

Project Proposal: Automatic Sight Correction Device Bracket

TEAM#21

Weichong Chen, Xiaoyu Xu, Yilun Chen

March 23, 2026

I INTRODUCTION

A.A Background

The pervasive use of portable electronic devices has led to a significant increase in "tech neck" and cervical spondylosis. Recent biomechanical studies confirm that smartphone usage significantly compromises cervical spine stability, leading to altered kinematics and increased risk of musculoskeletal disorders [1]. Traditional phone mounts are static, forcing users to adapt their posture to the device. Prolonged deviation from a neutral spine position causes chronic muscle strain. Current market solutions lack dynamic feedback mechanisms to actively correct user posture in real-time.

A.B Objective

The objective of this project is to design and prototype an **Automatic Sight Correction Device Bracket**. This smart mount will dynamically adjust its height and tilt angle based on real-time user posture detection using computer vision and inertial sensing. The system aims to ensure the user's line of sight remains horizontal, thereby reducing spinal pressure. Key goals include supporting heavy devices (up to 5.0 kg), ensuring robust operation under varying lighting conditions, and maintaining strict user privacy through local-only data processing.

A.C High-Level Needs

The project must satisfy the following three core high-level requirements:

- **H1 (Response Efficiency):** The system shall complete the full posture correction cycle (detection to stable position) within ≤ 10 seconds of activation.

- **H2 (Recognition Accuracy):** The facial detection algorithm shall achieve $\geq 95\%$ accuracy in identifying eye-line deviation under varying lighting conditions (50–1000 lux).
- **H3 (Load Capacity):** The mechanical structure shall securely support a maximum load of ≥ 5.0 kg (accommodating heavy tablets and ruggedized phones) without structural deformation or motor slip.

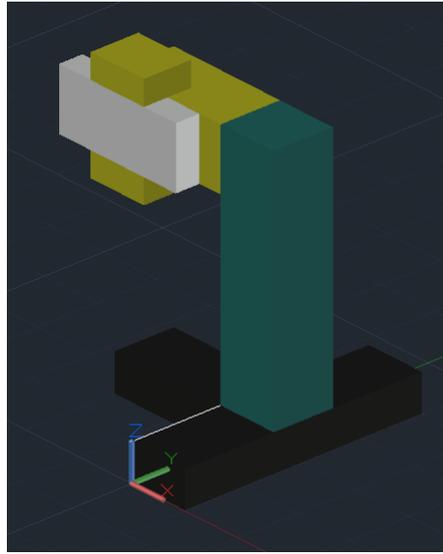


Figure 1: Device Physical Design

II DESIGN AND REQUIREMENTS

B.A Functional Overview

The system operates as a closed-loop control system with a unique dual-stage mechanical architecture:

1. **Sensing:** A miniature camera and 6-axis IMU, mounted on the rotating turntable, capture user facial data and current tilt angle.
2. **Processing:** An embedded processor runs a Haar Cascade Classifier for face detection and a Kalman Filter for noise reduction. It calculates the error between the current and ideal eye-line.
3. **Actuation:**
 - A **Base-Mounted Lifting Motor** drives a vertical lead screw to raise/lower the entire upper assembly.
 - A **Rotation Motor** mounted on the lift stage drives a turntable to adjust the tilt angle of the device clamp.

4. **Control:** A PID controller regulates both motors to minimize error while ensuring stability under the 5.0 kg load.

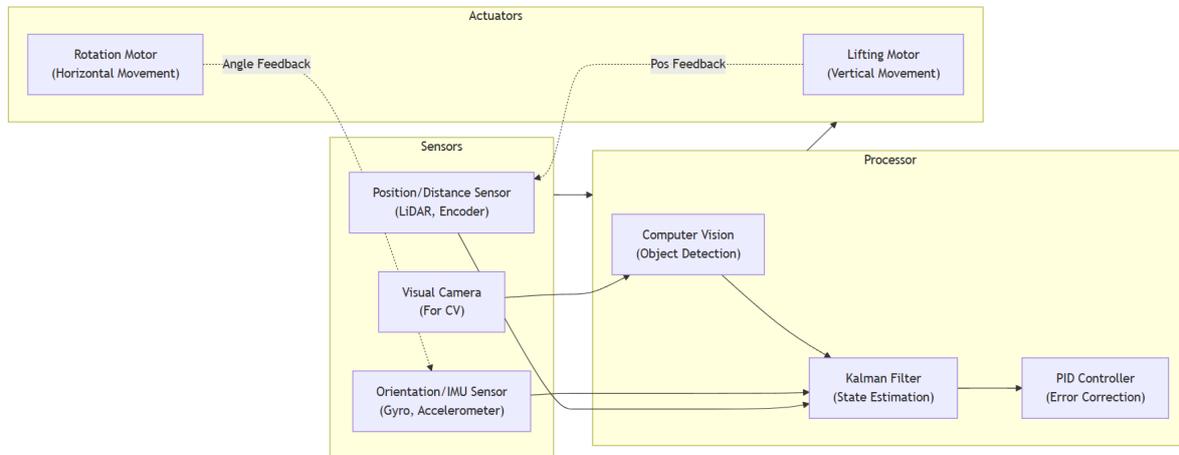


Figure 2: Functional Block Diagram of the AutoSight System.

