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(57) Abstract:

An intent-aware input apparatus (100) comprises a device body (1), a button lever (2), a mechanical switch (3), a first piezoelectric transducer (4), a second piezoelectric transducer (5), a controller (6), and a human interface device interface (7). The controller (6) continuously retains a rolling pre-contact buffer of vibration signals received from the second piezoelectric transducer (5), captures a mechanical transient generated during button actuation through the first piezoelectric transducer (4), extracts morphology-based features excluding peak amplitude, determines a pre-contact tremor-state parameter, and jointly classifies the actuation as volitional or non-volitional using the transient morphology and the pre-contact tremor state. Based on the classification, the controller (6) selectively permits or suppresses transmission of a corresponding input event through the human interface device interface (7). The apparatus performs local real-time intent classification using transient morphology and buffered pre-contact vibration information Fig 1

FORM 2

THE PATENTS ACT, 1970

(39 of 1970)

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COMPLETE SPECIFICATION

(see section 10)

An Intent-Aware Input Apparatus and Method for Volitional Actuation Classification

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The following specification particularly describes the invention and the manner in which it is to be performed

FIELD OF INVENTION

The present invention relates generally to human-computer interface devices and, more particularly, to an intent-aware input apparatus and method for discriminating between volitional and non-volitional physical input actuations. More specifically, the invention relates to piezoelectric sensing, transient waveform morphology analysis, pre-contact tremor-state estimation, embedded real-time signal processing, and human interface device (HID) control for selectively permitting or suppressing input events generated by manually actuated switches.

BACKGROUND OF THE INVENTION

Human-computer input devices such as computer mice, trackballs, handheld controllers and similar manually operated peripherals frequently rely on mechanical switches to generate user input events. Individuals affected by movement disorders, including Parkinson's disease and essential tremor, often experience involuntary oscillatory hand movements that generate unintended switch actuations. Such unintended actuations may result in accidental selection of interface elements, deletion of stored information, transmission of unintended communications, or execution of irreversible operations, thereby significantly reducing usability, productivity and user confidence. Existing technologies primarily focus on filtering cursor movement, thresholding contact force or applying timing-based rejection mechanisms, which do not reliably distinguish intentional user actions from involuntary tremor-induced button actuations.

Various solutions have been proposed to address accidental input events. For example, US Patent No. 10,578,499 B2 assigned to Microsoft Technology Licensing discloses a piezo-actuated touch interface that differentiates intentional actuation primarily based on contact pressure magnitude, displacement and contact geometry. However, the disclosed system relies on actuation magnitude rather than the morphology of the mechanical transient and is designed for touch surfaces rather than physical switches. Consequently, the disclosed approach is unable to accurately distinguish user intent in individuals exhibiting tremor, where intentional and involuntary actuations may possess similar force characteristics.

Another existing solution, US Patent No. 11,262,864 B2 assigned to Qeexo Co., classifies touch interactions based on vibro-acoustic signatures for identifying the contacting object, such as a fingertip, fingernail, knuckle or stylus. Although the system performs transient signal

classification, it neither evaluates the user's volitional intent nor utilizes pre-contact tremor information for controlling physical switch actuation. The disclosed technology therefore remains incapable of selectively permitting or suppressing switch-generated input events according to user intention.

60 Accordingly, there exists a need for an improved input apparatus capable of accurately distinguishing intentional and unintentional physical switch actuations without relying on contact-force magnitude, elapsed time thresholds or cursor-motion filtering. There is a further need for an apparatus that jointly evaluates mechanical transient morphology and pre-contact tremor characteristics to determine user intent in real time while operating as a standard human interface
65 device without requiring additional software installation or device drivers.

The present invention addresses the above-mentioned deficiencies by providing an intent-aware input apparatus configured to acquire transient mechanical characteristics of each button actuation together with a buffered pre-contact tremor state, classify the actuation as volitional or non-volitional using both sources of information, and selectively emit or suppress the corresponding
70 input event, thereby significantly improving reliability of human-computer interaction for users affected by involuntary tremor.

OBJECTIVE OF THE INVENTION

The primary objective of the present invention is to provide an intent-aware input apparatus capable of distinguishing between volitional and non-volitional physical switch actuations by
75 jointly analyzing the mechanical transient morphology of a button actuation and a pre-contact tremor context. The invention seeks to overcome the limitations of existing input devices that rely on contact force, displacement magnitude, elapsed time thresholds, or cursor-motion filtering, which are ineffective in accurately determining user intent for individuals affected by involuntary tremor.

80 Another objective of the present invention is to implement a transient morphology analysis mechanism configured to extract waveform characteristics including attack slope, ringdown decay, transient duration, spectral centroid, and other shape-based features while deliberately excluding peak amplitude from the intent determination process. This enables reliable differentiation between intentional and involuntary button actuations irrespective of actuation force.

85 A further objective of the invention is to incorporate a pre-contact tremor-state estimation mechanism configured to continuously buffer vibration signals generated by the device body, determine tremor-band amplitude and phase immediately preceding a button actuation, and utilize the derived pre-contact information together with transient morphology to improve intent classification accuracy.

