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(54) **SYSTEM AND METHOD FOR TRACKING AN OBJECT DURING VIDEO COMMUNICATION**

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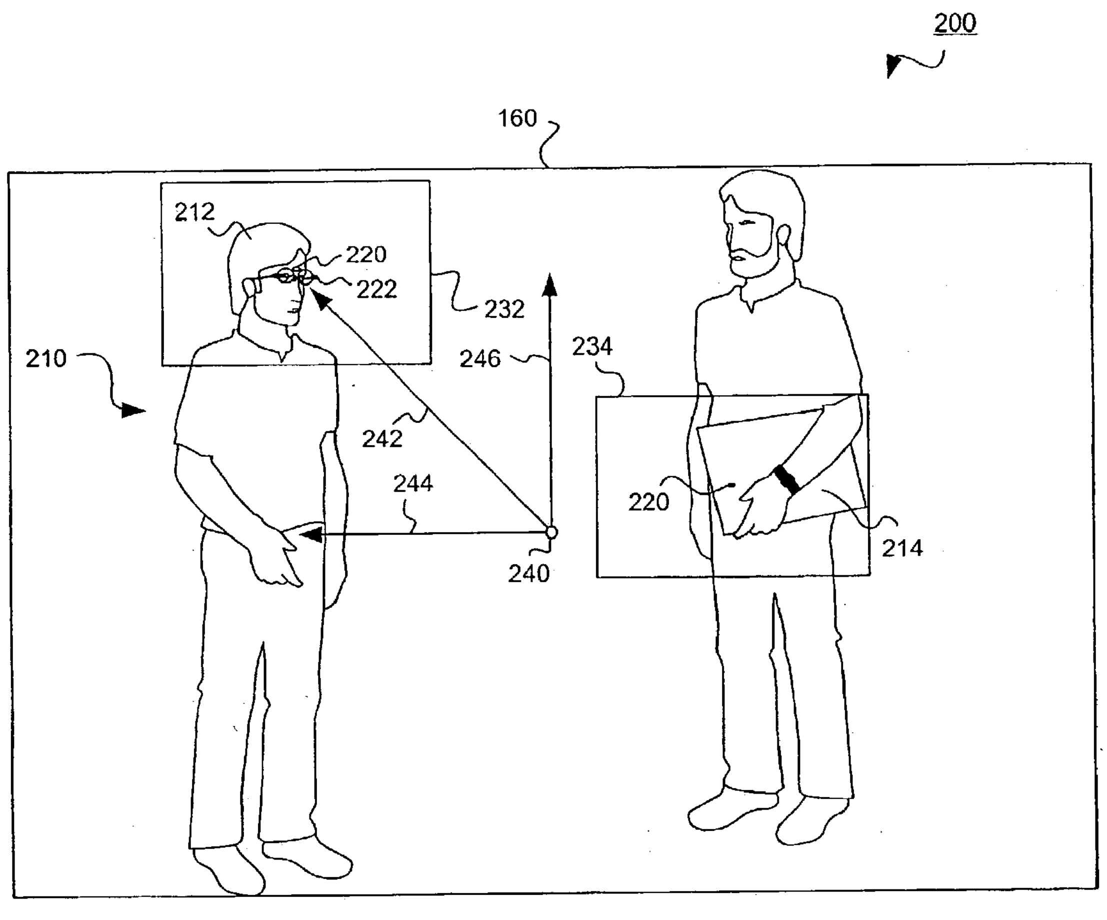
(57) **ABSTRACT**

An object is tracked with a camera that is sensitive to both visible and invisible light. An invisible light reflector attached to the object may reflect a target of invisible light, which is provided by an invisible light emitter. The camera processes the invisible light and moves the field of view of the camera so that the object is centered within the field of view. The camera may also zoom the field of view to a desired magnification level.



