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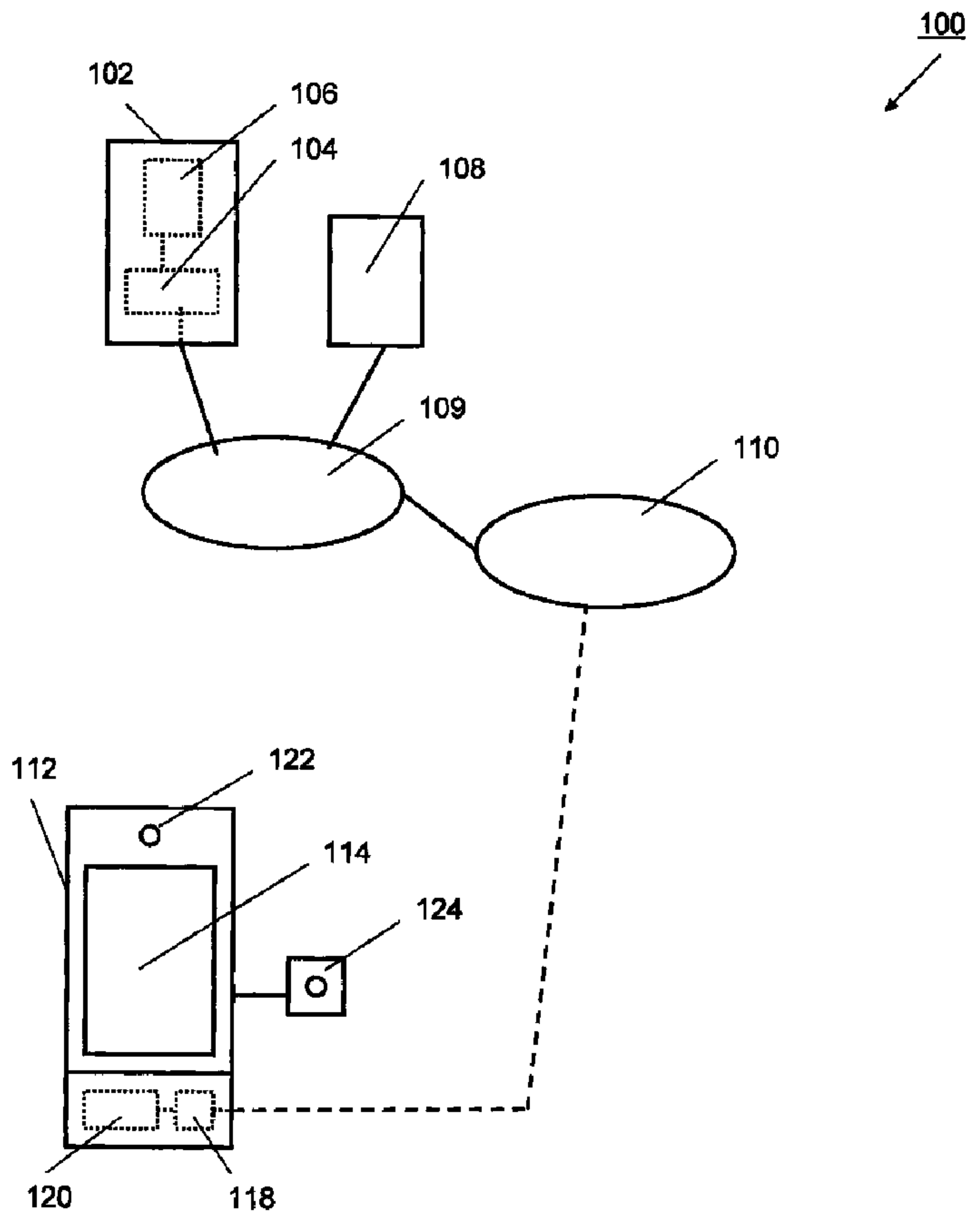
(54) Titre : PROCEDE ET SYSTEME POUR L'ETALONNAGE A DISTANCE DE L'AFFICHAGE DE DONNEES D'IMAGERIE

(54) Title: METHOD AND SYSTEM FOR REMOTELY CALIBRATING DISPLAY OF IMAGE DATA




(57) Abrégé/Abstract:
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(57) Abrégé(suite)/Abstract(continued):
the display. The display data are then transmitted to a server computer. Using a processor of the server computer display adjustment data are determined in dependence upon the display data. The display adjustment data are then transmitted to the client computer. Alternatively, image data for displaying on the display are received. Adjusted image data are then determined in dependence upon the received image data and the display adjustment data and transmitted to the client computer.

# ABSTRACT

A method for remotely calibrating display of image data is provided. Using a processor of the client computer display data are determined. The display data are indicative of a luminance dynamic range of the display and of an ambient lighting environment of the display. The display data are then transmitted to a server computer. Using a processor of the server computer display adjustment data are determined in dependence upon the display data. The display adjustment data are then transmitted to the client computer. Alternatively, image data for displaying on the display are received. Adjusted image data are then determined in dependence upon the received image data and the display adjustment data and transmitted to the client computer.

# METHOD AND SYSTEM FOR REMOTELY CALIBRATING DISPLAY OF IMAGE DATA

## FIELD OF THE INVENTION

The instant invention relates to the technical field of calibrating a display and in particular to a method and system for remotely calibrating display of image data.