90 Another objective of the present invention is to provide an intelligent intent-classification module configured to classify each detected actuation as either volitional or non-volitional and selectively emit or suppress the corresponding input event based on the classification outcome, thereby minimizing unintended activations while preserving intended user interactions.

Another objective of the invention is to provide a dual-transducer sensing architecture comprising
95 a first piezoelectric transducer configured to capture the mechanical transient generated during button actuation and a second piezoelectric transducer configured to capture vibration propagated through the device body, thereby enabling simultaneous acquisition of actuation characteristics and tremor context for enhanced intent determination.

A further objective of the present invention is to provide an embedded real-time signal processing
100 system configured to continuously maintain a rolling pre-contact signal buffer, extract transient and tremor features, execute intent classification with minimal computational latency, and generate a decision without imposing a predefined minimum inter-actuation interval.

Another objective of the invention is to provide an adaptive decision mechanism capable of updating the intent-classification boundary according to user-specific interaction characteristics
105 and optionally employing differential analysis between the button-mounted and body-mounted transducers for rejecting common-mode whole-hand tremor while preserving localized intentional finger movements.

A further objective of the present invention is to provide an input apparatus that operates as a standard Human Interface Device (HID), enabling deployment in new or retrofit input devices
110 without requiring dedicated drivers, software installation, administrative privileges, or modification of host computing systems, thereby facilitating seamless integration across diverse computing environments.

SUMMARY OF THE INVENTION

115 The following summary is provided to facilitate a clear understanding of the new features in the disclosed embodiment and it is not intended to be a full, detailed description. A detailed description of all the aspects of the disclosed invention can be understood by reviewing the full specification, the drawing and the claims and the abstract, as a whole.

120 In one aspect, the present invention provides an intent-aware input apparatus configured to distinguish between volitional and non-volitional physical switch actuations by jointly evaluating the morphology of a mechanical button-actuation transient and a pre-contact tremor state, thereby selectively permitting or suppressing corresponding input events before transmission to a host device.

125 In one aspect, the apparatus comprises a physical button coupled to a mechanical switch, a first piezoelectric transducer mechanically coupled to the button or switch for capturing a transient waveform generated during actuation, a second piezoelectric transducer coupled to a body of the input device for sensing vibration propagated from a user's hand, and a controller configured to process signals received from both transducers.

130 In one aspect, the invention comprises a pre-contact tremor acquisition module configured to continuously buffer vibration signals captured by the second piezoelectric transducer within a rolling time window preceding every actuation, determine tremor-band amplitude and phase corresponding to an actuation onset, and provide contextual information representative of the user's pre-contact hand motion.

135 In one aspect, the invention includes a transient morphology extraction module configured to derive one or more waveform characteristics from the mechanical transient, including attack slope, ringdown decay, transient duration, spectral centroid, spectral energy distribution, and related morphology-based parameters while excluding peak amplitude from the intent determination process.

140 In one aspect, the system further comprises an intent-classification module configured to receive the extracted transient morphology features together with the pre-contact tremor state, evaluate the combined feature representation, and classify each detected actuation as either volitional or non-volitional using a real-time decision process.

In one aspect, the invention comprises an event-gating module configured to selectively emit a corresponding human-interface-device input event to a host computing device when a volitional actuation is identified and suppress transmission of the input event when the actuation is classified as non-volitional, thereby reducing unintended input events without introducing a predefined minimum inter-actuation interval.

In one aspect, the present invention addresses the technical problem of accurately determining user intent during physical switch actuation in the presence of involuntary tremor, where conventional force-threshold, timing-based, and cursor-motion filtering techniques fail to reliably differentiate intentional and unintentional inputs, by introducing a joint intent-classification framework utilizing transient waveform morphology together with buffered pre-contact tremor context.

In one aspect, the invention provides the technical advantage of improved discrimination between intentional and involuntary actuations independent of contact-force magnitude, reduced false activations, lower processing latency, enhanced robustness against tremor-induced disturbances, and compatibility with both newly manufactured and retrofit input devices while maintaining standard Human Interface Device functionality without requiring additional software or device drivers.

In one aspect, the invention enables real-time assistive human-computer interaction through an embedded intent-aware input apparatus suitable for computer mice, pointing devices, handheld controllers, industrial control interfaces, vehicle control devices, and other physical-input systems requiring reliable discrimination between intentional and involuntary user actuations

BRIEF DESCRIPTION OF THE DRAWINGS

The manner in which the present invention is formulated is given a more particular description below, briefly summarized above, may be had by reference to the components, some of which is illustrated in the appended drawing It is to be noted; however, that the appended drawing illustrates only typical embodiments of this invention and are therefore should not be considered limiting of its scope, for the system may admit to other equally effective embodiments.

Throughout the drawings, the same drawing reference numerals will be understood to refer to the same elements and features.

