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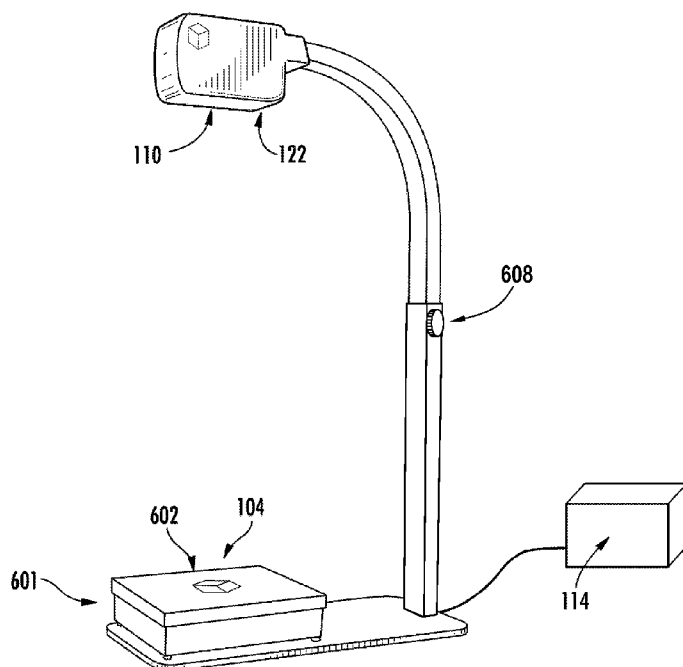


Fig. 6D

(57) Abstract: An apparatus for enrolling a package is disclosed including: a receiving surface for receiving the package; at least one weight sensor in communication with the receiving surface which generates a weight signal indicative of the weight of the package; at least one RGB video camera which generates a first video signal indicative of an image of the package on the receiving surface; at least one infrared three-dimensional camera which generates a second video signal indicative of the dimensions of the package; and a processor in communication with the at least one weight sensor and the at least one video camera.



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ENROLLMENT APPARATUS, SYSTEM, AND METHOD FEATURING THREE DIMENSIONAL CAMERA

CROSS REFERENCE TO RELATED APPLICATIONS

5 The present applications claims the benefit of U.S. Provisional Patent Application Ser. No. 61/485,004, filed May 11, 2011 the entire contents of which are incorporated herein by reference.

 The present application is also related to U.S. Patent Application Ser. No. 12/323,204 filed November 26, 2008 and corresponding U.S. Pat. No. 8,140,395
10 issued on March 20, 2012, the entire contents of each of which are incorporated herein by reference.

 The present application is also related to U.S. Patent Application Ser. No. 13/410,977 filed May 2, 2012, the entire contents of which are incorporated herein by reference.

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BACKGROUND

 In industries such as the postal, courier, and supply chain industries, package
20 objects (e.g. letters or parcels) are enrolled into a system for tracking and/or delivery. For example, items presented at post offices and related locations for onward delivery currently require the counter staff and/or customers to manually enter data regarding address information, weight, dimensional information, and other shipment characteristics. The manual collection of this information is costly,
25 in terms of time, error rates on manual data entry, plus errors in correctly rating items. Retail locations are also typically required to maintain space for both the scale and the metering devices.

 Some postal authorities mandate the capture of additional information for items being accepted across post office counters. It is now a common requirement
30 that dimensions, destination, and sender information be captured. Complexity is increasing while the ability to maintain a well trained counter staff is declining.

Increasing use of franchise points of presence is causing compliance, training, accounting, and security problems.

For example, a customer may bring a package to a post office point of sale. A postal employee will receive the package, gather information related to the package (e.g. intended destination, package dimensions, package weight, type of delivery, desired delivery date, customer information, payment information etc.). In typical situations, the information is gathered manually, and in a highly linear and labor intensive fashion. For example, in a typical transaction, a postal employee might receive a package, weigh it, measure its dimensions with a tape measure, enter this information into a computer, read a label on the package, enter delivery address information found on this label, query the customer about desired delivery type and date, enter this information into a computer, provide pricing information to the customer, accept payment, etc.

Improvement in enrollment efficiency could provide substantial savings in, for example, labor costs, error costs, and time.

SUMMARY

The inventors have realized that enrollment efficiency can be increased by automatically, and substantially simultaneously collecting multiple types of information about an item being enrolled in a delivery system.

In one aspect, an enrollment device is disclosed which will replace both the traditional weigh scale, as well as the postage meter, which are currently found at induction points for Postal, Courier and Supply Chain operations. A combination of Optical Character Recognition (OCR) and dimension capture (e.g. using optical dimension capture and/or ultrasonic range-finding technologies) is used to capture and convert addressing, payment, account and shipment related data, plus weight and dimensional information (when relevant) from packages, letters, and documentation which are placed on, in, or near the device.

Such a device provides a “front end” mechanism for entering shipment related data into a business environment (e. g. postal environment) and simultaneously automates the rating and data collection process for accepting goods

and services, automates the process of capturing dimensional data in the course of rating shipments at point of induction into the business environment, reduces or eliminates the requirement for a separate weigh scale, reduces or eliminates the requirement for a separate metering device, and presents data to the organization's
5 back-end and enterprise systems at point of induction.

In one aspect, an apparatus for enrolling a package is disclosed including: a receiving surface for receiving the package; at least one weight sensor in communication with the receiving surface which generates a weight signal indicative of the weight of the package; at least one video camera which generates a
10 video signal indicative of an image of the package on the receiving surface; and a processor in communication with the at least one weight sensor and the at least one video camera. The processor includes: a weight module which produces, in response to the weight signal, weight data indicative of the weight of the package; and a dimension capture module which produces, in response to the video signal,
15 dimension data indicative of the size of the package. In some embodiments, the processor further includes a recognition module which produces, in response to the video signal, character data indicative of one or more characters present on the package.

Some embodiments include a range finder sensor in communication with the
20 processor which produces a range finder signal indicative of the size of the package, and where the dimension capture module produces, in response to the video signal and the range finder signal, dimension data indicative of the size of the package. In some embodiments, the dimension capture module produces, in response to the video signal, dimension data indicative of the size of the package along two axes
25 lying in a plane substantially parallel to the receiving surface, and produces, in response to the range finder signal, dimension data indicative of the size of the package along an axis transverse to the plane.

In some embodiments, the dimension capture module includes a tracking module which produces, in response to the video signal, tracking data indicative of
30 the presence and location of the package on the receiving surface.

In some embodiments, the at least one camera selectively operates in a first mode characterized by a relatively large field of view to generate a video signal

characterized by a relatively low resolution and relatively high frame rate, and a second mode characterized by a relatively small field of view to generate a video signal characterized by a relatively high resolution and a relatively low frame rate.

5 In some embodiments, the tracking module produces, in response to the video signal generated by the at least one camera in the first mode, tracking data indicative of the presence and location of the package on the receiving surface. The recognition module produces, in response to the video signal generated by the at least one camera in the second mode, character data indicative of one or more characters present on the package.

10 In some embodiments, the dimension capture module includes an edge finder module which produces, in response to the video signal, edge data indicative of the location of one or more edges on the package.

In some embodiments, the dimension capture module includes one or more of: a frame differencing module which generates difference images from two or
15 more images of the video signal; and a color masking module configured to generate information indicative of the presence or location of the package based on color information from the video signal.

In some embodiments, the dimension capture module includes a Hough transformation module which applies the Hough transformation to one or more
20 images from the video signal, and analyzes the transformed images to determine information indicative of the size or location of edges on the package. Some embodiments further include a rectangle tracking module configured to track the location of a substantially rectangular package based on the information indicative of the size or location of edges on the package.

25 In some embodiments, the recognition module includes: an image processing module for processing one or more images from the video signal; and an analysis module which analyzes the one or more processed images to produce the character data indicative of one or more characters present on the package.

In some embodiments, the image processing module includes at least one of:
30 a color manipulating module for modifying the color of the one or more images; a linear filter module for applying a linear image filter to the one or more images; and

a morphological filter module for applying one or more morphological operations to the one or more images.

In some embodiments, the image processing module includes an image segmentation module for segmenting the one or more images into one or more
5 regions of interest based on the content of the images.

In some embodiments, the image processing module includes an image rotation module which rotates at least a portion of the one or more images. In some embodiments, the image rotation module is in communication with the dimension capture module, and rotates at least a portion of the one or more images based on
10 information from the dimension capture module indicative of the location of the package.

In some embodiments, the at least one camera include at least two cameras, each generating a respective video signal, and where the cameras have least partially overlapping fields of view. The processor includes an image stitching module
15 which, in response to the respective video signals, combines overlapping images from the at least two cameras to produce a single image of the combined field of view of the cameras.

In some embodiments, each of the at least one cameras has a respective field of view. Substantially all locations on the receiving surface fall within the
20 respective field of view. In some embodiments, the at least one camera consists of a single camera.

In some embodiments, the receiving surface is at least partially transparent, and where the at least one camera is positioned below the receiving surface to image the package through the receiving surface.

25 In some embodiments, the at least one camera is positioned above the receiving surface.

In some embodiments, the receiving surface includes at least one indicia for aligning or focusing the at least one camera.

In some embodiments, the at least one camera includes an autofocus.

30 Some embodiments include an integrated housing including the receiving surface and processor.

Some embodiments include an arm extending between a proximal end connected to the housing and a distal end positioned above the receiving surface, the distal end including at least one chosen from the group consisting of: a range finder, and the at least one camera.

5 Some embodiments include an RFID reader, and/or a bar code reader.

In some embodiments, the rangefinder includes at least one of: an ultrasonic range finder, a RADAR range finder, a LIDAR range finder, a laser range finder, an LED based range finder, a mechanical range finder, and an optical range finder.

10 In some embodiments, the at least one weight sensor includes: a load cell, a MEMs device, a piezoelectric device, a spring scale, and a balance scale.

In some embodiments, the data indicative of one or more characters present on the package include data indicative of at least one chosen from the group consisting of: an alphanumeric character, a symbol, a postal code, a post mark, a bar code, and a two dimensional bar code.

15 Some embodiments include a postal meter in communication with the processor and/or a printer in communication with the processor.

In another aspect, a method of enrolling a package is disclosed including: providing an enrollment apparatus of the type described herein, using the enrollment apparatus to determine information indicative of the size of the package; using the
20 enrollment apparatus to determine information indicative of the size of the package indicative of one or more characters present on the package; and outputting the information indicative of the weight, size, and one or more characters present on the package.

25 In some embodiments, the information indicative of the weight, size, and one or more characters present on the package, respectively, are determined substantially in parallel.

In another aspect, a system is disclosed including: an enrollment apparatus of the type described herein and a package management system. The enrollment apparatus is in communication with the package management system to provide
30 information indicative of the weight, size, and one or more characters present on the package.

In some embodiments, the package management system includes at least one of: a package delivery system, a supply chain management system, an inventory management system, and a chain of custody management system.

In some embodiments, the package management system includes a point of sale unit, and where the point of sale unit generates and displays, in response to the information indicative of the weight, size, and one or more characters present on the package, information indicative of one or more available service options. In some embodiments, the point of sale unit includes an input unit for receiving information from a user; and a service unit for providing information indicative of one or more available service options based on the information from the user and information indicative of the weight, size, and one or more characters present on the package. In some embodiments, where the input unit includes the enrollment apparatus.

In some embodiments, the input unit receives a series of instructions from the user, and the service unit includes a backwards chaining logic unit which dynamically determines and displays available service options based on the series of instructions and based information indicative of the weight, size, and one or more characters present on the package.

In some embodiments, the package management system includes a point of service unit, and further including a handler module for facilitating communication between the enrollment apparatus and the point of service unit.

In one aspect, an apparatus for enrolling a package is disclosed including: a receiving surface for receiving the package; at least one weight sensor in communication with the receiving surface which generates a weight signal indicative of the weight of the package; at least one red-green-blue (RGB) video camera which generates a video signal indicative of an image of the package on the receiving surface to capture data from labels or other surfaces containing relevant data; at least one infrared (IR) three-dimensional camera, wherein the IR three-dimensional camera generates data for estimation of the width, length, and height of objects using background differencing; and a processor in communication with the at least one weight sensor and the at least one video camera. The processor includes: a weight module which produces, in response to the weight signal, weight data indicative of the weight of the package; and a dimension capture module which

produces, in response to the data from the IR three-dimensional camera, dimension data indicative of the size of the package. In some embodiments, the processor further includes a recognition module which produces, in response to the video signal, character data indicative of one or more characters present on the package.

5 In one aspect, an apparatus for enrolling a package is disclosed including: a receiving surface for receiving the package; at least one weight sensor in communication with the receiving surface which generates a weight signal indicative of the weight of the package; at least one IR three-dimensional camera comprising an infrared laser projector and a sensor, wherein the IR three-
10 dimensional camera generates data for estimation of the width, length, and height of objects using background differencing; and a processor in communication with the at least one weight sensor and the at least one video camera. The processor includes: a weight module which produces, in response to the weight signal, weight data indicative of the weight of the package; and a dimension capture module which
15 produces, in response to the data from the IR three-dimensional camera, dimension data indicative of the size of the package. In some embodiments, the processor further includes a recognition module which produces, in response to the video signal, character data indicative of one or more characters present on the package.

 In another aspect, an apparatus for enrolling a package positioned on a
20 receiving surface is disclosed, the apparatus including: at least one weight sensor in communication with the receiving surface which generates a weight signal indicative of the weight of the package; a camera unit located to view the receiving surface, the camera unit including at least one three dimensional camera configured to obtain a depth image of at least a portion of the receiving surface; and a processor
25 in communication with the at least one weight sensor and the camera unit. In some embodiments, the processor includes: a weight module which produces, in response to the weight signal, weight data indicative of the weight of the package; and a dimension capture module which processes the depth image to produce dimension data indicative of the size of the package.

30 In some embodiments, the dimension capture module is configured to process the depth image to generate dimension data including: length and width dimension data indicative of the size of the package along two axes lying in a plane

parallel to the receiving surface, and height dimension data indicative of the size of the package along an axis transverse to the plane parallel to the receiving surface.

In some embodiments, the camera unit further includes a two dimensional camera, and the dimension capture module is configured to determine, based on the height dimension data, if the height of the package is below a threshold height. In some embodiments if the height of the package is below the threshold height the modules is configured to acquire at least one two dimensional image of the package using the two dimensional camera; and process the two dimensional image to determine secondary length and width dimension data indicative of the size of the package along two axes lying in a plane parallel to the receiving surface.

In some embodiments, the dimension capture module is configured to: further process the depth image based on the secondary length and width dimension data to determined refined height dimension data indicative of the size of the package along an axis transverse to the plane parallel to the receiving surface.

In some embodiments, the dimension capture module is configured to: use the secondary length and width dimension data to determine a region of the depth image corresponding to the location of the package; and process the region of the depth image corresponding to the location of the package to determine the refined height dimension data.

In some embodiments, threshold is greater than a depth noise of the depth image.

In some embodiments, the dimension capture module is configured to: process the depth image to determine information indicative of a region of the image corresponding to a face of the package located closest to the camera unit.

In some embodiments, the dimension capture module is configured to: process the depth image to generate the dimension data based on the information indicative of a region of the image corresponding to a face of the package located closest to the camera unit.

In some embodiments, the dimension capture module is configured to: when processing the depth image to generate the dimension data based on the information indicative of a region of the image corresponding to a face of the package located closest to the camera unit, exclude at least a portion of the depth image located

outside of the region of the image corresponding to a face of the package located closest to the camera unit.

In some embodiments, the excluded portion of the of the depth image has a corresponding depth value within a threshold amount of the depth value
5 corresponding to the region of the image corresponding to a face of the package located closest to the camera unit.

In some embodiments, the three dimension camera is an infrared camera.

In some embodiments, the two dimensional camera is a visible light camera e.g., an RGB camera).

10 In some embodiments, the receiving surface is a stationary surface.

In some embodiments, the receiving surface is non-stationary. In some embodiments, the receiving surface includes a conveyor belt.

In some embodiments, the camera unit generates a video signal of the package on the receiving surface.

15 In some embodiments, the dimension capture module includes an edge finder module that produces, in response to a video signal from the camera unit, edge data indicative of the location of one or more edges of the package.

In some embodiments, the dimension capture module includes a frame differencing module which generates two dimensional difference images from two or more
20 images of the video signal

In some embodiments, the dimension capture module includes a color masking module configured to generate information indicative of the presence or location of the package based on color information from the video signal.

In some embodiments, the dimension capture module includes a Hough
25 transformation module that applies the Hough transformation to one or more images from the video signal, and analyzes the transformed images to determine information indicative of the size or location of edges on the package.

In some embodiments, the video signal includes at least one of: a stream of depth images generated by the three dimensional camera, and a stream of images
30 from a two dimensional camera.

Some embodiments include an integrated housing including the receiving surface and processor.

Some embodiments include an integrated housing including the camera unit and the processor.

In some embodiments, the camera unit is mounted on a support arm extending over the receiving surface.

5 In some embodiments, the support arm extends between a proximal end connected to a housing including the receiving surface and a distal end positioned above the receiving surface, the distal end supporting the camera unit.

In some embodiments, the at least one weight sensor includes at least one selected from the list consisting of: a load cell, a MEMs device, a piezoelectric
10 device, a spring scale, and a balance scale.

Some embodiments include a postal meter in communication with the processor.

In another aspect, a method of enrolling a package is disclosed including: providing the enrollment apparatus of any of the types described above; using the enrollment
15 apparatus to determine information indicative of the weight of the package; using the enrollment apparatus to determine information indicative of the size of the package; and outputting the information indicative of the weight, and size of the package.

In some embodiments, the information indicative of the weight, and size of
20 the package are determined substantially in parallel.

In another aspect, a system is disclosed including: the enrollment apparatus of the type described above; and a package management system, where the enrollment apparatus is in communication with the package management system to provide information indicative of the weight and size if the package.

25 In some embodiments, the package management system includes at least one chosen from the list consisting of: a package delivery system, a supply chain management system, an inventory management system, and a chain of custody management system.

In some embodiments, the package management system includes a point of
30 sale unit, and where the point of sale unit generates and displays, in response to the information from the enrollment apparatus, information indicative of one or more available service options.

In some embodiments, the point of sale unit includes: an input unit for receiving information from a user; and a service unit for providing information indicative of one or more available service options based on the information from the user and information from the enrollment apparatus.

5 In some embodiments, the input unit includes the enrollment apparatus.

In some embodiments, the input unit receives a series of instructions from the user, and the service unit includes a backwards chaining logic unit which dynamically determines and displays available service options based on the series of instructions and based information from the enrollment apparatus.

10 In some embodiments, the package management system includes a point of service unit, and further including a handler module for facilitating communication between the enrollment apparatus and the point of service unit.

As used herein, the “location” of a package refers to its position in space and its orientation.

15 Various embodiments may include any of the features described above, either alone or in any combination.

The details of one or more embodiments are set forth in the accompanying drawings and the description below. Other features and advantages will be apparent from the description and drawings.

20

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1a-1c show views of an enrollment device.

25 Fig. 2 shows and illustration of the connections and control of the various components of an enrollment device.

Fig. 3 shows exemplary specifications for an enrollment device.

30 Figs. 4a-4e are photographs of a working example of an enrollment device.

Figs. 5, 6a, 6b, 6c and 6d show views of alternate embodiments of an enrollment device.

35 Fig. 7 is a flow diagram illustrating operation of an enrollment device.

Fig. 8 is a diagram of an exemplary processor.

Fig. 9 is an illustration of a system featuring an enrollment device.

Fig. 10 illustrates modules included in an enrollment device.

5

Fig. 11 illustrates image processing by an enrollment device.

Fig. 12 illustrates a Hough transform.

10 Fig. 13 illustrates segmented address information.

Figs. 14, 14a-14b, 15a-15c, and 16 illustrate graphical user interface screens for an enrollment device.

15 Fig. 17a is an illustration of a depth image of a package on a receiving surface of an enrollment device.

Fig. 17b is an illustration of the depth image of Fig. 17A after processing to reduce background noise.

20

Fig. 18 is a flow diagram illustrating a method of processing a depth image

Fig. 19 is a flow diagram illustrating a dimension capture process for an enrollment apparatus featuring a two dimensional camera and a three dimensional camera.

25

DETAILED DESCRIPTION

Figs. 1a, 1b, and 1c illustrate an exemplary embodiment of an enrollment device 100. Referring to the cutaway view of Fig. 1a, the device body 102 (also referred to herein as “main enclosure”) includes a transparent tempered glass surface 104 for receiving a package 106 (shown in Figs. 1b and 1c). Load cells 108 (e.g. solid state load cells) are located at the corners of the glass surface and provide weight information for items placed on the surface 104.

The device body 102 includes two cameras 110. First and second surface mirrors 112 are disposed to direct an image of a package placed on the surface to the cameras. The marginal rays of the camera/mirror systems are indicated in Fig. 1a. As shown, the combined field of view of the two cameras 110 substantially covers the area of the glass surface 104, allowing image capture of package 106 placed at an arbitrary position on the glass surface 104.

The device body also includes a computer processor 114 which may be coupled to the various components of the device and/or to external systems or devices. For example, the computer processor 114 may be an x86 platform capable of running Linux or embedded Microsoft Windows products. In various embodiments, this computer may run the internal “firmware” for the device as well as support application facilities such as a Web Server and postal rating (i.e. pricing/metering) engine.

In some embodiments, the device body 102 includes one or more lighting modules (not shown), such as light emitting diode modules, to illuminate the package placed on the glass surface.

A support arm 116 (also referred to herein as an “extension arm”) extends above the surface 104. The support arm 116 includes control buttons 118 (e.g. power control, measurement units control, scale tare, etc.). A display 120 provides information to the user or users (e.g. postal clerk and/or customer) and may include for example, a character display (e.g. LCD display). The support arm 116 also includes an ultrasonic transducer rangefinder 122 which operates to capture one or more dimensions of package 106 placed on the glass surface 104 (e.g. the height dimension as shown in Figs. 1b and 1c). In some embodiments, the device 100 may

include additional or alternative rangefinders (e.g. infrared rangefinder, mechanical rangefinder, laser rangefinder, radar range finder, LED based rangefinder, one or more cameras, etc.)

Fig. 2 illustrates the connections and control of the various components of an enrollment device of the type described above. Compact personal computer (PC) 202 (e.g. comprising processor 114) is connected to a microcontroller 204. The microcontroller receives analog inputs from four load cells 206 and an infrared rangefinder 208, along with digital inputs from an ultrasonic rangefinder 210 and user control buttons 212. Information from these inputs can be passed back to the compact PC 202 for processing. The microcontroller 204 also provides digital control outputs to a display 214, LED indicators 216, and a beeper 218. The compact PC 202 receives image information from each of two cameras 220 for processing (e.g. image processing, OCR, dimension capture, etc). The compact PC 202 is further connected to various peripherals 221 via a connection such as a universal serial bus (USB) hub 222. The peripherals may include a printer, an RFID reader capable of receiving signals from an RFID tag on the package, and various displays and controllers (e.g. keyboard, touch screen display, touchpad, etc.).