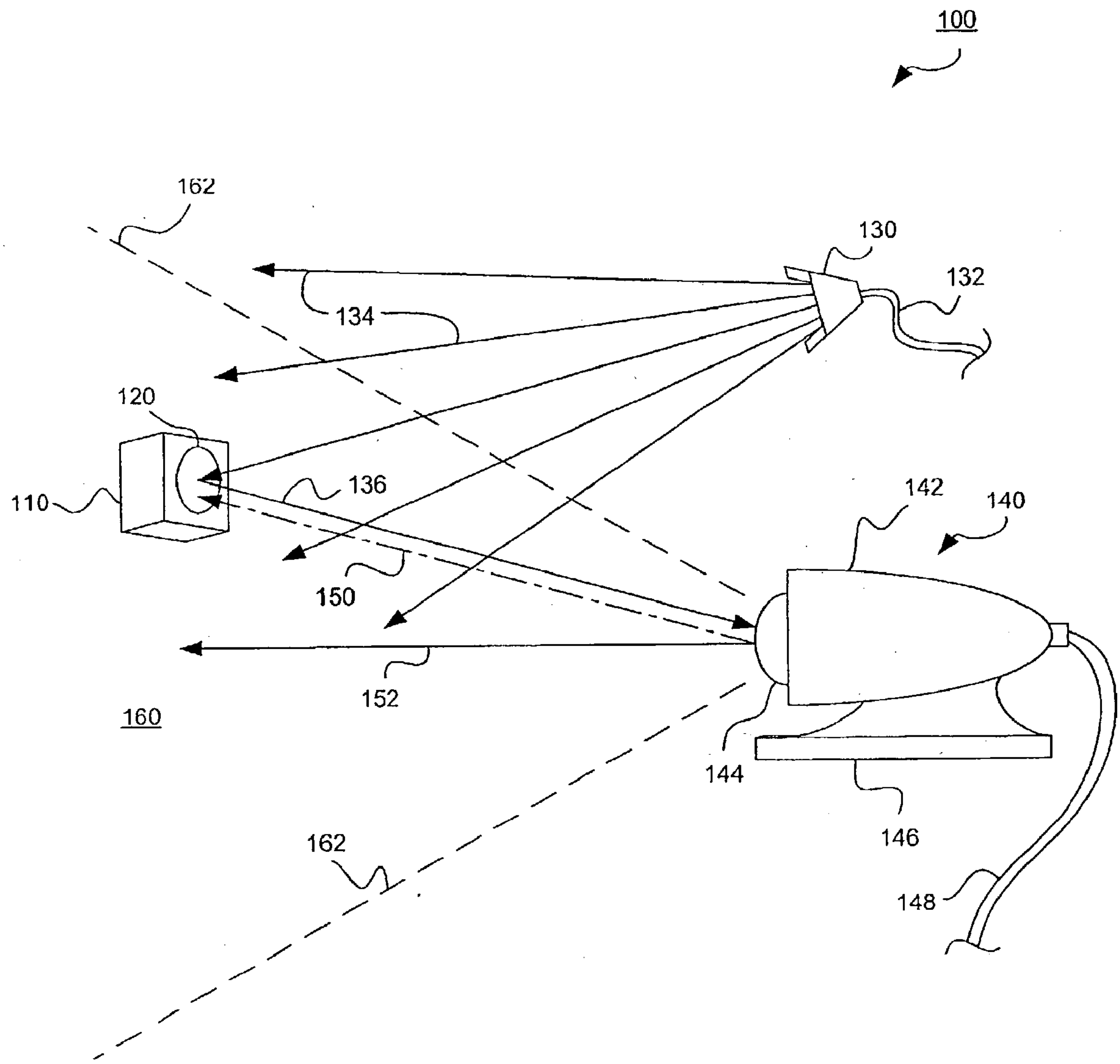

100
162
130
132
134
120
136
110
142
140
150
152
160
144
146
162
148

FIG. 1

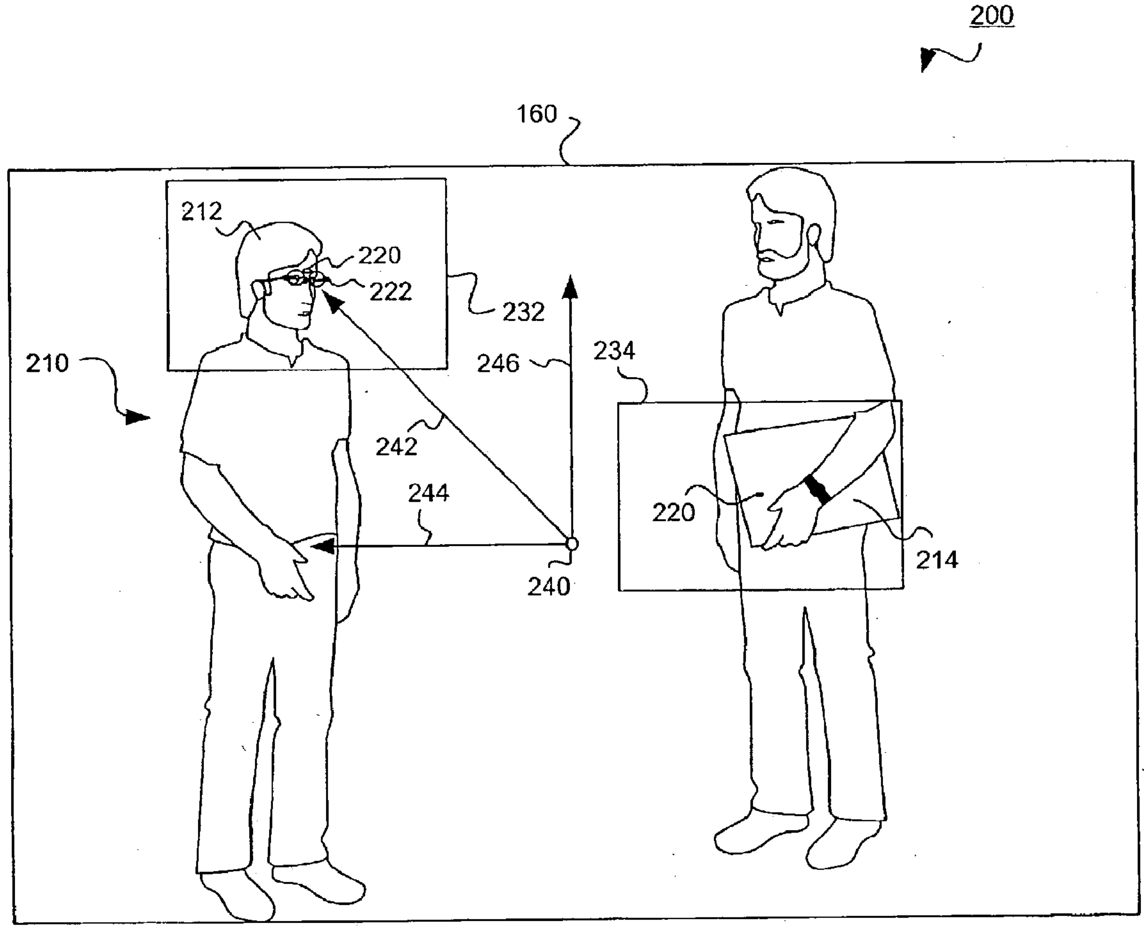


FIG. 2

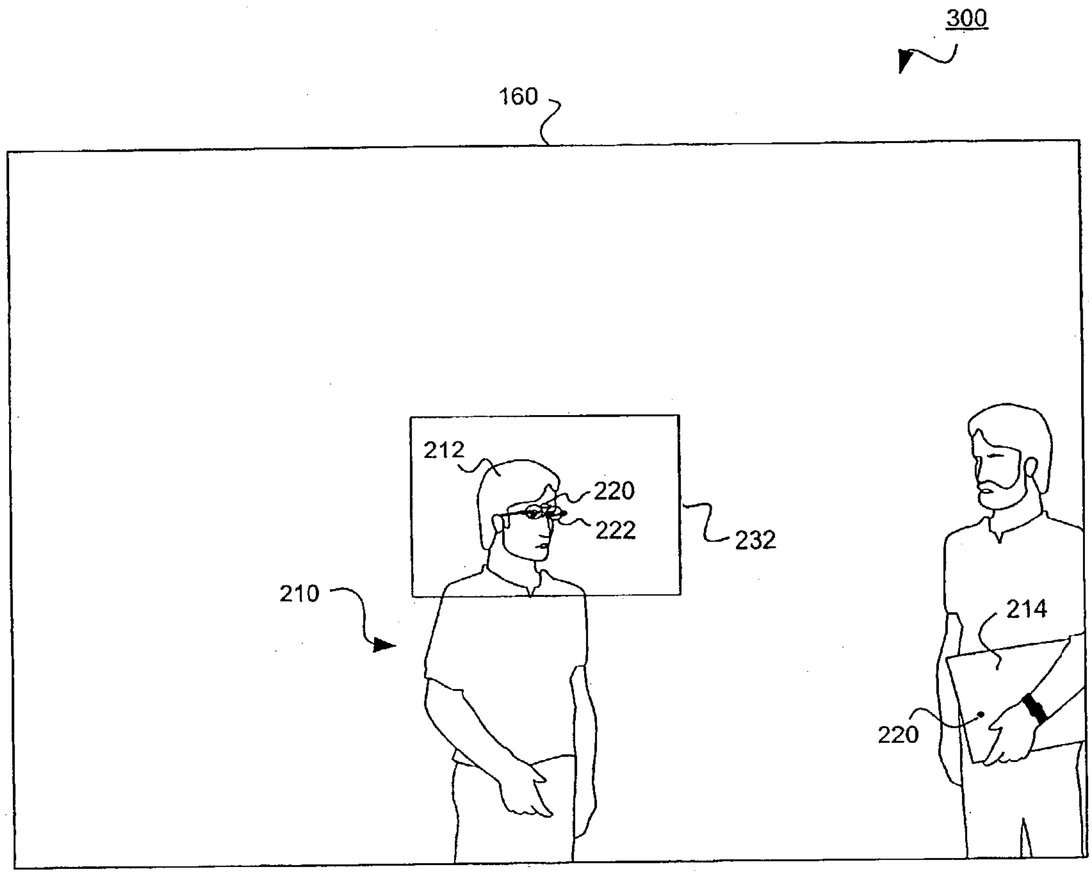


FIG. 3

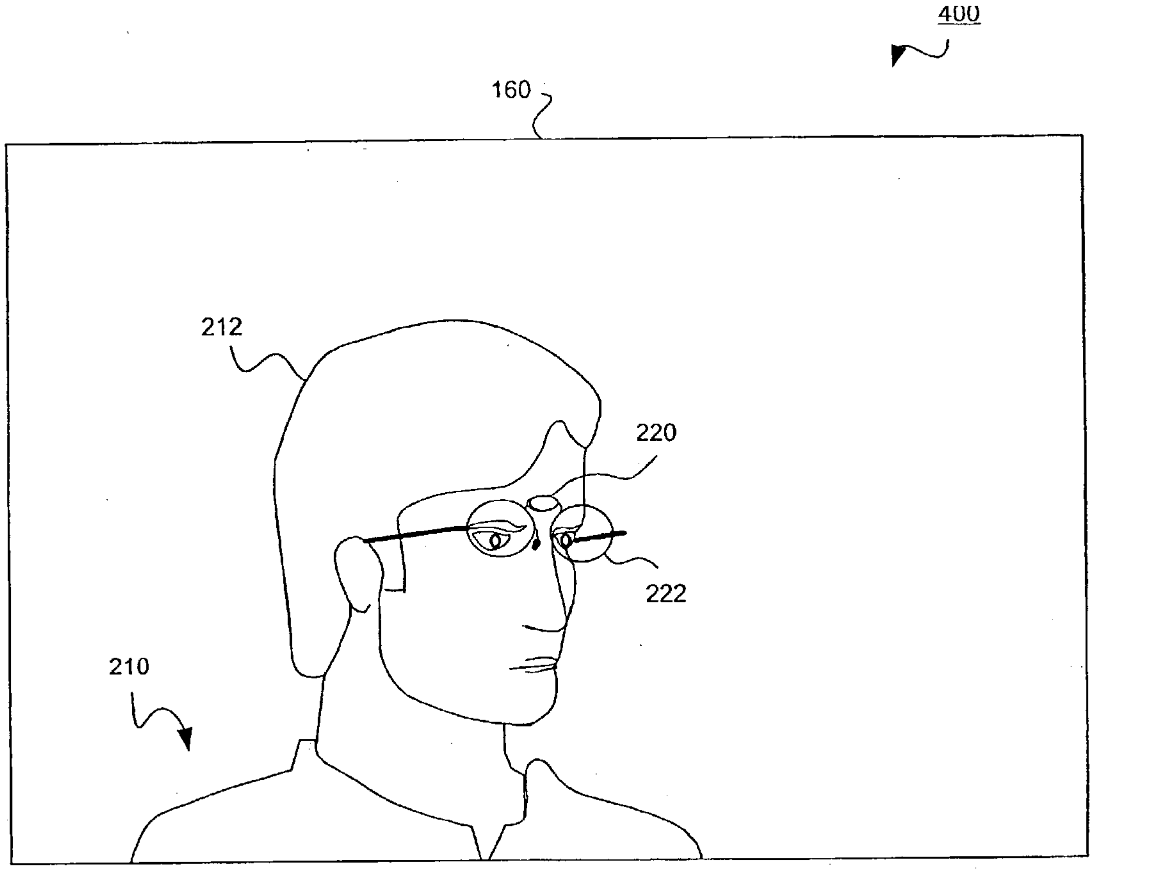


FIG. 4

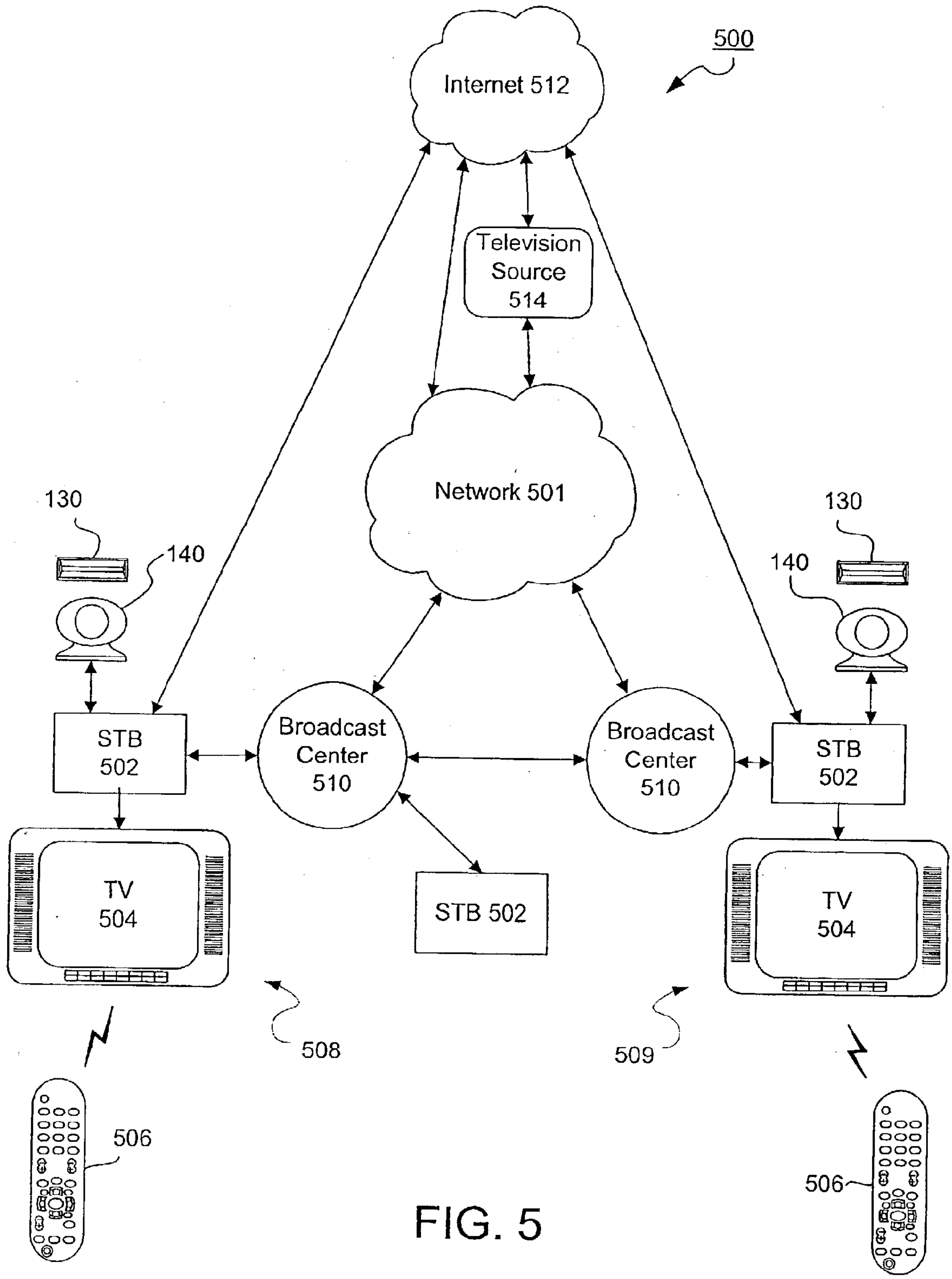

500
Internet 512
Television Source 514
Network 501
130
140
130
140
STB 502
Broadcast Center 510
Broadcast Center 510
STB 502
TV 504
STB 502
TV 504
508
509
506
506

FIG. 5

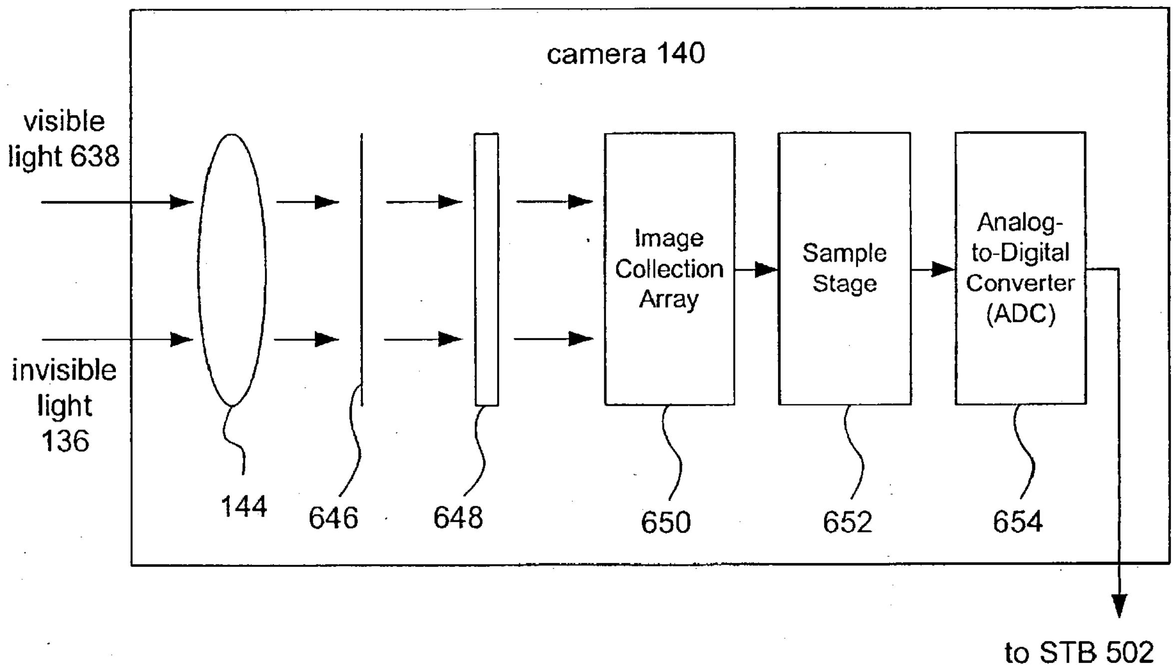

camera 140
visible light 638
invisible light 136
Image Collection Array
Sample Stage
Analog-to-Digital Converter (ADC)
144
646
648
650
652
654
to STB 502

FIG. 6

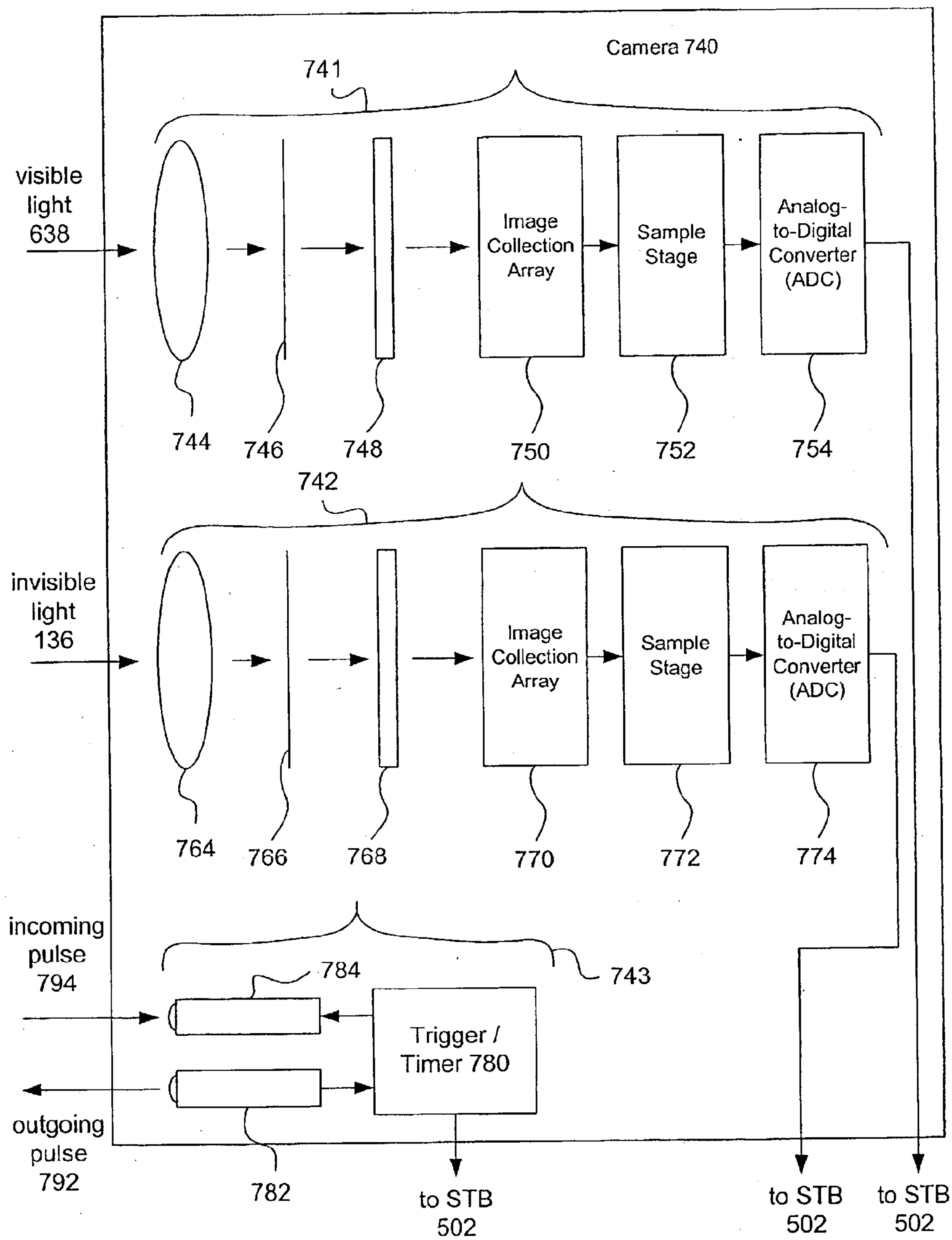

Camera 740
741
visible
light
638
Image
Collection
Array
Sample
Stage
Analog-
to-Digital
Converter
(ADC)
744
746
748
750
752
754
742
invisible
light
136
Image
Collection
Array
Sample
Stage
Analog-
to-Digital
Converter
(ADC)
764
766
768
770
772
774
incoming
pulse
794
784
743
Trigger /
Timer 780
outgoing
pulse
792
782
to STB
502
to STB
502
to STB
502