170 The features and advantages of the present invention will become more apparent from the following detailed description along with the accompanying figures, which forms a part of this application and in which:

Figure 1 illustrates a flow diagram of an intent-aware actuation classification method,

Figure 2 illustrates a sectional view of an intent-aware input apparatus

175 Figure 3 illustrates a signal-processing architecture of the proposed input apparatus,

Figure 4 illustrates the inventive intent-classification principle by comparing transient waveform morphologies corresponding to volitional and non-volitional actuations,

Figure 5 illustrates operation of a click-gating mechanism configured to evaluate every detected button actuation using the intent-classification process and selectively transmit only volitional
180 input events to a host computing device while suppressing non-volitional actuations without imposing a minimum inter-actuation interval.

REFERENCE NUMERALS

- 1 -Device body / chassis
- 185 2 -Manually actuatable button lever
- 3 -Mechanical switch
- 4 -T1 piezoelectric transducer on the button capturing the press transient
- 5 -T2 piezoelectric transducer on the body capturing the tremor reference
- 6 -Controller
- 190 7 -Standard Human Interface Device (HID) interface
- 8 -User's hand

DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described in detail with reference to the accompanying drawing. The following description is provided to illustrate the invention and should not be construed as
195 limiting the scope of the invention.

The present invention provides an intent-aware input apparatus configured to distinguish between a volitional actuation and a non-volitional actuation of a physical button by jointly analysing the morphology of a mechanical transient produced during the actuation and a vibration state of the apparatus immediately preceding the actuation. The apparatus comprises a device body (1), a manually actuable button lever (2), a mechanical switch (3), a first piezoelectric transducer (4) mechanically coupled to the button lever (2) or the mechanical switch (3), a second piezoelectric transducer (5) mechanically coupled to the device body (1), a controller (6), and a standard Human Interface Device interface (7). The first piezoelectric transducer (4) captures the mechanical transient generated by each physical button actuation, while the second piezoelectric transducer (5) captures vibrations propagated from the user's hand (8) into the device body (1). The controller (6) continuously retains a rolling pre-contact window of the signal received from the second piezoelectric transducer (5). Upon detecting an actuation, the controller (6) extracts one or more morphology-based features from the press transient, determines a tremor-band state from the retained pre-contact window, classifies the actuation as volitional or non-volitional using the two sets of information together, and permits the corresponding input event to reach a host only when the actuation is classified as volitional. When the actuation is classified as non-volitional, the corresponding input event is suppressed.

Figure 1 illustrates a method implemented by the intent-aware input apparatus for classifying a physical button actuation and selectively emitting or suppressing the corresponding input event.

As shown in Figure 1, the method begins with continuous buffering of a shell-channel or body-channel signal. The body-channel signal is generated by the second piezoelectric transducer (5), which is mechanically coupled to the device body (1) at a location spaced apart from the button lever (2). The second piezoelectric transducer (5) senses vibration entering the device body (1) from the user's hand (8), including vibration associated with involuntary oscillation.

The controller (6) continuously samples the body-channel signal and stores the most recent portion of the signal in a rolling pre-contact ring buffer. The rolling buffer retains a time window of approximately one hundred milliseconds to three hundred milliseconds preceding any detected actuation. Because the signal is buffered continuously, a record of the vibration state immediately before contact with the button lever (2) remains available whenever an actuation occurs.

While maintaining the pre-contact buffer, the controller (6) also obtains a running estimate of the tremor-band component of the body-channel signal. In the disclosed embodiment, the tremor-band component is approximately three hertz to eight hertz. The estimate includes at least an amplitude and a phase of the tremor-band vibration.

When an actuation onset is detected, the controller (6) captures the press transient generated by the first piezoelectric transducer (4). The onset may be detected from the button-channel signal generated by the first piezoelectric transducer (4), from an electrical edge produced by the mechanical switch (3), or from both. The captured transient extends across a window that includes the rise or attack portion of the actuation and the subsequent ringdown portion.

The controller (6) thereafter extracts one or more morphological features from the captured press transient. The morphological features are features relating to the shape of the transient and are selected independently of the peak amplitude of the transient. The extracted features may include an attack slope, a ringdown decay characteristic, a transient duration, a spectral centroid, and one or more band-energy ratios.

The controller (6) also extracts the pre-contact tremor state from the retained body-channel window. The pre-contact tremor state represents the amplitude and phase of the tremor-band vibration present at or immediately before the onset of the button actuation.

The transient morphology features and the pre-contact tremor-state features are then jointly supplied to an intent-classification process. The controller (6) classifies the actuation as either volitional or non-volitional based on the combination of the transient morphology and the vibration context existing before contact.

When the actuation is classified as volitional, the corresponding input event is emitted through the standard HID interface (7) to the host. When the actuation is classified as non-volitional, the input event is suppressed and is not transmitted to the host. An indication may optionally be provided to the user to communicate that the actuation has been suppressed.

The classification does not depend on the interval elapsed since a preceding actuation. Therefore, the process does not require a minimum interval between successive actuations. The processing latency is instead bounded by the duration of the captured transient required for classification.