## BACKGROUND OF THE INVENTION

In many fields it is important that images displayed on electronic displays appear the same over time and on different displays. For example, in radiology it is important that a displayed medical image appears having the same contrast from year to year as a disease is followed or as the image is viewed on different displays. Therefore, standards exist for the calibration of displays to ensure consistency of display between devices and over time. In radiology, one industry standard for grayscale display and calibration is in Digital Imaging and Communications in Medicine (DICOM) Part 14, the Gray Scale Display Function (GSDF).

Recently, there has been an increase in usage of client-server systems for the display of medical images. In this case, rather than images being generated on a designated medical device such as, for example, a PACS workstation or modality console with integral display components, the medical images are rendered on a central server and displayed on a client device which can be separated a large distance from the server, and even outside the hospital where the server is deployed. The client devices have evolved from closely controlled components of the medical device to commodity computers, laptops, tablet computers and even smart phones. The capacity of these devices to support internal or third party calibration varies widely.

While the designated medical devices have been used at fixed locations such as, for example, dark rooms or radiology reading rooms, the new devices are mobile and, therefore, introduce widely varying ambient light levels as a new variable to the calibration of image display. Mobile devices are used in widely varying situations such as, for example, offices, various other indoor locations (restaurants, theatres, residences) as well as outdoors, thus creating a wide range of possible lighting environments.

It is desirable to provide a method and system for remotely calibrating display of image data.

It is also desirable to provide a method and system for remotely calibrating display of image data under a wide range of ambient lighting environments.

It is also desirable to provide a method and system for remotely calibrating display of image data using displays that do not support calibration.

## SUMMARY OF THE INVENTION

Accordingly, one object of the present invention is to provide a method and system for remotely calibrating display of image data.

Another object of the present invention is to provide a method and system for remotely calibrating display of image data under a wide range of ambient lighting environments.

Another object of the present invention is to provide a method and system for remotely calibrating display of image data using displays that do not support calibration.

According to one aspect of the present invention, there is provided a method for remotely calibrating display of image data. Using a processor of the client computer display data are determined. The display data are indicative of a luminance dynamic range of the display and of an ambient lighting environment of the display. The display data are then transmitted to a server computer. Using a processor of the server computer display adjustment data are determined in dependence upon the display data. The display adjustment data are then transmitted to the client computer. Alternatively, image data for displaying on the display are received. Adjusted image data are then determined in dependence upon the received image data and the display adjustment data and transmitted to the client computer.

According to the aspect of the present invention, there is provided a method for remotely calibrating display of image data. Using a processor of the client computer display data are determined. The display data are indicative of a luminance dynamic range of the display and of an ambient lighting environment of the display. The display data are determined by the user of the client computer. A minimum just noticeable difference is determined by displaying a first series of contrast images, each image comprising a target and a surround with the surround having pixel values determined, for example, by common practice or as specified in applicable standard and an increasing target pixel value for subsequent images. The user determines the contrast image where the target is first distinguishable from the surround. A maximum just noticeable difference is determined by displaying a second series of contrast images, each image comprising a target and a surround with the surround having high-valued pixels determined, for example, by common practice or as specified in an applicable standard and a decreasing target pixel value for subsequent images. The user determines the contrast image where the target is first distinguishable from the surround. A perceptual dynamic range is determined in dependence upon the maximum just noticeable difference and the minimum just noticeable difference. The display data are then transmitted to a server computer. Using a processor of the server computer display adjustment data are determined in dependence upon the display data. The display adjustment data are then transmitted to the client computer. Alternatively, image data for displaying on the display are received. Adjusted image data are then determined in dependence upon the received image data and the display adjustment data and transmitted to the client computer.

According to the aspect of the present invention, there is provided a method for remotely calibrating display of image data. Using a processor of the client computer display data are determined. The display data are indicative of a luminance dynamic range of the display and of an ambient lighting environment of the display. The display data are then transmitted to a server computer. Using a processor of the server computer display adjustment data are determined in dependence upon the display data. The display adjustment data are then transmitted to the client computer. Alternatively, image data for displaying on the display are received. Adjusted image data are then determined in dependence upon the received image data and the display adjustment data and transmitted to the client computer. Using the processor of the client computer data indicative of a change of the ambient lighting environment of the display are determined and transmitted to the server computer. Using the processor of the server computer updated display adjustment data are determined. The updated display adjustment data are then transmitted to the client computer. Alternatively, image data for displaying on the display are received. Updated adjusted image data are then determined in dependence upon the received image data and the updated display adjustment data and transmitted to the client computer.

The advantage of the present invention is that it provides a method and system for remotely calibrating display of image data.

A further advantage of the present invention is that it provides a method and system for remotely calibrating display of image data under a wide range of ambient lighting environments.

A further advantage of the present invention is that it provides a method and system for remotely calibrating display of image data using displays that do not support calibration.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the present invention is described below with reference to the accompanying drawings, in which:

Figure 1 is a simplified block diagram illustrating a system for remotely calibrating display of image data according to a preferred embodiment of the invention;

Figure 2 is a simplified flow diagram illustrating a method for remotely calibrating display of image data according to a preferred embodiment of the invention;

Figure 3a is a simplified block diagram illustrating a screen for determining ambient lighting of the display in the method illustrated in Figure 2; and,

Figures 3b and 3c are simplified block diagrams illustrating contrast images for determining display data in the method illustrated in Figure 2.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are now described.

While embodiments of the invention will be described for providing remote calibration of display of medical images, it will become evident to those skilled in the art that the embodiments of the invention are not limited thereto, but are applicable for providing remote calibration in numerous other fields such as, for example, in the printing and publishing industry, in color matching, and photography. Furthermore, while the embodiments of the invention will be described for display of images for the sake of clarity, it will become apparent that to those skilled in the art that the embodiments of the invention are also applicable for the display of video data.

