UDC 004.93:613.62

Y. O. Sulima

INTELLIGENT SYSTEMS FOR MONITORING ERGONOMICS OF THE PROGRAMMER'S WORKPLACE FOR PREVENTION OF OCCUPATIONAL DISEASES

Vinnytsia National Technical University

Анотація

Публікація присвячена дослідженню інтелектуальних систем моніторингу ергономіки робочого місця на основі комп'ютерного зору та штучного інтелекту для запобігання професійним захворюванням програмістів. На прикладі реальних продуктів аналізуються основні методи детекції постави, алгоритми моніторингу та системи нагадування про розминку. Розглядаються сучасні техніки реального часу обробки відеопотоку, включаючи глибокі нейронні мережі (OpenPose, MediaPipe, YOLO) та їхню ефективність у виявленні аномалій постави. Крім того, здійснюється оцінка економічного впливу впровадження таких систем та дискутуються виклики, пов'язані з приватністю даних та адаптивністю. Ця стаття може бути корисною для фахівців у сфері інформаційних технологій, дослідників та роботодавців, які зацікавлені у збереженні здоров'я працівників.

Ключові слова: ергономіка, моніторинг постави, комп'ютерний зір, штучний інтелект, MediaPipe, OpenPose, синдром карпального каналу, остеохондроз, система нагадування, розминка, CV (Computer Vision), глибокі нейронні мережі.

Abstract

The publication is devoted to the study of intelligent workplace ergonomics monitoring systems based on computer vision and artificial intelligence to prevent occupational diseases in programmers. Using real products as examples, the main methods of posture detection, monitoring algorithms and break reminder systems are analyzed. Modern real-time video stream processing techniques are considered, including deep neural networks (OpenPose, MediaPipe, YOLO) and their effectiveness in detecting posture anomalies. Additionally, an assessment of the economic impact of implementing such systems is made and challenges related to data privacy and adaptability are discussed. This article can be useful for information technology professionals, researchers and employers interested in preserving employee health.

Keywords: ergonomics, posture monitoring, computer vision, artificial intelligence, MediaPipe, OpenPose, carpal tunnel syndrome, osteochondrosis, reminder system, exercise, CV, deep neural networks.

Introduction

The profession of a programmer in the modern world is considered one of the most prestigious and highly paid, but it is accompanied by significant health risks. Long-term work at a computer leads to the development of a number of occupational diseases [1-3]: osteochondrosis of the cervical and lumbar spine, carpal tunnel syndrome, dry eye syndrome and other pathologies of the musculoskeletal system. Statistics show that more than 70% of programmers suffer from back and neck pain caused by incorrect posture during work [4].

Workplace ergonomics is a scientific discipline that studies the interaction of a person and the working environment in order to optimize working conditions and reduce the risk of developing occupational diseases [5-7]. In recent years, the development of artificial intelligence and computer vision technologies has opened up new opportunities for monitoring and controlling workplace ergonomics.

Using computer vision for posture analysis

Computer vision is a branch of artificial intelligence that deals with the development of algorithms for processing and analyzing digital images. In the context of ergonomics, computer vision is used to detect and analyze the user's body position, determine joint coordinates, and estimate bending angles in various joints [8].

Fig. 1 shows a generalized scheme of using computer vision, which shows the main stages of the process: from receiving input data through a sensor device to interpreting it and forming the final result. This architecture allows you to convert visual information into structured data that can be used for further analysis and decision-making.

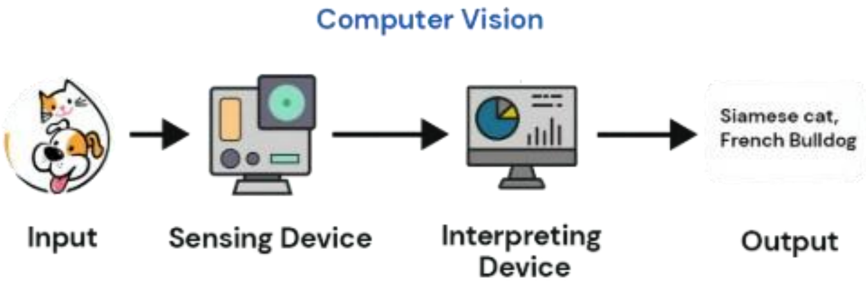

Fig. 1. The principle of computer vision

The basis of the posture monitoring system is the algorithms of human detection and keypoint detection. The most effective of them are based on deep neural networks, such as OpenPose, MediaPipe and YOLO. These models are capable of detecting in real time the main points on the human body, namely the head, shoulders, elbows, wrists, hips and knees.