FIG. 7

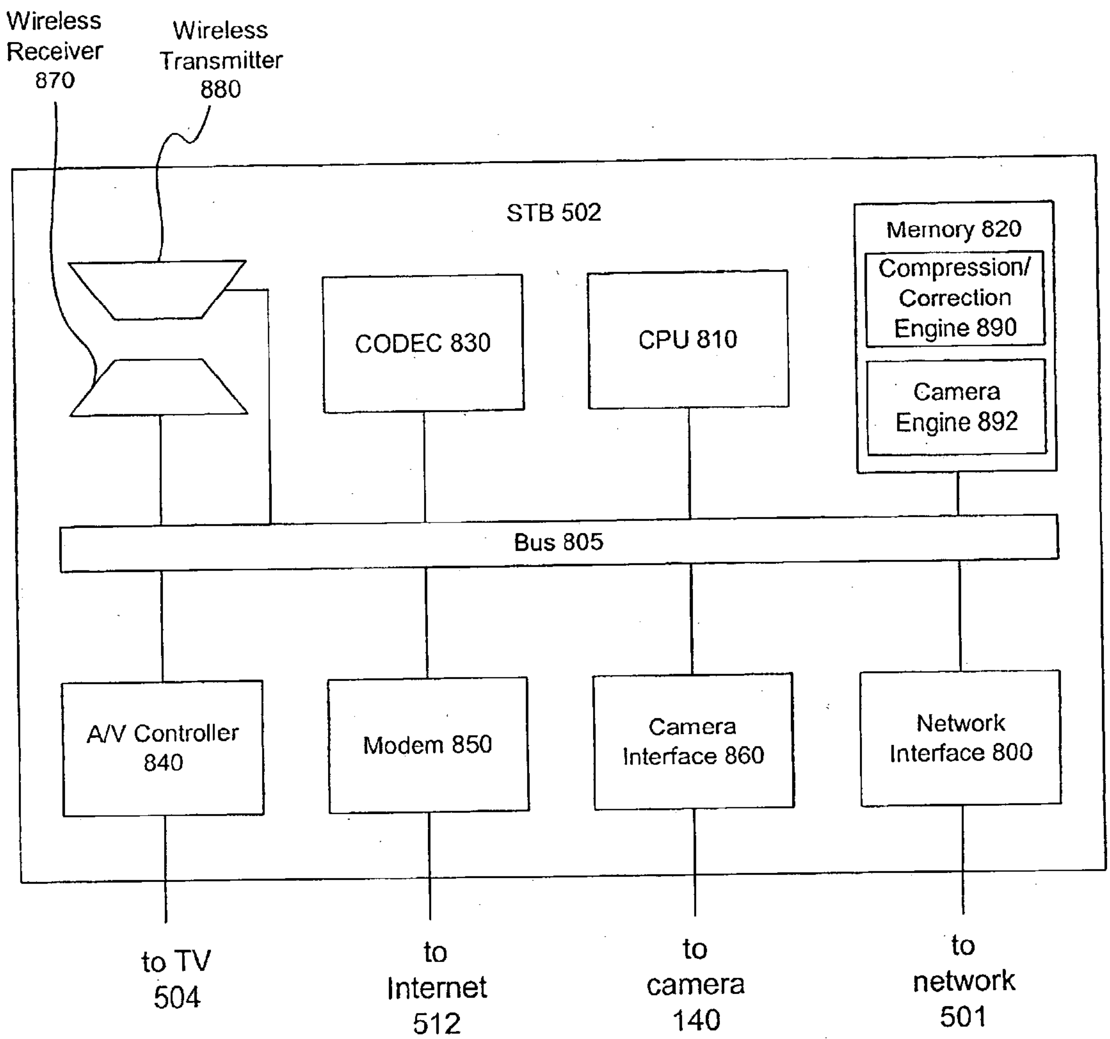

Wireless Receiver 870
Wireless Transmitter 880
STB 502
CODEC 830
CPU 810
Memory 820
Compression/ Correction Engine 890
Camera Engine 892
Bus 805
A/V Controller 840
Modem 850
Camera Interface 860
Network Interface 800
to TV 504
to Internet 512
to camera 140
to network 501

FIG. 8

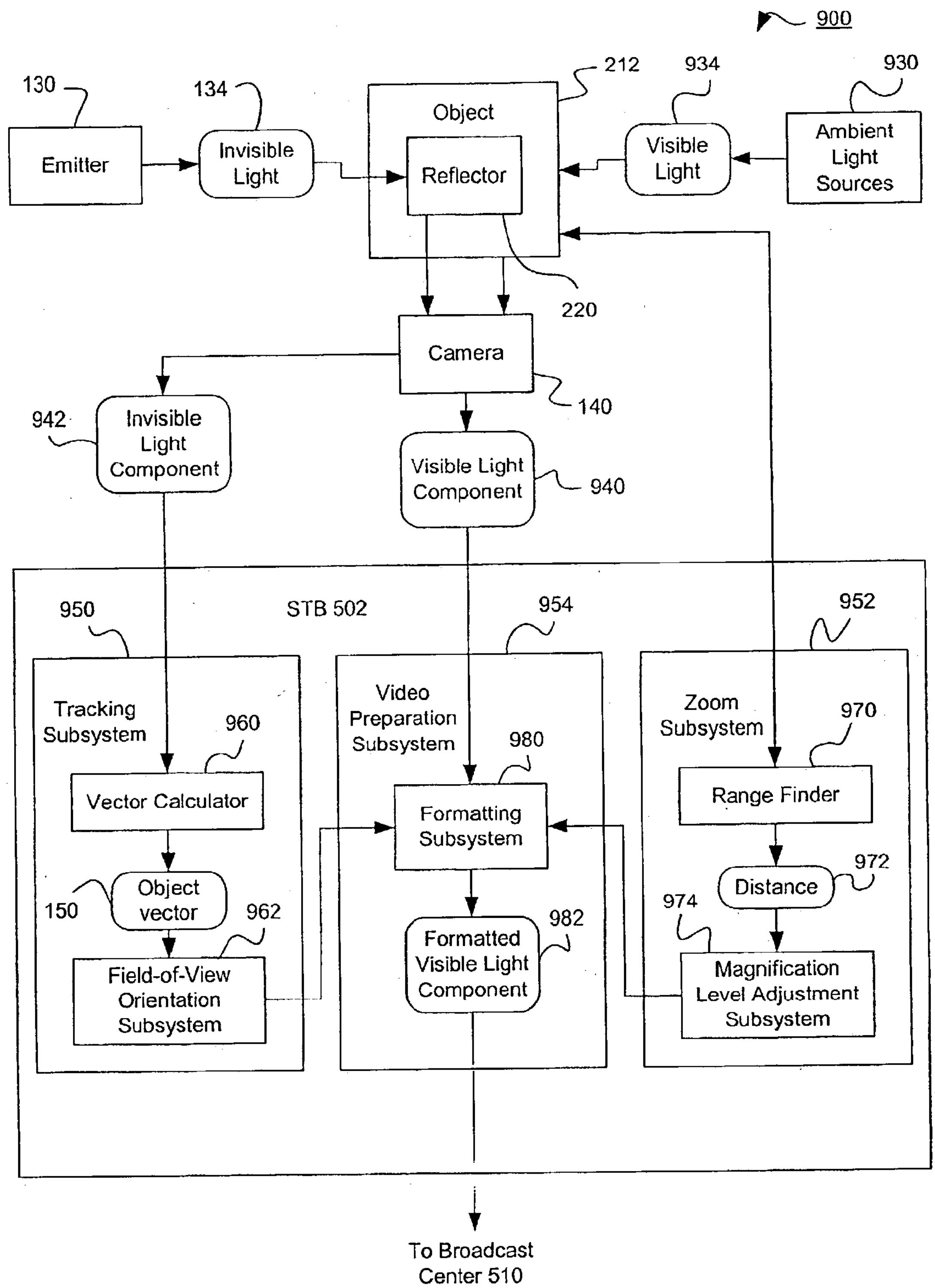

900
130
Emitter
134
Invisible Light
212
Object
Reflector
934
Visible Light
930
Ambient Light Sources
220
Camera
140
942
Invisible Light Component
Visible Light Component
940
STB 502
950
Tracking Subsystem
960
Vector Calculator
150
Object vector
962
Field-of-View Orientation Subsystem
954
Video Preparation Subsystem
980
Formatting Subsystem
982
Formatted Visible Light Component
952
Zoom Subsystem
970
Range Finder
972
Distance
974
Magnification Level Adjustment Subsystem
To Broadcast Center 510

FIG. 9

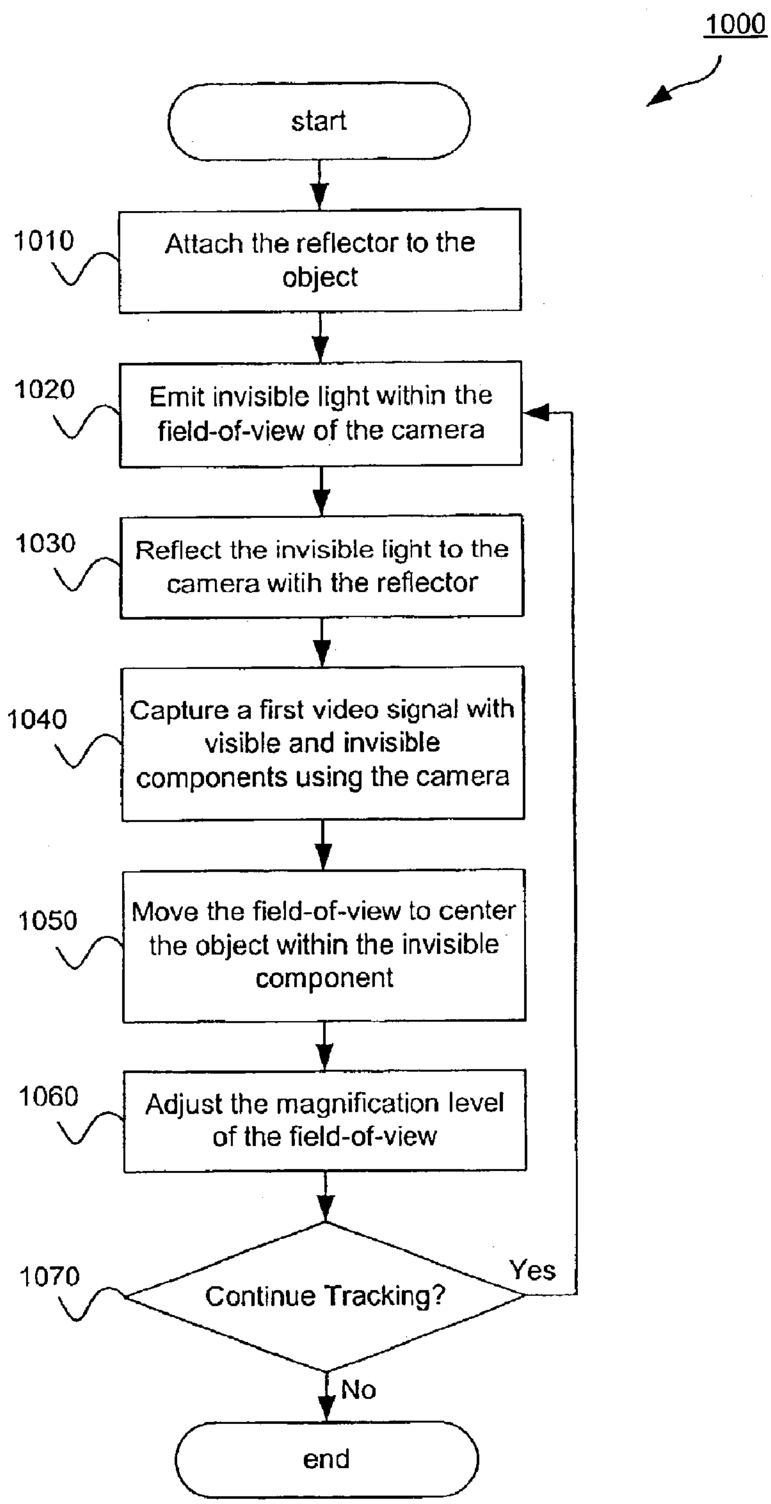

1000
start
1010
Attach the reflector to the object
1020
Emit invisible light within the field-of-view of the camera
1030
Reflect the invisible light to the camera witih the reflector
1040
Capture a first video signal with visible and invisible components using the camera
1050
Move the field-of-view to center the object within the invisible component
1060
Adjust the magnification level of the field-of-view
1070
Continue Tracking?
Yes
No
end