Referring to Figure 1, a system 100 for providing remote calibration via a computer network according to a preferred embodiment of the invention is shown. The system comprises a client computer 112 – for example, a wireless handheld device such as an iPhone™ or a Blackberry™ – connected via a computer network 110 such as, for example, the Internet, to server computer 102. The server computer 102 is part of Local Area Network (LAN) 109, for example, the LAN of a hospital. The remote calibration is performed by executing executable commands of a client calibration program stored in memory 120 using processor 118 of the client computer 112. The client calibration program determines display data indicative of a luminance dynamic range of the display 114 and of an ambient lighting environment of the display 114. The display data are then transmitted via the computer networks 110 and 109 to the server computer 102. Executable commands of a server calibration program stored in memory 106 are executed using processor 104 of the server computer 102 to determine display adjustment data in dependence upon the display data. In case the display 114 supports calibration, the processor 104 retrieves the image data for display from database 108 and provides the same together with the display adjustment data to the processor 118 of the client computer 112. In case the display 114 does not support calibration, the processor 104 retrieves the image data for display from database 108, determines adjusted image data in dependence upon the image data and the display adjustment data, and transmits the adjusted image data to the processor 118 of the client computer 112. Upon receipt, the processor 118 of the client computer 112 controls the display 114 in dependence upon the display adjustment data and provides the image data for display, or provides the adjusted image data for display. Alternatively, the server calibration program is executed on a processor of a second server computer connected to the server computer 102 and the client computer 112 via the computer network 110. Optionally, provision of a client calibration program is omitted and the display data are provided, for example, as user input data via a suitable web browser.

Referring to Figure 2, a flow diagram of a method for remotely calibrating display of image data according to a preferred embodiment of the invention is provided. At 10, display data are determined using processor 118 of the client computer 112. The display data are indicative of a luminance dynamic range of the display and of an ambient lighting environment of the display. Data indicative of the luminance dynamic range of the display are, for example, provided by the manufacturer of the display and retrievably stored in memory 120 of the client computer 112. Alternatively, data indicative of a plurality of dynamic luminance dynamic ranges such as, for example, 8-bit range (255 pixel values) or 10-bit range (1024 pixel values) and their association to respective types of displays are stored in the form of a look-up table in the memory 106 of the server computer 102. Upon receipt of data indicative of the type of display – for example, provided by the user or retrieved from the memory 120 of the client computer 112 – the processor retrieves the respective luminance dynamic range using the look-up table. Further alternatively, the data indicative of the luminance dynamic range are obtained using an external photometer 124. First, the minimum illumination is measured by filling the display 114 with the lowest intensity pixel value and measuring the minimum output luminance of the display. Second, the maximum illumination is measured by filling the display 114 with the highest intensity pixel value and measuring the maximum output luminance of the display. The luminance dynamic range is then determined as the difference between the maximum output luminance and the minimum output luminance. This is performed, for example, once before using the display and the data are stored in memory 120 of the client computer 112. Optionally, the measurement is repeated in predetermined intervals to update the luminance dynamic range of the display 114 to take, for example, aging effects of the display 114 into account.

For determining the data indicative of the ambient lighting environment of the display 114, the user of the client computer 112 is, for example, provided with a list of representative lighting environments, as illustrated in Figure 3a. Representative ambient lighting environments are, for example, dark room or minimum lighting (approx. 30lux), radiology reading room (approx. 100lux), standard office lighting (approx. 300lux), and outdoors (approx. 450lux). Alternatively, the ambient lighting is measured using a photometer integral to the client computer 112 such as, for example, built-in camera 122 or an external photometer connected to the client computer 112. Using the processor 118, data indicative of the measured ambient lighting is processed and transmitted – 12 - together with the data indicative of the luminance dynamic range of the display 114 to the server computer 102.

Upon receipt of the display data display adjustment data are determined – 14 – using the processor 104 of the server computer 102. In a first step, a lowest and a highest Just Noticeable Difference (JND) are determined as follows:

$$JND_{min} = JND(Luminance_{min} + \text{Ambient Lighting})$$
$$JND_{max} = JND(Luminance_{max} + \text{Ambient Lighting})$$

followed by the determination of the perceptual dynamic range:

$$JND_{perc} = JND_{max} - JND_{min}.$$

Display adjustment data are then determined such that the adjusted luminance dynamic range of the display 114 substantially matches the perceptual dynamic range. For example, the GSDF function is employed to determine the pixel values that will step the display one JND at a time in a nonlinear fashion using the remaining luminosity capability of the display 114. Alternatively, the pixel values are determined using other functions or a look-up table.

Alternatively, the perceptual dynamic range is directly determined by the user. For example, the user is presented with a first series of contrast images. Two exemplary contrast images are illustrated in Figures 3b and 3c. Each contrast image comprises a target 132 and a surround 130 with the surround having pixels values determined, for example, by common practice or as specified in applicable standard (eg VESA Flat Panel Display Measurement, ACR Task Group 18, DICOM Part 14, SMPTE) and an increasing target pixel value for subsequent images. The user then identifies the contrast image in which the target 132 is first distinguishable from the surround 130, which is associated with the $JND_{min}$. The user is then presented with a second series of contrast images. Each contrast image comprises a target 132 and a surround 130 with the surround having high-valued pixels determined, for example, by common practice or as specified in an applicable standard and a decreasing target pixel value for subsequent images. The user again identifies the contrast image in which the target 132 is first distinguishable from the surround 130, which is associated with the $JND_{max}$. The target 132 comprises, for example, one block of pixels placed approximately in the center of the display 114. Alternatively, the target 132 comprises a plurality of pixels forming a predetermined shape such as, for example, a circle, a rectangle, a cross, etc. Alternatively, the target 132 is displaced to a random location on the screen or comprises a group of targets as determined by common practice or as specified in applicable standards.