Figure 2 illustrates a sectional elevation of the intent-aware input apparatus and shows the mechanical arrangement of the two sensing channels.

The apparatus comprises the device body (1), which may be the shell or housing of a pointing device of otherwise conventional construction. The device body (1) supports the manually actuable
260 button lever (2), the mechanical switch (3), the first piezoelectric transducer (4), the second piezoelectric transducer (5), the controller (6), and the standard HID interface (7).

The button lever (2) is positioned so that it can be manually operated by the user's hand (8). The button lever (2) is mechanically associated with the mechanical switch (3). Depression of the button lever (2) causes mechanical operation of the mechanical switch (3). The mechanical switch
265 (3) is retained in the apparatus so that the tactile character and reliability of the physical actuation remain unaltered.

The first piezoelectric transducer (4), identified as T1 in Figure 2, is mechanically coupled to the underside of the button lever (2) or to a mounting portion of the mechanical switch (3). The first piezoelectric transducer (4) may be a ceramic piezoelectric disc or an element formed from
270 polyvinylidene fluoride film. By being coupled to the button lever (2) or the mechanical switch (3), the first piezoelectric transducer (4) receives the mechanical transient substantially at the origin of the actuation.

When the button lever (2) is depressed, mechanical loading of the button lever (2) and operation of the mechanical switch (3) generate a transient vibration. The transient includes an initial rise or
275 attack portion corresponding to the loading of the button lever (2), followed by a ringdown portion corresponding to mechanical vibration and decay of the button-switch assembly. The first piezoelectric transducer (4) converts this mechanical transient into an electrical button-channel signal.

The second piezoelectric transducer (5), identified as T2 in Figure 2, is mechanically coupled to
280 the device body (1) at a location spaced from the button lever (2). The second piezoelectric transducer (5) therefore primarily senses vibration propagated from the user's hand (8) into the device body (1), including vibration arising from involuntary hand oscillation.

The spatial separation between the first piezoelectric transducer (4) and the second piezoelectric transducer (5) enables the apparatus to acquire two related but distinguishable categories of information. The first piezoelectric transducer (4) provides information concerning the localised mechanical event at the button lever (2), while the second piezoelectric transducer (5) provides information concerning the state of the device body (1) and the user's hand (8) before and during the actuation.

The controller (6) receives the signals generated by the first piezoelectric transducer (4) and the second piezoelectric transducer (5). The controller (6) samples and processes both signals, maintains the pre-contact ring buffer, detects the actuation onset, extracts the relevant features, evaluates the intent classifier, and controls whether the switch-generated input event is permitted to reach the standard HID interface (7).

The standard HID interface (7) communicates the permitted input event to the host. The interface may be a standard USB HID interface or a Bluetooth Low Energy HID interface. The classification is performed locally within the apparatus so that the host receives only the input events allowed by the controller (6). Accordingly, the apparatus may present itself to the host as a standard human interface device without requiring a dedicated driver, software installation, or administrative privilege.

Figure 3 illustrates the signal-chain block diagram of the apparatus. The signal chain comprises a button-transient sensing channel associated with the first piezoelectric transducer (4), a tremor-reference sensing channel associated with the second piezoelectric transducer (5), signal-conditioning paths, the controller (6), an intent classifier, a click gate, and the standard HID interface (7).

The T1 block represents the first piezoelectric transducer (4) mechanically coupled to the button lever (2) or the mechanical switch (3). The T1 block converts the mechanical transient of a button actuation into an electrical signal.

310 The signal from the T1 block contains the rise, impact, loading, damping, and ringdown characteristics of the physical button actuation. The signal is supplied to an analog front end and thereafter to a wideband signal-conditioning path.

The wideband signal-conditioning block preserves the rise and ringdown portions of the transient
315 generated during the button actuation. The wideband path may include a charge amplifier or a high-impedance instrumentation amplifier. The bandwidth of the wideband path extends into the low-kilohertz region. This bandwidth enables the signal path to preserve the transient shape required for morphological analysis, including the attack slope, ringdown decay, transient duration, spectral centroid, and band-energy distribution.

320 The purpose of the wideband block is not merely to determine whether a button actuation has occurred. The block preserves sufficient waveform information for the controller (6) to determine how the actuation developed and how the resulting mechanical vibration decayed.

The output of the wideband path is supplied to an onset-detection block. The onset-detection block
325 identifies the beginning of a physical button actuation.

The actuation onset may additionally or alternatively be detected from the electrical edge generated by the mechanical switch (3). Once the onset is detected, the controller (6) captures a transient window spanning the rise of the actuation and its ringdown. The detected onset also identifies the relevant instant within the continuously stored pre-contact body-channel signal. The controller (6)
330 can therefore associate the transient generated by the first piezoelectric transducer (4) with the tremor state existing immediately before that same actuation.

The morphological feature-extraction block processes the captured transient from the first piezoelectric transducer (4). The block extracts one or more features relating to the shape of the
335 transient rather than its peak amplitude.

