United States Patent Application Publication	20250264935
Kind Code	A1
Publication Date	August 21, 2025
Inventor(s)	XU; Qiang et al.

METHODS AND SYSTEMS SUPPORTING MULTI-DISPLAY INTERACTION USING WEARABLE DEVICE

Abstract

Methods and systems supporting multi-display interaction using a wearable device are disclosed. A first set of inertial measurements representing motion of a head of a user is obtained. A first mapping between the first set of inertial measurements and a first display device is determined when detecting a first user interaction associated with the first display device of a plurality of display devices.

Inventors: **XU; Qiang (Kanata, CA), LI; Ting (Shenzhen, CN), SINGH; Gaganpreet (Kanata, CA), FANG; Tia (Kanata, CA), SUN; Junwei (Kanata, CA)**

Applicant: **HUAWEI TECHNOLOGIES CO., LTD.** (Shenzhen, CN)

Family ID: **1000008586486**

Appl. No.: **19/196851**

Filed: **May 02, 2025**

Related U.S. Application Data

parent WO continuation PCT/CN2022/130094 20221104 PENDING child US 19196851

Publication Classification

Int. Cl.: **G06F3/01** (20060101); **G06F3/0346** (20130101)

U.S. Cl.:

CPC **G06F3/012** (20130101); **G06F3/0346** (20130101);

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] The present disclosure is a continuation of PCT Application No. PCT/CN2022/130094, filed on Nov. 4, 2022, entitled “METHODS AND SYSTEMS SUPPORTING MULTI-DISPLAY INTERACTION USING WEARABLE DEVICE”, the disclosure of which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to methods and systems supporting multi-display user interactions, where a wearable device having an inertial sensor (e.g., inertial measurement unit (IMU) or inertial-magnetic measurement unit (IMMU)) is used.

BACKGROUND

[0003] A user may have multiple display devices (e.g., multiple screens) displaying content and may switch attention between different display devices while working. Conventionally, a user must manually (e.g., using an input device such as a mouse) move a cursor between the display devices in order to interact with content on the different display devices.

[0004] To help improve efficiency of user interactions, there have been developments that attempt to track or detect the display device that the user is currently looking at, so that the user does not need to manually move the cursor to the display device of interest. Existing techniques may use infrared light-emitting diode (LED) markers and/or cameras to track a user's visual attention (e.g., using gaze tracking technology). However, such techniques may be costly to implement (e.g., requiring the use of many costly infrared markers and cameras) and/or may be computationally complex (which may result in inefficient use of computing resources).

[0005] Accordingly, it would be useful to provide improved methods and systems that support multi-display interactions.

SUMMARY

[0006] In various examples, the present disclosure describes methods and systems supporting multi-display user interactions. A wearable device (e.g., smartglasses, smart earphones, head-mounted display, etc.) having an inertial sensor (e.g., an IMU or an IMMU) is used to detect a user's head pose. A first set of inertial measurements may be detected together with detection of user interaction associated with a first display device (e.g., user interaction with content displayed on the first display device), in order to register a mapping between the first set of inertial measurements and the first display device. The mapping may then be used to infer user attention and facilitate user interactions on the first display device when the first set of inertial measurements is again detected.

[0007] Examples of the present disclosure may provide a more intuitive and/or efficient way for a user to interact with multiple display devices. By registering a mapping between a detected head pose and a particular display device, a user's visual attention on that particular display device can be determined, which may provide a technical advantage in that the use of costly hardware or complex computations related to gaze tracking may be avoided.

[0008] In some examples, different types of user interactions may be supported, including various head-based user interactions. This may provide unique ways for a user to interact with content in a multi-display setup.

[0009] In some example aspects, the present disclosure describes a method including: obtaining a first set of inertial measurements representing motion of a head of a user; and determining a first mapping between the first set of inertial measurements and a first display device when detecting a first user interaction associated with the first display device of a plurality of display devices.

[0010] In an example of the preceding example aspect of the method, the method may also include: causing the first mapping to be stored.

[0011] In an example of any of the preceding example aspects of the method, the method may also include: obtaining a subsequent set of inertial measurements representing subsequent motion of the head of the user; identifying the first mapping matching the subsequent set of inertial measurements; and enabling further user interaction with content displayed on the first display device, based on the identified first mapping.
[0012] In an example of the preceding example aspect of the method, enabling the further user interaction may include: activating a cursor on the first display device, the cursor being activated at a location corresponding to a last user interaction on the first display device.
[0013] In an example of a preceding example aspect of the method, enabling the further user interaction may include: detecting scrolling input; and causing content displayed on the first display device to be scrolled based on the scrolling input.
[0014] In an example of a preceding example aspect of the method, enabling the further user interaction may include: controlling a display parameter of the first display device.
[0015] In an example of any of the preceding example aspects of the method, the first user interaction may be one of: voice input identifying the first display device; keyboard input to interact with content displayed on the first display device; mouse input to interact with content displayed on the first display device; or touch input sensed by a touch sensor of the first display device.
[0016] In an example of any of the preceding example aspects of the method, the method may include: obtaining a second set of inertial measurements representing motion of the head of the user; and determining a second mapping between the second set of inertial measurements and a second display device when detecting a second user interaction associated with the second display device of the plurality of display devices; where, in response to obtaining another set of inertial measurements matching the first mapping, user interaction with content displayed on the first display device may be enabled; and where, in response to obtaining another set of inertial measurements matching the second mapping, user interaction with content displayed on the second display device may be enabled.
[0017] In an example of the preceding example aspect of the method, the method may include: causing the second mapping to be stored.
[0018] In an example of the preceding example aspect of the method, the method may include: detecting selection of an object displayed on the first display device; obtaining a third set of inertial measurements representing motion of the head of the user; identifying the second mapping matching the third set of inertial measurements; and causing the selected object to be moved to be displayed on the second display device, based on the identified second mapping.
[0019] In an example of any of the preceding example aspects of the method, the method may include: obtaining a further set of inertial measurements indicating user movement above a defined threshold; and causing all stored mappings to be deleted.
[0020] In an example of any of the preceding example aspects of the method, the plurality of display devices may be controlled by a single electronic device.
[0021] In an example of any of the preceding example aspects of the method, the plurality of display devices may be controlled by multiple electronic devices.
[0022] In an example of any of the preceding example aspects of the method, inertial measurements may be obtained from an inertial sensor of a wearable device worn on or near the head of the user.
[0023] In some example aspects, the present disclosure describes a computing system including a processing unit configured to execute computer readable instructions to cause the computing system to perform any of the preceding example aspects of the method.
[0024] In an example of the preceding example aspect of the computing system, the computing system may include: an inertial sensor configured to obtain the set of inertial measurements; where the computing system may be configured to be wearable on or near the head of the user.