FIG. 10

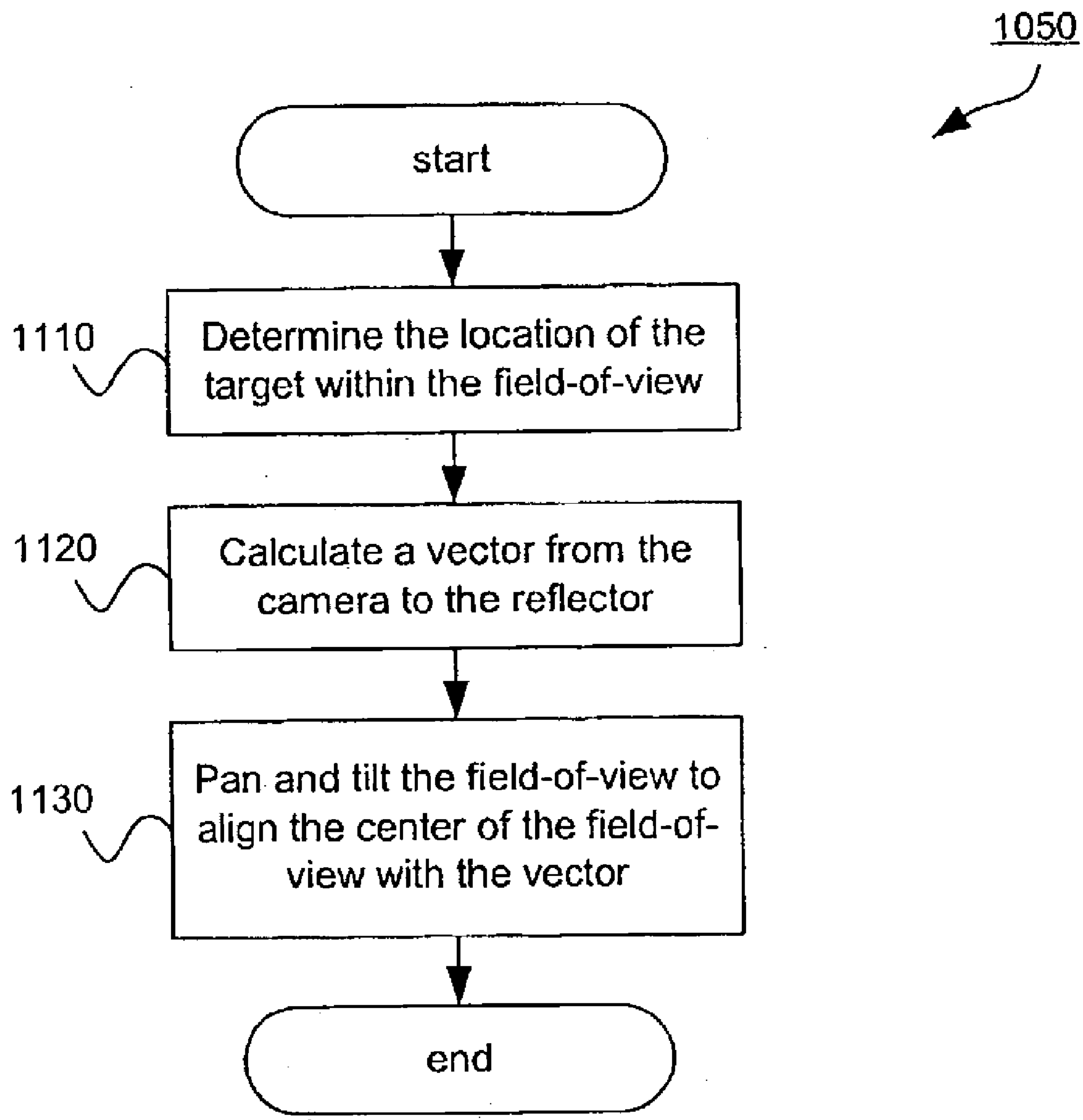

1050
start
1110
Determine the location of the target within the field-of-view
1120
Calculate a vector from the camera to the reflector
1130
Pan and tilt the field-of-view to align the center of the field-of-view with the vector
end

FIG. 11

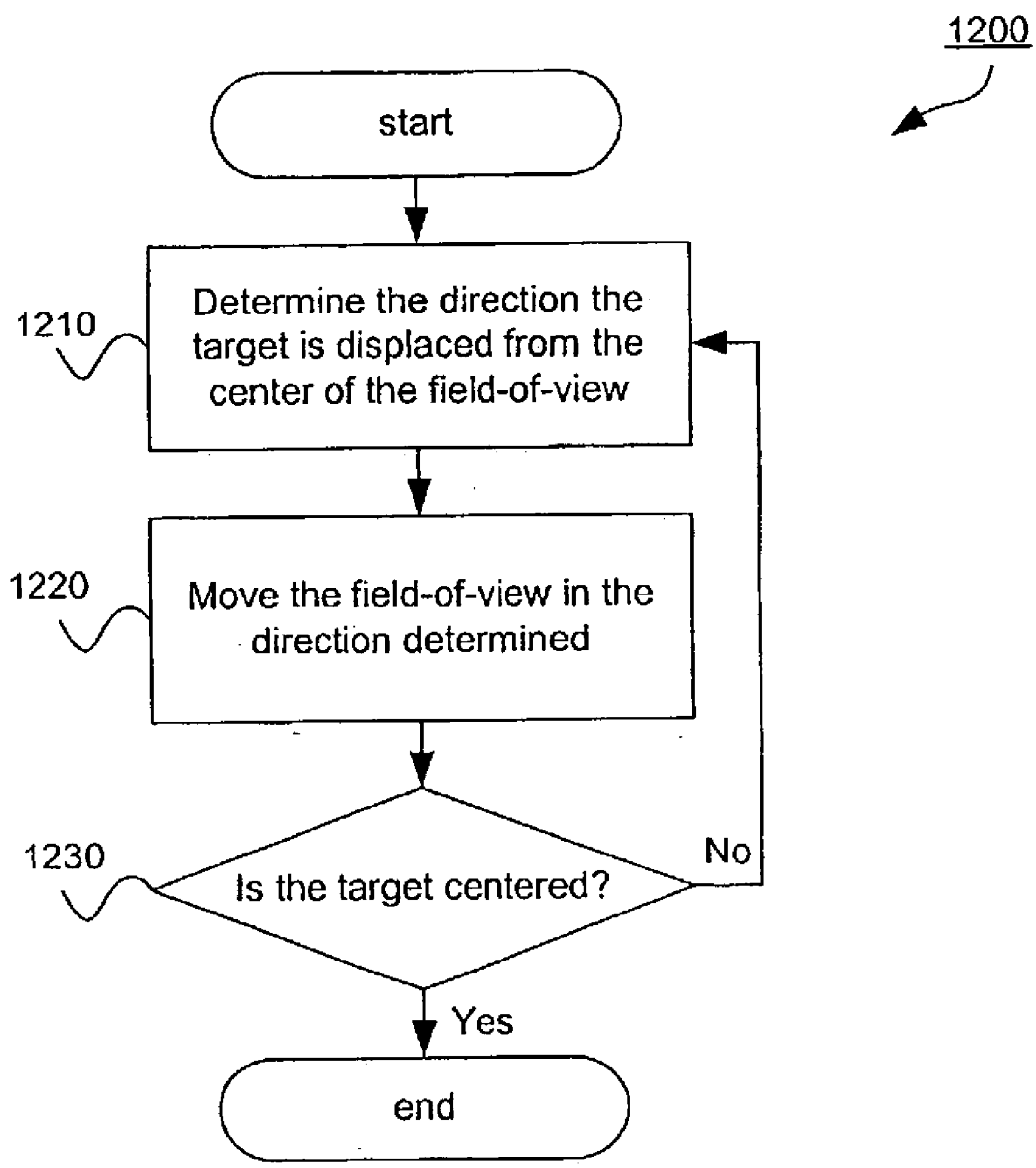

1200
start
1210
Determine the direction the target is displaced from the center of the field-of-view
1220
Move the field-of-view in the direction determined
1230
Is the target centered?
No
Yes
end

FIG. 12

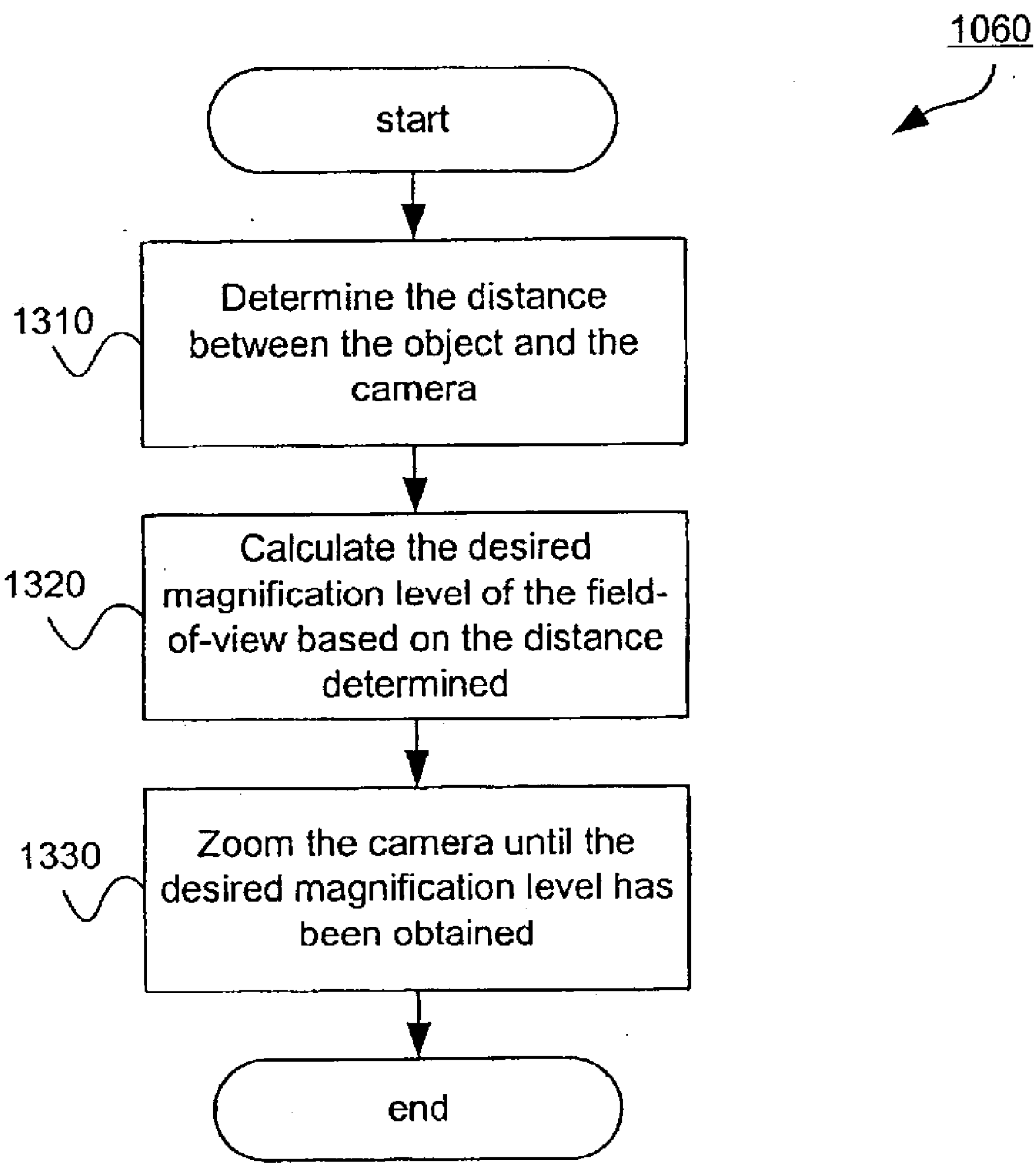

1060
start
1310
Determine the distance between the object and the camera
1320
Calculate the desired magnification level of the field-of-view based on the distance determined
1330
Zoom the camera until the desired magnification level has been obtained
end

FIG. 13

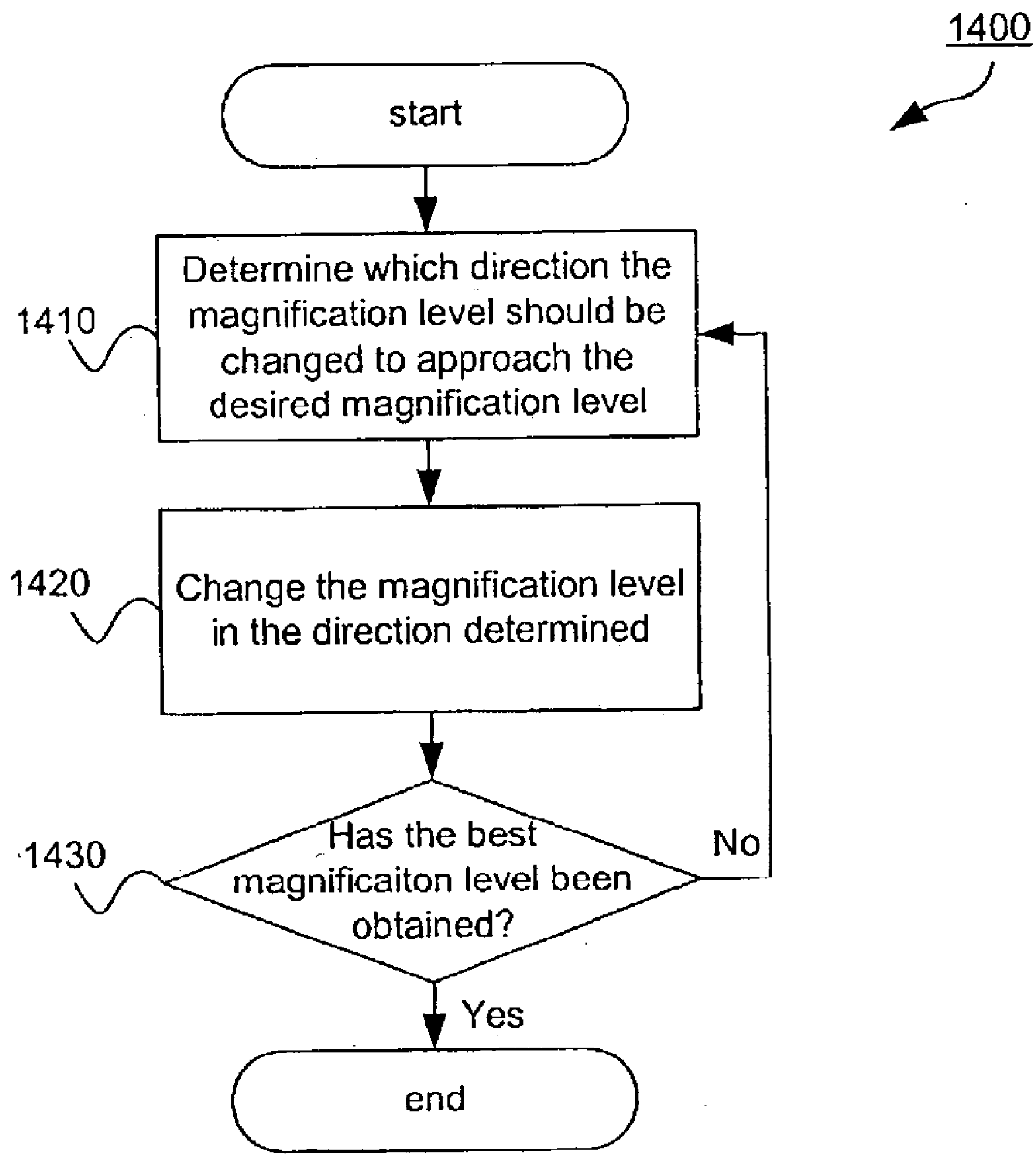

1400
start
Determine which direction the magnification level should be changed to approach the desired magnification level
1410
Change the magnification level in the direction determined
1420
Has the best magnificaiton level been obtained?
1430
No
Yes
end

FIG. 14

SYSTEM AND METHOD FOR TRACKING AN OBJECT DURING VIDEO COMMUNICATION

BACKGROUND

[0001] 1. Field of the Invention

[0002] The present invention relates generally to the field of video communication. More specifically, the present invention relates to a system and method for automatically tracking an object with a camera during video communication.

