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Perceptual Correction of Touch Contact Locations

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Perceptual Correction of a Location of a Touch Contact

Abstract:

This publication describes techniques directed to perceptual correction of a location of a touch contact a user makes to a touch interface of an electronic device. Instructions included in a touch-contact location manager application, when executed by logic of the electronic device, cause the electronic device to perform multiple operations that manage the location of the touch contact. Such operations include detecting a region associated with the touch contact, computing a touch location estimate, determining an orientation of the touch interface of the electronic device and an orientation of the user's finger during the touch contact, and performing a perceptual correction to the touch location estimate.

Keywords:

touch interface, touch screen, touch location, touch cells, touch-location estimate, touch-location correction, perceptual correction, touch contact offset

Background:

An electronic device is often equipped with a touch interface that includes a display and mechanisms for detecting a user's touch contact to the display. Example mechanisms for detecting the user's touch contact include capacitance-sensing mechanisms, resistance-sensing mechanisms, and interruption-sensing mechanisms that are part of the touch interface. Determining a correct location of the user's touch contact is important for the electronic device to interpret an input of the user, such as a selection of an icon or a sliding of a scroll bar that the display is presenting to the user.

The user interacting with a touch interface, in general, expects a degree of accuracy when providing an input to the interface so that the electronic device can determine a correct touch contact location. A variety of factors can influence accuracies associated with determining the correct location of the touch contact, including resolution of electrodes of the touch mechanism, distribution of a finger contact area and forces that may be associated with the touch contact, as well as an orientation of a user's finger relative to the electronic device during the touch contact.

Research today indicates that a weighted average of the finger contact area with the touch interface will introduce a perceptual alignment error in relation to an aim target of the user (*e.g.*, a correct touch location as perceived by the user). Fig. 1, below, illustrates this perceptual alignment error:

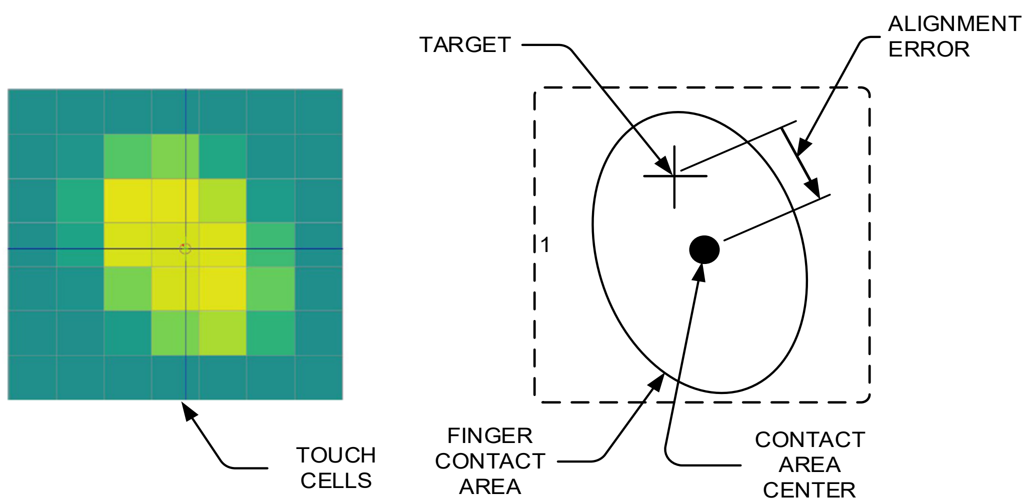

Fig. 1

As illustrated at the left of Fig. 1, an array of touch cells of the touch interface (*e.g.*, capacitance-sensing mechanisms that sense capacitance deltas of the array of touch cells) signal to the electronic device a pattern that is associated with a touch region (*e.g.*, the finger contact area), where brighter areas indicate higher mutual capacitance delta values. As illustrated in the right portion of Fig. 1, a touch location estimate (*e.g.*, the finger contact area center that is computed using weighted averages of the touch region capacitance deltas) introduces the perceptual alignment error, represented as a vector between the touch location estimate and the aim target intended by the user. Today, this perceptual alignment error is typically corrected through the electronic device applying a constant offset along a predetermined axis (such as a y-axis corresponding to a "vertical" orientation of the touch interface) to the touch location estimate. In certain instances, this correction can introduce deficiencies.