[0025] In some example aspects, the present disclosure describes a non-transitory computer readable medium having instructions encoded thereon, where the instructions are executable by a processing unit of a computing system to cause the computing system to perform any of the preceding example aspects of the method.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Reference will now be made, by way of example, to the accompanying drawings which show example embodiments of the present application, and in which:

[0027] FIG. **1** is a schematic diagram illustrating an example of a user interacting with multiple display devices, in accordance with examples of the present disclosure;

[0028] FIG. **2** is a block diagram illustrating an example of a setup with multiple display devices, in accordance with examples of the present disclosure;

[0029] FIG. **3** is a block diagram illustrating some components of an example computing system, in accordance with examples of the present disclosure;

[0030] FIG. **4** is a flowchart illustrating an example method for enabling user interaction in a multi-display setup, in accordance with examples of the present disclosure;

[0031] FIGS. **5**A-**5**F illustrate an example implementation of the method of FIG. **4**; and

[0032] FIG. **6** is a block diagram illustrating another example of a setup with multiple display devices, in accordance with examples of the present disclosure.

[0033] Similar reference numerals may have been used in different figures to denote similar components.

DETAILED DESCRIPTION

[0034] Existing techniques for tracking a user's visual attention in a multi-display environment typically require the use of gaze tracking technology. This may require marking the different display devices with infrared light-emitting diode (LED) markers and/or using infrared cameras to detect and track the user's eyes. In addition to the need for costly hardware, complex computations may also be required. For example, to enable tracking of the user's visual attention, each display device may need to be registered in memory, then a camera may capture a scene that includes the multiple display devices in order to register the position of each display device. This information may then need to be correlated with data provided by the eye tracking camera. Finally, based on the registration of the display devices and the results of gaze detection algorithms an approximate fixation point representing the user's visual attention is calculated. As may be appreciated by one skilled in the art, such existing techniques may be costly and/or computationally complex, which may limit practical implementation.

[0035] A wearable device with an inertial sensor, such as an inertial measurement unit (IMU) or an inertial-magnetic measurement unit (IMMU), may be used to detect a user's head pose. However, there are difficulties to using an inertial sensor to track a user's visual attention. For example, it is often difficult to obtain accurate measurements of the user's head pose from an inertial sensor over a long time duration, due to drift and/or error accumulation in the sensor measurements. This means that frequent recalibration of the inertial sensor is required, for example using external cameras, which can be impractical in real-world applications.

[0036] The present disclosure provides examples which can use an inertial sensor on a wearable device to detect a user's visual attention on a particular display device in a multi-display setup, without the need for additional hardware. In examples disclosed herein, the need for explicit recalibration of the inertial sensor can be avoided by inferring the display device that is currently the target of the user's attention.

[0037] FIG. **1** illustrates an example of a user **10** interacting with multiple display devices, specifically first display device **220***a* and second display device **220***b* (generically referred to as display device **220**), in a multi-display setup. Although two display devices **220** are shown, it should be understood that this is only exemplary and there may be more than two display devices **220** in a multi-display setup. The display devices **220***a*, **220***b* may be in communication with the same processing unit (e.g., a single desktop computer) or different processing units (e.g., two different laptop computers). The two display devices **220***a*, **220***b* may display different visual content, or may display multiple views of the same content (e.g., multiple views of the same software application). The user's visual attention, indicated by a dashed line, may be currently targeted on one display device **220***a*. In this example, the user **10** is wearing a wearable device **100** (e.g., an earpiece) on the head.

[0038] FIG. **2** is a block diagram illustrating some example computing hardware, which may be used in the example of FIG. **1**.

[0039] In this example, each display device **220***a*, **220***b* is in communication (e.g., via a wired connection) with an electronic device **200** (e.g., a desktop computer). The electronic device **200** is also in communication with an input device **210** (e.g., a mouse, keyboard, touch interface, microphone, etc.). The user (not shown in FIG. **2**) may interact with content displayed on each of the display devices **220***a*, **220***b* using the input device **210**.

