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Claxton et al.

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(54) **IMAGE FEATURE MEASUREMENT**

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G06V 10/772 (2022.01)

(52) **U.S. Cl.**
CPC ***G06T 7/60*** (2013.01); ***G06V 10/764*** (2022.01); ***G06V 10/772*** (2022.01)

(58) **Field of Classification Search**
CPC ... G06T 7/62; G06T 7/60; G06T 2207/10024; G06T 2207/30164; G06V 10/772; G06V 10/764
See application file for complete search history.

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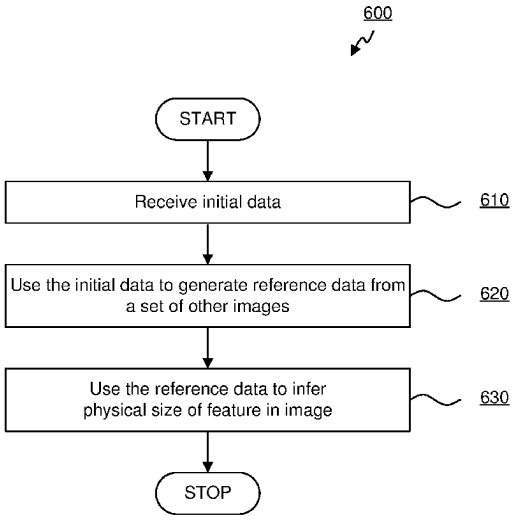
(74) *Attorney, Agent, or Firm* — Nixon & Vanderhye P.C.

(57) **ABSTRACT**

A computer implemented method for determining a physical size of a feature represented in an image is provided together with computer systems and programs for carrying out the method. The method receives initial data comprising an indication of a respective physical size of one or more known types of object. The method uses the initial data to generate reference data from a first reference image. The generated reference data comprises an indication of a respective inferred physical size of one or more reference types of object. The method uses the generated reference data to determine the physical size of the feature based, at least in part, on: a size of a representation of one of the reference types of object in the image; the inferred physical size of that reference type of object; and a size of the representation of the feature in the image.

21 Claims, 9 Drawing Sheets



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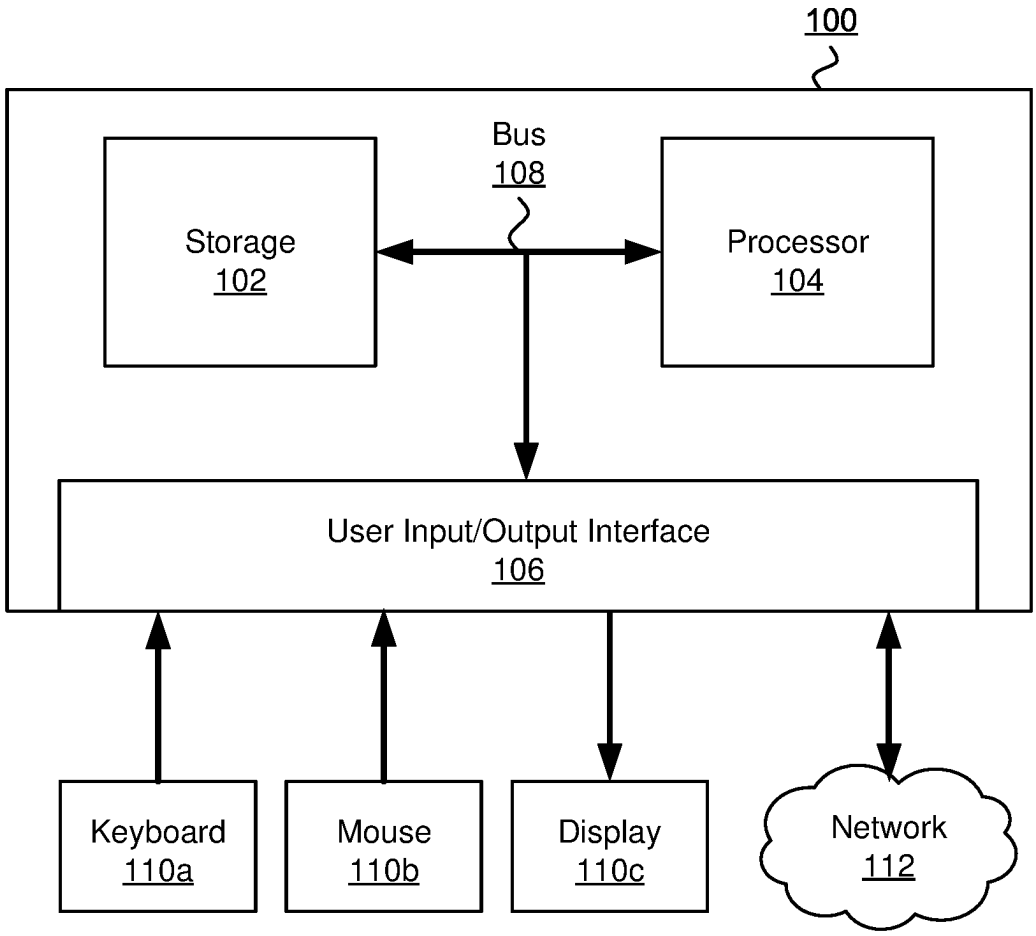
100
Bus
108
Storage
102
Processor
104
User Input/Output Interface
106
Keyboard
110a
Mouse
110b
Display
110c
Network
112

