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Miller et al.

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(54) **DUAL CAMERA MAGNET ARRANGEMENT**

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(51) **Int. Cl.**

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H04N 5/225	(2006.01)
G02B 13/00	(2006.01)
G02B 7/09	(2006.01)

(52) **U.S. Cl.**
CPC ***H04N 5/23287*** (2013.01); ***G02B 7/09*** (2013.01); ***G02B 13/001*** (2013.01); ***H04N 5/2257*** (2013.01); ***H04N 5/2258*** (2013.01)

(58) **Field of Classification Search**
CPC H04N 5/23287
USPC 348/357
See application file for complete search history.

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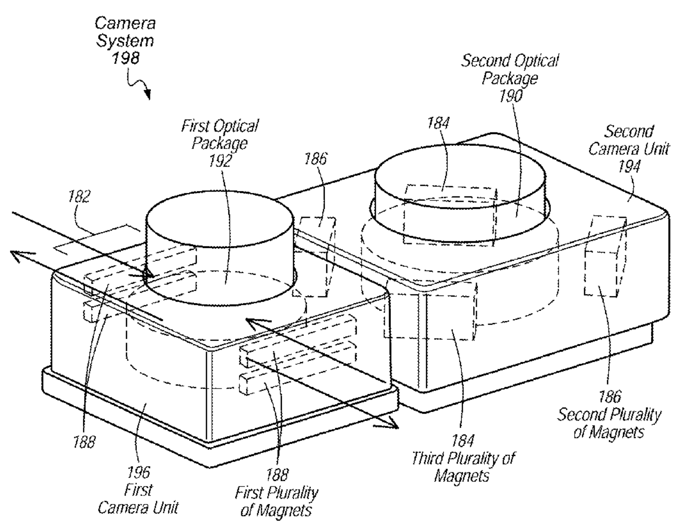
Primary Examiner — Usman Khan
(74) *Attorney, Agent, or Firm* — Robert C. Kowert; Meyertons, Hood, Kivlin, Kowert & Goetzel, P.C.

(57) **ABSTRACT**

Some embodiments include a camera system having a first camera unit and a second camera unit. The first camera unit includes an autofocus actuator. The autofocus actuator includes a first plurality of magnets for autofocus motion control of components of a first optical package. The first plurality of magnets is positioned to generate magnetic fields aligned in parallel with a first magnetic axis at a right angle to the optical axis of the first optical package. The second camera unit includes an optical image stabilization and autofocus actuator. The optical image stabilization and autofocus actuator includes a second plurality of magnets positioned to generate magnetic fields aligned along a second magnet axis at 45-degrees to the first magnetic axis. The second camera unit includes a third plurality of magnets positioned to generate magnetic fields aligned along a third magnetic axis at 135-degrees to the first magnetic axis.

20 Claims, 11 Drawing Sheets



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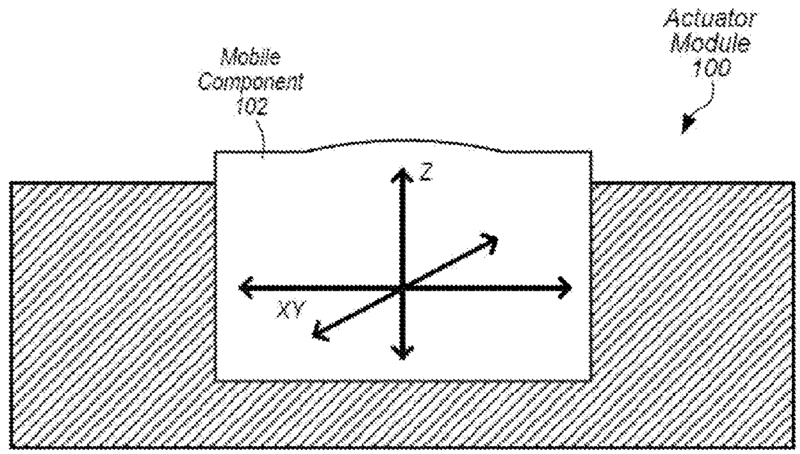

Actuator
Module
100
Mobile
Component
102
Z
XY

FIG. 1A

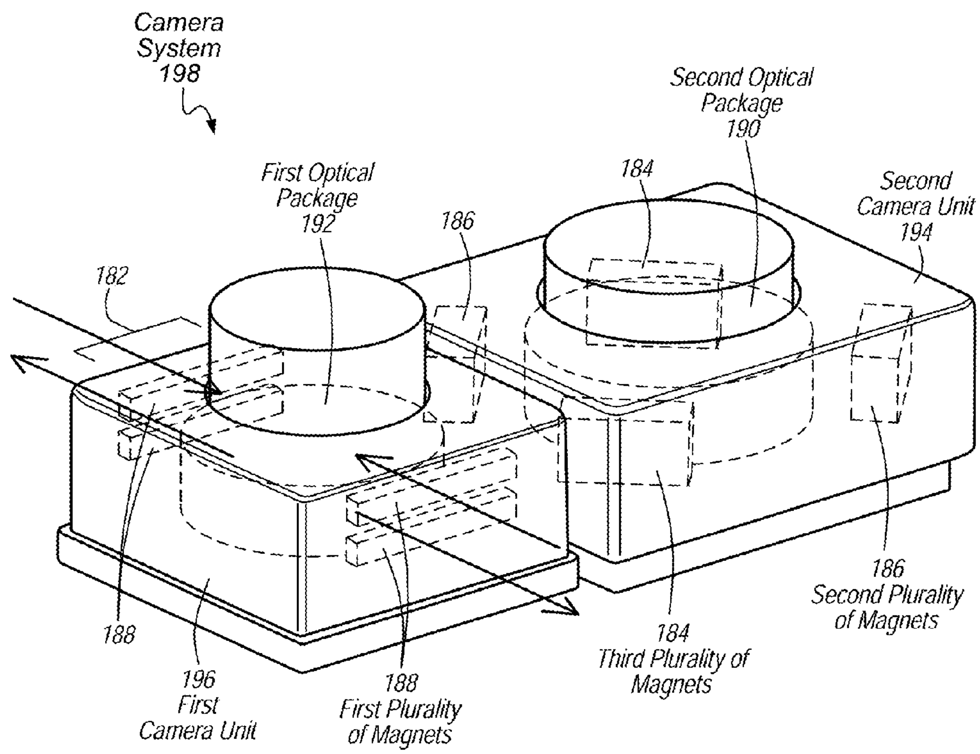

Camera
System
198
First Optical
Package
192
Second Optical
Package
190
184
186
Second
Camera Unit
194
182
188
196
First
Camera Unit
188
First Plurality
of Magnets
184
Third Plurality of
Magnets
186
Second Plurality
of Magnets

FIG. 1B

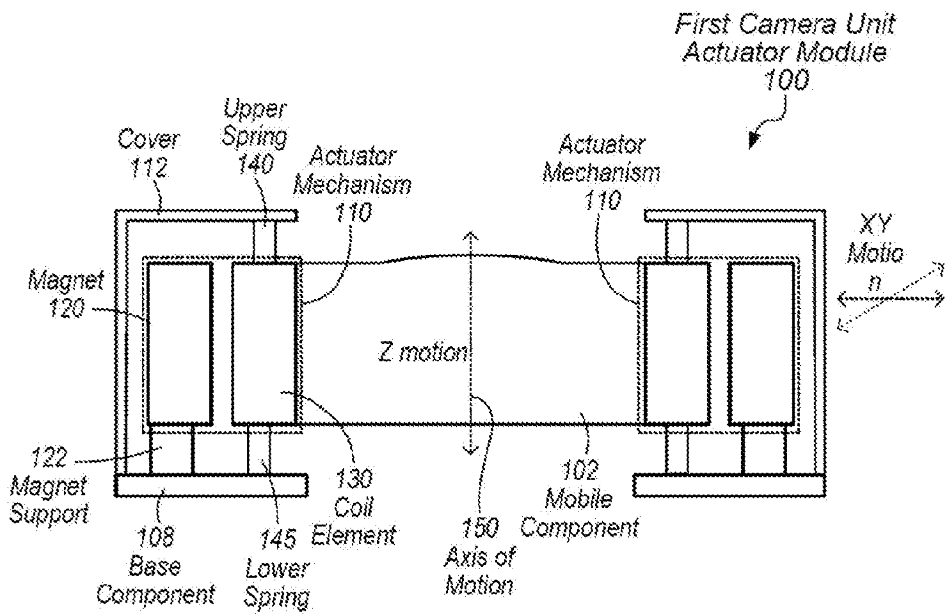

First Camera Unit
Actuator Module
100
Cover
112
Upper
Spring
140
Actuator
Mechanism
110
Actuator
Mechanism
110
XY
Motio
n
Magnet
120
Z motion
122
Magnet
Support
108
Base
Component
145
Lower
Spring
130
Coil
Element
150
Axis of
Motion
102
Mobile
Component

FIG. 1C

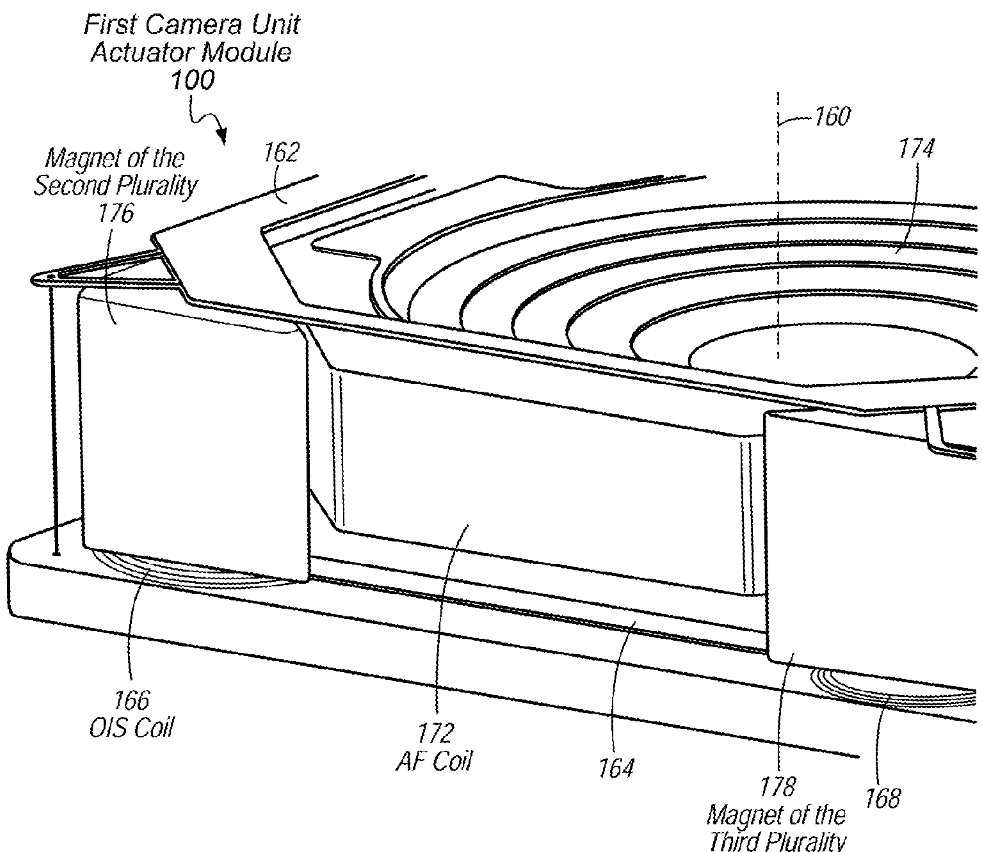
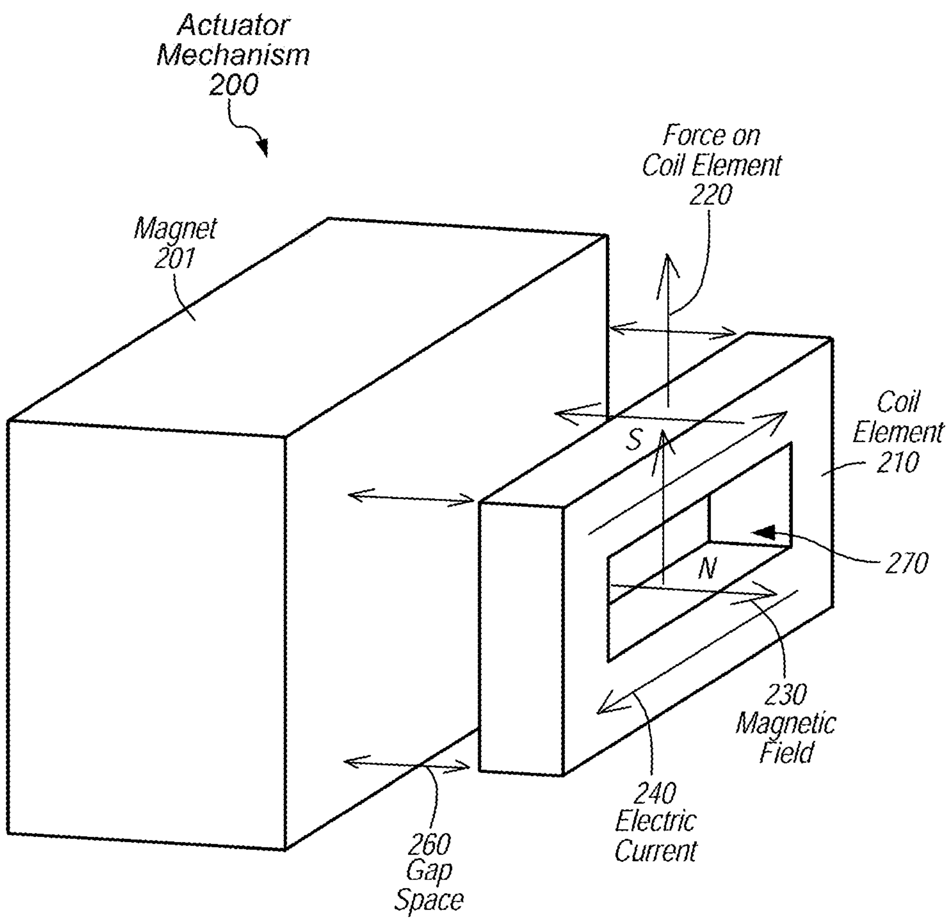

First Camera Unit
Actuator Module
100
160
174
162
Magnet of the
Second Plurality
176
166
OIS Coil
172
AF Coil
164
178
Magnet of the
Third Plurality
168

FIG. 1D



Actuator
Mechanism
200
Magnet
201
Force on
Coil Element
220
S
Coil
Element
210
N
270
230
Magnetic
Field
240
Electric
Current
260
Gap
Space

