

Intentional Interaction for Screenless Rectangular AI Wearables via Dual-Side Touch

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Abstract The development of human-computer interaction for wearables is driven by two major factors. Firstly, there has been a proliferation of screenless AI assistants. Secondly, there have been heightened privacy concerns regarding "always-listening" models. A theoretical framework is proposed for manual activation to ensure voice-based communication is initiated only through deliberate intent. A rectangular device with opposite-side touch interfaces is utilised to facilitate eyes-free command execution. The two-finger "grasp" algorithm has been developed to ensure reliable activation and navigation, including volume control, playback rollback, and deactivation. User privacy and energy efficiency are prioritised, whilst the necessity for visual confirmation is eliminated and unauthorised data collection is mitigated.

Keywords: Wearable, Screenless Interface, AI Assistant, Two-finger Touch, Privacy.

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1. Introduction

In recent years, the proliferation of wearable devices has precipitated their entry into the mainstream market, thereby constituting a substantial segment of the global technology economy [1]. The global wearable technology market was valued at approximately USD 55.5 billion in 2022 [1]. Projections indicate that this figure will reach USD 142.4 billion by 2030. These systems currently possess greater computational power, memory and communication capabilities than average personal computers did two decades ago [2]. Notwithstanding this continuous technical refinement, user-device interaction techniques remain largely analogous to those observed in classic electronic watches or smartphones. However, as devices become smaller to remain socially acceptable and unobtrusive, they encounter the 'fat finger' problem, whereby the user's own finger inevitably obscures the visual interface or small target icons during interaction [3].

The physical form of wrist-worn devices imposes limitations on the number of mechanical input devices with which they can be equipped, and their diminutive screen size imposes further restrictions on the amount of textual and graphical information they can display [4]. Alphanumeric user interfaces utilising typed commands are deemed unsuitable for this domain, owing to the lack of available space on the device to implement a standard keyboard. The advent of voice-centric AI assistants has precipitated an escalating adoption of screenless designs within the industry [2, 5]. Nevertheless, this transition has given rise to substantial concerns regarding user privacy,

as 'always-listening' microphones are generally necessary for voice activation. It has been posited that intuitive, trustworthy AI-human interfaces must strike a balance between efficiency and transparency in order to mitigate user anxiety regarding unauthorised data collection [6].

The defining characteristic of traditional wearables is their rigidity, which often results in an inability to establish reliable, conforming contact with the human body's curved surfaces [1]. Contemporary research in this field is focused on the development of thinner, smaller and more unobtrusive devices [1]. The reduced screen size of wrist-worn devices renders graphical user interfaces (GUIs) dependent on cursor manipulation unsuitable, as these require significant visual attention, which can pose a problem in mobile settings where the user must be aware of their surroundings [4]. It is therefore proposed that a rectangular form factor with dual-sided touch sensors be utilised to enable eyes-free intentional command execution and improved privacy. The activation of the system necessitates a deliberate manual action, thereby preserving battery life while the system remains in power-saving mode [7]. Moreover, high-power modules, such as hardware accelerators for neural network inference, can remain dormant until user intent is confirmed physically [8].

2. Related Work

Researchers have extensively explored surfaces beyond the display for human-computer interaction (HCI) to mitigate line-of-sight obstruction on small displays [5, 9]. The interaction between the perpendicular edges of a device has been evaluated to ensure that the user's fingers and the screen remain clearly visible during targeting operations [9]. It is evident that major vendors have implemented mechanical solutions, including rotating



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bezels and digital crowns, in order to address the issue of 'fat fingers' [2]. However, these solutions typically necessitate a conventional button press for initial activation, thus failing to address the requirement for an instant, gesture-based wake-up [7].

Research into alternative sensing areas has expanded the input expressivity of smartwatches. These include pressure-sensitive multi-touch interaction on a wristband (BandSense), which provides a more expansive interaction area with reduced occlusion [10]. Interacting with the back of the device (nanoTouch) has been proposed as a method of eliminating interference between the fingers and the screen. This method of visual feedback is intended to inform the user of their finger position via an on-screen pointer or pseudo-transparency [5]. A number of studies have explored the potential of utilising side-pressure sensors (PressTact) to facilitate bi-directional navigation, including functions such as zooming and scrolling, by employing varying levels of force [11].

As indicated in the preceding research carried out at the Technical University of Varna, a substantial foundation has been laid concerning the effectiveness of bezel-based interaction. Research has demonstrated that fundamental interface operations can be identified through the utilisation of a two-finger touch on the device bezel [12]. Initial studies employed a 3D-printed smartwatch model, measuring 44 mm in diameter, which was equipped with capacitive sensors connected to an Arduino Mega 2560 and an MPR121 extension board [12]. It was determined that during a manual "grasp," sufficient non-touched space (specifically two or more sensors) exists between the thumb and index finger to unambiguously detect a deliberate action in 100% of user attempts [7]. This finding is critical for distinguishing intentional activation from accidental contact with clothing or skin [7].