Optionally, the ambient lighting is measured when the user identifies $JND_{min}$ and $JND_{max}$, resulting in an association of the $JND_{min}$ and $JND_{max}$ with an ambient lighting. The $JND_{min}$ and $JND_{max}$ and the associated ambient lighting data are then stored in memory 120 of the client computer, for example, in the form of a look-up table. When during future use of the client computer 112 an ambient lighting is measured which is within a predetermined range of the stored ambient lighting, determination of the $JND_{min}$ and $JND_{max}$ by the user is omitted and the respective data are retrieved from the memory 120 and provided to the server computer 102.

In case – 16 - the display 114 supports calibration, the processor 104 retrieves the image data for display from database 108 and provides the same – 18 - together with the display adjustment data to the processor 118 of the client computer 112. Optionally, the processor 104 provides only the display adjustment data while the image data are provided from another location. In case – 16 - the display 114 does not support calibration, the processor 104 retrieves the image data for display from database 108, determines – 20 - adjusted image data in dependence upon the image data and the display adjustment data, and transmits the adjusted image data to the processor 118 of the client computer 112.

Further optionally, the display adjustment data are used for display of video data. For example, the display adjustment data are transmitted once before display of a sequence of image frames of the video data or an adjusted image frame is determined for each image frame of the video data using the display adjustment data.

Upon receipt, the processor 118 of the client computer 112 controls the display 114 in dependence upon the display adjustment data and provides the image data for display, or provides the adjusted image data for display.

Optionally, the ambient lighting is measured during display of the image data, for example, in predetermined time intervals and when a change in the ambient lighting is detected data indicative of the new ambient lighting are provided to the server computer 102, which then updates the display adjustment data for adjusting the display of the image to the changed ambient lighting. Updating of the data indicative of the ambient lighting is useful during display of an image for a longer time interval, when a user changes his/her location, or during display of video data. For example, during display of video data the display adjustment data are changed for the display of subsequent image frames of the video if a change of the ambient lighting is detected. The server computer 102 then provides updated display adjustment data to the client computer 112 or determines the adjusted image frames of the video using the updated display adjustment data.

Further optionally, data indicative of the luminance dynamic range of the image to be displayed are determined in dependence upon the display adjustment data and provided for display to the user. This feature provides the user with a quantitative assessment of the luminance dynamic range of the image. Further optionally, the user is provided with an indication if predetermined standards are not met by the current display of the image.

The method for remotely calibrating display of image data is implemented using standard programming technologies and standard digital encoding formats for processing the image/video data. Software for the central server system is programmed using, for example, the Microsoft Visual Studio development environment. Client devices are programmed using native application programming interfaces and software in languages appropriate to each device, for example, Objective C, C# and Java.

The present invention has been described herein with regard to preferred embodiments. However, it will be obvious to persons skilled in the art that a number of variations and modifications can be made without departing from the scope of the invention as described herein.

**THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:**

1. A method for remotely calibrating display of image data comprising:
providing a server computer connected to a client computer via a computer network;
using a processor of the client computer determining display data, the display data being indicative of a luminance dynamic range of the display and of an ambient lighting environment of the display;
transmitting the display data to the server computer;
using a processor of the server computer determining display adjustment data in dependence upon the display data; and,
using the processor of the server computer performing one of:
 transmitting the display adjustment data to the client computer; and,
 receiving image data for displaying on the display, determining adjusted image data in dependence upon the received image data and the display adjustment data, and transmitting the adjusted image data to the client computer.