[0040] The electronic device **200** is also in communication with the wearable device **100**, for example using a wireless connection such as a Bluetooth connection or using a wired connection. The wearable device **100** may be any smart device (e.g., an electronic device with wired or wireless communication capabilities) that can be worn on or near the user's head, such as smartglasses, smart earphones, head-mounted displays (HMDs), etc. The wearable device includes an inertial sensor **110** (e.g., IMU or IMMU). The inertial sensor **110** may be any suitable sensor capable of measuring the user's head pose, such as a 9-axis IMMU (e.g., having a 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer), or other types of inertial sensors that may have higher or lower precision. In the example shown, the wearable device **100** includes a memory **120**, which may store instructions for performing at least some of the functions disclosed herein. In other examples, the wearable device **100** may be in communication with an external memory (e.g., a memory of the electronic device **200**, or a memory of another external device (not shown)).

[0041] FIG. **3** is a block diagram showing some components of an example computing system **300** (which may also be referred to generally as an apparatus), which may be used to implement embodiments of the present disclosure. The computing system **300** may be used to perform methods disclosed herein. The computing system **300** may represent the wearable device **100**, the electronic device **200**, or another device that is in communication with the wearable device **100** and the electronic device **200**. Although an example embodiment of the computing system **300** is shown and discussed below, other embodiments may be used to implement examples disclosed herein, which may include components different from those shown. Although FIG. **3** shows a single instance of each component, there may be multiple instances of each component shown.

[0042] The computing system **300** includes at least one processing unit **302**, such as a processor, a microprocessor, an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a dedicated logic circuitry, a dedicated artificial intelligence processor unit, or combinations thereof. A processing unit **302** may have one or more processor cores.

[0043] The computing system **300** may include an input/output (I/O) interface **304**. The I/O interface **304** may interface with input devices and/or output devices, depending on the embodiment. For example, if the computing system **300** represents the electronic device **200**, the I/O interface **304** may interface with the input device **210** and the display devices **220**. If the computing system **300** represents the wearable device **100**, the I/O interface **304** may interface with the inertial sensor **110**.

[0044] The computing system **300** may include a network interface **306** for wired or wireless communication with a network (e.g., an intranet, the Internet, a P2P network, a WAN and/or a

LAN) or other device. For example, wired or wireless communication between the electronic device **200** and the wearable device **100** may be enabled by the network interface **306**.
[0045] The computing system **300** includes a memory **308**, which may include a volatile or non-volatile memory (e.g., a flash memory, a random access memory (RAM), and/or a read-only memory (ROM)). The non-transitory memory **308** may store instructions for execution by the processing unit **302**, such as to carry out examples described in the present disclosure. For example, the memory **308** may include instructions, executable by the processing unit **302**, to implement a display registration module **310**, discussed further below. The memory **308** may include other software instructions, such as for implementing an operating system and other applications/functions. For example, the memory **308** may include software instructions for mapping a user's head pose to input commands, as disclosed herein.
[0046] In some examples, the computing system **300** may also include other electronic storage units (not shown), such as a solid state drive, a hard disk drive, a magnetic disk drive and/or an optical disk drive. In some examples, one or more data sets and/or modules may be provided by an external memory (e.g., an external drive in wired or wireless communication with the computing system **300**) or may be provided by a transitory or non-transitory computer-readable medium. Examples of non-transitory computer readable media include a RAM, a ROM, an erasable programmable ROM (EPROM), an electrically erasable programmable ROM (EEPROM), a flash memory, a CD-ROM, or other portable memory storage. The components of the computing system **300** may communicate with each other via a bus, for example.
[0047] In examples of the present disclosure, inertial measurements from the wearable device **100** (e.g., obtained from the inertial sensor **110** of the wearable device **100**) can be used to determine the head pose of the user **10** (e.g., relative to a global frame of reference, such as relative to the direction of gravity). In some examples, inertial measurements may be continuously obtained from the wearable device **100** when the wearable device **100** is active and in communication with the electronic device **200**. When user interaction associated with the first display device **220***a* is detected, the display registration module **310** is used to obtain the current inertial measurements (which are used as a proxy for the user's head pose) and generate a mapping between the current inertial measurement and the first display device **220***a*. The mapping may be stored as a set of inertial measurements that is associated with the first display device **220***a*. The first display device **220***a* may then be considered “registered” with the display registration module **310**. A similar process may be used to generate and store mappings for each other display device **220**. The stored mappings may then be used later to determine whether the user **10** is looking at a particular display device **220**. For example, if the inertial measurements obtained from the wearable device **100** correspond to the stored inertial measurements of a given mapping (e.g., the inertial measurements are within a defined range of the stored inertial measurements of the given mapping), then the content displayed on the display device **220** indicated by the given mapping may automatically be selected for user interaction (e.g., a cursor is activated for interacting with the content displayed on the display device **220**).
[0048] In this way, the inertial sensor **110** can be implicitly calibrated to register the spatial relationship between each display device **220** and the inertial measurements. The user interaction that is associated with a given display device **220** is used to infer that the user **10** is looking at the given display device **220**, and the inertial sensor **110** can be calibrated relative to the given display device **220** accordingly. The user interaction may be any user interaction that is indicative of a specific display device **220**, including an interaction with content displayed on the specific display device **220** (e.g., via a mouse input (e.g., mouse click), via keyboard input (e.g., text input), or via touch input (e.g., touch gesture on a touch-sensitive display device **220**)), or interaction that selects the specific display device **220** (e.g., via voice input (e.g., voice input that is recognized as identifying a specific display device **220**), or via touch input (e.g., touch gesture on a touch-sensitive display device **220**)), among other possibilities. In this way, the need for explicit

calibration of the inertial sensor **110** (e.g., requiring extensive explicit user input and/or requiring the use of external cameras) may be avoided. Further details will be described with respect to FIG. **4**.