[0003] 2. Description of Related Background Art

[0004] Videoconferencing is rapidly becoming the communication method-of-choice for remote parties who wish to approximate face-to-face contact without the time and expense of travel. As bandwidth limitations cease to become a concern, a greater number of traditionally face-to-face events, such as business meetings, family discussions, and shopping, may be expected to take place through videoconferencing.

[0005] Unfortunately, videoconferencing has been limited in the past by a number of factors. One of the most appealing aspects of face-to-face communication is that people are able to see each other's facial gestures and expressions. Such expressions lend an additional dimension to a conversation; this dimension cannot be conveyed through a solely auditory medium. Hence, videoconferencing is typically carried out with the camera zoomed in to focus on the subject's head.

[0006] Such a focused view may be acceptable if neither person needs to move their head more than a few inches during the conversation. However, for lengthy conversations, it can be quite tiring to hold one's head in the same position continuously. Additionally, while a person can move about and perform tasks with their hands while talking on a telephone, such movement is severely restricted by the focused camera angles used in teleconferencing. Hence, it is difficult for a person to teleconference while performing other tasks. Additionally, conversation may be somewhat unnatural due to the necessity of maintaining the head and face in a single position.

[0007] Accordingly, what is needed is a system and method for tracking an object, such as a person, with a camera. Such a system should be usable for videoconferencing applications, and should not inhibit free motion of the person or object. Additionally, such a system and method should be operable with comparatively simple equipment and procedures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Non-exhaustive embodiments of the invention are described with reference to the figures, in which:

[0009] **FIG. 1** is an illustration of one embodiment of a tracking system according to the invention;

[0010] **FIG. 2** is an illustration of a pre-tracking frame from the camera of **FIG. 1**;

[0011] **FIG. 3** is an illustration of a centered frame from the camera of **FIG. 1**;

[0012] **FIG. 4** is an illustration of a centered and zoomed frame from the camera of **FIG. 1**;

[0013] **FIG. 5** is a schematic block diagram of one embodiment of a videoconferencing system in which the tracking system of **FIG. 1** may be employed;

[0014] **FIG. 6** is a schematic block diagram of the camera of **FIG. 1**;

[0015] **FIG. 7** is a schematic block diagram of another embodiment of a camera suitable for tracking,

[0016] **FIG. 8** is a schematic block diagram of one embodiment of a set top box usable in connection with the videoconferencing system of **FIG. 5**;

[0017] **FIG. 9** is a logical block diagram depicting the operation of the tracking system of **FIG. 1**;

[0018] **FIG. 10** is a flowchart of one embodiment of a tracking method according to the invention;

[0019] **FIG. 11** is a flowchart depicting one embodiment of a centering method suitable for the tracking method of **FIG. 10**;

[0020] **FIG. 12** is a flowchart depicting another embodiment of a centering method suitable for the tracking method of **FIG. 10**;

[0021] **FIG. 13** is a flowchart depicting one embodiment of a zooming method suitable for the tracking method of **FIG. 10**; and

[0022] **FIG. 14** is a flowchart depicting another embodiment of a zooming method suitable for the tracking method of **FIG. 10**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] The present invention solves the foregoing problems and disadvantages by providing a system and method for tracking objects with a camera during video communication. Of course, the described system and method are usable in a wide variety of other contexts, including security, manufacturing, law enforcement, and the like.

[0024] In one implementation, a reflector that reflects a form of invisible light, such as infrared light, is attached to an object to be tracked. Where the object is a person, such a reflector may be attached (by an adhesive or the like) to an article worn by the person, such a pair of glasses, a shirt collar, a tie clip, etc. The reflector may also be applied directly to the skin of the person. An invisible light emitter, such as an infrared illuminator, projects invisible light in the direction of the reflector. The invisible light is then reflected back to a camera that detects both visible and invisible light.

[0025] The camera provides a video signal with visible and invisible components. The invisible component is utilized by a tracking subsystem to center the field-of-view of the camera on the reflector. Centering may be accomplished with a mechanical camera by physically panning and tilting the camera until the reflector is in the center of the field-of-view. The camera may alternatively be a software steerable type, in which case centering is accomplished by cropping the camera image such that the reflector is in the center of the remaining portion.

[0026] The tracking component may mathematically determine the location of the reflector and then align the center of the field-of-view with the reflector. Alternatively, the tracking component may simply move the center of the field-of-view toward the reflector in stepwise fashion until alignment has been achieved.

[0027] A zooming subsystem may utilize the invisible and/or the visible component to "zoom," or magnify, the field-of-view to reach a desired magnification level. As with tracking, such zooming may be accomplished mechanically or through software, using mathematical calculation and alignment or stepwise adjustment.

[0028] As an alternative embodiment, a portable emitter may be used in place of the reflector/emitter combination. Like the reflector, the portable emitter may be attached to the object to be tracked. The emitter may be powered by an integrated power source, such as a battery. Tracking and zooming may then be accomplished as described above.

[0029] As another alternative embodiment, the camera may simply receive the infrared signature of a human body, and may utilize the same to provide the invisible component of the video signal. Centering and zooming may then be accomplished with reference to the infrared signature, in much the same manner as described above. Additional steps may be performed to isolate the head and identify the person, if desired.

[0030] Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment.

[0031] Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the following description, numerous specific details are provided, such as examples of programming, user selections, network transactions, database queries, database structures, etc., to provide a thorough understanding of embodiments of the invention. One skilled in the relevant art will recognize, however, that the invention can be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the invention.

[0032] The following discussion makes particular reference to two-way video communication. However, those skilled in the art recognize that video communication typically includes two-way audio communication. Thus, where video communication and corresponding components are specifically illustrated, audio communication and corresponding components may be implied.

[0033] Referring to **FIG. 1**, one embodiment of a tracking system **100** according to the invention is shown. The object **110** may be inanimate, or may be a person, animal, or the like. The object **110** may have an invisible light reflector **120**, or reflector **120**, disposed on the object **110**. As used herein, "invisible light" refers to electromagnetic energy with any frequency imperceptible to the human eye. Infrared light may advantageously be used due to the ease with which it can be generated and reflected; however, a wide variety of other electromagnetic spectra may also be utilized according to the invention, such as ultraviolet.

[0034] The reflector **120** may consist, for example, of a solid body with a reflective side coated with or formed of a substance that reflects invisible light. Such a surface may be covered by glass or plastic that protects the surface and/or serves as a barrier to the transmission of electromagnetic energy of undesired frequencies, such as those of the visible spectrum. The reflector **120** may have an adhesive surface facing opposite the reflective surface; the adhesive surface may be used to attach the reflector **120** to the object **110**. Of course, the reflector **120** could also be attached to the object **110** using any other attachment method.

[0035] An invisible light emitter **130**, or emitter **130**, may be used to emit invisible light toward the object **110**. The emitter **130** may be embodied, for example, as an infrared emitter, well known to those skilled in the art. As another example, the emitter **130** may take the form of a ultraviolet (UV) emitter.

[0036] The invisible light emitter **130** may receive electrical power through a power cord **132** or battery (not shown), and may project invisible light **134** over a broad angle so that the object **110** can move through a comparatively large space without the reflector **120** passing beyond the illuminated space.

[0037] Conventional light sources, including natural and artificial lighting, are also present and project visible light that is reflected by the object **110**. Such light sources are not illustrated in **FIG. 1** to avoid obscuring aspects of the invention.

[0038] A portion **136** of the invisible light **134** may be reflected by the reflector **120** to reach a camera **140**. In one embodiment, the camera **140** is sensitive to both visible light and invisible light of the frequency reflected by the reflector **120**. The camera **140** may have a housing **142** that contains and protects the internal components of the camera **140**, a lens **144** through which the portion **136** of the invisible light **134** is able to enter the housing **142**, a base **146** that supports the housing **142**, and an output cord **148** through which a video signal is provided by the camera **140**. Of course, the camera **140** may be configured in other ways without departing from the spirit of the invention. For instance, the camera **140** may lack a separate housing and may be integrated with another device, such as a set top box (STB) for an interactive television system.

[0039] The video signal produced by the camera **140** may simply include a static image, or may include real-time video motion suitable for videoconferencing. The video signal may also include audio information, and may have a visible component derived from visible light received by the camera **140** as well as an invisible component derived from the portion **136** of the invisible light **134**.

[0040] The object **110** may have a vector **150** with respect to the camera **140**. The vector **150** is depicted as arrow pointing from the camera **140** to the object **110**, with a length equal to the distance between the object **110** and the camera **140**. A center vector **152** points directly outward from the camera **140**, into the center of a field-of-view **160** of the camera **140**.

[0041] The field-of-view **160** of the camera **140** is simply the volume of space that is "visible" to the camera **140**, or the volume that will be visible in an output image from the camera **140**. The field-of-view **160** may be generally conical or pyramidal in shape. Thus, boundaries of the field-of-view **160** are indicated by dashed lines **162** that form a generally triangular cross section. The field-of-view **160** may be variable in size if the camera **140** has a "zoom," or magnification feature.

[**0042**] As described in greater detail below, the present invention provides a system and method by which the center vector **152** can be automatically aligned with the object vector **150**. Such alignment may take place in real time, such that the field-of-view. **160** of the camera **140** follows the object **110** as the object **110** moves. Optionally, the camera **140** may automatically zoom, or magnify, the object **110** within the field-of-view **160**. The operation of these processes, and their effect on the visible output of the camera **140**, will be shown and described in greater detail in connection with **FIGS. 2 through 4**.

[**0043**] Referring to **FIG. 2**, an exemplary pre-tracking view **200** of visible output, i.e., a display of the visible component of the video signal, is shown. Since the pre-tracking view **200** is taken from the point of view of the camera **140**, a rectangular cross-sectional view of the field-of-view **160** is shown. The field-of-view **160** is thus assumed to be rectangular-pyramidal in shape; if the field-of-view **160** were conical, the view depicted in **FIG. 2** would be circular.

[**0044**] In **FIG. 2, a** person **210** takes the place of the generalized object **110** of **FIG. 1**. The camera **140** may be configured to track the person **210**, or if desired, a head **212** of the person, while the person **210** moves. The camera **140** may also be used to track an inanimate object such as a folder **214**. Reflectors **220** may be attached to the person **210** and/or the folder **214** in order to facilitate tracking.

[**0045**] In the case of the person **210**, the reflectors **220** may be affixed to an article worn by the person **210**, such as a pair of glasses, a piece of jewelry, a tie clip, or the like. Like the reflector **110** of **FIG. 1**, the reflector **210** may have a reflective side and a non-reflective side that can be attached through the use of a clip, clamp, adhesive, magnet, pin, or the like. A reflector **220** may then be affixed to an object such as a pair of glasses **222** or, in the alternative, directly to the person **210**. A reflector **220** may be easily affixed to the folder **214** in much the same fashion.

[**0046**] Indeed, if desired, an invisible light reflector need not be a solid object, but may be a paint, makeup, or other coating applicable directly to an object or to the skin of the person **210**. Such a coating need simply be formulated to reflect the proper frequency of invisible light. The coating may even be substantially transparent to visible light.

[**0047**] The person **210**, or the head **212** of the person **210**, may have a desired view **232**, or an optimal alignment and magnification level for video communications. Similarly, the folder **214** may have a desired view **234**. The reflectors **220** may be positioned at the respective centers of the desired views **232, 234**, so that the field-of-view **160** may be aligned with such a desired view.

[**0048**] Each of the reflectors **220** provides a "target," or a bright spot within the invisible component of the video signal from the camera **140**. Thus, each reflector **220** enables the camera **140** to determine the direction in which the associated object vector **150** points. Once the object vector **150** is determined, the tracking system **100** may proceed to align the object vector **150** with the center vector **152**.

[**0049**] More specifically, a center **240** of the field-of-view **160** is an end view of the center vector **152** depicted in **FIG. 1**. In the view of **FIG. 2**, the reflector **220** disposed on the person **210** is an end view of the object vector **150**. Thus, "tracking," refers to motion of the field-of-view **160** until the center **240** is superimposed on the reflector **220**. Consequently, the center **240** is to be moved along a displacement **242** between the center **240** and the reflector **220**.

[**0050**] Such movement may be broken down into two separate dimensions: a pan displacement **244** and a tilt displacement **246**. The pan displacement **244** represents the amount "panning," or horizontal camera rotation, that would be required to align the center **240** with the reflector **220**. The tilt displacement **246** represents the amount of "tilting," or vertical camera rotation, that would be required to align the center **240** with the reflector **220**.

[**0051**] Panning and tilting may be carried out by physically moving the camera **140**. More specifically, physical motion of the camera **140** may be carried out through the use of a camera alignment subsystem (not shown) that employs mechanical devices, such as rotary stepper motors. Two such motors may be used: one that pans the camera **140**, and one that tilts the camera **140**.