FIG. 2

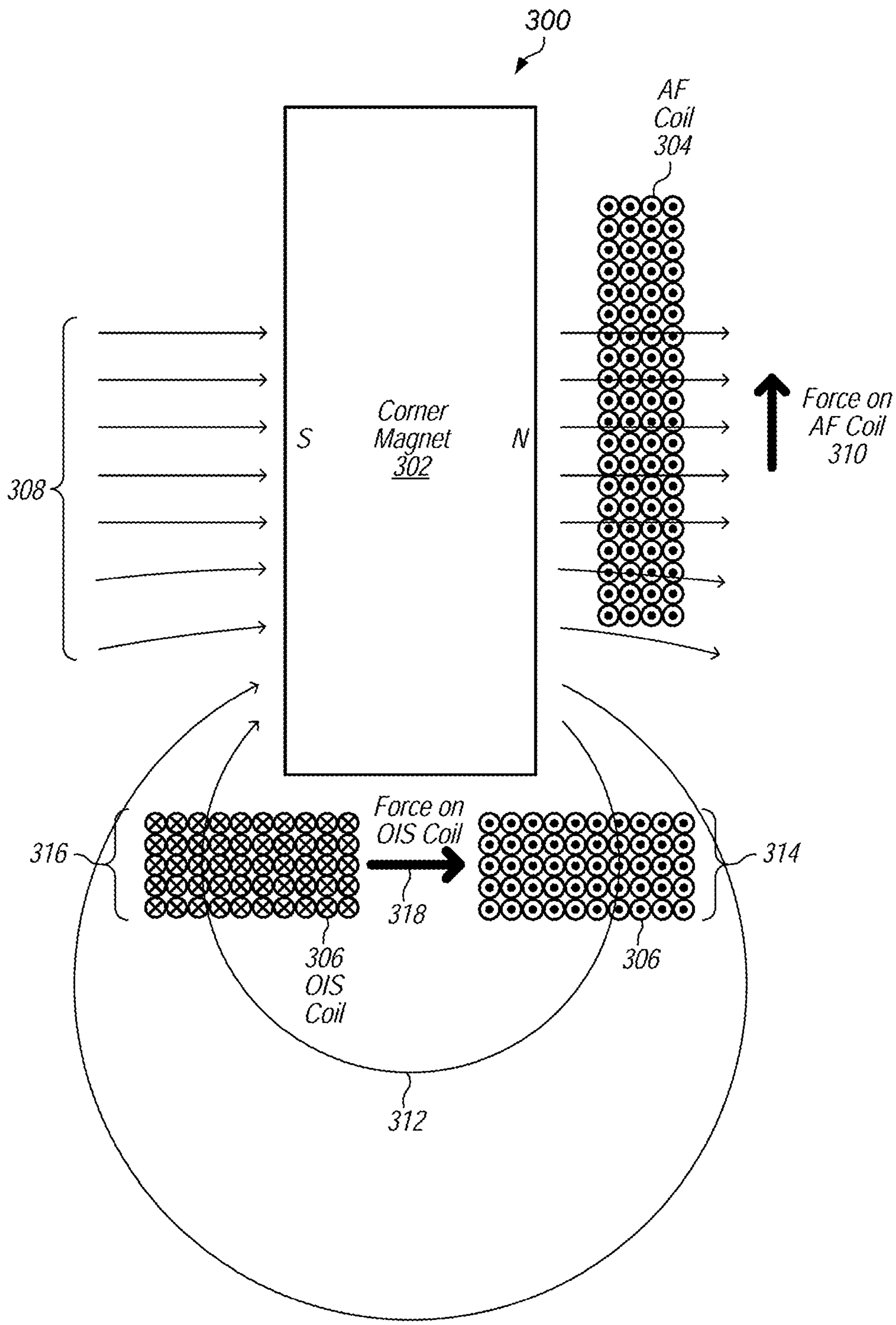

300
AF Coil 304
Corner Magnet 302
S
N
308
Force on AF Coil 310
316
Force on OIS Coil
318
314
306 OIS Coil
306
312

FIG. 3

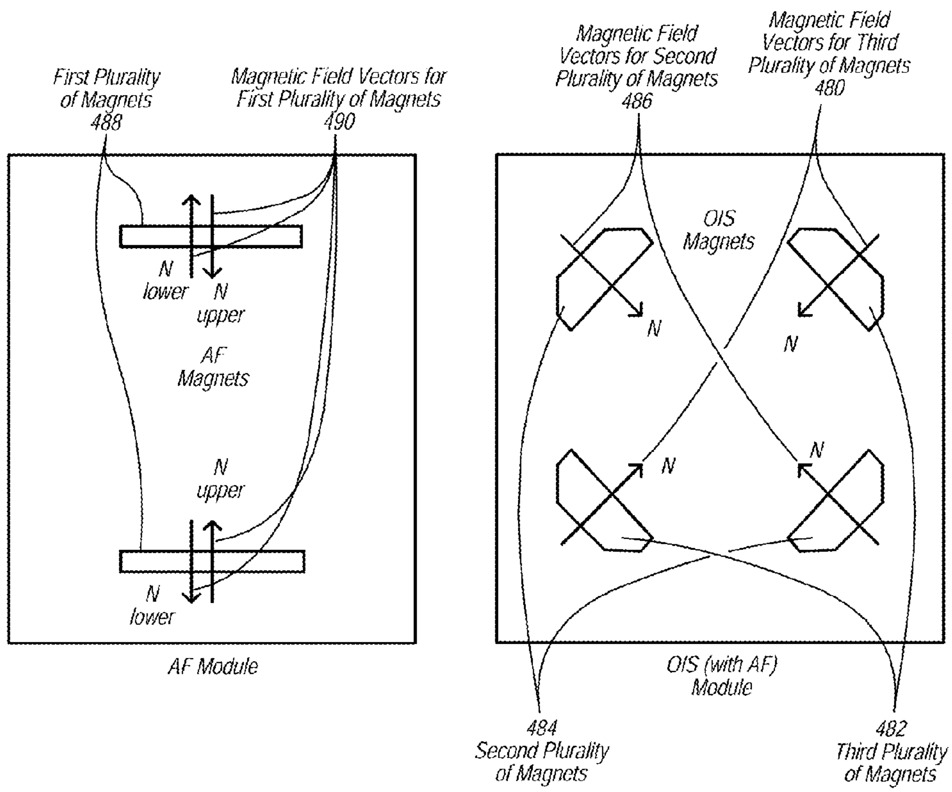

First Plurality of Magnets 488
Magnetic Field Vectors for First Plurality of Magnets 490
N lower
N upper
AF Magnets
N upper
N lower
AF Module
Magnetic Field Vectors for Second Plurality of Magnets 486
Magnetic Field Vectors for Third Plurality of Magnets 480
OIS Magnets
N
N
N
N
OIS (with AF) Module
484 Second Plurality of Magnets
482 Third Plurality of Magnets

FIG. 4

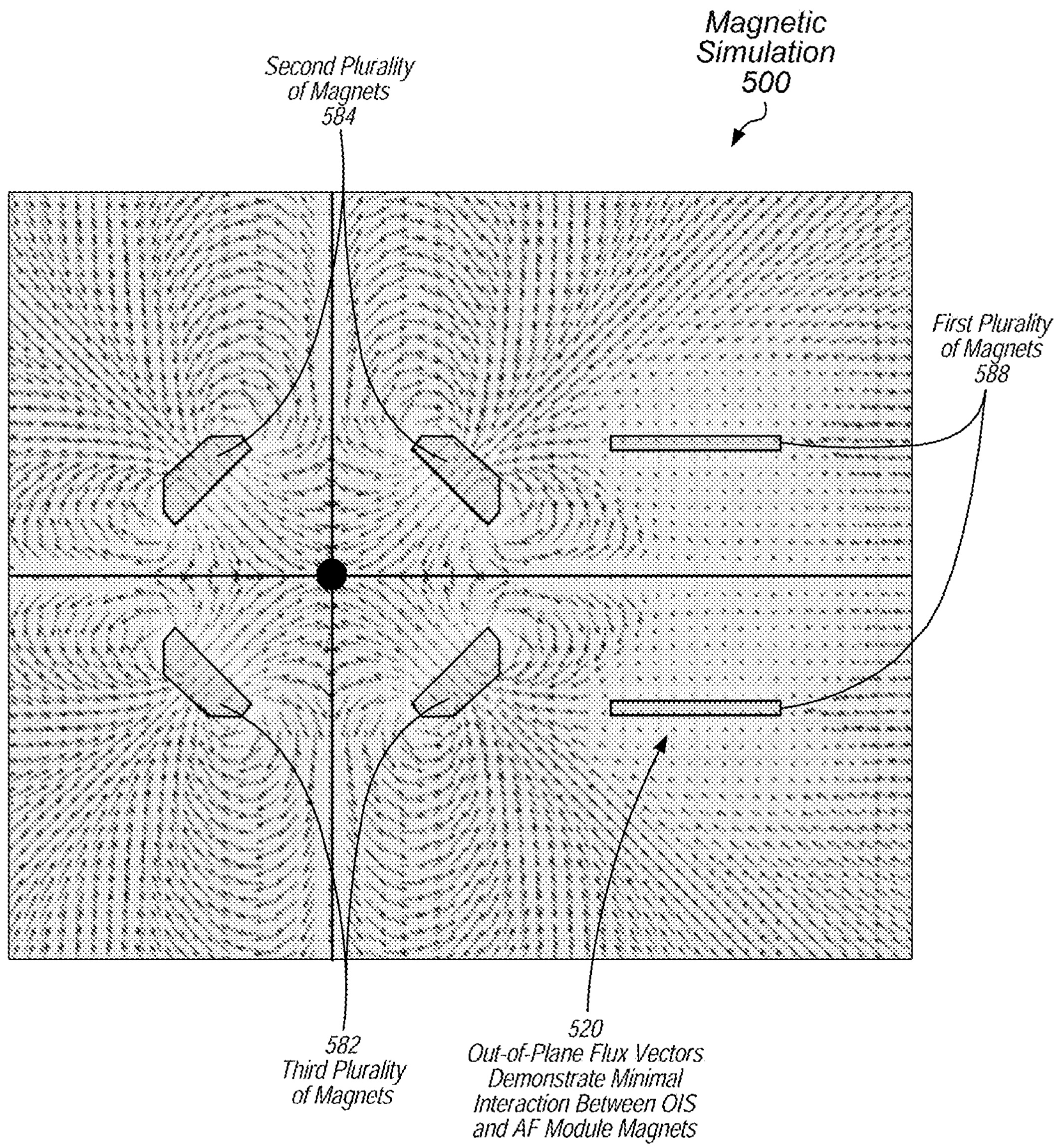

Magnetic Simulation 500
Second Plurality of Magnets 584
First Plurality of Magnets 588
582 Third Plurality of Magnets
520 Out-of-Plane Flux Vectors Demonstrate Minimal Interaction Between OIS and AF Module Magnets

FIG. 5

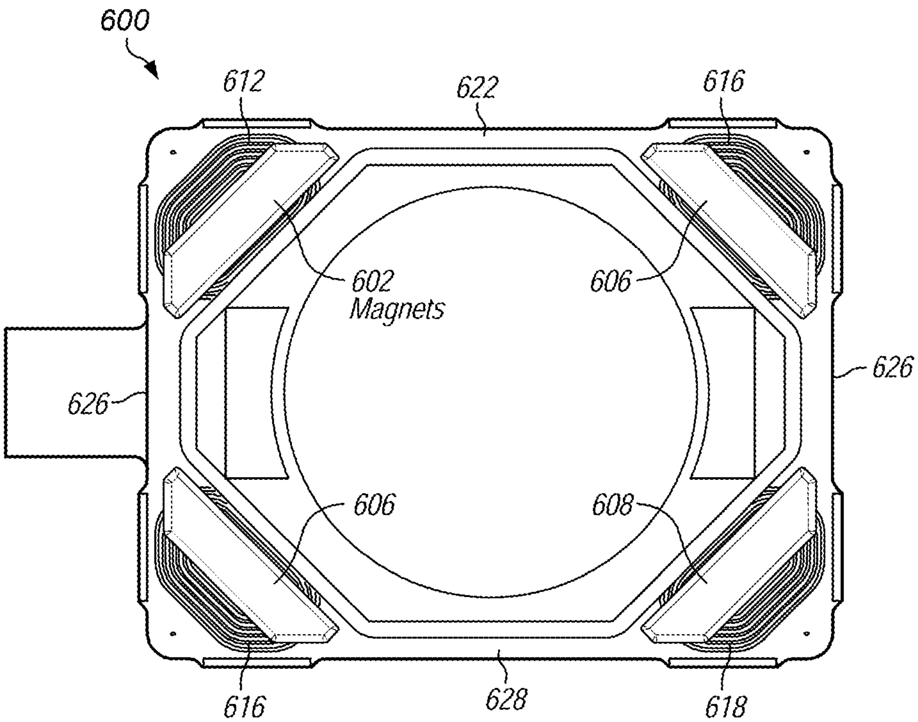


FIG. 6

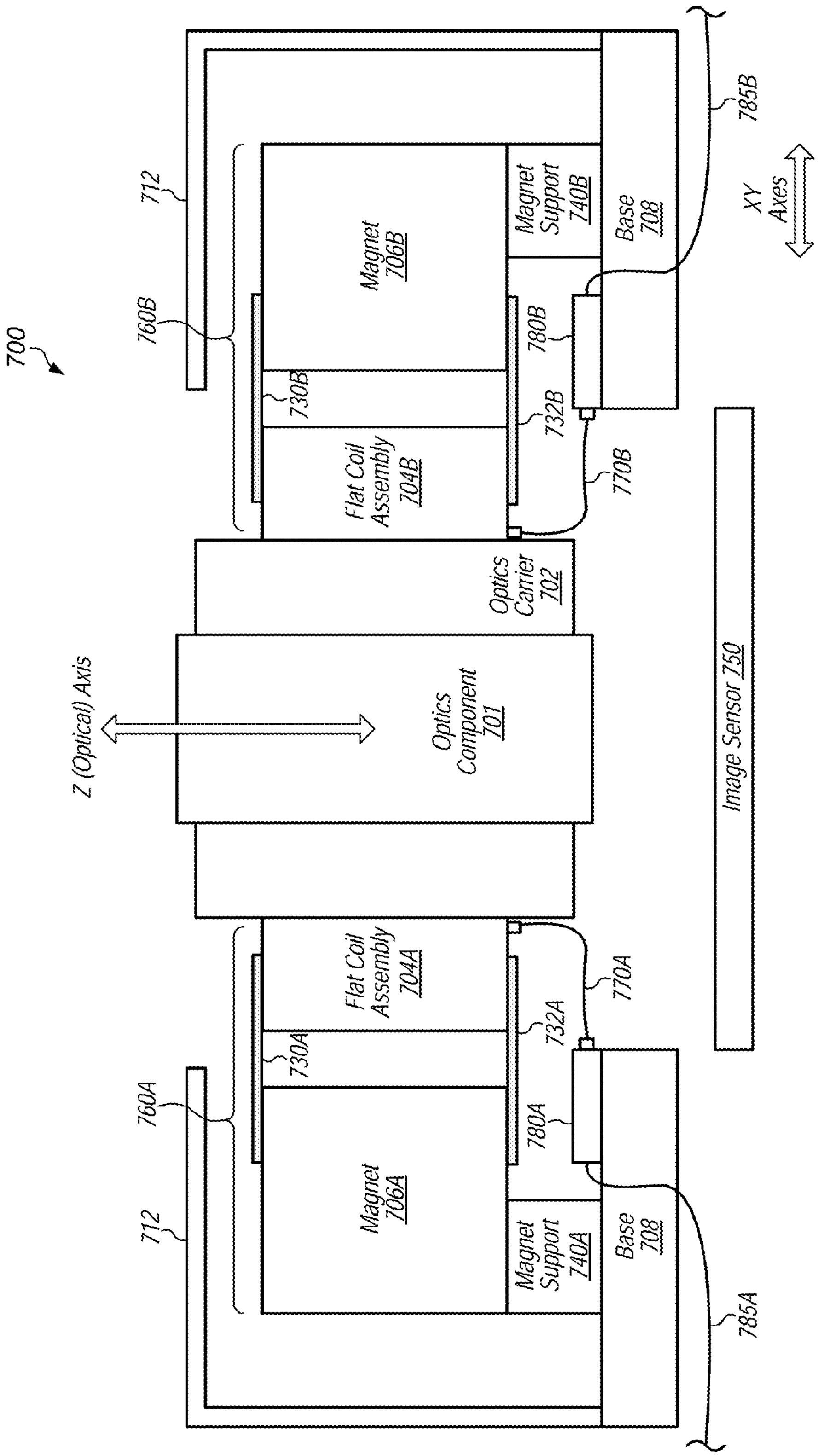

700
712
760B
Magnet 706B
730B
Flat Coil Assembly 704B
Magnet Support 740B
Base 708
780B
732B
770B
785B
XY Axes
Optics Carrier 702
Optics Component 701
Z (Optical) Axis
Image Sensor 750
Flat Coil Assembly 704A
730A
732A
770A
760A
780A
Magnet 706A
Magnet Support 740A
Base 708
712
785A