Table 1 describes the most common pathologies that arise as a result of ignoring ergonomic norms during long-term software development.

Table 1 – Characteristics of the main occupational diseases of IT specialists and their causes

Disease	Main reason (ergonomic factor)	Symptoms
Osteochondrosis	Prolonged static posture, incorrect head tilt	Neck pain, dizziness, shoulder tension
Carpal tunnel syndrome	Incorrect wrist angle relative to the keyboard/mouse	Numbness of fingers, weakness of the hand
Dry eye syndrome	Rare blinking, incorrect distance to the monitor	Eye pain, redness, decreased visual acuity
Kyphosis ("computer neck")	Forward Head Posture	Spinal curvature, respiratory disorders [9-11]

MediaPipe is a framework from Google, developed for real-time posture analysis with an accuracy of about 95%. The system works even with low video quality and low light [12-14]. After detecting the main points, the system calculates parameters for assessing the quality of posture: angles of bending in the cervical region, angles of tilt of the torso, position of the shoulders and head. Normal parameters are determined based on the recommendations of labor protection organizations. For example, the angle of tilt of the head should not exceed 20°, and the angle in the elbow joint should be close to 90–100°. Using such a metric base allows minimizing the number of false positives of the system, since it reacts to a real change in body geometry, and not to random movements in the frame. In addition to posture analysis, intelligent ergonomics systems include modules to remind the user of the need for warm-up and rest. Such systems are based on time management principles and recommendations for the frequency and duration of breaks in work.

Studies show that workers who regularly take breaks of 5-10 minutes every 50-60 minutes of work have 34% fewer cases of carpal tunnel syndrome and 27% fewer complaints of back pain [15]. Reminder software should be adaptive, taking into account the individual characteristics of the user and the intensity of his work.

Intelligent software uses analysis of user activity (number of keystrokes, mouse movements) to determine the optimal time for a break. The system can offer a set of exercises specially designed for programmers aimed at relaxing the muscles of the neck, back and shoulders. The system builds a digital skeleton (skeletonization), where each segment has its own coordinates in 2D or 3D space [16]. Based on the vector between the “ear-shoulder” points, the angle of inclination of the head α is calculated, and between the “shoulder-hip” points, the angle of inclination of the back β is calculated.

Commercial solutions such as ErgoBreak, Workrave and StretchilyApp offer integrated systems with personalized exercises and motivational elements. These systems often include functions for tracking progress and generating reports on the user's health.

Table 2 provides a comparative analysis of the functionality of traditional software solutions and innovative intelligent posture monitoring systems.

Table 2 – Comparative characteristics of ergonomics control software

Software name	Control method	Availability of exercises	Posture analysis (CV)	Adaptability
Workrave	Timer (Pomodoro)	Yes	No	Low
Stretchily	Hard breaks	Yes	No	Medium
Modern IS (AI)	Video stream analysis	Yes (personalized)	Yes	High

Benchmarking data shows that intelligent AI-based systems provide significantly higher levels of personalization and monitoring accuracy compared to traditional timers. By integrating computer vision, such solutions are able not only to remind about rest, but also to dynamically adjust the work habits of a specialist in real time.

Recommended exercises for IT professionals

An effective intelligent ergonomics system is based on a comprehensive set of exercises that specifically affect the areas of the highest static load: the cervical spine, shoulder girdle, wrists and lower back muscles. The basis of the preventive complex is dynamic stretching and isometric exercises that are easily integrated into the workflow without the use of additional equipment. In particular, to prevent the development of "computer neck", head retractions (the "double chin" exercise) are recommended, which restore the natural axis of the spine, as well as circular shoulder rotations to open the chest and eliminate stooping. To protect the carpal tunnel, the system offers a set of hand extensions and the "prayer" exercise, which reduce compression of the median nerve, which occurs due to intensive use of the mouse and keyboard.

An important component is the “20-20-20” rule for the prevention of dry eye syndrome, according to which every 20 minutes the developer should focus his eyes on an object 20 feet away for 20 seconds. Regular performance of these actions not only relieves muscle hypertonicity, but also significantly improves overall blood circulation, preventing stagnation in the pelvis and lower extremities [17]. Modern monitoring systems using computer vision algorithms are able to automatically recognize patterns of performing these exercises in real time. This allows not only to remind about the break, but also to verify the quality of the warm-up performed, providing the user with feedback on the amplitude of movements and correct posture, which turns a regular timer program into a full-fledged digital health assistant.