[**0052**] In the alternative, panning and tilting may be carried out by leaving the camera **140** stationary and modifying the video signal. For example, panning and tilting may be performed in conjunction with zooming by cropping the video signal. The video signal is obtained by capturing a second field-of-view (not shown) that covers a comparatively broad area. For example, a wide-angle, or "fish-eye" lens could be used for the lens **144** of the camera **140** to provide a wide second field-of-view. The first field-of-view **160** is then obtained by cropping the second field-of-view and correcting any distortion caused by the wide angle of the lens **144**.

[**0053**] Panning and tilting without moving the camera **140** may be referred to as "software steerable" panning and tilting, although the subsystems that carry out the tracking may exist in software, hardware, firmware, or any combination thereof. Software steerable panning and tilting will be described in greater detail subsequently.

[**0054**] Referring to **FIG. 3, a** centered view **300** of visible output from the camera **140** is shown. The field-of-view **160** has been panned and tilted through mechanical or software steerable processing such that the center **240** is aligned with the reflector **220** on the person **210**; consequently, tracking has been performed. The center **240** is not shown in **FIG. 3** for clarity. The desired view **232** of the head **212** of the person **210** is now centered within the field-of-view **160**. However, the field-of-view **160** has not been resized to match the desired view **232**; hence, no zooming has occurred. "Centering," as used herein, may not require precise positioning of the head within the center **240** of the field-of-view **160**. In the view of **FIG. 3**, the head **212** is positioned slightly leftward of the center **240** of the field-of-view **160**. This is due to the fact that the person **210** is not looking directly at the camera **140**; hence, the reflector **220** is disposed toward the right side of the head **212**, from the perspective of the camera **140**. Consequently, the reflector **220** is disposed at the center **240** of the field-of-view **160**, but the head **212** is slightly offset. Such offsetting is unlikely to seriously impede videoconferencing unless the field-of-view **160** is excessively narrow.

[**0055**] Referring to **FIG. 4, a** zoomed and centered view **400** of visible output from the camera **140** is shown. The reflector **220** is still centered within the field-of-view **160**, and the field-of-view **160** has been collapsed to match the desired view **232**, in which the head **212** appears large enough to read facial expressions during verbal communication with the person **210** Consequently, both tracking (centering) and zooming have been performed.

[**0056**] As with tracking, zooming may be performed mechanically, or "optically." Optical zooming typically entails moving the lens or lenses of the camera to change the size of the field-of-view **160**. Additionally, lenses may be mechanically added, removed, or replaced to provide additional zooming capability.

[**0057**] In the alternative, zooming may also be performed through software. For example, an image may be cropped and scaled to effectively zoom in on the remaining portion. Such zooming may be referred to as software, or "digital" zooming.

[**0058**] The tracking and zooming functions have been illustrated as separate steps for clarity; however, tracking need not be carried out prior to zooming. Indeed, tracking and zooming may occur simultaneously in real-time as the person **210** moves within the field-of-view **160**. The head **212** of the person **210** may thus be maintained continuously centered at the proper magnification level during video communication. A similar process may be carried out with the folder **214**, or with any other object with a reflector **220** attached. The following discussion assumes that the head **212** of the person **210** is the object to be tracked.

[**0059**] The tracking system **100**, or multiple such tracking systems, may be used in a wide variety of applications. As mentioned previously, videoconferencing is one application in which such tracking systems may find particular application.

[**0060**] Referring to **FIG. 5**, one embodiment of a videoconferencing system **500** that may incorporate one or more tracking systems **100** is shown. In one implementation, the videoconferencing system **500** relies on a communication subsystem **501**, or network **501**, for communication. The network **501** may take the form of a cable network, direct satellite broadcast (DBS) network, or other communications network.

[**0061**] The videoconferencing system **500** may include a plurality of set top boxes (STBs) **502** located, for instance, at customer homes or offices. Generally, an STB **502** is a consumer electronics device that serves as a gateway between a customer's television **504** and the network **501**. In alternative embodiments, an STB **502** may be embodied more generally as a personal computer (PC), an advanced television **504** with STB functionality, or other customer premises equipment (CPE).

[**0062**] An STB **502** receives encoded television signals and other information from the network **501** and decodes the same for display on the television **504** or other display device, such as a computer monitor, flat panel display, or the like. As its name implies, an STB **502** is typically located on top of, or in close proximity to, the television **504**.

[**0063**] Each STB **502** may be distinguished from other network components by a unique identifier, number, code, or address, examples of which include an Internet Protocol (IP) address (e.g., an IPv6 address), a Media Access Control (MAC) address, or the like. Thus, video streams and other information may be transmitted from the network **501** to a specific STB **502** by specifying the corresponding address, after which the network **501** routes the transmission to its destination using conventional techniques.

[**0064**] A remote control **506** is provided, in one configuration, for convenient remote operation of the STB **502** and the television **504**. The remote control **506** may use infrared (IR), radio frequency (RF), or other wireless technologies to transmit control signals to the STB **502** and the television **504**. Other remote control devices are also contemplated, such as a wired or wireless mouse or keyboard (not shown).

[**0065**] For purposes of the following description, one STB **502**, TV **504**, remote control **506**, camera **140**, and emitter **130** combination is designated a local terminal **508**, and another such combination is designated a remote terminal **509**. Each of the terminals **508**, **509** is designed to provide videoconferencing capability, i.e., video signal capture, transmission, reception, and display.

[**0066**] The components of the terminals **508**, **509** may be as shown, or may be different, as will be appreciated by those of skill in the art. For example, the TVs **504** may be replaced by computer monitors, webpads, PDA's, computer screens, or the like. The remote controls **506** may enhance the convenience of the terminals **508**, **509**, but are not necessary for their operation. As mentioned previously, the STB **502** maybe configured in a variety of different ways. The camera **140** and the emitter **130** may also be reconfigured or omitted, as will be described subsequently.

[**0067**] Each STB **502** may be coupled to the network **501** via a broadcast center **510**. In the context of a cable network, a broadcast center **510** may be embodied as a "head-end", which is generally a centrally-located facility within a community where television programming is received from a local cable TV satellite downlink or other source and packaged together for transmission to customer homes. In one configuration, a head-end also functions as a Central Office (CO) in the telecommunication industry, routing video streams and other data to and from the various STBs **502** serviced thereby.

[**0068**] A broadcast center **510** may also be embodied as a satellite broadcast center within a direct broadcast satellite (DBS) system. A DBS system may utilize a small 18-inch satellite dish, which is an antenna for receiving a satellite broadcast signal. Each STB **502** may be integrated with a digital integrated receiver/decoder (IRD), which separates each channel, and decompresses and translates the digital signal from the satellite dish to be displayed by the television **504**.

[**0069**] Programming for a DBS system may be distributed, for example, by multiple high-power satellites in geosynchronous orbit, each with multiple transponders. Compression (e.g., MPEG) may be used to increase the amount of programming that can be transmitted in the available bandwidth.

[0070] The broadcast centers **510** may be used to gather programming content, ensure its digital quality, and uplink the signal to the satellites. Programming may be received by the broadcast centers **510** from content providers (CNN®, ESPN®, HBO®, TBS®, etc.) via satellite, fiber optic cable and/or special digital tape. Satellite-delivered programming is typically immediately digitized, encrypted and uplinked to the orbiting satellites. The satellites retransmit the signal back down to every earth-station, e.g., every compatible DBS system receiver dish at customers' homes and businesses.

[0071] Some broadcast programs may be recorded on digital videotape in the broadcast center **510** to be broadcast later. Before any recorded programs are viewed by customers, technicians may use post-production equipment to view and analyze each tape to ensure audio and video quality. Tapes may then be loaded into a robotic tape handling systems, and playback may be triggered by a computerized signal sent from a broadcast automation system. Back-up videotape playback equipment may ensure uninterrupted transmission at all times.

[0072] Regardless of the nature of the network **501**, the broadcast centers **510** may be coupled directly to one another or through the network **501**. In alternative embodiments, broadcast centers **510** may be connected via a separate network, one particular example of which is the Internet **512**. The Internet **512** is a "network of networks" and is well known to those skilled in the art. Communication over the Internet **512** is accomplished using standard protocols, such as TCP/IP (Transmission Control Protocol/Internet Protocol) and the like. If desired, each of the STBs **502** may also be connected directly to the Internet **512** by a dial-up connection, broadband connection, or the like.

[0073] A broadcast center **510** may receive television programming for distribution to the STBs **502** from one or more television programming sources **514** coupled to the network **501**. Preferably, television programs are distributed in an encoded format, such as MPEG (Moving Picture Experts Group). Various MPEG standards are known, such as MPEG-2, MPEG-4, MPEG-7, and the like. Thus, the term "MPEG," as used herein, contemplates all MPEG standards. Moreover, other video encoding/compression standards exist other than MPEG, such as JPEG, JPEG-LS, H.261, and H.263. Accordingly, the invention should not be construed as being limited only to MPEG.

[0074] Broadcast centers **510** may be used to enable audio and video communications between STBs **502**. Transmission between broadcast centers **510** may occur (i) via a direct peer-to-peer connection between broadcast centers **510**, (ii) upstream from a first broadcast center **510** to the network **501** and then downstream to a second broadcast center **510**, or (iii) via the Internet **512**. For instance, a first STB **502** may send a video transmission upstream to a first broadcast center **510**, then to a second broadcast center **510**, and finally downstream to a second STB **502**.

[0075] Each of a number of the STBs **502** may have a camera **140** connected to the STB **502** and an emitter **130** positioned in close proximity to the camera **140** to permit videoconferencing between users of the network **501**. More specifically, each camera **140** may be used to provide a video signal of a user. Each video signal may be transmitted over the network **501** and displayed on the TV **504** of a different user. Thus, one-way or multiple-way communication may be carried out over the videoconferencing system **500**, using the network **501**. Of course, the videoconferencing system **500** illustrated in **FIG. 5** is merely exemplary, and other types of devices and networks may be used within the scope of the invention.

[0076] Referring to **FIG. 6, a** block diagram shows one embodiment of a camera **140** according to the invention. The camera **140** may receive both visible and invisible light through the lens **144**, and may process both types of light with a single set of hardware to provide the video signal. In addition to the lens **144**, the camera **140** may include a shutter **646**, a filter **648**, an image collection array **650**, a sample stage **652**, and an analog-to-digital converter (ADC) **654**.

[0077] As mentioned previously, if software steerable panning and tilting are to be utilized, the lens **144** may be a wide angle lens that has an angular field of, for example, 140 degrees. Using a wide angle lens allows the camera **140** to capture a larger image area than a conventional camera. The shutter **646** may open and close at a predetermined rate to allow the visible and invisible light into the interior of the camera **140** and onto the filter **648**.

[0078] The filter **648** may allow the image collection array **650** to accurately capture different colors. The filter **648** may include a static filter such as a Bayer filter, or may utilize a dynamic filter such as a spinning disk filter. Alternatively, the filter **648** may be replaced with a beam splitter or other color differentiation device. As yet another alternative, the camera **140** may be made to operate without any filter or other color differentiation device.

[0079] The image collection array **650** may included charge coupled device (CCD) sensors, complementary metal oxide semiconductor (CMOS) sensors, or other sensors that convert electromagnetic energy into readable image signals. If software steerable panning and tilting are to be used, the size of the image collection array **650** may be comparatively large such as, for example, 1024×768, 1200×768, or 2000×1000. Such a large size permits the image collection array **650** to capture a large image to form the video signal from the comparatively large second field-of-view. The large image can then be cropped and/or distortion-corrected to provide the properly oriented first field-of-view **160** without producing an overly grainy or diminutive image.

[0080] The sample stage **652** may read the image data from the image collection array **650** when the shutter **646** is closed. The ADC **654** may then convert the image data from analog to digital form to provide the video signal ultimately output by the camera **140**. The video signal may then be transmitted to the STB **502**, for example, via the output cord **148** depicted in **FIG. 1** for processing and/or transmission. In the alternative, the video signal may be processed entirely by components of the camera **140** and transmitted from the camera **140** directly to the network **501**, the Internet **512**, or other digital communication devices.

[0081] Those of skill in the art will recognize that a number of known components may also be used in conjunction with the camera **140**. For purposes of explaining the functionality of the invention, such known components that may be included in the camera **140** have been omitted from the description and drawings.

[0082] Referring to **FIG. 7**, another embodiment of a camera **740** according to the invention is depicted. Rather than processing visible and invisible light simultaneously with a single set of hardware, the camera **740** may have a visible light assembly **741** that processes visible light and an invisible light assembly **742** that processes invisible light. The camera **740** may also have a range finding assembly **743** that determines the length of the object vector **150**, which is the distance between the camera **140** and the person **210**.

[0083] The visible light assembly **741** may have a lens **744**, a shutter **746**, a filter **748**, an image collection array **750**, a sample stage **752**, and an analog-to-digital converter (ADC) **754**. The various components of the visible light assembly **741** maybe configured in a manner similar to the camera **140** of **FIG. 6**, except that the visible light assembly **741** need not process invisible light. If desired, the lens **744** may be made to block out a comparatively wide range of invisible light. Similarly, the image collection array **750** may record only visible light.

[0084] By the same token, the invisible light assembly **742** may have a lens **764**, a shutter **766**, a filter **768**, an image collection array **770**, a sample stage **772**, and an analog-to-digital converter (ADC) **774** similar to those of the visible light assembly **741**, but configured to receive invisible rather than visible light. Consequently, if desired, the lens **764** may be tinted, coated, or otherwise configured to block out all but the frequencies of light reflected by the reflector **220**. Similarly, the image collection array **770** may record only the frequencies of light reflected by the reflector.

[0085] Ultimately, the visible light assembly **741** may produce the visible component of the video signal, and the invisible light assembly **742** may produce the invisible component of the video signal. The visible and invisible components may then be delivered separately to the STB **502**, as shown in **FIG. 7**, or merged within the camera **140** prior to delivery to the STB **502**. The visible and invisible light assemblies **741**, **742** need not be entirely separate as shown, but may utilize some common elements. For example, a single lens may be used to receive both visible and invisible light, while separate image collection arrays are used for visible and invisible light. Alternatively, a single image collection array may be used, but may be coupled to separate sample stages. Many similar variations may be made. As used herein, the term "camera" may refer to either the camera **140**, the camera **740**, or different variations thereof.

