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(54) Title: CAPTURE OF VIBRO-ACOUSTIC DATA USED TO DETERMINE TOUCH TYPES

(57) Abstract: An electronic device includes a touch-sensitive surface, for example a touch pad or touch screen. The user physically interacts with the touch-sensitive surface, producing touch events. The resulting interface actions taken depend at least in part on the touch type. The type of touch is determined in part based on vibro-acoustic data and touch data produced by the touch event.

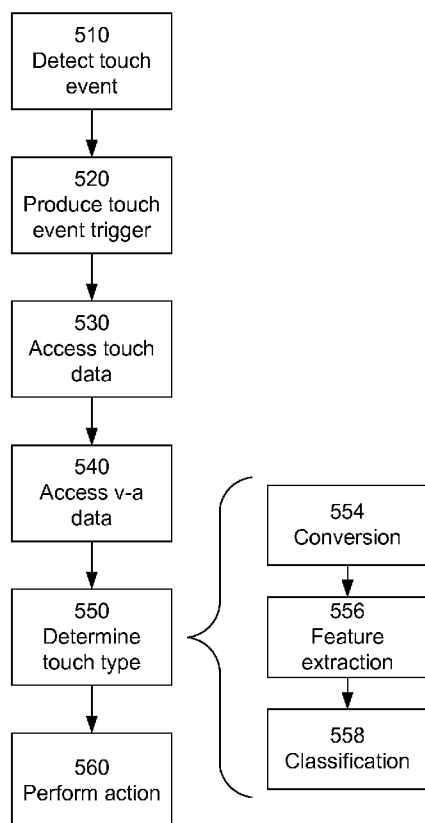


FIG. 5



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CAPTURE OF VIBRO-ACOUSTIC DATA USED TO DETERMINE TOUCH TYPES**BACKGROUND OF THE INVENTION**1. **Field of the Invention**

[0001] This invention relates generally to interacting with electronic devices via a touch-sensitive surface.

2. **Description of the Related Art**

[0002] Many touch pads and touch screens today are able to support a small set of gestures. For example, one finger is typically used to manipulate a cursor or to scroll the display. Another example is using two fingers in a pinching manner to zoom in and out of content, such as a photograph or map. However, this is a gross simplification of what fingers and hands are capable of doing. Fingers are diverse appendages, both in their motor capabilities and their anatomical composition. Furthermore, fingers and hands can also be used to manipulate tools, in addition to making gestures themselves.

[0003] Thus, there is a need for better utilization of the capabilities of fingers and hands to control interactions with electronic devices.

SUMMARY OF THE INVENTION

[0004] The present invention allows users to interact with touch-sensitive surfaces in a manner that distinguishes different touch types. For example, the same touch events performed by a finger pad, a finger nail, a knuckle or different types of instruments may result in the execution of different actions on the electronic device.

[0005] In one approach, a user uses his finger(s) or an instrument to interact with an electronic device via a touch-sensitive surface, such as a touch pad or a touch screen. A touch event trigger indicates an occurrence of a touch event between the user and the touch-sensitive surface. Touch data and vibro-acoustic data produced by the physical touch event are used to determine the touch type for the touch event. However, the touch event trigger may take some time to generate due to, for example, sensing latency and filtering. Further, the event trigger may take some time to propagate in the device due to, for example, software processing, hysteresis, and overhead from processing a low level event (e.g., interrupt) up through the operating system to end user applications. Because there will always be some

amount of latency, the vibro-acoustic data from the touch impact will always have occurred prior to receipt of the touch event trigger.

[0006] On most mobile electronic devices, the distinguishing components of the vibro-acoustic signal (i.e., those which are most useful for classification) occur in the first 10 ms of a touch impact. For current mobile electronics, the touch event trigger is typically received on the order of tens of milliseconds after the physical touch contact. Therefore, if vibro-acoustic data is captured only upon receipt of a touch event trigger, the most important part of the vibro-acoustic signal will have already occurred and will be lost (i.e., never captured). This precludes reliable touch type classification for many platforms.

[0007] In one approach, vibro-acoustic data is continuously captured and buffered, for example, with a circular buffer. After receipt of the touch event trigger, an appropriate window (based on device latency) of vibro-acoustic data (which can include times prior to receipt of the touch event trigger or even prior to the physical touch event) is then accessed from the buffer. For example, a 10ms window beginning 30ms prior to receipt of the touch event trigger (i.e., from -30ms to -20ms) can be accessed. Additionally, the system can wait after the receipt of a touch event trigger for a predefined length of time before extracting a window of vibro-acoustic data. For example, the system can wait 20ms after receipt of a touch event trigger, and then extract from the buffer the prior 100ms of data.

[0008] In an alternate approach, the occurrence of the touch event is predicted beforehand. For example, the touch-sensitive surface may sense proximity of a finger before actual contact (e.g., using hover sensing capabilities of capacitive screens, diffuse illumination optical screens, and other technologies). This prediction is then used to trigger capture of vibro-acoustic data or to initiate vibro-acoustic data capturing and buffering. If the predicted touch event does not occur, capturing and/or buffering can cease, waiting for another predicted touch.

[0009] In another aspect, the touch type for the touch event determines subsequent actions. An action is taken on the electronic device in response to the touch event and to the touch type. That is, the same touch event can result in the execution of one action for one touch type and a different action for a different touch type.

[0010] Other aspects of the invention include methods, devices, systems, components and applications related to the approaches described above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The invention has other advantages and features which will be more readily apparent from the following detailed description of the invention and the appended claims, when taken in conjunction with the accompanying drawings, in which:

[0012] FIG. 1 is a block diagram of an electronic device according to the present invention.

[0013] FIG. 2A is timing diagrams illustrating a delayed touch event trigger.

[0014] FIGS. 2B-2C are timing diagrams illustrating appropriate windows for vibro-acoustic data.

[0015] FIGS. 3A-3B are a block diagram and timing diagram of one implementation for accessing earlier vibro-acoustic data.

[0016] FIGS. 4A-4B are a block diagram and timing diagram of another implementation for accessing earlier vibro-acoustic data.

[0017] FIG. 5 is a flow diagram illustrating touch event analysis using the device of FIG. 1.

[0018] FIG. 6 is a spectrogram of three types of touches.

[0019] The figures depict embodiments of the present invention for purposes of illustration only. One skilled in the art will readily recognize from the following discussion that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles of the invention described herein.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] The figures and the following description relate to preferred embodiments by way of illustration only. It should be noted that from the following discussion, alternative embodiments of the structures and methods disclosed herein will be readily recognized as viable alternatives that may be employed without departing from the principles of what is claimed.