[0049] FIG. **4** is a flowchart illustrating an example method **400** for multi-display interactions using inertial measurements obtained from a wearable device. The method **400** may be executed by a computing system (e.g., the computing system **300**, which may be embodied as the electronic device **200**, the wearable device **100**, or another computing device in communication with the electronic device **300** and the wearable device **100**). The method **400** may include functions of the display registration module **310** and may be performed by a processing unit executing instructions to implement the display registration module **310**, for example.

[0050] At **402**, optionally, the method **400** may be initiated by detecting that the wearable device **100** is in communication with the electronic device **200** (e.g., a wireless connection has been established and is active between the wearable device **100** and the electronic device **200**).

[0051] At **404**, a set of inertial measurements is obtained representing motion of the user's head. For example, if the inertial sensor **110** of the wearable device **100** is a 9-axis IMMU, the set of inertial measurements may include nine measurements (corresponding to the 3 axes of an accelerometer, 3 axes of a gyroscope and 3 axes of a magnetometer). The set of inertial measurements may contain greater or fewer number of measurements, depending on the implementation of the inertial sensor **110**.

[0052] How the set of inertial measurements is obtained may depend on the embodiment of the computing system that is carrying out the method **400**. For example, if the method **400** is being implemented on the wearable device **100**, the set of inertial measurements may be obtained by collecting data directly from the inertial sensor **110**. If the method **400** is being implemented on the electronic device **200** or another computing device, the set of inertial measurements may be obtained by receiving the set of inertial measurements from the wearable device **100**.

[0053] Optionally, at **406**, if it is determined that the set of inertial measurements indicate user movement greater than a defined threshold, any registered display devices **220** may be deregistered from the display registration module **310**, and any stored mappings between a display device **220** and a set of inertial measurements may be deleted. For example, if the set of inertial measurements indicate that the user is walking or is moving at a speed greater than a defined threshold, this may mean that the user has moved away from the display devices **220**. Even if the user returns to the display devices **220** later, it may be necessary to generate new mappings because the inertial measurements may have drifted during the time the user had moved away. Following step **406**, the method **400** may return to step **404** to continue monitoring the inertial measurements.

[0054] Optionally, at **408**, if there is already a stored mapping matching the set of inertial measurements that mapping may be identified, and user interactions may be enabled for the display device **220** mapped by the identified mapping. Identifying the mapping may involve querying a table of stored mappings, which may be stored locally or externally.

[0055] A match between the set of inertial measurements and a stored mapping may be determined if the set of inertial measurements is within a defined range of the inertial measurements stored for the mapping. For example, if the mapping is stored with a set of inertial measurements represented by an inertial vector [ax, ay, az, gx, gy, gz, mx, my, mz] (corresponding to the 3 axes of an accelerometer, 3 axes of a gyroscope and 3 axes of a magnetometer), then the set of inertial measurements may be considered to be a match if the set of inertial measurements fall within a range of +/−10% for each entry in the stored inertial vector, or other defined range. In some examples, the range may be defined based on the known or expected dimensions of the display devices **220**, among other possibilities.

[0056] After a mapping has been identified, the display device **220** mapped by the identified mapping may be identified (e.g., each display device **220** may have a unique identifier that can be used to identify each display device **220** in the stored mappings). The content displayed on the identified display device **220** may then be automatically selected to enable user interaction. For example, a cursor may be displayed or otherwise activated on the identified display device **220**. The cursor may be displayed or activated at a previously saved location in the displayed content (e.g., if the user was previously interacting with the content displayed on the identified display device **220**, the cursor may be activated again at the location of the last user interaction). Thus, the user may immediately begin interacting with the content displayed on the identified display device **220**, without having to manually select the content.

[0057] In some examples, step **408** may be performed after determining that the inertial measurements have been relatively steady (e.g., changing by less than 5%) for a defined period of time (e.g., **0**.5*s*), to avoid inadvertently enabling user interactions when the user is still moving their head. Following step **408**, the method **400** may return to step **404** to continue monitoring the inertial measurements.

[0058] Returning to step **404**, if the set of inertial measurements do not indicate user movement above a defined threshold and there is no stored mapping matching the set of inertial measurements, the method **400** proceeds to step **410**.

[0059] At **410**, a user interaction associated with a given display device **220** is detected (if there is no user interaction detected contemporaneous with the obtained set of inertial measurements, the method **400** may return to step **404**). The user interaction may be, for example, user input (e.g., via mouse input, keyboard input, touch input, etc.) to interact with content displayed on the given display device **220**, or user input selecting the given display device **220** (e.g., via voice input identifying the given display device **220**, via input of a function key to select the display device **220**, etc.). The detected user interaction indicates that the user's visual attention is currently on the given display device **220**. The detected user interaction occurs contemporaneously with the set of inertial measurements obtained at step **404**.

[0060] How the user interaction is detected may depend on the embodiment of the computing system that is carrying out the method **400**. For example, if the method **400** is being implemented on the electronic device **200**, the electronic device **200** may directly detect the user interaction and identify the given display device **220** associated with the user interaction. If the method **400** is being implemented on the wearable device **100**, the user interaction and the given display device **220** associated with the user interaction may be directly detected by the electronic device **200**. The electronic device **200** may then send a signal to the wearable device **100** indicating the detection of the user interaction associated with the given display device **220**; in this way, the wearable device **100** may indirectly detect the user interaction associated with the given display device **220**. A similar process may occur if the method **400** is being implemented on another computing device (e.g., a smartphone) that is not the electronic device **200**.

[0061] At **412**, a mapping is generated to map between the set of inertial measurements and the given display device **220**. The mapping is caused to be stored in memory. The given display device **220** is now considered to be registered by the display registration module **310**. In this way, the inertial sensor **110** of the wearable device **100** may be implicitly calibrated with respect to the given display device **220**. In some examples, the mapping is generated when the inertial measurements have been relatively steady (e.g., changing by less than 5%) for a defined period of time (e.g., **0**.5*s*).