FIGURE 1

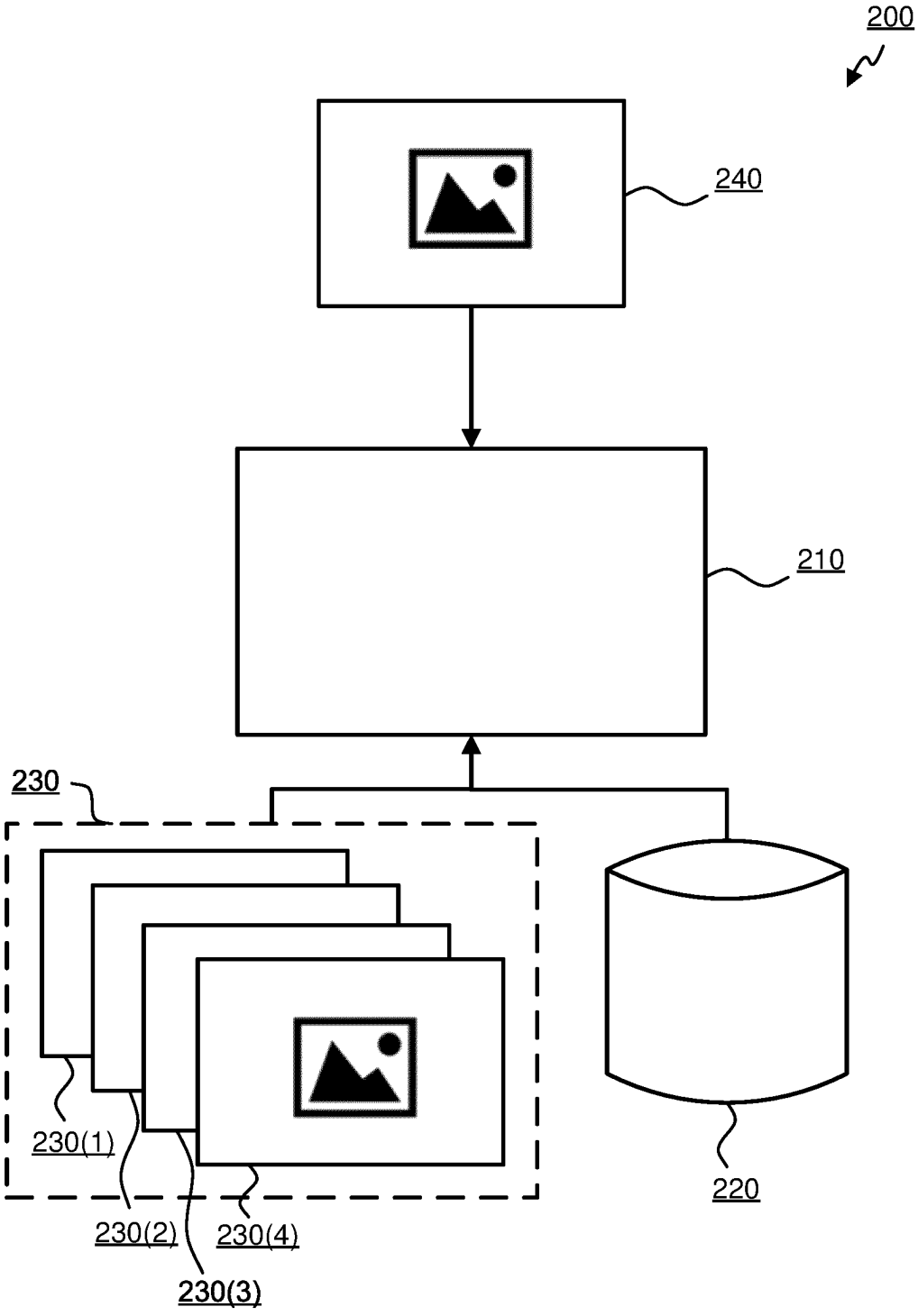

FIGURE 2

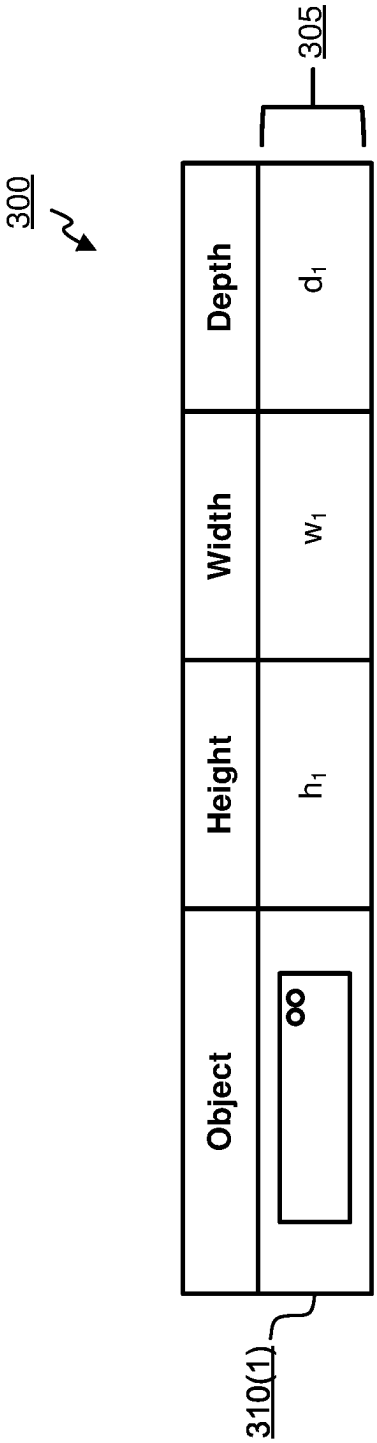

FIGURE 3

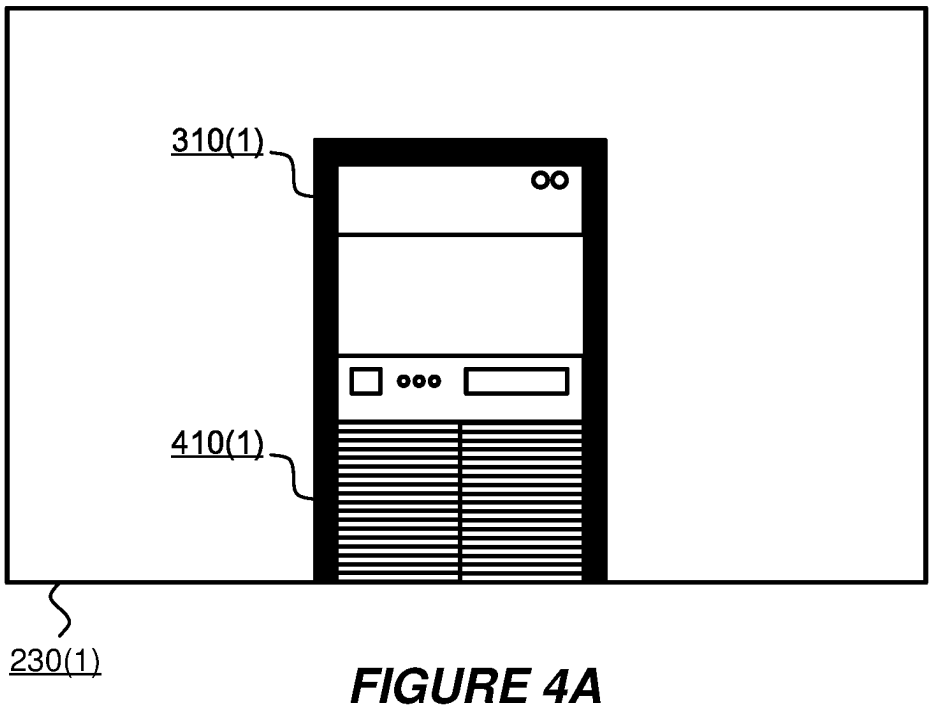

FIGURE 4A

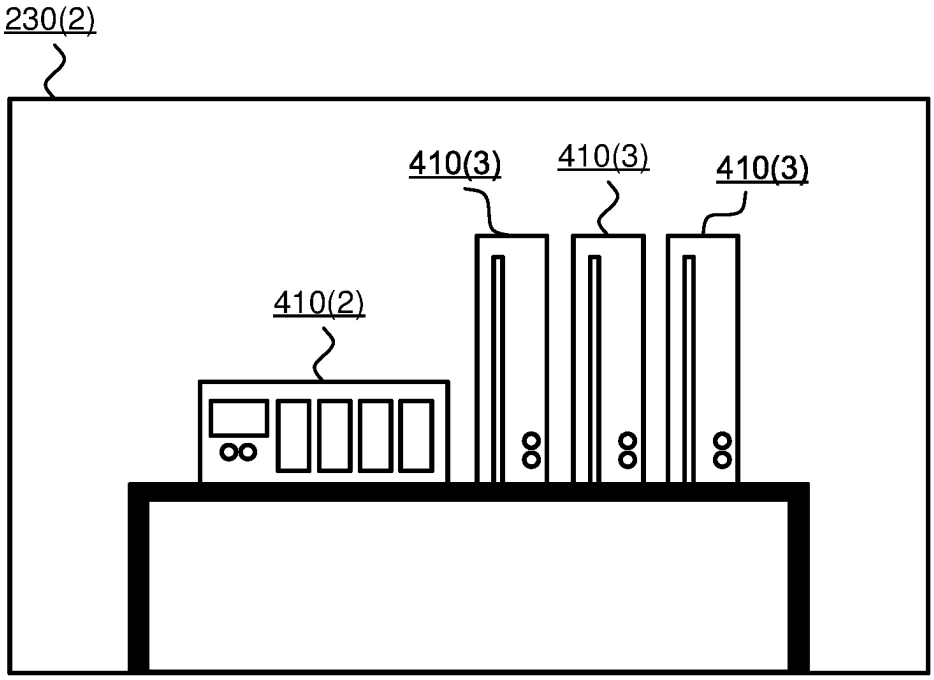

FIGURE 4B

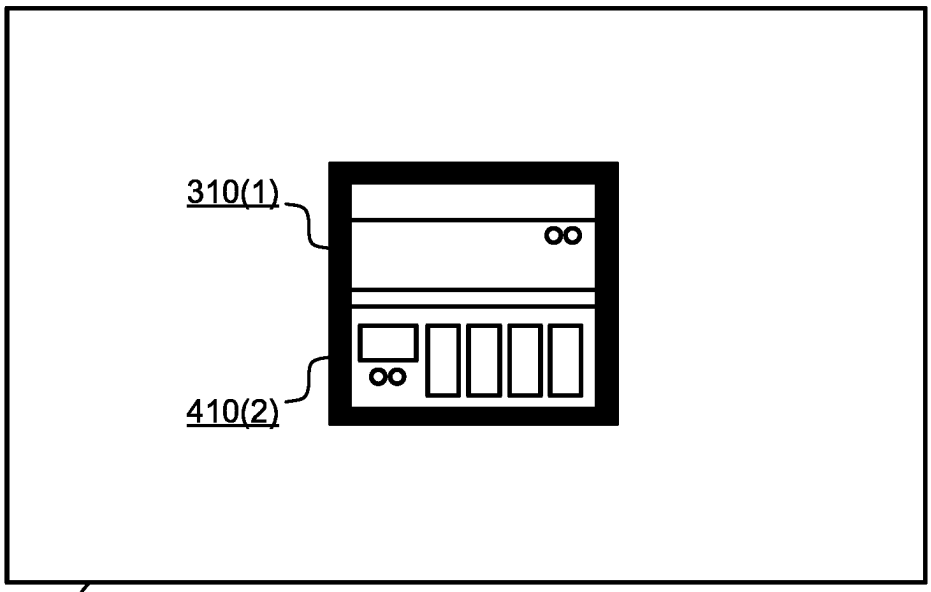

FIGURE 4C

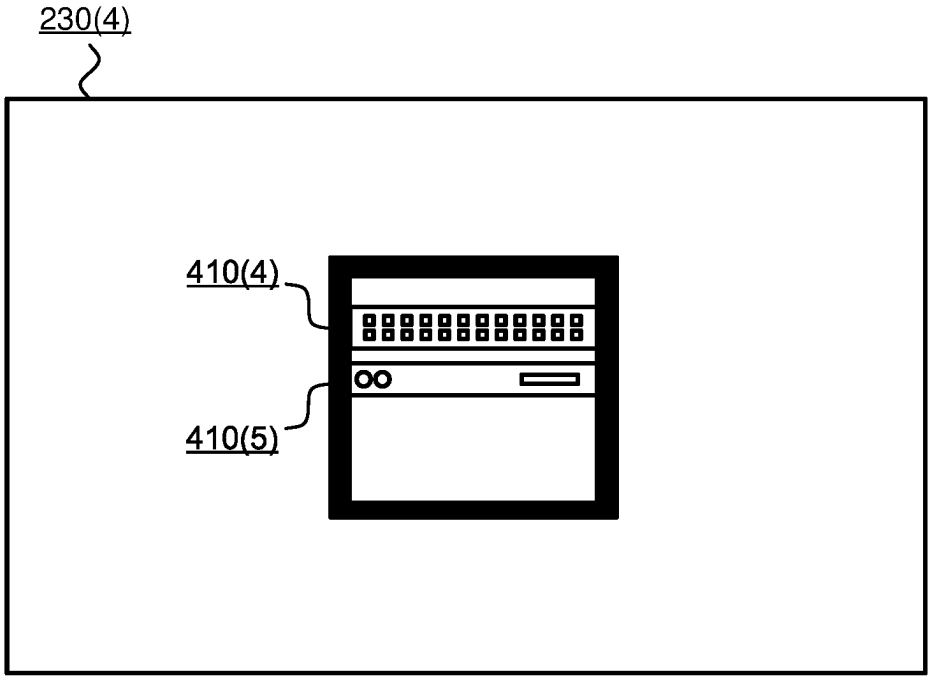

FIGURE 4D

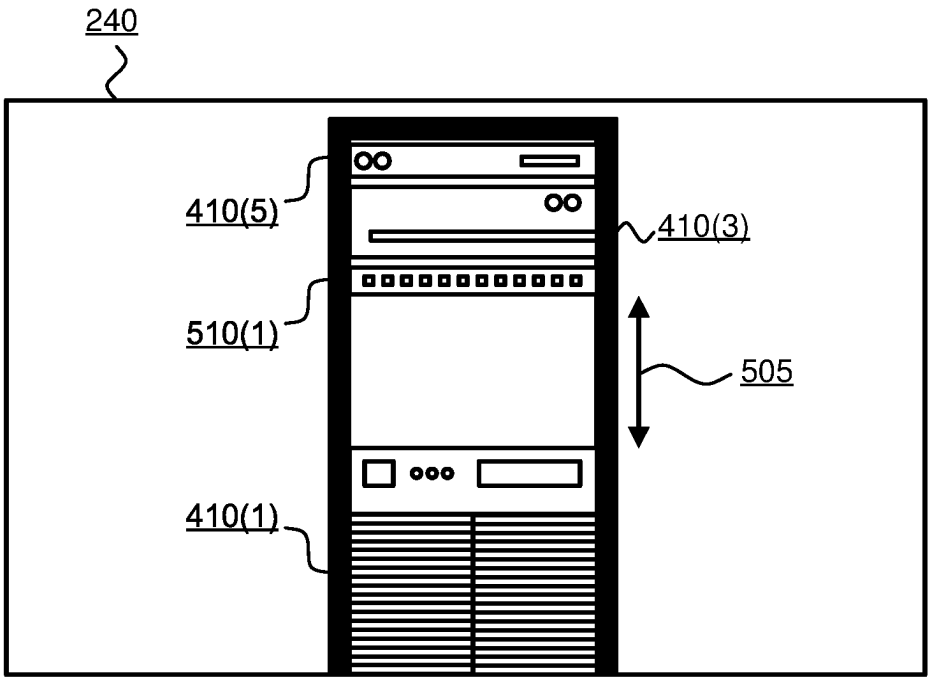

FIGURE 5

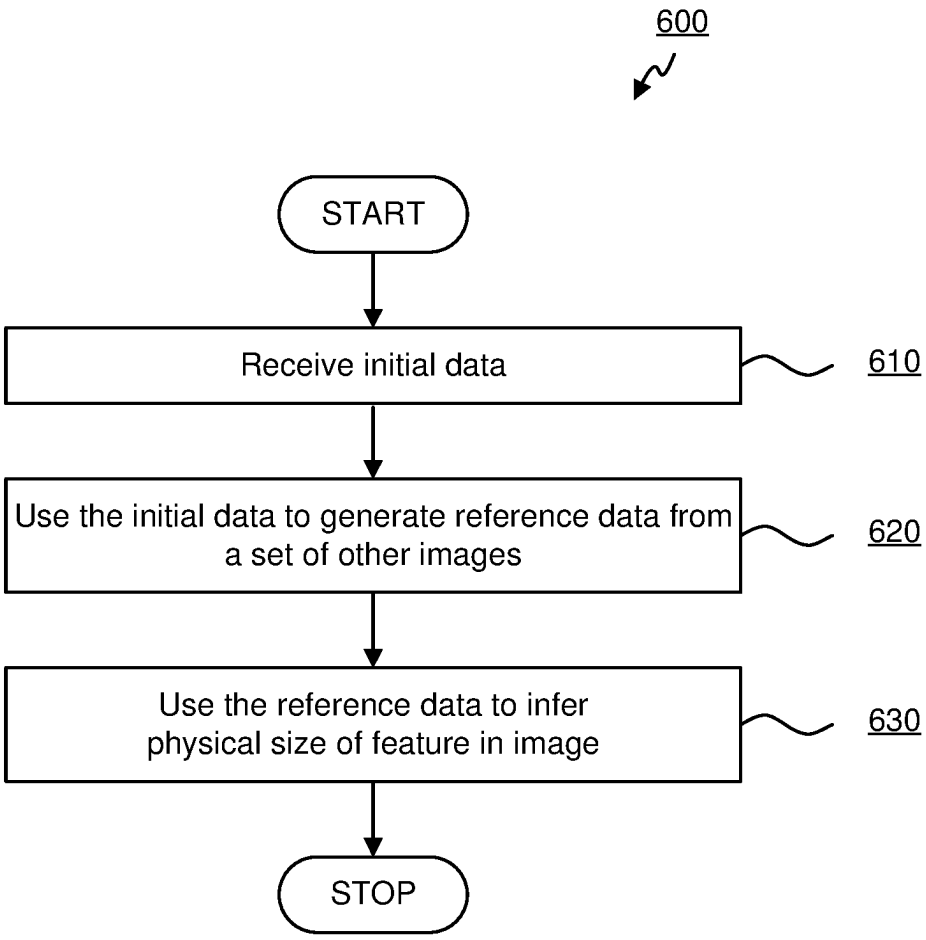