As will be understood by one skilled in the art, Fig. 3 lists various parameters and specifications for a working example of an enrollment device of the type described above, along with target performance specifications corresponding to typical applications. Note that the majority of performance characteristics of the working example are in general compliance with target values.

Figs. 4a-4e are photographs of a working example of an enrollment device of the type described above. Fig. 4a shows the device with a package placed on the glass surface. Fig. 4b shows the device along with display and control peripherals. Fig. 4c shows a compact PC integrated into the main enclosure. Figs. 4d and 4e show examples of image processing, dimension capture, and OCR, as will be discussed in greater detail below.

Although an exemplary embodiment is presented above, it is to be understood that other suitable configurations for the enrollment device may be used. For example, Fig. 5 shows a perspective view of an exemplary embodiment of an enrollment device 100. In this configuration, instruments such as an ultrasonic

rangefinder 122 and/or RFID reader are incorporated in a spherical enclosure 502 on top of an extension arm positioned at the corner of the device's main enclosure 102. Control buttons 118 and an organic LED (OLED) display 120 are positioned on the main enclosure 102.

5 Fig. 6a shows another exemplary embodiment, in which cameras 110 are placed on the extension arm 116 instead of in a main enclosure of the device, thereby providing a top down view of a package placed on the surface 104 of a weight scale 601. In some applications, this configuration may provide additional comfort for users accustomed to placing packages with labels or other printed
10 information "face up", while still allowing for dimension capture, OCR, etc. As shown, processor 114 is located externally, but in other embodiments it may be located integrally.

 Fig. 6b shows a similar embodiment featuring a single camera 110. Camera 110 may have a field of view larger than and encompassing surface 104, such that
15 even packages which are as large or larger than package receiving surface 104 of weight scale 601 may be imaged. Camera 110 may include an autofocus or other focusing and/or alignment systems. Indicia 602 on surface 104 may be used to aid in focusing and/or alignment of camera 110.

 Fig. 6c shows another exemplary embodiment, in which an RGB camera 110
20 and an infrared (IR) three-dimensional camera 610 are placed on the extension arm 116 thereby providing a top down view of a package placed on the surface 104 of a weight scale 601. The IR three-dimensional camera includes an infrared illuminator 604 (e.g., an LED or laser projector) and sensor 606, such as a CMOS sensor. The infrared illuminator 604 projects near-infrared light and the sensor 606 receives the
25 returning lightwaves. In some applications, the placement of the RGB camera on the extension arm 116 may provide additional comfort for users accustomed to placing packages with labels or other printed information "face up", while still allowing for dimension capture, OCR, etc. As shown, processor 114 is located externally, but in other embodiments it may be located integrally. In some embodiments the extension
30 arm 116 can be adjusted various heights. In various embodiments, the IR camera 610 is insensitive or substantially insensitive to changes in ambient lighting in the visible spectrum.

In some embodiments, an enrollment device may include only an IR three-dimensional camera 610, which includes at least an infrared illuminator 604 and a sensor 606, and a weight scale 601. The IR three-dimensional camera 610 of the device would be used to capture some or all of the dimensions of the object. In
5 some embodiments, the IR three-dimensional camera 610 may be mounted on an extension arm 116. In some embodiments, the extension arm 116 may be adjusted to permit the IR three-dimensional camera 610 to be raised or lowered, depending on the dimensions of the object. Although the system illustrated in Fig. 6c shows an embodiment of the enrollment device including an RGB camera 110 and an IR three
10 dimensional camera 610, other embodiments may differ from the system shown. In some embodiments, the system may include one or more IR three-dimensional cameras and no RGB or optical cameras. Such embodiments may be useful in situations where character recognition is not needed. In some embodiments, the enrollment device may include one or more optical or RGB cameras to capture data
15 on different sides of an object or package and where package dimensioning is unnecessary or not needed. In some embodiments, the cameras may be mounted on multiple extension arms 116 of a device.

Fig. 6d shows a similar embodiment featuring a single RGB camera 110, an IR three-dimensional camera 610, which includes an infrared illuminator 604 and
20 sensor 606, placed on the extension arm 116. Although the embodiment illustrated describes an infrared laser illuminator 604, in some embodiments, the IR three-dimensional camera 610 may include any source for projecting infrared light onto an object or package. In some embodiments, the infrared structured-light is emitted from a component of the IR three-dimensional camera. In some embodiments, the
25 infrared illuminator 604 may be omitted, and ambient infrared light used to for infrared imaging by the IR camera 610.

The RGB camera 110 and the IR three-dimensional camera 610 may each have a field of view larger than and encompassing surface 104, such that even packages which are as large or larger than package receiving surface 104 of weight
30 scale 601 may be imaged. The RGB camera 110 may include an autofocus or other focusing and/or alignment systems. Indicia 602 on surface 104 may be used to aid in focusing and/or alignment of camera 110. In some embodiments, the extension arm

116 may be adjusted using a mechanism such as knob 608. In other embodiments, the extension arm 116 may include other mechanisms for adjusting the height of the extension arm 116. In some embodiments, the enrollment device includes the IR three-dimensional camera 610 and does not include the RGB camera 110 used to
5 capture character data that may be located on or near the object.

In some embodiments, the use of an IR camera (three dimensional or otherwise) advantageously reduces or eliminates imaging problems resulting from variable visible ambient lighting which may make image sensing difficult for an optical (i.e., RGB) camera. By using infrared cameras and sensors, the system may
10 be used even in complete darkness as infrared imaging is generally immune to variations in background or ambient lighting. Infrared imaging may be used to increase the versatility and accuracy of the system due to its ability to provided accurate and comprehensive depth imaging, regardless of the lighting conditions of an environment. Because of its ability to capture accurate and comprehensive
15 information despite the lighting conditions, the use of an IR three-dimensional camera may improve the dimension capture capabilities of some existing systems.

As is known in the art, infrared light is electromagnetic radiation with a wavelength longer than that of visible light. IR light is measured from the nominal edge of visible red light at 0.7 micrometers and extending conventionally to 300
20 micrometers. Infrared can be commonly sub-divided into the following categories: near-infrared (0.75-1.4 μm in wavelength); short-wavelength infrared (1.4-3 μm); mid-wavelength infrared or intermediate infrared (3-8 μm); long-wavelength (8-15 μm); and far infrared (15-1,000 μm). Although an IR three dimensional camera projecting near-infrared is described, an enrollment device may comprise an IR three
25 dimensional camera using any range of infrared.

In some embodiments, the IR three-dimensional camera 610 is a range camera technology, e.g. of the type available from PrimeSense 104 Cambay Ct. Cary, North Carolina, which interprets 3D scene information from a continuously-projected infrared structured light. For example, one PrimeSense 3D scanner,
30 marketed as as Light Coding, employs a variant of image-based 3D reconstructions. Light Coding works by coding the scene volume with near-IR light. The IR Light Coding is invisible to the human eye. A sensor, such as a CMOS image sensor,

reads the coded light back from the scene. PrimeSense's system on a chip (SoC) is connected to the sensor and executes a parallel computational algorithm to decipher the received light coding and produce a depth image of the scene. The sensor is generally unaffected by ambient lighting changes, especially those in the visible
5 portion of the spectrum.

In some embodiments, the IR three-dimensional camera of an enrollment device includes an infrared laser projector 604 and sensor 606, such as a CMOS sensor. The infrared laser projector 604 transmits infrared light onto the object and measures its "time of flight" after it reflects off an object, similar to sonar
10 technology. The infrared laser projector pulses infrared light towards the object at a frequency of, e.g., several megahertz. The pulses are reflected back, captured by the sensor 606 and turned into a distance measurement to determine depth or height of an object.

In some embodiments, the IR three-dimensional camera encodes information
15 in the infrared light patterns emitted by the infrared laser projector 604, the infrared laser projector emits the light onto the object, and the sensor captures and analyzes the deformation of the patterns resulting from the encoding of the infrared light. The deformations in the light patterns are caused by object's presence. Detecting and using the deformations of the infrared light patterns can help generate finer image of
20 the object's three-dimensional texture, not just their depth. In some embodiments, the three-dimensional camera may distinguish objects' depth within 1 centimeter or less and their length and width within 3 mm or less.

In the embodiments shown in Fig. 6a, the enrolled package is placed on a stationary receiving surface. However, it is to be understood that in some
25 embodiments, a non-stationary surface, such as a conveyor belt may be used. In some embodiments, the dimension capture may be performed while the package is in motion on the surface. In other embodiments, the motion of the surface is controlled to pause during the dimension capture process.

Fig. 7 illustrates the flow of an enrollment process 700 using a device 100 of
30 the type described above. Initially, in step 701 the package to be enrolled is received on the receiving surface 104 of the enrollment device 100. In step 702, the presence

of the package is detected, for example, as described in greater detail below, by processing a stream of video images captured by the cameras (or camera) 110.

Once the presence of the package is detected, multiple types of information about the package are captured in parallel steps. In step 702, the weight of the
5 object is captured, e.g. by the load cells 198 or scale 601.

In step 702, the cameras 110 capture one or more images of the package. The images undergo a processing step 703 to provide information about the package. For example, in step 705 machine vision applications (e.g. edge detection) may be used to capture one or more dimensions (e.g. length, width) of the package. Optical
10 character recognition techniques can be used in step 704 to capture text or other markings on the package (e.g., postal markings/permits, bar codes, etc.).

In step 706, one or more dimensions of the package are captured. For example, the height of the package may be determined by the ultrasonic range finder 122. This information can be combined with dimension information determined in
15 the image processing step to provide complete dimensional information (e.g. length, width and height) of the package.

In step 707, the enrollment device 100 captures other types of information related to the package. For example, an RFID reader connected to or integrated with the enrollment device can gather information from an RFID tag on the package.
20

In step 708, the information captured in the above described steps is then collected, processed, and/or stored. The information may also be output, for example to a delivery service business system. The information may be output in any suitable form including electronic data, an analog signal, printed material, visual display, etc.

For example, in some embodiments, information is displayed to a user via a graphical user interface. The user may confirm or edit the captured information, enter additional information, query a customer as to a choice of delivery options or additional services, etc. In some embodiments, printed material (e.g. labels, stamps, etc.) may be output from an attached or integral printer. In some embodiments,
25 output can include markings (e.g. barcodes) printed directly onto the package using, for example, an attached or integral spray printing system, or through attaching
30

separately printed labels with bar code, postage, or related package information – based on information derived from the device.

In some embodiments, the performance of one or more steps might depend on the results of other steps. For example, the imaging and OCR of a package might
5 determine that the package was a “flat rate” envelope of the type common in postal and delivery services. In such a case, weight and dimensional information is not relevant, and thus the steps used to capture this type of information may be omitted.

Fig. 8a shows an exemplary embodiment of processor 114. Video signals from cameras 110 are input to frame stitching module 801 which combines multiple
10 overlapping views of surface 104 into a single view (in embodiments featuring a single camera may omit this module). The combined video signal is passed to dimension capture module 802 and recognition module 803. Rangefinder signal may also be passed from rangefinder 122 to dimension capture module 802 and recognition module 803. Using, e.g. the techniques described herein, dimension
15 capture module 802 operates to produce dimension data indicative of the size (e.g. length, width, and/or height) of a package based on the input signals. For example, module 802 may determine the length and width of the object based on edge finding processing of the combined video signal and the height of the package based on the rangefinder signal.

20 Using, e.g. the techniques described herein, recognition module 804 operates to produce character data related to one or more characters (e.g. alphanumeric address, bar code, postal mark, symbols, etc) found on the package.

Weight module 804 receives a weight signal input from a weight sensor such as load cells 122 or scale 601, and produces weight data indicative of the weight of a
25 package placed on surface 104.

Processor 114 combines the weight, dimension, and character data from modules 802, 803, and 804 and outputs the data from output 805. The operation of the modules described above will be further described below.

Fig. 9 illustrates the integration of an enrollment device 100 into an
30 exemplary delivery system 900. As described above, an enrollment device 100(captures numerous pieces of information which are passed on to and processed by processor 114 (e.g. via firmware run by a compact PC integrated with or linked to

device 100). Processor 114 may communicate (e.g. using a network connection), with one or more servers 901. For example, an address management server could exchange information related to redirection or alternate delivery. A rights management server could exchange information to validate permits or confirm postage. A supervised delivery server could exchange information related to package tracking or chain of custody (e.g. for prescription medications or legal evidence). In some embodiments, these servers might further interact with other “back end” applications including supervised delivery application 902 and database management applications 903. Such applications could be connected via a network 904 (e.g., an intranet, extranet, the world wide web, etc.)

Processor 114 interacts with a point of service (POS) system 905 (e.g. a postal service counter sales system) to provide, for example, validated address or redirection information, weight, dimensions, etc. Interactions might be mediated by an event handler application 906 which interrupts or otherwise communicates with the POS system to provide, for example, invalid permit, address, or delivery point warnings, redirection information, scale/OCR timeout indications, etc.

Enrollment Functions

The following describes more detailed examples of the various functions which may be carried out by enrollment device 100.

Scale Function

In some embodiments, the enrollment device 100 includes a scale 601 for acquiring information about the weight of a package. For example, in various embodiments, a solid state weighing device (e.g. including one or more load cells 118) operates with accuracies consistent with relevant standards (e.g. US Postal Service and/or Royal Mail requirements). Direct management of a display device may be provided in support of weights and measure requirement.

In some embodiments, detailed usage history is kept in order to ensure accurate performance throughout the life of the scale. Remote supervision may be

provided (e.g. via an internet connection provided through an integrated compact PC). Suspect scales can be identified via an analytics application.

Imaging Function

5

In typical applications, the enrollment device 100 detects the presence of a package and captures an image of at least a portion of the package. The image is processed to derive information from the package (e.g. from mailing labels or printed markings) including: printed address/destination info, sending identification
10 information, postal markings, and other information such as proprietary barcode information. In various embodiments the enrollment device acquires this information in an automated fashion, performed in such a way as to have reduced negative impact on currently sorting.

Referring to Fig. 10, in some embodiments, the image related tasks of the
15 enrollment device are performed by four modules: the imaging device module 1001, the tracking module, the image enhancement and dimension capture module 1003 and the recognition module 1004. All or portions of the above modules may be included in processor 114.

The imaging device module 1001 employs one or more cameras 110 to
20 obtain images of a package. The imaging device module 1001 may operate to meet two different sets of requirements imposed by the tracking module 1002 and the recognition module 1004. As will be described below, mail piece tracking module 1002 typically requires image capture with a relatively large field of view and a relatively high frame rate, but can tolerate relatively low resolution. The recognition
25 module 1004, on the other hand, requires relatively high resolution images (e.g. about 200 dots per inch, “dpi”), but can typically tolerate a relatively narrow field of view and relatively slower frame rate. Accordingly, in some embodiments, the imaging device module 1001 operates in a first mode to provide a low resolution but large field of view (e.g. substantially covering the surface 104 of a device 100) and
30 high frame rate image stream to the tracking module 1002. When a package is placed on receiving surface 104 of the enrollment device 100, the tracking module identifies the package’s presence, location (i.e. position and/or orientation), and size.

The imaging module 1001, using information from the tracking module 1002, then switches to a high resolution mode to capture high quality images of areas of interest (e.g. an area including an address label) on the package.

5 Note that in various embodiments these modules may be implemented in hardware (e.g. using multiple cameras or sensors of varying resolution) or in software (e.g. using image processing techniques known in the art) or in a combination thereof.

As mentioned above, the tracking module 1002 operates to monitor a stream of image information from the imaging device module 1001 to detect the presence of
10 and determine the size and location/orientation of a package placed on receiving surface 104 of the enrollment device 100. Several tracking techniques will be described herein, however, it is to be understood that the tracking function may be performed by any suitable techniques (e.g. using known machine vision applications).

15 In some embodiments, the tracking module 1002 employs a color masking module 1005. Color masking is a technique used when looking for an object which leverages unique color information that the object might have (e.g., brow coloring for parcels) and/or that the background may have (e.g. the known color of surface 104). In typical applications, the color masking process consists of removing any
20 pixel of an image that deviates to a specific range of color values.

For this type of approach, the well known RGB color space is sometimes not the most appropriate if one wants to avoid artifacts due to lighting inconsistencies. Instead, computing color deviations in the YUV or the YCbCr color spaces typically leads to better results. For reference, Y is usually referred to a luminance and
25 turning an RGB color value in the YCbCr color space can be done through these simple relationships:

$$Y = 0.31 R + 0.59 G + 0.11 B; Cr = R - Y; Cb = B - Y$$

The advantage of this color representation is that lighting inconsistencies will
30 typically incur radial shifts of the (Cb, Cr) value around the center of this plane. Hence the angle of a polar representation of this color plane can be fairly invariant

through lighting changes. It is also noteworthy to notice that this angle is closely related to the concept of a color's hue.

In some embodiments, the tracking module 1002 employs motion analysis using, for example, frame differencing module 1006. For example, one way to
5 detect motion is through a frame differencing process. As the system (e.g. featuring a stationary camera) gathers successive video frames it simply compares each pixel value to its value in the previous frames and removes those that have not changed significantly. When the images are provided as grayscale, intensity is the only available parameter but in the case of color images there are alternative ways to
10 perform these differences depending on the color space.

Such a frame differencing process is effectively a temporal high-pass filter and as such it is highly prone to pixel noise. Therefore it is often coupled with subsequent image processing stages such as linear or morphologic filters, which are discussed below.

15 Fig. 11 shows an example of frame difference tracking. A short series of video frames 1101 were captured of an envelope being handled in a "visually busy" environment. These frames were further imported within the Matlab environment where the differences between successive frames were computed. These difference images 1102, illustrated in the second row of Fig. 10b, reveal the mail piece.
20 However, the frame differencing also reveals any other moving object, such as the person's hand and arm.

In order to identify a rectangular object (e.g. a package or envelope) in the frame differences, in some embodiments, the tracking module 1002 employs the Hough transform module 1007 to transform the frame differenced data 1102 to
25 produce Hough domain images 1103. The primary purpose of this transform is to extract linear graphic elements (i.e. straight lines) from an image. It effectively does so by maintaining a series of accumulators that keep track of all lines that pass through a set of points. As many of these points are collinear, the largest of these accumulators reveal the equation of that line in the Hough domain. In that domain,
30 the y-axis corresponds to the orientation of that line and the x-axis corresponds to the distance between that line and an origin one chooses in the image. This mapping is shown in Fig. 12. For example, Fig. 12 shows three points in the spatial domain.

For each one of these points, all the lines that pass through it are represented by a “vertical sinusoid” in the Hough domain. Because these three points were chosen to be collinear, notice that the three corresponding sinusoids intersect. The coordinates (θ, ρ) of this intersection describe the line that passes through all three points uniquely.

Referring back to Fig. 11, the third row of Hough domain images 1103 shows the Hough domain that corresponds to each frame difference 1102. As the motion of the mail piece slows down (i.e. third column in the Fig. 11) and the difference frame starts to show a clear rectangular outline of the mail piece.

Note, as shown in the inset of Fig. 11, that the Hough domain sharpens up, revealing two noticeable peaks lined up horizontally. The fact that these peaks live on the same horizon in the Hough domain reveals that these two corresponding lines are parallel: one has thus found the upper and lower edges of the mail piece.

If one were to further look for linear features that are perpendicular to these edges one would simply look for local maximums in the Hough domain at the horizon corresponding to a 90 degrees rotation. In the case of the current example this would further reveal an estimation of the left and right edges of the mail piece.

Rectangle tracking module 1008 can leverage information of the type described above to track the location/orientation of rectangular packages. Frame differencing and a Hough transform provide a solid basis for the tracking of a moving rectangular object. It has the great benefits of further providing orientation estimation for the mail piece in the same process, while requiring no further assumption concerning the size or even the aspect ratio of the rectangular object.

In typical applications, color masking and motion analysis can reveal “blobs” (connected regions) of pixels that maybe of interest. In some cases this might be not enough to locate the target or an area of interest. As previously noted, shape-related image analysis techniques such as the Hough transformation can provide additional information. Some techniques useful for tracking include, for example blob segmentation clustering. One useful step is to group pixels that may belong to the same spatial blob. These techniques are discussed further in the context of image enhancement and OCR below.

One way to quantify a blob of pixels is by measuring its spatial moments. The first order moment is simply the blob's center of mass. Its second order moments provide measures about how "spread" the blob is around its center of mass. Through a simple diagonalization process these second order moments can
5 further lead to the blob's principal components, which provide a general measure of the object's aspect ratio and its orientation. In a 1962 publication, Ming-Kuei Hu suggested a means to normalize and combine the second and third central moments of a graphical object, leading to a set of 7 descriptors that have since been referred to as the Hu-moments. These 7 features have the highly desirable properties of being
10 translation, rotation and scale invariant. A number of OCR engines have subsequently been developed based on these features.

Extracting the edges of a visual object is also a very common step that may come handy as one searches for a target mail piece. One of the most popular methods is the Canny edge detection algorithm. It is equivalent to the location of
15 local maximums in the output of a high frequency (gradient) filter. The method actually starts with the application of a low-pass filter in order to reduce noise in the image so the whole process can be seen as some band-pass filtering stage followed by a morphologic processing stage.

Once a package presence has been detected and location, orientation, and
20 size determined by the tracking module 1002, one or more images of the package at a desired resolution are obtained by the imaging device module and passed on to the image enhancement module 1003. In various embodiments, this module operates to process these images to compensate for the amount of rotation from ideal registration (i.e. registration with the edges of the surface 104 of the enrollment
25 device 100) that was detected by the mail piece tracking module. As is known in the art, this can be achieved through, for example, a resampling stage. In typical applications, this resampling stage does not require any more than a bilinear interpolation between pixels.

As required by the application or environment at hand, some embodiments
30 employ other image enhancement processing techniques to provide a high quality image to the recognition module 1004 for, for example, accurate OCR.

Depending on the OCR performance achieved, a further segmentation module 1009 may be added to the image enhancements module. The typical image analysis technique will make a certain number of assumptions concerning the input image. Some of these assumptions might be reasonable in the context of the application and some others might require a little bit of work on the input. This is where preprocessing typically comes into play. As a general rule, the object of a preprocessing stage is to emphasize or reveal salient features of an image while damping irrelevant or undesirable ones before attempting to perform further analysis of the image's content. There are numerous types of processing known in the art that may share such an objective. Some such processing types are composed of elementary stages that fall within one of the following major categories: color manipulations, linear filters, morphological image processing, or image segmentation.