[0062] The generation of the mapping and the storing of the mapping may take place in different computing systems. For example, if the method **400** is being implemented on the wearable device **100** and the wearable device **100** lacks sufficient storage, the generated mapping may be communicated by the wearable device **100** to another computing system (e.g., to the electronic device **200** or to another computing device such as a smartphone) for storage. In another example, if the wearable device **100** has sufficient storage or if the method **400** is being implemented on the electronic device **200** (or another computing system having a memory), the generation and storing of the mapping may take place on the same computing system.

[0063] In some examples, a mapping may be stored in the form of a table that associates an inertial vector representing the set of inertial measurements with an identifier of the given display device **220**. In some examples, the set of inertial measurements stored with the mapping may be an average of the inertial measurements obtained over the defined period of time (e.g., **0**.**5**) when the inertial measurements have been relatively steady.

[0064] The user may perform further interactions with the given display device **220**. The method **400** may return to step **404** to continue monitoring the inertial measurements.

[0065] If the user looks away from the given display device **220** and/or interacts with a different display device **220**, and then later returns to looking at the given display device **220**, the stored mapping may be used to automatically enable user interactions with the given display device **220** again (e.g., as described at step **408**).

[0066] As previously mentioned, the method **400** may be performed by the wearable device **100**, the electronic device **200** or another computing device.

[0067] In some examples, the method **400** may be performed by the wearable device **100**. The wearable device **100** may have a processing unit with sufficient processing power to generate the mapping between the inertial measurements and a given display device **220**. The wearable device **100** may also have a memory in which the generated mapping may be stored. In other examples, the wearable device **100** may be capable of generating the mapping between the inertial measurements and the given display device **220**, but may rely on an external device (e.g., the electronic device **200** or another computing device, such as a smartphone, in communication with the wearable device **100**) to store the mapping. In yet other examples, the method **400** may be performed by the electronic device **200** or another computing device, using inertial measurements obtained from the wearable device **100**.

[0068] In some examples, each mapping that is stored may be stored together with a timestamp indicating the time when the mapping was generated and stored. Because an inertial sensor **110** may exhibit drift over time, the stored timestamp may be a useful indicator that a stored mapping needs to be updated. For example, the method **400** may include an additional step of checking the timestamp stored with each stored mapping. If a timestamp stored with a particular mapping is older than a predefined time period (e.g., older than 1 minute compared to the current timestamp), that mapping may be deleted. This may enable a new mapping to be generated and stored, thus enabling updating of the implicit calibration of the inertial sensor **110**. At the step **408**, if a stored mapping matching the set of inertial measurements is identified, it may be determined whether the timestamp of the identified mapping is older than the predefined time period. If the timestamp of the identified mapping is within the predefined time period, then that mapping may be sufficiently recent and step **408** may proceed as described above. If the timestamp of the identified mapping exceeds the predefined time period, the identified mapping may be deleted and the method **400** may proceed to step **410** instead.

[0069] FIGS. **5**A-**5**F illustrate an example implementation of the method **400** in a multi-display desktop setup. In this example, the method **400** may be performed by the electronic device **200** that is in communication with the first and second display devices **220***a*, **220***b* and also in communication with the wearable device **100** being worn at or near the head of the user **10**. To assist in understanding, FIGS. **5**A-**5**F include a schematic **500** to help illustrating mappings between inertial measurements and the display devices **220**, however it may not be necessarily to explicitly generate or display the schematic **500**.

[0070] FIGS. **5**A-**5**F illustrate a common setup in which the user **10** is interacting with a desktop computer (e.g., the electronic device **200**, not shown) over two or more display devices **220**, while wearing a wearable device **100** (e.g., headphones) having inertial sensors. The user **10** can interact with content displayed on the display devices **220** using input devices **210** such as a keyboard and a mouse.

[0071] In FIG. **5**A, there is no mapping between any set of inertial measurements and any of the display devices **220** (as represented by absence of links between the first and second displays and inertial measurements in the schematic **500**). A table **510** (which may be stored in a memory of the electronic device **200**) storing any generated mappings between inertial measurements (represented by inertial vectors) and display devices may be empty. For example, the user **10** may have just started working and has not yet provided any input or interactions.

[0072] In FIG. **5**B, there is user interaction associated with the first display device **220***a*. In this case, the user **10** has inputted text (e.g., using the keyboard) in a text editing application displayed on the first display device **220***a*, and an active text insertion cursor is displayed on the first display device **220***a*. In other examples, the user interaction may be touch input, mouse input, voice input, etc. At the same time, a set of inertial measurements is obtained from the wearable device **100**, which corresponds to the user's head position while looking at the first display device **220***a* (indicated by a dashed line). A first mapping is thus generated between the current set of inertial measurements and the first display device **220***a* (as represented by a new link between the first display and inertial measurements in the schematic **500**). The first mapping between the current set of inertial measurements, represented by an inertial vector v1, and the first display device **220***a*, identified by the device identifier ID_1, is stored in the table **510**. In this way, the inertial measurements obtained by the inertial sensor **110** have been implicated calibrated with respect to the first display device **220***a*.