Consider, for example, an instance where a configuration of the electronic device is directed to apply a three-pixel offset along a vector that corresponds to a vertical axis of the display. If the user is viewing content presented through the display of the electronic device in a horizontal fashion (*e.g.*, viewing the content while the electronic device presents the content in a landscape mode), and the electronic device detects a touch contact from the user, the electronic device will apply the three-pixel offset in a direction that is orthogonal to a direction necessary to identify a touch location that the user perceives to be correct.

As another example, and in the same instance where the electronic device applies the three-pixel offset along the vector that corresponds to the vertical axis of the display, consider a situation during which a user makes a touch contact using a finger that is oriented at an angle from the vertical axis (*e.g.*, the user may be holding the electronic device in one hand and making the touch contact with the thumb of that hand). In this instance, the electronic device will apply the three-pixel offset vertically (not taking into account the angle of the user's thumb) and identify a touch location that the user perceives to be incorrect.

Description:

This publication describes techniques directed to perceptual correction of a location of a touch contact a user makes to a touch interface of an electronic device. Instructions included in a touch-contact location manager application, when executed by logic of the electronic device, cause the electronic device to perform multiple operations that manage the location of the touch contact. Such operations include detecting a region associated with the touch contact, computing a touch location estimate, determining an orientation of the touch interface of the electronic device and an orientation of the user's finger during the touch contact, and performing a perceptual correction to the touch location estimate.

Fig. 2, below, illustrates examples of an electronic device and elements of the electronic device that support perceptual correction of a touch contact location as described herein:

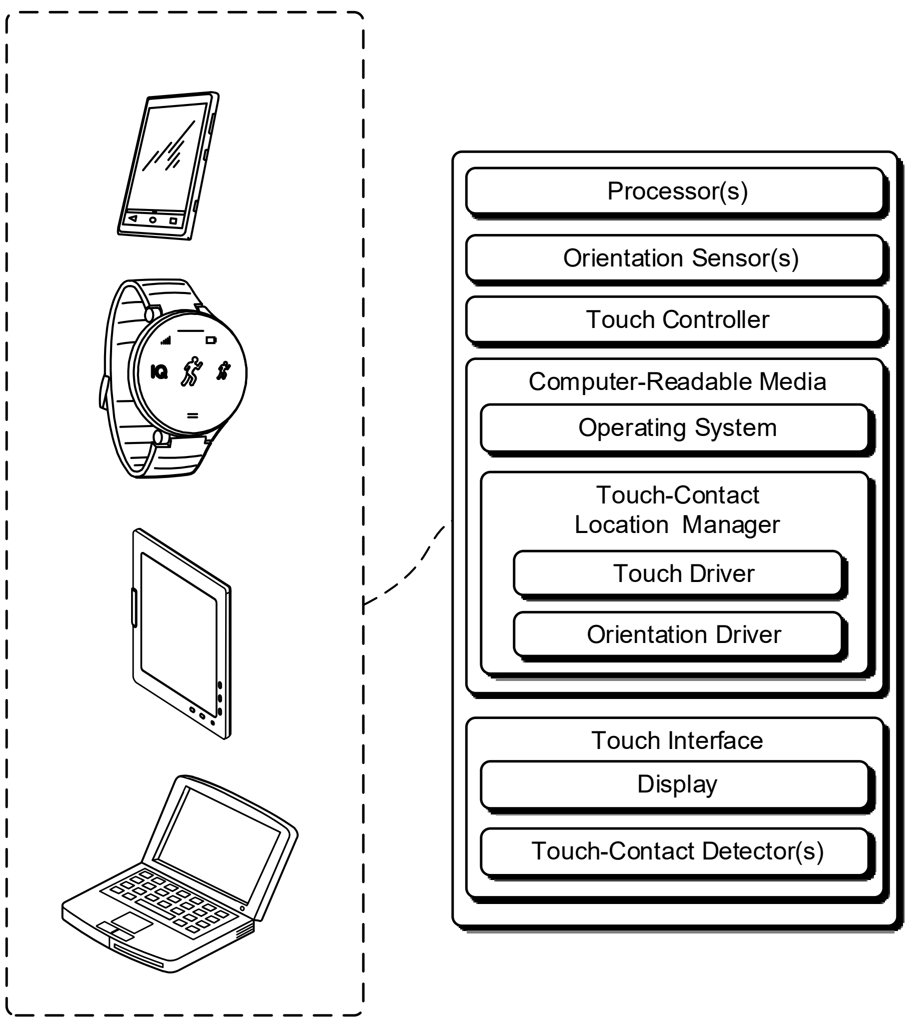

Fig. 2

As illustrated and as non-limiting examples, the electronic device may be a smartphone, a wearable device, a tablet, or a laptop computer. The electronic device includes at least one processor having logic for executing instructions that may manage the electronic device or be associated with a user application. The processor may be a single core processor or a multiple core processor composed of a variety of materials, such as silicon, polysilicon, high-K dielectric, copper, and so on. The electronic device also includes at least one orientation sensor (such as an accelerometer) to detect an orientation of the electronic device, as well as touch controller having logic for executing instructions directed to managing touch interactions with the electronic device.

The electronic device also includes a computer-readable medium (CRM). The CRM may include any suitable memory or storage device such as random-access memory (RAM), static RAM (SRAM), dynamic RAM (DRAM), non-volatile RAM (NVRAM), read-only memory (ROM), or Flash memory. The CRM stores multiple applications having executable instructions, including an operating system application and a touch-contact location manager application. The touch-contact location manager application has subsets of executable instructions that include a touch driver and an orientation driver.

The electronic device also includes a touch interface that includes a display for presenting content and at least one touch-contact detector mechanism for detecting a touch contact region. As an example, the touch-contact detector mechanism may be a mechanism that is a capacitance-sensing mechanism, a resistance-sensing mechanism, an interruption-sensing mechanism, or a combination thereof.

In general, the touch driver and the orientation driver of the touch-contact location manager application, when executed by logic of the touch controller and the processor, direct the electronic device to perform a perceptual correction of an estimated location of a touch contact through a combination of operations. The combination of operations, which the electronic device may perform in different sequences, includes (i) determining an orientation of the electronic device or the display, (ii) detecting a touch contact region and computing a touch location estimate, (iii) determining an orientation of a major axis of the detected touch contact region (iv) determining an amount of perceptual correction needed along the major axis to correct a perceptual alignment error, (v) adjusting, along the major axis, the touch location estimate by the determined amount of perceptual correction, and (vi) reporting the adjustment to a user application.

Determining the orientation of the electronic device or display may include multiple aspects as illustrated by Fig. 3 below:

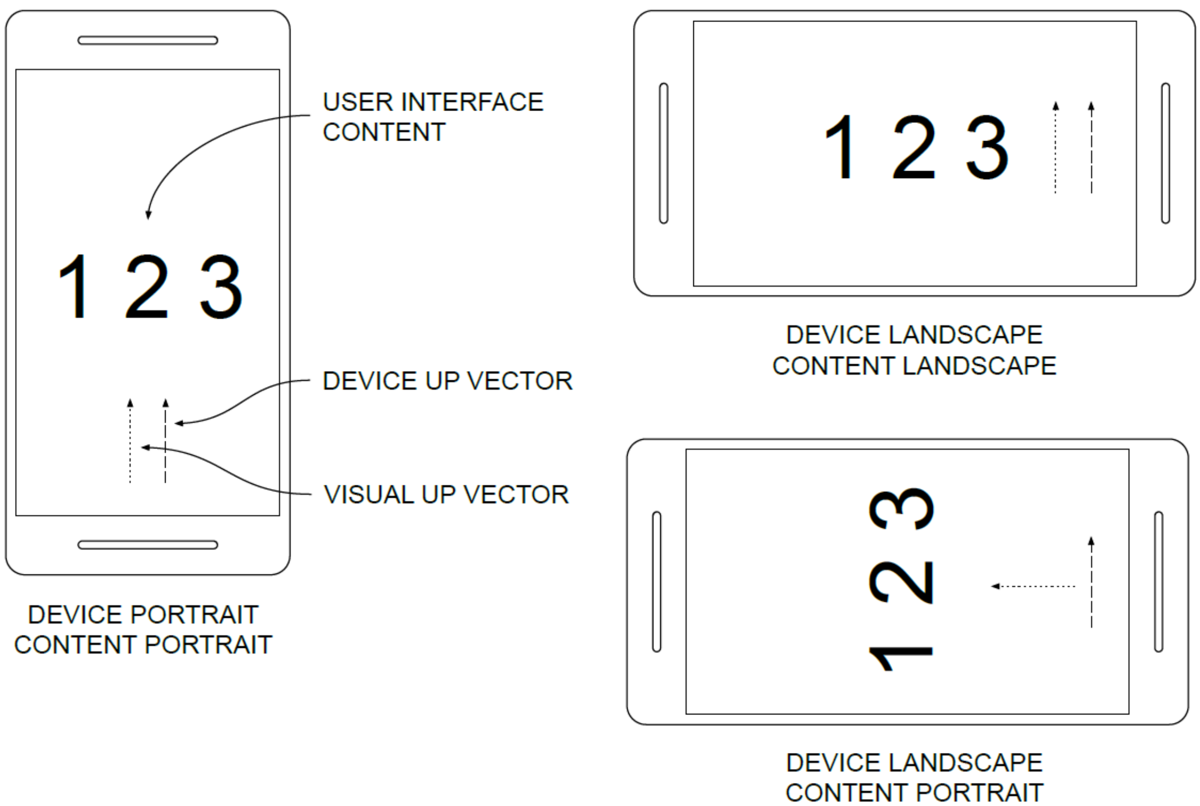

Fig. 3

In general, orientation of the electronic device is with respect to gravity, whereas orientation of the display is with respect to the orientation of content that is presented through the display of the electronic device. The processor of the electronic device, as well as the touch controller, may utilize information from the orientation sensor(s) while executing instructions of the touch-contact location manager to perform the aforementioned operations.

Detecting the touch region, using an example instance where the touch-contact detector mechanism uses capacitance-sensing mechanisms, can include the touch controller interacting with the touch driver to detect, through the capacitance-sensing mechanisms, a profile of differences in mutual capacitance between the user's finger and a region of the display that the user's finger is contacting. Based on this profile that defines the touch region, the touch controller can, using weighted averages, compute the touch location estimate.

Determining the orientation of the major axis of the touch region may include a series of computations that compute the example parameters illustrated in Fig. 4:

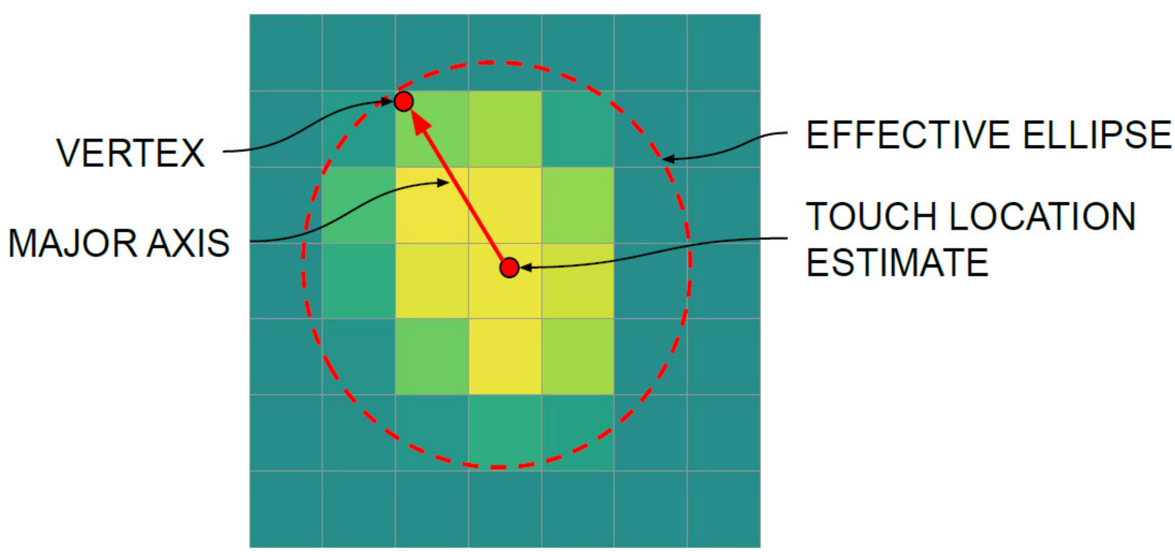

Fig. 4

The example parameters of Fig. 4 include an effective ellipse that is optimized around the touch location estimate and a vertex. The series of computations, performed by the touch controller interacting with the touch driver, may include techniques that determine contact bounds of the touch region by creating bounding polygons or bounding boxes. As illustrated, the vector between the touch location estimate and the vertex defines the orientation of the major axis (*e.g.*, an orientation that corresponds to a finger touching a touch contact region).

Determining the amount of perceptual correction needed to compensate for the perceptual alignment error may include multiple aspects. This determination, for example, can include the touch controller interacting with the touch driver to compute an offset amount that takes into account eccentricity of the effective ellipse, an area of the effective ellipse, and an angle of the major axis. In some instances, the computation of the offset amount may be filtered spatially or temporarily to enhance stability in the presence of noise from the touch-contact detector mechanism or jitter in the user's movements.

Adjusting the touch location estimate by the determined amount of perceptual correction along the major axis may in some instances require use of vector computations. Such computations may include the touch controller interacting with the touch driver to perform the vector computations, wherein:

- $\boldsymbol{a}$ is a two-dimensional vector representing the major axis of the touch region
- $\boldsymbol{u}$ is a two-dimensional vector representing a predetermined vector of the display
- $\boldsymbol{p}$ is a two-dimensional point containing the touch location estimate
- o is a scalar value containing the computed offset amount

Given the above vector relationships, the touch controller may compute an adjusted touch location $\boldsymbol{p}^*$ that is a perceptual correction to the touch location estimate, wherein:

- $\boldsymbol{p}^* = \boldsymbol{p} + o[\mathrm{sgn}(\boldsymbol{a} \bullet \boldsymbol{u})\hat{\boldsymbol{a}}]$

and;

- $\bullet$ is a vector dot product
- $\hat{\boldsymbol{a}}$ is the normalized version of $\boldsymbol{a}$
- *sgn* is the sign function

Reporting the adjustment to the user application may include the touch driver reporting the adjustment to the operating system, which may then in turn route the adjustment as an input (such as a selection input or a scrolling input) to a user application operating on the electronic device.

The techniques described above overcome deficiencies today that may be associated with perceptual corrections that are constant in magnitude and direction with respect to a touch location estimate computed using weighted averages. Furthermore, the techniques are not limited to the user's finger and can apply to other input mechanism that interact with the touchscreen, such as a stylus.