Color manipulations include grayscale conversion from a color image, color depth reduction, thresholding (to a binary image for instance), brightness and contrast modifications, color clipping, negation and many others. In such processes, the color value of an output pixel is a direct function of the input color value of that same pixel and some global parameters. In some cases, these global parameters might be derived from an overall analysis of the input image but once chosen they remain the same during the processing of all pixels in the image.

Linear image filters can typically be seen as a convolution between the input image and another (usually smaller) image that's sometime referred to as a kernel. Their objective is to reveal certain spatial frequency components of the image while damping others. The most commonly used linear filters are either blurring (low-pass) or sharpening (high-pass) the image. Gradients and differentiators used for edge detection are another commonly used type of high-pass linear filters. Performing a brute force 2D convolution can be a computationally expensive proposition. Indeed if the filter kernel M is a square image counting N rows and N columns, processing a single input pixel through the kernel will require N^2 operations. One way to overcome this prohibitive scaling is to use what are sometimes referred to as separable filters. Those are filters for which the kernel M is

an outer-product of two vectors: i.e. $M=UV^T$, where U and V are vectors of length N.

With such a choice for the filter, the sliding correlation with the matrix M over the entire image can be expressed as the cascade of two 1D filtering stages over the two dimensions (horizontal and vertical) of the image. The elements of the vector V are the impulse response of the 1D filtering stage we first apply to each row and the elements of the vector U are the impulse response of the 1D filtering stage we subsequently apply to each column. Each 1D filtering stage involves N operations per pixel and therefore, the entire sliding correlation with the matrix M involves only 2N operations (as opposed to N^2 if the filter were not separable).

The most common separable filters are Gaussian low-pass filters. The separability of their kernel falls out from the fact that the product of two Gaussians is also a Gaussian. Note that the same technique can be applied for separable kernels that are not square (i.e. the vectors U and V have different lengths). In cases where the kernel is not separable, one may use techniques known in the art to approximate the kernel as a combination of separable filtering stages. These techniques will typically perform an eigenvalue decomposition of the kernel.

Other noteworthy special cases of separable linear filters are filters for which the kernel matrix is filled with the same value. These are effectively low pass filters that average all pixel values over a rectangular neighborhood centered on the pixel position. Although they might exhibit less than ideal frequency responses they have the great advantage of being computationally cheap. Indeed regardless of the kernel size, their computation consists of simple running sums performed subsequently over the horizontal and vertical direction of the image, requiring a total of only 4 operations per pixel.

Morphological image processing is a type of processing in which the spatial form or structure of objects within an image are modified. Dilation (objects grow uniformly), erosion (objects shrink uniformly) and skeletonization (objects are reduced to “stick figures”) are three fundamental morphological operations. Typically, these operations are performed over binary images for which there is a clear concept of presence and absence of an object at every pixel position but these concepts have also been extended to grayscale images.

Binary image morphological operations are based on the concept of connectivity between pixels of the same class. From an implementation point of view, these operations typically consist of a few iterations through a set of hit or miss transformations. A hit or miss transformation is effectively a binary pattern lookup table. While a linear filter would apply a fixed linear combination of the input in order to set the output value of a pixel, this process will set a pixel to either 1 or 0 depending on whether its surrounding pattern is found in the table or not (Hence the terms “hit or miss”). Depending on the lookup table, this can effectively implement a highly non-linear operation.

Image segmentation includes the division of an image into regions (or blobs) of similar attributes. As discussed below, an OCR system will typically include at least one image segmentation stage. In fact, many suitable image analysis algorithms aiming to localize, identify or recognize graphical elements perform some form of image segmentation.

In general terms this process may consists of a clustering or classification of pixel positions based on a local graphical measure. This graphical measure is the image attribute that should be fairly uniform over a region. In other words, the resulting regions or blobs should be homogeneous with respect to some local image characteristic. This local measure may simply consist of the pixel’s color but some applications may require more sophisticated measures of the image’s local texture around that pixel position. It is also generally understood that a segmentation process should aim to reveal regions or blobs that exhibit rather simple interiors without too many small holes.

The nature of the chosen graphical attribute depends entirely on the application and the type of blobs one is trying to isolate. For example, segmenting an image into text versus non-text regions will require some sort of texture attribute while segmenting light versus dark areas will only require color intensity as an attribute.

Once the chosen attribute has been computed throughout the image, the remainder of the segmentation process will typically use an ad-hoc algorithm. One of the most intuitive techniques is sometimes referred to a region growing and its recursive nature is very similar in spirit to a floodfill algorithm. More sophisticated

techniques implement clustering processes using classical iterative algorithms known in the art such as *k-means* or *ISODATA*.

In some applications, it may be necessary to increase the resolution of the captured image or images. In some embodiments, resolution of the image may be increased using a technique known as superresolution. The Nyquist sampling criterion requires that the sampling frequency should be at least double for the highest frequency of the signal or image features one wishes to resolve. For a given image module 1001 focal length, this typically implies that the smallest optical feature one can resolve will never be smaller than 2 pixels-worth of a pixelated sensor's (e.g. CCD's) resolution.

A common practice to overcome this theoretical limit is to combine multiple captures of the same object from slightly different perspectives. While each capture suffers from Nyquist's limit they form, together, a non-uniform but higher frequency sampling of the object. The key to this process is the ability to align these multiple captures with sub-sample accuracy. Once the individual captures are up-sampled and aligned, they can be carefully averaged based on their sampling phase. This process effectively re-constructs a capture of the object with higher sampling frequency, and hence a higher image resolution. Variations of such techniques are known from, for example, the field of image processing.

Once an image has been processed by the image enhancement module 1003, it is passed on to the recognition module 1004. The recognition module operates to derive information from, for example, labels or printed markings on the object using e.g., OCR. While it is to be understood that any suitable OCR technique or tool may be used, in the following several exemplary OCR techniques will be described.

Various embodiments provide the ability to isolate text within a provided image and to turn it reliably into text, e.g., ASCII codes. A goal of OCR is to recognize machine printed text using, e.g., a single font of a single size or even multi-font text having a range of character sizes.

Some OCR techniques exploit the regularity of spatial patterns. Techniques like template matching use the shape of single-font characters to locate them in textual images. Other techniques do not rely solely on the spatial patterns but instead characterize the structure of characters based on the strokes used to generate them.

Despite the considerable variety in the techniques employed, many suitable OCR systems share a similar set of processing stages.

One OCR stage may include extraction of the character regions from an image: This stage will typically use ancillary information known in order to select
5 image properties that are sufficiently different for the text regions and the background regions as the basis for distinguishing one from the other. One common technique when the background is a known solid color (white for instance) is to apply iterative dichotomies based on color histograms. Other techniques might make use of known character sizes or other spatial arrangements.

10 Another OCR stage may include segmentation of the image into text and background. Once provided with image regions that contain text the goal of this stage is to identify image pixels that belong to text and those that belong to the background. The most common technique used here is a threshold applied to the grayscale image. The threshold value may be fixed using ancillary knowledge about
15 the application or by using measures calculated in the neighborhood of each pixel to determine an adaptive local threshold.

Another OCR stage may include conditioning of the image: The image segments resulting from segmentation may contain some pixels identified as belonging to the wrong group. This stage consists of a variety of techniques used to
20 clean it up and delete noise.

Yet another OCR stage may include segmentation of characters: Some techniques will subsequently segment the input image into regions that contain individual characters but other algorithms will avoid this stage and proceed with character recognition without prior character segmentation. This latter technique is
25 driven by the realization that in many cases character segmentation turns out to be a more difficult problem than recognition itself.

Some OCR stages include normalization of character size: Once the image is segmented into characters, one may adjust the size of the character regions so that the following stages can assume a standard character size. Systems that rely on size-
30 independent topological features for their character recognition stages might not require such normalization.

OCR systems typically include feature detection: Many different feature detection techniques are known in the art. Some template matching is used to find the whole character as a feature, while other systems seek sub features of the characters. These may include boundary outlines, the character skeleton or medial axis, the Fourier or Wavelet coefficients of the spatial pattern, various spatial
5 moments and topological properties such as the number of holes in a pattern.

A classification stage may be used to assign, to a character region, the character whose properties best match the properties stored in the feature vector of the region. Some systems use structural classifiers consisting of a set of tests and heuristics based on the designer's understanding of character formation. Other
5 classifiers take a statistical rather than structural approach, relying on a set of training samples and using statistical techniques to build a classifier. These approaches include the Bayes decision rule, nearest neighbor lookups, decision trees, and neural networks.

In a verification stage knowledge about the expected result is used to check if
10 the recognized text is consistent with the expected text. Such verification may include confirming that the extracted words are found in a dictionary, or otherwise match some external source of information (e.g. if city information and zip code information in a U.S. postal address match). This stage is obviously application dependent.

15 In various embodiments, the recognition module 1004 may employ any of the above described techniques, alone or in combination.

Recognition of handwritten characters (sometimes referred to as ICR) may, in some applications, be more challenging. In the context of applications such as tablet computers or PDA, the ICR engine will often take advantage of pen stroke
20 dynamics. Of course this type of information is not available from the optical capture of a hand-written document. Such applications may require the system to be restricted to a smaller number of permissible characters (e.g. upper caps or numeral) and/or rely heavily on a small lexicon

For example, when text is handwritten in cursive it is often difficult to
25 segment each letter separately so rather than operating as an optical character recognition, an ICR system will often operate as a "Word recognizer", looking to the best match between the graphical object and a small lexicon of recognizable words. In order to achieve a satisfactory recognition rate, this lexicon might need to be as small as 10 words or so.

In various embodiments, the performance of an OCR system may be increased by specializing to the task at hand by restricting its lexicon or dictionary so that it can effectively recover from few character recognition errors the same way a computer (e.g. running a word processor) might be able to correct a typo.

5 Maintaining a restricted and dynamic lexicon is more effective when a document has a rigid and known structure. Without such structure it might not be possible to use a lexicon any smaller than a dictionary for the language at hand.

Fortunately, as shown in Fig. 13 an address appearing on a mail piece is typically a relatively highly structured a document. This is why the USPS can OCR
10 a large part of the machinable mail pieces even when address are hand-written.

In typical embodiments, a proper usage of OCR should take into account some typical shortcomings. Generality must be considered versus accuracy. A single classifier might be trained to get improved results in limited circumstances (a single font for instance) but its performance will typically drop when the size of
15 its training set increases. Consequently, modern classifiers are in fact conglomerates of classifiers coupled with a mechanism to consolidate their results. This in turn will tend to further increase the already substantial computational requirements of the system if it is intended to cope with a large variety of fonts.

Non uniform backgrounds may present challenges. OCR algorithms
20 typically take advantage of the fact that the text is presented on a uniform background that has sufficiently high contrast between text and background colors. When the background is not uniform, OCR recognition rates are substantially decreased. In those cases and in order to remove a non-uniform background from the image, additional preprocessing stages might be required prior to the various
25 ones we've presented above.

Image resolution should be considered. OCR technologies were developed within the context of scanned physical documents. Although optical scanning might lead to various artifacts such as noise and slight skewing, these will also typically operate at higher image resolutions (< 200dpi). As discussed above, imaging
30 module 1001 may provide images at such resolutions, e.g. by employing digital cameras known in the art.

Most mail pieces will already convey some machine-readable data (e.g. bar codes, postal marks) by the time it reaches an enrollment device. In various embodiments, the enrollment device may read these markings using OCR, or using additional sensors (e.g. a barcode reader).

5 Fig. 4d shows the output display of an exemplary embodiment of an enrollment device 100. The display shows the captured image of a package placed on the device, along with information acquired from labels and markings on the package using the OCR techniques described above. This embodiment was able to accommodate OCR of packages placed at an arbitrary angle on receiving surface
10 104, using, for example, the rotation correction techniques described above.

Information obtained using OCR is passed on for, for example, address quality, meter enforcement, value added service subsystems, and operator input. In some embodiments, the OCR facility will be able to read documents such as passports, driver licenses, credit cards, coupons, tickets, etc. Simply placing the
15 document anywhere on the receiving surface 104 will trigger a read and document analysis. Form capture is also supported with the ability to allow customers to, for example, present completed forms for immediate OCR results available to the postal clerk. Certain forms such as customs declarations can be handled much more efficiently with this facility.

20

Dimension Capture Function

In typical applications, accurately determining the dimensions of a package at enrollment may be crucial for determining, for example, the rate of postage. For
25 example, postal rates may depend on an objects length, width, height, and/or combinations thereof.

As noted above, during image acquisition and processing, one or more dimensions of a package placed on an enrollment device may be determined. For example, Fig. 4e shows an output display of an exemplary embodiment of an
30 enrollment device 100. The display shows the captured image 401 of a package, a difference image 402, and a Hough plane image 403 generated using the techniques described above. As indicated in the captured image 401, the system has

successfully identified the edges of the face of the object imaged by the device. This allows the device to calculate and output the length and width of the package.

The height dimension is captured using, for example, ultrasonic range finder 122, thereby providing complete dimensional information. An ultrasonic transducer
5 emits sound waves and receives sound waves reflected by objects in its environment. The received signals are processed to provide information about the spatial location of the objects. For example, in the embodiment shown in Figs. 1a-1c, the rangefinder can determine the vertical position of the top surface of the package 106 relative to the receiving surface 104. One advantage of ultrasonic rangefinder over
10 optical rangefinders is that it is able to unambiguously detect optically transparent surfaces (e.g. the glass surface 104 of Figs. 1a-1c).

In some embodiments, the height dimension is captured using, for example, an IR three-dimensional camera 610, thereby providing complete dimensional information. The IR three-dimensional camera 610 includes an infrared laser
15 projector 604 and a sensor 606. The infrared laser projector 604 emits near-IR light and the sensor 606, such as a CMOS sensor, which is a type of active-pixel sensor, receives the near-IR light and captures the data in 3D video. The sensor 606 may receive the light waves under any ambient visible lighting conditions, including complete darkness. The data received by the sensor 606 is processed to provide
20 information about the spatial location of the objects, including detailed measure of its height, width and length. In some embodiments, the detailed measure of the objects height permit the reliable dimensioning of objects with a more arbitrary shape than boxes and flat envelopes.

In some embodiments, the IR three-dimensional camera 610 utilizes
25 background differencing during the estimation of the object's measurements. In some embodiments, the image processing algorithms that lead to the tracking of a fitting rectangular object are those that are described herein, such as the Hough transform. In some embodiments, a segmentation stage may be applied to the depth image captured by the IR three-dimensional camera 610 to isolate individual
30 contiguous objects based on their distance from the sensor 606 (e.g., as detailed below).

A. Dimension Capture Processing with a Three Dimensional Camera

In some embodiments, where the enrollment device features a three-dimensional (3D) camera (e.g., an IR 3D camera of the type described above), special processing techniques may be used for dimension capture. In typical
5 embodiments, the IR 3D camera will produce a depth image of the enrolled package on a receiving surface. The pixels in the depth image contain information related to the distance of points in the field of view of the 3D camera from the camera itself. Based on this depth information, and information about the position of the camera relative to the package receiving surface, the height of objects in the image
10 (including the package) above the receiving surface may be determined. This information can be leverage to further facilitate the dimension capture process, as described below.

For example, Fig. 17a is an illustration of an exemplary depth image taken by a 3D camera of an enrollment device. A package 1701 is located in the center of the field of view, while several other image features 1702 are scattered about the
15 field of view. The features 1702 may correspond to, e.g., stray marks on the package receiving surface, reflections or shadows cast from objects in the ambient environment, etc. If the image was processed conventionally, without leveraging depth information, it is possible that the presence of the features 1702 could cause errors in determining the dimensions of the package. For example, the feature 1702
20 located close to the perimeter of the package 1701 could be misinterpreted as a portion of the package, leading to an overestimation of the length dimension of the package. However, by using the depth information contained in the depth images, errors of this type may be avoided. For example, consider the case where the feature
25 1702 is a flat mark on the receiving surface while the top face of the package 1701 is located at a height above the surface. In this case, depth image points belonging to the feature 1702 will have different associated depths than points corresponding to the package surface. This fact may be used to exclude the feature 1702 from the dimension capture process, thereby reducing or eliminating the potential error.

30 Fig. 18 illustrates a process for using depth information from the depth image to reduce or eliminate errors caused by background noise in the image, e.g., of the type shown in Fig. 17a. In step 1801, the depth image is received. In step

1802, the image is processed to determine a region of the image that likely corresponds to the package. For example, in most cases, the topmost face of the package may be expected to be the closest object located near the center of the field of view of the 3D camera. Accordingly, the region that corresponds to the package can be identified as the set of points near the center of the depth image with the minimum associated depth values. Additionally or alternatively, the edge of the top face can be identified based on the discontinuity of depth between the package and the underlying receiving surface. In Fig. 17a, the identified region is indicated with a dashed line.

10 In step 1803, once this region has been identified, other regions in the image can be excluded (or otherwise subtracted or removed from the image) prior to reduce or eliminate their deleterious effect on dimension capture. For example, in order to isolate the top face of the package, all points in the image having depths that differ by more than a threshold amount from the depth associated with the package region may be excluded. In the example discussed above with reference to Fig. 17a, this would result in removal of any stray image features 1702 that are located on depth planes other than that of the top face of the objects (e.g., flat marks on the receiving surface). Fig. 17b shows the depth image of Fig. 17a after this exclusion process.

 In various embodiments, the depth variance threshold may be set to any suitable value. In some embodiments, the value may be chosen as a percentage of the depth associated with the region corresponding to the packages. In some embodiments, the threshold may be user adjustable. In some embodiments, the threshold is in the range of 0.1 mm to 10 cm or any subrange thereof.

 In step 1804, the resulting depth image (e.g., as shown in Fig. 17b) is processed to determine dimension information for the package. For example, any of the techniques described herein may be used to identify the edges of the package and to extract the length and width of the package. Height information may be generated based on the depth information for the region of the image associated with package, and information regarding the position of the camera relative to the receiving surface. For example, the height of the package can be determined based on the average depth for the identified region. As will be understood by one skilled in the art, in various embodiments, the package height may be determined using other

approaches, e.g., based on the depth at the center of the region associated with the package, based on the depth at a region in the image associated with the package and having low local variation in depth, etc.

While the examples above describe the processing of a single depth image of an object, it is to be understood that in some embodiments multiple images maybe used. For example, multiple sparse depth images may be combined to generate a composite image. This composite image may then be processed as described above.

In some embodiments, each of several images can be separately processed to determine the object dimensions. The repeated dimension measurements can then be combined (e.g. averaged) to produce an improved dimension estimate. In some embodiments, the multiple dimension measurements may be used to estimate the accuracy of the measurements. For example, if the dimensions found in the multiple measurements differ from each other by more than a threshold amount, an error warning may be output indicating a possibly faulty result.

B. Dimension Capture Processing Using Both Two and Three Dimensional Cameras

As described above, in some embodiments, the enrollment apparatus may feature both a two dimensional camera (e.g., a conventional RGB digital camera) and a 3D camera (e.g., a 3D IR camera). In some such embodiments, it may be advantageous to use images from both cameras during the dimension capture processing.

For example, as described above, when the enrolled package has a significant height dimension, the depth image may be processed to remove background noise, allowing for more accurate capture of the length and width dimensions. However, for relatively flat packages, e.g., packages having a height dimension approaching or below the depth noise floor of the 3D camera, these techniques may not be effective, resulting in noisy or unreliable dimension capture.

Accordingly in some embodiments, the enrollment apparatus performs the length and width dimension capture processing on a conventional two dimensional image of the package captured with the 2D camera. In some embodiments, this 2D image processing is performed when the height of the package, as determined from the depth image or any other suitable technique, is below a threshold value. In some

embodiments, the 2D image processing may performed when the processing of the depth image returns dimensions outside of a normal range, or when some other error in the 3D dimension capture is indicated. In some embodiments, the 2D dimension capture processing may be performed even when no problem with the 3D dimension capture is indicated, e.g., to “double check” or otherwise confirm the dimension data provided using the 3D camera.

In some embodiments, the dimension capture or other information obtained by processing the 2D camera image may be used to refine or otherwise be used in the dimension capture processing of the 3D camera depth image. For example, the 2D image may be used to identify the lateral position of the package on the receiving surface. This information may be used to restrict the portion of the 3D image processed to determine the height of the package.

For example, Fig. 19 illustrates a process for dimension capture using 3D and 2D camera images. In step 1901, the processor receives a depth image of the package on the receiving surface. In step 1902 the processor processes the depth image to determine the height of the package. In step 1903, the processor determines if the package height is below a threshold level.

In various embodiments, the minimum height threshold may be set to any suitable value. In some embodiments, the value may be chosen based on the depth noise floor for the 3D camera. In some embodiments, the threshold may be user adjustable. In some embodiments, the threshold is in the range of 0.1 mm to 10 cm or any subrange thereof.

If the package height is not below the threshold level, in step 1904 the length and width dimension information is determined from the depth image, e.g., using the techniques described above. The dimension information is then output in step 1905.

If the package height is not below the threshold level, in step 1906 the processor receives a two dimensional image of the package on the receiving surface from the 2D camera. In step 1907, the processor processes the 2D image to determine information such as the length and width dimensions of the package and/or information related to the location of the package on the receiving surface.

In step 1908, the information determined from processing the 2D image is used to refine or otherwise aid in the dimension capture processing of the 3D camera

depth image. For example, referring to the depth image shown in Fig. 17A the 2D image may be used to identify the lateral position of the package on the receiving surface, identified in the figure by a dashed line. This information may be used to restrict the portion of the 3D image processed to determine the height of the package, thereby removing background noise in the depth image (as shown in Fig. 17B). Refined height dimension information is then obtained, e.g., as described above, using the restricted depth image.

The process proceeds from step 1908 to step 1905, outputting the dimension data determined from the 2D and 3D images.

While the examples above describe the processing of a single depth image and a single 2D image of an object, it is to be understood that in some embodiments multiple images of each type may be used. For example, multiple sparse depth images acquired within a short time of each other (e.g., short enough that motion of the dimension capture device 101 is not an issue) may be combined to generate a composite image. This composite image may then be processed as described above.

In some embodiments, each of several sets of 2D and depth images can be separately processed to determine the object dimensions. The repeated dimension measurements can then be combined (e.g. averaged) to produce an improved dimension estimate. In some embodiments, the multiple dimension measurements may be used to estimate the accuracy of the measurements. For example, if the dimensions found in the multiple measurements differ from each other by more than a threshold amount, an error warning may be output indicating a possibly faulty result.

It is to be understood that, in various embodiments, other suitable dimension capture techniques may be used. Some embodiments may employ other types of rangefinders (e.g. optical sensors). In some embodiments, the top (or other) surface of a package may be located mechanically by bringing a sliding arm or a user held wand in contact with the surface package, and detecting the position of the arm or wand. In some embodiments, more than two dimensions of the package may be determined based on captured image data, for example, by stereoscopically imaging the object from multiple perspectives.