Intelligent system architecture

The design of an intelligent ergonomics system is based on a multi-level architecture that combines real-time signal processing methods and machine learning algorithms. The main input channel is a video stream capture module that integrates with the user's webcam and transmits frames to the posture analysis module. At this stage, the main skeletonization process takes place: the neural network identifies 33 body reference points (according to the MediaPipe Pose standard [18]), which allows building a dynamic model of the musculoskeletal system. To ensure high performance, the system uses lightweight detection models that are capable of processing video at a frequency of at least 30 FPS without significant load on the central processor. The mathematical core of the system is concentrated in the anomaly detection module. The functioning of this module is based on a continuous comparison of current joint vectors with biomechanically correct reference values. In particular, the main parameters are analyzed: the angle of inclination of the head relative to the vertical axis, the symmetry of the shoulder girdle and the angle of flexion in the elbow joints. The algorithm uses a time window to filter out random movements: if the deviation $\Delta > 15^{\circ}$ is observed for a long interval (more than 5 minutes), the system classifies such a condition as a stable incorrect posture. This triggers the logic of the reminder module, which generates an unobtrusive notification through the OS graphical interface.

Special attention is paid to confidentiality and security during development. The system is implemented according to the principle of local processing (On-Device Processing), which excludes the transfer of images or video streams to cloud servers [19]. All calculations and analysis of coordinates occur exclusively within the RAM of the local machine, and only anonymized statistical metadata (for example, the total time spent working with incorrect posture) can be transferred to the server for further analysis. This method not only guarantees privacy, but also provides minimal latency, which is critical for the correct operation of adaptive user interaction mechanisms. The system intelligently adjusts to the individual anthropometric characteristics of each programmer, allowing calibration of reference values depending on the height of the desktop and the type of chair.

Economic impact of implementation

The implementation of intelligent ergonomic systems is not only a social initiative, but also a strategically profitable investment project for IT-business. According to the analysis using the ROI (Return on Investment) methodology, the use of such systems allows to significantly optimize the company's operating costs. In particular, due to preventive monitoring of posture and timely breaks, the costs of paying sick leave are reduced by an average of 15–20% per year, which for one specialist is equivalent to savings of 800 to 1200 US dollars [20]. At the same time, there is a decrease in the costs of corporate health insurance by 12–18%, since the number of appeals to specialized specialists (vertebral surgeons, ophthalmologists) decreases.

Of particular importance is the impact of the system on labor productivity. Studies confirm that maintaining optimal blood circulation in the brain and relieving muscle tension increase the cognitive endurance of programmers, which translates into an increase in individual efficiency by 8–15%, especially during peak hours in the second half of the working day. For a medium-sized company (about 100 developers), the total annual savings and additional profit can reach 80,000–120,000 USD. Given the relatively low cost of software deployment, the payback period of the system is from 6 to 10 months, providing an ROI of 200–300% already in the first year of operation. It is also worth considering the indirect economic effect: reducing staff turnover due to improved working conditions allows you to avoid significant costs for recruiting and adapting new specialists.

Conclusions

Intelligent ergonomic monitoring systems for programmers workplaces represent a significant advance in ensuring the health and safety of IT workers. The combination of computer vision for posture analysis and adaptive warm-up reminder systems creates a comprehensive approach to preventing occupational diseases.

The introduction of such systems at programmers workplaces can lead to a significant reduction in the number of cases of osteochondrosis, carpal tunnel syndrome and other pathologies. The systems have a positive impact on productivity, as healthier workers show better results.

Further development of these systems should focus on increasing the accuracy of posture detection, developing more personalized recommendations and ensuring user privacy. Investments in ergonomics and employee health are a cost-effective strategy for employers.

References

1. Горбатюк С.М., Хлєстова С.С., Шевчук Т.І., Климчук І.М. Вплив довгострокового забруднення повітря діоксидом азоту на генетичну схильність до порушень психічного розвитку та депресії. Перспективи та інновації науки. 2026. № 4(62). С. 3503-3514.

2. Rusnak I. Conceptual options for the development and improvement of medical science and psychology. International Science Group, 2023. 117 p.

3. Березюк Л.Л. та ін. Екологічна безпека продуктів харчування. Енергія. Бізнес. Комфорт: матеріали науково-практичної конференції, 26 грудня 2018 р. Одеса: ОНАХТ, 2019. С. 7-9.

4. Як зберегти здоров’я програмісту? [Електронний ресурс]. URL: https://www.vitaliypodoba.com/2016/02/programmer-healthcare/

5. Піскун Р.П., Горбатюк С.М. Функціональна морфологія головного мозку при атеросклерозі в експерименті та під впливом вінпоцетіну. Таврійський медико-біологічний вісник. 2006. Т. 9. № 3. С. 100-113.

