societal need for safety among aging populations and individuals with disabilities. Through a systematic exploration of wearable sensor-based and vision-based approaches, two innovative algorithms were designed, implemented, and rigorously tested.

Algorithm Development

The triaxial accelerometer-based algorithm achieved a 91.23% accuracy in detecting falls, with a sensitivity of 94% and specificity of 89.06%. By analyzing acceleration ranges, zero-crossing points, and polarity changes, the algorithm demonstrated robustness in distinguishing falls from activities of daily living (ADLs), despite challenges in high-motion scenarios (e.g., sprinting).

The KNN-based vision algorithm combined MediaPipe pose estimation with a weighted KNN classifier, achieving 95.2% accuracy and 93.8% recall. The integration of PCA-based dimensionality reduction and Kalman filtering significantly improved real-time performance and stability, enabling sub-second fall detection.

Technological Integration

The wearable system leveraged low-power Bluetooth and WeChat Mini Programs for seamless data transmission, emergency alerts, and user interaction, ensuring practicality in real-world settings.

The vision-based system utilized edge computing and multi-threaded architecture to balance computational efficiency and accuracy, achieving 20–30 FPS on mobile GPUs.

Comparative Advantages

Compared to existing methods, the triaxial accelerometer approach outperformed basic wearable solutions (e.g., 91.2% vs. 85.1% for YOLO-based models) while maintaining cost-effectiveness.

The vision-based algorithm rivaled millimeter-wave radar systems (95.2% vs. 96.67%) without requiring expensive depth sensors, making it accessible for widespread deployment.

Practical Implications

The developed systems hold significant potential for enhancing elderly care, public safety, and healthcare monitoring. By enabling real-time fall detection and automated emergency responses, they reduce reliance on manual intervention and mitigate risks of delayed assistance.

Limitations and Future Directions

Limitations:

Wearable systems faced occasional false alarms during high-intensity activities.

Vision-based detection struggled under occlusion or low-light conditions.

Both algorithms relied on limited datasets, necessitating broader validation.

Future Work:

Integrate multimodal data fusion (e.g., combining accelerometer, radar, and audio inputs) to improve robustness.

Optimize privacy-preserving techniques for vision-based systems, such as federated learning or edge-only processing.

Expand dataset diversity to include more complex scenarios (e.g., crowded environments, varied lighting).

Enhance adaptive learning mechanisms to personalize detection thresholds for individual users.

In conclusion, this research advances the field of fall detection by balancing accuracy, practicality, and scalability. The proposed algorithms not only contribute to academic discourse but also pave the way for safer, more independent living for vulnerable populations through practical applications in scenarios such as nursing homes, hospitals, home care systems, and public spaces (e.g., shopping malls and subway stations). Future efforts should focus on refining these systems to address current limitations and broaden their applicability across diverse real-world contexts.

LIST OF PUBLISHED WORKS

1-A. Yulong, Z. Algorithms for recognizing people falling. / Yulong, Z, Rybak, V. A. // Proc. of the 60th scientific conference of graduate students, undergraduates and students / BSUIR, Minsk – 2024. – P. 43.

2-A. Yulong, Z. A fall detection algorithm based on three-axis acceleration. / Yulong, Z, Rybak, V. A. // Information Technologies and Systems 2024 (ITS 2024): Proc. of the international scientific conference, Minsk, November 20, 2024 / BSUIR, Minsk – 2024. – P. 193.