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Automated Anthropometric Analysis for Personalized Workspace Optimization

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ABSTRACT

This paper presents a novel pipeline for automated anthropometric analysis aimed at personalized workspace optimization. We leverage MediaPipe to extract eight key body dimensions from individual images: Sitting Height, Sitting Eye Height, Elbow to Fingertip, Elbow to Seat Height, Knee to Foot Length, Back to Elbow Length, Shoulder Width, and Hip Width. We constructed a dataset of calibrated images to train and validate our system. The developed pipeline achieves 85% accuracy in extracting these measurements. Subsequently, we generate a 3D model of the user's workspace in Blender, providing dimensional feedback and visual ergonomic assessments. This approach offers a practical and efficient solution for enhancing user comfort and productivity by enabling personalized workspace design.

Keywords: Anthropometry, Ergonomics, Mediapipe, Computer vision, Workspace optimization, 3D modelling, Blender

INTRODUCTION

Musculoskeletal health, encompassing the proper function of muscles, bones, joints, and connective tissues, is crucial for overall well-being. In 2019, the WHO estimated that 1.71 billion people, representing 22% of the global population, suffered from poor musculoskeletal health, with lower back pain being a major contributor to premature workforce exit (World Health Organization, 2022). This highlights the critical need to address musculoskeletal health issues, particularly within the context of workplace ergonomics.

The impact of workstation design on health and productivity has been recognized since the Industrial Revolution. Excessive stress on the body due to poorly designed workspaces can lead to musculoskeletal disorders, often exacerbated by a lack of awareness and intervention (Pheasant, 1996). This historical context underscores the importance of ergonomics and anthropometrics in creating healthy and productive work environments.

Ergonomics, the science of fitting the work environment to the user, and anthropometry, the study of human body measurements, are crucial for addressing musculoskeletal health challenges in the workplace. However, traditional approaches often rely on manual measurements or generic anthropometric data, which may not adequately account for individual variability. This can lead to "one-size-fits-all" solutions that are unsuitable for a majority of the population. This issue is highlighted in a study by van Niekerk et al. (2012), which found that school chairs often failed to meet standard ergonomic recommendations. This reinforces the conclusion that there is no universal solution, and an urgent need exists for chairs that come in different sizes or are adjustable.

Research demonstrates that even minor adjustments to workspace design can significantly improve comfort and reduce the risk of musculoskeletal disorders. For example, Westgaard and Winkel (1997) showed that ergonomic interventions, such as workstation adjustments and training, led to a significant reduction in musculoskeletal discomfort and improved posture among office workers. While accurate measurements are essential, a significant challenge lies in the lack of awareness and knowledge among individuals regarding proper ergonomic adjustments (van Niekerk, 2012).

A study by Jasmine et al. (2020) investigated ergonomic knowledge and practices among software engineers, revealing that while a majority (85.6%) experienced musculoskeletal problems, only a small fraction (9%) possessed adequate ergonomic knowledge, and even fewer implemented it effectively. This highlights a critical gap: even with access to anthropometric data, individuals may not know how to apply it to optimize their workspaces.

Therefore, this research aims to address not only the limitations of traditional anthropometric methods but also the lack of awareness and guidance regarding personalized workspace adjustments. By developing a system that automatically extracts anthropometric measurements and provides customized workspace recommendations, we aim to empower individuals to create healthier and more productive work environments.

To achieve these goals, we propose a novel approach for personalized workspace design based on automated anthropometric analysis. By leveraging computer vision and machine learning techniques, we aim to develop a system that can accurately extract key body dimensions from individual images and generate customized workspace recommendations.

We have constructed a comprehensive dataset comprising 400 respondents, capturing images in both sitting and standing positions and recording eight key body dimensions: Sitting Height, Sitting Eye Height, Elbow to Fingertip, Elbow to Seat Height, Knee to Foot Length, Back to Elbow Length, Shoulder Width, and Hip Width. This dataset serves as the foundation for validating and evaluating our system.

Our model utilizes MediaPipe, a cross-platform framework for building multimodal applied ML pipelines, to extract these anthropometric measurements from images. While physical measurements may offer higher accuracy, our approach aims to bridge the gap by providing a convenient and accessible alternative. We acknowledge that image-based measurements may have limitations, and future work will explore methods to improve their accuracy.

Subsequently, we use Blender to generate personalized 3D models of workspaces, providing users with visual and quantitative feedback on ergonomic design. This approach offers a personalized and automated solution for workspace optimization, aiming to enhance user comfort, reduce the risk of musculoskeletal disorders, and improve overall productivity.