600
START
Receive initial data
610
Use the initial data to generate reference data from a set of other images
620
Use the reference data to infer physical size of feature in image
630
STOP

FIGURE 6

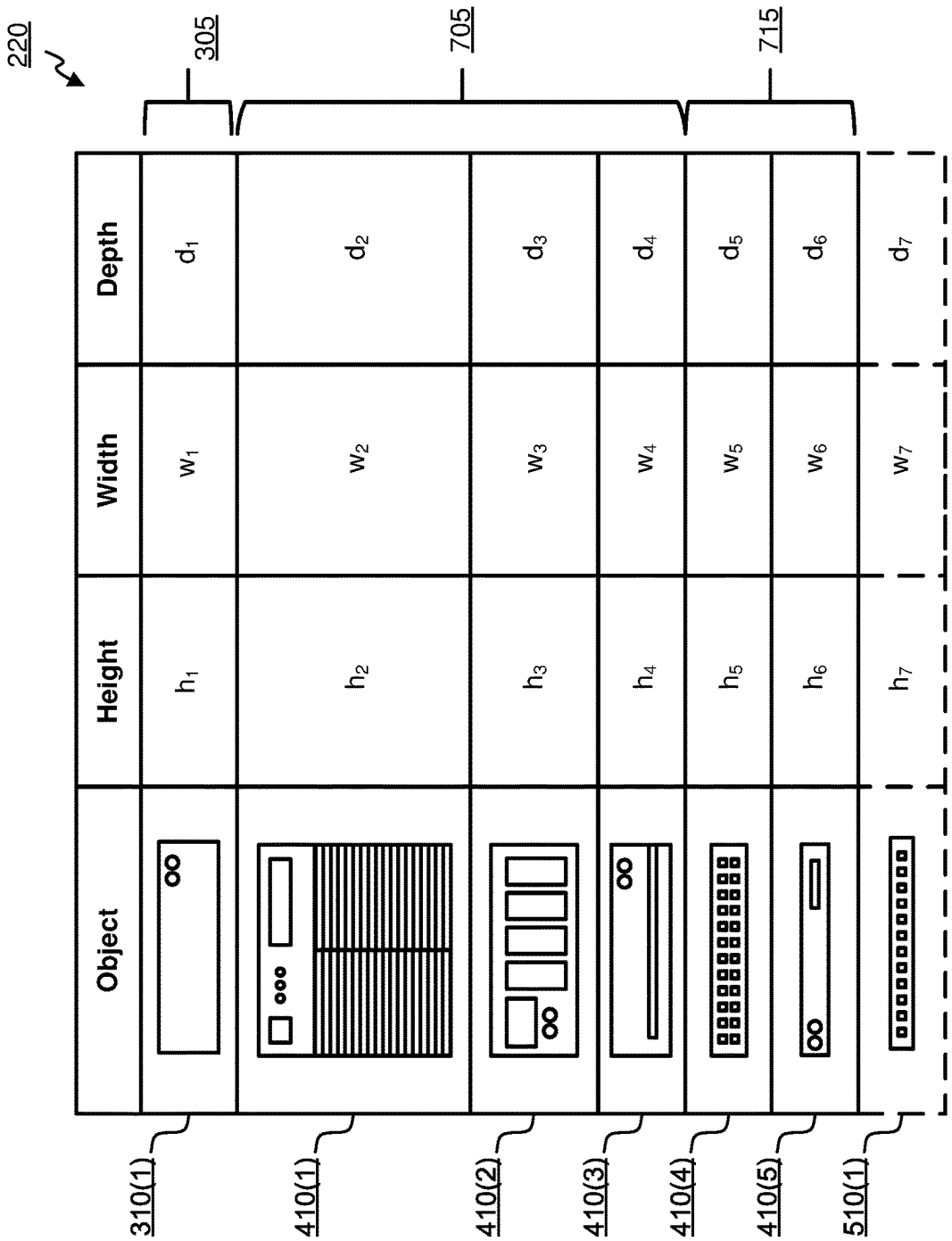
220
305
705
715
Object
Height
Width
Depth
h_1 w_1 d_1
h_2 w_2 d_2
h_3 w_3 d_3
h_4 w_4 d_4
h_5 w_5 d_5
h_6 w_6 d_6
h_7 w_7 d_7
310(1)
410(1)
410(2)
410(3)
410(4)
410(5)
510(1)