[0021] FIG. 1 is a block diagram of an electronic device 100 according to the present invention. The device 100 includes a touch-sensitive surface 110, for example a touch pad or touch screen. It also includes computing resources, such as processor 102, memory 104 and data storage 106 (e.g., an optical drive, a magnetic media hard drive or a solid state drive). Sensor circuitry 112 provides an interface between the touch-sensitive surface 110 and the rest of the device 100. Instructions 124 (e.g., software), when executed by the processor 102, cause the device to perform certain functions. In this example, instructions 124 include a

touch analysis module that analyzes the user interactions with the touch-sensitive surface 110. The instructions 124 also allow the processor 102 to control a display 120 and to perform other actions on the electronic device.

[0022] In a common architecture, the data storage 106 includes a machine-readable medium which stores the main body of instructions 124 (e.g., software). The instructions 124 may also reside, completely or at least partially, within the memory 104 or within the processor 102 (e.g., within a processor's cache memory) during execution. The memory 104 and the processor 102 also constitute machine-readable media.

[0023] In this example, the different components communicate using a common bus, although other communication mechanisms could be used. As one example, the processor 102 could act as a hub with direct access or control over each of the other components.

[0024] The device 100 may be a server computer, a client computer, a personal computer (PC), or any device capable of executing instructions 124 (sequential or otherwise) that specify actions to be taken by that device. Further, while only a single device is illustrated, the term "device" shall also be taken to include any collection of devices that individually or jointly execute instructions 124 to perform any one or more of the methodologies discussed herein. The same is true for each of the individual components. For example, the processor 102 may be a multicore processor, or multiple processors working in a coordinated fashion. It may also be or include a central processing unit (CPU), a graphics processing unit (GPU), a network processing unit (NPU), a digital signal processor (DSP), one or more application specific integrated circuits (ASICs), or combinations of the foregoing. The memory 104 and data storage 106 may be dedicated to individual processors, shared by many processors, or a single processor may be served by many memories and data storage.

[0025] As one example, the device 100 could be a self-contained mobile device, such as a cell phone or tablet computer with a touch screen. In that case, the touch screen serves as both the touch-sensitive surface 110 and the display 120. As another example, the device 100 could be implemented in a distributed fashion over a network. The processor 102 could be part of a cloud-based offering (e.g., renting processor time from a cloud offering), the data storage 106 could be network attached storage or other distributed or shared data storage, and the memory 104 could similarly be distributed or shared. The touch-sensitive surface 110 and display 120 could be user I/O devices to allow the user to interact with the different networked components.

[0026] Returning to FIG. 1, the sensor circuitry 112 includes two parts: touch sensor 112A and vibro-acoustic sensor 112B. The touch sensor 112A senses the touch contact caused by the user with the touch-sensitive surface. For example, the touch-sensitive surface may be based on capacitive, optical, resistive, electric field, acoustic or other technologies that form the underlying basis for the touch sensing. The touch sensor 112A includes the components that sense the selected phenomenon.

[0027] Touch events also physically cause vibrations or acoustic signals. Touching the surface may cause acoustic signals (such as the sound of a fingernail or finger pad contacting glass) and/or may cause vibrations in the underlying structure of an electronic device, e.g., chassis, enclosure, electronics boards (e.g., PCBs). The sensor circuitry 112 includes sensors 112B to detect the vibro-acoustic signal. The vibro-acoustic sensors may be arranged at a rear side of the touch-sensitive surface so that the vibro-acoustic signal caused by the physical touch event can be captured. They could also be mounted in any number of locations inside the device, including by not limited to the chassis, touch screen, main board, printed circuit board, display panel, and enclosure. Examples of vibro-acoustic sensors include impact sensors, vibration sensors, accelerometers, strain gauges, and acoustic sensors such as a condenser microphone, a piezoelectric microphone, MEMS microphone and the like. Additional sensor types include piezo bender elements, piezo film, accelerometers (e.g., linear variable differential transformer (LVDT), potentiometric, variable reluctance, piezoelectric, piezoresistive, capacitive, servo (force balance), MEMS), displacement sensors, velocity sensors, vibration sensors, gyroscopes, proximity sensors, electric microphones, hydrophones, condenser microphones, electret condenser microphones, dynamic microphones, ribbon microphones, carbon microphones, piezoelectric microphones, fiber optic microphones, laser microphones, liquid microphones, and MEMS microphones. Many touch screen computing devices today already have microphones and accelerometers built in (e.g., for voice and input sensing). These can be utilized without the need for additional sensors, or can work in concert with specialized sensors.

[0028] Whatever the underlying principle of operation, touches on the touch-sensitive surface will result in signals – both touch signals and vibro-acoustic signals. However, these raw signals typically are not directly useable in a digital computing environment. For example, the signals may be analog in nature. The sensor circuitry 112A-B typically provides an intermediate stage to process and/or condition these signals so that they are suitable for use in a digital computing environment. As shown in FIG. 1, the touch sensor

circuitry 112A produces touch data for subsequent processing and the vibro-acoustic sensor circuitry 112B produces vibro-acoustic data for subsequent processing.

[0029] The touch sensor circuitry 112A also produces a touch event trigger, which indicates the occurrence of a touch event. Touch event triggers could appear in different forms. For example, the touch event trigger might be an interrupt from a processor controlling the touch sensing system. Alternately, the touch event trigger could be a change in a polled status of the touchscreen controller. It could also be implemented as a modification of a device file (e.g., "/dev/input/event6") on the file system, or as a message posted to a driver work queue. As a final example, the touch event trigger could be implemented as an onTouchDown() event in a graphical user interface program.

[0030] However, the generation and receipt of the touch event trigger may be delayed due to latency in touch sensor circuitry 112A. Thus, if vibro-acoustic sensor circuitry 112B were to wait until it received the touch event trigger and then turn on, it may miss the beginning portion of the vibro-acoustic data.

[0031] FIG. 2A illustrates this situation. Signal 210 shows the time duration of the touch event. Signal 210A shows the corresponding touch signal and signal 210B shows the corresponding vibro-acoustic signal. The touch sensor circuitry 112A (and possibly also instructions 124) processes the touch signal 210A to produce the touch event trigger 212. This processing requires some amount of time, labeled as Δt in FIG. 2. If capture of the vibro-acoustic signal begins at that time, the vibro-acoustic signal prior to that time will have been lost.