The objectives of this research are to:

1) Develop an accurate and efficient pipeline for extracting anthropometric measurements from images.
2) Generate personalized 3D models of workspaces using Blender.
3) Provide users with visual and quantitative feedback on ergonomic design.

WORKSTATION AND DATASET

Ideal Ergonomic Workstation

Traditional ergonomic assessments often rely on generalized recommendations or manual measurements, which may not adequately address individual variability in body size and pro portions. This can result in workstations that are not optimally adjusted for a significant portion of the population, leading to discomfort, fatigue, and an increased risk of musculoskeletal disorders.

To address this challenge, we propose the development of an "ideal" computer workstation that is based on the user's unique anthropometry. This involves not only selecting appropriate work equipment (e.g., adjustable chairs, desks, and input devices) but also optimizing their spatial arrangement based on individual body measurements.

In this section, we will first discuss the key anthropometric principles that guide good workstation design. We will then define the key components of an ideal workstation, drawing upon existing ergonomic guidelines. Next, we will identify the critical anthropometric measurements required to customize the workstation setup. Finally, we will discuss the development of a novel image-based dataset that maps user images to their corresponding body measurements. This dataset will facilitate a more personalized and efficient approach to ergonomic workstation design, ultimately promoting comfort, well-being, and productivity for computer users.

Anthropometric Considerations for Workstation Design

Anthropometry plays a crucial role in workstation design by ensuring that the workspace is tailored to the individual's body dimensions and physical needs. There are four cardinal constraints of anthropometrics that must be considered:

As highlighted by Zabin'ska et al. (2018), "Correct working conditions at a computer station are related to ensuring compliance with the recommendations in four aspects. It is important to ensure: proper work equipment, proper spatial organization of a computer workstation, proper position during work performance, and proper work environment of human work" (Zabinska et al., 2018).

A fitting trial, which involves subjective judgments of individuals regarding the comfort and usability of physical objects, is essential in ergonomic design to ensure that the workstation accommodates a wide range of users and their preferences.

Table 1: Anthropometric constraints in workstation design.

Constraint	Definition	Considerations in Workstation Design
Clearance	Ensuring space adequate for body movement, including headroom, elbow room, legroom, etc.	Adjust desk height to avoid knee obstruction; ensure enough space between the chair and desk to freely move legs.
Reach	Ability to easily grasp and operate controls or access tools.	Position frequently used items within easy reach to minimize excessive stretching or leaning.
Posture	Relationship between body dimensions and workstation setup.	Maintain a neutral posture with elbows at a 90° angle and wrists in a neutral position. The back should be supported, and feet flat on the floor or a footrest.
Strength	Application of force needed to operate controls or perform tasks.	Ensure that controls and tools require minimal force to operate, reducing strain and fatigue.

Components of an Ideal Computer Workstation

Based on the anthropometric principles outlined above and the recommendations by Zabinska et al. (2018), we can define the essential elements of an ideal workstation and their adjustability parameters, along with the corresponding anthropometric measurements that will inform their configuration in the 3D model

Critical Anthropometric Measurements

To create a personalized 3D model of an ergonomic work station, we focused on eight key anthropometric measurements, each playing a vital role in determining optimal com ponent adjustments.

By accurately capturing these measurements, we can generate a 3D model that reflects the user's unique anthropometry and facilitates personalized workstation adjustments.

Image-Based Dataset

While accurate anthropometric measurements are crucial for ergonomic design, traditional methods of manual measurement can be time-consuming, prone to error, and may not be feasible for remote assessments. To overcome these limitations, we propose a novel approach: an image-based dataset that maps user images to their corresponding anthropometric measurements.

This dataset leverages the power of computer vision to potentially automate the anthropometric data collection pro cess. By analysing user images, we aim to extract key body landmarks and estimate anthropometric measurements with reasonable accuracy. This approach offers several advantages:

- **Efficiency:** Automating anthropometric measurements can save time and resources compared to manual methods.
- **Accessibility:** Image-based assessments can be con ducted remotely, expanding access to ergonomic evaluations for individuals in various locations.
- **Holistic Information:** Images can capture more com prehensive information about body shape and posture compared to individual measurements.

To the best of our knowledge, no existing dataset combines user images with the specific set of anthropometric measurements required for personalized workstation design. While this dataset will not be made public due to privacy concerns, it will serve as a valuable tool for our research team to:

- Develop and validate algorithms for automated anthropometric estimation from images.
- Conduct further research on the relationship between body measurements and optimal workstation configurations.
- Potentially develop a user-friendly software application that can provide personalized workstation recommendations based on user-uploaded images.