FIGURE 7

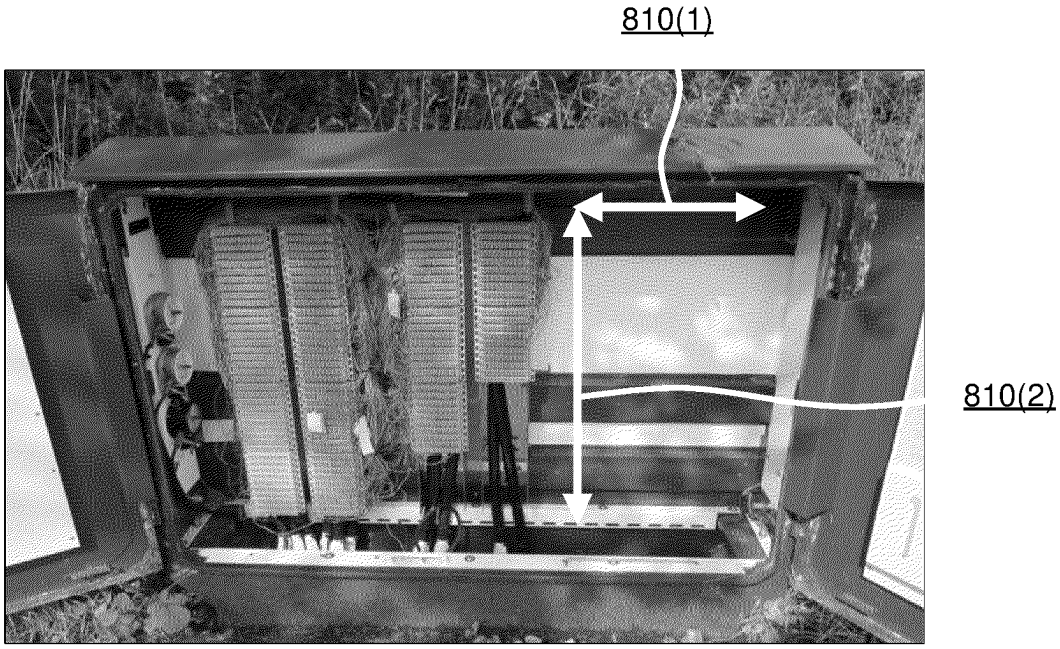

FIGURE 8A

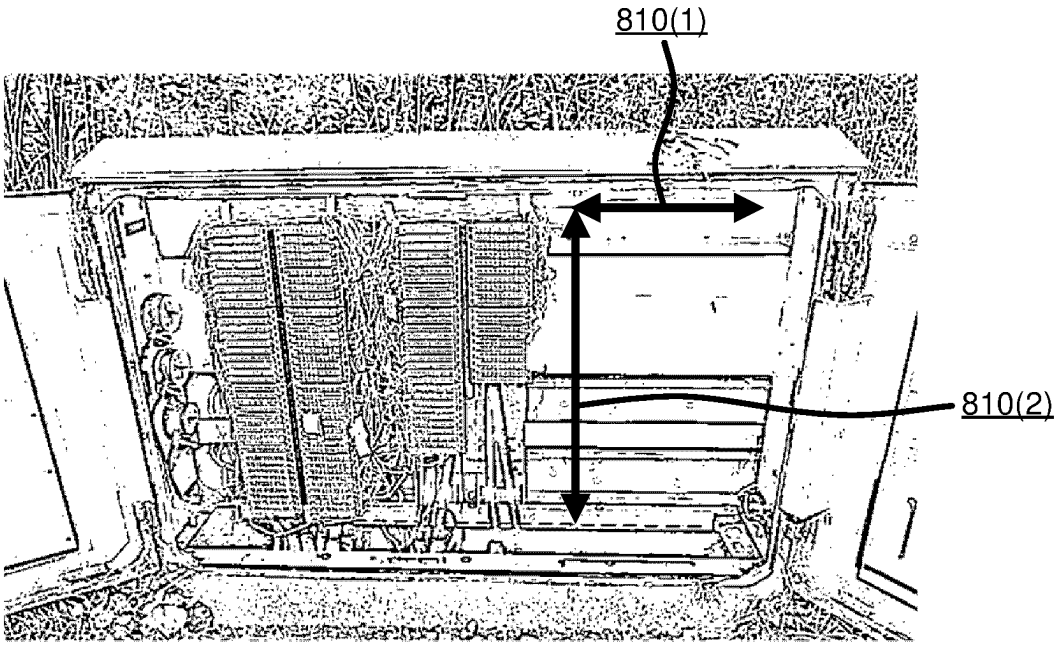

FIGURE 8B

IMAGE FEATURE MEASUREMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is the U.S. national phase of International Application No. PCT/EP2021/055865 filed Mar. 9, 2021 which designated the U.S. and claims priority to EP Patent Application No. 20164709.6 filed Mar. 20, 2020, and GB Patent Application No. 2004103.4 filed Mar. 20, 2020, the entire contents of each of which are hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to a method for determining a physical size of a feature represented in an image.

BACKGROUND TO THE INVENTION

Being able to determine the physical size of a feature represented in an image, that is to say the actual size of the feature in the real world, as measured, for example, in meters or inches, rather than its virtual size in the image, as measured, for example, in pixels, is useful for a wide range of applications.

Existing methods for determining the physical size of features in images typically require a specific pre-defined reference object of known physical size to be included in the image. Such methods can then attempt to find the pre-determined reference feature in an image and use the known size of the reference feature to infer the size of other objects in the image. For example, U.S. Pat. No. 9,691,163 B2 discloses a system and method which requires a reference object displaying known fiducial patterns to be included in an image for the purposes of measuring a target object in the image.

Other known methods for determining the physical size of features in images require the equipment that is used to capture the image to be pre-calibrated to provide additional metadata for the image that can be used for calculating the size of the features in the images. For example, US 2012/0224052 A1 discloses a method for measuring the real size of an object in which the image-capture equipment additionally records a focus distance and uses a distance sensor to measure the distance between the camera and an object in the image. This additional information is then used in determining a physical size of the object from its representation in the image.

SUMMARY OF THE INVENTION

According to a first aspect of the invention, there is provided a computer implemented method for determining a physical size of a feature represented in an image, the method comprising: receiving initial data comprising data for identifying one or more known types of object and an indication of a respective physical size of each of the one or more known types of object; generating reference data from a first reference image by identifying one or more new types of object represented in the first reference image and using the initial data to infer a respective physical size of each of the one or more new types of object, the one or more new types of object forming one or more reference types of object for determining the physical size of the feature; and using the reference data to determine the physical size of the feature based, at least in part, on: a size of a representation of one of the reference types of object in the image; the inferred physical size of that reference type of object; and a size of the representation of the feature in the image.

The reference data may be generated by directly inferring a physical size of at least one of the reference types of object from a respective one of the known types of object. The physical size may be directly inferred based on: a size of a representation of the reference type of object in the first reference image; a size of a representation of the known type of object in the first reference image; and the physical size of the known type of object as indicated by the initial data.

The first reference image may be one of a set of reference images, in which case the reference data may be generated from the reference data indirectly by inferring a physical size of at least one of the reference types of object from a respective one of the known types of object based on: a size of a representation of the reference type of object in the first reference image; a size of a representation of an intermediate type of object in the first reference image; a size of a representation of the intermediate type of object in a second image of the set of reference images; a size of a representation of the known type of object in the second image; and the physical size of the known type of object as indicated by the initial data.

Generating the reference data may comprise determining a respective plurality of candidate physical sizes for at least one of the reference types of object and determining a respective inferred physical size for the reference type of object based on the plurality of candidate physical sizes. The plurality of the respective candidate physical sizes for the reference type of object may be inferred from different representations of a known type of object. The respective plurality of candidate physical sizes comprise at least one directly inferred physical size and at least one indirectly inferred physical size. A plurality of respective candidate physical sizes may be indirectly inferred from the same representation of a known type of object based on different representations of the intermediate type of object in either the first reference image, the second reference image, or both the first and second reference image. A plurality of respective candidate physical sizes may be indirectly inferred from the same representation of a known type of object based on representations of different intermediate types of object in the first and second reference images. Where the initial data comprises an indication of a respective physical size of a plurality of known types of object, a plurality of the respective candidate physical sizes may be inferred either directly or indirectly from respective representations of each of the plurality of known types of object.

The inferred physical size of the one or more reference types of object comprises an indication of a range of physical sizes and the determined physical size of the feature may comprise an indication of a range of physical sizes.

A confidence with the inferred physical size may be determined for each of the one or more reference types and an indication of a respective confidence in the inferred physical size of the feature may be provided.

The reference data may be generated iteratively from the reference images. Each subsequent iteration may either increases the number of reference type of objects in the reference data or refines the inferred physical sizes for one or more reference type of objects in the reference data, or both.

The image may be stored as a reference image to be used in determining a physical size of a feature represented in a further image.

The determined physical size of the feature may be used to determine a physical interaction with an object represented in the image. The determination may be a determination of a quantity, or type, or both, of equipment to be installed in a telecommunications cabinet.

According to a second aspect of the invention, there is provided a computer system comprising a processor and a memory storing computer program code for performing the steps of a method according to the first aspect.

According to a third aspect of the invention, there is provided a computer program which, when executed by one or more processors, is arranged to carry out a method according to the first aspect.

BRIEF DESCRIPTION OF THE FIGURES

In order that the present invention may be better understood, embodiments thereof will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIG. **1** is a block diagram of a computer system suitable for the operation of embodiments of the present invention;

FIG. **2** is a block diagram of an exemplary image processing system according to the invention;

FIG. **3** shows a table that is populated with some exemplary initial data;

FIGS. **4**A, **4**B, **4**C and **4**D illustrate some exemplary images included in the set of other images;

FIG. **5** illustrates an exemplary input image which is to be analysed by the image processing system to determine the size of a feature represented therein;

FIG. **6** is a flowchart illustrating a method for determining a physical size of a feature in an image according to the invention;

FIG. **7** shows the table of FIG. **3** in which the initial data has been augmented with generated reference data; and

FIGS. **8**A and **8**B show exemplary images that may be used in one exemplary application of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. **1** is a block diagram of a computer system **100** suitable for the operation of embodiments of the present invention. The system **100** comprises: a storage **102**, a processor **104** and an input/output (I/O) interface **106**, which are all communicatively linked over one or more communication buses **108**.

The storage (or storage medium or memory) **102** can be any volatile read/write storage device such as a random access memory (RAM) or a non-volatile storage device such as a hard disk drive, magnetic disc, optical disc, ROM and so on. The storage **102** can be formed as a hierarchy of a plurality of different storage devices, including both volatile and non-volatile storage devices, with the different storage devices in the hierarchy providing differing capacities and response time, as is well known in the art.

The processor **104** may be any processing unit, such as a central processing unit (CPU), which is suitable for executing one or more computer programs (or software or instructions or code). These computer programs may be stored in the storage **102**. During operation of the system, the computer programs may be provided from the storage **102** to the processor **104** via the one or more buses **108** for execution. One or more of the stored computer programs which, when executed by the processor **104**, cause the processor **104** to carry out a method according to an embodiment of the invention, as discussed below (and accordingly configure the system **100** to be a system **100** according to an embodiment of the invention).