The extracted features may include the attack slope, which represents the manner in which the button lever (2) is loaded through its actuation point. A directed volitional actuation may load the button lever (2) through the actuation point in a single controlled movement.

340 The extracted features may further include a ringdown decay characteristic. When a finger remains deliberately in contact with the button lever (2), the finger mass-loads and damps the mechanical assembly, thereby shortening the ringdown. In contrast, an incidental or involuntary contact may leave the button-switch assembly comparatively free to vibrate, thereby producing a different ringdown profile.

345 Other extracted morphological features may include transient duration, spectral centroid, and band-energy ratios. These features represent differences in the distribution and decay of mechanical energy produced by different mechanisms of actuation.

Peak amplitude is not used as the basis for discrimination. Consequently, two actuations having substantially the same peak amplitude may nevertheless be distinguished based on differences in attack slope, ringdown, duration, spectral distribution, or other morphology-based characteristics.

350

The T2 block represents the second piezoelectric transducer (5) mounted on the device body (1). The T2 block senses vibration propagated into the device body (1) from the user's hand (8).

355 The second piezoelectric transducer (5) continuously generates a body-channel or shell-channel signal. Unlike the first piezoelectric transducer (4), which captures the localised press transient, the second piezoelectric transducer (5) provides contextual information concerning the state of the user's hand (8) and the device body (1).

360 The signal generated by the second piezoelectric transducer (5) is supplied through an analog front end to a band-limited signal-conditioning path. The band-limited path is restricted to approximately three hertz to eight hertz for estimating the tremor-band state.

The band-limited path isolates the lower-frequency vibration component associated with hand oscillation from higher-frequency components. The conditioned body-channel signal is continuously supplied to the pre-contact ring buffer.

365 The wideband path associated with the first piezoelectric transducer (4) and the band-limited path associated with the second piezoelectric transducer (5) therefore process signals occupying different frequency ranges. The wideband path preserves the rapid mechanical transient of the press, whereas the band-limited path identifies the slower oscillatory state existing before the press.

370 The pre-contact ring-buffer block continuously retains a rolling time window of the band-limited signal generated by the second piezoelectric transducer (5). The retained window is approximately one hundred milliseconds to three hundred milliseconds.

As new body-channel samples are received, older samples are replaced so that the buffer always contains the most recent interval preceding the current instant. When a button actuation begins, the buffer already contains the vibration signal that occurred immediately before contact.

375 The pre-contact information is important because the vibration state existing before the button actuation cannot be reconstructed solely from the actuation transient. For example, an actuation beginning at or near a peak of a substantial tremor-band oscillation may be more likely to have arisen from involuntary movement.

380 The tremor-state estimation block processes the buffered body-channel signal to determine the tremor-band state at the onset of the actuation. The tremor-band state includes at least an amplitude and a phase of the oscillatory component.

The amplitude represents the strength of the tremor-band vibration immediately preceding the actuation. The phase indicates the position of the vibration cycle at which the actuation began.

385 The estimated amplitude and phase are supplied as contextual features to the intent-classification block. The classifier therefore does not evaluate the press transient in isolation but evaluates the press transient in view of the movement state existing before contact.

Differential T1–T2 Block

Figure 3 further shows an optional differential processing block associated with the signals from
390 T1 and T2. The differential block compares or combines the signals generated by the first
piezoelectric transducer (4) and the second piezoelectric transducer (5).

Whole-hand tremor may be present as a common-mode component in both sensing channels.
Differential processing can reject or reduce the common-mode whole-hand vibration while
retaining the localised finger impulse captured more strongly by the first piezoelectric transducer
395 (4).

The differential output may be supplied as an additional feature to the intent classifier. In the IDF,
the differential feature is described as a supporting or dependent feature rather than the primary
basis of the classification.

400 The intent-classifier block receives the morphological features extracted from the T1 transient and
the pre-contact tremor-state features derived from the T2 buffer. The classifier may also receive
the optional T1–T2 differential feature.

The classifier evaluates the input features together and determines whether the detected actuation
is volitional or non-volitional. The decision is therefore based on both the mechanical form of the
405 actuation and the vibration context immediately preceding it.

A volitional actuation may exhibit a controlled attack, a damped ringdown caused by deliberate
finger contact, and a pre-contact vibration state consistent with a directed movement. A non-
volitional actuation may exhibit a different loading and ringdown morphology and may begin at a
phase and amplitude of tremor-band oscillation indicative of incidental contact.

410 The classifier may operate using a decision boundary. The decision boundary may optionally be
adapted for an individual user based on accumulated examples. The accumulated examples may
be obtained through an express training procedure or from labels inferred from subsequent
corrective behaviour of the user.

415 The per-user adaptation block adjusts the decision boundary used by the intent classifier according
to characteristics of a particular user's actuations.

The adaptation may account for differences between users in intentional pressing style, tremor behaviour, loading of the button lever (2), or damping of the mechanical assembly. The per-user adaptation is an optional supporting feature. A user-settable operating point may also govern the
420 balance between suppressing volitional actuations and emitting non-volitional actuations. The operating point can therefore be selected according to the individual user's preference.