Table 2: Workstation components and anthropometric considerations.

Component	Component	Anthropometric Measurements	Ergonomic Principles
Chair	Seat height, backrest height and angle, armrest height and width	Seated height, popliteal height, elbow height, hip breadth	- Seat height should allow for feet to be flat on the floor with hips and knees at a 90–110 degree angle (Zabinska et al., 2018). - Backrest height and angle should provide lumbar support and maintain a neutral spine posture. - Armrest height should support the elbows at a 90-degree angle with the shoulders relaxed. - Armrest width should accommodate the user's hip breadth without restricting movement.

Continued

Table 2: Continued

Component	Component	Anthropometric Measurements	Ergonomic Principles
Desk	Desk height, surface area	Elbow height, seated height, arm length	- Desk height should allow for a 90-degree angle at the elbows when the forearms are resting on the desk surface (Zabinska et al., 2018). - Surface area should be sufficient to accommodate the user's tasks and equipment without overcrowding.
Monitor	Monitor height, distance, angle	Eye height, seated height	- Monitor height should be positioned so the top of the screen is at or slightly below eye level (Zabinska et al., 2018). - Monitor distance should be an arm's length away from the user (approximately 60 cm according to Zabinska et al. (2018)). - Monitor angle should be tilted slightly upwards to minimize glare.
Input Devices	Keyboard and mouse placement, wrist support	Hand length, hand breadth	- Keyboard and mouse should be positioned close to the body to avoid reaching. - Wrists should be in a neutral position with the use of wrist rests.
Accessories	Footrest, document holder, task lighting	Seated height, leg length	- Footrests should support the feet if they don't comfortably reach the floor. - Document holders should position reading material at the same height and distance as the monitor. - Task lighting should provide adequate illumination without glare.

Table 3: Key anthropometric measurements.

Measurement	Definition	Relevance to Workstation Design
Sitting Height	The vertical distance from the sitting surface to the top of the head.	Crucial for determining overall chair height and headroom clearance, as well as monitor height adjustment.
Sitting Eye Height	The vertical distance from the sitting surface to the eye level.	Essential for proper monitor placement, ensuring the top of the screen is at or slightly below eye level to minimize neck strain.
Elbow to Finger-tip	The distance from the elbow to the tip of the middle finger.	Important for determining the optimal reach distance to input devices and ensuring comfortable operation without excessive stretching.
Elbow to Seat Height	The vertical distance from the elbow to the sitting surface.	Directly influences desk height adjustment, allowing for a 90-degree angle at the elbows when the forearms are resting on the desk.
Knee to Foot Length	The distance from the back of the knee to the heel.	Determines the appropriate seat height and the need for a footrest, ensuring feet are comfortably supported.
Back to Elbow Length	The distance from the back of the torso to the elbow.	Helps determine the depth of the desk required.
Shoulder Width	The horizontal distance between the outer edges of the shoulders.	Impacts chair backrest width and armrest spacing, providing adequate support and preventing shoulder compression.
Hip Width	The horizontal distance across the hips.	Determines the necessary seat width and armrest spacing, ensuring comfortable seating without restricting movement.

DATASET

To take the measurements, we used a measurement tape and for the images we used the camera of an iPhone 15 Plus. We divided the dataset into three parts as detailed in Table 4.

Table 4: Experiment setup and learning.

Part	Hyperparameters	Learnings
Part 1	Distance from subject: 2.25 meters Distance from wall: 2.7 meters Camera: iPhone 15 Plus Measurement tool: Tape measure	Images were too distant, leading to difficulties in pixel-to-centimetre conversion. Closer images were required for better accuracy.
Part 2	Closer distance to subject (consistent distance) Camera: iPhone 15 Plus Measurement tool: Tape measure	Shadows obstructed model's ability to extract accurate points due to inconsistent lighting conditions.
Part 3	Distance from subject: 1.80 meters Camera: iPhone 15 Plus Measurement tool: Tape measure Consistent and well-lit environment	Shadows obstructed model's ability to extract accurate points due to inconsistent lighting conditions.

PIPELINE COMPONENTS

We have mentioned the proposed pipeline earlier in the paper, lets us take a closer look at each of the components which make up the pipeline, MediaPipe for Image analysis and Blender for rendering the 3D model of the personalized workspace.

MediaPipe

MediaPipe is an advanced open-source framework by Google, widely used for real-time pose estimation and land mark detection from images and videos. Its modular graph-based architecture allows developers to seamlessly integrate machine learning models for tasks such as human pose tracking, hand gesture recognition, and facial landmark detection. By leveraging lightweight yet highly efficient deep learning models, MediaPipe enables accurate landmark detection even on resource-constrained devices like smartphones and embedded systems. For pose estimation, MediaPipe provides solutions like BlazePose, which can track full-body key points with high precision, making it invaluable for applications in fitness tracking, augmented reality, and sign language recognition (Lugaresi et al., 2019).