Subsequent development of this paradigm resulted in the creation of a "Novel" interface, which was compared to a "Standard" model featuring side push buttons [13]. The Novel interface incorporated a 46 mm 3D-printed chassis, with the bezel itself serving as the primary input surface [12]. Research findings demonstrated that scrolling actions for menu navigation could be recognised with a high degree of stability, requiring a minimum of two sensor transitions per gesture attempt [12]. In comparative studies, it was found that the Novel touch interface outperformed the Standard button-based model in terms of operation speed. Specifically, execution times for complex command sequences were found to be 9.56% faster when using the touch-based approach [13].

The feasibility of eyes-free command execution, such as "Up", "Down", "Enter" and "Back", was confirmed through the development of specialised Arduino software that processed simultaneous inputs from multiple sensors to distinguish between a static "support" finger and an "active" moving finger [12, 13]. It was observed that while the Novel interface initially exhibited a higher error rate due to user familiarity with traditional buttons, the performance benefit increased as the set of commands became longer and more complex [13]. Furthermore, research into user pose recognition has indicated that the symmetrical results of touch zones allow for the determination of the user's physical state [standing, sitting,

and lying] based on the probability of specific sensors being activated [14]. A range of techniques, including tilting operations, have been examined with a view to expanding input vocabularies. The results of this research demonstrate that, in general, greater accuracy is achieved through the inclination of the arm (x-axis) than through the rotation of the wrist (y-axis) [15]. However, these sensors frequently necessitate the user to strike specific angular targets, which can be obscured by the finger depending on the quadrant of the watch face [16]. The present study extends these findings by adapting the dual-touch model to a screenless rectangular chassis designed specifically for intentional AI assistant control and eyes-free parameter adjustment.

3. Materials and Methods

3.1. Hardware Architecture

The experimental prototype was driven by an Arduino Mega 2560 microcontroller [12]. The capacitive sensing process was facilitated by an MPR121 extension board, which featured 12 sensing ports, as demonstrated on Fig 1. The device body was manufactured using 3D printing with white PETG material, chosen to mimic the aesthetics of commercial wearables [7]. The sensors were constructed from steel elements with rounded ends, thus ensuring a smooth tactile surface across the opposite sides of the rectangular frame [12]. The maintenance of data integrity was ensured through the implementation of e-shielded cabling, a measure employed to mitigate electromagnetic interference emanating from the user's body [13].



Fig. 1. Internal view of the rectangular prototype showing the MPR121 board and internal wiring.

3.2. Software Development

Specialised software was developed for the Arduino platform to facilitate the experiments [12]. The software was developed utilising the Arduino programming language (C-based) to detect the initiation (contact) and cessation (release) of each capacitive sensor independently [12]. The algorithm was designed to process simultaneous inputs from multiple sensors to distinguish between a static "support" finger and an "active" moving finger [12]. The real-time data output was facilitated by the Arduino IDE Serial Monitor and subsequently transferred to MS Excel for processing [12].

3.3. Activation and Command Execution Logic

The intentional activation of the device was achieved through the detection of a simultaneous two-finger touch on opposite longitudinal sides. The interface was programmed to transition from idle mode only when a specific temporal threshold of contact was maintained and a minimum non-touched space was recorded [7]. Following activation, the subsequent command set was implemented for the purpose of eyes-free management of the AI assistant [12]:

- **UP/DOWN** (Navigation): A sliding motion along the side sensors while the thumb remained static.
- **VOLUME** (Increase/Decrease): Sliding motion utilised during active audio playback.
- **STOP** (Cancel/Mute): A double-tap on the index finger side.
- **ROLLBACK** (Replay last 10 seconds): A specific reverse sliding gesture.
- **DEACTIVATION**: Immediate return to a low-power "sleep" state upon the release of the thumb contact.

The obtained results are shown in Table 1.

Table 1. Experimental Study Results

User	Activation	UP	STOP	De-Activ.
1 lapel	Successful	Successful	Successful	Successful
2 lapel	Successful	Successful	Successful	Successful
3 lapel	Successful	Successful	Successful	Successful
4 lapel	Successful	Successful	Successful	Successful
5 lapel	Successful	Successful	Successful	Successful
1 belt	Successful	Successful	Successful	Successful
2 belt	Successful	Successful	Successful	Successful
3 belt	Successful	Successful	Successful	Successful
4 belt	Successful	Successful	Successful	Successful
5 belt	Successful	Successful	Successful	Successful

4. Experimental Study

The study was conducted with a group of 5 volunteers in standard office conditions. Participants were required to "grasp" the rectangular device, attached to the lapel, to activate the interface, followed by the execution of pre-defined command sequences without looking at the device as demonstrated on Fig 2.