The output of the intent classifier controls the click-gate block. The raw electrical edge generated by the mechanical switch (3) is not automatically passed to the host. Instead, the switch edge must
425 pass through the click gate. When the classifier determines that the actuation is volitional, the click gate is enabled and the corresponding input event is passed to the standard HID interface (7). When the classifier determines that the actuation is non-volitional, the click gate blocks the input event.

The click gate therefore changes what the apparatus physically emits to the host. The host receives an input event only when the apparatus has classified the underlying physical actuation as
430 volitional.

The standard HID interface (7) receives the permitted input event from the click gate and communicates the event to the host. The interface may operate through USB or Bluetooth Low Energy and presents the apparatus as a standard human interface device. Because the intent determination and gating are performed locally within the apparatus, the host does not need to
435 perform tremor analysis or intent classification. The host therefore receives a conventional input event when an actuation is permitted and receives no input event when the actuation is suppressed. No dedicated driver or host-side software is required.

Figure 4 illustrates the inventive principle underlying the distinction between volitional and non-
440 volitional actuations. Figure 4 includes three portions relating respectively to transient morphology, the pre-contact tremor window, and differential sensing. Figure 4(a): Transient Morphology at the Same Peak Amplitude Figure 4(a) compares a volitional press transient and a non-volitional press transient having substantially the same peak amplitude.

The comparison demonstrates that peak amplitude alone does not reliably represent the user's intention. An intentional actuation may be relatively weak, while an involuntary contact may be sharp. Accordingly, the apparatus distinguishes the two actuations based on differences in transient shape. The volitional transient may exhibit a controlled attack slope because the user deliberately loads the button lever (2) through the actuation point. The user's finger may remain in contact with the button lever (2), thereby mass-loading and damping the mechanical assembly and producing a shorter ringdown.

The non-volitional transient may be generated by an oscillatory perturbation or incidental contact. Such a contact may have a different attack profile and may leave the button-switch assembly comparatively free to ring, producing a different decay characteristic. The controller (6) therefore evaluates the attack slope, ringdown decay, transient duration, spectral centroid, band-energy ratios, or combinations thereof. The classification is based on these morphology-based differences and not on the maximum amplitude reached by the signal.

Figure 4(b) illustrates the pre-contact vibration window retained from the second piezoelectric transducer (5). The window contains the vibration state of the device body (1) during the interval immediately preceding the actuation. The controller (6) uses this interval to determine the amplitude and phase of the tremor-band oscillation at press onset. Where an actuation begins at or near a peak of a substantial oscillation, the pre-contact context biases the classification toward a non-volitional determination. In contrast, the body-channel pattern preceding a directed intentional movement may provide a different context.

The pre-contact window provides evidence that is available only before contact. Such evidence cannot be recovered merely by examining the actuation transient after contact, the duration of the actuation, or the interval between successive actuations. The pre-contact context also enables the apparatus to classify the first actuation in a sequence without waiting for a subsequent actuation. The classification is therefore performed independently of any minimum inter-actuation interval.

Figure 4(c) illustrates differential processing between the signal generated by the first piezoelectric transducer (4) and the signal generated by the second piezoelectric transducer (5).

Vibration resulting from whole-hand tremor may propagate through the device body (1) and appear in both channels as a common-mode component. The differential operation reduces the common-

mode component. A localised finger impulse occurring at the button lever (2) is captured more directly by the first piezoelectric transducer (4). Differential analysis therefore assists in isolating the localised press transient from vibration affecting the apparatus as a whole.

The differential feature may be supplied to the intent classifier together with the transient morphology and the pre-contact tremor-state information.

Figure 5 illustrates the operation of the click gate for selectively transmitting volitional input events and suppressing non-volitional input events. Every physical actuation of the button lever (2) operates the mechanical switch (3) and produces a corresponding transient sensed by the first piezoelectric transducer (4). However, the electrical switch edge is not transmitted directly to the host. Upon each actuation, the controller (6) captures the transient, extracts the morphology-based features, obtains the pre-contact tremor state from the buffered signal of the second piezoelectric transducer (5), and classifies the actuation.

When the classifier output identifies the actuation as volitional, the controller (6) permits the raw switch event to pass through the click gate. The event is then supplied through the standard HID interface (7) and emitted to the host as a standard input event. When the classifier output identifies the actuation as non-volitional, the controller (6) prevents the raw switch event from passing through the click gate. The corresponding event is thereby suppressed and is not received by the host.

An indicator may optionally signal that an actuation has been suppressed. The indication enables the user to distinguish a deliberate suppression from a failure of the apparatus to register the button actuation. The click-gating operation is performed independently for every detected actuation. The controller (6) does not determine intent by waiting for a repeat actuation or by applying a minimum time interval between successive inputs. Consequently, a rapid intended actuation is not rejected merely because it occurs within a predefined interval after a preceding actuation.

