

Computer Vision Project Report

Slouch Detector: Real-Time Posture Monitoring for Improved Health and Well-being

Written by: **Venkatakrishnan Ranganathan**

Date: **7 June, 2023**

1. Views on Computer Vision:

Throughout this course, I have had the opportunity to delve into fundamentals of computer vision. I have gained valuable insights into the power of these techniques and how they can revolutionize countless industries and domains. This course has equipped me with a comprehensive foundation in the fundamentals of computer vision, enabling me to grasp concepts such as image processing, object detection, and motion tracking. When I think about applications, one documentary came to mind which talked about the MEDEA Program. It involved the declassification of highly classified data from the US Intelligence Community and the Defense Department, which was made available to scientists working in Earth science disciplines. The program aimed to utilize this previously untapped global information to enhance our understanding of Earth's environment.

Given the recent advancements in computer vision (CV) techniques, it's possible to imagine how these techniques could have been beneficial for the MEDEA program. Here are a few ways CV techniques could have been applied:

1. **Image Analysis:** CV techniques could have been utilized to analyze satellite imagery and other visual data sources to extract valuable environmental information. For example, algorithms could be developed to identify and track changes in land use patterns, deforestation, urban growth, or ice cover.
2. **Object Detection and Classification:** By applying object detection and classification algorithms, scientists could have automatically identified and categorized various features in the environment, such as cloud cover,

atmospheric conditions, or oceanographic phenomena. This could have provided a more comprehensive understanding of Earth processes.

3. **Monitoring and Surveillance:** Computer vision algorithms could have been used for continuous monitoring and surveillance of critical environmental parameters. For instance, the detection of pollution sources, illegal deforestation activities, or changes in glacier movements could have been automated using CV techniques, enabling timely response and intervention.
4. **Visualization and Communication:** Image generation could have supported the visualization and communication of complex environmental data. By converting large volumes of data into visual representations, such as heatmaps, overlays, or animations, scientists and policymakers could have more easily understood and communicated the findings to a wider audience.
5. **Image Stitching:** Computer vision algorithms could have been employed to stitch together multiple images taken from different viewpoints or satellite passes. This would have allowed the creation of seamless, high-resolution composite images covering larger geographic areas. By stitching together images with overlapping regions, scientists could have obtained a more comprehensive and detailed view of Earth's surface.
6. **Change Detection:** Computer vision techniques could have been used to compare stitched images taken at different time points and automatically detect changes in the environment. By analyzing pixel-level differences or applying more sophisticated algorithms, scientists could have identified alterations such as

urban expansion, deforestation, or changes in land cover over time. This would have facilitated the monitoring of environmental changes on a global scale.

7. **Time-Series Analysis:** By leveraging image stitching and change detection techniques, scientists could have created time-series visualizations to track and analyze long-term changes in specific regions or environmental parameters. This would have provided valuable insights into the dynamics of climate patterns, vegetation health, and other environmental factors.
8. **Data Fusion with Other Sensors:** In addition to image stitching, computer vision techniques could have been combined with data from other sensors, such as radar or LiDAR, to enhance the accuracy and completeness of change detection. These multi-modal data fusion approaches would have allowed for a more comprehensive understanding of Earth's environment and its changes.
9. **Automated Monitoring and Alert Systems:** With image stitching and change detection algorithms in place, an automated monitoring and alert system could have been developed. This system would continuously analyze newly acquired imagery and promptly notify scientists or relevant authorities about significant environmental changes, enabling timely responses or further investigations.
10. **Tracking Moving Objects:** Motion tracking algorithms can be applied to identify and track moving objects within the environment. For example, ships, aircraft, or vehicles can be detected and monitored using satellite or aerial imagery. By tracking these objects over time, valuable insights can be gained regarding transportation patterns, human activities, or illegal operations in certain areas.