FIG. 7

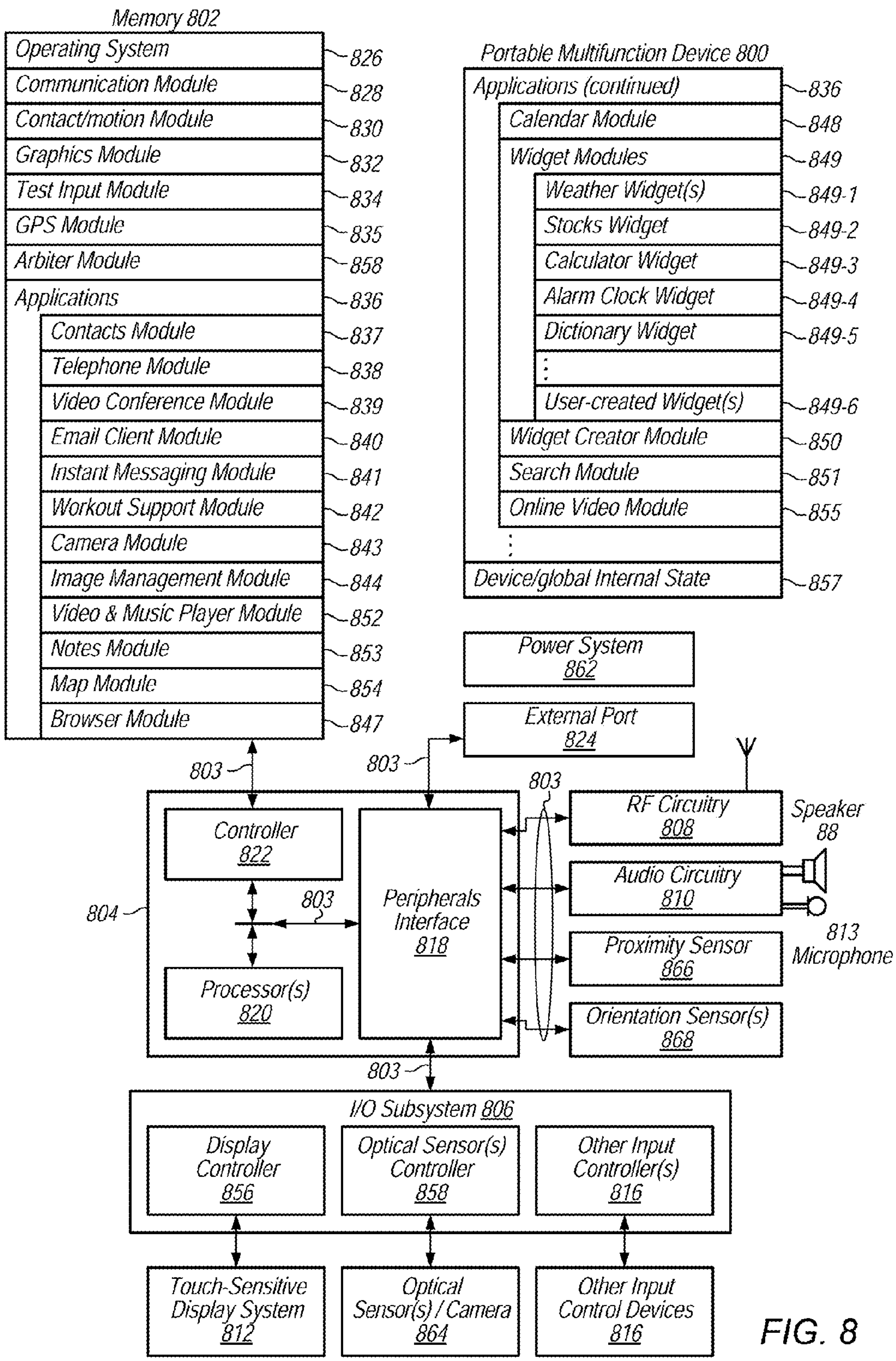
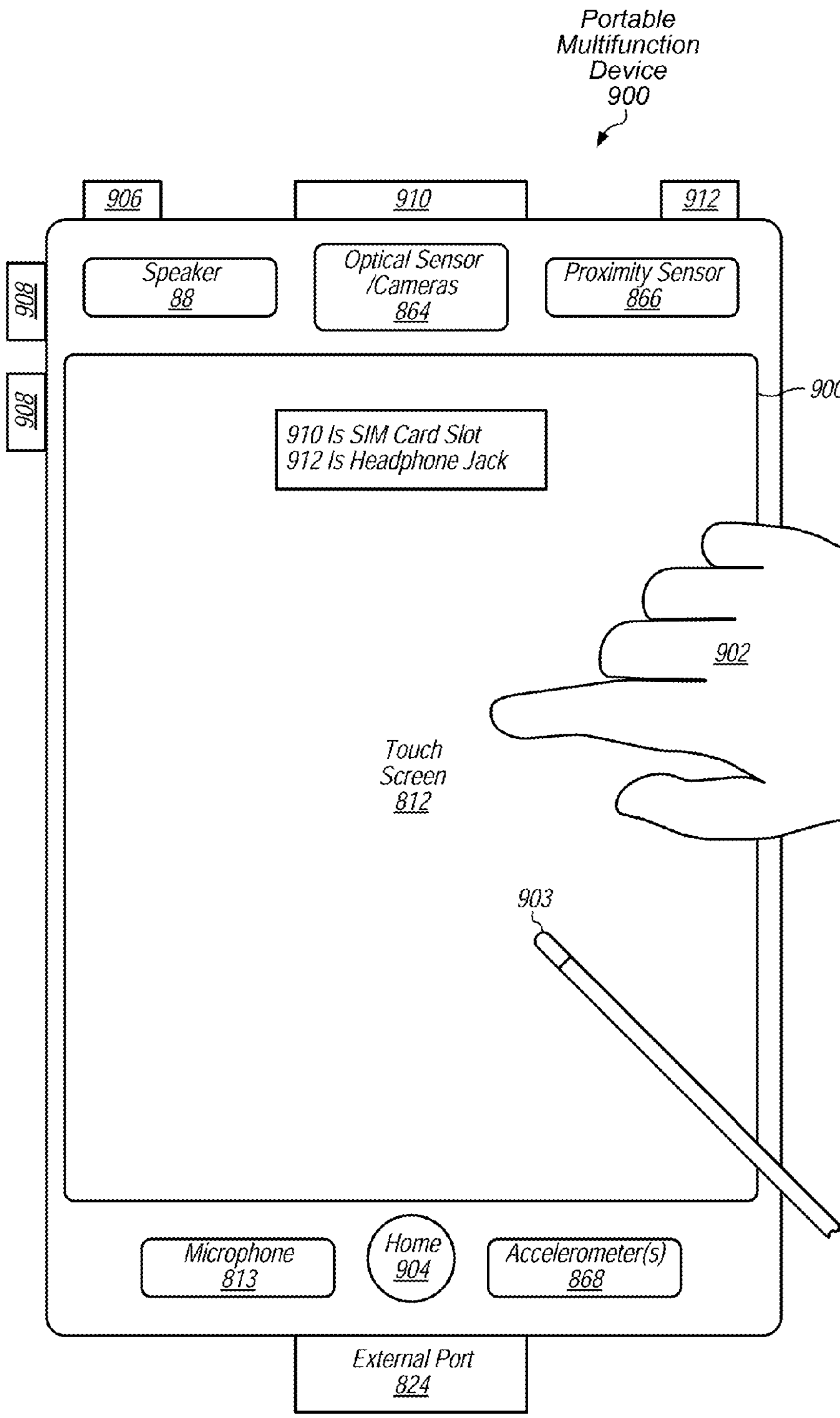

Memory 802
Operating System
826
Communication Module
828
Contact/motion Module
830
Graphics Module
832
Test Input Module
834
GPS Module
835
Arbiter Module
858
Applications
836
Contacts Module
837
Telephone Module
838
Video Conference Module
839
Email Client Module
840
Instant Messaging Module
841
Workout Support Module
842
Camera Module
843
Image Management Module
844
Video & Music Player Module
852
Notes Module
853
Map Module
854
Browser Module
847
Portable Multifunction Device 800
Applications (continued)
836
Calendar Module
848
Widget Modules
849
Weather Widget(s)
849-1
Stocks Widget
849-2
Calculator Widget
849-3
Alarm Clock Widget
849-4
Dictionary Widget
849-5
User-created Widget(s)
849-6
Widget Creator Module
850
Search Module
851
Online Video Module
855
Device/global Internal State
857
Power System
862
External Port
824
803
803
803
RF Circuitry
808
Speaker
88
Audio Circuitry
810
813
Microphone
Proximity Sensor
866
Orientation Sensor(s)
868
Controller
822
803
Peripherals Interface
818
804
Processor(s)
820
803
I/O Subsystem 806
Display Controller
856
Optical Sensor(s) Controller
858
Other Input Controller(s)
816
Touch-Sensitive Display System
812
Optical Sensor(s) / Camera
864
Other Input Control Devices
816

FIG. 8



Portable Multifunction Device 900
906
910
912
908
908
Speaker 88
Optical Sensor /Cameras 864
Proximity Sensor 866
900
910 Is SIM Card Slot
912 Is Headphone Jack
902
Touch Screen 812
903
Microphone 813
Home 904
Accelerometer(s) 868
External Port 824

FIG. 9

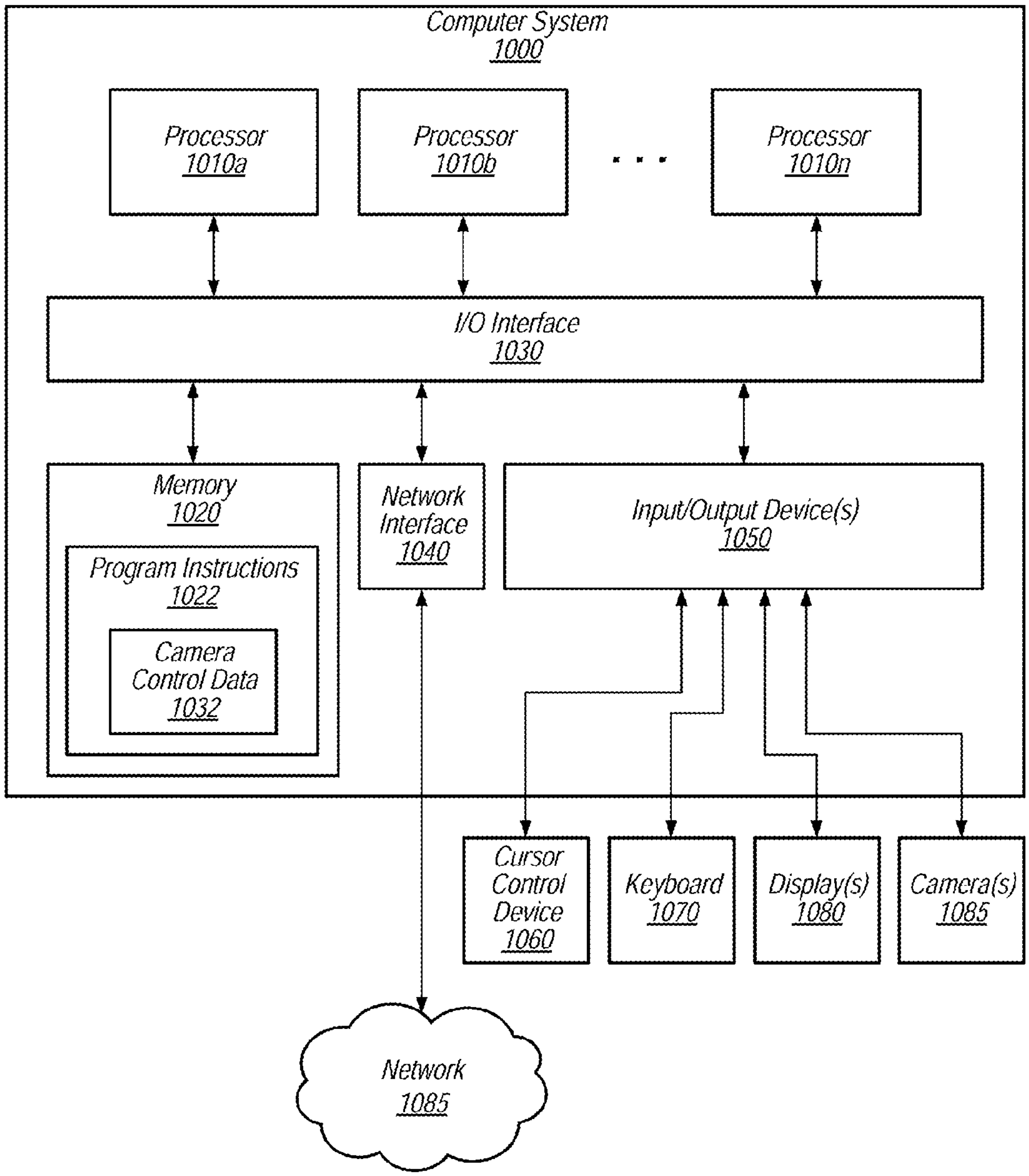

Computer System
1000
Processor
1010a
Processor
1010b
Processor
1010n
I/O Interface
1030
Memory
1020
Program Instructions
1022
Camera
Control Data
1032
Network
Interface
1040
Input/Output Device(s)
1050
Cursor
Control
Device
1060
Keyboard
1070
Display(s)
1080
Camera(s)
1085
Network
1085

FIG. 10

DUAL CAMERA MAGNET ARRANGEMENT

This application claims benefit of priority to U.S. Provisional Application No. 62/116,269 filed Feb. 13, 2015, entitled "Dual Camera Magnet Arrangement", and claims benefit of priority to U.S. Provisional Application No. 62/201,547 filed Aug. 5, 2015, entitled "Dual Camera Magnet Arrangement", both of which are hereby incorporated by reference in their entireties.

BACKGROUND

Technical Field

This disclosure relates generally to control of the motion of mobile components, relative to static components, based at least in part upon a linear actuator mechanism using Lorentz forces, also referred to herein as a Lorentz actuator mechanism.

Description of the Related Art

For small devices, including high-end miniature cameras, it is common to configure certain components included in the devices to be movably adjusted, relative to other components. In miniature cameras, such configuration can include configuring one or more components to enable an auto-focus' (AF) function, whereby the object focal distance is adjusted to allow objects at different distances to be in sharp focus at the image plane, to be captured by a digital image sensor. There have been many proposals for achieving such adjustments of mobile components, relative to static components, including adjustment of focal position.

For example, with regard to miniature camera devices, the most common solution is to move the whole optical lens as a single rigid body along the optical axis. Positions of the lens closer to the image sensor correspond to object focal distances further from the camera. Demands on improvements to performance of such miniature cameras are constant, as are demands for continued miniaturization, given the added features and devices added to such mobile devices.

In particular, high image quality is easier to achieve if the lens motion along the optical axis is accompanied by minimal parasitic motion in the other degrees of freedom, particularly tilt about axes orthogonal to the optical axis.

Further to this, there is a strong desire, for a given size of camera, to fit bigger lenses and image sensors to improve image quality, and hence there is a desire to reduce the size of components such as actuator mechanisms. However, some small-sized components, including various components included in actuator mechanisms, can be relatively complex to assemble and can be vulnerable to failure, based at least in part upon small size and complexity of various components.

SUMMARY OF EMBODIMENTS

Some embodiments provide a camera system having a first camera unit and a second camera unit. The first camera unit includes an autofocus actuator. The autofocus actuator includes a first plurality of magnets for autofocus motion control of components of a first optical package. The first plurality of magnets is positioned to generate magnetic fields aligned in parallel with a first magnetic axis at a right angle to the optical axis of the first optical package. The second camera unit includes an optical image stabilization and autofocus actuator. The optical image stabilization and autofocus actuator includes a second plurality of magnets positioned to generate magnetic fields aligned along a second magnet axis at 45-degrees to the first magnetic axis. The second camera unit includes a third plurality of magnets positioned to generate magnetic fields aligned along a third magnetic axis at 135-degrees to the first magnetic axis.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A illustrates motion of a mobile component, relative to a static component, within an actuator module, according to at least some embodiments.

FIG. 1B depicts a dual camera arrangement, according to at least some embodiments.

FIG. 1C illustrates motion of a mobile component, relative to a static component, within an actuator module, according to at least some embodiments.

FIG. 1D depicts an actuator for a camera with autofocus and optical image stabilization, according to some embodiments.

FIG. 2 illustrates a schematic of a magnet and flat coil assembly configuration, according to some embodiments.

FIG. 3 depicts a schematic view of a magnet and coil configuration, according to some embodiments.

FIG. 4 illustrates arrangement of magnets in a dual camera arrangement, according to at least some embodiments.

FIG. 5 depicts magnetic fields associated with magnets in a dual camera arrangement, according to at least some embodiments.

FIG. 6 illustrates an actuator in top view with the outer screening can and yoke hidden, according to some embodiments.

FIG. 7 illustrates a side view of an example actuator module included in a camera component and configured to adjust a mobile component which includes a lens carrier along an optical axis relative to an image sensor, according to some embodiments.

FIG. 8 illustrates a block diagram of a portable multifunction device with a camera, according to some embodiments.

FIG. 9 depicts a portable multifunction device having a camera, according to some embodiments.

FIG. 10 illustrates an example computer system configured to implement aspects of a system and method for camera control, according to some embodiments.

This specification includes references to "one embodiment" or "an embodiment." The appearances of the phrases "in one embodiment" or "in an embodiment" do not necessarily refer to the same embodiment. Particular features, structures, or characteristics may be combined in any suitable manner consistent with this disclosure.

"Comprising." This term is open-ended. As used in the appended claims, this term does not foreclose additional structure or steps. Consider a claim that recites: "An apparatus comprising one or more processor units . . . " Such a claim does not foreclose the apparatus from including additional components (e.g., a network interface unit, graphics circuitry, etc.).