The time added by the classification process is bounded by the duration of the mechanical transient being analysed. Once sufficient transient information has been captured and evaluated, the event is either emitted or suppressed. The same sensing, buffering, classification and gating arrangement may be embodied in a retrofit module. In the retrofit embodiment, the module is interposed between the button assembly of an existing input device and its host interface. The module receives

the switch actuation, performs the intent classification, and presents the permitted input events to the host through the standard HID interface (7), thereby enabling the user to retain an existing input device

505 In an alternative embodiment, the transducers, signal-conditioning circuitry, pre-contact buffer, controller, intent classifier and click gate are provided as a retrofit module configured to be interposed between the button assembly of an existing input device and its host interface. The retrofit module receives the mechanical actuation and switch signals, classifies each actuation using the transient morphology and buffered pre-contact tremor state, and emits only permitted
510 input events while enumerating to the host as a standard Human Interface Device. The apparatus may thereby be added to an existing input device without requiring a dedicated driver, software installation or administrative privilege.

In another embodiment, differential processing is performed between the signals generated by the first piezoelectric transducer (4) and the second piezoelectric transducer (5) to reject whole-hand
515 tremor appearing as a common-mode component and isolate the localised finger impulse. The decision boundary may be adapted to an individual user through an express training procedure or through labels inferred from subsequent corrective behaviour. A user-settable operating point may control the balance between suppressed volitional actuations and emitted non-volitional actuations, and an indicator may inform the user whenever an actuation has been suppressed. The
520 same volitional-versus-incident actuation discrimination may also be applied to industrial or vehicle controls subject to vibration.

In the best mode, the apparatus is embodied in a pointing device having the first piezoelectric transducer (4) mechanically coupled to the underside of the button lever (2) or to the mounting of
525 the mechanical switch (3), and the second piezoelectric transducer (5) coupled to the device body (1) at a location spaced from the button lever (2). The controller (6) continuously samples the second piezoelectric transducer (5), retains a rolling pre-contact window of approximately one hundred milliseconds to three hundred milliseconds, and estimates the amplitude and phase of a tremor-band component of approximately three hertz to eight hertz. Upon detecting an actuation,
530 the controller (6) captures the button transient through a wideband path extending into the low-kilohertz region, extracts at least an attack-slope feature or a ringdown-decay feature

independently of peak amplitude, and jointly evaluates the extracted morphology and the pre-contact tremor state. The controller (6) then permits a volitional actuation to pass through the click gate to the standard HID interface (7) and suppresses a non-volitional actuation, without applying
535 a minimum interval between successive actuations.

The present invention provides reliable discrimination between volitional and non-volitional physical button actuations by evaluating the shape of the mechanical transient together with vibration information obtained immediately before contact. Unlike pressure- or displacement-
540 based systems, the apparatus does not rely on peak actuation magnitude, which may be poorly correlated with intent where an intended press is weak and an involuntary contact is sharp. Further, unlike cursor-motion filtering, the invention acts directly upon the physical input event, and unlike timing-based rejection mechanisms, it correctly processes the first actuation of a sequence without requiring a subsequent actuation or imposing a minimum inter-actuation interval.

The invention further provides low-latency, real-time operation because the added latency is bounded by the duration of the captured transient rather than by a predetermined discrimination delay. The dual-transducer arrangement enables acquisition of both a localised press transient and a pre-contact tremor reference, while optional differential processing reduces common-mode whole-hand tremor. Local processing and standard USB or BLE HID enumeration permit driver-
550 free operation on managed or shared host systems, and the retrofit configuration enables a user to retain an existing input device. Per-user adaptation, a user-settable operating point and a suppression indicator further improve individual usability and transparency of operation.

Experimental Validation Results:

A prototype implementation of the proposed intent-aware input apparatus is under development
555 for validating the disclosed intent-classification mechanism. The prototype comprises a donor wired pointing device integrated with piezoelectric discs or polyvinylidene fluoride (PVDF) sensing elements, charge or instrumentation amplifiers, an RP2040- or ESP32-class microcontroller implementing a USB Human Interface Device (HID) interface, a reference inertial sensor for ground-truth acquisition, and a vibration motor or eccentric-mass shaker configured to
560 simulate tremor conditions.

Experimental validation is planned by acquiring several hundred labelled intentional button actuations together with several hundred tremor-simulated non-volitional contacts to evaluate the separability of transient morphology features, particularly attack slope and ringdown decay, while demonstrating that peak amplitude alone does not reliably distinguish user intent. Further validation includes comparative evaluation of the classifier with and without the buffered pre-contact tremor-state features to quantify the contribution of the pre-contact context, comparison against force/amplitude-threshold and timing-based detection approaches using confusion matrices and receiver operating characteristic (ROC) curves, latency measurement from physical actuation to emitted HID event, assessment of the benefit obtained by employing the body-mounted reference transducer in addition to the button-mounted transducer, and, subject to institutional ethics approval and informed consent, a limited user study evaluating unintended-click reduction during task performance without performing clinical assessment, diagnosis, or tremor-severity scoring.