11. **Oceanographic Tracking:** Motion tracking techniques can be employed to monitor ocean currents, eddies, and other dynamic water movements. By analyzing satellite data or oceanographic measurements, scientists can track the motion of water masses and study their impact on climate, marine ecosystems, and the spread of pollutants. This information can contribute to better understanding ocean dynamics and its influence on the environment.
12. **Glacier Movement Monitoring:** Glacier movement plays a crucial role in understanding climate change and its impact on polar regions. Motion tracking algorithms can be used to analyze satellite imagery or time-lapse photography to track the movement of glaciers. This allows scientists to quantify their speed, direction, and changes over time, providing insights into the effects of climate change on ice formations.
13. **Land Subsidence and Earthquake Monitoring:** Motion tracking techniques can help monitor subtle ground movements, such as land subsidence or tectonic plate shifts. By comparing satellite imagery or radar measurements taken at different time points, scientists can detect and track changes in land elevation, identifying areas prone to subsidence or seismic activity. This information is vital for assessing geological hazards and informing land-use planning.
14. **Vegetation Dynamics:** Motion tracking can also be applied to monitor the growth and dynamics of vegetation over time. By analyzing satellite imagery or drone footage, algorithms can track changes in plant cover, detect forest fires, monitor deforestation activities, or assess the health and productivity of

agricultural lands. This information aids in ecosystem management, biodiversity conservation, and understanding the impacts of climate change on vegetation.

2. Slouch Detector

2.1. Introduction:

Posture-related problems have become increasingly prevalent in modern society, with reports from the National Institutes of Health (NIH) indicating that a staggering 80% of Americans experience issues associated with poor posture. The implications of this statistic are profound, as improper sitting posture can exert significant pressure on spinal disks, the low back, and the neck, leading to discomfort, pain, and potentially more severe health complications. Biomechanics experts emphasize that misalignments, such as rounded upper backs, forward-rolled shoulders, and heads carried in front of the center of gravity, can contribute to a host of adverse health effects.

2.2. Motivation:

Considering the widespread prevalence of posture-related problems and their impact on individuals' well-being, there is a compelling need for proactive measures to address this issue. The motivation behind our project, the Slouch Detector, is to provide real-time feedback on sitting posture to users while they are engaged with their computers. By leveraging the power of computer vision technologies, specifically MediaPipe and OpenCV, we aim to empower individuals to monitor and correct their sitting posture, ultimately leading to improved health and enhanced quality of life.

Posture correction is crucial for preventing and mitigating the adverse effects associated with misalignments. By alerting users to poor posture habits in real time, our Slouch Detector offers an immediate, intuitive solution to combat this pervasive problem. By harnessing the capabilities of a simple webcam input, we enable individuals to actively address their sitting posture during computer use, fostering better spinal alignment and reducing the risk of future health complications.

The Slouch Detector project aligns with the growing trend of using computer vision techniques to address real-world problems. By leveraging the capabilities of MediaPipe and OpenCV, we can analyze a user's sitting posture, detect signs of slouching or misalignment, and provide personalized feedback. The potential benefits are vast, ranging from enhanced comfort and reduced pain to the prevention of chronic issues related to poor posture.

Our Slouch Detector project aims to address the pressing need for improved posture management in the digital age. By offering real-time feedback and encouraging users to correct their sitting posture while using their computers, we hope to empower individuals to take proactive steps towards a healthier and pain-free lifestyle. By leveraging the power of computer vision, we believe that this project has the potential to make a significant positive impact on the well-being of individuals, promoting healthier habits and preventing future health complications associated with poor posture.

2.3. Goals:

The primary goals of the Slouch Detector project are as follows:

1. **Continuous Real-Time Monitoring:** Develop a robust system that can continuously monitor the user's sitting posture in real-time using a webcam input. By leveraging computer vision techniques, specifically MediaPipe and OpenCV, we aim to analyze the user's body position and identify any signs of slouching or poor posture. The system should provide accurate and reliable posture detection capabilities.
2. **Immediate Feedback:** Provide immediate and actionable feedback to the user regarding their sitting posture. The system should promptly alert the user whenever it detects deviations from proper posture. This feedback can be in the form of visual cues, auditory signals, or any other intuitive mechanism that effectively conveys the necessary information to the user.
3. **Guidelines for Posture Maintenance:** Alongside the real-time feedback, the Slouch Detector should offer practical guidelines on how to maintain correct sitting posture. This can be in the form of visual instructions, textual tips, or even interactive demonstrations. The goal is to educate and empower users to adopt healthy sitting habits and make informed adjustments to their posture.
4. **Minimal Setup and Device Requirements:** Ensure that the Slouch Detector project remains accessible and user-friendly by eliminating the need for additional devices or complex setups. The system should be designed to work seamlessly with a standard webcam, leveraging existing hardware commonly available on computers. This will facilitate widespread adoption and encourage users to incorporate posture monitoring into their daily computer usage without significant barriers.