The input/output (I/O) interface **106** provides interfaces to devices **110** for the input or output of data, or for both the input and output of data. The devices **110** may include user input interfaces, such as a keyboard **110***a* or mouse **110***b* as well as user output interfaces, such as a display **110***c*. Other devices, such a touch screen monitor (not shown) may provide means for both inputting and outputting data. The input/output (I/O) interface **106** may additionally or alternatively enable the computer system **100** to communicate with other computer systems via one or more networks **112**. It will be appreciated that there are many different types of I/O interface that may be used with computer system **100** and that, in some cases, computer system **100**, may include more than one I/O interface. Furthermore, there are many different types of device **100** that may be used with computer system **100**. The devices **110** that interface with the computer system **100** may vary considerably depending on the nature of the computer system **100** and may include devices not explicitly mentioned above, as would be apparent to the skilled person. For example, in some cases, computer system **100** may be a server without any connected user input/output devices. Such a server may receive data via a network **112**, carry out processing according to the received data and provide the results of the processing via a network **112**.

It will be appreciated that the architecture of the system **100** illustrated in FIG. **1** and described above is merely exemplary and that other computer systems **100** with different architectures (such as those having fewer components, additional components and/or alternative components to those shown in FIG. **1**) may be used in embodiments of the invention. As examples, the computer system **100** could comprise one or more of: a personal computer; a laptop; a tablet; a mobile telephone (or smartphone); a television set (or set top box); a games console; an augmented/virtual reality headset; a server; or indeed any other computing device with sufficient computing resources to carry out a method according to this invention.

FIG. **2** is a block diagram of an exemplary image processing system **200** according to the invention. The image processing system **200** comprises an image processing unit **210**, which is communicatively coupled to a database **220** and has access to a set (or repository) of images **230**.

The image processing unit **210** is arranged to receive an image **240** containing a feature whose physical size is to be determined (also referred to herein as the input image). The image processing unit **210** may be implemented on any suitable type of computer system **100** which is able to carry out a method to be discussed below in more detail below in conjunction with FIG. **6**. As will be appreciated by the skilled person, the computer system **100** on which the image processing unit is implemented may be dedicated to the task of carrying out the image processing according to this invention or may carry out other computational tasks in addition to doing so.

The database **220** stores data relating to the physical sizes of different types of object. The database **220** may reside on the same computer system **100** as the image processing unit or may be provided by a separate computer system **100**. Furthermore, it will be appreciated that although a database is included in the exemplary system illustrated in FIG. **2**, any other suitable way of making this data available to the image

processing unit **210** (such as a web service which is configured to provide the data to image processing unit **210**) may be used instead.

FIG. **3** shows a table **300** that is populated with some exemplary initial data **305**, such as may be stored in database **220**. This data is referred to herein as initial data **305** because it relates to the data that was already available prior to the processing according to this invention (or an iteration of such processing) being carried out. In the example illustrated in FIG. **3**, the initial data **305** comprises data relating to a single known type of object **310**(**1**). The data relating to this single known type of object **310**(**1**) includes data to allow the type of object to be identified as well as an indication of its physical size. In the example illustrated in FIG. **3**, the initial data **305** indicates a height h_1, width w_1 and depth dl for the known type of object **310**(**1**). However, it will be appreciated that in some cases the invention may only be concerned with fewer dimensions, in which case table **300** may only record indications of the physical sizes in those dimensions. Similarly, only some dimensions of the known type of object **310**(**1**) may be known, the other unknown dimensions may be recorded in a manner which indicates that they are unknown (such as by storing a null value).

The set of images **230** comprises images which are different from the input image **240** (and may therefore also referred to herein as other images or reference images). These other images **230** may be made available to the image processing unit **210** in any appropriate manner, as will be understood by a person skilled in the art. For example, the set of images could be stored locally on the image processing unit **210** or otherwise accessed from remote storage, such as database **220** or from any other repository of images, which may or may not be cloud based, or provided to the image processing unit **210** in any other way. Indeed, the set of images **230** may represent a combined set of images **230** available from multiple different sources. Although FIG. **2** shows four images in the set of images **230**, it will be appreciated that any number of images, including a single image, may be included in the set.

FIGS. **4**A, **4**B, **4**C and **4**D illustrate some exemplary images included in the set of other images **230**. The set of other images **230** generally comprise representations of one or more types of object that are not already known. That is to say, there is an instance of at least one type of object represented in at least one of the other images **230** which is not included in the initial data **305** stored in the database **220** (and, in most cases, there will probably be many more).

In the first exemplary image **230**(**1**) shown in FIG. **4**A, there is a representation of a type of object **410**(**1**) which is not yet known. There is also a representation of the object type **310**(**1**) that is already known.

In the second exemplary image **230**(**2**) shown in FIG. **4**B, there are representations of two different types of unknown object, **410**(**2**) and **410**(**3**). There are not any representations of any objects of the type **310**(**1**) that is already known.

In the third exemplary image **230**(**3**) shown in FIG. **4**C, there is a representation of an unknown type of object **410**(**2**). A representation of this unknown type of object is also present in the second exemplary image **230**(**2**). Additionally, there is also a representation of the object type **310**(**1**) that is already known.

In the fourth exemplary image **230**(**4**) shown in FIG. **4**D, there are representations of two further types of object **410**(**4**) and **410**(**5**) that are not yet known. These two further types of object **410**(**4**) and **410**(**5**) do not appear in any of the other images **230**. Additionally, there are not any representations of the type **310**(**1**) that is already known.

Although the exemplary image processing system **200** that is illustrated in FIG. **2** is shown having access to a set of images **230** that consists of four images, it will be appreciated that any number of images can be included in the set **230**. For example, the set of images **230** may, in the most simple of cases, contain a single image. However, in most cases the number of images in the set **230** will be much higher. Indeed, in some cases, the set of images **230** can be expected to grow over time, as will be discussed further below.

FIG. **5** illustrates an exemplary input image **240** which is to be analysed by the image processing system **200** to determine the size of a feature **505** represented therein. This exemplary input image **240** comprises representations of various types of object **410**(**1**), **410**(**4**), **410**(**5**) which are also represented in the set of other images **230**. The input image **240** does not contain any representations of the known type of object **310**(**1**) included in the initial data **305**. Additionally, the input image **240** includes a representation **510**(**1**) of a type of object that is neither included in the initial data **305** nor represented in the set of images **230**. In some cases, the feature **505** whose size is to be determined may be a dimension of an object in the image, for example, it may be desired to identify the physical size of the object **410**(**3**). However, in other cases, the feature **505** may simply be an arbitrary distance between two points on the image, such as illustrated by the arrow in FIG. **5**.

FIG. **6** is a flowchart illustrating a method **600** for determining a physical size of a feature in an image according to the invention. The method **600** is performed by the image processing unit **210** in order to determine the physical size of the feature **505** on the input image **240**. The method begins at an operation **610**.

At operation **610**, the method **600** receives initial data **305** comprising an indication of a respective physical size of one or more known types of object. For example, this initial data **305** is available from the database **220**. In this case, receiving the data comprises being provided with (or gaining) access to the database **220** without necessarily needing to transfer any data from the database **220**. Alternatively or additionally, some initial data **305** may be explicitly provided in addition to the input image **240**, in which case, the method **600** may store the initial data **305** in the database **220**. The method **600** then proceeds to an operation **620**.

At operation **620**, the method **600** uses the initial data **610** to generate reference data from the set of other images **230**. At operation **630**, the reference data that is generated can then be used for sizing objects in an input image **240**.

In general, this is achieved by identifying representations of new (i.e. previously unknown) types of objects in the one or more set of other images and using the initial data **305** to infer the sizes of those new types of objects from representations of known types of objects in the set of images **230**. These new types of objects together with their respective inferred physical sizes collectively forming the reference data that is generated by operation **620**. These new type of objects may also be referred to herein as reference types of objects to distinguish them from the known type of objects that were present in the initial data prior to operation **620** being performed.

To identify the representations of objects in an image, an image segmentation mechanism may be used together with an object recognition system. The image segmentation mechanism identifies regions of interest in the image which represent discrete objects and assigns them a unique iden-

tifier. An object recognition system can then be used to analyse the representation of each discrete object and assign it to a particular class. The class to which the representation of a discrete object is assigned may be an existing class if the discrete object corresponds to a type of object that has already been seen or to a new class if it does not. Accordingly, the class assigned to each region of interest corresponds to the type of the object represented in that region of interest. In some cases, these two activities can be carried out simultaneously by a single process. For example, a fully convolutional neural network (FCNN) may be used to simultaneous segment the image into discrete objects and classify those objects into classes. An example of how this may be implemented can be found, for example, in the paper "*Fully Convolutional Networks for Semantic Segmentation*" by Jonathan Long, Evan Shelhamer and Trever Darrel (available at https://people.eecs.berkeley.edu/~jonlong/long_shelhamer_fcn.pdf). However, there are many known image segmentation and object classification techniques that are known and, in general, any suitable combination of image segmentation and object classification techniques may be used instead to achieve the same outcome.

Turning to the exemplary images **230(1)**, **230(2)**, **230(3)** and **230(4)** illustrated in FIGS. **4**A, **4**B, **4**C and **4**D, the operation **620** may, for example, process each of the other images **230(1)**, **230(2)**, **230(3)** and **230(4)** in turn to identify and classify the representations of discrete objects within each image.

After processing the first image **230(1)**, for example, the operation **620** will have identified representations of two discrete objects. The first discrete object is already known and so is classified in the same class as the known type of object **310(1)**. The second discrete image has not been encountered before and so is classified in a new class representing a new type of object **410(1)**.

The operation **620** may then process the second image **230(2)**, following which, in this example, the operation **620** will have identified representations of four discrete objects. The first discrete object has not been encountered before and so is classified in a new class representing a new type of object **410(2)**. The second discrete object has also not been encountered before and so is classified in a new class representing a new type of object **410(3)**. The third and fourth discrete objects are identified as being the same type of object as the second discrete object and so are classified in the same new class **410(3)**.

The operation **620** may then process the third image **230(3)**, following which, in this example, the operation **620** will have identified representations of two discrete objects. The first discrete object is already known and so is classified in the same class as the known type of object **310(1)**. The second discrete object has also been encountered before in the second image **230(2)** (even though it was not known prior to beginning the processing of operation **620**) and so is assigned to the new class that was created for that type of object **410(2)** when processing the second image **230(2)**.