[0073] In FIG. **5**C, there is user interaction associated with the second display device **220***b*. In this case, the user **10** has performed a mouse click or moved a chevron cursor (e.g., using the mouse) on content displayed on the second display device **220***b* (it may be noted that the text insertion cursor is no longer active on the first display device **220***a*). In other examples, the user interaction may be touch input, mouse input, voice input, etc. At the same time, another set of inertial measurements is obtained from the wearable device **100**, which corresponds to the user's head position while looking at the second display device **220***b* (indicated by a dashed line). A second mapping is thus generated between the new set of inertial measurements and the second display device **220***b* (as represented by a new link between the second display and inertial measurements in the schematic **500**). The second mapping between the set of inertial measurements, represented by an inertial vector v2, and the second display device **220***b*, identified by the device identifier ID_2, is stored in the table **510**. In this way, the inertial measurements obtained by the inertial sensor **110** have been implicated calibrated with respect to the second display device **220***b*.

[0074] Both the first and second display devices **220***a*, **220***b* are now considered to be registered.

[0075] In FIG. **5**D, the user **10** again turns their head position to look (indicated by a dashed line) at the first display device **220***a*, but the user **10** does not perform any interaction to select the first display device **220***a* (indicated by the absence of input devices **210**). The table **510** of stored mappings is used to identify if there is any stored mapping that matches the current set of inertial measurements obtained from the wearable device **100**. In this case, a match is found with the first mapping (indicated by a thicker link in the schematic **500**, and by a thicker outline in the table **510**). It may be noted that the first mapping may be identified as matching the current inertial measurements even if the current inertial measurements do not exactly match the stored inertial vector v1. For example, if the current inertial measurements is within a defined margin (e.g., 10%) of the stored inertial vector v1, a match may be identified. This may be represented by the user's head position (indicated by a dashed line) being slightly different between FIG. **5**B and FIG. **5**D.

[0076] As a result of the identified first mapping, the first display device **220***a* is identified and user interaction with content displayed on the first display device **220***a* is enabled. For example, the text insertion cursor is activated and displayed again on the first display device **220***a*. The text insertion cursor may be activated at the same location as the previous user interaction on the first display device **220***a* (e.g., at the same location as that shown in FIG. **5**B). The user may thus immediately begin interacting with content on the first display device **220***a* (e.g., to enter more text into the text editing application, at the location where they previously were typing) without having to first explicitly select the first display device **220***a* using mouse input or keyboard input. Thus, examples of the present disclosure may enable the user **10** to more easily transition between different display devices **220**, simply based on which display device **220** they are looking at and without requiring explicit selection of the target display device **220**. Improved efficiency, for example by decreasing the amount of explicit input that needs to be processed, may be achieved.

[0077] In FIG. **5**F, the user **10** has moved away from the display devices **220**. The inertial measurements obtained from the wearable device **100** indicates user movement above a defined threshold. Accordingly, the display devices **220** are deregistered and the stored mappings are deleted (indicated by the links being removed from the schematic **500**, and the table **510** being empty). This deleting of stored mappings may be performed because may inertial sensors **110** tend to exhibit drift in inertial measurements over time. Thus, if the user **10** moves away from the display devices **220** and later returns, the mappings that were previously generated may no longer be valid and new mappings may need to be generated.

[0078] If the user **10** moves back to the display devices **220** again (e.g., returning to FIG. **5**A), new mappings will be generated and stored.

[0079] Optionally, feedback may be provided to the user **10** to indicate that a display device **220** has been registered or that user attention on a particular display device **220** has been determined. For example, a graphical representation similar to the schematic **500** may be displayed (e.g., as a small inset) to show the user **10** whether or not a display device **220** has been registered. In another example, when a stored mapping matches the current inertial measurements and a particular display device **220** has been identified based on the matching mapping, that particular display device **220***a* may be briefly highlighted (e.g., brightness increased). Other such feedback mechanisms may be used.

[0080] Although the previous examples have been described in the context of multi-display interactions where there is a single electronic device **200** in communication with multiple display devices **220**, examples of the present disclosure may also support multi-display interactions where there are multiple electronic devices **200** that communicate with the multiple display devices **220**. For example, the present disclosure may enable multi-display interactions where there are multiple single-screen electronic devices **200** (e.g., a laptop and a tablet), as well as multi-display interactions where there are multiple electronic devices **200** including an electronic device **200** that controls two or more display devices **220** (e.g., a tablet and a desktop computer, where the desktop computer is connected to two display screens). The different electronic devices **200** may use same or different input modalities (e.g., a tablet may support touch input but a desktop computer may not support touch input).

[0081] FIG. **6** is a block diagram illustrating an example of the present disclosure implemented in a scenario having multiple electronic devices **200** in communication with the multiple display devices **220**.

[0082] The example of FIG. **6** is similar to the example of FIG. **2**, however there are three display devices **220***a*, **220***b*, **220***c* being controlled by two electronic devices **200***a*, **200***b*. In this example, the first electronic device **200***a* (e.g., a desktop computer) is in communication with the first and second display devices **220***a*, **220***b*, and the second electronic device **200***b* (e.g., a table) is in communication with the third display device **220***c*. Each electronic device **200***a*, **200***b* may receive user input via a respective input device **210***a*, **210***b*. The two input devices **210***a*, **210***b* may support same or different input modalities.

[0083] In this example, the second electronic device **200***b* is in communication with the first electronic device **200***a* but not in communication with the wearable device **100**. Communications between the wearable device **100** and the second electronic device **200***b* (e.g., communication of inertial measurements, detected user interactions, etc.) may be via the first electronic device **200***a*. In other examples, there may be communication directly between the second electronic device **200***b* and the wearable device **100**.