[0032] In many cases, the delay Δt can be very significant. It could be longer than the entire signal window. For example, typical delays Δt for current devices are 20ms, 35ms, 50ms, or possibly longer; while the desired vibro-acoustic signal window 210B can be the first 5ms, for example. In these cases, waiting for the touch event trigger 212 may miss the entire vibro-acoustic signal. Other times, the delay Δt can be short and the window long, for example, a 10ms delay with a 100ms window.

[0033] FIGS. 2B-2C are timing diagrams illustrating some examples of appropriate windows for vibro-acoustic data. In FIG. 2B, the physical touch event begins at time 211 and there is a delay Δt before the touch event trigger 212 is ready. The signal shown in FIG. 2B is the vibro-acoustic data 210B, which also starts at time 211. The desired time window for the vibro-acoustic data 210B begins at time 214 and ends at time 215. Note that the window begins 214 slightly before the physical touch event begins 211, and ends 215 before both the

touch event trigger 212 and the end of the vibro-acoustic data. That is, not all of the vibro-acoustic data is used.

[0034] In some cases, useful vibro acoustic data can persist after the receipt of the touch event trigger 212. In this case, a small waiting period can be used before accessing the vibro-acoustic buffer, which can contain periods both before and after the touch event trigger. This is shown in FIG. 2C. In this example, the desired window extends beyond the touch event trigger 212. If the buffer were accessed at the time of the touch event trigger 212, the last portion of the window would be missed. Instead, the device waits for time period 217 and then accesses the buffer.

[0035] FIGS. 3 and 4 are block diagrams illustrating two different ways to access vibro-acoustic data for times prior to receipt of the touch event trigger. In FIG. 3A, the vibro-acoustic signal from the touch-sensitive surface is continuously captured and buffered. Buffer 310 contains a certain sample window of vibro-acoustic data, including data captured prior to the current time. The touch event trigger 212 and possibly also touch data are used by module 311 to determine the relevant time window 210B. In one approach, the length of the time window is predetermined. For example, it may be known that the latency for the touch event trigger is between 20 and 40ms, so the system may be designed assuming a worst case latency (40ms) but with sufficient buffer size and window size to accommodate shorter latencies (20ms). On some systems, the latency is very consistent, e.g., always 30ms. In that case, the time windows and buffer sizes can be more tightly designed.

[0036] The vibro-acoustic data for this time window are then accessed from buffer 310. In other words, the approach of FIG. 3 still uses the delayed trigger 212, but the buffer 310 allows the device to effectively reach back in time to access the vibro-acoustic data from the beginning of the time window 210. This is indicated by the arrows 312 in FIGS. 3A-B, which indicate moving back in time relative to the touch event trigger 212.

[0037] In FIG. 4A, a faster trigger is used. In one approach, the touch event is predicted prior to its occurrence. For example, the touch data may be predictive or the touch-sensitive surface may be capable of detecting proximity before actual contact, as indicated by window 410 in FIG. 4B. That is, the touch-event surface may be able to sense a finger or instrument approaching the touch-sensitive surface. From this data, module 411 predicts when actual contact will occur, as indicated by arrows 512 in FIGS. 4A-B. This begins capture and buffering of the vibro-acoustic signal. In this way, the vibro-acoustic data of the touch impact can be captured.

[0038] FIG. 5 is a flow diagram illustrating a touch event using device 100. The user uses his finger(s) or other instruments to interact with the touch-sensitive surface 110. For example, he may use his finger to touch an element displayed on the device, or to touch-and-drag an element, or to touch-and-drag his finger over a certain region. These interactions are meant to instruct the electronic device to perform corresponding actions. The touch-sensitive surface 110 and sensor circuitry 112 detect 510 the occurrence of the touch event and produce 520 a touch event trigger. The device accesses 530 touch data produced by the touch event and also accesses 540 vibro-acoustic data produced by the touch event. Due to the delay in producing the touch event trigger, the time window for the vibro-acoustic data includes times that are prior to receipt of the touch event trigger 520. The touch data and vibro-acoustic data are used to determine 550 a touch type for the touch event.

[0039] Touch types can be defined according to different criteria. For example, different touch types can be defined depending on the number of contacts. A “uni-touch” occurs when the touch event is defined by interaction with a single portion of a single finger (or instrument), although the interaction could occur over time. Examples of uni-touch include a simple touch (e.g., a single tap), touch-and-drag, and double-touch (e.g., a double-tap – two taps in quick succession). In multi-touch, the touch event is defined by combinations of different fingers or finger parts. For example, a touch event where two fingers are simultaneously touching is a multi-touch. Another example would be when different parts of the same finger are used, either simultaneously or over time.

[0040] Touch types can also be classified according to which part of the finger or instrument touches. For example, touch by the finger pad, finger nail or knuckle could be considered different touch types. The finger pad is the fleshy part around the tip of the finger. It includes both the fleshy tip and the fleshy region from the tip to the first joint. The knuckle refers to any of the finger joints. The term “finger” is also meant to include the thumb. It should be understood that the finger itself is not required to be used for touching; similar touches may be produced in other ways. For example, the “finger pad” touch type is really a class of touch events that have similar characteristics as those produced by a finger pad touching the touch-sensitive surface, but the actual touching object may be a man-made instrument or a gloved hand or covered finger, so long as the touching characteristics are similar enough to a finger pad so as to fall within the class.

[0041] The touch type is determined in part by a classification of vibro-acoustic signals from the touch event. When an object strikes a certain material, vibro-acoustic waves propagate outward through the material or along the surface of the material. Typically,

touch-sensitive surface 110 uses rigid materials, such as plastic or glass, which both quickly distribute and faithfully preserve the signal. As such, when respective finger parts touch or contact the surface of the touch-sensitive surface 110, vibro-acoustic responses are produced. The vibro-acoustic characteristics of the respective finger parts are unique, mirroring their unique anatomical compositions.

[0042] For example, FIG. 6 illustrates an example vibro-acoustic spectrogram of three types of finger touches. As shown in FIG. 6, the finger pad, knuckle, and finger nail produce different vibro-acoustic responses. Tapping on different materials, with different fingers/finger parts, with different microphones, in different circumstances can result in different spectrograms. Once the vibro-acoustic signal has been captured, a vibro-acoustic classifier (mostly implemented as part of instructions 124 in FIG. 1) processes the vibro-acoustic signal to determine the touch type.