CLAIMS

590 I/We Claim:

An intent-aware input apparatus (100) for classifying a physical button actuation, the apparatus (100) comprising:

a device body (1);

a manually actuable button lever (2) coupled to a mechanical switch (3);

595 a first piezoelectric transducer (4) mechanically coupled to the button lever (2) or the mechanical switch (3) and configured to generate a first signal corresponding to a mechanical transient produced during actuation of the button lever (2);

a second piezoelectric transducer (5) mechanically coupled to the device body (1) at a location spaced from the button lever (2) and configured to generate a second signal
600 representative of vibration propagated through the device body (1);

a controller (6) operatively coupled to the first piezoelectric transducer (4), the second piezoelectric transducer (5), the mechanical switch (3), and a human interface device interface (7),

wherein the controller (6) is configured to:

605 continuously retain a rolling pre-contact buffer of the second signal preceding each detected actuation;

detect an onset of the physical button actuation;

capture the mechanical transient generated during the actuation;

extract one or more morphology-based features from the captured mechanical transient
610 excluding peak amplitude;

determine a tremor-state parameter from the retained pre-contact buffer corresponding to the detected onset;

classify the detected actuation as either a volitional actuation or a non-volitional actuation using the one or more morphology-based features and the tremor-state parameter; and

615 selectively permit or suppress transmission of a corresponding input event through the human interface device interface (7) according to the classification.

2. The apparatus (100) as claimed in claim 1, wherein the morphology-based features comprise one or more of an attack slope, ringdown decay characteristic, transient duration,
620 spectral centroid, and spectral energy distribution derived from the captured mechanical transient generated by the first piezoelectric transducer (4).

3. The apparatus (100) as claimed in claim 1, wherein the rolling pre-contact buffer stores the second signal for a duration of approximately 100 milliseconds to 300 milliseconds immediately preceding the detected actuation.

625 4. The apparatus (100) as claimed in claim 1, wherein the tremor-state parameter comprises at least a tremor-band amplitude and a tremor-band phase determined from a vibration component within a frequency band of approximately 3 Hz to 8 Hz.

5. The apparatus (100) as claimed in claim 1, wherein the controller (6) comprises a wideband signal-conditioning path configured to preserve rise and ringdown
630 characteristics of the first signal and a band-limited signal-conditioning path configured to estimate the tremor-state parameter from the second signal.

6. The apparatus (100) as claimed in claim 1, wherein the controller (6) is further configured to perform differential processing between the first signal and the second signal to reduce common-mode vibration components before classifying the detected actuation.

635 7. The apparatus (100) as claimed in claim 1, wherein the controller (6) is configured to adapt a decision boundary of the classification using accumulated user-specific actuation characteristics obtained through a training procedure or inferred corrective behaviour.

8. The apparatus (100) as claimed in claim 1, further comprising a user-configurable operating parameter configured to modify a decision threshold for classification and a
640 suppression indicator configured to indicate suppression of an input event classified as non-volitional.

9. The apparatus (100) as claimed in claim 1, wherein the human interface device interface (7) is configured to enumerate the apparatus (100) as a standard Human Interface Device for communicating selectively permitted input events.

645 10. A method for classifying a physical button actuation in an intent-aware input apparatus (100), the method comprising:

continuously acquiring a first signal from a first piezoelectric transducer (4) coupled to a button lever (2) or a mechanical switch (3);

650 continuously acquiring a second signal from a second piezoelectric transducer (5) coupled to a device body (1);

maintaining a rolling pre-contact buffer of the second signal;

detecting an onset of a physical button actuation;

capturing a mechanical transient corresponding to the detected actuation;

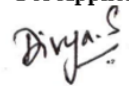
655 extracting one or more morphology-based features excluding peak amplitude from the captured mechanical transient;

determining a tremor-state parameter from the rolling pre-contact buffer corresponding to the detected onset;

classifying the detected actuation as a volitional actuation or a non-volitional actuation using the extracted morphology-based features and the tremor-state parameter; and

660 selectively transmitting or suppressing a corresponding input event through a human interface device interface (7) according to the classification.

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An Intent-Aware Input Apparatus and Method for Volitional Actuation Classification

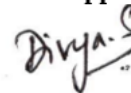
ABSTRACT

670 An intent-aware input apparatus (100) comprises a device body (1), a button lever (2), a mechanical switch (3), a first piezoelectric transducer (4), a second piezoelectric transducer (5), a controller (6), and a human interface device interface (7). The controller (6) continuously retains a rolling pre-contact buffer of vibration signals received from the second piezoelectric transducer (5), captures a mechanical transient generated during button actuation through the first piezoelectric transducer (4), extracts morphology-based features excluding peak amplitude, determines a pre-contact tremor-state parameter, and jointly classifies the actuation
675 as volitional or non-volitional using the transient morphology and the pre-contact tremor state. Based on the classification, the controller (6) selectively permits or suppresses transmission of a corresponding input event through the human interface device interface (7). The apparatus performs local real-time intent classification using transient morphology and buffered pre-contact vibration information

680 Fig 1

Date: 26.08.2026

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