[0084] It should be understood that the method **400** may be implemented in the scenario of FIG. **6**. For example, if the method **400** is implemented on the first electronic device **200***a*, the first electronic device **200***a* may receive communications from the second electronic device **200***b* to detect a user interaction associated with the third display device **220***c*. At the same time, the first electronic device **200***a* may receive a set of inertial measurements from the wearable device **100**. The first electronic device **200***a* may then generate and store a mapping between the received set of inertial measurements and the third display device **220***c*.

[0085] For example, the user may touch a touchscreen of a tablet while looking at the display of the tablet, and the user may input a mouse click while looking at each of the screens connected to the desktop computer. In another example, the user may provide voice input identifying each display device **220** (e.g., verbal input such as "left screen", "right screen", "tablet") while looking at each respective display device **220**. In this way, mappings may be generated and stored to register each of the display devices **220**.

[0086] Then at a later time, when inertial measurements from the wearable device **100** match the stored mapping, the first electronic device **200***a* may identify the third display device **220***c* as the target of the user's visual attention, and may communicate with the second electronic device **200***b* to enable user interaction with content displayed on the third display device **220***c*.

[0087] In this way, enabling user interaction to easily transition between different display devices **220** may implicitly also enable the user to easily interact between different electronic devices **200**. In some examples, if the different electronic devices **200** support a common input modality, the different electronic devices **200** may communicate user input with each other, so that user input received at the first input device **210***a* connected to the first electronic device **200***a* may be communicated to the second electronic device **200***b*. This may enable the user to interact with the different electronic devices **200** with a single input device **210** (that uses the common input modality), by using head movement to transition between the different display devices **220** of the different electronic devices **200** instead of having to switch to a different input device **210** for interacting with each different electronic device **200**.

[0088] In some examples, after each display device has been registered (i.e., a respective mapping has been generated and stored), head-based user interactions may be supported while the user is wearing the wearable device **100** with inertial sensor **110**.

[0089] In an example, each display device **220** may maintain display of a cursor at the location of the last user interaction, even if the cursor is not active (i.e., even if the cursor is not currently being used for user interaction). Then, when the user's attention turns to a particular display device **220** (as determined by the inertial measurements matching a mapping corresponding to the particular display device **220**), the user may immediately begin interacting with the content starting from the position of the now-activated cursor.

[0090] In another example, scrolling input (e.g., using a scroll button on a mouse) while the user's attention is on a particular display device **220** (as determined by the inertial measurements matching a mapping corresponding to the particular display device **220**) may be used as a command to scroll the content displayed on the particular display device **220**.

[0091] In another example, while the user's attention is on the first display device **220***a* (as determined by the inertial measurements matching a mapping corresponding to the first display device **220***a*), the user may select (e.g., using a mouse click) an object (e.g., icon, window, etc.) displayed on the first display device **220***a*. Then instead of using conventional drag input (e.g., using movement of the mouse) to move the selected object, the user may move their head to drag the selected object. This may be used to drag the selected object within the first display device **220***a*, or may be used to drag the selected object to a different display device (e.g., to the second display device **220***b*), for example.

[0092] In another example, while the user's attention is on the first display device **220***a* (as determined by the inertial measurements matching a mapping corresponding to the first display device **220***a*), the user may use a defined head motion or defined head pose (e.g., moving head up or down) to control display parameters (e.g., brightness).

[0093] In another example, while the user's attention is on the first display device **220***a* (as determined by the inertial measurements matching a mapping corresponding to the first display device **220***a*), the user may be typing text input that is displayed on the second display device **220***b*. For example, the user may be reading text content displayed on the first display device **220***a* and typing the text content into a text entry field displayed on the second display device **220***b*. The user's visual attention may be initially on the second display device **220***b* on which the text is being inputted, then while continuing to provide text input the user's visual attention may turn to the first display device **220***a*. An overlay or textbox may be displayed on the first display device **220***a* to show a portion of the text being typed (e.g., a portion of the text input displayed on the second display device **220***b*), so that the user can more easily check their text input without having to switch attention between the first and second display devices **220***a*, **220***b*. It may be noted that such a user interaction, in which the user's visual attention is on one display device **220** while user input is provided on a different display device **220**, may take place after mappings for all display devices **220** have been generated and stored. Further, in this example, the continuous user input associated with the second display device **220***b* may override activation of a cursor on the first display device **220***a* (which would otherwise occur when the user turns their visual attention to the first display device **220***a* in absence of continuous user input associated with the second display device **220***b*).

[0094] In various examples, the present disclosure has described methods and systems that enable an inertial sensor of a wearable device (e.g., smartglasses, smart headphone, etc. having an IMU or IMMU) to be implicitly calibrated with display devices in a multi-display setup. This may help to improve the efficiency of user interactions, as well as improving efficiency in processing since fewer user inputs may be required.

[0095] Examples of the present disclosure may be used to generate and store mappings between inertial measurements and display devices, based on user interactions associated with each display device. Possible user interactions include mouse input, keyboard input, touch input, and voice input, among others.

[0096] Using examples disclosed herein, a user may more easily switch the active cursor between different display devices. When a cursor is activated on a display device, the cursor may be automatically located at the position of the last user interaction on that display device, without requiring explicit user input.

[0097] Examples of the present disclosure may be implemented in a multi-display setup where the multiple display devices are controlled by a single electronic device, or where the multiple display devices are controlled by multiple electronic devices, which may use the same or different input modalities.

[0098] Although the present disclosure describes methods and processes with steps in a certain order, one or more steps of the methods and processes may be omitted or altered as appropriate. One or more steps may take place in an order other than that in which they are described, as appropriate.