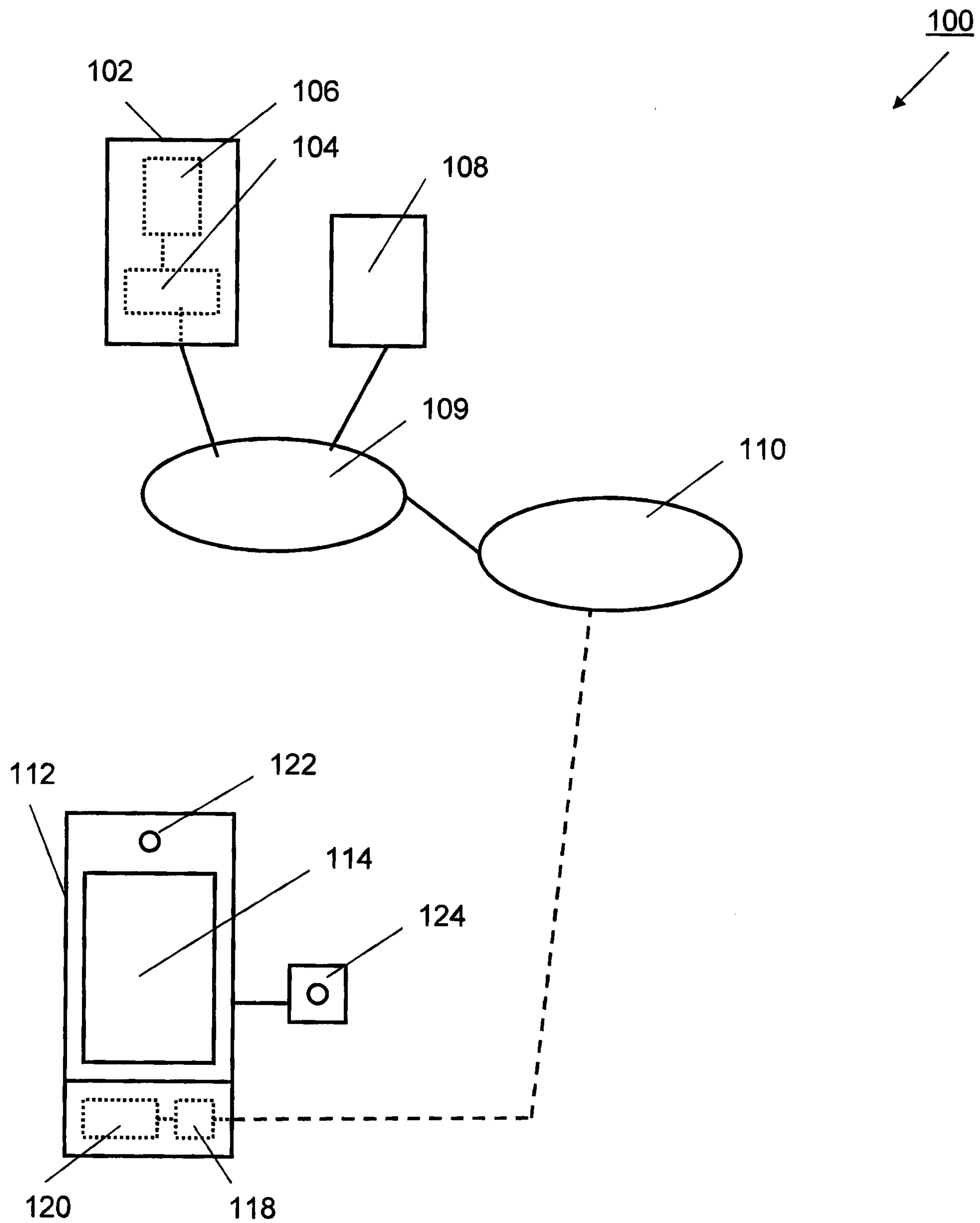



**Figure. 1**

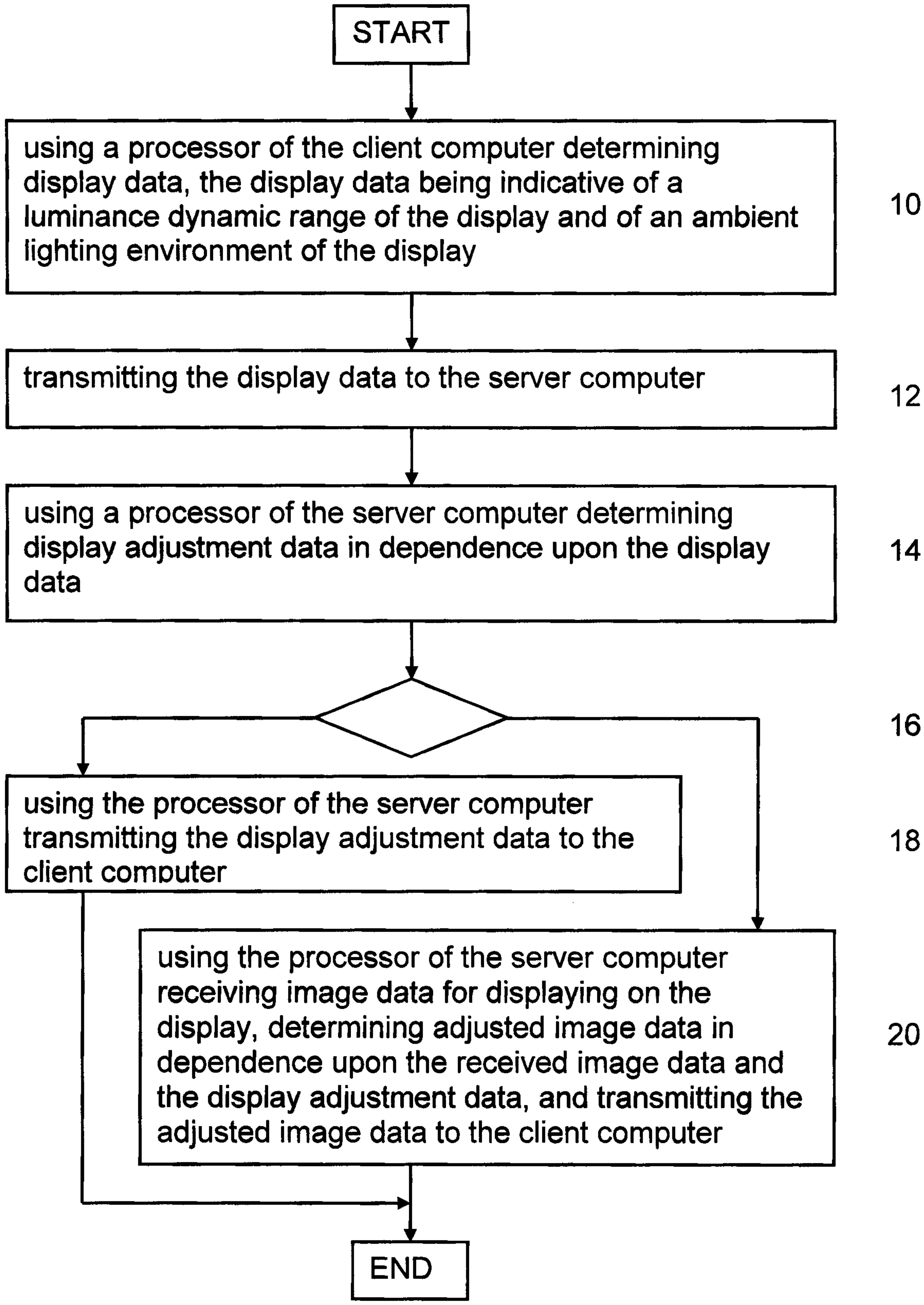

START
using a processor of the client computer determining display data, the display data being indicative of a luminance dynamic range of the display and of an ambient lighting environment of the display
10
transmitting the display data to the server computer
12
using a processor of the server computer determining display adjustment data in dependence upon the display data
14
16
using the processor of the server computer transmitting the display adjustment data to the client computer
18
using the processor of the server computer receiving image data for displaying on the display, determining adjusted image data in dependence upon the received image data and the display adjustment data, and transmitting the adjusted image data to the client computer
20
END