[0086] The range finding assembly **743** may have a trigger/timer **780** designed to initiate range finding and relay the results of range finding to the STB **502**. The trigger/timer **780** may be coupled to a transmitter **782** and a receiver **784**. When triggered by the trigger/timer **780**, the transmitter **782** sends an outgoing pulse **792**, such as an infrared or sonic pulse, toward the head **212** of the person **210**. The outgoing pulse **792** bounces off the head **212** and returns in the form of an incoming pulse **794** that can be received by the receiver **784**.

[0087] The trigger/timer **780** may measure the time differential between transmission of the outgoing pulse **792** and receipt of the incoming pulse **794**; the distance between the head **212** and the camera **740** is proportional to the time differential. The raw time differential or a calculated distance measurement may be transmitted by the trigger/timer **780** to the STB **502**. Determining the distance between the head **212** and the camera **740** may be helpful in zooming the first field-of-view **160** to the proper magnification level to obtain the desired view **232**.

[0088] Numerous other camera embodiments may be used according to the invention. Indeed, a more traditional analog camera may be used to read visible and invisible light. Such an analog camera may provide an analog video signal that can be subsequently digitized, or may include analog-to-digital conversion circuitry like the ADC **754** and the ADC **774**. For the sake of brevity, the following discussion assumes the use of the camera **140**.

[0089] If desired, the video signal may be processed outside the camera **140**. If software steerable panning and tilting is utilized, such processing may include cropping and distortion correction of the video signal. If the camera **140** is used as part of a videoconferencing system like the videoconferencing system **500**, the STB **502** may be a logical place in which to carry out such processing.

[0090] Referring to **FIG. 8**, there is shown a block diagram of physical components of an STB **502** according to an embodiment of the invention. The STB **502** may include a network interface **800** through which television signals, video signals, and other data may be received from the network **501** via one of the broadcast centers **510**. The network interface **800** may include conventional tuning circuitry for receiving, demodulating, and demultiplexing MPEG-encoded television signals, e.g., digital cable or satellite TV signals. In certain embodiments, the network interface **800** may include analog tuning circuitry for tuning to analog television signals, e.g., analog cable TV signals.

[0091] The network interface **800** may also include conventional modem circuitry for sending or receiving data. For example, the network interface **800** may conform to the DOCSIS (Data Over Cable Service Interface Specification) or DAVIC (Digital Audio-Visual Council) cable modem standards. Of course, the network interface and tuning functions could be performed by separate components within the scope of the invention.

[0092] In one configuration, one or more. frequency bands (for example, from 5 to 30 MHz) may be reserved for upstream transmission. Digital modulation (for example, quadrature amplitude modulation or vestigial sideband modulation) may be used to send digital signals in the upstream transmission. Of course, upstream transmission may be accomplished differently for different networks **501**. Alternative ways to accomplish upstream transmission include using a back channel transmission, which is typically sent via an analog telephone line, ISDN, DSL, or other techniques.

[0093] A bus **805** may couple the network interface **800** to a processor **810**, or CPU **810**, as well as other components of the STB **502**. The CPU **810** controls the operation of the STB **502**, including the other components thereof. The CPU **810** may be embodied as a microprocessor, a microcontroller, a digital signal processor (DSP) or other device known in the art. For instance, the CPU **810** may be embodied as an Intel® x86 processor. The CPU **810** may perform logical and arithmetic operations based on program code stored within a memory **820**.

[0094] The memory **820** may take the form of random access memory (RAM), for storing temporary data and/or read-only memory (ROM) for storing more permanent data such as fixed code and configuration information. The memory **820** may also include a mass storage device such as a hard disk drive (HDD) designed for high volume, non-volatile data storage.

[0095] Such a mass storage device may be configured to store encoded television broadcasts and retrieve the same at a later time for display. In one embodiment, such a mass storage device may be used as a personal video recorder (PVR), enabling scheduled recording of television programs, pausing (buffering) live video, etc.

[0096] A mass storage device may also be used in various embodiments to store viewer preferences, parental lock settings, electronic program guide (EPG) data, passwords, e-mail messages, and the like. In one implementation, the memory **820** stores an operating system (OS) for the STB **502**, such as Windows CE® or Linux®; such operating systems may be stored within ROM or a mass storage device.

[0097] The STB **502** also preferably includes a codec (encoder/decoder) **830**, which serves to encode audio/video signals into a network-compatible data stream for transmission over the network **501**. The codec **830** also serves to decode a network-compatible data stream received from the network **501**. The codec **830** may be implemented in hardware, firmware, and/or software. Moreover, the codec **830** may use various algorithms, such as MPEG or Voice over IP (VoIP), for encoding and decoding.

[0098] In one embodiment, an audio/video (A/V) controller **840** is provided for converting digital audio/video signals into analog signals for playback/display on the television **504**. The A/V controller **840** may be implemented using one or more physical devices, such as separate graphics and sound controllers. The A/V controller **840** may include graphics hardware for performing bit-block transfers (bit-blits) and other graphical operations for displaying a graphical user interface (GUI) on the television **504**.

[0099] The STB **502** may also include a modem **850** by which the STB **502** is connected directly to the Internet **512**. The modem **850** may be a dial-up modem connected to a standard telephone line, or may be a broadband connection such as cable, DSL, ISDN, or a wireless Internet service. The modem **850** may be used to send and receive various types of information, conduct videoconferencing without the network **501**, or the like.

[0100] A camera interface **860** may coupled to receive the video signal from the camera **140**. The camera interface **860** may include, for example, a universal serial bus (USB) port, a parallel port, an infrared (IR) receiver, an IEEE 1394 ("firewire") port, or other suitable device for receiving data from the camera **140**. The camera interface **860** may also include decoding and/or decompression circuitry that modifies the format of the video signal.

[0101] Additionally, the STB **502** may include a wireless receiver **870** for receiving control signals sent by the remote control **506** and a wireless transmitter **880** for transmitting signals, such as responses to user commands, to the remote control **506**. The wireless receiver **870** and the wireless transmitter **880** may utilize infrared signals, radio signals, or any other electromagnetic emission.

[0102] A compression/correction engine **890** and a camera engine **892** may be stored in the memory **820**. The compression/correction engine **890** may perform compression and distortion compensation on the video signal received from the camera **140**. Such compensation may permit a wide-angle, highly distorted "fish-eye" image to be shown in an undistorted form. The camera engine **892** may accept and process user commands relating to the pan, tilt, and/or zoom functions of the camera **140**. A user may, for example, select the object to be tracked, select the zoom level, or other parameters related to the operation of the tracking system **100**.

[0103] Of course, **FIG. 8** illustrates only one possible configuration of an STB **502**. Those skilled in the art will recognize that various other architectures and components may be provided within the scope of the invention. In addition, various standard components are not illustrated in order to avoid obscuring aspects of the invention.

[0104] Referring to **FIG. 9, a** logical block diagram **900** shows one possible manner in which light and signals may interact in the tracking system **100** of **FIG. 1**. The illustrated steps/components may be implemented in hardware, software, or firmware, using any of the components of **FIG. 8**, alone or in combination. While various components are illustrated as being disposed within a STB **502**, those skilled in the art will recognize that similar components may be included within the camera, itself.

[0105] As described previously, the emitter **130** emits invisible light **134** that is reflected by the reflector **220**. Ambient light sources **930** have not been shown in **FIG. 1** for clarity; the ambient light sources **930** may include the sun, incandescent lights, fluorescent lights, or any other source that produces visible light **934**. The visible light **934** reflects off of the object **212** (e.g., head), and possibly the reflector **220**.

[0106] Both visible and invisible light are reflected to the camera **140**, which produces a video signal with a visible light component **940** and an invisible light component **942**. The visible light component **940** and the invisible light component **942** are conveyed to the STB **502**. If a camera such as the camera **740** is used, the camera **740** may also transmit the distance between the camera **740** and the object **212**, which is determined by the range finding assembly **743**, to the STB **502**.

[0107] The invisible light component **942** may be processed by a tracking subsystem **950** that utilizes the invisible light component **942** to orient the field-of-view **160**. For example, the tracking subsystem **950** may move the field-of-view **160** from that shown in **FIG. 2** to that shown in **FIG. 3**.

[0108] The tracking subsystem **950** may have a vector calculator **960** that determines the direction .in which the object vector **150** points. Such a determination may be relatively easily made, for example, by determining which pixels of the digitized invisible light component **942** contain the target reflected by the reflector **220**.

[0109] The vector calculator **960** may, for example, measure luminance values or the like to determine which pixels correspond to the reflector. The target reflected by the reflector **220** can be expected to be the brightest portion of the invisible component **942**. The frequency and intensity of the invisible light emitted by the emitter **130** may be selected to ensure that the brightest invisible light received by the camera **140** is that reflected by the reflector **220**.

[**0110**] Alternatively, the field-of-view orientation subsystem **962** may determine the location of the reflector **220** through software such as an objectivication algorithm that analyzes motion of the reflector **220** with respect to surrounding objects. Such an objectivication algorithm may separate the field-of-view **160** into "objects," or portions that appear to move together, and are therefore assumed to be part of a common solid body. Thus, the field-of-view orientation subsystem **962** may resolve the reflector **220** into such an object, and perform tracking based on that object. As one example, an algorithm such as MPEG-4 may be used.

[**0111**] In any case, the vector calculator **960** may provide the object vector **150** to a field-of-view orientation subsystem **962**. The field-of-view orientation subsystem **962** may then center the camera **140** on the object **212** (e.g., aligning the center vector **152** with the object vector **150**.

[**0112**] Thus, the field-of-view orientation subsystem **962** may perform the centering operation shown in **FIG. 2** to align the center **240** of the field-of-view **160** with the target reflected by the reflector **220**. The field-of-view orientation subsystem **962** may, for example, determine the magnitudes of the pan displacement **244** and the tilt displacement **246**, and perform the operations necessary to pan and tilt the field-of-view **160** by the appropriate distances. As mentioned previously, panning and tilting may be performed mechanically, or through software.

[**0113**] The magnitudes of the pan and tilt displacements **244**, **246** do not depend on the distance between the object **212** and the camera **140**. Consequently, the tracking subsystem **950** need not determine how far the object **212** is from the camera **140** to carry out tracking. A two-dimensional object vector **150**, i.e., a vector with an unspecified length, is sufficient for tracking.

[**0114**] As an alternative to the analytical tracking method described above, the tracking subsystem **950** may perform tracking through trial and error. For example, the tracking subsystem **950** need not determine the object vector **150**, but may simply determine which direction the field-of-view **160** must move to bring the object **212** nearer the center **240**. In other words, the tracking subsystem **950** need not determine the magnitudes of the pan and tilt displacements **244**, **246**, but may simply determine their directions, i.e., up or down and left or right. The field-of-view **160** may then be repeatedly panned and/or tilted by a preset or dynamically changing incremental displacement until the object **212** is centered within the field-of-view **160**.

[**0115**] The STB **502** may also have a zoom subsystem **952** that widens or narrows the field-of-view **160** to the appropriate degree. The zoom subsystem **952** may, for example, modify the field-of-view **160** from that shown in **FIG. 3** to that shown in **FIG. 4**.

[**0116**] Since the camera **140** shown in **FIG. 9**. does not have range finding hardware, the zoom subsystem **952** may have a range finder **970** that determines a distance **972** between the camera **140**, or the STB **502**, and the object **212**. The range finder **970** may be configured in a manner similar to the range finding assembly **743** of the camera **740**, with a trigger/timer, transmitter, and receiver (not shown) that cooperate to send and receive an infrared or sonic pulse and determine the distance based on the lag between outgoing and incoming pulses.

[**0117**] If a camera with a range finding assembly **743** or other range finding hardware, such as the camera **740**, were to be used in place of the camera **140**, the STB **502** may not require a range finder **970**. The tracking system **100** may alternatively determine the distance between the camera **140** and the object **212** through software such as an objectivication algorithm that determines the size of the head **212** within the field-of-view **160** based on analyzing motion of the head **212** with respect to surrounding objects. Such an objectivication algorithm may, for example, be MPEG 4 or any other known objectivication algorithm.

[**0118**] The distance **972** obtained by the range finder **970** may be conveyed to a magnification level adjustment subsystem **974**, which may use the distance **972** to zoom the field-of-view **160** to an appropriate magnification level. The magnification level may be fixed, intelligently determined by the magnification level subsystem **974**, or selected by the user.

[**0119**] In any case, the magnification level may vary in real-time such that the object **212** always appears to be the same size within the field-of-view **160**. Such zooming may be performed, for example, through the use of a simple linear mathematical relationship between the distance **972** and the size of the field-of-view **160**. More specifically, the ratio of object size to field-of-view size may be kept constant.

[**0120**] For example,when the head **212** of the person **210** moves away from the camera **140**, the magnification level adjustment subsystem **974** may narrow the field-of-view **160**, or "zoom in" so that the ratio of sizes between the head **212** and the field-of-view **160** remains the same. The field-of-view size refers to the size of the rectangular area processed by the camera, such as the views of **FIG. 2**, **FIG. 3**, and **FIG. 4**. If the head **212** moves toward the camera **140**, the field-of-view **160** may be broadened, "or zoomed out," to maintain the same ratio. Thus, the facial features of the person **210** will still be easily visible when the person **210** moves toward or away from the camera **140**.

[**0121**] In the alternative to the analytical zooming method described above, zooming may also be performed through trial and error. For example, the magnification level adjustment subsystem **974** may simply determine whether the field-of-view **160** is too large or too small. The field-of-view **160** may then be repeatedly broadened or narrowed by a preset increment until the field-of-view **160** is zoomed to the proper magnification level, i.e., until the ratio between the size of the object **212** and the size of the field-of-view **160** is as desired.

[**0122**] The visible light component **940** of the video signal from the camera **140** may be conveyed to a video preparation subsystem **954** of the STB **502**. The video preparation subsystem **954** may have a formatting subsystem **980** that transforms the visible light component **940** into a formatted visible component **982** suitable for transmission, for example, to the broadcast center **510** to which the STB **502** is connected. The formatted visible component **982** may also be displayed on the TV **504** connected to the STB **502**, for example, if the person **210** wishes to verify that the camera **140** is tracking his or her head **212** properly.