By achieving these goals, the Slouch Detector project aims to provide individuals with a practical and convenient tool for actively monitoring and improving their sitting posture while using a computer. The system's real-time monitoring, immediate feedback, posture maintenance guidelines, and ease of use will collectively contribute to fostering healthier posture habits and reducing the risk of associated health complications. Ultimately, the project strives to empower users to take charge of their posture and promote well-being in their daily lives.

2.4. Approach:

The Slouch Detector project utilizes a range of technologies to achieve its objectives.

Here is a description of the technologies used:

1. **OpenCV:** OpenCV (Open Source Computer Vision Library) is a widely used open-source library for computer vision and image processing tasks. It provides a comprehensive set of functions and algorithms for image and video manipulation, including video capture, image processing, and feature detection. OpenCV serves as the foundation for various computer vision operations in the project.
2. **Video Capture:** The video capture functionality of OpenCV is employed to access the webcam input and retrieve video frames in real-time. This allows the project to continuously monitor the user's sitting posture using the live video feed from the webcam.
3. **MediaPipe Pose:** MediaPipe Pose is a computer vision module within the MediaPipe framework that enables accurate and real-time body pose estimation. It leverages machine learning techniques, including CNN models, to detect and

track the positions of various body joints or landmarks, such as shoulders, elbows, wrists, hips, knees, and ankles. MediaPipe Pose plays a crucial role in analyzing the user's sitting posture and providing feedback.

4. **Application on Pose Estimation, Object Detection, and Gesture**

Recognition: The project leverages the capabilities of the MediaPipe to perform various tasks, including pose estimation, object detection, and gesture recognition. These functionalities enable the Slouch Detector to not only monitor the user's sitting posture but also provide additional features related to object detection and gesture-based interaction.

5. **Prediction of 3D Coordinates:** MediaPipe predicts the 3D coordinates of various body joints or landmarks. This information provides a deeper understanding of the user's posture and allows for more comprehensive analysis and feedback generation.

6. **Plyer (Notification):** Plyer is a Python library that provides a unified API for accessing various platform-specific features, including notifications, on different operating systems. It is likely utilized in the project to generate notifications or alerts to the user regarding their sitting posture, leveraging Plyer's capabilities for cross-platform compatibility.

In summary, the Slouch Detector project makes use of technologies such as OpenCV, MediaPipe Pose, and the Plyer library for notifications. These technologies collectively enable real-time monitoring of the user's sitting posture, accurate pose estimation, and the provision of immediate feedback to promote correct sitting habits and address posture-related issues.

2.5. Why MediaPipe?

MediaPipe's Pose Detection module achieves real-time performance primarily through a combination of model design optimizations, efficient inference techniques, and hardware acceleration. Here are some factors that contribute to its speed:

1. **Model Architecture:** The underlying pose estimation models used in MediaPipe are designed to strike a balance between accuracy and efficiency. These models typically employ lightweight architectures, such as MobileNet, that are specifically tailored for real-time processing on resource-constrained devices. By reducing the model's complexity and parameter count, the inference speed is significantly improved without sacrificing too much accuracy.
2. **Model Quantization:** MediaPipe incorporates model quantization techniques to further optimize the pose estimation models. Quantization reduces the precision of the model's weights and activations, typically from floating-point representation to lower-bit fixed-point or integer representations. This reduction in precision significantly reduces memory requirements and improves computational efficiency during inference.
3. **Hardware Acceleration:** MediaPipe leverages hardware acceleration, such as GPUs (Graphics Processing Units) or specialized neural network inference accelerators (e.g., Google's Edge TPU), to accelerate the pose estimation computations. These hardware accelerators are optimized for matrix operations and parallel processing, which are fundamental to deep learning computations. By offloading computations to dedicated hardware, MediaPipe achieves significant speed-ups compared to running the models solely on CPUs.