Although the examples above generally include dimension capture of rectangular box shaped objects, it is to be understood that the techniques described above can be extended to objects of any arbitrary shape.

5 *RFID Function*

If an item has an RFID tag it will be detected and read by an RFID peripheral attached to or integrated with the enrollment device 100. The acquired data is then available for further processing and/or output to downstream applications.

10

Processing and User Interface Functions

As discussed above, the enrollment device may process the myriad of captured data related to a package and output relevant information to a user. In some embodiments, information is displayed to a user through an interactive graphical user interface (GUI). For example, as shown in Fig. 14, the user may navigate back and forth through a series of screens 1401a, 1401b, and 1401c using, for example, a mouse, keyboard, or touch screen device. Referring to Fig. 14a, screen 1401a shows an image of the package along with captured data. The user may confirm the captured information and/or choose to proceed to screen 1401b, shown in detail in Fig. 14b, for editing the captured data and/or adding additional data. Once all relevant information about the package has been captured and confirmed or otherwise entered, a further screen 1401c presents various delivery service options.

In some embodiments an expert system employing “backward chaining” logic may be employed to receive and analyze the wealth of information coming from the enrolment device. As is known in the art, in typical applications, backward chaining starts with a list of goals (or a hypothesis) and works backwards from the consequent to the antecedent to see if there is data available that will support any of these consequents. An inference engine using backward chaining would search the inference rules until it finds one which has a consequent (Then clause) that matches a desired goal. If the antecedent (If clause) of that rule is not known to be true, then it is added to the list of goals (in order for your goal to be confirmed you must also provide data that confirms this new rule).

The system can use such techniques to generate multiple service options based on the captured information and/or user requirements. As shown in Fig. 15a, 15b, and 15c, these options may be organized and presented (e.g. to a customer or salesperson) in a convenient fashion using, for example, a touch screen interface.

Figure 16 shows another example of a sequence of GUI screens.

In some embodiments, USB and Ethernet connections will be provided. Some embodiments will include additional USB, keyboard, and display connections. In some embodiments the firmware/software will support Simple Object Access

Protocol/Service Oriented Architecture Protocol (SOAP) calls. Some embodiments will support a Web Server, rating engine, and/or maintenance facilities.

5 In some embodiments, an embedded computing platform, e.g. processor 114, contained in or peripheral to the enrolment device 100 allows it to operate as a stand alone postage meter. In some embodiments, the enrolment device 100 brings an intelligent item assessment capability to the corporate mail room. Shippers can be assured that the services they require will be correctly calculated and that items shipped will be in full compliance with the terms of service. Additionally, in some
10 embodiments, the enrolment device will be able to communicate directly with the post office allowing billing directly from SAP, sales and marketing support, and convenient automatic scheduling of pick ups. Rates and incentives can be system wide, applied to a subset of customers, or even be specific to an individual customer.

Display and Control Functions

15 In some embodiments, the main on-device control function is presented by three OLED captioned buttons. The captions are dynamic and are managed by the firmware. An application programming interface (API) allows (possibly external) applications to control the buttons when the firmware is not using them.
20 Operational, maintenance, and diagnostic functions are supported. If required, the extension arm can have a display attached, for example, if required by local regulation.

Additional Features

25 Various embodiments include one or more of the following features:

- The embedded computing platform will have a PSD (Postal Security Device) built in.
- 30 - The enrolment device will use available information (e.g. from an intranet or internet connection) to establish its location.

- The embedded electronics will have a secure “black box” data recorder for audit and control purposes. This capability can be remotely accessed (e.g. via an intranet or internet connection).
- Cryptographic capabilities consistent with export regulations will be available.
- User management and tokens will be supported. Departmental accounting is possible. SAP codes will be supported.
- Work Flow Systems Integration and support for manufacturing systems will be available.
- Dashboard facilities with remote access will be supported.
- Automatic integration with dispatch centers will be supported.
- Embedded wireless broadband will be available.
- Ability to read full size checks and bill payment forms.
- Ability to capture signed documents for onward processing or item truncation.
- Extensive device support including but not limited to;
 - Card Readers,
 - Printers,
 - Postal Label Printers,
 - Interactive Customer Display,
 - Pin Input devices,
 - Keyboards.

Exemplary Applications

Based on the ability to provide the general business benefits described above, the devices techniques described have commercial applications in the following market segments:

30 Managed Content

The evolution of the letter stream as a facility to carry packets suitable for delivery to unattended delivery points requires the addition of infrastructure

allowing that activity. The enrolment of such items requires the ability to capture all of the information required for all items to be sent through the mail stream as well as new value added services. The ability to tag items with services such as cold stream, work flow notifications, risk management, call center notifications, and conditional
5 deliveries will be required. In some embodiments, the enrollment device would be located in locations such as pharmacies or dedicated shipping centers where prescriptions were being prepared for shipment to patients.

Postal Operators & Courier Companies:

- 10 - For the highly automated postal operators and courier companies, the enrollment device provides automated “front end” data collection, leveraging their existing investment in systems and technology.
- For the low or non-automated strata of postal operators and courier companies, the enrollment device provides a low-cost automation solution for the
15 capture and management of shipment related information at their counter locations, eliminating a range of paper-based processes and enabling integration with 3rd party carriers and systems.

The Pharmaceutical Industry:

- 20 - The enrollment device provides the pharmaceutical industry with a means of automating the Provenance and Chain of Custody aspects of their business.

Civil Defense:

- 25 - The enrollment device provides a mechanism for the mass distribution of products and services with a clear Chain of Custody from point of Induction.

Goods Distribution Companies:

- It is anticipated that Goods Distribution companies will benefit from the ability to use the enrollment device to manage and prepare their “one-to many”
30 shipments.

One or more or any part thereof of the techniques described above can be implemented in computer hardware or software, or a combination of both. The methods can be implemented in computer programs using standard programming techniques following the examples described herein. Program code is applied to
5 input data to perform the functions described herein and generate output information. The output information is applied to one or more output devices such as a display monitor. Each program may be implemented in a high level procedural or object oriented programming language to communicate with a computer system. However, the programs can be implemented in assembly or machine language, if
10 desired. In any case, the language can be a compiled or interpreted language. Moreover, the program can run on dedicated integrated circuits preprogrammed for that purpose.

Each such computer program is preferably stored on a storage medium or device (e.g., ROM or magnetic diskette) readable by a general or special purpose
15 programmable computer, for configuring and operating the computer when the storage media or device is read by the computer to perform the procedures described herein. The computer program can also reside in cache or main memory during program execution. The analysis method can also be implemented as a computer-readable storage medium, configured with a computer program, where the storage
20 medium so configured causes a computer to operate in a specific and predefined manner to perform the functions described herein.

A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention.

25 As used herein the terms “light” and “optical” and related terms are to be understood to include electromagnetic radiation both within and outside of the visible spectrum, including, for example, ultraviolet and infrared radiation.

The examples above refer to a package received by the enrollment device. It is to be understood that suitable item may be received and enrolled, including: mail
30 pieces, pharmaceutical items, evidentiary items, documents, containers of any type, etc.

A number of references have been incorporated in the current application. In the event that the definition or meaning of any technical term found in the references conflicts with that found herein, it is to be understood that the meaning or definition from the instant application holds.

5

CLAIMS

What is claimed is:

- 5 1. An apparatus for enrolling a package positioned on a receiving surface, the apparatus comprising:
- at least one weight sensor in communication with the receiving surface which generates a weight signal indicative of the weight of the package;
- a camera unit located to view the receiving surface, the camera unit
- 10 comprising at least one three dimensional camera configured to obtain a depth image of at least a portion of the receiving surface; and
- a processor in communication with the at least one weight sensor and the camera unit, the processor comprising:
- a weight module which produces, in response to the weight signal,
- 15 weight data indicative of the weight of the package; and
- a dimension capture module which processes the depth image to produce dimension data indicative of the size of the package.
2. The apparatus of claim 1, wherein the dimension capture module is configured to
- 20 process the depth image to generate dimension data comprising:
- length and width dimension data indicative of the size of the package along two axes lying in a plane parallel to the receiving surface, and
- height dimension data indicative of the size of the package along an axis transverse to the plane parallel to the receiving surface.
- 25 3. The apparatus of claim 2, wherein the camera unit further comprises a two dimensional camera, and wherein the dimension capture module is configured to:
- determine, based on the height dimension data, if the height of the package is below a threshold height; and
- 30 if the height of the package is below the threshold height:
- acquire at least one two dimensional image of the package using the two dimensional camera;

process the two dimensional image to determine secondary length and width dimension data indicative of the size of the package along two axes lying in a plane parallel to the receiving surface.

- 5 4. The apparatus of claim 3, wherein the dimension capture module is configured to:

 further process the depth image based on the secondary length and width dimension data to determined refined height dimension data indicative of the size of the package along an axis transverse to the plane parallel to the receiving surface.

10

5. The apparatus of claim 4, wherein the dimension capture module is configured to:

 use the secondary length and width dimension data to determine a region of the depth image corresponding to the location of the package; and

- 15 process the region of the depth image corresponding to the location of the package to determine the refined height dimension data.

6. The apparatus of any one of claims 3-5, wherein the threshold is greater than a depth noise of the depth image.

20

7. The apparatus of any one of claims 2-5, wherein the dimension capture module is configured to:

 process the depth image to determine information indicative of a region of the image corresponding to a face of the package located closest to the camera unit.

25

8. The apparatus of claim 7, wherein the dimension capture module is configured to:

 process the depth image to generate the dimension data based on the information indicative of a region of the image corresponding to a face of the package located closest to the camera unit.

30

9. The apparatus of claim 8, wherein the dimension capture module is configured to:

- when processing the depth image to generate the dimension data based on the information indicative of a region of the image corresponding to a face of the package located closest to the camera unit, exclude at least a portion of the depth image located outside of the region of the image corresponding to a face of the package located closest to the camera unit.
- 5
10. The apparatus of claim 9, wherein the excluded portion of the of the depth image has a corresponding depth value within a threshold amount of the depth value corresponding to the region of the image corresponding to a face of the package
- 10 located closest to the camera unit.
11. The apparatus of any preceding claim, wherein the three dimension camera is an infrared camera.
- 15 12. The apparatus of any one of claims 3-11, wherein the two dimensional camera is a visible light camera.
13. The apparatus of any preceding claim, wherein the receiving surface is a stationary surface.
- 20
14. The apparatus of any preceding claim, wherein the receiving surface is non-stationary.
15. The apparatus of claim 14, wherein the receiving surface comprises a conveyor
- 25 belt.
16. The apparatus any preceding claim wherein the camera unit generates a video signal of the package on the receiving surface.
- 30 17. The apparatus of claim 16, wherein the dimension capture module comprises an edge finder module that produces, in response to a video signal from the camera unit, edge data indicative of the location of one or more edges of the package.

18. The apparatus of claim 16, wherein the dimension capture module comprises a color masking module configured to generate information indicative of the presence or location of the package based on color information from the video signal.

5

19. The apparatus of claim 16, wherein the dimension capture module comprises a Hough transformation module that applies the Hough transformation to one or more images from the video signal, and analyzes the transformed images to determine information indicative of the size or location of edges on the package.

10

20. The apparatus of any one of claims 16-19, wherein the video signal comprises at least one of:

a stream of depth images generated by the three dimensional camera, and
a stream of images from a two dimensional camera.

15

21. The apparatus of any preceding claim, comprising an integrated housing comprising the receiving surface and processor.

22. The apparatus of any preceding claim, comprising an integrated housing
20 comprising the camera unit and the processor.

23. The apparatus of any preceding claim, wherein the camera unit is mounted on a support arm extending over the receiving surface.

25 24. The apparatus of claim 23, wherein the support arm extends between a proximal end connected to a housing comprising the receiving surface and a distal end positioned above the receiving surface, the distal end supporting the camera unit.

25. The apparatus of any preceding claim, wherein the at least one weight sensor
30 comprises at least one selected from the list consisting of: a load cell, a MEMs device, a piezoelectric device, a spring scale, and a balance scale.

26. The apparatus of any preceding claim, further comprising a postal meter in communication with the processor.

27. A method of enrolling a package comprising:

- 5 providing the enrollment apparatus of any one of claims 1-26;
 using the enrollment apparatus to determine information indicative of the weight of the package;
 using the enrollment apparatus to determine information indicative of the size of the package; and
10 outputting the information indicative of the weight, and size of the package.

28. The method of claim 27, wherein the information indicative of the weight, and size of the package are determined substantially in parallel.

15 29. A system comprising:

 the enrollment apparatus of any one of claims 1-26; and
 a package management system, wherein the enrollment apparatus is in communication with the package management system to provide information indicative of the weight and size if the package.

20

30. The system of claim 29, wherein the package management system comprises at least one chosen from the list consisting of: a package delivery system, a supply chain management system, an inventory management system, and a chain of custody management system.

25

31. The system of claim 29, wherein the package management system comprises a point of sale unit, and wherein the point of sale unit generates and displays, in response to the information from the enrollment apparatus, information indicative of one or more available service options.

30

32. The system of claim 31, wherein the point of sale unit comprises:
 an input unit for receiving information from a user; and

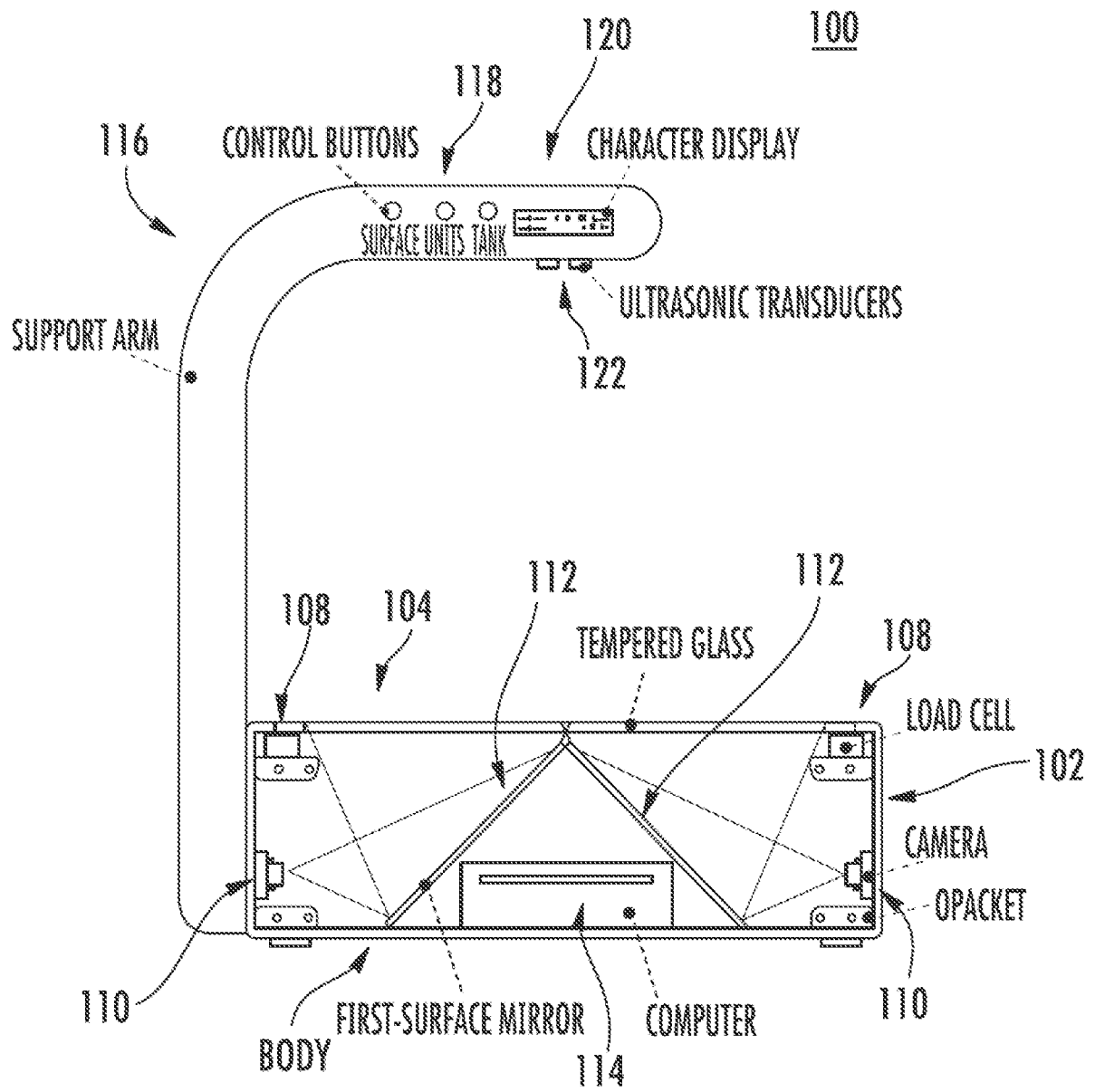
a service unit for providing information indicative of one or more available service options based on the information from the user and information from the enrollment apparatus.

5 33. The system of claim 32, wherein the input unit comprises the enrollment apparatus.

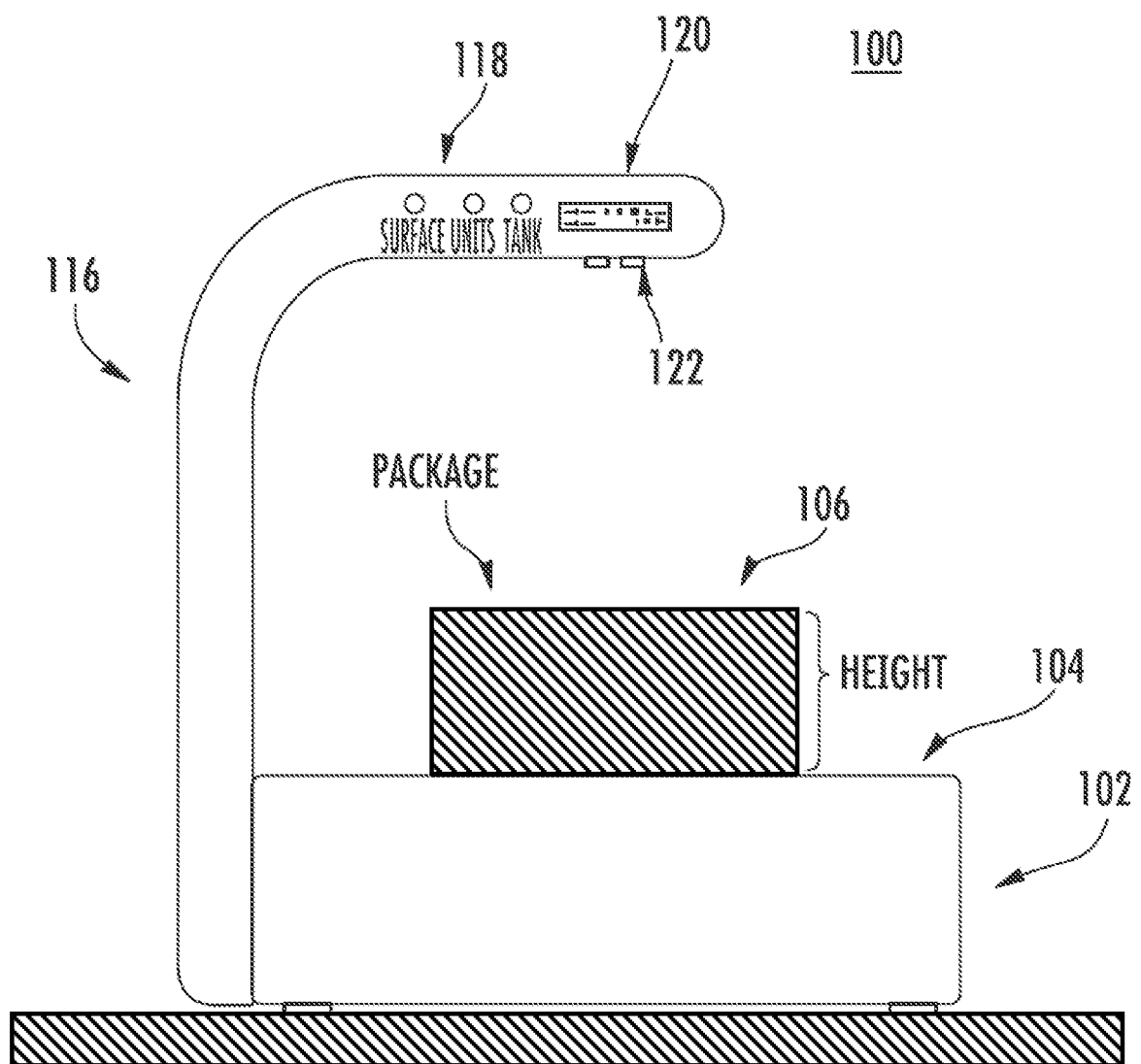
34. The system of claim 32, wherein the input unit receives a series of instructions from the user, and the service unit comprises a backwards chaining logic unit which
10 dynamically determines and displays available service options based on the series of instructions and based information from the enrollment apparatus.

35. The system of claim 29, wherein the package management system comprises a point of service unit, and further comprising a handler module for facilitating
15 communication between the enrollment apparatus and the point of service unit.