6. Березюк О.В., Горбатюк С.М., Березюк Л.Л. Залежність поширеності хвороб від відстані між населеним пунктом і полігоном твердих побутових відходів. Наукові праці ВНТУ. 2020. № 4. С. 1-6.

7. Шевчук Т.І., Шкарупа В.М., Хлєстова С.С. Антропогенна зміна довкілля як фактор поширення паразитарних захворювань людини. Довкілля і здоров'я: матеріали наук.-практ. конф., 27-28 квіт. 2017 р. Тернопіль, 2017. С. 220-222.

8. Що таке комп’ютерний зір: пояснення, принцип роботи та застосування [Електронний ресурс]. URL: https://university.sigma.software/what-is-computer-vision/

9. Березюк О.В., Васенко Т.Б., Горбатюк С.М., Шевчук Т.І. Регресійна залежність показників захворюваності на хвороби органів дихання від продуктивності сміттєспалювального заводу. Наукові праці ВНТУ. 2023. № 1. С. 3-8.
10. Khrebtii H. Innovative ways of improving medicine, psychology and biology. International Science Group, 2023. 305 p.
11. Березюк О.В., Гудзевич Л.С., Хлєстова С.С., Климчук І.М. Регресійна залежність захворюваності населення м. Києва на рак органів дихання від забрудненості атмосферного повітря бенз[а]піреном. Наукові праці ВНТУ. 2024. № 1. С. 67-72.
12. Римар В.В. та ін. Універсальний акустичний датчик-вимикач із затримкою вимикання для регулювання освітлення виробничих приміщень. Безпека життя і діяльності людини – освіта, наука, практика: Матеріали XVI Міжнародної науково-методичної конференції БЖДЛ-2018, 25-27 квітня 2018 р. Львів, 2018. С. 167-168.
13. Березюк О.В. Використання віртуального лабораторного стенда для проведення лабораторної роботи «Дослідження ефективності освітлення у виробничих приміщеннях». Педагогіка безпеки. 2017. № 1. С. 35-39.
14. Смоляк В.В. та ін. Практикум з попередньої оцінки та розрахунку освітлення інженерних споруд, виробничих будівель: практикум. Вінниця: ВНТУ, 2020. 81 с.
15. Чому варто робити перерви під час роботи за комп'ютером [Електронний ресурс]. URL: https://pecherskykh-clinic.com.ua/blog/chomu-varto-robyty-perervy-pid-chas-roboty-za-kompyuterom/
16. Skeletonization [Електронний ресурс]. URL: https://www.ebsco.com/research-starters/anthropology/skeletonization
17. Гіпертонус м'язів: причини та способи усунення [Електронний ресурс]. URL: https://kostrova-studio.com/uk/gipertonus-myaziv-prichini-ta-sposobi-usunennya/
18. MediaPipe Explained: The Framework Behind Real-Time Face, Hand, and Pose Detection [Електронний ресурс]. URL: https://medium.com/@amnamubarakk/mediapipe-explained-the-framework-behind-real-time-face-hand-and-pose-detection-01705034e256
19. What Is On-Device Processing? [Електронний ресурс]. URL: https://spruceid.com/learn/on-device
20. Біомеханічні порушення постави: діагностичні підходи та менеджмент [Електронний ресурс]. URL: https://umj.com.ua/en/publication-263234-biomehanichni-porushennya-postavi-diagnostichni-pidhodi-ta-menedzhment

Суліма Юрій Олександрович – студент групи 5ПІ-23б, факультет інформаційних технологій та комп'ютерної інженерії, Вінницький національний технічний університет, м. Вінниця, e-mail: yurijsulima876@gmail.com

Науковий керівник: ***Березюк Олег Володимирович*** – доктор технічних наук, доцент, професор кафедри безпеки життєдіяльності та педагогіки безпеки, Вінницький національний технічний університет, м. Вінниця, e-mail: berezyukoleg@i.ua

Sulima Yurii O. – Faculty of Information Technologies and Computer Engineering, Vinnytsia National Technical University, Vinnytsia, e-mail: yurijsulima876@gmail.com

Supervisor: ***Bereziuk Oleg V.*** – Doct. Sc. (Eng.), Associate Professor, Professor of the Department of Life Safety and Safety Pedagogy, Vinnytsia National Technical University, Vinnytsia, e-mail: berezyukoleg@i.ua