4. **Model Optimization:** MediaPipe employs various optimization techniques to further enhance the efficiency of the pose estimation models. These techniques include network pruning, weight sharing, and layer fusion, among others. By eliminating redundant computations and reducing memory footprint, these optimizations lead to faster inference speeds without compromising accuracy.
5. **Parallel Processing:** MediaPipe takes advantage of parallel processing capabilities available on modern devices to accelerate pose estimation. By dividing the input image or frame into smaller regions, multiple pose estimation computations can be performed simultaneously on different regions using multi-threading or distributed processing. This parallelization technique allows for efficient processing and improved real-time performance.

Overall, MediaPipe combines model design optimizations, model quantization, hardware acceleration, and parallel processing techniques to achieve real-time performance in its Pose Detection module. By carefully balancing accuracy, efficiency, and computational resources, MediaPipe enables fast and reliable pose estimation, making it suitable for real-time applications where low latency is crucial.

2.6. Design:

The design of the Slouch Detector project incorporates several key components and techniques to enable the detection and analysis of slouching postures in real-time. The design considerations include self-defined values for calibration and thresholding, the relative distance of the midline, shoulder angle measurement, the ratio of face area to

shoulder width, face upward angle assessment, shoulder z difference calculation, real-time posture notifications, and the ability to run the system in the background.

1. **Slouching Detection using Self-Defined Values (Calibration & Threshold):**

The system employs self-defined values for calibration and thresholding to determine what constitutes a slouching posture. These values can be adjusted based on individual preferences and comfort levels. By setting appropriate thresholds, the system can effectively identify and differentiate between correct sitting posture and slouching.

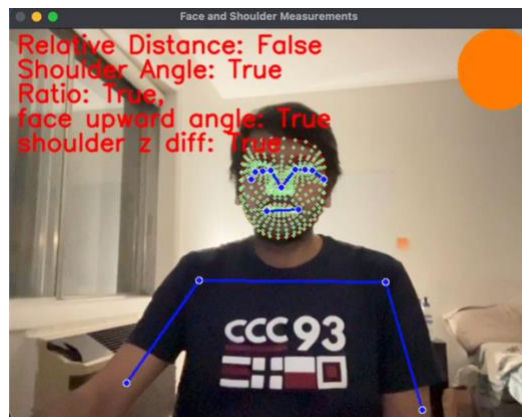
- a. **Relative Distance of Midline (Based on Shoulder Width):** The relative distance of the midline, calculated based on the shoulder width, is used as a measure to assess the alignment of the upper body. Deviations from an optimal midline position can indicate slouching. By continuously monitoring and analyzing the relative distance of the midline, the system can detect and alert the user about any significant misalignments.
- b. **Shoulder Angle:** The shoulder angle is an important factor in assessing sitting posture. The system measures the angle formed by the shoulders to evaluate the forward or rounded posture. An abnormal shoulder angle suggests slouching, and the system can provide real-time feedback to the user regarding this misalignment.
- c. **Ratio of Face Area and Shoulder Width:** The ratio of the face area to the shoulder width is another metric employed in the posture analysis. A large ratio may indicate that the user's head is carried in front of the center

of gravity, potentially leading to slouching. By monitoring and analyzing this ratio, the system can detect such postural deviations and notify the user accordingly.