"Configured To." Various units, circuits, or other components may be described or claimed as "configured to" perform a task or tasks. In such contexts, "configured to" is used to connote structure by indicating that the units/circuits/components include structure (e.g., circuitry) that performs those task or tasks during operation. As such, the unit/circuit/component can be said to be configured to perform the task even when the specified unit/circuit/component is not currently operational (e.g., is not on). The units/circuits/components used with the "configured to" language include hardware—for example, circuits, memory storing program instructions executable to implement the operation, etc. Reciting that a unit/circuit/component is "configured to" perform one or more tasks is expressly intended not to invoke 35 U.S.C. §112, sixth paragraph, for that unit/circuit/component. Additionally, "configured to" can include generic structure (e.g., generic circuitry) that is manipulated by software and/or firmware (e.g., an FPGA or a general-purpose processor executing software) to operate in manner that is capable of performing the task(s) at issue. "Configure to" may also include adapting a manufacturing process (e.g., a semiconductor fabrication facility) to fabricate devices (e.g., integrated circuits) that are adapted to implement or perform one or more tasks.

"First," "Second," etc. As used herein, these terms are used as labels for nouns that they precede, and do not imply any type of ordering (e.g., spatial, temporal, logical, etc.). For example, a buffer circuit may be described herein as performing write operations for "first" and "second" values. The terms "first" and "second" do not necessarily imply that the first value must be written before the second value.

"Based On." As used herein, this term is used to describe one or more factors that affect a determination. This term does not foreclose additional factors that may affect a determination. That is, a determination may be solely based on those factors or based, at least in part, on those factors. Consider the phrase "determine A based on B." While in this case, B is a factor that affects the determination of A, such a phrase does not foreclose the determination of A from also being based on C. In other instances, A may be determined based solely on B.

DETAILED DESCRIPTION

Introduction

Some embodiments provide an apparatus for controlling the motion of mobile components relative to static components. The apparatus can include linear actuators that controls the motion of the mobile components based at least in part upon Lorentz forces. Such linear actuators can be referred to herein as actuator mechanisms. In some embodiments, at least the mobile components included in a camera components or camera systems, such that the actuator mechanisms control the motion of optics carriers, which themselves include one or more optics components and can include one or more optical lenses, relative to one or more image sensors.

In some embodiments, a multifunction mobile computing device includes a first camera unit housed within the multifunction mobile computing device for capturing at a first image sensor a first image of a first visual field through a first optical package and a second camera unit housed within the multifunction mobile computing device. In some embodiments, the term optical package refers to a lens and any components physically attached to move in rigid orientation with the lens. Examples of an optical package include a lens barrel, lens stack or optical carrier. In some embodiments, the first camera unit includes an autofocus actuator. In some embodiments, the autofocus actuator includes a first plurality of magnets for autofocus motion control of components of the first optical package, and the first plurality of magnets is positioned to generate magnetic fields aligned in parallel with a first magnetic axis through a center of the first optical package at a right angle to the optical axis of the first optical package.

In some embodiments, the second camera unit includes an optical image stabilization and autofocus actuator. In some embodiments, the optical image stabilization and autofocus actuator includes a second plurality of magnets positioned to generate magnetic fields aligned along a second magnet axis at a first angle bisecting a right angle relative to the first magnetic axis for optical image stabilization and autofocus motion control of components of the second optical package, and the second camera unit includes a third plurality of magnets positioned to generate magnetic fields aligned along a third magnetic axis at a second angle bisecting a right angle relative to the first magnetic axis for optical image stabilization and autofocus motion control of components of the second optical package.

In some embodiments, the first camera unit includes a first optical package with a first focal length. In some embodiments, the second camera unit includes a second optical package with a second focal length for a first visual field. In some embodiments, the first focal length is different from the second focal length for a second visual field, and the first visual field is a subset of the second visual field.

In some embodiments, the autofocus actuator is configured to generate motion of the first optical package along an optical axis of the first optical package for autofocus adjustments without optical image stabilization.

In some embodiments, the optical image stabilization and autofocus actuator is configured both to generate motion of a second optical package along an optical axis of the second optical package for autofocus adjustments and to generate motion of the second optical package in directions orthogonal to the optical axis of the second optical package for optical image stabilization.

In some embodiments, the second camera unit includes a second camera unit for simultaneously capturing at a second image sensor a second image of a second visual field through the second optical package.

In some embodiments, a plurality of autofocus coils is affixed to the first optical package and situated between the first optical package and respective ones of the first plurality of magnets.

In some embodiments, the second camera unit of the multifunction device is installed in a second camera package located physically adjacent to a first camera package in which the first camera module is installed, and the second camera unit is located in a position along a line orthogonal to the first magnetic axis.

In some embodiments, a camera system includes a first camera unit and a second camera unit. In some embodiments, the first camera unit includes an autofocus actuator, the autofocus actuator includes a first plurality of magnets for autofocus motion control of components of a first optical package, and the first plurality of magnets is positioned to generate magnetic fields aligned in parallel with a first magnetic axis at a right angle to the optical axis of the first optical package. The second camera unit includes an optical image stabilization and autofocus actuator. The optical image stabilization and autofocus actuator includes a second plurality of magnets positioned to generate magnetic fields aligned along a second magnet axis at 45-degrees to the first magnetic axis. The second camera unit includes a third plurality of magnets positioned to generate magnetic fields aligned along a third magnetic axis at 135-degrees to the first magnetic axis.

In some embodiments, the first camera unit includes a first optical package with a first focal length. The second camera unit includes a second optical package with a second focal length, and the first focal length is different from the second focal length.

In some embodiments, the autofocus actuator is configured to generate motion of the first optical package along an optical axis of the first optical package for autofocus adjustments without optical image stabilization.

In some embodiments, the optical image stabilization and autofocus actuator is configured both to generate motion of a second optical package along an optical axis of the second optical package for autofocus adjustments and to generate motion of the second optical package in directions orthogonal to the optical axis.

In some embodiments, the second camera unit includes a second camera unit for simultaneously capturing at a second image sensor a second image of a second visual field through the second optical package. Some embodiments further include a plurality of autofocus coils affixed to the first optical package and situated between the first optical package and respective ones of the first plurality of magnets.

In some embodiments, the second camera unit of the multifunction device is installed in a second camera package located physically adjacent to a first camera package in which the first camera module is installed, and the second camera unit is located in a position along a line orthogonal to the first magnetic axis.

In some embodiments, a camera system includes a first camera unit and a second camera unit. In some embodiments, the first camera unit includes an autofocus actuator and a first image sensor. In some embodiments, the autofocus actuator includes a first plurality of magnets for autofocus motion control of components of a first optical package relative to the image sensor. In some embodiments, the first plurality of magnets is positioned to generate magnetic fields aligned in parallel with a first magnetic axis at a right angle to the optical axis of the first optical package.

In some embodiments, the second camera unit includes an optical image stabilization and autofocus actuator and a second image sensor. In some embodiments, the optical image stabilization and autofocus actuator includes a second plurality of magnets positioned to generate magnetic fields aligned along a second magnet axis at 45-degrees to the first magnetic axis, and the second camera unit includes a third plurality of magnets positioned to generate magnetic fields aligned along a third magnetic axis at 135-degrees to the first magnetic axis.

In some embodiments, the first camera unit includes a first optical package with a first focal length, the second camera unit includes a second optical package with a second focal length, and the first focal length is different from the second focal length.

In some embodiments, the autofocus actuator is configured to generate motion of the first image sensor along an optical axis of the first optical package for autofocus adjustments without optical image stabilization.

In some embodiments, the optical image stabilization and autofocus actuator is configured both to generate motion of the second image sensor along an optical axis of the second optical package for autofocus adjustments and to generate motion of the second optical package in directions orthogonal to the optical axis.

In some embodiments, a plurality of autofocus coils is affixed to the first optical package and situated between the first optical package and respective ones of the first plurality of magnets.

In some embodiments, the second camera unit of the multifunction device is installed in a second camera package located physically adjacent to a first camera package in which the first camera module is installed, and the second camera unit is located in a position along a line orthogonal to the first magnetic axis.

In some embodiments, the first camera unit includes an apparatus for controlling the motion of a mobile component relative to a static component, with multiple magnets coupled to the static component and a flat coil assembly physically coupled to the mobile component in a magnetic field of one or more magnets of the plurality of magnets and electrically coupled to a power source. Each magnet of the plurality of magnets is poled with magnetic domains substantially aligned in the same direction throughout each magnet. The flat coil assembly is configured to adjust a position of the mobile component, relative to the static component, based at least in part upon Lorentz forces. The flat coil assembly includes a set of conductor elements at least partially bounded by a set of insulator elements within an interior of the flat coil assembly. The set of conductor elements form a coil structure, within the interior of the flat coil assembly, which is configured to generate the Lorentz forces based at least in part upon an electrical current through the conductor elements.

In some embodiments, the flat coil assembly includes multiple physically coupled layers which collectively establish the coil structure within the interior of the flat coil assembly. One or more of the plurality of physically coupled layers can include a particular pattern of conductor elements and insulator elements.

In some embodiments, the flat coil assembly includes one or more flat coils, where each flat coil includes a separate set of conductor elements forming a coil structure within the respective flat coil. In some embodiments, the flat coil assembly includes multiple flat coils which are each coupled to separate sides of the mobile component. In some embodiments, the flat coils are coupled to opposite sides of the mobile component. In some embodiments, the plurality of flat coils are configured to be electrically coupled to a power source in series.

In some embodiments, the mobile component includes an optics carrier included in a camera device and including an optics component, and the flat coil assembly is configured to adjust a position of the optics carrier, relative to an image sensor in the camera device along an axis parallel to the optical axis for focus adjustment. The optics component can include one or more optical lenses.

In some embodiments, the flat coil assembly is configured to be coupled to the mobile component as a monolithic component. In some embodiments, the flat coil assembly is configured to be coupled to the mobile component in an automatic process which is independent of manual intervention. Such an automatic process can be implemented by one or more robotic mechanisms which are controlled by one or more computer systems.

In some embodiments, the flat coil assembly includes a flexible electrical connection which is physically coupled to an electrical terminal to electrically couple the flat coil assembly to the power source. The flexible electrical connection is configured to flex, to maintain the electrical coupling of the flat coil assembly and the power source, as the mobile component moves, relative to the static component.

In some embodiments, the first camera unit includes an apparatus with a Lorentz actuator mechanism configured to adjustably position a mobile component, relative to a static component, based at least in part upon Lorentz forces. The Lorentz actuator mechanism can include one or more flat coil assemblies configured to couple directly with the mobile component and generate Lorentz forces based at least in part upon an electrical current applied to the flat coil assembly. The flat coil assembly can include at least one set of conductor elements coupled in series through an interior of the one or more flat coil assemblies to collectively form a coil structure within the interior of the one or more flat coil assemblies. The coil structure is configured to generate the Lorentz forces based at least in part upon an electrical current through the conductor elements.

In some embodiments, the one or more flat coil assemblies includes a multilayer structure of multiple physically coupled layers which collectively establish the coil structure based at least in part upon the physically coupling of the layers to electrically couple the particular patterns of conductor elements. At least one layer in the plurality of layers can include a particular pattern of conductor elements and insulator elements.

In some embodiments, the one or more flat coil assemblies is configured to be coupled to the static component via one or more spring assemblies. The one or more spring assemblies can be configured to at least partially restrict a range of motion of the mobile component.

In some embodiments, the one or more flat coil assemblies includes a frame structure coupled to the mobile component assembly, and multiple flat coils coupled to opposite sides of the frame structure, such that the plurality of flat coils are positioned at opposite sides of the mobile component assembly.

In some embodiments, the one or more flat coil assemblies is configured to couple directly with the mobile component as a monolithic component.

In some embodiments, the mobile component includes an optics carrier included in a camera device and further includes an optics component. The flat coil assembly can be configured to adjust a position of the optics carrier, relative to an image sensor in the camera device along an axis parallel to the optical axis for focus adjustment of the optics component. Such focus adjustment can include auto-focusing.

In some embodiments, the flat coil assembly includes a flexible electrical connection which is configured to flex, to maintain an electrical connection between the flat coil assembly and a power source, concurrently with the flat coil assembly generating Lorentz forces to adjust a position of the mobile component, relative to the static component.

Adjustably positioning the mobile component, relative to the static component, based at least in part upon a current applied to one or more flat coil assemblies included in one or more actuator mechanisms can be controlled, at least partially, by a non-transitory, computer-readable storage medium and one or more processors (e.g., CPUs and/or GPUs) of a computing apparatus. The computer-readable storage medium may store program instructions executable by the one or more processors to cause the computing apparatus to perform calculating an equilibrium position of the mobile component relative to one or more static components in a static component assembly, detecting a current position of the mobile component relative to the static component and calculating a displacement of the mobile component by the actuator mechanism necessary to move the mobile component to the equilibrium position, as described herein. Other embodiments of the non-uniform paint loading module may be at least partially implemented by hardware circuitry and/or firmware stored, for example, in a non-volatile memory.

Multifunction Device

Reference will now be made in detail to embodiments, examples of which are illustrated in the accompanying drawings. In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be apparent to one of ordinary skill in the art that some embodiments may be practiced without these specific details. In other instances, well-known methods, procedures, components, circuits, and networks have not been described in detail so as not to unnecessarily obscure aspects of the embodiments.

It will also be understood that, although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first contact could be termed a second contact, and, similarly, a second contact could be termed a first contact, without departing from the intended scope. The first contact and the second contact are both contacts, but they are not the same contact.

The terminology used in the description herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used in the description and the appended claims, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will also be understood that the term “and/or” as used herein refers to and encompasses any and all possible combinations of one or more of the associated listed items. It will be further understood that the terms “includes,” “including,” “comprises,” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

As used herein, the term “if” may be construed to mean “when” or “upon” or “in response to determining” or “in response to detecting,” depending on the context. Similarly, the phrase “if it is determined” or “if [a stated condition or event] is detected” may be construed to mean “upon determining” or “in response to determining” or “upon detecting [the stated condition or event]” or “in response to detecting [the stated condition or event],” depending on the context.

Embodiments of electronic devices, user interfaces for such devices, and associated processes for using such devices are described. In some embodiments, the device is a portable communications device, such as a mobile telephone, that also contains other functions, such as PDA and/or music player functions. Other portable electronic devices, such as laptops or tablet computers with touch-sensitive surfaces (e.g., touch screen displays and/or touch pads), may also be used. It should also be understood that, in some embodiments, the device is not a portable communications device, but is a desktop computer with a touch-sensitive surface (e.g., a touch screen display and/or a touch pad). In some embodiments, the device is a gaming computer with orientation sensors (e.g., orientation sensors in a gaming controller). In other embodiments, the device is not a portable communications device, but is a camera.

In the discussion that follows, an electronic device that includes a display and a touch-sensitive surface is described. It should be understood, however, that the electronic device may include one or more other physical user-interface devices, such as a physical keyboard, a mouse and/or a joystick.

The device typically supports a variety of applications, such as one or more of the following: a drawing application, a presentation application, a word processing application, a website creation application, a disk authoring application, a spreadsheet application, a gaming application, a telephone application, a video conferencing application, an e-mail application, an instant messaging application, a workout support application, a photo management application, a digital camera application, a digital video camera application, a web browsing application, a digital music player application, and/or a digital video player application.

The various applications that may be executed on the device may use one or more common physical user-interface devices, such as the touch-sensitive surface. One or more functions of the touch-sensitive surface as well as corresponding information displayed on the device may be adjusted and/or varied from one application to the next and/or within a respective application. In this way, a common physical architecture (such as the touch-sensitive surface) of the device may support the variety of applications with user interfaces that are intuitive and transparent to the user.

Some embodiments include a dual-camera module or a set of camera modules for use in one or more various devices. Such devices can include one or more miniature cameras, such as those used in mobile handheld devices or other multifunction devices. For high-end miniature cameras, it is common to incorporate 'auto-focus' (AF) functionality, whereby the object focal distance is adjusted to allow objects at different distances to be in sharp focus at the image plane, to be captured by the digital image sensor. Some embodiments allow improvements to performance of such miniature cameras, as well as continued miniaturization, to accommodate added features and devices added to such mobile devices.

Some embodiments include an actuator mechanism which includes one or more Lorentz actuator mechanisms. For such actuator mechanisms, a current carrying conductor element in a magnetic field experiences a force proportional to the cross product of the current applied to the conductor element and the magnetic field. This force is known as the Lorentz force. In some embodiments, the Lorentz force is greatest if the direction of the magnetic field is orthogonal to the direction of the current flow, and the resulting force on the conductor is orthogonal to both. The Lorentz force is proportional to the magnetic field density and the current through the conductor. The conductor element can be included in a coil structure, which includes a coil formed of one or more conductor elements. Some embodiments use an actuator mechanism configured to have a substantially constant magnetic field cutting the coil element for all positions of the actuator mechanism, such that the force produced is proportional to the current through the one or more conductor elements included in the coil element. In some embodiments, the actuator mechanism includes a voice coil motor (VCM), where the coil element, and the coil structure included therein, includes a voice coil formed of one or more instances of conductor elements (which can include one or more instances of conductor wiring, conductor cabling, some combination thereof, etc.) wound to form the coil structure. Some embodiments make further use of voice coil motor technology and include an actuator architecture suitable for improving power consumption, performance, reducing size, and adding extra functionality, including optical image stabilization.