The operation **620** may then process the fourth image **230(4)**, following which, in this example, the operation **620** will have identified representations of two discrete objects, neither of which have been encountered before and so are assigned to new classes representing the two new types of object **410(4)** and **410(5)**.

Having identified at least some of the new types of objects that are represented in the set of other images **230(3)** (i.e. as identified by the new classes that have been created), the operation infers physical sizes for the new types of objects either directly or indirectly from the initial data **305**.

Where representations of a new type of object and a known type of object can be found in the same image, the physical size p_n (e.g. in meters) of the new type of object may be directly inferred from the known type of object. This inference is based on the size of the representation of the new type of object in the image r_n (e.g. in pixels), the size of the representation of the known type of object in the image r_k (e.g. in pixels) and the physical size of the known type of object p_k (e.g. in meters). From this information, it is possible to determine the physical size represented by each pixel (e.g. metres per pixel) based on the ratio between the size of the representation of the known type of object in the image r_k and the physical size of the known type of object p_k, and therefore determine the physical size of the new type of object e.g.

$$p_n = \frac{r_n \times p_k}{r_k}$$

Returning to the earlier example discussed in relation to the exemplary images **230(1)**-**(4)**, both the first and third images **230(1)** and **230(2)** include representations of known types of object and newly identified types of object. Therefore, the operation **620** may use direct inference to infer physical sizes for the newly identified types of object from the known types of object. For example, the operation **620** may directly infer a size for the new type of object **410(1)** represented in the first image **230(1)** based on the sizes of the representations of the new type of object **410(1)** and the known type of object **310(1)** in the first image **230(1)**, as well as the physical size of the known type of object **310(1)** indicated by the initial data **305**. Similarly, the operation **620** may directly infer a size for the new type of object **410(2)** represented in the third image **230(3)** based on the sizes of the representations of the new type of object **410(2)** and the known type of object **310(1)** in the third image **230(1)**, as well as the physical size of the known type of object **310(1)** indicated by the initial data **305**.

Even where some images of the set other images **230** do not contain any representations of known types of object (that is types of objects for which a physical size is indicated in the initial data), it may still be possible to indirectly infer a physical size for new types of object represented in such images. This is achieved by using the inferred physical sizes for the reference objects that have been detected in others images in the set of images **230**. That is to say, where an image includes a representation of a reference object for which a physical size has already been inferred from another image, it is possible to use that inferred physical size to indirectly infer the physical sizes of the other types of object represented in the image. Such reference objects may be referred to as intermediate objects (or intermediate types of objects), as they are used to perform an intermediate inference between the objects represented in separate images of the set of other images **230**, allowing the indirect inference of the size of an object type represented in one image based on a representation of a known type of object in another image. It will be appreciated that the technique for doing so is the same as that used for direct inference, but instead of using the size of a representation of a known type of object in the image r_k, the size of a representation of the reference type of object in the image r_r is used, and instead of using

the physical size of the known type of object p_k, the inferred physical size of the representation of the reference type of object p_r is used, i.e.

$$p_n = \frac{r_n \times p_r}{r_r}$$

Returning to the earlier example discussed in relation to the exemplary images **230(1)-(4)**, the second image **230(2)** does not include any representations of known types of object and so the sizes of the new types of object **410(2)** and **410(3)** represented in the second image **230(2)** cannot be directly inferred. However, as discussed above, a physical size for one of the new types of object **410(2)** represented in the second image **230(2)** can be directly inferred from the third image **230(3)**. Therefore, this new type of object **410(2)** can be used as an intermediate reference object to indirectly infer the physical size of the other new type of object **410(3)** represented in the second image **230(2)**. The operation **620** may therefore indirectly infer the physical size of the new type of object **410(3)** based on the size of the representations of the reference type of object **410(2)** and the new type of object **410(3)** in the second image **230(2)** and the physical size of the reference type of object **410(2)** that was directly inferred from the third image **230(3)**.

It will be appreciated that, whilst not illustrated in the exemplary images **230(1)-(4)**, a new type of object for which a physical size has been indirectly inferred may itself be used as an intermediate reference type of object for further indirectly inferring the physical sizes of other types of object.

The operation **620** may store the generated reference data in the database **220**.

FIG. **7** shows the table of FIG. **3** in which the initial data **305** has been augmented with generated reference data **705**. That is to say, in addition to the record for the known type of object **310(1)** that was indicated in the initial data **305**, new records for the new types of object **410(1)**, **410(2)** and **410(3)** have been added, which collectively form the reference data **705** generated by operation **620**. The inferred height h_n, width w_n and depth d_n dimensions for each new type of object may be recorded. Again, it will be appreciated that where the invention is concerned with fewer dimensions, only those dimensions of interest may be inferred and stored for the new types of object. Whilst it is convenient to store the generated reference data **705** together with the initial data **305** (as together they represent a set of data which can be used to infer physical sizes of objects in images), it will be appreciated that this need not necessarily be the case and the generated reference data **410** may be stored in any other suitable manner either together with or separately from the initial data **305**.

The operation **620** may also store records **715** for new types of object that have been detected but for which no physical size can yet be inferred. For example, it is not possible, at this stage, for operation **620** to infer physical sizes for the new types of object **410(4)** and **410(5)** represented in the fourth image **230(4)** because there are no representations of any known objects from which a physical size could be directly inferred, nor are there any representations of any reference objects **410(1)**, **410(2)**, **410(3)** from which a physical size could be indirectly inferred. The physical size for these types of object **410(4)** and **410(5)** may be recorded in a manner that indicates that they are not known (such as by storing a null value for each dimension). Such records **715** act as placeholders for these new types of objects allowing the image processing unit **210** to identify new types of objects that have already been encountered in the set of reference images **230**, as will be discussed further below. Again, although it may be useful to store such records **715** to aid in future processing, it will be appreciated that it is not necessary to do so.

Having generated the reference data at operation **620**, the method proceeds to an operation **630**.

At operation **630**, the method **600** uses the reference data **705** to determine the physical size of the feature **505** in the input image **240**. To achieve this, at operation **630**, the method **600** analyses the input image to identify and classify the representations of discrete objects in the input image **240**. This can be done in the same way as discussed above in relation to the analysis of the set of other images **230**. The method **600** then determines whether any of the identified objects belong to the same class (i.e. are of the same type) as the reference objects identified in the reference data **705**.

The representation of a reference type of object in the input image **240** can be used to infer a physical size of the feature **505** in much the same way as discussed above in relation to the analysis of the set of other images **230**. In particular, the inference is based on the sizes of the representations of the feature **505** r_f and the reference type of object in the image (e.g. in pixels) r_r and the inferred physical size of the reference type of object (e.g. in metres) p_r as indicated in the reference data **705**. Again, from this information, it is possible to determine the physical size represented by each pixel (e.g. metres per pixel) based on the ratio between the size of the representation of the reference type of object in the image r_r and the physical size of the reference type of object p_r, and to then use this to determine the physical size of the feature **505** p_f e.g.

$$p_f = \frac{r_f \times p_r}{r_r}$$

For example, when processing the exemplary input image **240** illustrated in FIG. **5**, the operation **630** identifies representations of four discrete objects **410(1)**, **410(3)**, **410(5)** and **510(1)** in the input image **240**. Two of these discrete objects **410(1)** and **410(3)** are types of object that are included in the reference data **705** and so may be used as reference objects for determining the physical size of the feature **505** in the input image **240**. As discussed above, a physical size for the first type of possible reference object **410(1)** was directly inferred during operation **620** from a representation of the known type of object **310(1)** in the first reference image **230(1)**. Meanwhile, the physical size for the second type of possible reference object **410(3)** was indirectly inferred from the second image **230(2)** during operation **620** from a representation of the known type of object **310(1)** in the third image **230(3)** using object type **410(2)** as an intermediate reference object (since it appears in both images). Accordingly, the method **600** may determine a size of the feature **505** using either object type **410(1)** or object type **410(3)**.

It will be appreciated that the physical size of the feature **505** determined using this method **600** may be subject to a certain level of inaccuracy. Two possible sources of such inaccuracy include: (a) introduction of discretization errors resulting from the representation of the objects in pixels in the image; and (b) differences in the depths of the different representations of the objects in the image. Whilst the

accuracy that can be achieved by method **600** may be suitable for some applications, it may be desirable to help reduce the errors that are introduced into the inferred physical sizes of both the reference types of objects in the reference data **705** and the feature **505** in the input image.

Accordingly, in some cases, inferring the physical size of a type of object (either a reference type of object or a feature in the input image **240**) may involve inferring a plurality of candidate physical sizes for the type of object and determining a physical size for the type of object based on the plurality of candidate physical sizes. It will be appreciated from the above description that there are likely to be a number of different ways in which a physical size for a particular type of object (or feature) can be inferred. As examples, any combination of the following techniques may be employed to infer multiple candidate physical sizes:

a) where the particular type of object is represented in multiple images of the set of images, a respective candidate size for the type of object can be inferred from each such image (either directly or indirectly);

b) where multiple representations of the particular type of object is represented in a single image, a respective candidate size for the type of object can be inferred from each such representation (either directly or indirectly);

c) where multiple representations of the same known type of object or reference type of object are present in an image, a respective candidate size may be inferred from each representation; and/or

d) where multiple different types of known type of object and/or reference type of object are represented in an image, a respective candidate size may be inferred separately from each type of object.

In any case, having obtained a plurality of candidate physical sizes for a type of object (or feature), there are many different ways that they can be used to provide a more accurate indication of the size of a type of object (or feature), as will be appreciated by the skilled person. For example, the candidate physical sizes may be averaged, such as by taking the mean or the mode of the inferred physical sizes for the type of object.

In some cases, it may be desirable to provide an indication of the accuracy of an inferred physical size for a type of object (or feature). Accordingly, a range of physical sizes for a type of object (or feature) may be determined from the plurality of candidate physical sizes that have been inferred. As will be appreciated, the range may be based on particular percentiles of the inferred candidate physical sizes (such as the 10^{th}-90^{th}, 20^{th}-80^{th} or 25^{th}-75^{th} percentiles) so as to exclude outliers.