[0043] FIG. 5 also shows a block diagram of an example touch analysis module 550. It includes conversion 554, feature extraction 556, and classification 558. The conversion module 554 performs a frequency domain transform (e.g., a Fourier transform or method) on the sampled time-dependent vibro-acoustic signal in the buffer. For example, the Fourier transform of this window may produce 2048 bands of frequency power. The conversion module 554 may also perform other functions. These could include filtering the waveform (e.g., Kalman filter, exponential moving average, 2kHz high pass filter, One Euro filter, Savitzky-Golay filter). It could also include transformation into other representations (e.g., wavelet transform, derivative), including frequency domain representations (e.g., spectral plot, periodogram, method of averaged periodograms, Fourier transform, least-squares spectral analysis, Welch's method, discrete cosine transform (DCT), fast folding algorithm).

[0044] The feature extraction module 556 then generates various features. These features can include time domain and/or frequency domain representations of the vibro-acoustic signal (or its filtered versions), as well as first, second, and higher order derivatives thereof. These features can also include down-sampling the time and frequency domain data into additional vectors (e.g., buckets of ten), providing different aliasing. Additional features can be further derived from the time domain and/or frequency domain representations and their derivatives, including average, standard deviation, standard deviation (normalized by overall amplitude), range, variance, skewness, kurtosis, sum, absolute sum, root mean square (rms), crest factor, dispersion, entropy, power sum, center of mass (centroid), coefficient of variation, cross correlation (e.g., sliding dot product), zero-crossings, seasonality (i.e., cyclic variation), and DC bias. Additional features based on frequency domain representations and

their derivatives include power in different bands of the frequency domain representation (e.g., power in linear bins or octaves) and ratios of the power in different bands (e.g., ratio of power in octave 1 to power in octave 4).

[0045] Features could also include template match scores for a set of known exemplar signals using any of the following methods: convolution, inverse filter matching technique, sum-squared difference (SSD), dynamic time warping, and elastic matching.

[0046] Spectral centroid, spectral density, spherical harmonics, total average spectral energy, spectral rolloff, spectral flatness, band energy ratio (e.g., for every octave), and log spectral band ratios (e.g., for every pair of octaves, and every pair of thirds) are features that can be derived from frequency domain representations.

[0047] Additional vibro-acoustic features include linear prediction-based cepstral coefficients (LPCC), perceptual linear prediction (PLP) cepstral coefficients, cepstrum coefficients, mel-frequency cepstral coefficients (MFCC), and frequency phases (e.g., as generated by an FFT). The above features can be computed on the entire window of vibro-acoustic data, but could also be computed for sub regions (e.g., around the peak of the waveform, at the end of the waveform). Further, the above vibro-acoustic features can be combined to form hybrid features, for example a ratio (e.g., zero-crossings / spectral centroid) or difference (zero-crossings - spectral centroid).

[0048] The feature extraction module 556 can also generate features from the touch data. Examples include location of the touch (2D, or 3D in the case of curved glass or other non-planar geometry), size and shape of the touch (some touch technologies provide an ellipse of the touch with major and minor axes, eccentricity, and/or ratio of major and minor axes), orientation of the touch, surface area of the touch (e.g., in squared mm or pixels), number of touches, pressure of the touch (available on some touch systems), and shear of the touch. “Shear stress,” also called “tangential force,” arises from a force vector perpendicular to the surface normal of a touch screen, i.e., parallel to the touch screen surface. This is similar to normal stress – what is commonly called pressure – which arises from a force vector parallel to the surface normal. Some features depend on the type of touch-sensitive surface. For example, capacitance of touch, swept frequency capacitance of touch, and swept frequency impedance of touch may be available for (swept frequency) capacitive touch screens. Derivatives of the above quantities can also be computed as features. The derivatives may be computed over a short period of time, for example, touch velocity and pressure velocity. Another possible feature is an image of the hand pose (as imaged by e.g., an optical sensor, diffuse illuminated surface with camera, near-range capacitive sensing).

[0049] The classification module 558 classifies the touch using extracted features from the vibro-acoustic signal as well as possibly other non-vibro-acoustic features, including touch features. In one exemplary embodiment, the classification module 558 is implemented with a support vector machine (SVM) for feature classification. The SVM is a supervised learning model with associated learning algorithms that analyze data and recognize patterns, used for classification and regression analysis. To aid classification, the user can provide supplemental training samples to the vibro-acoustic classifier. Other techniques appropriate for the classification module 558 include basic heuristics, decision trees, random forest, naive Bayes, elastic matching, dynamic time warping, template matching, k-means clustering, K-nearest neighbors algorithm, neural network, multilayer perceptron, multinomial logistic regression, Gaussian mixture models, and AdaBoost.

[0050] Returning to FIG. 5, the device analyzes the touch event to determine 550 the touch type. Based on this analysis, the processor 102 then performs 560 the appropriate actions. The appropriate action depends on the touch event (e.g., touch, touch-and-drag, etc.) but it also depends on the touch type. The same touch event can result in different actions by processor 102, for different touch types. For example, a touch by the finger pad, a touch by the finger nail and a touch by an instrument may trigger three different actions.

[0051] This approach allows the same touch event to control more than one action. This can be desirable for various reasons. First, it increases the number of available actions for a given set of touch events. For example, if touch types are not distinguished, then a single tap can be used for only one purpose, because a single tap by a finger pad, a single tap by a finger nail and a single tap by an instrument cannot be distinguished. However, if all three of these touch types can be distinguished, then a single tap can be used for three different purposes, depending on the touch type.

[0052] Conversely, for a given number of actions, this approach can reduce the number of user inputs needed to reach that action. Continuing, the above example, if three actions are desired, by distinguishing touch types, the user will be able to initiate the action by a single motion – a single tap. If touch types are not distinguished, then more complex motions or a deeper interface decision tree may be required. For example, without different touch types, the user might be required to first make a single tap to bring up a menu of the three choices. He would then make a second touch to choose from the menu.

[0053] Although the detailed description contains many specifics, these should not be construed as limiting the scope of the invention but merely as illustrating different examples and aspects of the invention. It should be appreciated that the scope of the invention includes

other embodiments not discussed in detail above. Various other modifications, changes and variations which will be apparent to those skilled in the art may be made in the arrangement, operation and details of the method and apparatus of the present invention disclosed herein without departing from the spirit and scope of the invention as defined in the appended claims. Therefore, the scope of the invention should be determined by the appended claims and their legal equivalents.

[0054] The term “module” is not meant to be limited to a specific physical form. Depending on the specific application, modules can be implemented as hardware, firmware, software, and/or combinations of these. Furthermore, different modules can share common components or even be implemented by the same components. There may or may not be a clear boundary between different modules.