Some embodiments include a dual-camera module including a camera equipped for autofocus and a second camera configured for both autofocus and optical image stabilization. In some embodiments, the cameras each include a static component assembly which includes a photosensor configured to capture light projected onto a surface of the photosensor. In some embodiments, the cameras each include an actuator module. In some embodiments, the actuator modules each include a mobile component assembly which includes an optics assembly configured to refract light from an object field located in front of the camera onto the photosensor. In some embodiments, one or more actuator modules includes an actuator mechanism configured to move the optics assembly within the actuator module on one or more axes orthogonal to an optical axis of the camera to automatically focus an image formed by the optics assembly at the photosensor. In some embodiments, an optics assembly is suspended by one or more sets of spring assemblies on the static component assembly.

Some embodiments allow a reduction in the complexity and size of components such as actuator mechanisms. Some embodiments allow assembly of an actuator module which includes a mobile component within a mobile component assembly to be simplified and streamlined, based at least in part upon the actuator mechanism including a flat coil assembly which includes a coil structure of one or more conductor elements within an interior of the flat coil assembly. The flat coil assembly can be coupled directly to the mobile component as a monolithic component, thereby simplifying assembly of the actuator mechanism, relative to an actuator mechanism which includes a voice coil motor (VCM), as winding of one or more conductor cablings to form a coil structure is precluded. In addition, as the coil structure is located within the interior of the flat coil assembly, the conductor elements are less vulnerable to exposure and damage, relative to wound conductor cabling included in a coil element of a VCM.

An apparatus for controlling motions of a mobile component relative to an static component within a device, which can include controlling motions of an optics component relative to an image sensor within a camera device, may include an actuator mechanism for controlling the position of the mobile component relative to the static component along two axes (X, Y) orthogonal to the optical (Z) axis of the device. The apparatus may be referred to herein as an actuator module. In some embodiments, a mobile component assembly that includes the mobile component and that may also include at least some components of the actuator mechanism (e.g., magnets and/or coil elements) may be suspended on one or more sets of spring assemblies, wires, beams, etc. over a base of the actuator module. Each set of spring assemblies may be substantially parallel to an axis of motion of the mobile component. In at least some embodiments, the spring assemblies are substantially perpendicular to the axis of motion of the mobile component and are capable of bending deformations that allow the mobile component assembly to move in linear directions parallel to the axis of motion (i.e., on the Z plane). Where the actuator module includes an optical component included in a camera device, the actuator mechanism may provide autofocus for the camera device, and in some embodiments may be implemented as a voice coil motor (VCM) actuator mechanism. The actuator module may, for example, be used as or in a miniature or small form factor camera as part of a dual-camera module suitable for small, mobile multipurpose devices such as cell phones, smartphones, and pad or tablet devices. In at least some embodiments, the actuator module may also include a focusing mechanism for moving the optics component along an optical (Z) axis within the optics assembly.

Lorentz Actuator Mechanism

FIG. **1**A and FIG. **1**C illustrate motion of a mobile component **102** within an actuator module **100**, according to at least some embodiments. As shown in FIG. **1**A, where the mobile component **102** includes an optics component, an actuator module **100** may provide optical image autofocusing and/or optical image stabilization for the optics component **102**. In at least some embodiments, the actuator module **100** may include a Lorentz actuator mechanism, herein referred to as an "actuator mechanism", which can include a voice coil motor (VCM) actuator mechanism, a flat coil assembly actuator mechanism, some combination thereof, etc. An actuator module **100** such as a flat coil actuator module may provide motion to mobile component **102** in the Z axis. An actuator module **100** such as a voice coil motor actuator module may provide motion to mobile component **102** in the Z axis, as well as the X axis and Y axis. The Z axis motion may, for example, be for optical focusing or autofocus purposes in cameras that incorporate focusing/autofocus mechanisms. The X and Y axis motion may, for example, be for optical focusing, optical image stabilization or autofocus purposes in cameras that incorporate focusing/autofocus mechanisms. An example embodiment of an optical image focusing actuator mechanism are illustrated as actuator module **100** in FIG. **1**C. An example embodiment of an optical image stabilization actuator mechanism are illustrated as an actuator module **180** in FIG. **1**D. Embodiments of the actuator module **100** may, for example, be used in a miniature or small form factor camera suitable for small, mobile multipurpose devices such as cell phones, smartphones, and pad or tablet devices, as described below with respect to FIGS. **8-9**. Embodiments of the actuator module **180** may, for example, be used in a miniature or small form factor camera suitable for small, mobile multipurpose devices such as cell phones, smartphones, and pad or tablet devices, as described below with respect to FIG. **8-9**.

FIG. **1**B depicts a dual camera arrangement, according to at least some embodiments. A camera system contains a first camera unit **198** and a second camera unit **194**. In first camera unit **194**, an autofocus actuator, moves a first optical package **192**. The autofocus actuator includes a first plurality of magnets **188** for autofocus motion control of components of first optical package **192**, and the first plurality of magnets **188** is positioned to generate magnetic fields aligned in parallel with a first magnetic axis at a right angle to the optical axis of the first optical package **192**. Second camera unit **194** includes an optical image stabilization and autofocus actuator, which includes a second plurality of magnets **186** positioned to generate magnetic fields aligned along a second magnet axis at 45-degrees to the first magnetic axis, and a third plurality of magnets **184** positioned to generate magnetic fields aligned along a third magnetic axis at 135-degrees to the first magnetic axis.

In some embodiments, the first camera unit **196** includes a first optical package **192** with a first focal length, and the second camera unit **194** includes a second optical package **190** with a second focal length. In some embodiments, the autofocus actuator of first camera unit **196** is configured to generate motion of the first optical package **192** along an optical axis of the first optical package **192** for autofocus adjustments without optical image stabilization. In some embodiments, magnets of the first plurality of magnets are paired in a first pair **182** and a second pair **180**. Each of first pair **182** and second pair **180** contains both an upper magnet with a field oriented north toward the first optical package **192** and a lower magnet with a field oriented north away from the first optical package **192**. In the interest of enhanced visual simplicity, magnetic fields of the third plurality of magnets **184** and the second plurality of magnets **186** are not shown. In some embodiments, magnetic fields of the third plurality of magnets **184** and the second plurality of magnets **186** are oriented north toward the first optical package **192** oriented north toward the second optical package **192**. As used herein, arrowheads of magnetic field vectors indicate magnetic north orientation.

In some embodiments, the optical image stabilization and autofocus actuator of second camera unit **194** is configured both to generate motion of a second optical package **190** along an optical axis of the second optical package for autofocus adjustments and to generate motion of the second optical package **190** in directions orthogonal to the optical axis of second optical package **190**.

In some embodiments, the second camera unit **194** includes or is a second camera unit for simultaneously capturing at a second image sensor a second image of a second visual field through the second optical package **190**. In some embodiments, a plurality of autofocus coils is affixed to the first optical package **192** and situated between the first optical package **192** and respective ones of the first plurality of magnets **188**.

In some embodiments, the second camera unit **194** is installed in a second camera package located physically adjacent to a first camera package in which the first camera unit **196** is installed, and the second camera unit **194** is located in a position along a line orthogonal to the first magnetic axis.

FIG. **1**C illustrates components of an example actuator module **100** (e.g., an actuator module of the first camera unit **196**) that provides Z axis (autofocus) motions **150** for a mobile component **102** (e.g., first optical package **192**) based at least in part upon Lorentz forces generated in one or more actuator mechanisms **110** included therein, according to some embodiments. In some embodiments, a mobile component **102** of the actuator module **100** may include an optics component (e.g., first optical package **192**) that is coupled to an actuator mechanism **110** and is coupled to various elements of a static component assembly, including a base component **108** and a cover **112**, via one or more sets of spring assemblies **140**, **145**.

The actuator mechanism **110** can include one or more magnets **120** (e.g., of first plurality of magnets **188**), coil elements **130**, etc. Each magnet **120** can be poled so as to generate a magnetic field, the useful component of which for the function of moving the mobile component **102** is orthogonal to the axis **150**, and orthogonal to the plane of each magnet **120** proximate to the coil element **130**, and magnetic fields for all magnets **120** are all either directed towards a given coil element **130**, or away from the coil element **130**, so that the Lorentz forces from all magnets **120** act in the same direction along the axis of motion **150**.

Where the actuator mechanism **110** includes a Lorentz actuator mechanism, a given mechanism **110** can include a coil element **130** positioned in a magnetic field generated by a magnet **120** and configured to generate Lorentz forces based at least in part upon an electrical current applied to the coil element. As shown in FIG. **1**C, the coil elements **130** illustrated therein are coupled, orthogonally to axis **150**, to one or more external sides, also referred to as exterior sides, of the mobile component **102** which extend in parallel to axis **150**. The spring assemblies **140**, **145** can be flexible to allow motion of the mobile component **102** on the Z axis **150** relative to one or more static components (e.g., base **108**, cover **112**, magnet **120**, magnet support **122**, etc.) included in a static component assembly. In the illustrated embodiment, a portion of the actuator mechanism **110**, the coil element **130**, is coupled to the mobile component **102** to form a mobile component assembly, and the magnet **120** can be coupled to one or more portions of the static component assembly via one or more magnet support elements **122**. As a result, the actuator mechanism **110** can move the mobile component assembly on the Z axis within the actuator module **100**, and relative to the static component assembly, so that the coil element **130** included in the mobile component assembly moves with the mobile component **102** and relative to the magnet **120**, which remains included in, and affixed to other static components included in, the static component assembly. An actuator mechanism **110** may be configured to move the mobile component **102** on the Z axis **150** within the actuator module **100** to provide focusing or autofocus for a camera, for example where the static component assembly includes an image sensor (not shown) and the mobile component **102** includes an optics carrier which accommodates one or more optics components, including one or more optical lenses.

In some embodiments, the mobile component assembly, which can include the mobile component **102** and one or more coil elements **130** of one or more actuator mechanisms **110**, is at least partially suspended within the actuator module **100** on one or more sets of spring assemblies **140**, **145**. For example, in the illustrated embodiment, the set of spring assemblies **145** are coupled directly to base component **108**, and the set of spring assemblies **140** are coupled directly to cover **112**. The spring assemblies may be flexible to allow motion of the mobile component assembly which includes the mobile component **102** and coil elements **130**, on the Z axis, XY axis, some combination thereof, or the like. Where the actuator module is included in a camera device, and the mobile component **102** includes an optics component, the actuator mechanisms **110** can move the mobile component assembly, and thus the mobile component **102** on the Z axis within the actuator module **100**, to provide optical image focusing for the camera device.

In this way, when an electric current is applied to one or more of the coil elements **130**, Lorentz forces are developed due to the presence of the magnets **120**, and a force substantially parallel to the axis **150** is generated to move the mobile component **102**, and one or more components included therein, along the axis **150**, relative to the various static components **108**, **112**, **120**, **122** included in the static component assembly. In addition to suspending the mobile component assembly and substantially eliminating parasitic motions, the upper spring assemblies **140** and lower spring assemblies **145** also resist the Lorentz forces generated in coil elements **130**, and hence convert the forces to a displacement of the lens. This basic architecture in FIG. **1**C is typical of first camera unit **196** in some embodiments.

Some embodiments further provide a drive scheme for an actuator mechanism for a miniature camera, such as may be used in a mobile handheld device or other multifunction device. Some embodiments provide a flat coil assembly actuator mechanism configuration, which uses 'fixed' magnets and a moving flat coil assembly coupled to a mobile component which includes an optics carrier that itself includes, accommodates, etc. one or more optics components. The optics carrier can include a threaded lens carrier, on which is mounted an optics component which includes one or more a threaded lens. Some embodiments further incorporate a method for assembling the actuator mechanism and a method of driving the actuator mechanism.

In some embodiments, the actuator module includes multiple separate coil elements, which can include multiple flat coils, multiple flat coil assemblies, some combination thereof, etc. Each flat coil, flat coil assembly, etc. can be located on separate sides of the mobile component and can further be accompanied by its own magnet. In order to deliver Lorentz forces in the same direction from each side of each coil, some embodiments use dual-pole magnets, where the domains in different portions of the magnet are aligned in opposite directions.

FIG. **1**D illustrates an actuator for a camera with autofocus and optical image stabilization, according to some embodiments. A basic autofocus voice coil motor configuration of actuator **170** (e.g., the actuator of second camera unit **194**) includes a single autofocus coil **172** wound onto a threaded lens carrier **174**, into which the lens (not shown, e.g., second optical package **190**) is subsequently screwed. An autofocus yoke component (not shown) supports and houses four magnets (e.g., magnet of the second plurality **176** and magnet of the second plurality **178**) in the corners. Each magnet (e.g., e.g., magnet of the second plurality **176** and magnet of the second plurality **178**) is poled so as to generate a magnetic field, the useful component of which for the autofocus function is orthogonal to the optical axis **160**, and orthogonal to the plane of each magnet (e.g., e.g., magnet of the second plurality **176** and magnet of the second plurality **178**) proximate to the autofocus coil **172**, and where the field for all four magnets are all either directed towards the autofocus coil **172**, or away from the autofocus coil **172**, so that the Lorentz forces from all four magnets (e.g., e.g., magnet of the second plurality **176** and magnet of the second plurality **178**) act in the same direction along the optical axis **160**.

The autofocus yoke (not shown) acts as the support chassis structure for the autofocus mechanism of actuator **170**. The lens carrier **174** is suspended on the autofocus yoke by an upper spring **162** and a lower spring **164**. In this way when an electric current is applied to autofocus coil **172**, Lorentz forces are developed due to the presence of the four magnets (e.g., e.g., magnet of the second plurality **176** and magnet of the second plurality **178**), and a force substantially parallel to the optical axis **160** is generated to move the lens carrier **174**, and hence lens, along the optical axis **160**, relative to the support structure of the autofocus mechanism of actuator **170**, so as to focus the lens. In addition to suspending the lens carrier **174** and substantially eliminating parasitic motions, the upper spring **162** and lower spring **164** also resist the Lorentz forces, and hence convert the forces to a displacement of the lens. This basic architecture is typical of the second camera unit some embodiments, in which optical image stabilization function includes moving the entire autofocus mechanism of actuator **170** (supported by the autofocus yoke) in linear directions orthogonal to the optical axis **160**, in response to user handshake, as detected by some means, such a two or three axis gyroscope, which senses angular velocity. The handshake of interest is the changing angular tilt of the camera in 'pitch and yaw directions', which can be compensated by said linear movements of the lens relative to the image sensor.

Embodiments achieve this two independent degree-of-freedom motion by using two pairs of optical image stabilization coils (e.g., such as **166** and **168**), each pair acting together to deliver controlled motion in one linear axis orthogonal to the optical axis **160**, and each pair delivering controlled motion in a direction substantially orthogonal to the other pair. These optical image stabilization coils **166** and **168** are fixed to the camera actuator **170** support structure, and when current is appropriately applied, optical image stabilization coils **166** and **168** generate Lorentz forces on the entire autofocus mechanism of actuator **170**, moving it as desired. The required magnetic fields for the Lorentz forces are produced by the same four magnets (e.g., magnet of the second plurality **176** and magnet of the second plurality **178**) that enable to the Lorentz forces for the autofocus function. However, since the directions of motion of the optical image stabilization movements are orthogonal to the autofocus movements, it is the fringing field of the four magnets (e.g., magnet of the second plurality **176** and magnet of the second plurality **178**) that are employed, which have components of magnetic field in directions parallel to the optical axis **160**.

Some embodiments include a first camera unit **196** housed within a multifunction mobile computing device for capturing at a first image sensor (not shown) a first image of a first visual field through a first optical package **192**. In some embodiments, the first camera unit includes an autofocus actuator **100**. The autofocus actuator includes a first plurality of magnets **120** for autofocus motion control of components of the first optical package **192**, and the first plurality of magnets **120** is positioned to generate magnetic fields aligned in parallel with a first magnetic axis **150** through a center of the first optical package **192** at a right angle to the optical axis **150** of the first optical package **192**.

In some embodiments a second camera unit **194** is housed within the multifunction mobile computing device. the second camera unit includes an optical image stabilization and autofocus actuator **170**. The optical image stabilization and autofocus actuator **170** includes a second plurality of magnets **186** positioned to generate magnetic fields aligned along a second magnetic axis at a first angle bisecting a right angle relative to the first magnetic axis **160** for optical image stabilization and autofocus motion control of components of the second optical package **190**. The second camera unit includes a third plurality of magnets **184** positioned to generate magnetic fields aligned along a third magnetic axis at a second angle bisecting a right angle relative to the first magnetic axis for optical image stabilization and autofocus motion control of components of the second optical package **190**.