B.B Subsystem Requirements

Derived from the high-level needs, the specific subsystem requirements are:

B.B.1 Mechanical Subsystem

- **M1:** The vertical column must be constructed of aluminum alloy or carbon fiber to limit deflection to < 1.0 mm under a 5.0 kg load.
- **M2:** The rotation mechanism must utilize self-locking worm gears with backlash $< 0.5^\circ$.
- **M3:** The lifting mechanism must provide a safety factor of 2.0 (rated for 10 kg) to prevent catastrophic failure.

B.B.2 Electrical Subsystem

- **E1:** Motors must provide sufficient holding torque to maintain position under 5.0 kg load during power loss.
- **E2:** Peak current draw during simultaneous lifting and tilting must not exceed 3.0 A.
- **E3:** An emergency stop circuit must cut power to all actuators within 100 ms.

B.B.3 Software Subsystem

- **S1:** Image processing latency must be < 100 ms/frame.
- **S2:** The PID controller must eliminate steady-state error caused by static friction in the lifting mechanism.
- **S3:** All image data must be processed in RAM and discarded immediately; no storage or transmission is permitted.

B.C Risk Analysis

B.C.1 Highest Risk Block

The **Rotating Assembly Block** (comprising the rotation motor, turntable, device clamp, camera, and IMU) is identified as the highest risk component. **Reasoning:** This block carries the full 5.0 kg payload at the end of the vertical arm. Any failure in the rotation motor's gear engagement or the turntable's structural integrity could result in the device falling or the assembly detaching, posing a significant safety hazard. Furthermore, vibration in this block directly affects the camera's ability to detect facial landmarks accurately.

B.C.2 Risk Mitigation Plan

1. **Weeks 1-2:** Select high-torque motors and verify gear material strength via simulation. Assemble the rotating block with redundant fasteners.
2. **Week 3 (Lighting & Vibration Test):** Test the Haar Cascade classifier under 4 lighting scenarios while the rotating block is subjected to simulated operational vibrations with a 5.0 kg load.
3. **Week 4:** Implement software-based vibration damping. If IMU detects resonance, the system will pause movement. Add mechanical dampers if necessary.
4. **Week 5:** Final stress test of the rotating block connection points under 1.5x max load (7.5 kg) to validate the safety margin.

III ETHICS AND SAFETY

C.A Ethical Considerations

Our design adheres to the **IEEE Code of Ethics** [5]:

- **Item 1 (Public Safety):** *"to hold paramount the safety, health, and welfare of the public."* Application: The device addresses cervical spine stability issues [1]. It contains no hazardous materials.

- **Item 6 (Privacy):** "to protect the privacy of individuals." Application: Strict **Local-Only Processing** policy. No image data leaves the device.

C.B Safety Analysis

- **Crushing Hazard:** The 5.0 kg lifting mass poses a crushing risk. *Mitigation:* Current-sensing anti-pinch logic and physical E-Stop.
- **Drop Hazard:** *Mitigation:* Self-locking worm gears and non-back-drivable lift screws ensure the load holds if power fails.
- **Structural Failure:** *Mitigation:* Design Factor of Safety (FoS) = 2.0 for all load-bearing parts.

IV VERIFICATION PLAN

Table 1: Verification Matrix for High-Level Needs

Need ID	Test Method	Tools	Pass Criteria
H1 (Response)	Measure time from activation to stability under 5.0 kg load.	Stopwatch, High-speed Cam	Avg time < 10s over 20 trials.
H2 (Accuracy)	Test detection rate across 4 lighting scenarios with 5.0 kg load vibration.	Lux Meter, Light Box, Logs	Accuracy $\geq 95\%$ (95/100 cases).
H3 (Load)	Static hold test with 5.0 kg for 1 hour; Dynamic lift/drop cycles.	Calibrated Weights, Dial Indicator	Deflection < 1mm; No slip/failure.

References

- [1] E. Kim, D. Song, D. Park, H. Kim, and G. Shin, "Effect of smartphone use on cervical spine stability," *Journal of Biomechanics*, vol. 166, p. 112053, 2024, doi: 10.1016/j.jbiomech.2024.112053.
- [2] P. Viola and M. Jones, "Rapid Object Detection using a Boosted Cascade of Simple Features," in *Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR)*, Kauai, HI, USA, 2001, pp. I-I.
- [3] R. E. Kalman, "A New Approach to Linear Filtering and Prediction Problems," *Journal of Basic Engineering*, vol. 82, no. 1, pp. 35–45, 1960.
- [4] K. J. Åström and T. Hägglund, *PID Controllers: Theory, Design, and Tuning*, 2nd ed. Research Triangle Park, NC: Instrument Society of America, 1995.

- [5] IEEE, "IEEE Code of Ethics," IEEE Board of Directors, revised 2020. [Online]. Available: <https://www.ieee.org/about/corporate/governance/p7-8.html>