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**Fig. 1A**

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**Fig. 1B**

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100

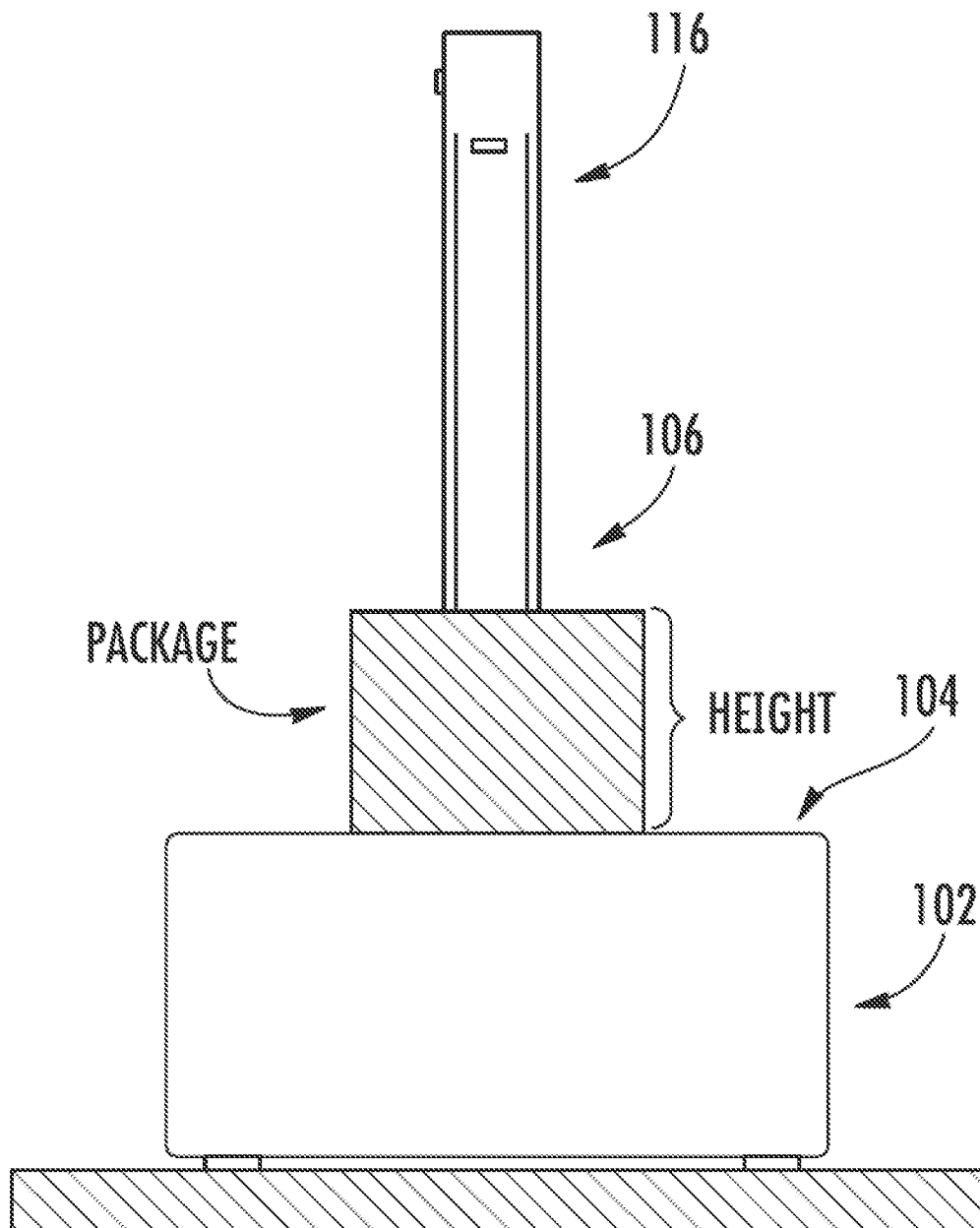


Fig. 1C

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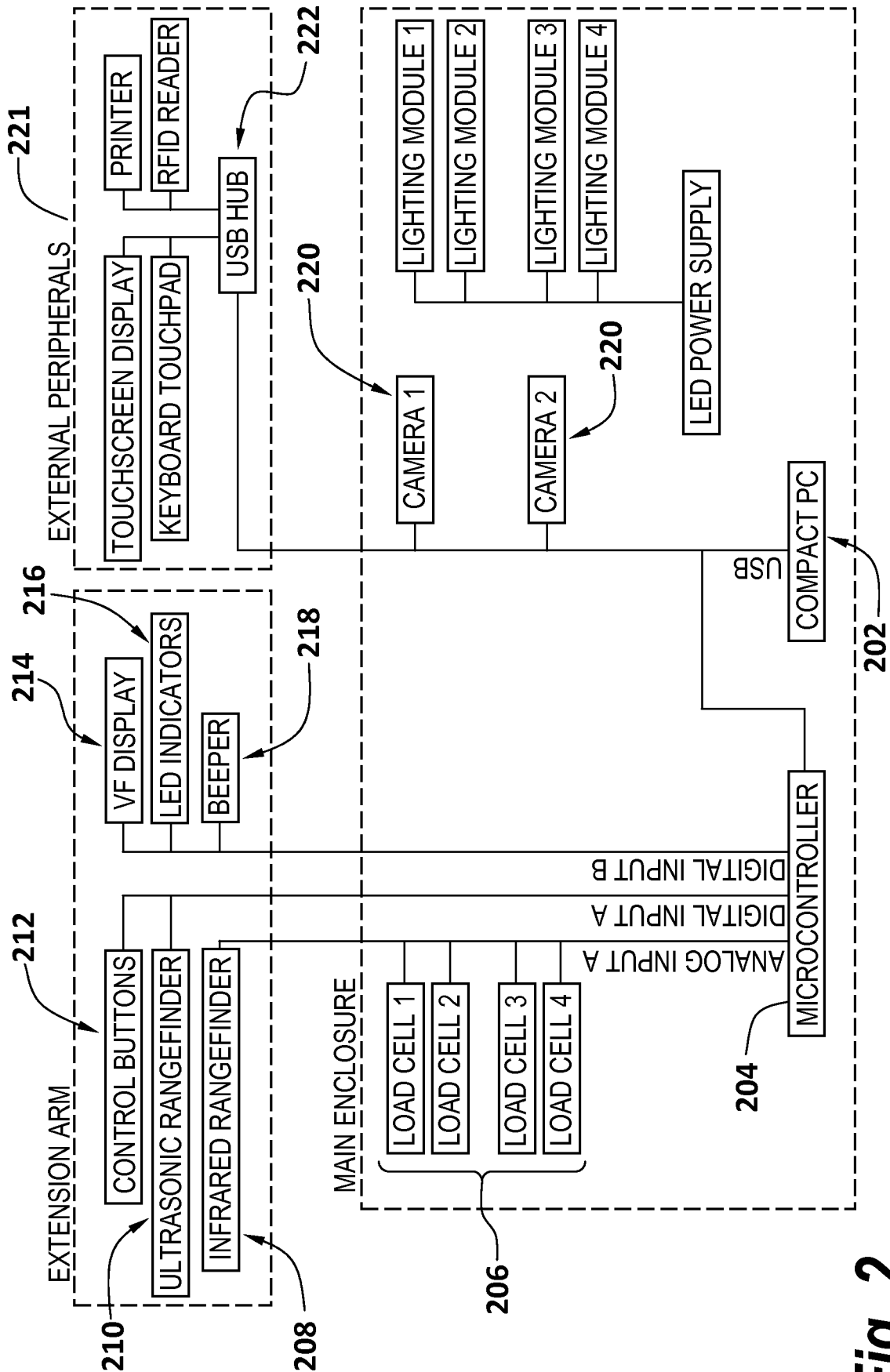


Fig. 2

5/31

SUBSYSTEM	SPEC	TARGET	ACTUAL
IMAGER	RESOLUTION	100 - 200dpi	138dpi
	IMAGING AREA	$\geq 8 \times 6"$	10.5 x 15.9"
	MAX MEASURABLE PARCEL LENGTH	$\geq 18"$	15.5"
	MAX MEASURABLE PARCEL WIDTH	$\geq 13"$	10.5"
RANGEFINDER	HEIGHT RESOLUTION		0.25"
	MAX MEASURABLE PARCEL HEIGHT	$\geq 7"$	12"
LOAD CELL	MAX MEASURABLE WEIGHT	≥ 15 lbs	22lbs.
	WEIGHT RESOLUTION (UNDER 1 lb)	≤ 0.5 oz	0.5 oz.
	WEIGHT RESOLUTION (OVER 1 lb)	≤ 2.0 oz	0.5 oz.
	WEIGHT ACCURACY	$\leq 1\%$ FULL SCALE	0.5% FULL SCALE
UNIT DIMENSIONS	WEIGHT	≤ 50 lbs	30lbs.
	LENGTH	$\leq 20"$	2.2" (BASE ONLY 20")
	WIDTH	$\leq 20"$	14"
	HEIGHT	$\leq 10"$	24" (BASE ONLY 7")

SURFACE MATERIAL

CLEAR TEMPERED GLASS 1/4"

INDICATORS

2x20 CHARACTER VACUUM FLUORESCENT DISPLAY, BEEPER

CONTROLS

BUTTONS FOR PC POWER, UNITS, TARE

SUPPORTED UNITS

METRIC (kg/cm), IMPERIAL (ounces/inches), RAW UNITS

PC CONNECTIVITY

USB 2.0x3

PC CONFIGURATION

CORE 2 DUO 2.4GHz, 4gb RAM, 100GB HD, WinXP SP2

PC POWER REQUIREMENTS

100-240VAC, 50-60Hz. 1.6A

SCALE LIGHTING POWER REQUIREMENTS

100-240VAC, 50-60Hz. 0.3A

Fig. 3

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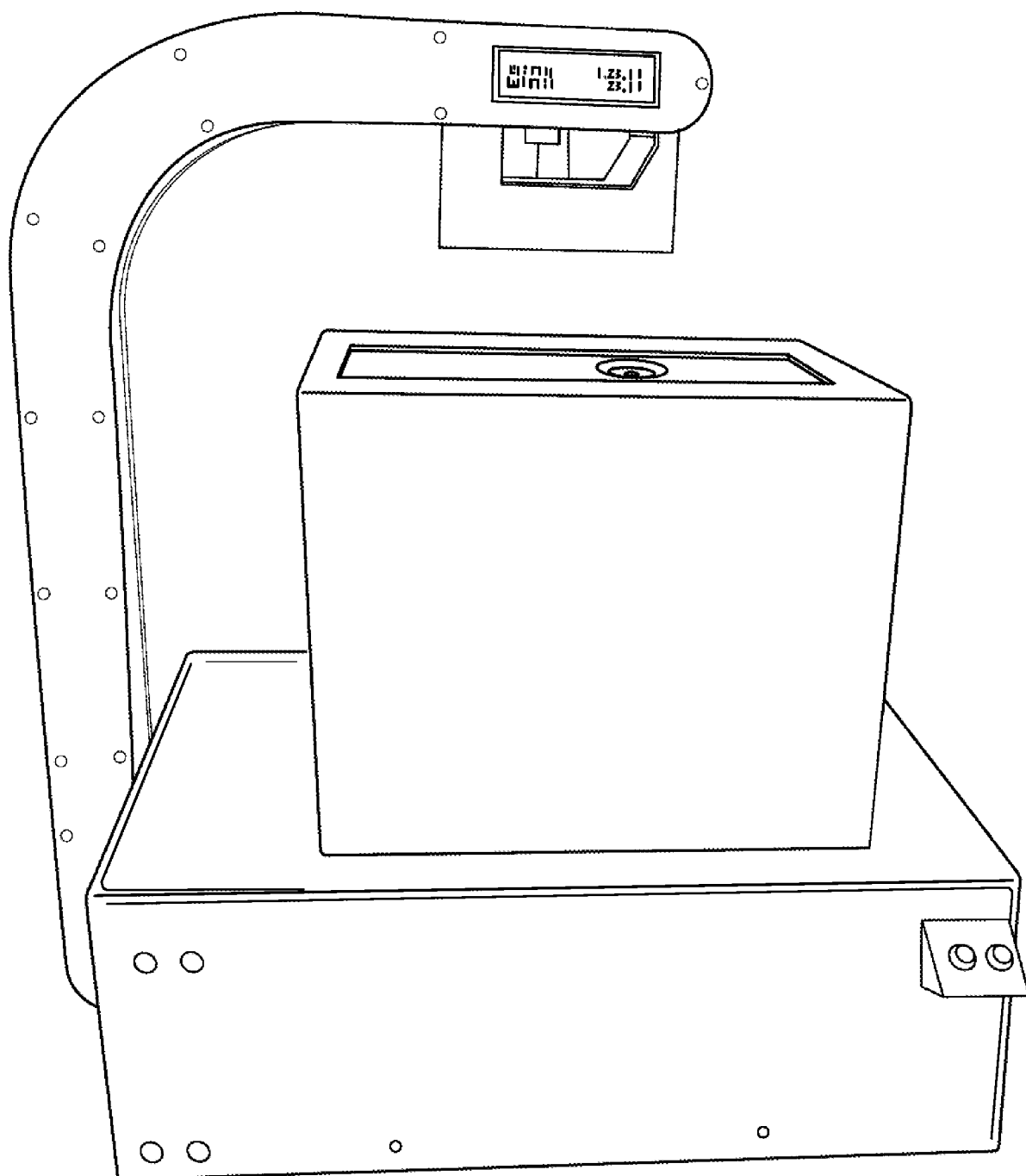


Fig. 4A

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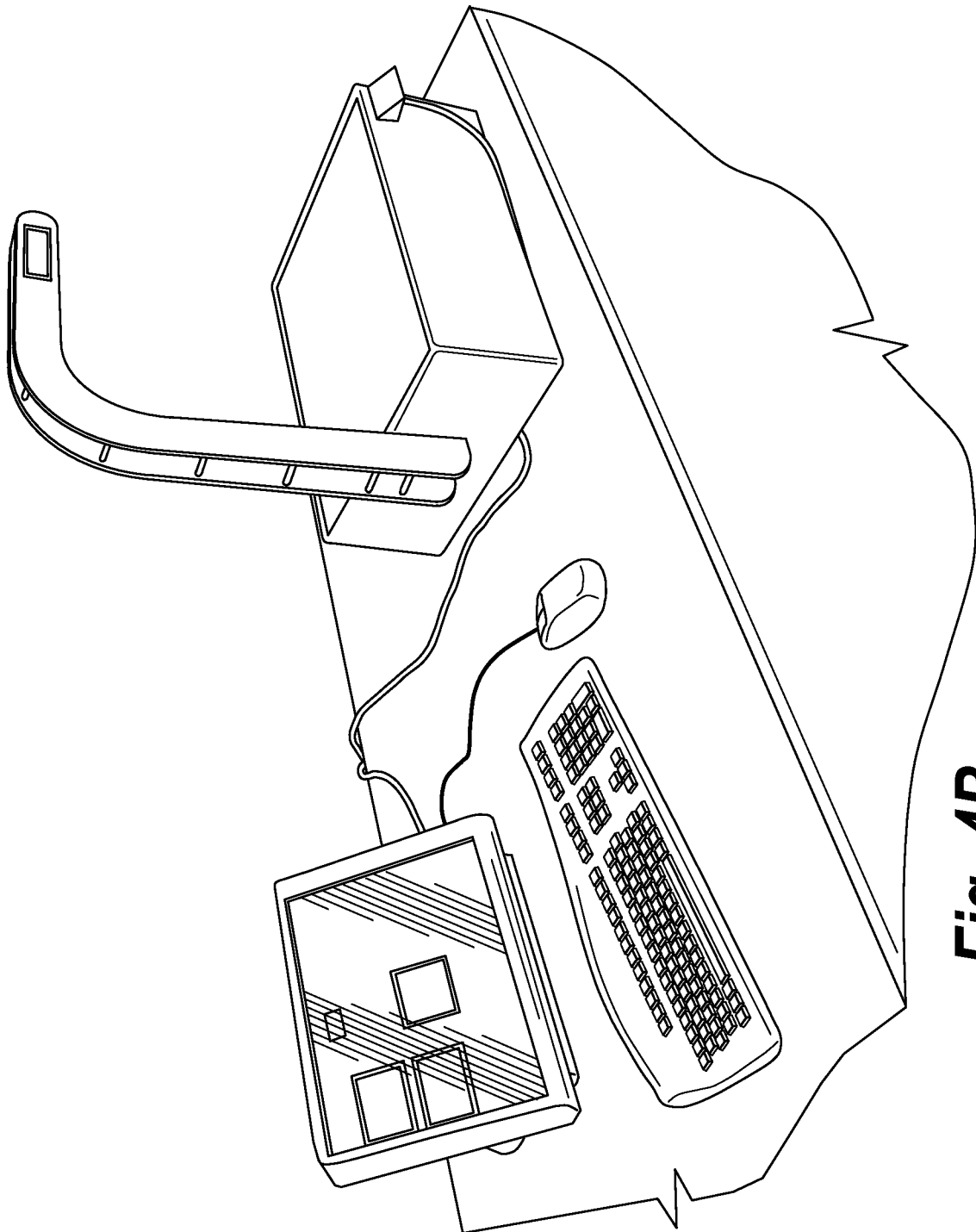


Fig. 4B

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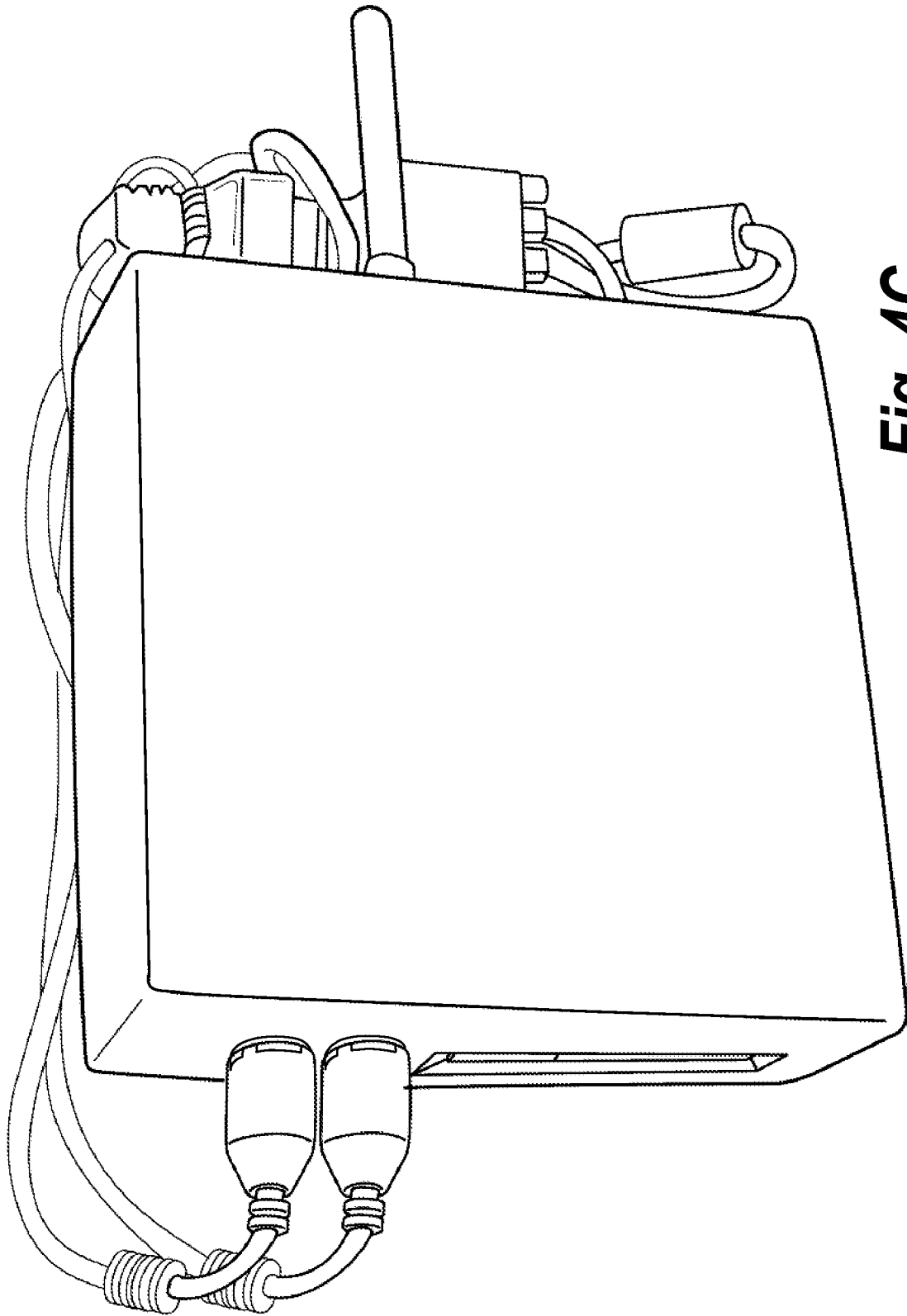


Fig. 4C

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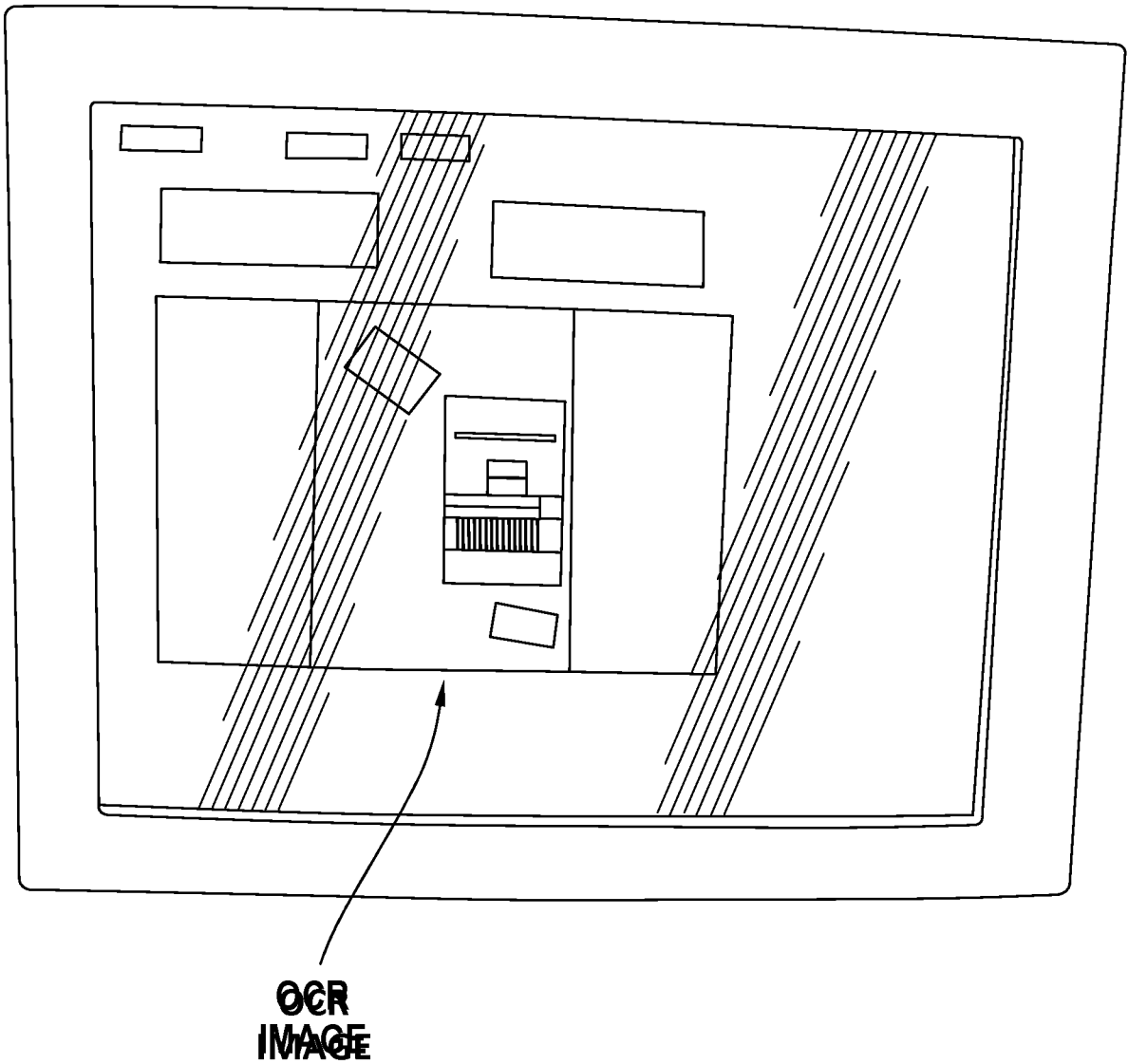