Alternatively, or additionally, an indication of the confidence of the inferred size may be provided. This may be based, for example, on a number of different candidate physical sizes that have been used to infer the size and/or on a number of different images (or number different representations within or more images) upon which the size has been inferred from, and/or the number of different reference objects used to determine the measurement and the variance or confidence of the physical size for those objects. For example, where the mode of the candidate physical sizes is used as the inferred physical size, the confidence value can be based on the number of candidate physical sizes that provided that value. However, it will be appreciated that any suitable way of deriving a confidence value that indicates a confidence in the accuracy of a measurement may be used.

The set of reference images **230** may be added to over time, such that new images are available to be analysed for reference data. For example, the input image **240** may be added to the set of reference images **230** after it has been processed by the method **600**. Other additional reference images may be added to the set **230** without having been used as an input image **240** for the method **600**. Similarly, new initial data **305** may be stored in the database **220** (in this sense, the new initial data may be considered to be data about the physical sizes of types of object that was derived by means other than inference from the set of images **240**, such by as a user providing a physical measurement of a type of object). Accordingly, the method **600** may be performed iteratively (either periodically or in response to a change in the set of reference images **230** or initial data **305**). By performing the method **600** iteratively, the method **600** can augment and/or refine the reference data **705** that has been generated by previous iterations, thereby generating updated reference data.

For example, following the above-described iteration of method **600**, the exemplary input image **240** illustrated in FIG. **5** may be added to the set of reference images **230**. Accordingly, in a subsequent iteration of the method **600**, the method **600** may identify the discrete objects represented in the newly added reference image **240** as being of four different types, namely two types of object **410**(**1**) and **410**(**3**) that are already known from the previously generated reference data **705**, a type of object **410**(**5**) that has already been encountered in the fourth image **230**(**4**) but not added to the reference data **705** due to it not being possible to infer a physical size during the previous iteration, and a new type of object **510**(**1**) that has not been previously encountered. A physical size for the types of object **410**(**5**) and **510**(**1**) that were not already in the reference data **705** can be inferred, for example from the representations of reference type of object **410**(**1**) and/or **410**(**3**). This also means that the physical size of the previously encountered type of object **410**(**4**) can also now be indirectly inferred from the fourth image **230**(**4**) by using object type **410**(**5**) as an intermediate reference type of object. Accordingly, in this subsequent iteration of the method **600**, the reference data **705** is updated to include new reference types of object **410**(**4**), **410**(**5**) and **510**(**1**).

Where the determined physical size of the reference types of objects is based on a plurality of candidate inferred physical sizes, the method **600** may also refine the previously determined physical sizes for previously identified reference types of objects. In particular, the inclusion of the new image **240** in the set of reference images **230** provides new ways of inferring additional candidate physical sizes for the pre-existing reference types of objects. For example, candidate physical size of the first type of reference object **410**(**1**) can now additionally be inferred from the new image **240** using reference object **410**(**3**). An additional candidate physical size can also be inferred from intermediate reference object **410**(**3**) using the representation of that type of object **410**(**3**) and the reference object **410**(**2**) in the second image **230**(**2**). By recording sufficient information in the database, such as by keeping a record of all previously inferred physical candidate sizes used to determine the physical size of a reference type of object, it is possible to update the physical size for a reference type of object based on the newly available information (e.g. the new ways of generating candidate physical sizes for that reference type of object from the enlarged set of reference images **230**).

Whilst the above described mechanisms can help improve the accuracy of the measurements that are provided by the invention (or at least convey the accuracy with which measurement has been determined), additional measures may also be deployed in order to further reduce some

potential inaccuracies that may be caused due to differences in the depths of the different representations of the objects in the image. For example, the set of reference images may be selected to be relatively planar (i.e. with minimal variations in depth), as is the case with the example that will be discussed in relation to FIG. **7**. However, where this is not the case, the method **600** may filter out any images which exhibit too great a range of depths. In particular, the method **600** may identify multiple different representations of known and/or reference types of object in an image and use the ratio of the size of each representation to the physical size of the associated object type as an indication of depth. Therefore, if the variation of the ratios for each of the representations of known and/or reference types of object in an image is too great (e.g. if it exceeds a pre-determined threshold), the method **600** may ignore that image and not use it for generating reference data **705**. Even if the variation of the ratios is not too great, the method **600** may, in some cases, ignore the representations of objects which are associated with ratios that are too different from the others represented in the image (e.g. a variance from the mean is above a predetermined threshold or number of standard deviations), such that those representations are not used for inferring physical sizes of object types. Additionally, or alternatively, the method **600** may only use representations of objects that are within a certain distance (e.g. predetermined number of pixels, or proportion of the overall size of the image, or distance in metres by using the ratio of a representation of a known or reference type of object and its physical size to determine a number of pixels that correspond to that distance, or that are overlay another type of object detected in the image, such as the cabinet discussed further below in relation to FIG. **7**). Whilst these techniques may help to reduce some potential inaccuracies that may be caused due to differences in the depths of the different representations of the objects in the image, it will be appreciated that even in the absence of such techniques, the invention can still operate to determine a range of possible measurements for such objects that can be refined based on different representations in the set of reference images **230**.

Having determined the size of the physical feature **505** in the input image **240**, this may be provided as a result directly to a user of the system. However, it will also be appreciated that the determined size may also be provided for use by other systems. Similarly, the image processing system **200** itself may make further use of the determined size to make further determinations about other properties of the input image **240** or the objects represented in it.

It will be appreciated that the examples used in the discussion of the invention so far have been simplified in order to more clearly convey its operation. A more complex example will now be discussed to further illustrate an application of the invention.

FIGS. **8**A and **8**B show exemplary images that may be used in one exemplary application of the invention. In particular, FIG. **8**A shows a photograph of a Primary Connection Point (PCP) cabinet which contains equipment for enabling broadband connections to end customers. In the UK, there are roughly 100,000 such cabinets that have been deployed over time as the network has been installed and upgraded. There may be many different types of such cabinets in a network, with a wide range of different types and quantity of equipment deployed within each of them. Operators looking to upgrade or expand such networks ideally seek to make use of existing cabinets for installing new equipment, rather than installing new cabinets specifically for that purpose, in order to prevent delay and reduce costs. However, it can be hard to know how much space is currently available for expansion (e.g. how many more connectors could be installed) within the existing cabinets and whether (or when) new cabinets will be required. This is especially true when dealing with a large network in which many cabinets are available. Of course, one approach could be to carry out inspections to survey the amount of available space, however this is likely to be a relatively slow and expensive process. The operator may have a library of photographs of the cabinets available, similar to that shown in FIG. **8**A, which may, for example, have resulted from photographs being taken when work was last undertaken on a cabinet. Although these photographs were not taken with the goal of determining measurements in mind, and so will typically not include pre-determined reference objects that have been included nor capture any additional meta information required for this purpose, this invention can be deployed in order to answer this question. For example, to work out the spare space in the cabinet in the photograph shown in FIG. **8**A, a user may use system **200** to determine the physical size of the available space in the cabinet by determining the measurements indicated by the arrows **810**(**1**) and **810**(**2**). The system **200** can be provided with some initial data **305**, such as the known sizes of some commonly used cabinets or components within cabinets, such as connectors. The system **200** can use this initial data **305** to generate reference data from the collection of photos. The generated reference data may include for example, inferred sizes of other types of cabinets or components within cabinets, such as connectors. Then, for any given photograph, this reference data can be used to infer the measurements **810**(**1**) and **810**(**2**) and determine the amount of available space within a cabinet. It will be appreciated that, in some cases, the set of images **240** may be a set of pre-processed images generated from the photographs. The pre-processing may assist in the object detection to be performed by the system **200** (although equally, this processing may be performed by system **200** itself as part of its processing). For example, FIG. **8**B shows the photograph shown in FIG. **8**A that has been processed by an edge detection algorithm.

Although an exemplary application of this invention has been discussed in relation to capacity management within network cabinets, it will be appreciated that the invention may be equally applied in any other application where it is desired to infer distances or dimensions within an image. In particular, the present invention allows sizes to be inferred in images which were not taken with the intention of allowing such inference to be made, such as historically captured images which were taken for some other purpose. That is to say, the invention does not require any pre-determined specific object to be included in an image, nor does it require the image capture device to have been pre-calibrated to capture additional metadata for the image. Instead, the invention provides a way of measuring features in images which makes use of a set of reference images to extract (or learn) reference information that can be used for this purpose. When applied iteratively, the accuracy of (and/or confidence in) this reference data can be improved, which can in turn improve the accuracy of (and/or confidence in) the measurements that are provided. Furthermore, if the set of reference images is added to over time, the invention can adapt to learn about new types of object.

Insofar as embodiments of the invention described are implementable, at least in part, using a software-controlled programmable processing device, such as a microprocessor, digital signal processor or other processing device, data

processing apparatus or system, it will be appreciated that a computer program for configuring a programmable device, apparatus or system to implement the foregoing described methods is envisaged as an aspect of the present invention. The computer program may be embodied as source code or undergo compilation for implementation on a processing device, apparatus or system or may be embodied as object code, for example. Suitably, the computer program is stored on a carrier medium in machine or device readable form, for example in solid-state memory, magnetic memory such as disk or tape, optically or magneto-optically readable memory such as compact disk or digital versatile disk etc., and the processing device utilises the program or a part thereof to configure it for operation. The computer program may be supplied from a remote source embodied in a communications medium such as an electronic signal, radio frequency carrier wave or optical carrier wave. Such carrier media are also envisaged as aspects of the present invention. It will be understood by those skilled in the art that, although the present invention has been described in relation to the above described example embodiments, the invention is not limited thereto and that there are many possible variations and modifications which fall within the scope of the invention. The scope of the present invention includes any novel features or combination of features disclosed herein. The applicant hereby gives notice that new claims may be formulated to such features or combination of features during prosecution of this application or of any such further applications derived therefrom. In particular, with reference to the appended claims, features from dependent claims may be combined with those of the independent claims and features from respective independent claims may be combined in any appropriate manner and not merely in the specific combinations enumerated in the claims.