[0055] Depending on the form of the modules, the “coupling” between modules may also take different forms. Dedicated circuitry can be coupled to each other by hardwiring or by accessing a common register or memory location, for example. Software “coupling” can occur by any number of ways to pass information between software components (or between software and hardware, if that is the case). The term “coupling” is meant to include all of these and is not meant to be limited to a hardwired permanent connection between two components. In addition, there may be intervening elements. For example, when two elements are described as being coupled to each other, this does not imply that the elements are directly coupled to each other nor does it preclude the use of other elements between the two.

WHAT IS CLAIMED IS:

1. A method of interaction between a user and an electronic device having a touch-sensitive surface, the method comprising:
 - receiving a touch event trigger that indicates an occurrence of a physical touch event on the touch-sensitive surface;
 - accessing touch data produced by the touch event;
 - accessing vibro-acoustic data for a vibro-acoustic signal produced by the physical touch event, for a time window that begins at a time that is prior to receipt of the touch event trigger; and
 - determining a touch type for the touch event based on the touch data and vibro-acoustic data.
2. The method of claim 1 wherein the step of accessing vibro-acoustic data for a time window comprises:
 - continuously capturing and maintaining a buffer of vibro-acoustic data associated with the touch-sensitive surface;
 - after receipt of the touch event trigger, determining the time window; and
 - accessing the buffered vibro-acoustic data for the determined time window.
3. The method of claim 1 wherein the step of accessing vibro-acoustic data for a time window comprises:
 - predicting a possible touch event, prior to occurrence of a physical touch; and
 - upon such a prediction, beginning capture of vibro-acoustic data associated with the touch-sensitive surface.
4. The method of claim 3 wherein the step of predicting a possible touch event comprises:
 - predicting a possible touch event, based on data from touch sensor associated with the touch-sensitive surface.
5. The method of claim 4 wherein said touch data is indicative of a finger or instrument in proximity to the touch-sensitive surface.
6. The method of claim 4 wherein said touch data is indicative of a finger or instrument approaching the touch-sensitive surface.

7. The method of claim 1 wherein a delay in receiving the touch event trigger is at least one millisecond after the occurrence of the physical touch event.
8. The method of claim 1 wherein the time window begins at a time that is prior to a beginning of the physical touch event.
9. The method of claim 1 wherein the time window ends at a time that is prior to receipt of the touch event trigger.
10. The method of claim 1 wherein a wait is used such that the time window ends at a time that is after receipt of the touch event trigger.
11. The method of claim 1 wherein the vibro-acoustic data includes vibration data caused by the physical touch event.
12. The method of claim 1 wherein the vibro-acoustic data includes acoustic data caused by the physical touch event.
13. The method of claim 1 wherein the step of determining a touch type comprises:
extracting features from the touch data and vibro-acoustic data; and
classifying the features to determine a touch type for the touch event.
14. The method of claim 13 wherein the extracted features include at least one feature based on a location, shape, orientation, and/or size of the touch event.
15. The method of claim 13 wherein the extracted features include at least one feature based on a major axis value, minor axis value, eccentricity, and/or ratio of major and minor axes of the touch event.
16. The method of claim 13 wherein the extracted features include at least one feature based on a pressure of the touch event.
17. The method of claim 13 wherein the extracted features include at least one feature based on a capacitance of the touch event.
18. The method of claim 13 wherein the extracted features include at least one feature based on a time domain representation of the vibro-acoustic data or on a derivative of the time domain representation of the vibro-acoustic data.

19. The method of claim 13 wherein the extracted features include at least one feature based on a frequency domain representation of the vibro-acoustic data or on a derivative of a frequency domain representation of the vibro-acoustic data.
20. The method of claim 13 wherein the extracted features include at least one feature based on powers in different bands of a frequency domain representation of the vibro-acoustic data or of a derivative of a frequency domain representation of the vibro-acoustic data.
21. The method of claim 13 wherein the extracted features include at least one feature based on a ratio of powers in different bands of a frequency domain representation of the vibro-acoustic data or of a derivative of a frequency domain representation of the vibro-acoustic data.
22. The method of claim 13 wherein the extracted features include at least one feature based on a statistical value of the vibro-acoustic data.
23. The method of claim 13 wherein the extracted features include at least one feature based on at least one of the following for the vibro-acoustic data: skewness, dispersion, root mean square, zero crossing, power sum, range, average value, center of mass and standard deviation.
24. The method of claim 13 wherein the step of classifying the features comprises using a Support Vector Machine, Neural Network, Decision Tree, or Random Forest to classify the features.
25. The method of claim 1 further comprising:
executing an action on the electronic device in response to the touch event and touch type, wherein the same touch event results in execution of a first action for a first touch type and results in execution of a second action for a second touch type.
26. The method of claim 1 wherein the touch-sensitive surface is a touch screen.
27. A machine-readable tangible storage medium having stored thereon data representing sequences of instructions, which when executed by an electronic device having a touch-sensitive surface, cause the electronic device to perform a method comprising the steps of:

receiving a touch event trigger that indicates an occurrence of a physical touch event on the touch-sensitive surface;
accessing touch data produced by the touch event;
accessing vibro-acoustic data for a time window, the vibro-acoustic data physically produced by the touch event, the time window beginning at a time that is prior to receipt of the touch event trigger; and
determining a touch type for the touch event based on the touch data and vibro-acoustic data.

28. An electronic device comprising:
a touch-sensitive surface;
means for receiving a touch event trigger that indicates an occurrence of a physical touch event on the touch-sensitive surface;
means for accessing touch data produced by the touch event;
means for accessing vibro-acoustic data for a time window, the vibro-acoustic data physically produced by the touch event, the time window beginning at a time that is prior to receipt of the touch event trigger; and
means for determining a touch type for the touch event based on the touch data and vibro-acoustic data.