In some embodiments. the first camera unit **196** includes a first optical package **192** with a first focal length for a first visual field, the second camera unit **194** includes a second optical package **190** with a second focal length for a second visual field, and the first focal length is different from the second focal length.

In some embodiments, the autofocus actuator **100** is configured to generate motion of the first optical package **192** along an optical axis **152** of the first optical package **192** for autofocus adjustments without optical image stabilization.

In some embodiments, the optical image stabilization and autofocus actuator **170** is configured both to generate motion of a second optical package **190** along an optical axis **160** of the second optical package **190** for autofocus adjustments and to generate motion of the second optical package **190** in directions orthogonal to the optical axis **160** of the second optical package **190** for optical image stabilization.

In some embodiments, the second camera unit **194** includes a second camera unit for simultaneously capturing at a second image sensor a second image of a second visual field through the second optical package **190**.

In some embodiments, the first camera unit includes a plurality of autofocus coils **130** affixed to the first optical package **192** and situated between the first optical package **192** and respective ones of the first plurality of magnets **120**.

In some embodiments, the second camera **194** unit of the multifunction device is installed in a second camera package located physically adjacent to a first camera package in which the first camera module or first camera unit **196** is installed, and the second camera unit is located in a position along a line orthogonal to the first magnetic axis.

FIG. **2** illustrates a schematic of an actuator mechanism **200** which includes a magnet **201** and flat coil assembly **210** configuration, according to some embodiments. A magnet **201** and accompanying magnetic field **230** are shown in conjunction with a flat coil assembly **210**. Based at least in part upon the magnetic field **230** generated by magnet **201**, electric current applied to flat coil assembly **210** can result in the generation of Lorentz forces **230**, which can result in force being applied to various components coupled to the flat coil assembly **210**.

FIG. **3** illustrates a schematic view of a magnet and coil configuration, according to some embodiments. FIG. **3** is a schematic representation **300** of a cross-section, through one magnet **302**, the autofocus coil **304** and an optical image stabilization coil **306**. A magnetic field component **308** is 'horizontal' and enables the Lorentz force for the autofocus function **310**. However, also note that the fringing field **312** cuts through each half of the optical image stabilization coil **306**, with the 'vertical' component of the field **312** in the opposite direction in each half of the optical image stabilization coil **306**. Note also that since the optical image stabilization coil **306** is contiguous, the direction of current flow in each half of the optical image stabilization coil **306** is also opposite. This is illustrated by the 'dots' **314** in each wire of one half of optical image stabilization coil **306** indicating current coming out of the page, whilst the 'crosses' **316** in each wire of the other half of optical image stabilization coil **306** indicating current going into the page. Hence the Lorentz force **318** generated in each half of optical image stabilization coil **306** is in the same direction, in this case to the right. And the Lorentz force in the autofocus coil **310** is upwards.

FIG. **4** illustrates arrangement of magnets in a dual camera arrangement, according to at least some embodiments. A first plurality of magnets **488** is shown with a plurality of magnetic field vectors **490** for the first plurality of magnets. A second plurality of magnets **484** is shown with a plurality of magnetic field vectors **486** for the second plurality of magnets. A third plurality of magnets **482** is shown with a plurality of magnetic field vectors **400** for the first plurality of magnets.

In some embodiments, a first camera unit includes an autofocus actuator and a first image sensor. The autofocus actuator includes a first plurality of magnets **488** for autofocus motion control of components of a first optical package relative to the image sensor, and the first plurality of magnets is positioned to generate magnetic fields **490** aligned in parallel with a first magnetic axis at a right angle to the optical axis of the first optical package. In some embodiments, a second camera unit includes an optical image stabilization and autofocus actuator and a second image sensor. The optical image stabilization and autofocus actuator includes a second plurality of magnets **484** positioned to generate magnetic fields **486** aligned along a second magnet axis at 45-degrees to the first magnetic axis, and the second camera unit includes a third plurality of magnets **482** positioned to generate magnetic fields **480** aligned along a third magnetic axis at 135-degrees to the first magnetic axis.

FIG. **5** depicts magnetic fields associated with magnets in a dual camera arrangement, according to at least some embodiments. A magnetic simulation **500** is shown. A first plurality of magnets **588** is shown with a plurality of magnetic field vectors for the first plurality of magnets. A second plurality of magnets **584** is shown with a plurality of magnetic field vectors for the second plurality of magnets. A third plurality of magnets **582** is shown with a plurality of magnetic field vectors for the third plurality of magnets. Out of plane flux vectors **520** demonstrate minimal interaction between the OIS and AF modules.

FIG. **6** illustrates an actuator in top view with the outer screening can and yoke hidden, according to some embodiments. Some embodiments feature advantageous arrangement of the position and orientation of the magnets **602-608**, with the magnets **602-608** at the corners, where the magnet, and its poling direction are substantially 45 degrees to each side **622-628** of the actuator module **600**. Optical image stabilization coils **612-618** can be seen either side of the magnets **602-608** (although one part is hidden by the autofocus coil and lens carrier). Some embodiments exploit the observation that, for some applications, the X dimension of the camera is less important than the Y dimension, and the magnets and optical image stabilization coils **612-618** are moved around the lens to eliminate any impact on the Y dimension.

Some embodiments still maintain the 45 degree angle of the magnets **602-608** and optical image stabilization coils **612-618**, so that each pair of optical image stabilization coils **612-618** produces forces substantially orthogonal to the other. However, now each of optical image stabilization coils **612-618** produces a force on the autofocus mechanism that no longer acts through the optical axis, and hence generates a torque around the lens. To combat this, it may be noted that the torque produced by each of optical image stabilization coils **612-618** is nominally equal in magnitude and opposite in direction to the torque produced by its diagonally opposite partner, hence there is nominally no net torque from the pair of optical image stabilization coils **612-618**.

In addition, some embodiments provide a mapping to convert the handshake tilt as measured by a tilt sensor (most typically the gyroscope) to movement of the lens in the directions of the two 45 degree axes. In some embodiments, this configuration of magnets **602-608** and optical image stabilization coils **612-618** eliminates the impact on the camera Y dimension from the presence of these components, and the use of the fringing field.

FIG. **7** illustrates a side view of an example actuator module included in a camera component and configured to adjust a mobile component which includes a lens carrier along an optical axis relative to an image sensor, according to some embodiments. The actuator module **700** can be included in the actuator module **100** illustrated in FIG. **1**A-B. The flat coil assemblies **704**A-B illustrated in FIG. **7** can include one or more of the flat coil assemblies illustrated in FIG. **2-6**, **10**.

Actuator module **700** includes a base assembly **708**, magnets **706**A-B, cover **712**, and support elements **740**A-B which collectively include a static component assembly. Image sensor **750** can be included in the static component assembly. The actuator module **700** also include an optics carrier **702** which is configured to accommodate one or more optics components **701** and includes the mobile component of the actuator module. The optics carrier **702**, along with the included optics component **701**, and the flat coil assemblies at least partially include the mobile component assembly of the actuator module **700**. The optics carrier can include a threaded optical lens carrier, and the optics component **701** can include one or more optical lenses mounted in the carrier. The actuator module **700** can include at least two separate actuator mechanisms **760**A-B which each include a separate set of magnets **706** and corresponding flat coil assemblies **704** coupled thereto via one or more spring assemblies **730**, **732**.

Each flat coil assembly **704**A-B is electrically coupled to one or more power source connections **785**A-B via a respective electrical terminal **780**A-B which is included in the static component assembly of the actuator module **700**. Each respective flat coil assembly **704**A-B is electrically coupled to a respective electrical terminal **780**A-B via a respective electrical connection **770**A-B. In some embodiments, one or more electrical connections **770**A-B include a flexible electrical connection which is configured to flex, as the mobile component assembly which includes the flat coil assemblies **704**A-B moves along the Z axis, to maintain the electrical connection between the coupled flat coil assembly **704** and electrical terminal **780**. In some embodiments, the flat coil assemblies **704**A-B are electrically coupled together via an electrical circuit (not shown in FIG. **7**), and each power source connection **785**A-B is coupled to a common power source, such that the flat coil assemblies **704**A-B are coupled to the common power source in series. In some embodiments, the flat coil assemblies **704**A-B are each coupled to one or more power sources in parallel.

In the illustrated embodiment, the actuator mechanisms **760** included in the actuator modules are configured to adjustably position the optics carrier along the optical axis to perform auto-focusing of the optics component **701** included in the optics carrier **702**, relative to the image sensor **750**. Such adjustably positioning can include inducing a current in one or more of the flat coil assemblies **704**A-B, via the electrical terminals **780**A-B, such that the one or more flat coil assemblies **704**A-B generate Lorentz forces, based at least in part upon the applied current and the magnetic field generated by one or more of the magnets **906**A-B. The generated Lorentz forces are applied to the optics carrier **702**, thereby causing the optics carrier **702** to be moved along the optical axis to one or more particular positions. The particular position to which the optics carrier is adjustably moved along the optical axis is based at least in part upon the current applied to the one or more flat coil assemblies **704**A-B.

As shown, spring assemblies **730**A-B, **732**A-B couple the flat coil assemblies **704**A-B to corresponding magnets **706**A-B. The spring assemblies exert spring forces on the mobile component assembly, via exerting spring forces upon the flat coil assemblies **704**A-B, as the mobile component assembly moves relative to the static component assembly which includes the magnets **706**A-B. As a result, the range of motion of the mobile component assembly is at least partially restricted, and the spring assemblies are configured to return the mobile component assembly to a particular equilibrium position, relative to at least the image sensor **750**, upon an absence of current through the flat coil assemblies **704**A-B, and thus Lorentz forces generated by same.

Multifunction Device Examples

Embodiments of electronic devices in which embodiments of camera systems **198** as described herein, user interfaces for such devices, and associated processes for using such devices are described. In some embodiments, the device is a portable communications device, such as a mobile telephone, that also contains other functions, such as PDA and/or music player functions. Other portable electronic devices, such as laptops, cell phones, pad devices, or tablet computers with touch-sensitive surfaces (e.g., touch screen displays and/or touch pads), may also be used. It should also be understood that, in some embodiments, the device is not a portable communications device, but is a desktop computer with a touch-sensitive surface (e.g., a touch screen display and/or a touch pad). In some embodiments, the device is a gaming computer with orientation sensors (e.g., orientation sensors in a gaming controller). In other embodiments, the device is not a portable communications device, but is a camera device.

In the discussion that follows, an electronic device that includes a display and a touch-sensitive surface is described. It should be understood, however, that the electronic device may include one or more other physical user-interface devices, such as a physical keyboard, a mouse and/or a joystick.

The device typically supports a variety of applications, such as one or more of the following: a drawing application, a presentation application, a word processing application, a website creation application, a disk authoring application, a spreadsheet application, a gaming application, a telephone application, a video conferencing application, an e-mail application, an instant messaging application, a workout support application, a photo management application, a digital camera application, a digital video camera application, a web browsing application, a digital music player application, and/or a digital video player application.

The various applications that may be executed on the device may one or more common physical user-interface devices, such as the touch-sensitive surface. One or more functions of the touch-sensitive surface as well as corresponding information displayed on the device may be adjusted and/or varied from one application to the next and/or within a respective application. In this way, a common physical architecture (such as the touch-sensitive surface) of the device may support the variety of applications with user interfaces that are intuitive and transparent to the user.

Attention is now directed toward embodiments of portable devices with cameras. FIG. **8** is a block diagram illustrating portable multifunction device **800** with camera **864** in accordance with some embodiments. Camera **864** is sometimes called an "optical sensor" for convenience, and may also be known as or called an optical sensor system. Embodiments of an actuator module **100**, **700**, etc., including one or more actuator modules that includes passive damping for auto-focusing, may be used in the optical sensor/camera(s) **864** of a device **800**.

Device **800** may include memory **802** (which may include one or more computer readable storage mediums), memory controller **822**, one or more processing units (CPU's) **820**, peripherals interface **818**, RF circuitry **808**, audio circuitry **810**, speaker **88**, touch-sensitive display system **812**, microphone **813**, input/output (I/O) subsystem **806**, other input or control devices **816**, and external port **824**. Device **800** may include one or more optical sensors **864**. These components may communicate over one or more communication buses or signal lines **803**.

It should be appreciated that device **800** is only one example of a portable multifunction device, and that device **800** may have more or fewer components than shown, may combine two or more components, or may have a different configuration or arrangement of the components. The various components shown in FIG. **8** may be implemented in hardware, software, or a combination of hardware and software, including one or more signal processing and/or application specific integrated circuits.

Memory **802** may include high-speed random access memory and may also include non-volatile memory, such as one or more magnetic disk storage devices, flash memory devices, or other non-volatile solid-state memory devices. Access to memory **802** by other components of device **800**, such as CPU **820** and the peripherals interface **818**, may be controlled by memory controller **822**.

Peripherals interface **818** can be used to couple input and output peripherals of the device to CPU **820** and memory **802**. The one or more processors **820** run or execute various software programs and/or sets of instructions stored in memory **802** to perform various functions for device **800** and to process data.

In some embodiments, peripherals interface **818**, CPU **820**, and memory controller **822** may be implemented on a single chip, such as chip **804**. In some other embodiments, they may be implemented on separate chips.

RF (radio frequency) circuitry **808** receives and sends RF signals, also called electromagnetic signals. RF circuitry **808** converts electrical signals to/from electromagnetic signals and communicates with communications networks and other communications devices via the electromagnetic signals. RF circuitry **808** may include well-known circuitry for performing these functions, including but not limited to an antenna system, an RF transceiver, one or more amplifiers, a tuner, one or more oscillators, a digital signal processor, a CODEC chipset, a subscriber identity module (SIM) card, memory, and so forth. RF circuitry **808** may communicate with networks, such as the Internet, also referred to as the World Wide Web (WWW), an intranet and/or a wireless network, such as a cellular telephone network, a wireless local area network (LAN) and/or a metropolitan area network (MAN), and other devices by wireless communication. The wireless communication may use any of a variety of communications standards, protocols and technologies, including but not limited to Global System for Mobile Communications (GSM), Enhanced Data GSM Environment (EDGE), high-speed downlink packet access (HSDPA), high-speed uplink packet access (HSUPA), wideband code division multiple access (W-CDMA), code division multiple access (CDMA), time division multiple access (TDMA), Bluetooth, Wireless Fidelity (Wi-Fi) (e.g., IEEE 802.8a, IEEE 802.8b, IEEE 802.8g and/or IEEE 802.8n), voice over Internet Protocol (VoIP), Wi-MAX, a protocol for e-mail (e.g., Internet message access protocol (IMAP) and/or post office protocol (POP)), instant messaging (e.g., extensible messaging and presence protocol (XMPP), Session Initiation Protocol for Instant Messaging and Presence Leveraging Extensions (SIMPLE), Instant Messaging and Presence Service (IMPS)), and/or Short Message Service (SMS), or any other suitable communication protocol, including communication protocols not yet developed as of the filing date of this document.

Audio circuitry **810**, speaker **88**, and microphone **813** provide an audio interface between a user and device **800**. Audio circuitry **810** receives audio data from peripherals interface **818**, converts the audio data to an electrical signal, and transmits the electrical signal to speaker **88**. Speaker **88** converts the electrical signal to human-audible sound waves. Audio circuitry **810** also receives electrical signals converted by microphone **813** from sound waves. Audio circuitry **810** converts the electrical signal to audio data and transmits the audio data to peripherals interface **818** for processing. Audio data may be retrieved from and/or transmitted to memory **102** and/or RF circuitry **808** by peripherals interface **818**. In some embodiments, audio circuitry **810** also includes a headset jack (e.g., **812**, FIG. **8**). The headset jack provides an interface between audio circuitry **810** and removable audio input/output peripherals, such as output-only headphones or a headset with both output (e.g., a headphone for one or both ears) and input (e.g., a microphone).

I/O subsystem **806** couples input/output peripherals on device **800**, such as touch screen **812** and other input control devices **816**, to peripherals interface **818**. I/O subsystem **806** may include display controller **856** and one or more input controllers **860** for other input or control devices. The one or more input controllers **160** receive/send electrical signals from/to other input or control devices **816**. The other input control devices **816** may include physical buttons (e.g., push buttons, rocker buttons, etc.), dials, slider switches, joysticks, click wheels, and so forth. In some alternative embodiments, input controller(s) **860** may be coupled to any (or none) of the following: a keyboard, infrared port, USB port, and a pointer device such as a mouse. The one or more buttons (e.g., **808**, FIG. **8**) may include an up/down button for volume control of speaker **88** and/or microphone **813**. The one or more buttons may include a push button (e.g., **806**, FIG. **8**).

Touch-sensitive display **812** provides an input interface and an output interface between the device and a user. Display controller **856** receives and/or sends electrical signals from/to touch screen **812**. Touch screen **812** displays visual output to the user. The visual output may include graphics, text, icons, video, and any combination thereof (collectively termed "graphics"). In some embodiments, some or all of the visual output may correspond to user-interface objects.