The invention described herein also relates to the following aspects:

1. A computer implemented method for determining a physical size of a feature represented in an image, the method comprising:
   - receiving initial data comprising an indication of a respective physical size of one or more known types of object;
   - using the initial data to generate reference data from a first reference image, the reference data comprising an indication of a respective inferred physical size of one or more reference types of object; and
   - using the reference data to determine the physical size of the feature based, at least in part, on:
     - a size of a representation of one of the reference types of object in the image;
     - the inferred physical size of that reference type of object; and
     - a size of the representation of the feature in the image.

2. The method of aspect 1, wherein generating the reference data comprises directly inferring a physical size of at least one of the reference types of object from a respective one of the known types of object based on:
   - a size of a representation of the reference type of object in the first reference image;
   - a size of a representation of the known type of object in the first reference image; and
   - the physical size of the known type of object as indicated by the initial data.

3. The method of aspect 1 or aspect 2, wherein the first reference image is one of a set of reference images and generating the reference data comprises indirectly inferring a physical size of at least one of the reference types of object from a respective one of the known types of object based on:
   - a size of a representation of the reference type of object in the first reference image;
   - a size of a representation of an intermediate type of object in the first reference image;
   - a size of a representation of the intermediate type of object in a second image of the set of reference images;
   - a size of a representation of the known type of object in the second image; and
   - the physical size of the known type of object as indicated by the initial data.

4. The method of aspect 2 or aspect 3, wherein generating the reference data comprises determining a respective plurality of candidate physical sizes for at least one of the reference types of object and determining a respective inferred physical size for the reference type of object based on the plurality of candidate physical sizes.

5. The method of aspect 4, wherein a plurality of the respective candidate physical sizes for the reference type of object are inferred from different representations of a known type of object.

6. The method of aspect 4 or aspect 5 when dependent on aspect 4, wherein the respective plurality of candidate physical sizes comprise at least one directly inferred physical size and at least one indirectly inferred physical size.

7. The method of any one of aspects 4 to 6 when dependent on aspect 3, wherein a plurality of the respective candidate physical sizes are indirectly inferred from the same representation of a known type of object based on different representations of the intermediate type of object in either the first reference image, the second reference image, or both the first and second reference image.

8. The method of any one of aspects 4 to 7 when dependent on aspect 3, wherein a plurality of the respective candidate physical sizes are indirectly inferred from the same representation of a known type of object based on representations of different intermediate types of object in the first and second reference images.

9. The method of any one of aspects 4 to 8, wherein:
   - the initial data comprises an indication of a respective physical size of a plurality of known types of object; and
   - a plurality of the respective candidate physical sizes are inferred either directly or indirectly from respective representations of each of the plurality of known types of object.

10. The method of any one of the preceding aspects, wherein:
   - the inferred physical size of the one or more reference types of object comprises an indication of a range of physical sizes; and
   - the determined physical size of the feature comprises an indication of a range of physical sizes.

11. The method of any one of the preceding aspects, further comprising determining a respective confidence with the inferred physical size of each of the one or more reference types and providing an indication of a respective confidence in the inferred physical size of the feature.

12. The method of any one of the preceding aspects, wherein the reference data is generated iteratively from the reference images, wherein each subsequent iteration either increases the number of reference type of objects in the reference data or refines the inferred physical sizes for one or more reference type of objects in the reference data, or both.

13. The method of any one of the preceding aspects, wherein the method further comprises storing the image as a reference image to be used in determining a physical size of a feature represented in a further image.

14. A computer system comprising a processor and a memory storing computer program code for performing the steps of any one of the preceding aspects.

15. A computer program which, when executed by one or more processors, is arranged to carry out a method according to any one of aspects 1 to 13.

The invention claimed is:

1. A computer implemented method for determining a physical size of a feature represented in an image, the method comprising:

receiving initial data comprising data for identifying one or more known types of object and an indication of a respective physical size of each of the one or more known types of object;

generating reference data from a first reference image by identifying one or more new types of object represented in the first reference image and using the initial data to infer a respective physical size of each of the one or more new types of object, the one or more new types of object forming one or more reference types of object for determining the physical size of the feature; and

using the reference data to determine the physical size of the feature based, at least in part, on:

a size of a representation of one of the reference types of object in the image;

the inferred physical size of that reference type of object; and

a size of the representation of the feature in the image.

2. The method of claim **1**, wherein generating the reference data comprises directly inferring a physical size of at least one of the reference types of object from a respective one of the known types of object based on:

a size of a representation of the reference type of object in the first reference image;

a size of a representation of the known type of object in the first reference image; and

the physical size of the known type of object as indicated by the initial data.

3. The method of claim **2**, wherein generating the reference data comprises determining a respective plurality of candidate physical sizes for at least one of the reference types of object and determining a respective inferred physical size for the reference type of object based on the plurality of candidate physical sizes.

4. The method of claim **3**, wherein a plurality of the respective candidate physical sizes for the reference type of object are inferred from different representations of a known type of object.

5. The method of claim **3**, wherein the respective plurality of candidate physical sizes comprise at least one directly inferred physical size and at least one indirectly inferred physical size.

6. The method of claim **3**, wherein:

the initial data comprises an indication of a respective physical size of a plurality of known types of object; and

a plurality of the respective candidate physical sizes are inferred either directly or indirectly from respective representations of each of the plurality of known types of object.

7. The method of claim **1**, wherein the first reference image is one of a set of reference images and generating the reference data comprises indirectly inferring a physical size of at least one of the reference types of object from a respective one of the known types of object based on:

a size of a representation of the reference type of object in the first reference image;

a size of a representation of an intermediate type of object in the first reference image;

a size of a representation of the intermediate type of object in a second image of the set of reference images;

a size of a representation of the known type of object in the second image; and

the physical size of the known type of object as indicated by the initial data.

8. The method of claim **1**,

wherein the first reference image is one of a set of reference images and generating the reference data comprises indirectly inferring a physical size of at least one of the reference types of object from a respective one of the known types of object based on;

a size of a representation of the reference type of object in the first reference image;

a size of a representation of an intermediate type of object in the first reference image;

a size of a representation of the intermediate type of object in a second image of the set of reference images;

a size of a representation of the known type of object in the second image;

the physical size of the known type of object as indicated by the initial data; and

wherein generating the reference data comprises determining a respective plurality of candidate physical sizes for at least one of the reference types of object and determining a respective inferred physical size for the reference type of object based on the plurality of candidate physical sizes;

wherein a plurality of the respective candidate physical sizes are indirectly inferred from the same representation of a known type of object based on different representations of the intermediate type of object in either the first reference image, the second reference image, or both the first and second reference image.

9. The method of claim **1**,

wherein the first reference image is one of a set of reference images and generating the reference data comprises indirectly inferring a physical size of at least one of the reference types of object from a respective one of the known types of object based on:

a size of a representation of the reference type of object in the first reference image;

a size of a representation of an intermediate type of object in the first reference image;

a size of a representation of the intermediate type of object in a second image of the set of reference images;

a size of a representation of the known type of object in the second image;

the physical size of the known type of object as indicated by the initial data;

wherein generating the reference data comprises determining a respective plurality of candidate physical sizes for at least one of the reference types of object and determining a respective inferred physical size for the reference type of object based on the plurality of candidate physical sizes; and

wherein a plurality of the respective candidate physical sizes are indirectly inferred from the same representation of a known type of object based on representations of different intermediate types of object in the first and second reference images.

10. The method of claim **1**, wherein:

the inferred physical size of the one or more reference types of object comprises an indication of a range of physical sizes; and

the determined physical size of the feature comprises an indication of a range of physical sizes.

11. The method of claim **1**, further comprising determining a respective confidence with the inferred physical size of each of the one or more reference types and providing an indication of a respective confidence in the inferred physical size of the feature.

12. The method of claim **1**, wherein the reference data is generated iteratively from the reference images, wherein each subsequent iteration either increases the number of reference type of objects in the reference data or refines the inferred physical sizes for one or more reference type of objects in the reference data, or both.

13. The method of claim **1**, wherein the method further comprises storing the image as a reference image to be used in determining a physical size of a feature represented in a further image.

14. A non-transitory computer-readable storage medium storing computer program code which, when executed by one or more processors, is arranged to carry out a method according to claim **1**.

15. The method of claim **1**, wherein the image having the feature represented therein does not contain any representation of the one or more known types of object.

16. A computer system for determining a physical size of a feature represented in an image, the computer system comprising a processor and a memory storing computer program code, wherein upon execution of the comp ter code by the processor, the computer system is at least configured to:

receive initial data comprising data for identifying one or more known types of object and an indication of a respective physical size of each of the one or more known types of object;

generate reference data from a first reference image by identifying one or more new types of object represented in the first reference image and use the initial data to infer a respective physical size of each of the one or more new types of object, the one or more new types of object forming one or more reference types of object for determining the physical size of the feature; and

use the reference data to determin be physical size of the feature based, at least in part. on:

a size of a representation of one of the reference types of object in the image;

the inferred physical size of that reference type of object; and

a size of the representation of the feature in the image.

17. The computer system of claim **16**, wherein the image having the feature represented therein does not contain any representation of the one or more known types of object.

18. The computer system of claim **16**, wherein the generation of the reference data comprises directly inferring a physical size of at least one of the reference types of object from a respective one of the known types of object based on:

a size of a representation of the reference type of object in the first reference image;

a size of a representation of the known type of object in the first reference image; and

the physical size of the known type of object as indicated by the initial data.

19. The computer system of claim **18**, wherein in order to generate the reference data, the computer system is further configured to determine a respective plurality of candidate physical sizes for at least one of the reference types of object and determine a respective inferred physical size for the reference type of object based on the plurality of candidate physical sizes.

20. The computer system of claim **19**, wherein a plurality of the respective candidate physical sizes for the reference type of object are inferred from different representations of a known type of object.

21. The computer system of claim **19**, wherein the respective plurality of candidate physical sizes comprise at least one directly inferred physical size and at least one indirectly inferred physical size.

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