- d. **Face Upward Angle:** The face upward angle is utilized to assess the tilt of the user's head. When the face upward angle exceeds certain thresholds, it may indicate a tendency towards slouching. By continuously tracking this angle, the system can provide real-time feedback to help the user maintain a neutral head position.
 - e. **Shoulder Z Difference:** The system calculates the difference in the z-axis coordinates of the shoulders to evaluate any imbalances or asymmetries in the user's posture. Significant discrepancies in the shoulder z difference may suggest poor posture. By monitoring and analyzing this metric, the system can alert the user to correct their sitting position.
- 2. **Notification Reflecting Real-Time Postures:** The Slouch Detector system generates real-time notifications or alerts based on the detected postures. These notifications serve as immediate feedback to the user, informing them about their current posture and encouraging them to make necessary adjustments to maintain proper alignment.
 - 3. **Allow Backstage Running:** The system is designed to run in the background, allowing users to continue their computer activities without interruption. By running silently in the background, the Slouch Detector remains active and continuously monitors the user's posture, providing feedback and alerts without interfering with their workflow.

By incorporating these design elements, the Slouch Detector project enables real-time monitoring and analysis of the user's sitting posture. The self-defined calibration and threshold values, along with the assessment of various postural metrics such as the relative distance of the midline, shoulder angle, face area ratio, face upward angle, and shoulder z difference, contribute to the accurate detection of slouching. The provision of real-time notifications ensures that the user receives immediate feedback, promoting improved posture habits and reducing the risk of associated health issues.

2.7. Results and Challenges:



The Slouch Detector project faces several challenges due to the inherent variations in individuals' sitting postures based on body shapes, habits, and comfort levels. To address these challenges, the posture detection system needs to account for these variations and provide flexibility in detecting and assessing postures. Here are the challenges that need to be considered:

1. **Individual Differences:** People have different body shapes, sizes, and proportions, which can result in variations in sitting postures. Some individuals

may naturally have a more rounded upper back or broader shoulder width, while others may have different body alignment tendencies. The posture detection system needs to accommodate these individual differences and avoid rigid assumptions about what constitutes the "ideal" posture.

2. **Comfort and Habits:** Sitting postures can be influenced by individual comfort preferences and long-standing habits. Some individuals may find certain postures more comfortable or habitual due to factors like ergonomic considerations or personal preference. The posture detection system should recognize a range of acceptable postures and avoid flagging every deviation from a textbook posture as slouching. Allowing flexibility in detecting and assessing postures ensures that the system doesn't generate false positives or unnecessarily alarm users.
3. **Subjectivity of Acceptable Postures:** Defining the range of acceptable postures can be subjective, as different sources may provide different guidelines. While certain postural deviations are generally recognized as problematic, there can be variations in the degree of deviation that is considered acceptable or tolerable. The system should account for these variations and provide customizable thresholds or parameters that can be adjusted based on user preferences or expert recommendations.
4. **Real-Time Detection Challenges:** Real-time posture detection adds complexity to the system. Processing the webcam feed and performing pose estimation in real-time requires efficient algorithms and optimized performance. Dealing with

varying lighting conditions, occlusions, and fast movements adds additional challenges to accurately and reliably detect and track postures.

5. **Training Data Diversity:** Building a robust posture detection system requires diverse and representative training data. The system should be trained on datasets that encompass a wide range of body shapes, sizes, and postural variations. Including data from different demographics and populations ensures that the system can generalize well and accommodate the variations encountered in real-world scenarios.
6. **User Adaptation and Feedback:** The system should be designed to adapt to individual users over time. Providing personalized feedback and guidance based on an individual's specific postural tendencies can help users gradually improve their sitting habits. The system should also be responsive to user feedback and allow for customization or fine-tuning based on individual needs and comfort.
7. **Variations in Chairs, Lighting, and Backgrounds:** Real-world settings introduce a wide range of variations, including different types of chairs, varying lighting conditions, and diverse backgrounds. Chairs can have different designs, sizes, and seating arrangements, affecting how individuals sit and their postural alignment. Lighting conditions can vary from well-lit environments to low-light or unevenly lit spaces. Backgrounds can also differ, with cluttered or complex backgrounds potentially impacting the accuracy of pose detection algorithms. The system should be able to handle these variations and maintain reliable performance across different settings.