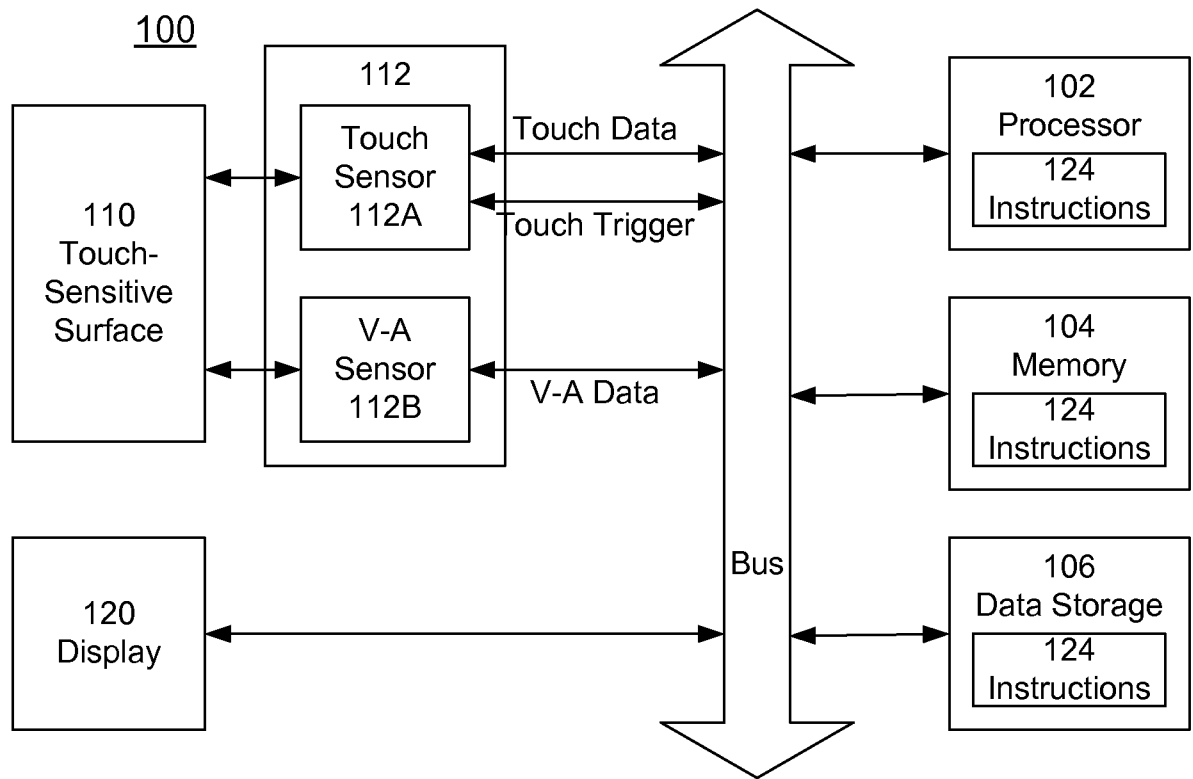


FIG. 1

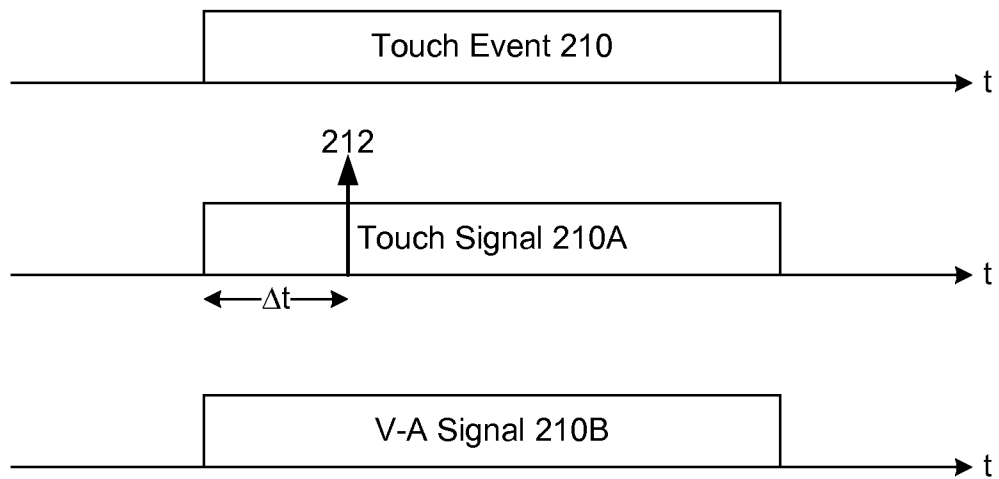


FIG. 2A

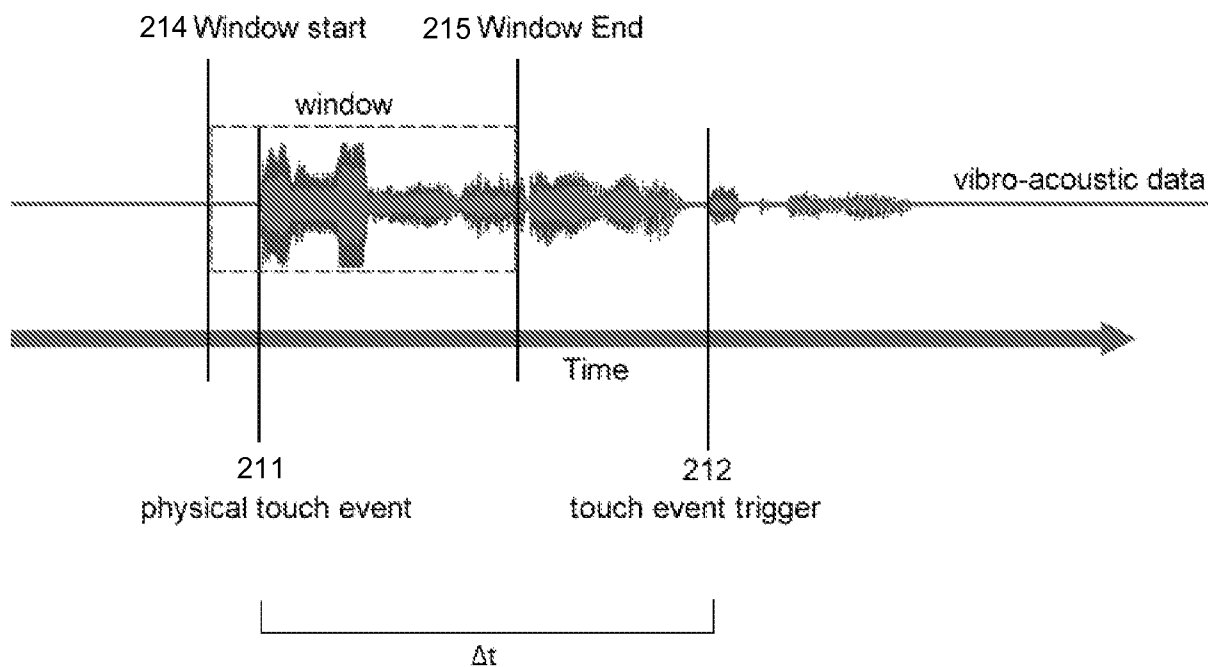


FIG. 2B