**Figure. 2**

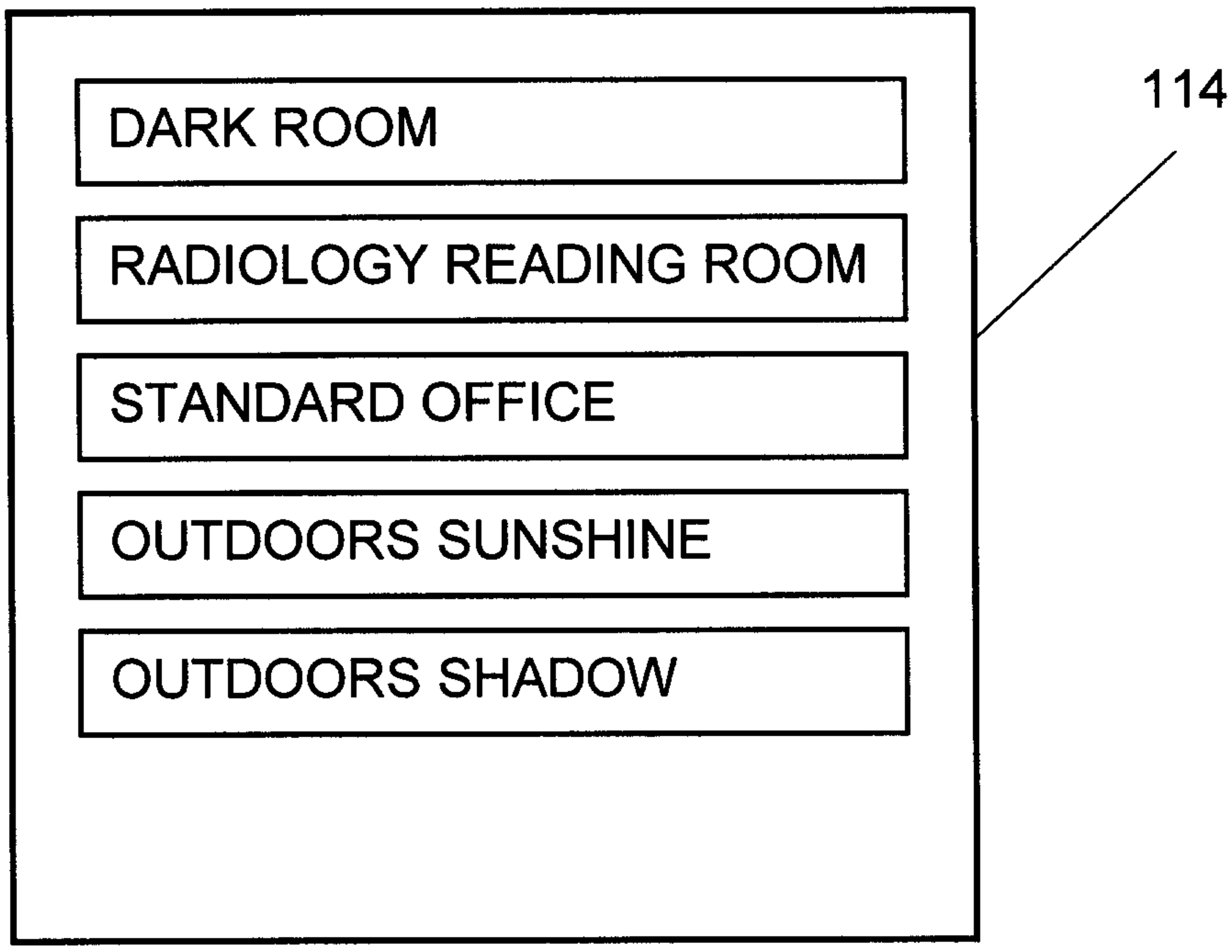

DARK ROOM
RADIOLOGY READING ROOM
STANDARD OFFICE
OUTDOORS SUNSHINE