[0099] Although the present disclosure is described, at least in part, in terms of methods, a person of ordinary skill in the art will understand that the present disclosure is also directed to the various components for performing at least some of the aspects and features of the described methods, be it by way of hardware components, software or any combination of the two. Accordingly, the technical solution of the present disclosure may be embodied in the form of a software product. A suitable software product may be stored in a pre-recorded storage device or other similar non-volatile or non-transitory computer readable medium, including DVDs, CD-ROMs, USB flash disk, a removable hard disk, or other storage media, for example. The software product includes instructions tangibly stored thereon that enable an electronic device to execute examples of the methods disclosed herein.

[0100] The present disclosure may be embodied in other specific forms without departing from the subject matter of the claims. The described example embodiments are to be considered in all respects as being only illustrative and not restrictive. Selected features from one or more of the above-described embodiments may be combined to create alternative embodiments not explicitly described, features suitable for such combinations being understood within the scope of this disclosure.
[0101] All values and sub-ranges within disclosed ranges are also disclosed. Also, although the systems, devices and processes disclosed and shown herein may comprise a specific number of elements/components, the systems, devices and assemblies could be modified to include additional or fewer of such elements/components. For example, although any of the elements/components disclosed may be referenced as being singular, the embodiments disclosed herein could be modified to include a plurality of such elements/components. The subject matter described herein intends to cover and embrace all suitable changes in technology.

Claims

1. A method comprising: obtaining a first set of inertial measurements representing motion of a head of a user; and determining a first mapping between the first set of inertial measurements and a first display device when detecting a first user interaction associated with the first display device of a plurality of display devices.
2. The method of claim 1, further comprising: causing the first mapping to be stored.
3. The method of claim 1, further comprising: obtaining a subsequent set of inertial measurements representing subsequent motion of the head of the user; identifying the first mapping matching the subsequent set of inertial measurements; and enabling further user interaction with content displayed on the first display device, based on the identified first mapping.
4. The method of claim 3, wherein enabling the further user interaction comprises: activating a cursor on the first display device, the cursor being activated at a location corresponding to a last user interaction on the first display device.
5. The method of claim 3, wherein enabling the further user interaction comprises: detecting scrolling input; and causing content displayed on the first display device to be scrolled based on the scrolling input.
6. The method of claim 3, wherein enabling the further user interaction comprises: controlling a display parameter of the first display device.
7. The method of claim 1, wherein the first user interaction is one of: voice input identifying the first display device; keyboard input to interact with content displayed on the first display device; mouse input to interact with content displayed on the first display device; or touch input sensed by a touch sensor of the first display device.
8. The method of claim 1, further comprising: obtaining a second set of inertial measurements representing motion of the head of the user; and determining a second mapping between the second set of inertial measurements and a second display device when detecting a second user interaction associated with the second display device of the plurality of display devices; wherein, in response to obtaining another set of inertial measurements matching the first mapping, user interaction with content displayed on the first display device is enabled; and wherein, in response to obtaining another set of inertial measurements matching the second mapping, user interaction with content displayed on the second display device is enabled.
9. The method of claim 8, further comprising: causing the second mapping to be stored.
10. The method of claim 8, further comprising: detecting selection of an object displayed on the first display device; obtaining a third set of inertial measurements representing motion of the head of the user; identifying the second mapping matching the third set of inertial measurements; and causing the selected object to be moved to be displayed on the second display device, based on the

identified second mapping.

11. The method of claim 1, further comprising: obtaining a further set of inertial measurements indicating user movement above a defined threshold; and causing all stored mappings to be deleted.

12. The method of claim 1, wherein the plurality of display devices is controlled by a single electronic device.

13. The method of claim 1, wherein the plurality of display devices is controlled by multiple electronic devices.

14. The method of claim 1, wherein inertial measurements are obtained from an inertial sensor of a wearable device worn on or near the head of the user.

15. A computing system comprising: a processing unit configured to execute computer readable instructions to cause the computing system to: obtain a first set of inertial measurements representing motion of a head of a user; and determine a first mapping between the first set of inertial measurements and a first display device when detecting a first user interaction associated with the first display device of a plurality of display devices.

16. The computing system of claim 15, wherein the processing unit is further configured to execute the computer readable instructions to cause the computing system to: obtain a subsequent set of inertial measurements representing subsequent motion of the head of the user; identify the first mapping matching the subsequent set of inertial measurements; and enable further user interaction with content displayed on the first display device, based on the identified first mapping.

17. The computing system of claim 15, wherein the first user interaction is one of: voice input identifying the first display device; keyboard input to interact with content displayed on the first display device; mouse input to interact with content displayed on the first display device; or touch input sensed by a touch sensor of the first display device.

18. The computing system of claim 15, wherein the processing unit is further configured to execute the computer readable instructions to cause the computing system to: obtain a second set of inertial measurements representing motion of the head of the user; and determine a second mapping between the second set of inertial measurements and a second display device when detecting a second user interaction associated with the second display device of the plurality of display devices; wherein, in response to obtaining another set of inertial measurements matching the first mapping, user interaction with content displayed on the first display device is enabled; and wherein, in response to obtaining another set of inertial measurements matching the second mapping, user interaction with content displayed on the second display device is enabled.

19. The computing system of claim 15, further comprising: an inertial sensor configured to obtain the set of inertial measurements; wherein the computing system is configured to be wearable on or near the head of the user.

20. A non-transitory computer readable medium having instructions encoded thereon, wherein the instructions are executable by a processing unit of a computing system to cause the computing system to: obtain a first set of inertial measurements representing motion of a head of a user; and determine a first mapping between the first set of inertial measurements and a first display device when detecting a first user interaction associated with the first display device of a plurality of display devices.