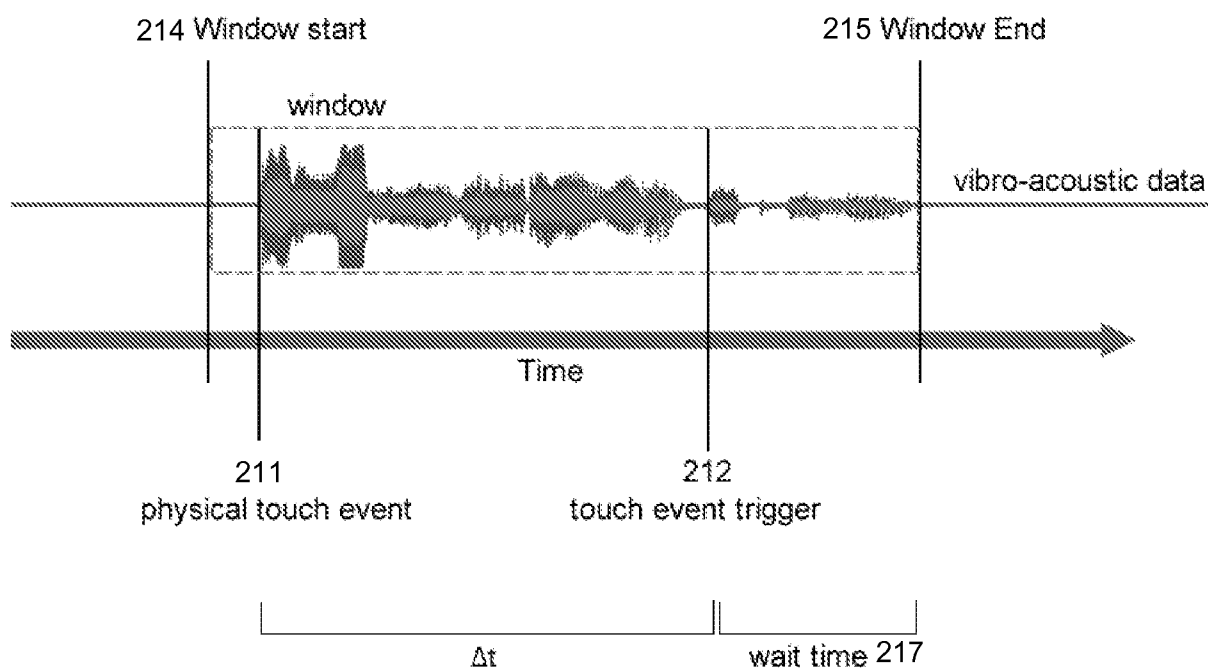


FIG. 2C

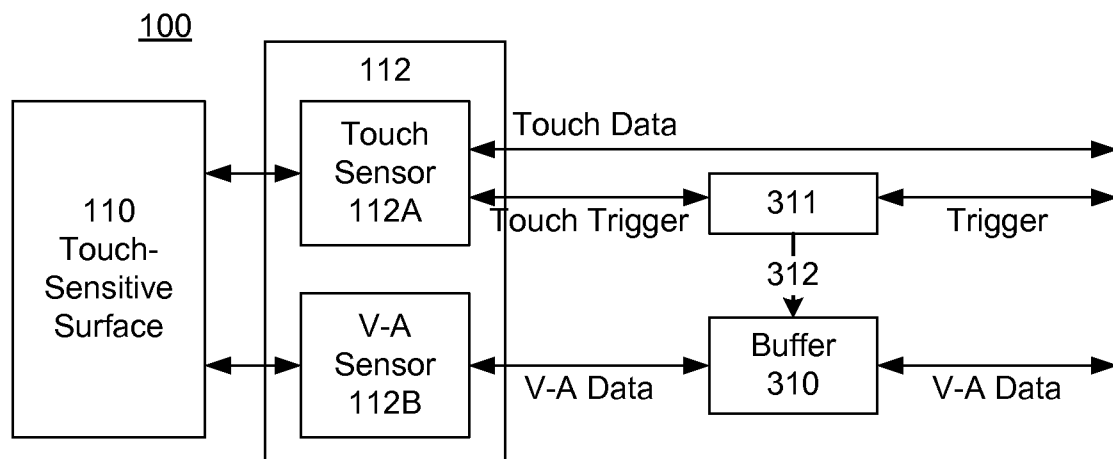


FIG. 3A

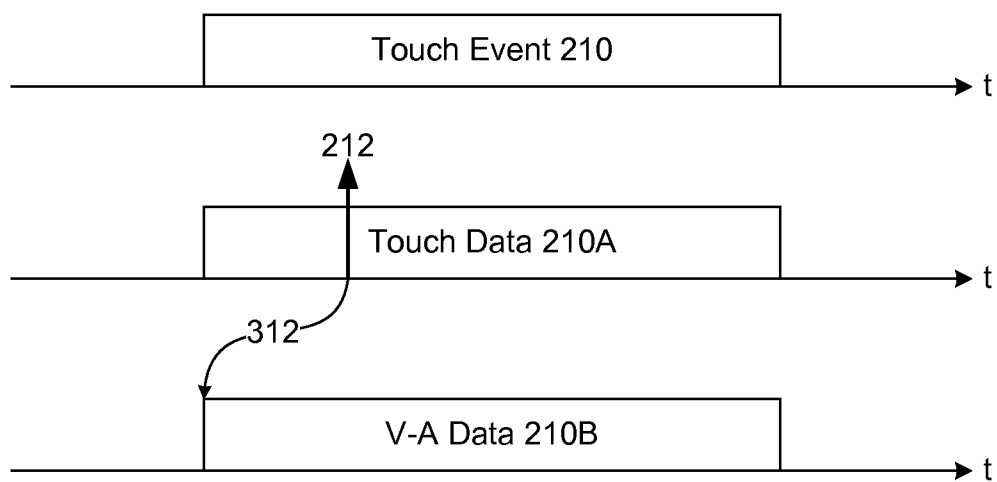


FIG. 3B

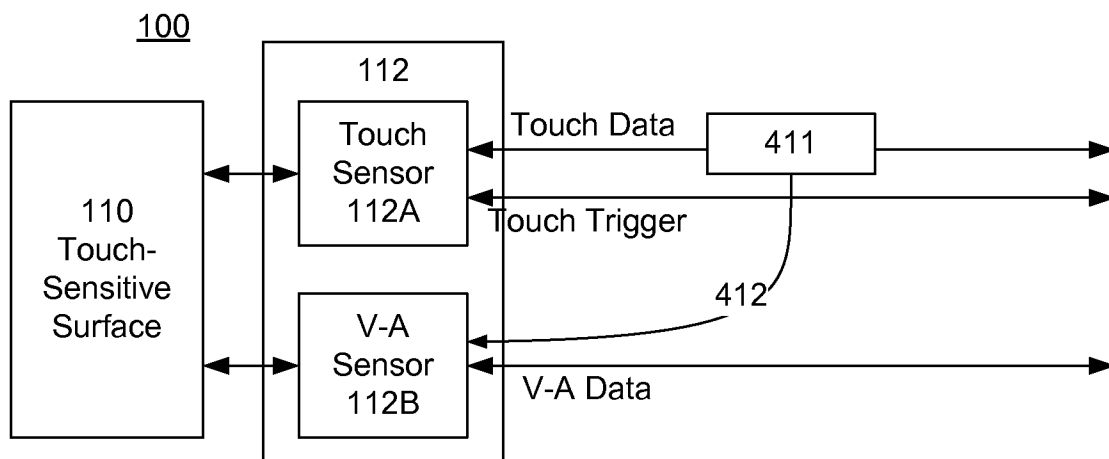