Fig. 2. A participant's hand performing the dual-side "grasp" on the rectangular prototype on lapel.

The experiment was repeated when the device was attached to the participants' belts. The software recorded the precise sensor identifiers that were triggered, in addition to the duration of each recorded gesture [12]. This facilitated the analysis of performance parameters [13].

5. Results

5.1. Reliability of Activation

The experimental trials that were conducted to investigate this issue conclusively demonstrated that a simultaneous two-finger touch on opposite sides of the rectangular body is unambiguously detectable in 100% of user attempts. The same applies to deactivating the interface by lifting your fingers from the interface areas of the wearable device.

5.2. Feasibility of Command Execution

The feasibility of implementing eyes-free commands for an AI assistant was demonstrated through the recognition of specific tactile gestures. It was established that scrolling actions for navigation or parameter adjustment could be recognised with a high degree of stability, as a minimum of two sensor transitions were recorded in every attempt at a gesture. The execution of discrete commands was confirmed via tap and double-tap gestures. These gestures were processed independently for the active finger. The execution of these commands included increasing volume and stopping communication, increasing volume, and performing a 10-second playback rollback. Finally, the reliability of deactivating the interface was verified, with the system returning to a low-power sleep state immediately upon the release of the thumb contact.

6. Discussion

The transition towards screenless AI wearables necessitates an interface architecture that does not rely on visual confirmation. The findings of this study suggest that the rectangular form factor, which incorporates touch-sensitive zones on opposite longitudinal sides, offers natural tactile landmarks that facilitate effective guidance of user interaction. This architecture addresses the "fat finger" problem by moving the interaction surface away from the visual output, thereby preventing content occlusion [12, 13]. The transfer of interface complexity from the screen to the physical body of the device has been demonstrated to result in a concomitant reduction in cognitive load during interaction.

Moreover, the implementation of a manual, intentional activation method provides a critical solution to contemporary user privacy concerns. The device has been designed in such a way that it can only be activated by a deliberate two-finger grasp, thus ensuring that voice-recognition modules cannot be triggered inadvertently in private or sensitive environments [6]. In principle, this "physical handshake" guarantees that data collection is confined to periods of active user intent, thereby fostering greater user trust in AI systems. Energy efficiency has also been significantly improved; high-power computational modules, such as AI inference accelerators, remain in a

dormant state until the tactile sensors confirm a legitimate grip [7, 8].

The hypothesis that the rectangular chassis is superior to the circular model is evidenced by the clear orientation it provides for spatial memory. Whilst circular bezels permit radial input, the distinct edges of a rectangle function as precise anchor points for the thumb and fingers, thereby enabling high-precision sliding gestures without visual feedback [4, 9]. This tactile guidance enables expert users to execute shortcuts and navigate hierarchical structures with minimal distraction [4]. Although users familiar with traditional button-based interfaces may initially experience a period of adjustment, the theoretical advantage of a continuous touch surface for complex command execution – such as scrolling through vast audio libraries or fine-tuning volume – is substantial [13]. The design has been developed to address the spatial and temporal aspects of the occlusion problem. It has been determined that smaller devices and larger fingers inevitably worsen content occlusion unless the interaction point is offset to the device perimeter [5].

7. Conclusion

A robust method for the intentional manual activation and command execution of screenless wearables has been presented. Through the development of a rectangular prototype, it has been demonstrated that a two-finger grip is a 100% reliable mechanism for waking a device from its idle state while simultaneously providing a secure, privacy-preserving trigger for AI assistants. The execution of commands such as navigation, volume adjustment, and playback rollback without the use of eyes was verified as both technically feasible and efficient.

The broader implications of wearable human-computer interaction (HCI) involve shifting the focus away from visual displays towards tactile and ergonomic ones. The reliability of the proposed dual-side touch interface suggests that it could serve as a primary input modality for future generations of unobtrusive AI assistants. Such systems would facilitate the maintenance of situational awareness by users, whilst concurrently enabling the execution of complex digital tasks through the utilisation of elementary manual gestures. This finding is consistent with the necessity for intuitive and trustworthy AI-human interfaces that enhance human lives through thoughtful design.

The findings indicate that the rectangular form factor is particularly well-suited for eyes-free control, as the physical edges provide consistent landmarks for spatial mapping. Subsequent research endeavours will concentrate on the incorporation of sophisticated machine learning (ML) algorithms with the objective of adapting the interface to the distinct "grasp" patterns exhibited by individual users. This integration has the potential to enhance sensitivity and reduce latency.

Furthermore, the incorporation of pressure-sensitive sensors could lead to a significant augmentation in the input vocabulary, thereby enabling the device to differentiate between varying force levels for multi-dimensional parameter control.

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