Fig. 4D

10/31

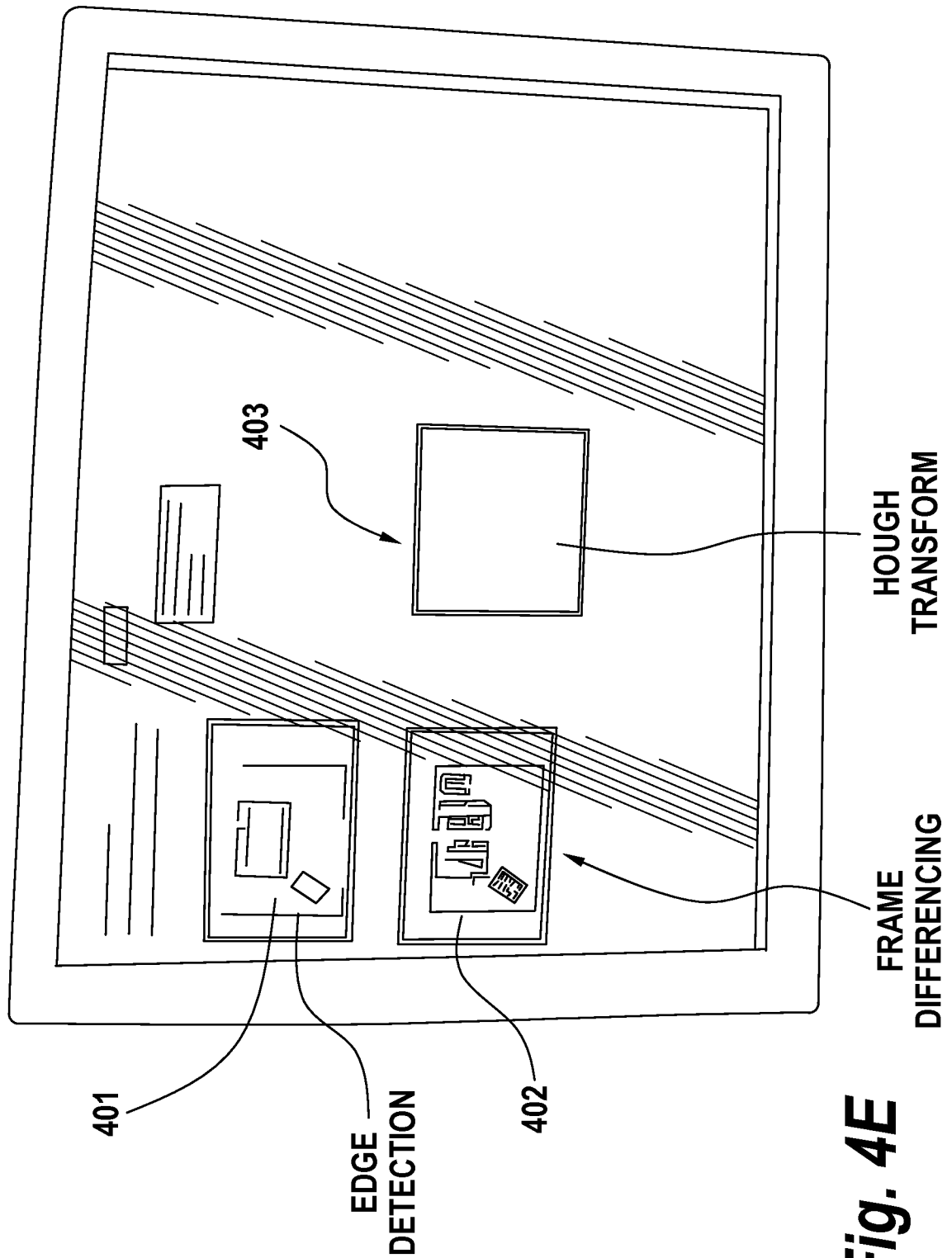


Fig. 4E

11/31

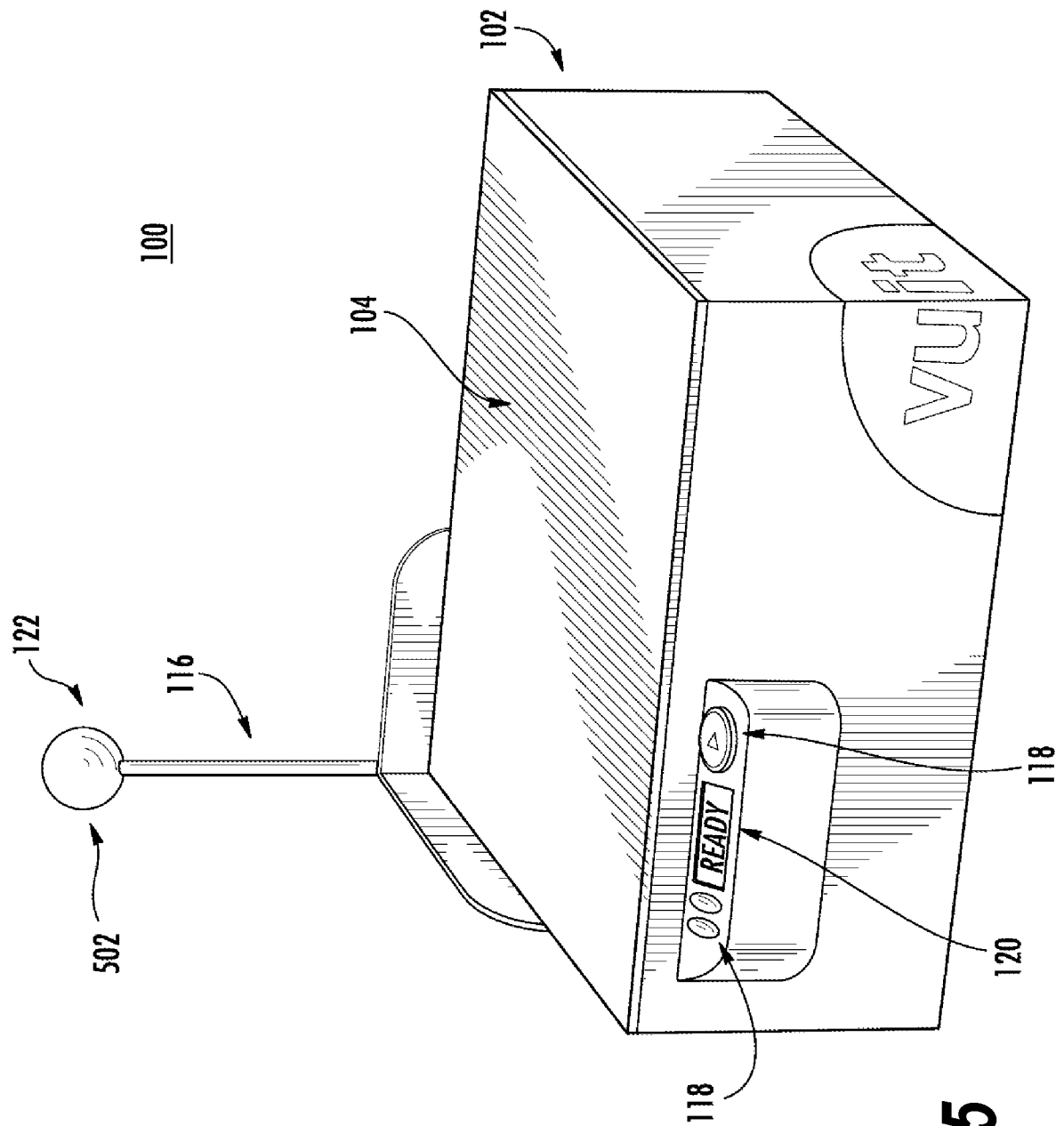


Fig. 5

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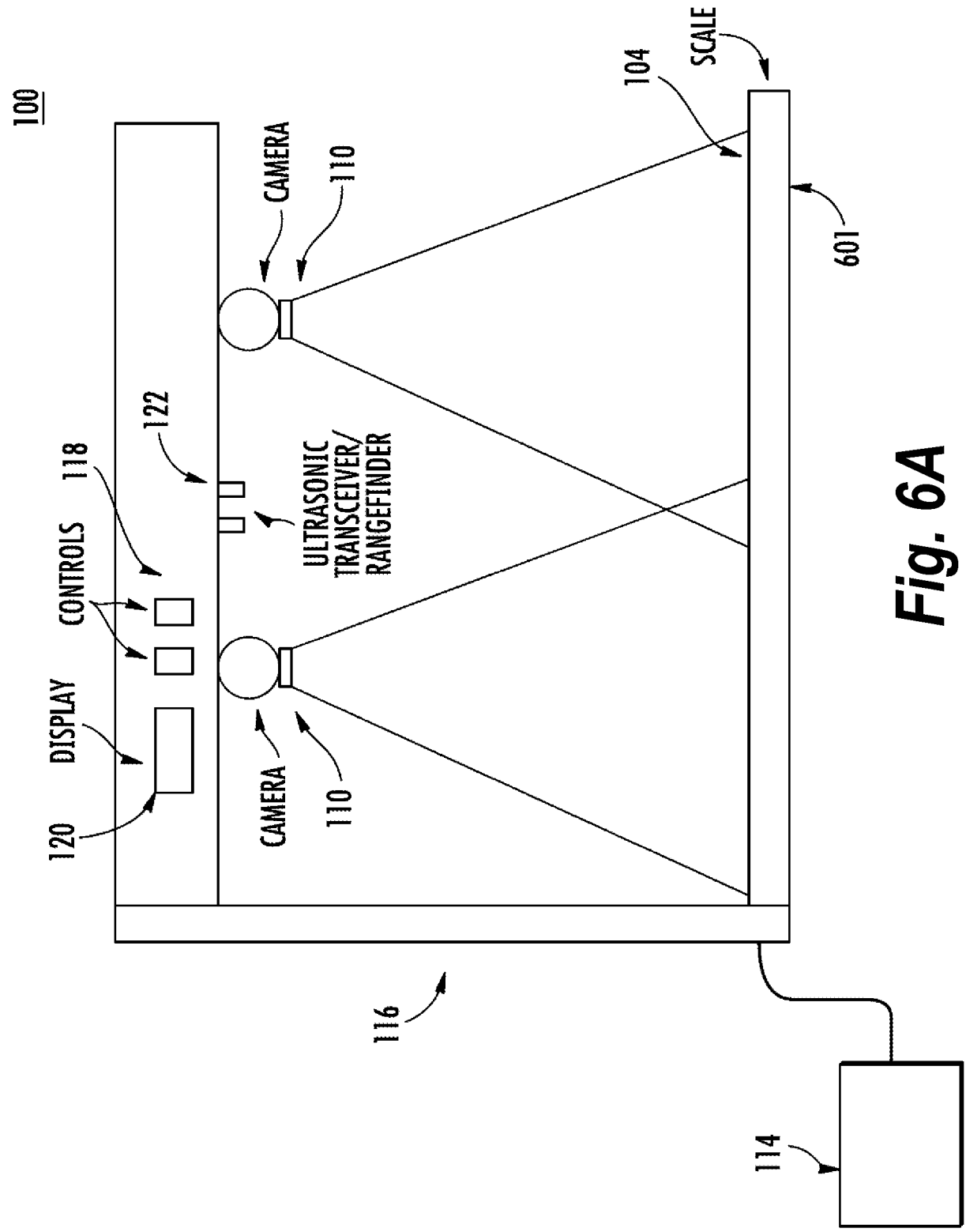


Fig. 6A

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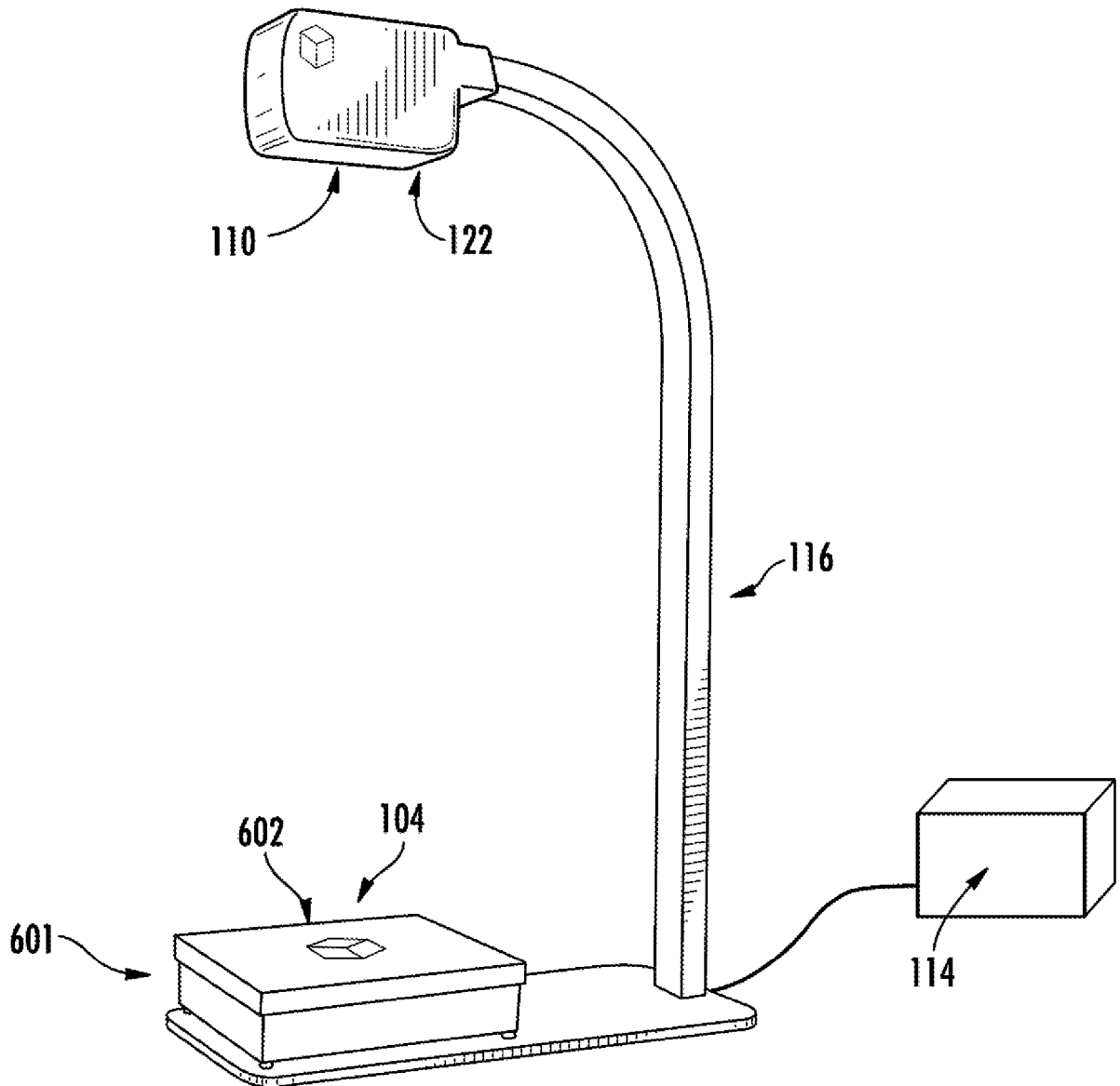
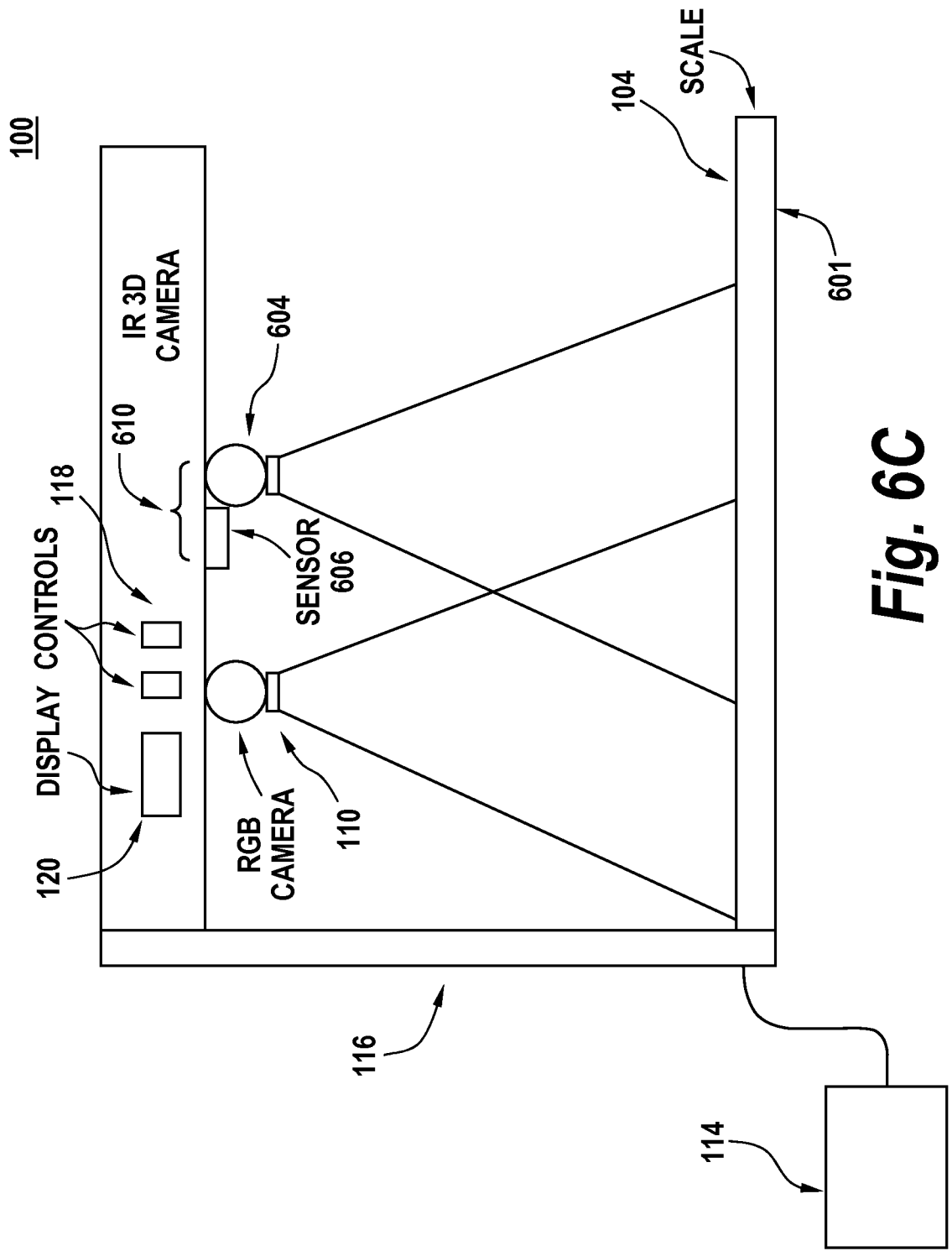
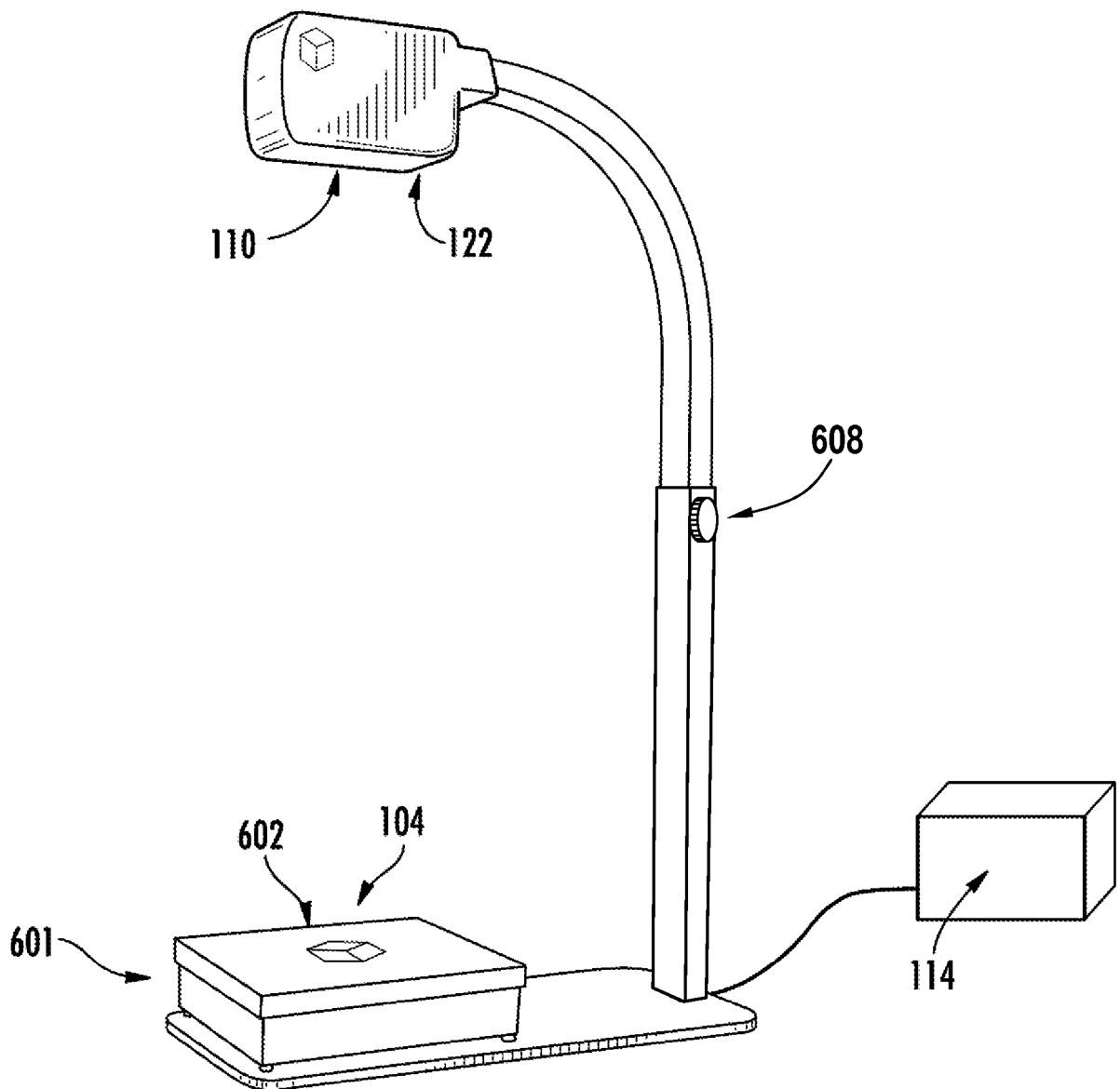