OUTDOORS SHADOW
114

**Figure. 3a**

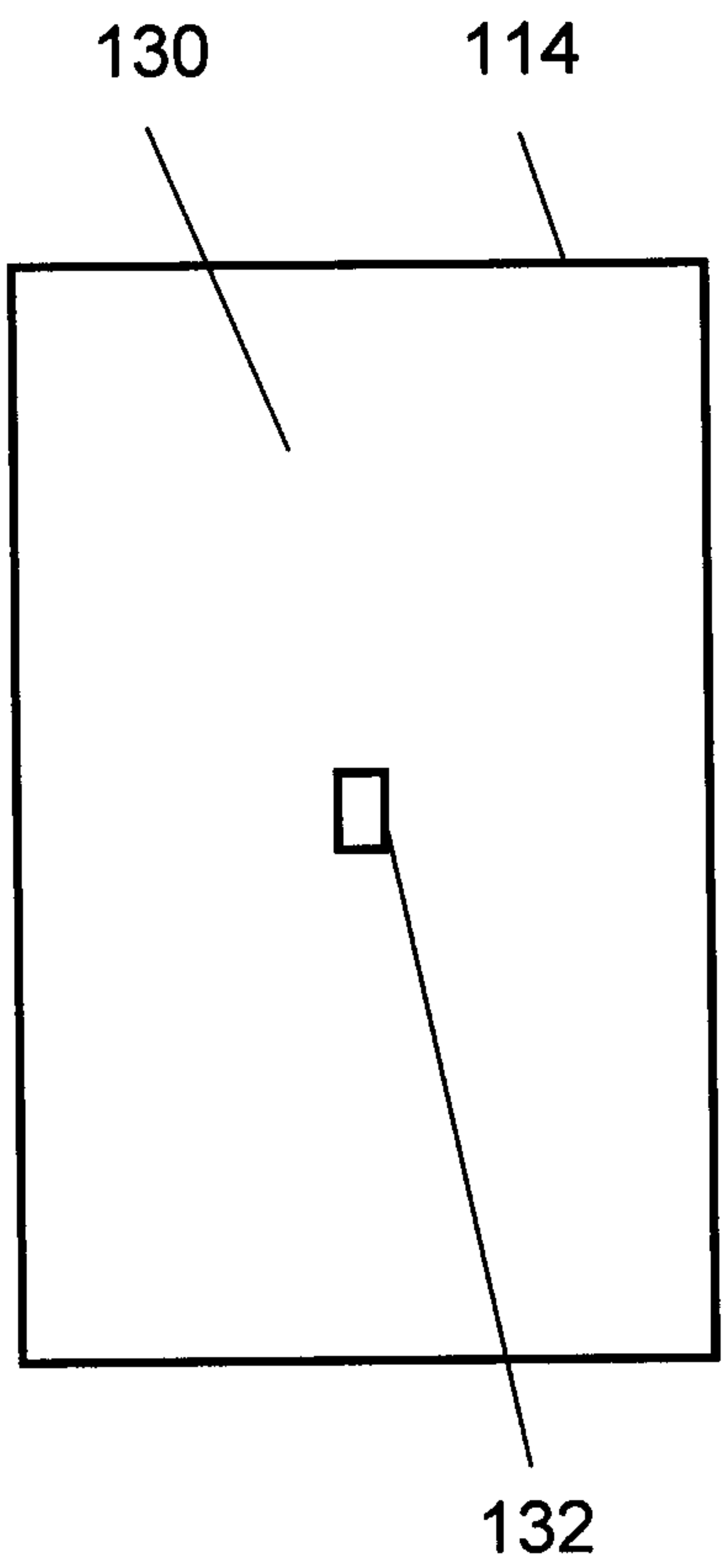



Figure. 3b

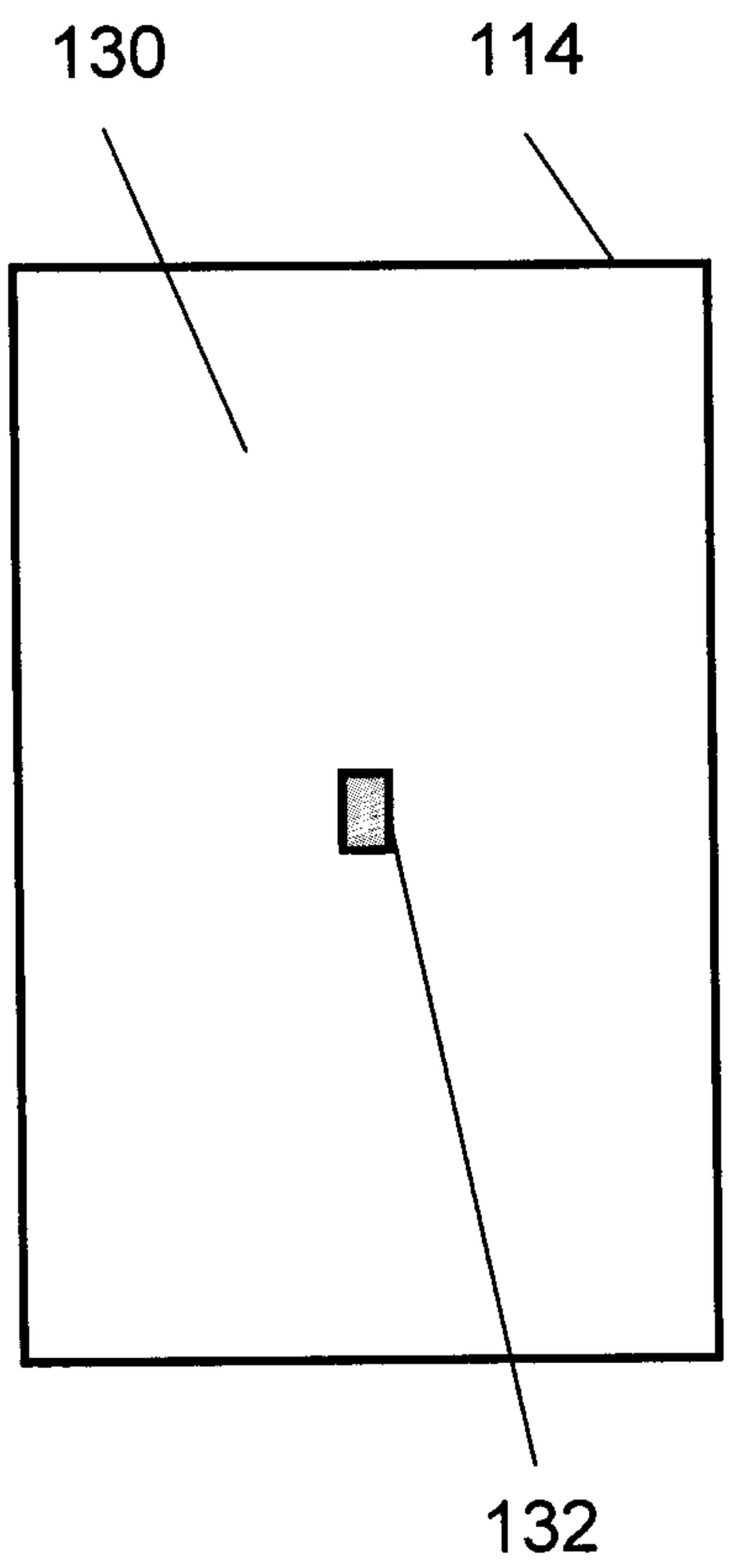