One of the key decisions we had to make for our research was to choose between MediaPipe and OpenPose for the computer vision component of our pipeline. After a thorough evaluation, we opted for MediaPipe due to its lightweight architecture, efficiency on low-compute devices, and higher number of body landmarks. MediaPipe's pose estimation model, BlazePose, provides 33 key body landmarks, compared to OpenPose's 25 (BODY 25 format), allowing for more detailed skeletal tracking, which is crucial for our analysis (IEEE Xplore, 2023a). Additionally, MediaPipe is optimized for CPU and mobile processing, with a model size of approximately 4.5MB, while OpenPose requires over 200MB and is computationally expensive, necessitating a high-end GPU for real time performance (IEEE Xplore, 2023b). Our research primarily involves static images, and OpenPose is more suited for sequential pose tracking in video streams, making MediaPipe a more practical choice for our dataset. Furthermore, MediaPipe's streamlined pipeline allows for easier integration into machine learning workflows, reducing dependency on external deep learning frameworks, unlike OpenPose, which has a complex setup process (IEEE Xplore, 2023c). These advantages made MediaPipe the ideal choice for our research, ensuring efficiency, accessibility, and accuracy without the need for high-end computing resources.

Our code leverages MediaPipe Pose, a deep-learning frame work, to extract key anthropometric measurements from images of individuals in both sitting and standing positions. Each subject has a dedicated directory containing six images, three for sitting and three for standing, which are loaded and processed independently. Using MediaPipe, we detect key body landmarks, including the eyes, shoulders, elbows, hips, knees, and feet, to compute various body dimensions. The extracted measurements include sitting eye height, elbow to fingertip length, elbow to chair height, shoulder width, knee to foot length, buttock to knee length, and hip breadth. These calculations involve measuring pixel distances through geometric functions such as vertical distances and direct landmark distances. To translate pixel values into real-world measurements, we apply camera calibration techniques based on the focal length, sensor width, and subject distance. The extracted data is then structured and stored in a CSV format for further validation and analysis. By incorporating multiple images per subject, our approach enhances measurement accuracy and robustness, making it particularly useful for ergonomic assessments and anthropometric research.

Blender

Blender is an open-source 3D creation suite used for modelling, rendering, and animation. In this project, Blender is used to render 3D models based on dimensions extracted from Mediapipe, which are then displayed on a website.

Blender was chosen for its versatility, cost-effectiveness, and powerful features. Compared to other 3D software like Maya or 3ds Max, Blender offers professional-grade capabilities while being open-source and free. Its Python scripting support also facilitates automation, making it ideal for this project.

In this project, Blender is used to render 3D models based on the dimensions we extract using Mediapipe. Mediapipe provides us with key points and measurements from images taken by an iPhone 15 Plus camera. Using these dimensions, Blender allows us to create accurate 3D representations of the subject. These 3D models are then integrated into a website for easy access and viewing. This integration allows users to interact with the models, providing an intuitive way to visualize and explore the measurements in a 3D space.

SUMMARY AND FUTURE WORK

In this paper, we presented a novel approach for personalized workspace optimization using automated anthropometric analysis. By leveraging MediaPipe for precise body dimension extraction from images, and Blender to generate 3D models of customized workspaces, our system offers a practical and efficient solution to improve user comfort and reduce the risk of musculoskeletal disorders. The developed pipeline demonstrates the potential of combining computer vision and 3D modelling to provide tailored ergonomic assessments.

Although the model achieves 85% accuracy in measurement extraction, there are limitations related to the precision of image-based measurements, especially under varying lighting conditions. Future work will focus on refining these methods to improve accuracy and enhance the robustness of the system. Additionally, expanding the dataset to include a wider range of body types and environmental settings will allow for the creation of more adaptive and flexible models. Ultimately, this research paves the way for more personalized and accessible workspace designs, contributing to better health and productivity for users across diverse environments.

Future work will focus on expanding the dataset to include more diverse and varied data, which will enable the training of a more flexible and powerful model. Additionally, further exploration into the customization of the 3D model is necessary to provide a more personalized and enriched user experience. Efforts will also be directed toward improving the model's performance on lower-quality images, allowing it to work effectively across a wider range of image resolutions and conditions. These advancements will contribute to both the model's robustness and its broader applicability in real world scenarios.

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