Touch screen **812** has a touch-sensitive surface, sensor or set of sensors that accepts input from the user based on haptic and/or tactile contact. Touch screen **812** and display controller **856** (along with any associated modules and/or sets of instructions in memory **802**) detect contact (and any movement or breaking of the contact) on touch screen **812** and converts the detected contact into interaction with user-interface objects (e.g., one or more soft keys, icons, web pages or images) that are displayed on touch screen **812**. In an example embodiment, a point of contact between touch screen **812** and the user corresponds to a finger of the user.

Touch screen **812** may use LCD (liquid crystal display) technology, LPD (light emitting polymer display) technology, or LED (light emitting diode) technology, although other display technologies may be used in other embodiments. Touch screen **812** and display controller **856** may detect contact and any movement or breaking thereof using any of a variety of touch sensing technologies now known or later developed, including but not limited to capacitive, resistive, infrared, and surface acoustic wave technologies, as well as other proximity sensor arrays or other elements for determining one or more points of contact with touch screen **812**. In an example embodiment, projected mutual capacitance sensing technology may be used.

Touch screen **812** may have a video resolution in excess of 100 dots per inch (dpi). In some embodiments, the touch screen has a video resolution of approximately 160 dpi. The user may make contact with touch screen **812** using any suitable object or appendage, such as a stylus, a finger, and so forth. In some embodiments, the user interface is designed to work primarily with finger-based contacts and gestures, which can be less precise than stylus-based input due to the larger area of contact of a finger on the touch screen. In some embodiments, the device translates the rough finger-based input into a precise pointer/cursor position or command for performing the actions desired by the user.

In some embodiments, in addition to the touch screen, device **800** may include a touchpad (not shown) for activating or deactivating particular functions. In some embodiments, the touchpad is a touch-sensitive area of the device that, unlike the touch screen, does not display visual output. The touchpad may be a touch-sensitive surface that is separate from touch screen **812** or an extension of the touch-sensitive surface formed by the touch screen.

Device **800** also includes power system **862** for powering the various components. Power system **862** may include a power management system, one or more power sources (e.g., battery, alternating current (AC)), a recharging system, a power failure detection circuit, a power converter or inverter, a power status indicator (e.g., a light-emitting diode (LED)) and any other components associated with the generation, management and distribution of power in portable devices.

Device **800** may also include one or more optical sensors or cameras **864**. FIG. **8** shows an optical sensor coupled to optical sensor controller **858** in I/O subsystem **806**. Optical sensor **864** may include charge-coupled device (CCD) or complementary metal-oxide semiconductor (CMOS) phototransistors. Optical sensor **864** receives light from the environment, projected through one or more lens, and converts the light to data representing an image. In conjunction with imaging module **843** (also called a camera module), optical sensor **864** may capture still images or video. In some embodiments, an optical sensor is located on the back of device **800**, opposite touch screen display **812** on the front of the device, so that the touch screen display may be used as a viewfinder for still and/or video image acquisition. In some embodiments, another optical sensor is located on the front of the device so that the user's image may be obtained for videoconferencing while the user views the other videoconference participants on the touch screen display.

Device **800** may also include one or more proximity sensors **866**. FIG. **8** shows proximity sensor **866** coupled to peripherals interface **818**. Alternatively, proximity sensor **866** may be coupled to input controller **860** in I/O subsystem **806**. In some embodiments, the proximity sensor turns off and disables touch screen **812** when the multifunction device is placed near the user's ear (e.g., when the user is making a phone call).

Device **800** includes one or more orientation sensors **868**. In some embodiments, the one or more orientation sensors include one or more accelerometers (e.g., one or more linear accelerometers and/or one or more rotational accelerometers). In some embodiments, the one or more orientation sensors include one or more gyroscopes. In some embodiments, the one or more orientation sensors include one or more magnetometers. In some embodiments, the one or more orientation sensors include one or more of global positioning system (GPS), Global Navigation Satellite System (GLONASS), and/or other global navigation system receivers. The GPS, GLONASS, and/or other global navigation system receivers may be used for obtaining information concerning the location and orientation (e.g., portrait or landscape) of device **800**. In some embodiments, the one or more orientation sensors include any combination of orientation/rotation sensors. FIG. **8** shows the one or more orientation sensors **868** coupled to peripherals interface **818**. Alternatively, the one or more orientation sensors **868** may be coupled to an input controller **860** in I/O subsystem **806**. In some embodiments, information is displayed on the touch screen display in a portrait view or a landscape view based on an analysis of data received from the one or more orientation sensors.

In some embodiments, the software components stored in memory **802** include operating system **826**, communication module (or set of instructions) **828**, contact/motion module (or set of instructions) **830**, graphics module (or set of instructions) **832**, text input module (or set of instructions) **834**, Global Positioning System (GPS) module (or set of instructions) **835**, arbiter module **857** and applications (or sets of instructions) **836**. Furthermore, in some embodiments memory **802** stores device/global internal state **857**, as shown in FIGS. **1**A-B and **7**. Device/global internal state **857** includes one or more of: active application state, indicating which applications, if any, are currently active; display state, indicating what applications, views or other information occupy various regions of touch screen display **812**; sensor state, including information obtained from the device's various sensors and input control devices **816**; and location information concerning the device's location and/or attitude.

Operating system **826** (e.g., Darwin, RTXC, LINUX, UNIX, OS X, WINDOWS, or an embedded operating system such as VxWorks) includes various software components and/or drivers for controlling and managing general system tasks (e.g., memory management, storage device control, power management, etc.) and facilitates communication between various hardware and software components.

Communication module **828** facilitates communication with other devices over one or more external ports **824** and also includes various software components for handling data received by RF circuitry **808** and/or external port **824**. External port **824** (e.g., Universal Serial Bus (USB), FIREWIRE, etc.) is adapted for coupling directly to other devices or indirectly over a network (e.g., the Internet, wireless LAN, etc.).

Contact/motion module **830** may detect contact with touch screen **812** (in conjunction with display controller **856**) and other touch sensitive devices (e.g., a touchpad or physical click wheel). Contact/motion module **830** includes various software components for performing various operations related to detection of contact, such as determining if contact has occurred (e.g., detecting a finger-down event), determining if there is movement of the contact and tracking the movement across the touch-sensitive surface (e.g., detecting one or more finger-dragging events), and determining if the contact has ceased (e.g., detecting a finger-up event or a break in contact). Contact/motion module **830** receives contact data from the touch-sensitive surface. Determining movement of the point of contact, which is represented by a series of contact data, may include determining speed (magnitude), velocity (magnitude and direction), and/or an acceleration (a change in magnitude and/or direction) of the point of contact. These operations may be applied to single contacts (e.g., one finger contacts) or to multiple simultaneous contacts (e.g., "multitouch"/multiple finger contacts). In some embodiments, contact/motion module **830** and display controller **856** detect contact on a touchpad.

Contact/motion module **830** may detect a gesture input by a user. Different gestures on the touch-sensitive surface have different contact patterns. Thus, a gesture may be detected by detecting a particular contact pattern. For example, detecting a finger tap gesture includes detecting a finger-down event followed by detecting a finger-up (lift off) event at the same position (or substantially the same position) as the finger-down event (e.g., at the position of an icon). As another example, detecting a finger swipe gesture on the touch-sensitive surface includes detecting a finger-down event followed by detecting one or more finger-dragging events, and subsequently followed by detecting a finger-up (lift off) event.

Graphics module **832** includes various known software components for rendering and displaying graphics on touch screen **812** or other display, including components for changing the intensity of graphics that are displayed. As used herein, the term "graphics" includes any object that can be displayed to a user, including without limitation text, web pages, icons (such as user-interface objects including soft keys), digital images, videos, animations and the like.

In some embodiments, graphics module **832** stores data representing graphics to be used. Each graphic may be assigned a corresponding code. Graphics module **832** receives, from applications etc., one or more codes specifying graphics to be displayed along with, if necessary, coordinate data and other graphic property data, and then generates screen image data to output to display controller **856**.

Text input module **834**, which may be a component of graphics module **832**, provides soft keyboards for entering text in various applications (e.g., contacts **837**, e-mail **840**, IM **141**, browser **847**, and any other application that needs text input).

GPS module **835** determines the location of the device and provides this information for use in various applications (e.g., to telephone **838** for use in location-based dialing, to camera module **843** as picture/video metadata, and to applications that provide location-based services such as weather widgets, local yellow page widgets, and map/navigation widgets).

Applications **836** may include the following modules (or sets of instructions), or a subset or superset thereof:

- contacts module **837** (sometimes called an address book or contact list);
- telephone module **838**;
- video conferencing module **839**;
- e-mail client module **840**;
- instant messaging (IM) module **841**;
- workout support module **842**;
- camera module **843** for still and/or video images;
- image management module **844**;
- browser module **847**;
- calendar module **848**;
- widget modules **849**, which may include one or more of: weather widget **849-1**, stocks widget **849-2**, calculator widget **849-3**, alarm clock widget **849-4**, dictionary widget **849-5**, and other widgets obtained by the user, as well as user-created widgets **849-6**;
- widget creator module **850** for making user-created widgets **849-6**;
- search module **851**;
- video and music player module **852**, which may be made up of a video player
- module and a music player module;
- notes module **853**;
- map module **854**; and/or
- online video module **855**.

Examples of other applications **836** that may be stored in memory **802** include other word processing applications, other image editing applications, drawing applications, presentation applications, JAVA-enabled applications, encryption, digital rights management, voice recognition, and voice replication.

In conjunction with touch screen **812**, display controller **856**, contact module **830**, graphics module **832**, and text input module **834**, contacts module **837** may be used to manage an address book or contact list (e.g., stored in application internal state **892** of contacts module **837** in memory **802**), including: adding name(s) to the address book; deleting name(s) from the address book; associating telephone number(s), e-mail address(es), physical address(es) or other information with a name; associating an image with a name; categorizing and sorting names; providing telephone numbers or e-mail addresses to initiate and/or facilitate communications by telephone **838**, video conference **839**, e-mail **840**, or IM **841**; and so forth.

In conjunction with RF circuitry **808**, audio circuitry **810**, speaker **88**, microphone **813**, touch screen **812**, display controller **856**, contact module **830**, graphics module **832**, and text input module **834**, telephone module **838** may be used to enter a sequence of characters corresponding to a telephone number, access one or more telephone numbers in address book **837**, modify a telephone number that has been entered, dial a respective telephone number, conduct a conversation and disconnect or hang up when the conversation is completed. As noted above, the wireless communication may use any of a variety of communications standards, protocols and technologies.

In conjunction with RF circuitry **808**, audio circuitry **810**, speaker **88**, microphone **813**, touch screen **812**, display controller **856**, optical sensor **864**, optical sensor controller **858**, contact module **830**, graphics module **832**, text input module **834**, contact list **837**, and telephone module **838**, videoconferencing module **89** includes executable instructions to initiate, conduct, and terminate a video conference between a user and one or more other participants in accordance with user instructions.

In conjunction with RF circuitry **808**, touch screen **812**, display controller **856**, contact module **830**, graphics module **832**, and text input module **834**, e-mail client module **840** includes executable instructions to create, send, receive, and manage e-mail in response to user instructions. In conjunction with image management module **844**, e-mail client module **840** makes it very easy to create and send e-mails with still or video images taken with camera module **843**.

In conjunction with RF circuitry **808**, touch screen **812**, display controller **856**, contact module **830**, graphics module **832**, and text input module **834**, the instant messaging module **841** includes executable instructions to enter a sequence of characters corresponding to an instant message, to modify previously entered characters, to transmit a respective instant message (for example, using a Short Message Service (SMS) or Multimedia Message Service (MMS) protocol for telephony-based instant messages or using XMPP, SIMPLE, or IMPS for Internet-based instant messages), to receive instant messages and to view received instant messages. In some embodiments, transmitted and/or received instant messages may include graphics, photos, audio files, video files and/or other attachments as are supported in a MMS and/or an Enhanced Messaging Service (EMS). As used herein, "instant messaging" refers to both telephony-based messages (e.g., messages sent using SMS or MMS) and Internet-based messages (e.g., messages sent using XMPP, SIMPLE, or IMPS).

In conjunction with RF circuitry **808**, touch screen **812**, display controller **856**, contact module **830**, graphics module **832**, text input module **834**, GPS module **835**, map module **854**, and music player module **846**, workout support module **842** includes executable instructions to create workouts (e.g., with time, distance, and/or calorie burning goals); communicate with workout sensors (sports devices); receive workout sensor data; calibrate sensors used to monitor a workout; select and play music for a workout; and display, store and transmit workout data.

In conjunction with touch screen **812**, display controller **856**, optical sensor(s) **864**, optical sensor controller **858**, contact module **830**, graphics module **832**, and image management module **844**, camera module **843** includes executable instructions to capture still images or video (including a video stream) and store them into memory **802**, modify characteristics of a still image or video, or delete a still image or video from memory **802**.

In conjunction with touch screen **812**, display controller **856**, contact module **830**, graphics module **832**, text input module **834**, and camera module **843**, image management module **844** includes executable instructions to arrange, modify (e.g., edit), or otherwise manipulate, label, delete, present (e.g., in a digital slide show or album), and store still and/or video images.

In conjunction with RF circuitry **808**, touch screen **812**, display system controller **856**, contact module **830**, graphics module **832**, and text input module **834**, browser module **847** includes executable instructions to browse the Internet in accordance with user instructions, including searching, linking to, receiving, and displaying web pages or portions thereof, as well as attachments and other files linked to web pages.

In conjunction with RF circuitry **808**, touch screen **812**, display system controller **856**, contact module **830**, graphics module **832**, text input module **834**, e-mail client module **840**, and browser module **847**, calendar module **848** includes executable instructions to create, display, modify, and store calendars and data associated with calendars (e.g., calendar entries, to do lists, etc.) in accordance with user instructions.

In conjunction with RF circuitry **808**, touch screen **812**, display system controller **856**, contact module **830**, graphics module **832**, text input module **834**, and browser module **847**, widget modules **849** are mini-applications that may be downloaded and used by a user (e.g., weather widget **849-1**, stocks widget **849-2**, calculator widget **8493**, alarm clock widget **849-4**, and dictionary widget **849-5**) or created by the user (e.g., user-created widget **849-6**). In some embodiments, a widget includes an HTML (Hypertext Markup Language) file, a CSS (Cascading Style Sheets) file, and a JavaScript file. In some embodiments, a widget includes an XML (Extensible Markup Language) file and a JavaScript file (e.g., Yahoo! Widgets).

In conjunction with RF circuitry **808**, touch screen **812**, display system controller **856**, contact module **830**, graphics module **832**, text input module **834**, and browser module **847**, the widget creator module **850** may be used by a user to create widgets (e.g., turning a user-specified portion of a web page into a widget).

In conjunction with touch screen **812**, display system controller **856**, contact module **830**, graphics module **832**, and text input module **834**, search module **851** includes executable instructions to search for text, music, sound, image, video, and/or other files in memory **802** that match one or more search criteria (e.g., one or more user-specified search terms) in accordance with user instructions.

In conjunction with touch screen **812**, display system controller **856**, contact module **830**, graphics module **832**, audio circuitry **810**, speaker **88**, RF circuitry **808**, and browser module **847**, video and music player module **852** includes executable instructions that allow the user to download and play back recorded music and other sound files stored in one or more file formats, such as MP3 or AAC files, and executable instructions to display, present or otherwise play back videos (e.g., on touch screen **812** or on an external, connected display via external port **824**). In some embodiments, device **800** may include the functionality of an MP3 player.

In conjunction with touch screen **812**, display controller **856**, contact module **830**, graphics module **832**, and text input module **834**, notes module **853** includes executable instructions to create and manage notes, to do lists, and the like in accordance with user instructions.

In conjunction with RF circuitry **808**, touch screen **812**, display system controller **856**, contact module **830**, graphics module **832**, text input module **834**, GPS module **835**, and browser module **847**, map module **854** may be used to receive, display, modify, and store maps and data associated with maps (e.g., driving directions; data on stores and other points of interest at or near a particular location; and other location-based data) in accordance with user instructions.

In conjunction with touch screen **812**, display system controller **856**, contact module **830**, graphics module **832**, audio circuitry **810**, speaker **88**, RF circuitry **808**, text input module **834**, e-mail client module **840**, and browser module **847**, online video module **855** includes instructions that allow the user to access, browse, receive (e.g., by streaming and/or download), play back (e.g., on the touch screen or on an external, connected display via external port **824**), send an e-mail with a link to a particular online video, and otherwise manage online videos in one or more file formats, such as H.264. In some embodiments, instant messaging module **841**, rather than e-mail client module **840**, is used to send a link to a particular online video.