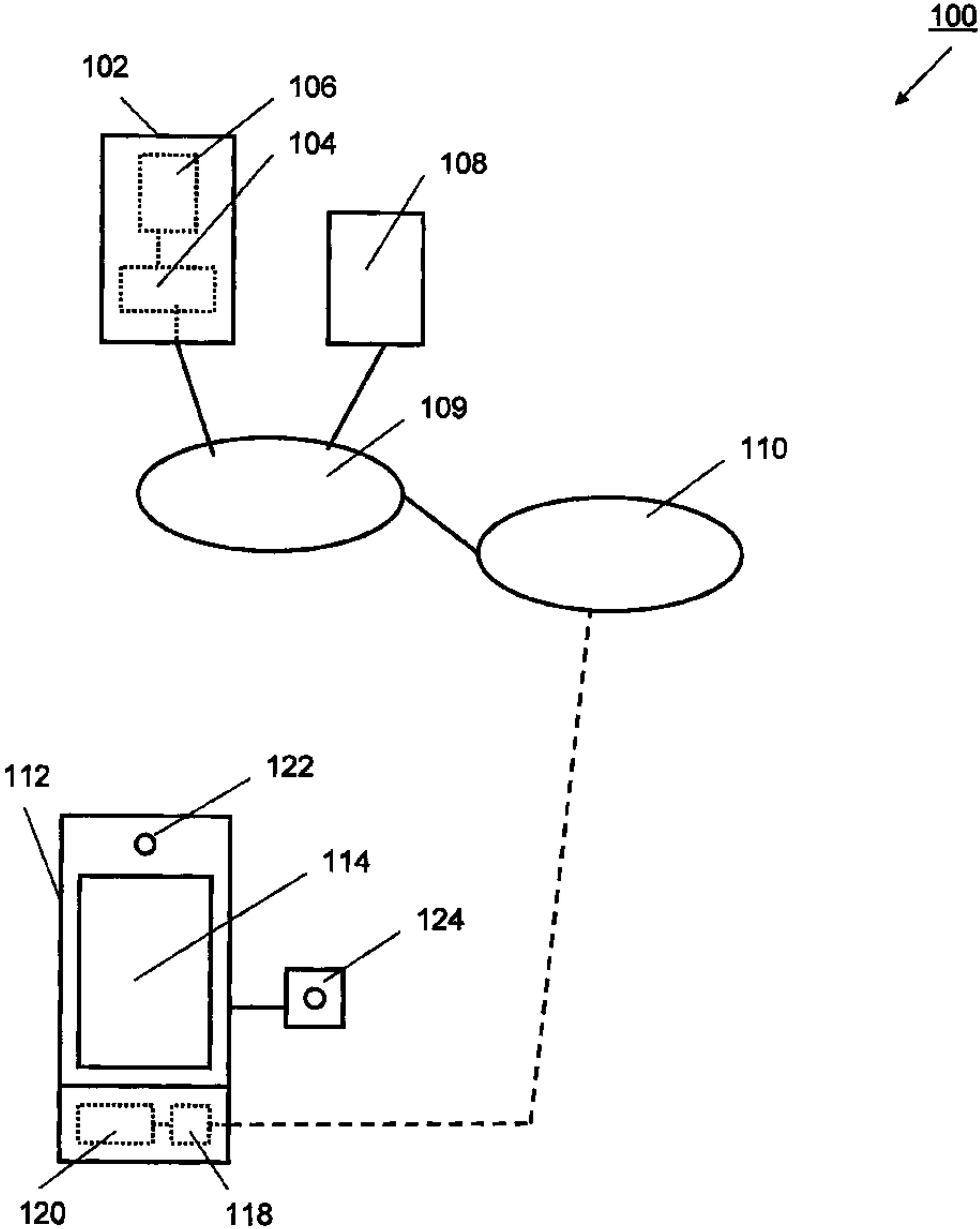



Figure. 3c



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