FIG. 4A

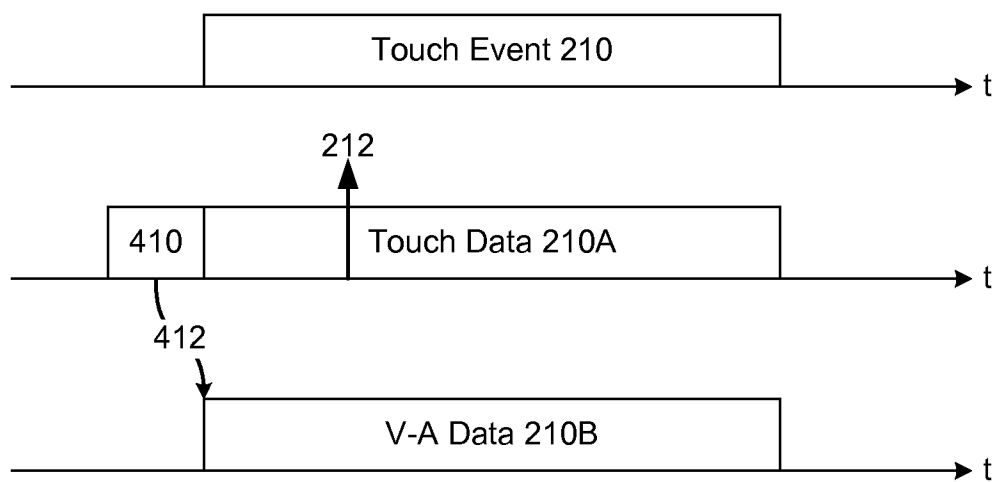


FIG. 4B

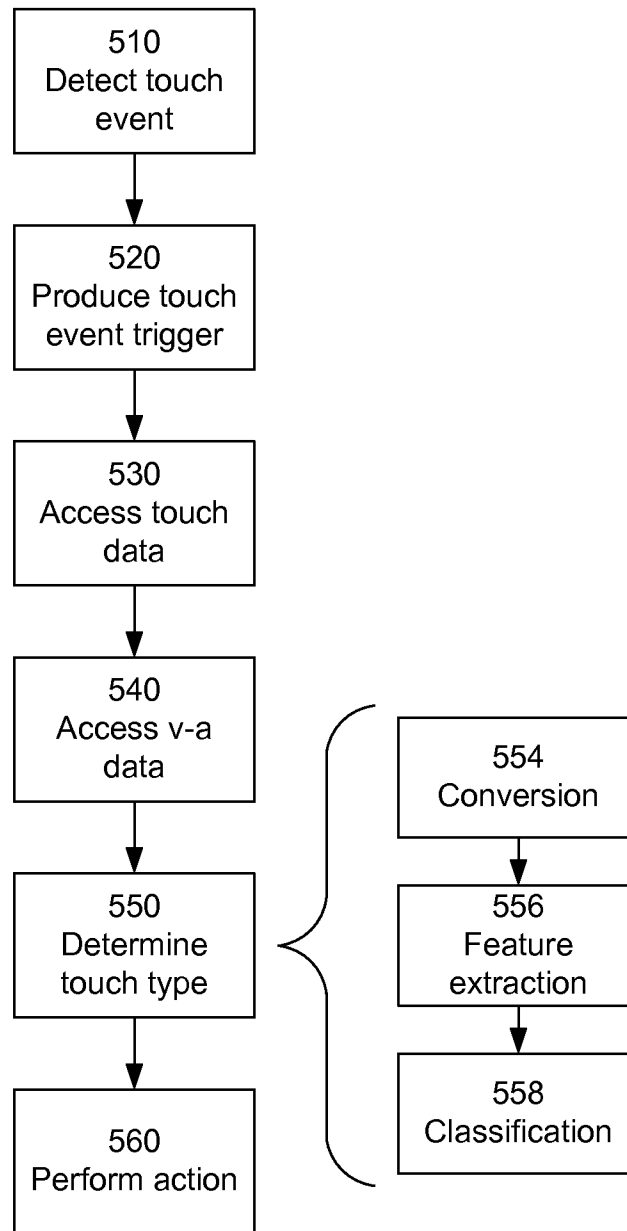


FIG. 5

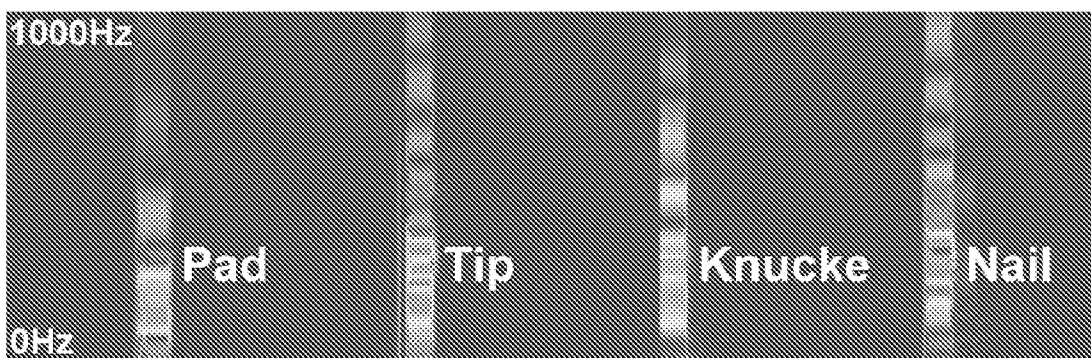


FIG. 6