Each of the above identified modules and applications correspond to a set of executable instructions for performing one or more functions described above and the methods described in this application (e.g., the computer-implemented methods and other information processing methods described herein). These modules (i.e., sets of instructions) need not be implemented as separate software programs, procedures or modules, and thus various subsets of these modules may be combined or otherwise re-arranged in various embodiments. In some embodiments, memory **802** may store a subset of the modules and data structures identified above. Furthermore, memory **802** may store additional modules and data structures not described above.

In some embodiments, device **800** is a device where operation of a predefined set of functions on the device is performed exclusively through a touch screen and/or a touchpad. By using a touch screen and/or a touchpad as the primary input control device for operation of device **800**, the number of physical input control devices (such as push buttons, dials, and the like) on device **800** may be reduced.

The predefined set of functions that may be performed exclusively through a touch screen and/or a touchpad include navigation between user interfaces. In some embodiments, the touchpad, when touched by the user, navigates device **800** to a main, home, or root menu from any user interface that may be displayed on device **800**. In such embodiments, the touchpad may be referred to as a "menu button." In some other embodiments, the menu button may be a physical push button or other physical input control device instead of a touchpad.

FIG. **9** illustrates a portable multifunction device **800** having a touch screen **812** and a camera system **864** in accordance with some embodiments. The touch screen may display one or more graphics within user interface (UI) **900**. In this embodiment, as well as others described below, a user may select one or more of the graphics by making a gesture on the graphics, for example, with one or more fingers **902** (not drawn to scale in the Figure) or one or more styluses **903** (not drawn to scale in the figure).

Device **800** may also include one or more physical buttons, such as "home" or menu button **904**. As described previously, menu button **904** may be used to navigate to any application **836** in a set of applications that may be executed on device **800**. Alternatively, in some embodiments, the menu button is implemented as a soft key in a graphics user interface (GUI) displayed on touch screen **812**.

In one embodiment, device **800** includes touch screen **812**, menu button **904**, push button **906** for powering the device on/off and locking the device, volume adjustment button(s) **908**, Subscriber Identity Module (SIM) card slot **910**, head set jack **99**, and docking/charging external port **824**. Push button **906** may be used to turn the power on/off on the device by depressing the button and holding the button in the depressed state for a predefined time interval; to lock the device by depressing the button and releasing the button before the predefined time interval has elapsed; and/or to unlock the device or initiate an unlock process. In an alternative embodiment, device **800** also may accept verbal input for activation or deactivation of some functions through microphone **813**.

It should be noted that, although many of the examples herein are given with reference to optical sensor/camera **864** (on the front of a device), a rear-facing camera system or optical sensor that is pointed opposite from the display may be used instead of or in addition to an optical sensor/camera or camera system **864** on the front of a device. Embodiments of camera system as described herein that includes passive damping for optical image stabilization (OIS) may be used in the optical sensor/camera(s) **864**.

Example Computer System

FIG. **10** illustrates an example computer system **1000** that may be configured to include or execute any or all of the embodiments described above. In different embodiments, computer system **1000** may be any of various types of devices, including, but not limited to, a personal computer system, desktop computer, laptop, notebook, tablet, slate, pad, or netbook computer, cell phone, smartphone, PDA, portable media device, mainframe computer system, handheld computer, workstation, network computer, a camera or video camera, a set top box, a mobile device, a consumer device, video game console, handheld video game device, application server, storage device, a television, a video recording device, a peripheral device such as a switch, modem, router, or in general any type of computing or electronic device.

Various embodiments of a camera motion control system as described herein, may be executed in one or more computer systems **1000**, which may interact with various other devices. Note that any component, action, or functionality described above with respect to FIGS. **1** through **9** may be implemented on one or more computers configured as computer system **1000** of FIG. **10**, equipped with cameras **1085** and camera systems as input/output devices **1050** according to various embodiments. In the illustrated embodiment, computer system **1000** includes one or more processors **1010** coupled to a system memory **1020** via an input/output (I/O) interface **1030**. Computer system **1000** further includes a network interface **1040** coupled to I/O interface **1030**, and one or more input/output devices **1050**, such as cursor control device **1060**, keyboard **1070**, and display(s) **1080**. In some cases, it is contemplated that embodiments may be implemented using a single instance of computer system **1000**, while in other embodiments multiple such systems, or multiple nodes making up computer system **1000**, may be configured to host different portions or instances of embodiments. For example, in one embodiment some elements may be implemented via one or more nodes of computer system **1000** that are distinct from those nodes implementing other elements.

In various embodiments, computer system **1000** may be a uniprocessor system including one processor **1010**, or a multiprocessor system including several processors **1010** (e.g., two, four, eight, or another suitable number). Processors **1010** may be any suitable processor capable of executing instructions. For example, in various embodiments processors **1010** may be general-purpose or embedded processors implementing any of a variety of instruction set architectures (ISAs), such as the x8 10, PowerPC, SPARC, or MIPS ISAs, or any other suitable ISA. In multiprocessor systems, each of processors **1010** may commonly, but not necessarily, implement the same ISA.

System memory **1020** may be configured to store camera control program instructions **1022** and/or camera control data accessible by processor **1010**. In various embodiments, system memory **1020** may be implemented using any suitable memory technology, such as static random access memory (SRAM), synchronous dynamic RAM (SDRAM), nonvolatile/Flash-type memory, or any other type of memory. In the illustrated embodiment, program instructions **1022** may be configured to implement a lens control application **1024** incorporating any of the functionality described above. Additionally, existing camera control data **1032** of memory **1020** may include any of the information or data structures described above. In some embodiments, program instructions and/or data may be received, sent or stored upon different types of computer-accessible media or on similar media separate from system memory **1020** or computer system **1000**. While computer system **1000** is described as implementing the functionality of functional blocks of previous Figures, any of the functionality described herein may be implemented via such a computer system.

In one embodiment, I/O interface **1030** may be configured to coordinate I/O traffic between processor **1010**, system memory **1020**, and any peripheral devices in the device, including network interface **1040** or other peripheral interfaces, such as input/output devices **1050**. In some embodiments, I/O interface **1030** may perform any necessary protocol, timing or other data transformations to convert data signals from one component (e.g., system memory **1020**) into a format suitable for use by another component (e.g., processor **1010**). In some embodiments, I/O interface **1030** may include support for devices attached through various types of peripheral buses, such as a variant of the Peripheral Component Interconnect (PCI) bus standard or the Universal Serial Bus (USB) standard, for example. In some embodiments, the function of I/O interface **1030** may be split into two or more separate components, such as a north bridge and a south bridge, for example. Also, in some embodiments some or all of the functionality of I/O interface **1030**, such as an interface to system memory **1020**, may be incorporated directly into processor **1010**.

Network interface **1040** may be configured to allow data to be exchanged between computer system **1000** and other devices attached to a network **1085** (e.g., carrier or agent devices) or between nodes of computer system **1000**. Network **1085** may in various embodiments include one or more networks including but not limited to Local Area Networks (LANs) (e.g., an Ethernet or corporate network), Wide Area Networks (WANs) (e.g., the Internet), wireless data networks, some other electronic data network, or some combination thereof. In various embodiments, network interface **1040** may support communication via wired or wireless general data networks, such as any suitable type of Ethernet network, for example; via telecommunications/telephony networks such as analog voice networks or digital fiber communications networks; via storage area networks such as Fibre Channel SANs, or via any other suitable type of network and/or protocol.

Input/output devices **1050** may, in some embodiments, include one or more display terminals, keyboards, keypads, touchpads, scanning devices, voice or optical recognition devices, or any other devices suitable for entering or accessing data by one or more computer systems **1000**. Multiple input/output devices **1050** may be present in computer system **1000** or may be distributed on various nodes of computer system **1000**. In some embodiments, similar input/output devices may be separate from computer system **1000** and may interact with one or more nodes of computer system **1000** through a wired or wireless connection, such as over network interface **1040**.

As shown in FIG. **10**, memory **1020** may include program instructions **1022**, which may be processor-executable to implement any element or action described above. In one embodiment, the program instructions may implement the methods described above. In other embodiments, different elements and data may be included. Note that data may include any data or information described above.

Those skilled in the art will appreciate that computer system **1000** is merely illustrative and is not intended to limit the scope of embodiments. In particular, the computer system and devices may include any combination of hardware or software that can perform the indicated functions, including computers, network devices, Internet appliances, PDAs, wireless phones, pagers, etc. Computer system **1000** may also be connected to other devices that are not illustrated, or instead may operate as a stand-alone system. In addition, the functionality provided by the illustrated components may in some embodiments be combined in fewer components or distributed in additional components. Similarly, in some embodiments, the functionality of some of the illustrated components may not be provided and/or other additional functionality may be available.

Those skilled in the art will also appreciate that, while various items are illustrated as being stored in memory or on storage while being used, these items or portions of them may be transferred between memory and other storage devices for purposes of memory management and data integrity. Alternatively, in other embodiments some or all of the software components may execute in memory on another device and communicate with the illustrated computer system via inter-computer communication. Some or all of the system components or data structures may also be stored (e.g., as instructions or structured data) on a computer-accessible medium or a portable article to be read by an appropriate drive, various examples of which are described above. In some embodiments, instructions stored on a computer-accessible medium separate from computer system **1000** may be transmitted to computer system **1000** via transmission media or signals such as electrical, electromagnetic, or digital signals, conveyed via a communication medium such as a network and/or a wireless link. Various embodiments may further include receiving, sending or storing instructions and/or data implemented in accordance with the foregoing description upon a computer-accessible medium. Generally speaking, a computer-accessible medium may include a non-transitory, computer-readable storage medium or memory medium such as magnetic or optical media, e.g., disk or DVD/CD-ROM, volatile or non-volatile media such as RAM (e.g. SDRAM, DDR, RDRAM, SRAM, etc.), ROM, etc. In some embodiments, a computer-accessible medium may include transmission media or signals such as electrical, electromagnetic, or digital signals, conveyed via a communication medium such as network and/or a wireless link.

The methods described herein may be implemented in software, hardware, or a combination thereof, in different embodiments. In addition, the order of the blocks of the methods may be changed, and various elements may be added, reordered, combined, omitted, modified, etc. Various modifications and changes may be made as would be obvious to a person skilled in the art having the benefit of this disclosure. The various embodiments described herein are meant to be illustrative and not limiting. Many variations, modifications, additions, and improvements are possible. Accordingly, plural instances may be provided for components described herein as a single instance. Boundaries between various components, operations and data stores are somewhat arbitrary, and particular operations are illustrated in the context of specific illustrative configurations. Other allocations of functionality are envisioned and may fall within the scope of claims that follow. Finally, structures and functionality presented as discrete components in the example configurations may be implemented as a combined structure or component. These and other variations, modifications, additions, and improvements may fall within the scope of embodiments as defined in the claims that follow.

What is claimed is:

1. A multifunction mobile computing device, comprising:

a first camera unit housed within the multifunction mobile computing device for capturing at a first image sensor a first image of a first visual field through a first optical package, wherein

the first camera unit comprises an autofocus actuator,

the autofocus actuator comprises a first plurality of magnets for autofocus motion control of components of the first optical package, and

the first plurality of magnets is positioned to generate magnetic fields aligned in parallel with a first magnetic axis through a center of the first optical package at a right angle to the optical axis of the first optical package; and

a second camera unit housed within the multifunction mobile computing device, wherein

the second camera unit comprises an optical image stabilization and autofocus actuator,

the optical image stabilization and autofocus actuator comprises a second plurality of magnets positioned to generate magnetic fields aligned along a second magnet axis at a first angle bisecting a right angle relative to the first magnetic axis for optical image stabilization and autofocus motion control of components of the second optical package, and

the second camera unit comprises a third plurality of magnets positioned to generate magnetic fields aligned along a third magnetic axis at a second angle bisecting a right angle relative to the first magnetic axis for optical image stabilization and autofocus motion control of components of a second optical package.

2. The multifunction mobile computing device of claim **1**, wherein

the first camera unit comprises a first optical package with a first focal length for a first visual field,

the second camera unit comprises the second optical package with a second focal length for a second visual field, and

the first focal length is different from the second focal length.

3. The multifunction mobile computing device of claim **1**, wherein

the autofocus actuator is configured to generate motion of the first optical package along an optical axis of the first optical package for autofocus adjustments without optical image stabilization, wherein the first optical package includes a lens and lens carrier.

4. The multifunction mobile computing device of claim **1**, wherein

the optical image stabilization and autofocus actuator is configured both to generate motion of a second optical package along an optical axis of the second optical package for autofocus adjustments and to generate motion of the second optical package in directions orthogonal to the optical axis of the second optical package for optical image stabilization.

5. The multifunction mobile computing device of claim **1**, wherein

the second camera unit comprises a second camera unit for simultaneously capturing at a second image sensor a second image of a second visual field through the second optical package.

6. The multifunction mobile computing device of claim **1**, further comprising

a plurality of autofocus coils affixed to the first optical package and situated between the first optical package and respective ones of the first plurality of magnets.

7. The multifunction mobile computing device of claim **1**, wherein

the second camera unit of the multifunction device is installed in a second camera package located physically adjacent to a first camera package in which the first camera module is installed, and

the second camera unit is located in a position along a line orthogonal to the first magnetic axis.

8. A camera system, comprising:

a first camera unit, wherein

the first camera unit comprises an autofocus actuator,

the autofocus actuator comprises a first plurality of magnets for autofocus motion control of components of a first optical package, and

the first plurality of magnets is positioned to generate magnetic fields aligned in parallel with a first magnetic axis at a right angle to the optical axis of the first optical package; and

a second camera unit, wherein

the second camera unit comprises an optical image stabilization and autofocus actuator,

the optical image stabilization and autofocus actuator comprises a second plurality of magnets positioned to generate magnetic fields aligned along a second magnet axis at 45-degrees to the first magnetic axis, and

the second camera unit comprises a third plurality of magnets positioned to generate magnetic fields aligned along a third magnetic axis at 135-degrees to the first magnetic axis.

9. The camera system of claim **8**, wherein the first camera unit comprises a first optical package with a first focal length, and the second camera unit comprises a second optical package with a second focal length.

10. The camera system of claim **8**, wherein the autofocus actuator is configured to generate motion of the first optical package along an optical axis of the first optical package for autofocus adjustments without optical image stabilization.

11. The camera system of claim **8**, wherein the optical image stabilization and autofocus actuator is configured both to generate motion of a second optical package along an optical axis of the second optical package for autofocus adjustments and to generate motion of the second optical package in directions orthogonal to the optical axis.

12. The camera system of claim **8**, wherein the second camera unit comprises a second camera unit for simultaneously capturing at a second image sensor a second image of a second visual field through the second optical package.

13. The camera system of claim **8**, further comprising a plurality of autofocus coils affixed to the first optical package and situated between the first optical package and respective ones of the first plurality of magnets.

14. The camera system of claim **8**, wherein the second camera unit of the camera system is installed in a second camera package located physically adjacent to a first camera package in which the first camera unit is installed, and the second camera unit is located in a position along a line orthogonal to the first magnetic axis.

15. A camera system, comprising:

a first camera unit, wherein

the first camera unit comprises an autofocus actuator and a first image sensor,

the autofocus actuator comprises a first plurality of magnets for autofocus motion control of components of a first optical package relative to the image sensor, and

the first plurality of magnets is positioned to generate magnetic fields aligned in parallel with a first magnetic axis at a right angle to the optical axis of the first optical package; and

a second camera unit, wherein

the second camera unit comprises an optical image stabilization and autofocus actuator and a second image sensor,

the optical image stabilization and autofocus actuator comprises a second plurality of magnets positioned to generate magnetic fields aligned along a second magnet axis at 45-degrees to the first magnetic axis, and

the second camera unit comprises a third plurality of magnets positioned to generate magnetic fields aligned along a third magnetic axis at 135-degrees to the first magnetic axis.

16. The camera system of claim **15**, wherein the first camera unit comprises a first optical package with a first focal length, the second camera unit comprises a second optical package with a second focal length, the first focal length is different from the second focal length.

17. The camera system of claim **15**, wherein the autofocus actuator is configured to generate motion of the first image sensor along an optical axis of the first optical package for autofocus adjustments without optical image stabilization.

18. The camera system of claim **15**, wherein the optical image stabilization and autofocus actuator is configured both to generate motion of the second image sensor along an optical axis of the second optical package for autofocus adjustments and to generate motion of the second optical package in directions orthogonal to the optical axis.

19. The camera system of claim **15**, further comprising a plurality of autofocus coils affixed to the first optical package and situated between the first optical package and respective ones of the first plurality of magnets.

20. The camera system of claim **15**, wherein the second camera unit of the multifunction device is installed in a second camera package located physically adjacent to a first camera package in which the first camera module is installed, and the second camera unit is located in a position along a line orthogonal to the first magnetic axis.

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