Chapter 6

Edge AI-enabled Smart Glasses and Companion Robots for In-home Health Monitoring and Medication Adherence

Michele Magno*, Joseph Paul, Davide Plozza, and Tommaso Polonelli

Department of Information Technology and Electrical Engineering, ETH Zurich, Switzerland

Abstract

Elderly and chronic disease patients face significant challenges in reliably receiving essential medical assistance and maintaining medication adherence at home, especially when not hospitalized. This paper presents an overview of novel technologies for personal health monitoring and medication adherence in home environments, combining innovative smart glasses with companion autonomous robotic systems. The pioneering aspects include the use of novel low-power radar sensing, ultra-wideband (UWB) positioning, hybrid electrooculography (EOG) eye-tracking, and Edge AI technologies, enabling accurate patient health monitoring, enhanced human-machine interaction (HMI), and intelligent robotic platforms that can make autonomous decisions using embedded reasoning. This improves privacy, response latency, and independence from internet connectivity. On the wearable side, through the fusion of low-power radars and efficient EOG-based eye tracking, it is possible to continuously track vital signs and gaze-based interactions, facilitating timely interventions and advanced HMI. These smart glasses detect early signs of health deterioration, potentially preventing severe health complications. Combining on-body monitoring with robotic assistance proactively reduces health risks. Edge AI-powered robots are proposed to support medication adherence and dietary management, addressing medication errors that currently affect nearly half of chronic illness patients receiving home care. Ultimately, the proposed approach delivers tangible improvements in health outcomes, quality of life, and societal well-being.

Keywords: *Smart Glasses, Radar Sensing, Eye Tracking, Human-Machine Interaction, Assistive Robotics*

Introduction

Global healthcare systems are under unprecedented strain due to demographic shifts, aging populations, and the prevalence of chronic diseases. Elderly individuals and patients with conditions such as cardiovascular disease, diabetes, and respiratory illnesses often require continuous monitoring and timely interventions. Yet, conventional solutions, hospital-based monitoring or consumer-grade wearable, are either too resource-intensive or insufficiently reliable for everyday living[1,2].

---

[1]Minjae Choi et al., "Living Longer but in Poor Health: Healthcare System Responses to Ageing Populations in Industrialised Countries Based on the Findings From the Global Burden of Disease Study 2019," *BMC Public Health* 24, no. 576 (February 22, 2024), https://doi.org/10.1186/s12889-024-18049-0

[2]World Health Organization: WHO. "Ageing and Health." October 1, 2025. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

DOI: 10.18502/rq457c78_6

This paper presents three key technological trends and pioneering technologies designed to address these challenges:

- Contactless radar-based vital sign monitoring: Recent advances in millimetre-wave radar allows the integration of non-contact heart rate and respiration sensing into smart glasses, providing unobtrusive and motion-resilient monitoring.
- Hybrid electrooculography (EOG) eye-tracking for natural interfaces: The ElectraSight system demonstrated a fully onboard, low-power, hybrid contact/non-contact EOG solution for smart glasses, achieving accurate gaze tracking at just 8.85 mW, with continuous operation beyond 3 days. This transforms glasses into intuitive human-machine interactions (HMIs), bridging user intention and digital/robotic systems.
- Semi-autonomous assistive robots: Quadruped robots, guided by gaze-based interaction, extend human capability in daily tasks, from fetching objects to medication delivery, with an average positioning error below 20 cm.

By combining these technologies, a unified framework can be envisioned: smart glasses serve as the hub, simultaneously sensing vital signs, tracking gaze, and acting as the interface to robotic companions. This dual role creates a human-centred assistive ecosystem that supports independence, improves healthcare outcomes, and preserves privacy by processing data locally through Edge AI.

Results

The system concept comprises of three elements illustrated in separate subsections.

Hybrid eye tracking with ElectraSight

ElectraSight introduces a hybrid eye-tracking solution based on EOG. By combining contact electrodes for high signal fidelity and capacitive electrodes for improved comfort, the system captures gaze data continuously. All processing is performed onboard a GreenWaves GAP9 RISC-V processor, using convolutional neural networks and temporal models optimised for embedded execution.

Testing confirmed a classification accuracy of 92% for basic gaze classes and 84% for extended classes, with a latency under 60 milliseconds and a sensing-to-decision pipeline contribution below 1 millisecond. The power consumption of 8.85 mW supports more than 3 days of continuous operation without recharging[3].

Radar-embedded smart glasses for autonomous vital sign monitoring

A pioneering approach to vital sign monitoring is the integration of radar sensors directly into the same form factor as smart glasses. These radar-enabled glasses perform autonomous, continuous vital sign monitoring without requiring skin contact. The proposed system incorporates a 60 GHz frequency-

[3] Schärer et al. "ElectraSight: Smart Glasses with Fully Onboard Non-Invasive Eye Tracking Using Hybrid Contact and Contactless EOG."

modulated continuous-wave (FMCW) radar (Infineon BGT60UTR13DAiP) together with a low-power microcontroller, enabling real-time, fully onboard signal processing. By detecting subtle arterial micro-motions, the radar eliminates the limitations of optical or electrode-based methods. The signal processing pipeline comprises chirp accumulation, fast Fourier transform (FFT), displacement estimation, and frequency analysis, achieving full execution in only 1.9 milliseconds. This design demonstrates that reliable and unobtrusive monitoring can be realised within the compact, socially acceptable form factor of smart glasses. Quantitative evaluation with three subjects showed mean errors of 5.20, 4.07, and 3.64 beats per minute compared to a Polar H10 chest strap reference. The device consumed only 29.7 mW, allowing more than 20 hours of continuous operation on a 175 mAh battery[4].