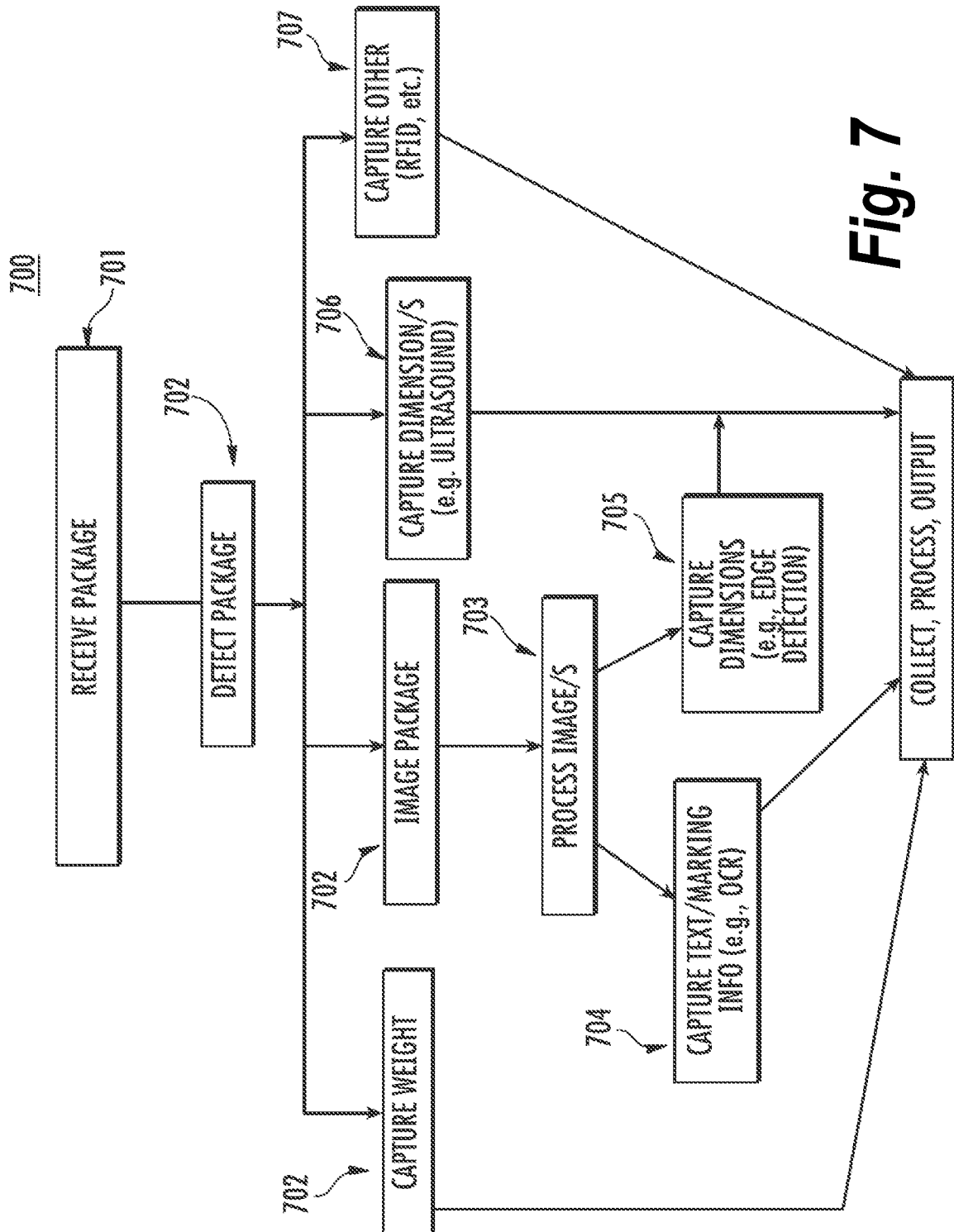
Fig. 6B



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**Fig. 6D**

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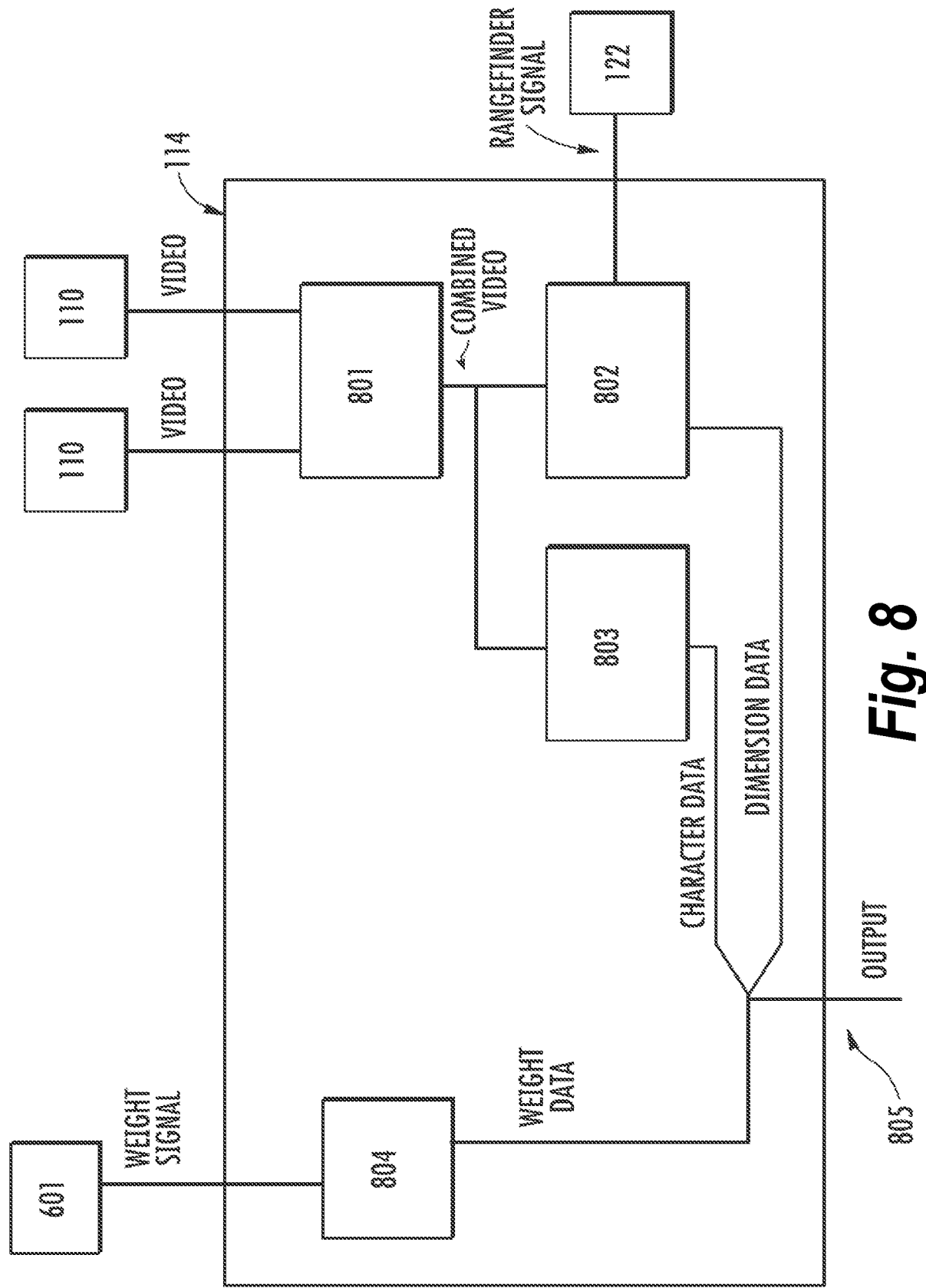
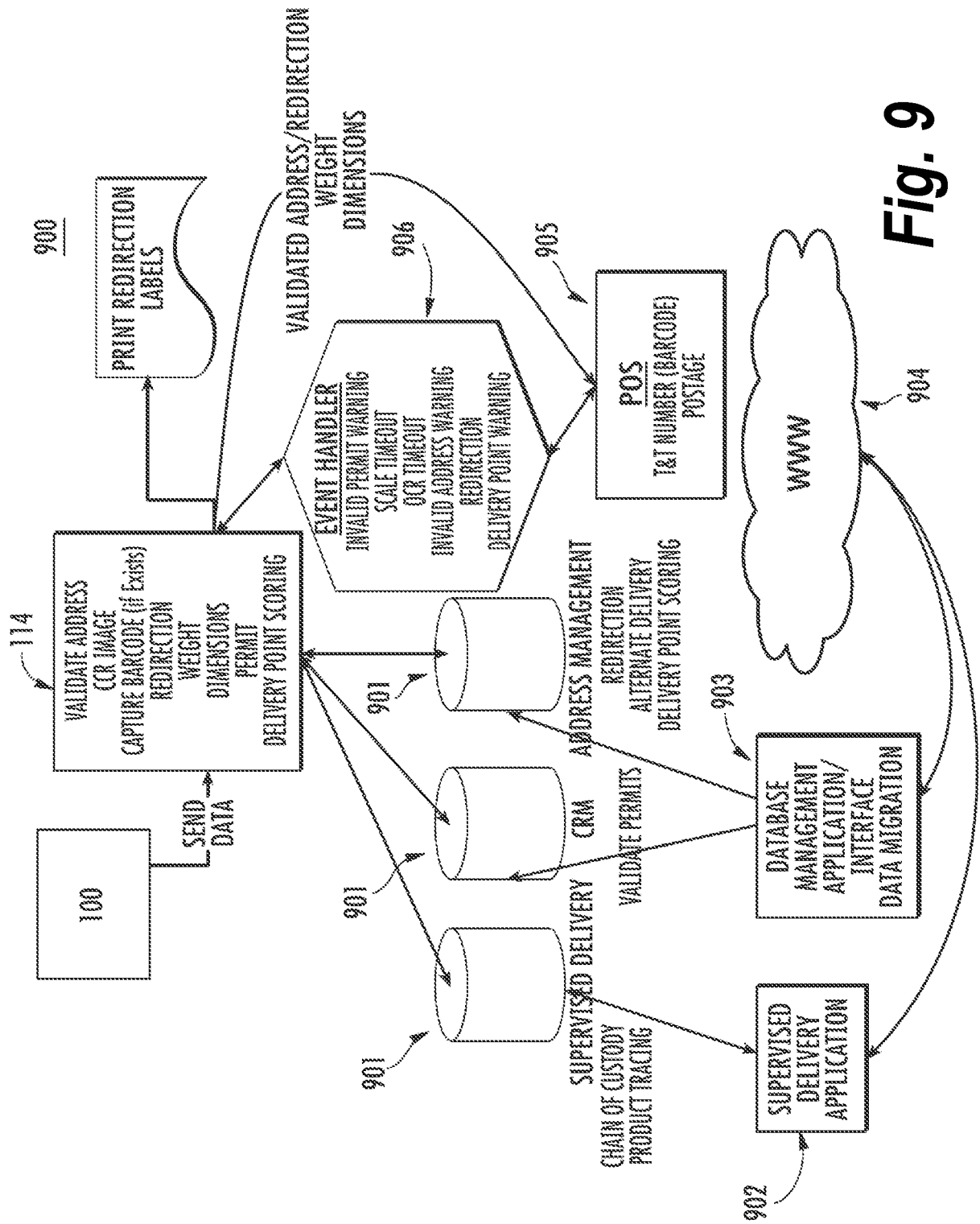


Fig. 8

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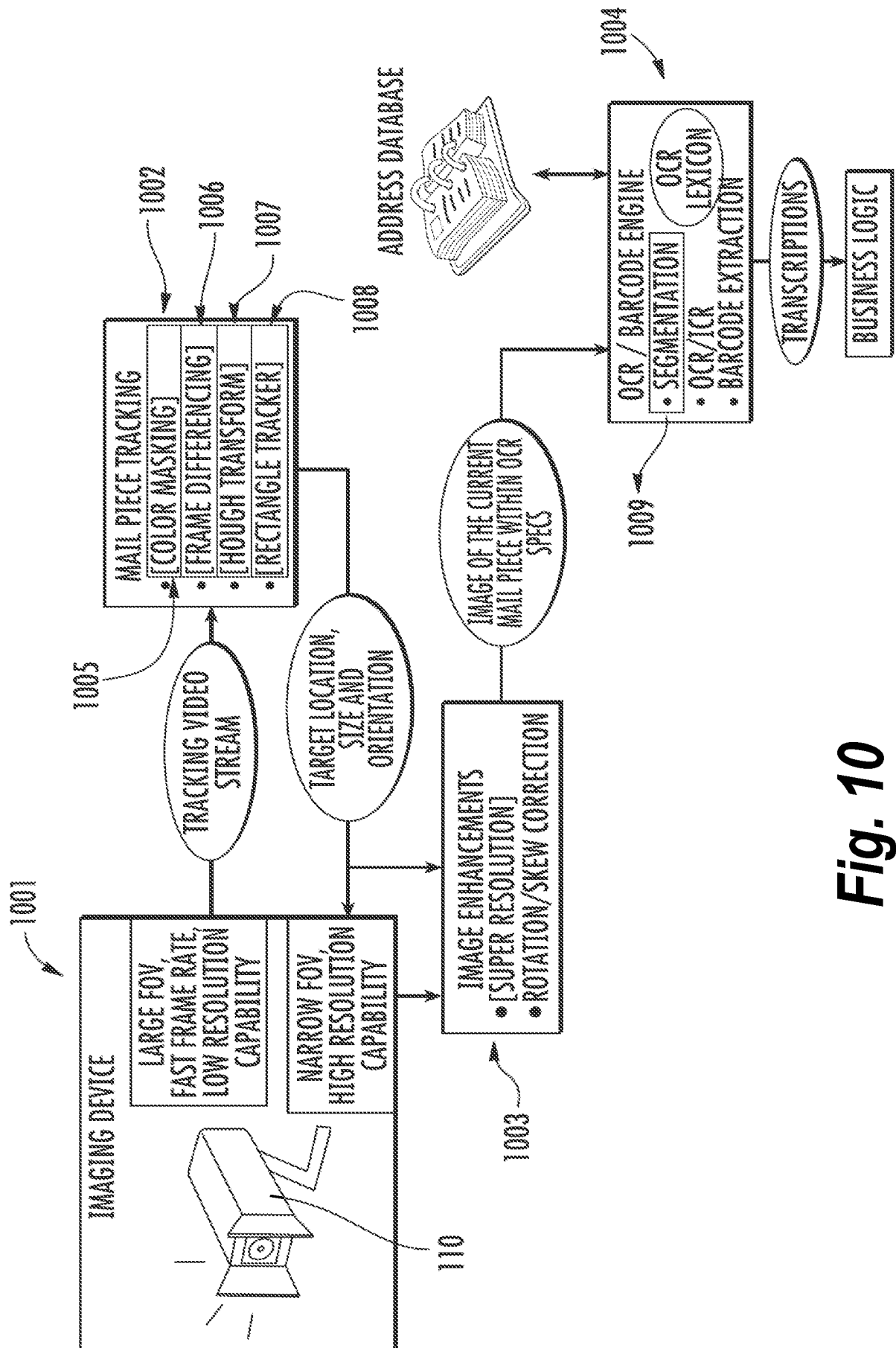
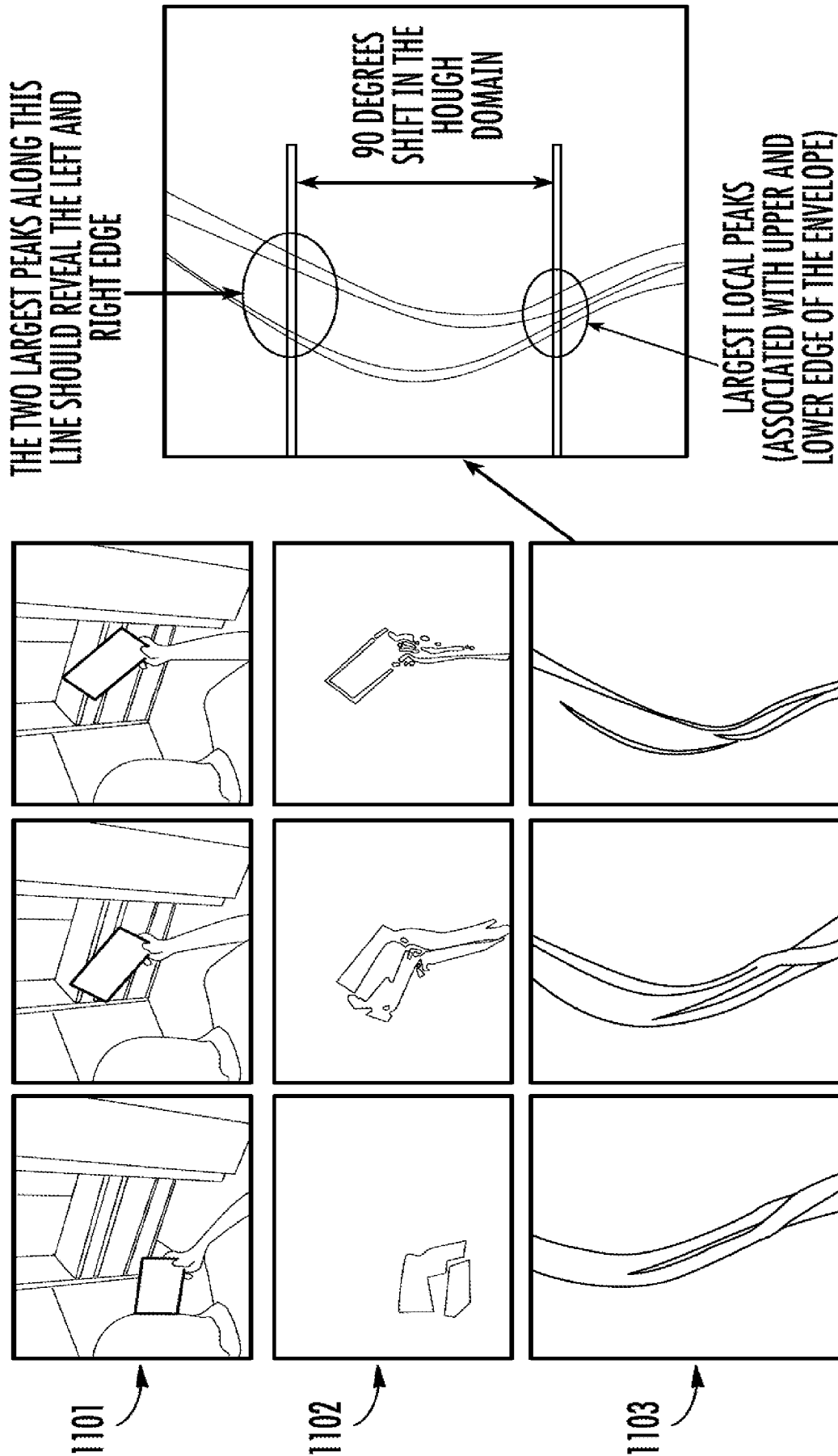


Fig. 10

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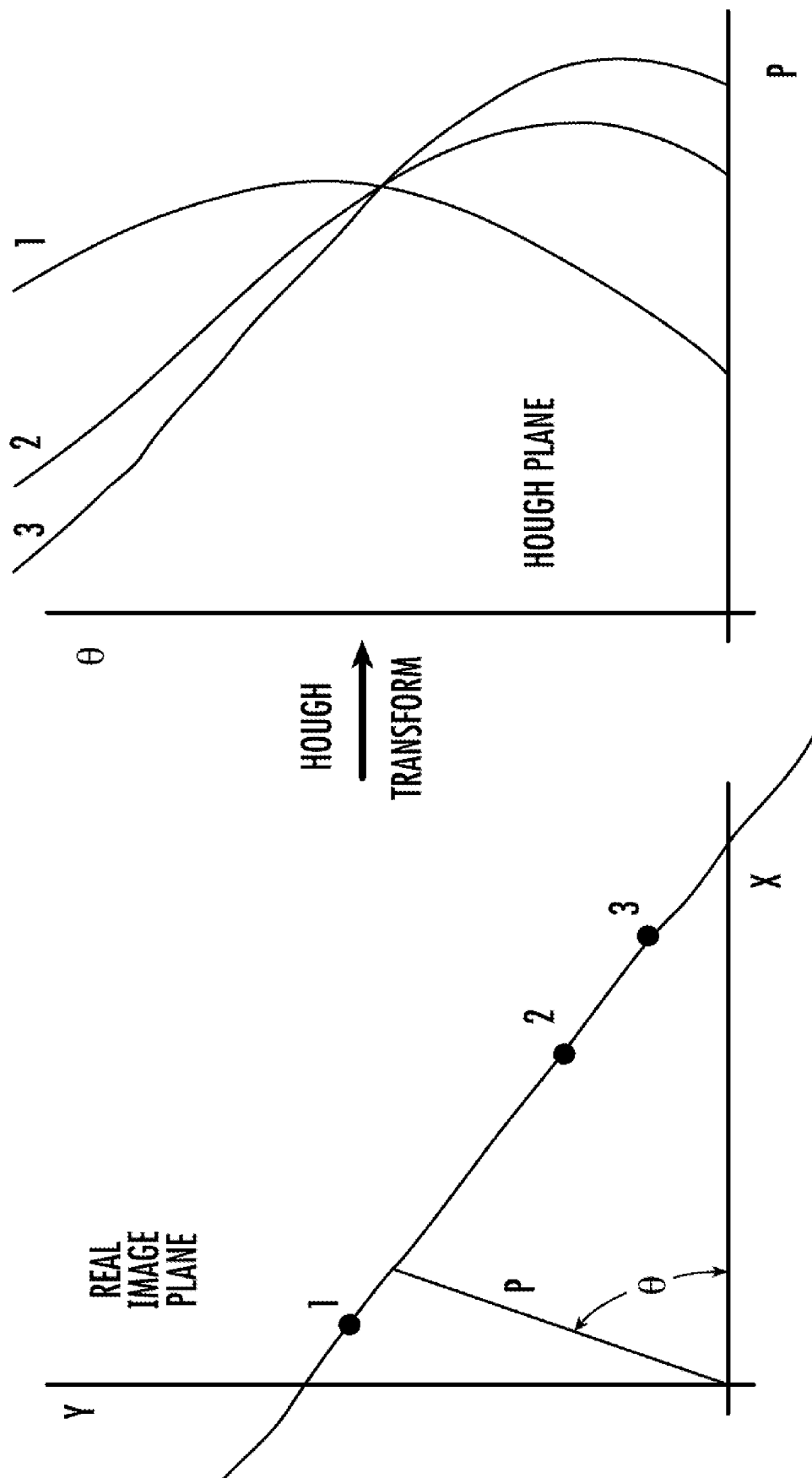