8. **Adaptability in Diverse Settings:** The Slouch Detector system needs to adapt and perform reliably in diverse environments. Users may be situated in various locations such as homes, offices, or public spaces, each with its unique characteristics. The system should be designed to handle these diverse settings and still provide accurate posture detection and feedback. Adaptability includes robustness to environmental changes, ability to adjust to different chair types, and flexibility in accommodating variations in lighting and background conditions.
9. **Robust Algorithms for Environmental Changes:** Robust algorithms are crucial to handle environmental changes while maintaining accurate posture detection. The system should be able to handle variations in lighting, including changes in brightness, shadows, or glare. It should also be resilient to background distractions or occlusions that may affect the accuracy of pose estimation. Robust algorithms should be able to adapt to different chair types, seating positions, and body proportions, ensuring accurate detection and feedback regardless of the environmental factors present.
10. **Maintaining Accuracy:** Accuracy is paramount in posture detection to ensure reliable feedback to users. The system should employ algorithms that maintain a high level of accuracy despite real-world challenges. This includes addressing factors such as occlusions, variations in body shapes and sizes, and potential errors in pose estimation due to lighting or background conditions. Maintaining accuracy is crucial to provide users with trustworthy feedback and promote effective posture correction.

2.8. Roadmap:

To ensure the effectiveness and adaptability of the Slouch Detector system, a comprehensive roadmap is proposed. This roadmap outlines the key steps and objectives to enhance the functionality and user experience of the system. The following are the proposed roadmap components:

- 1. Calibrating for Every User:** The system should provide the ability to calibrate and personalize the posture detection algorithm for each user. This calibration process takes into account individual body shapes, proportions, and comfort levels. By allowing users to calibrate the system to their specific requirements, the accuracy of posture detection can be significantly improved.
- 2. Calibrating for the Environment:** In addition to individual calibration, the system should also offer the option to calibrate for different environmental settings. Different chairs, lighting conditions, and backgrounds can impact the accuracy of posture detection. By calibrating the system to adapt to these variations, it can provide reliable results across diverse settings.
- 3. Measure Progress Over Time:** The Slouch Detector system should incorporate a mechanism to measure and track the user's progress over time. By analyzing data and comparing it with previous assessments, the system can provide insights into the user's posture improvement journey. This feature motivates users to maintain correct sitting postures and track their progress towards better overall posture habits.

4. Track the Most Common Mistakes of the User: The system should identify and track the most common mistakes or deviations from proper posture made by the user. By focusing on these specific areas of improvement, the system can provide targeted feedback and guidance to help users correct their posture more effectively.

5. Integration with Smart Watch for Notifications: The Slouch Detector system can be integrated with smartwatches or wearable devices to provide real-time posture notifications and reminders. By leveraging the smartwatch's capabilities, users can receive subtle vibration alerts or visual cues directly on their wrists, reinforcing the importance of maintaining good posture throughout the day.

6. Collect Data to Determine Average Sitting Postures: The system can collect anonymous data from users to establish a repository of average sitting postures across different populations and settings. By analyzing this data, the system can provide more accurate assessments and comparisons, allowing users to gauge their postural alignment relative to the average population.

By following this roadmap, the Slouch Detector project can enhance the user experience and effectiveness of the system. The implementation of user and environmental calibration, progress tracking, identification of common mistakes, smartwatch integration, and data collection will contribute to a comprehensive and adaptable posture detection solution.

3. Course feedback and suggestions:

The techniques taught in the course are extremely valuable and I am eager to have the opportunity to try an advanced computer vision course. I appreciate it when real-life examples are used to illustrate concepts, as it helps me understand how these techniques can be applied in practical situations. Additionally, I found the small stories shared by the professor during the class to be engaging and enjoyable, as they provided context and a deeper understanding of the material.

One aspect that could be further improved is the detailed illustration of the various applications of computer vision (CV). While the course provided a solid foundation and understanding of CV techniques, it would be beneficial to explore a wider range of real-life examples that highlight the diverse applications of CV. By delving into specific use cases across industries such as healthcare, autonomous vehicles, climate change, augmented reality, and robotics, we can gain a more comprehensive understanding of how CV technologies can be implemented to solve complex problems and enhance various aspects of our lives. This practical exposure to diverse applications would further enrich our learning experience and enable us to envision the vast possibilities of CV in different domains.