Gaze-guided semi-autonomous quadruped robots

The third component of this framework is the use of gaze to control assistive robots. A Unitree Go1 quadruped robot was equipped with LiDAR, RGB-D cameras, and an Intel NUC for onboard processing. Gaze data from Pupil Labs Neon glasses were transformed into the robot's perception frame using image matching. The Robot Operating System navigation stack was employed for obstacle avoidance and dynamic path planning. Experiments confirmed that the robot could reach gaze-indicated targets with an average positioning error of 19.7 cm (± 8.1 cm). When using the SURF image-matching algorithm, the system achieved 0.215 second processing latency with average power consumption of around 52 W, outperforming neural-based alternatives under CPU-only conditions. Navigation was reliable even in cluttered environments, and latency remained suitable for real-time interaction[5].

Results and Discussion

The results across these three systems demonstrate both feasibility and synergy. Radar-enabled smart glasses provided accurate, motion-resilient heart rate monitoring at less than 30 mW, supporting more than 20 hours of continuous operation. ElectraSight confirmed that eye tracking can be achieved entirely onboard, with accuracy above 90% and energy efficiency sufficient for 3 days of continuous use. The gaze-guided robot successfully navigated complex indoor environments, reaching targets within 20 cm on average and responding in under a quarter of a second. Together, these contributions create a new paradigm in assistive healthcare. The smart glasses act as both sensors and interfaces, continuously monitoring vital signs while simultaneously interpreting gaze commands. The robot serves as the physical actuator, executing tasks that extend the user's autonomy. For example, if radar-based monitoring detects an abnormal heart rate, the system could automatically dispatch the robot to retrieve medication or alert caregivers. Conversely, when the user requires assistance, they can direct the robot simply by looking at an object or location. The combination of continuous monitoring, natural

---

[4]Joseph et al. "Non-invasive Contactless Heart Rate Monitoring Onboard Ultra-low Power Smart-glasses." IEEE Sensors, October 19, 2025, 1–4.

[5]Paul Joseph et al., "Gaze-Guided Semi-Autonomous Quadruped Robot for Enhanced Assisted Living," *IEEE Sensors Applications Symposium (SAS)*, July 23, 2024, 1–6, https://doi.org/10.1109/sas60918.2024.10636523

interaction, and robotic support addresses key healthcare challenges, including medication adherence, fall prevention, and real-time emergency response. It also supports ethical principles of privacy, since all data are processed locally on embedded devices rather than transmitted to the cloud.

Conclusion

This paper presented a vision for integrating radar-based health monitoring, hybrid EOG eye tracking, and gaze-guided robotic assistance into a unified framework for assisted living and home healthcare. Radar-enabled glasses demonstrated real-time, low-power, and accurate heart rate monitoring. ElectraSight provided onboard gaze tracking at high accuracy and minimal power consumption, enabling intuitive interaction. The gaze-guided quadruped robot validated the feasibility of natural and semi-autonomous human-robot interaction in cluttered environments. Taken together, these innovations illustrate how smart glasses can serve as both a health monitor and a control interface, while robots act as mobile companions that provide physical support and ensure safety. This synergy directly addresses healthcare challenges related to aging populations and chronic disease management. Future research will extend biometric sensing, enhance robotic manipulation, and evaluate systems in real-world clinical environments. Ultimately, the combination of wearable sensing, intuitive gaze-based interaction, and robotic autonomy has the potential to transform healthcare delivery and improve independence, quality of life, and safety for millions of patients worldwide.

References

Choi, Minjae, Joshua Kirabo Sempungu, Eun Hae Lee, and Yo Han Lee. “Living Longer but in Poor Health: Healthcare System Responses to Ageing Populations in Industrialised Countries Based on the Findings from the Global Burden of Disease Study 2019.” *BMC Public Health* 24, no. 576 (Feb 2024). https://doi.org/10.1186/s12889-024-18049-0

World Health Organization: WHO. “Ageing and Health,” October 1, 2025. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

Joseph, Paul, Jonathan Hungerbühler, Tommaso Polonelli, and Michele Magno. “Non-invasive Contactless Heart Rate Monitoring Onboard Ultra-low Power Smart-glasses.” *IEEE Sensors*, October 19, 2025, 1–4.

Joseph, Paul, Davide Plozza, Luca Pascarella, and Michele Magno. “Gaze-guided Semi-autonomous Quadruped Robot for Enhanced Assisted Living.” *IEEE Sensors Applications Symposium (SAS),* July 23, 2024, 1–6. https://doi.org/10.1109/sas60918.2024.10636523

Schärer, Nicolas, Francesco Villani, Alessandro Melatur, Samuel Peter, Tommaso Polonelli, and Michele Magno. 2024. “ElectraSight: Smart Glasses with Fully Onboard Non-Invasive Eye Tracking Using Hybrid Contact and Contactless EOG.” arXiv preprint arXiv:2412.14848.