Fig. 12

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CEDAR		
520 STREET #	Lee STREET NAME	Entrance STREET NAME
Amherst CITY	NY STATE	14228 ZIP CODE

Fig. 13

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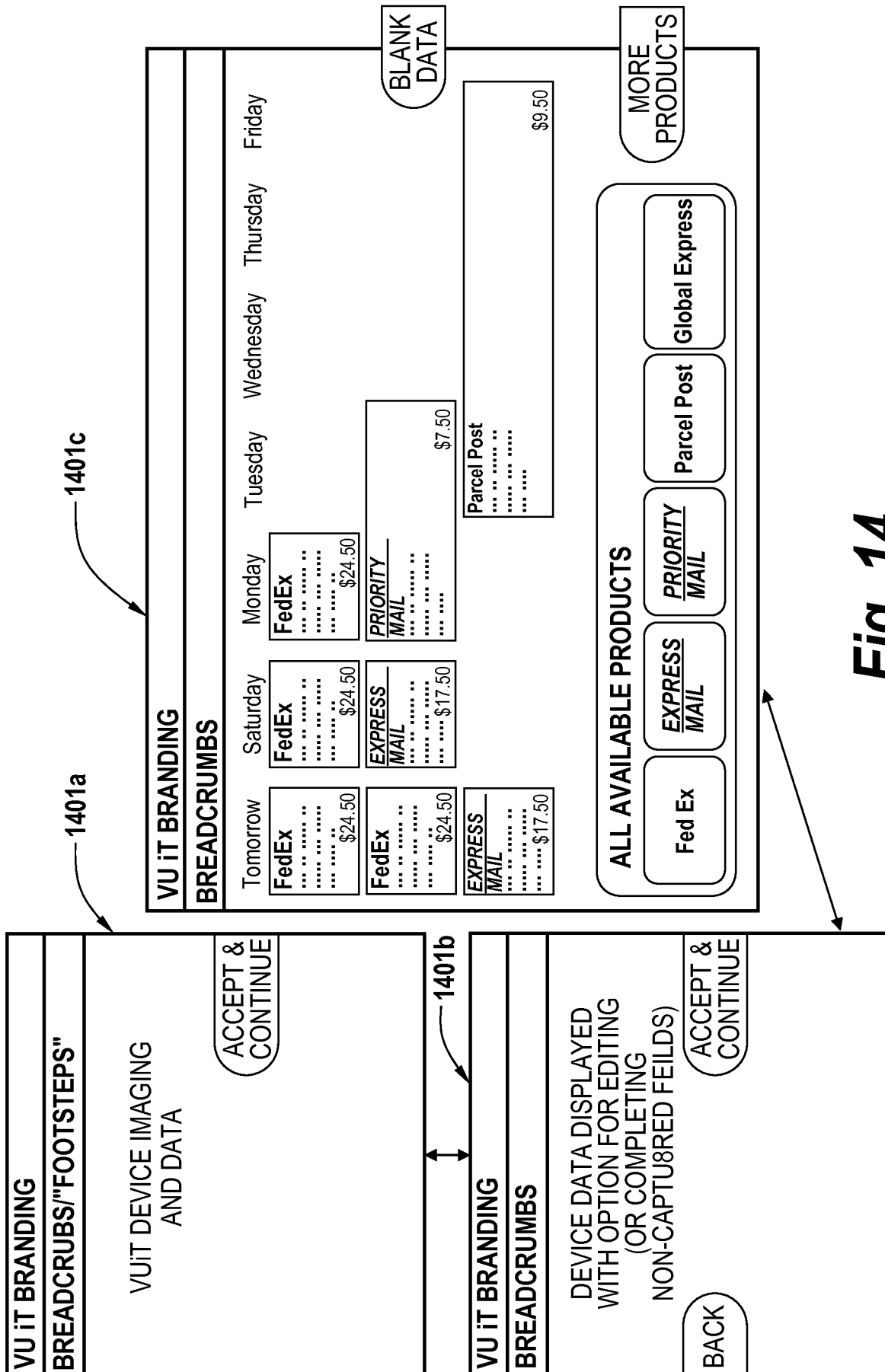
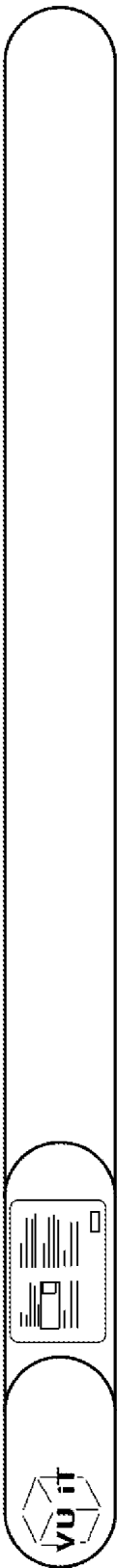


Fig. 14

1401a



OPEN IMMEDIATELY IMPORTANT INFORMATION RCN 100 BALTIMORE DRIVE WILKES-BARRE PA 18702-7939 MR. ERIC METOIS 5 ORTANA ST ARLINGTON, MA 12476-5760		ORIGIN ADDRESS Jennifer Stewart 416 Main St. Lebanon, KS 66952 USA DESTINATION ADDRESS Esther Chaifin 148 Old Street London EC1V 9HQ-England CONTACT INFORMATION Origin: (785) 389-8801 jenn99@gmail.com Dest: 08547-740-740 estherc@aol.com
PARCEL INFORMATION Weight: 2lbs 3oz Dimen: 14 x 9 x 3" POSTAGE AND SERVICES POSTAGE: NONE FOUND SERVICES: NONE FOUND	✓ ↗	

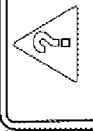
Fig. 14A

1401b





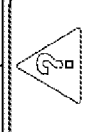
ORIGIN ADDRESS
Jennifer Stewart
416 Main St.
Lebanon, KS 66952
USA



DESTINATION ADDRESS
Esther Chairfin
148 Old Street
London
EC1V 9HQ, England



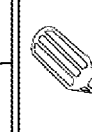
PARCEL INFORMATION
Weight: 2lbs 3oz
Dimen: 14 x 9 x 3"



POSTAGE AND SERVICES
POSTAGE:
SERVICES: Delivery Confirmation
Insurance



PHONE NUMBERS
Origin: (785) 389-8801
Dest: 08547-740-740



ANOTHER CATEGORY
Origin: (785) 389-8801
Dest: 08547-740-740



Fig. 14B

SUBSTITUTE SHEET (RULE 26)





Tomorrow	Saturday	Monday	Tuesday	Wednesday	Thursday	Friday
EXPRESS MAIL \$17.50	EXPRESS MAIL \$15.50	PRIORITY MAIL \$7.50				Print mat'ls \$7.50
FedEx \$24.50	FedEx \$34.50	FedEx \$17.50	Parcel Post \$9.50			
FedEx 10				ups GROUND \$12.50		

ALL AVAILABLE PRODUCTS

EXPRESS MAIL
PRIORITY MAIL
Parcel Post
Print mat'ls
FedEx


Fig. 15A

Tomorrow

EXPRESS MAIL
.....
\$17.50

FedEx 10
.....
\$17.50

FedEx 10
.....
\$17.50

Wednesday

EXPRESS MAIL
.....
\$17.50

FedEx 10
.....
\$17.50

Thursday

PRIORITY MAIL
.....
\$17.50

FedEx 10
.....
\$17.50

Friday

Parcel Post
.....
\$17.50

Saturday

UPS GROUND
.....
\$17.50

Sunday

Monday

Print mat'ls
.....
\$17.50

Available services

Fig. 15B

Tomorrow

Friday

Saturday

Sunday

Monday

Tuesday

Wednesday

EXPRESS MAIL
.....
..... \$17.50

EXPRESS MAIL
.....
..... \$17.50

EXPRESS MAIL
.....
..... \$17.50

EXPRESS MAIL
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..... \$17.50

EXPRESS MAIL
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EXPRESS MAIL
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EXPRESS MAIL
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EXPRESS MAIL
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EXPRESS MAIL
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FedEx 10
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FedEx 10
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FedEx 10
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FedEx 10
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FedEx 10
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FedEx 10
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FedEx 10
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FedEx 10
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FedEx 10
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Parcel Post
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Parcel Post
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Parcel Post
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Parcel Post
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Print mat'ls
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Print mat'ls
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Print mat'ls
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UPS GROUND
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UPS GROUND
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UPS GROUND
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UPS GROUND
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UPS GROUND
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..... \$17.50

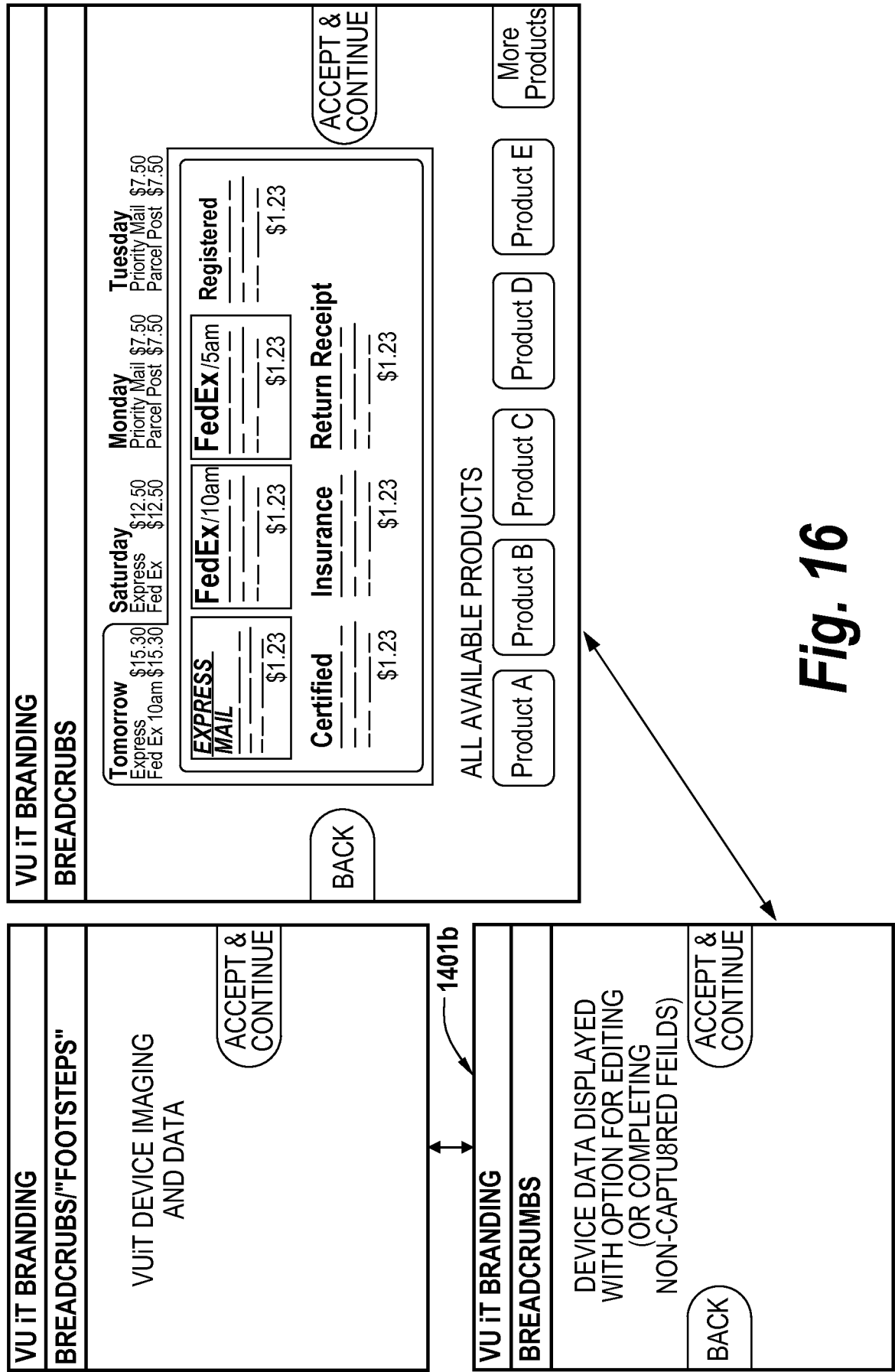
UPS GROUND
.....
..... \$17.50

UPS GROUND
.....
..... \$17.50

UPS GROUND
.....
..... \$17.50

Available services

Fig. 15C



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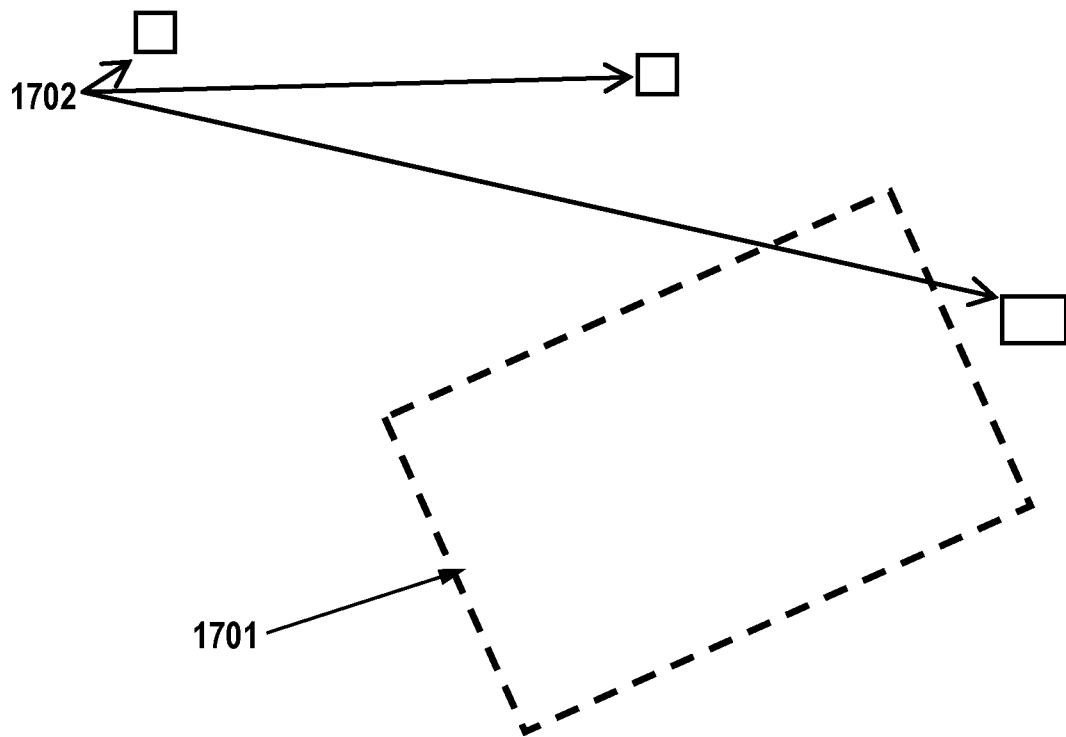


Fig. 17A

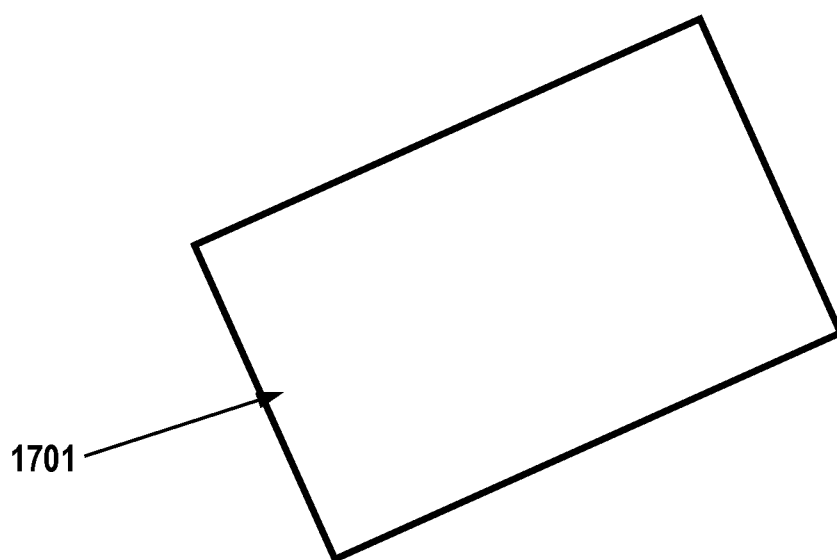
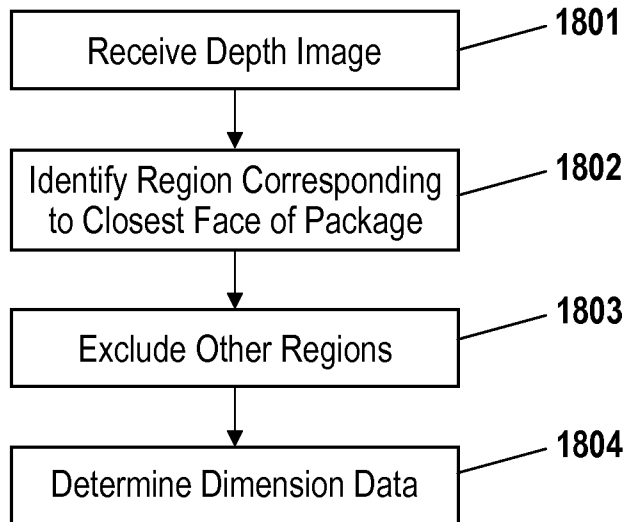
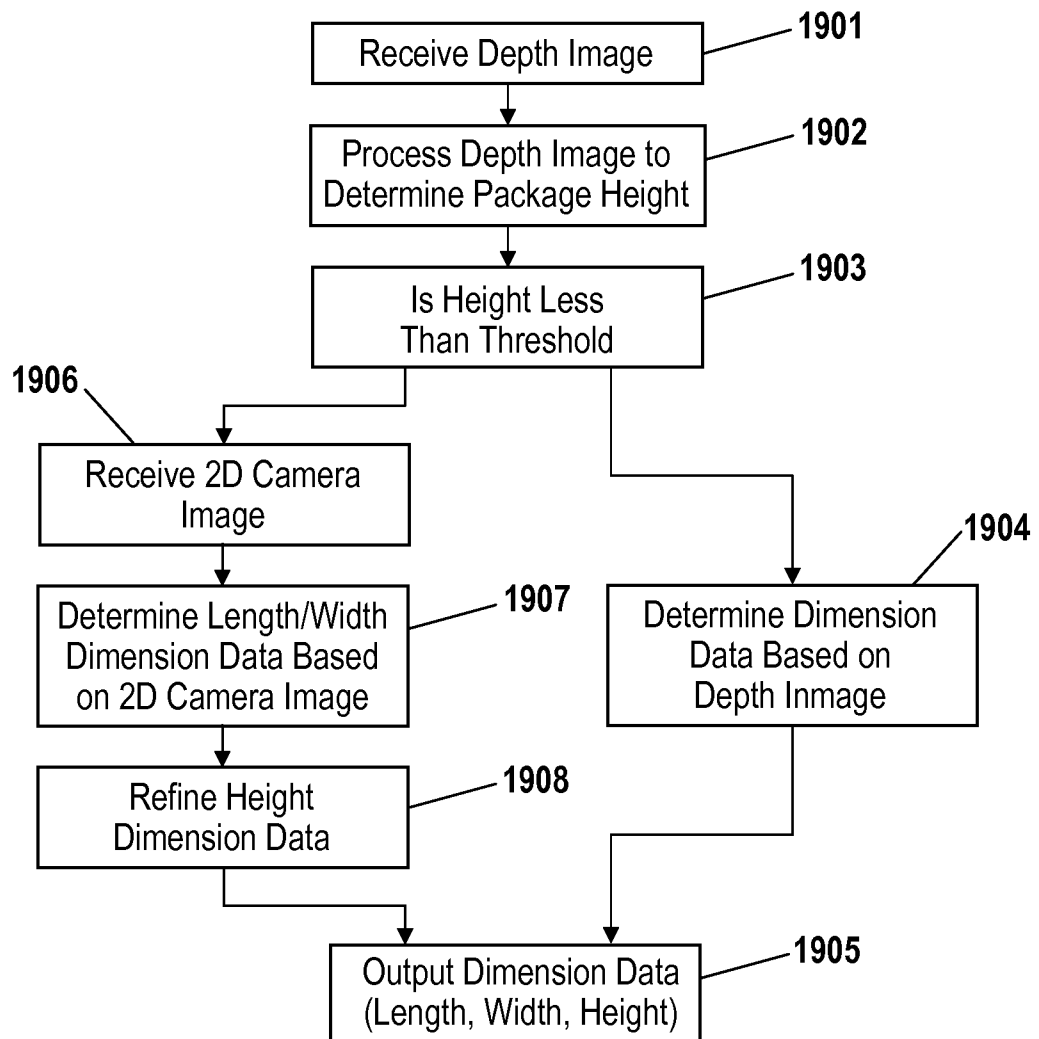


Fig. 17B

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**Fig. 18****Fig. 19**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/37642

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G06Q 30/00 (2012.01)

USPC - 705/332

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - G06Q 30/00 (2012.01)

USPC - 705/332

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

IPC(8) - G06Q 30/00 (2012.01) (text search)

USPC - 705/21; 705/330; 705/332 177/116; 226/10; 226/168; 235/453; 235/454 (text search)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PubWEST (PGPB, USPT, USOC, EPAB, JPAB), Google Patents, Google Scholar; Search terms used: package camera weight scale data depth dimension height length size width axis axes threshold plane parallel surface location region noise face closest address OCR region

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2009/0222354 A1 (Murphy et al.) 03 September 2009 (03.09.2009), entire document, especially Fig. 1A, 2, 4E, 8; Para [0010], [0058], [0061], [0075], [0077], [0122], [0141], [0142]	1-10
Y	US 2008/0156882 A1 (Tsikos et al.) 03 July 2008 (03.07.2008), entire document, especially, paras [1080], [01112]-[1115], [1143], [1147], [1148], [1162], [1173], [1183], [1186], [1235]	1-10
A	US 2003/0218606 A1 (Zhirkov et al.) 27 November 2003 (27.11.2003), entire document, especially Para [0088], [0297], [0454]	1-10
A	US 2006/0210145 A1 (Lee et al.) 21 September 2006 (21.09.2006), entire document	1-10

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

29 July 2012 (29.07.2012)

Date of mailing of the international search report

23 AUG 2012

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Lee W. Young

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/37642

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 11-35
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.