[0123] The field-of-view orientation subsystem **962** and the magnification level adjustment subsystem **974** determine the orientation and zoom level of the formatted visible light component **982**. In the case of mechanical panning, tilting, and zooming, the camera **140** may be controlled by the field-of-view orientation subsystem **962** and the magnification level adjustment subsystem **974**. Thus, the visible light component **940** would already be properly oriented and zoomed

[0124] However, the logical block diagram **900** of **FIG. 9** assumes that panning, tilting, and zooming are managed through software. Thus, the field-of-view orientation subsystem **962** and the magnification level adjustment subsystem **974** may interact directly with the formatting subsystem **980** to modify the visible light component **940**. More specifically, the formatting subsystem **980** may receive instructions from the field-of-view orientation subsystem **962** and the magnification level adjustment subsystem **974** to determine how to crop the visible light component **940**. After cropping, the formatted visible light component **982** provides a centered and zoomed image.

[0125] The formatted visible component **982** may be conveyed over the network **501** to the remote terminal **509**, which may take the form of another STB **502**, TV **504**, and/or camera **140** combination, as shown in **FIG. 5**. A user at the remote terminal **509** may view the formatted visible component **982**, and may transmit a visible component of a second video signal captured by the remote terminal **509** back to the local terminal **508** for viewing on the TV **504** of the local terminal **508**. Thus, the users of the local and remote terminals **508**, **509** may carry out two-way videoconferencing through the use of the communication subsystem **501**, or the network **501**.

[0126] If desired, software steerable technology may be used to provide a second formatted visible light component (not shown) of a different object. For example, the visible light component **940** of the video signal from the camera **140** may be cropped a first time to provide the desired view **232** of the head **212** of the person **210**, as shown in **FIG. 4**. The desired view **232** may be formatted to form the formatted visible component **982**. The visible light component **940** may be cropped a second time to provide the desired view **234** of the folder **214**. The desired view **234** of the folder **214** may be formatted to form the second formatted visible light component **982**.

[0127] In such a fashion, a plurality of additional cropped subsets of the visible light component **940** may be provided. Each cropped subset may be sent to a different remote terminal **509**, for example, if multiple parties wished to see different parts of the view of **FIG. 2**. Thus, multiple objects can be tracked and conveyed over the network **501** with a single camera **140**. Of course, one cropped subset could be displayed on the TV **504** of the local terminal **508** or recorded for future playback.

[0128] The tracking system **100** also may perform other functions aside from videoconferencing. For example, the tracking system **100** may be used to locate articles for a user. A reflector **220** may be attached to a set of car keys, the remote control **506**, or the like, so that a user can activate the tracking system **100** to track the car keys or the remote control **506**.

[0129] An object may, alternatively, be equipped with an active emitter that generates invisible light that can be received by the camera **140**. The remote control **506** may, for example, emit invisible light, either autonomously or in response to a user command, to trigger tracking and display of the current Whereabouts of the remote control **506** on the TV **504**.

[0130] The reflector **220** may also be disposed on a child to be watched. A user may then use the tracking system **100** to determine the current location of the child, and display the child's activities on the TV **504**. Thus, the tracking system **100** can be used in a wide variety of situations besides traditional videoconferencing.

[0131] Referring to **FIG. 10**, one possible embodiment of a tracking method **1000** that may be carried out in conjunction with the tracking system **100** is depicted. The reflector **220** may first be attached **1010** to the object **212**. Such attachment may be accomplished through any known attachment mechanism, including clamps, clips, pins, adhesives, or the like.

[0132] Invisible light **134** may then be emitted **1020** such that the invisible light **134** enters the field-of-view **160** and impinges against the reflector **220**. The reflector **220** reflects **1030** the portion **136** of the invisible light **134** to the camera **140**. The camera **140** captures **1040** a first video signal that includes the visible component **940** derived from visible light received by the camera **140** and the invisible component **942** derived from the portion **136** of invisible light received by the camera **140**.

[0133] The field-of-view **160** is then moved **1050** or oriented, for example, by the tracking subsystem **950** to center the object **212** within the invisible component **942**. The size of the field-of-view **160** may be adjusted by the zoom subsystem **952** to obtain the desired zoom factor.

[0134] Since the head **212** of the person **210** can be expected to move about within the field-of-view **160**, tracking and zooming may be carried out continuously until centering and zooming are no longer desired. If tracking is to continue **1070**, the steps from emitting **1020** invisible light through adjusting **1060** the magnification level may be repeated continuously. If there is no further need for tracking and zooming, i.e., if videoconferencing has been terminated or the user has otherwise selected to discontinue zooming and tracking, the tracking method **1000** may terminate.

[0135] For each of the steps of moving **1050** the field-of-view **160** and adjusting **1060** the magnification level of the field-of-view **160**, the tracking system **100** may perform multiple tasks. Such tasks will be outlined in greater detail in connection with **FIGS. 11 and 12**, which provide two embodiments for moving **1050** the field-of-view **160**, and **FIGS. 13 and 14**, which provide two embodiments for adjusting **1060** the magnification level of the field-of-view **160**.

[0136] Referring to **FIG. 11**, moving **1050** the field-of-view **160** may include determining **1110** the location of the target reflected by the reflector **220** within the field-of-view **160**. The object vector **150** may then be calculated **1120**, for example, by the vector calculator **960**. The field-of-view **160** may then be panned and tilted **1130** to align the center vector **152** of the field-of-view **160** with the object vector **150**.

[0137] Referring to **FIG. 12**, an alternative embodiment of a centering method **1200** is depicted, which may operate in place of the method **1050** described in **FIG. 11**. The method **1050** of **FIG. 11** may be referred to as analytical, while the method **1200** utilizes trial and error.

[0138] The centering method **1200** may commence with determining **1210** the direction the target, or the object **212**, is displaced from the center **240** of the field-of-view **160**. The field-of-view **160** may then be moved **1220**, or panned and tilted, so that the center **240** is brought closer to the target provided by the reflector **220**, or the object **212**. If the target is not yet centered, the steps of determining **1210** the direction to the target and moving **1220** the field-of-view **160** may be repeated until the target is centered, or within a threshold distance of the center **240** of the field-of-view **160**.

[0139] Referring to **FIG. 13**, adjusting **1060** the magnification level of the field-of-view **160** may commence with determining **1310** the distance **972** between the object **212** and the camera **140**. Determining **1310** the distance may be carried out by the range finder **970**, or by a range finding assembly **743** if a camera such as the camera **740** is used. The desired magnification level of the field-of-view **160** may then be calculated **1320** using the distance **972**, for example, by maintaining a constant ratio of the distance **972** to the size of the field-of-view **160**. The camera may then be zoomed **1330** until the desired magnification level has been achieved.

[0140] Referring to **FIG. 14**, an alternative embodiment of a zooming method **1400** is depicted, which may operate in place of the method **1060** described in **FIG. 13**. Like the method **1050** of **FIG. 11**, the method **1060** of **FIG. 13** may be referred to as analytical, while the method **1400** utilizes trial and error, like the method **1200**.

[0141] The method **1400** may first determine **1410** whether the magnification level is too large or too small, i.e., whether the object **212** appears too large or too small in the field-of-view **160**. The magnification level may then be changed **1420** incrementally in the direction required to approach the desired magnification level. If the best (i.e., desired) magnification level has not been obtained **1430**, the method **1400** may iteratively determine **1410** in which direction such a change is necessary and change **1420** the magnification level in the necessary direction, until the desired magnification level is obtained.

[0142] The methods presented in **FIGS. 10 through 14** may be utilized with a number of different embodiments besides those explicitly described in the foregoing examples. Furthermore, those of skill in the art will recognize that other methods may be used to carry out tracking and zooming according to the invention.

[0143] The tracking system **100** may be modified in a number of ways. For example, the emitter **130** and reflector **120**, or reflectors **220**, may be replaced by portable emitters that actively generate invisible light. Such emitters may, for example, take the form of a specialized bulb, lens, or bulb/lens combination connected to a portable power source such as a battery.

[0144] Such a portable emitter may then be used in much the same manner as the reflectors **220**, i.e., disposed on an object or an article worn by the person **210**. The portable emitter may therefore have an attachment mechanism such as a clip, clamp, adhesive, magnet, pin, or the like. The discussion of **FIGS. 2 through 9** applies to the portable emitter, with which tracking may be accomplished in substantially the same manner as previously described.

[0145] As yet another alternative, the invisible light produced by a normal human body may be used in place of the reflector **220** and emitter **130**. The human body radiates electromagnetic energy within the infrared spectrum; consequently, the camera **140** may receive invisible light from the person **210** without the aid of any emitter or reflector.

[0146] Tracking may be performed by determining the location of a "hot spot," or area of comparatively intense infrared radiation, such as the head **212**. The forehead and eyes tend to form such a hot spot; hence, tracking based on infrared intensity may provide easy centering on the eyes of the person. Other areas of relatively higher infrared intensity (e.g., the chest) are typically covered by clothing. Hence, for applications such as videoconferencing, tracking based on the intensity of infrared radiation from the human body provides a technique for centering the head **212** within the field-of-view **160**.

[0147] In the alternative, tracking may be performed by locating an area that emits a comparatively specific infrared frequency. If desired, the camera **140** and/or STB **502** may be calibrated to the individuals with which they will be used. Thus, the camera **140** will be able to perform tracking despite ordinary variations in body temperature from one person to the next.

[0148] An objectivication algorithm may also be used in conjunction with tracking based on the infrared radiation of the human body. More specifically, objectivication may be utilized to resolve the invisible component **942** into one or more people based on the shapes and/or motion of the infrared radiation received. Thus, the locations of people within the field-of-view **160** can be determined without the use of a reflector or emitter.

[0149] Those of skill in the art will recognize that tracking may also be accomplished in a number of ways within the scope of the invention. For example, low power microwave radiation may be emitted by an emitter similar to the emitter **130** of **FIG. 1**. Invisible light within the microwave frequency band may be somewhat more readily distinguished from ambient light, such as electromagnetic emissions from the sun, artificial lights, or other warm obmects. The light produced by such ambient sources may be mostly infrared or visible. Hence, the use of microwave radiation may enable more effective tracking by reducing ambient interference. Microwave radiation may be read and processed in substantially the same manner as described above.

[0150] Furthermore, regardless of the frequency of light detected, additional processing may be carried out to distinguish between objects to be tracked and surrounding objects. For example, through a method such as Doppler detection, differentials between emitted wavelengths and received wavelengths may be used to determine whether an object is moving toward or away from the camera. Objects in motion, such as people, may therefore reflect light with a frequency shifted somewhat from the frequency of the emitted light. Conversely, stationary objects may be assumed to reflect or emit a consistent frequency. Thus, a moving object may be distinguished from other changes in electromagnetic emission, such as changing sunlight patterns.

[0151] Based on the foregoing, the present invention offers a number of advantages not available in conventional approaches. During videoconferencing, a camera keeps a person or object continuously within its field-of-view. Moreover, the field-of-view is continuously zoomed to maintain the relative size of the person or object being tracked. Thus, a person need not remain in a fixed position during videoconferencing, but may freely move about a room, while still being visible to remote parties.

[0152] While specific embodiments and applications of the present invention have been illustrated and described, it is to be understood that the invention is not limited to the precise configuration and components disclosed herein. Various modifications, changes, and variations apparent to those skilled in the art may be made in the arrangement, operation, and details of the methods and systems of the present invention disclosed herein without departing from the spirit and scope of the invention.

What is claimed is:

1. A system for automatically tracking an object with a camera, the system comprising:

a reflector, disposed on an object to be tracked, that reflects a target of invisible light;

a camera, sensitive to invisible light, that captures a first video signal depicting the object, the first video signal having visible and invisible components; and

a tracking subsystem that utilizes the invisible component to orient a first field-of-view of the camera to center the target within the first field-of-view.

2. The system of claim 1, wherein the invisible light comprises infrared light.

3. The system of claim 1, wherein the invisible light comprises ultraviolet light.

4. The system of claim 1, wherein the tracking subsystem comprises a vector calculator that calculates a vector from the camera to the reflector based on a location of the target within the invisible component of the first video signal.

5. The system of claim 4, wherein the tracking subsystem comprises a camera alignment subsystem that physically aligns the camera along the calculated vector.

6. The system of claim 1, wherein the tracking subsystem determines whether the target is centered within the first field-of-view and, if the target is not centered, moves the first field-of-view of the camera in a direction calculated to center the target within the first field-of-view until the target is centered.

7. The system of claim 1, wherein the tracking subsystem comprises an objectivication algorithm that analyzes motion of the object to determine a shape of the object.

8. The system of claim 1, wherein the first field-of-view is a cropped subset of a second field-of-view of the camera, and wherein the tracking subsystem moves the first field-of-view to a location of the second field-of-view in which the target is centered.

9. The system of claim 1, wherein the reflector comprises a reflective side and a non-reflective side, the non-reflective side comprising an adhesive for affixing the reflector to the object to be tracked.

10. The system of claim 1, wherein the object to be tracked comprises a person engaged in video communication using the camera.

11. The system of claim 10, wherein the reflector is attached to an article worn by the person.

12. The system of claim 11, wherein the article is selected from the group consisting of a pair of glasses, a tie clip, and a piece of jewelry.

13. The system of claim 10, wherein the reflector comprises a coating applied directly to skin of the person, wherein the coating reflects invisible light.

14. The system of claim 1, wherein the object to be tracked is selected from the group consisting of a remote control device and a set of keys.

15. The system of claim 1, further comprising:

a local display device viewable from within the first field-of-view that displays at least a subset of the visible component of the first video signal.

16. The system of claim 1, further comprising:

a communication subsystem that transmits at least a subset of the visible component of the first video signal to a remote terminal for display.

17. The system of claim 16, wherein the communication subsystem is configured to use a network selected from the group consisting of a cable television network and a direct broadcast satellite network.

18. The system of claim 17, further comprising:

a codec that receives television programming from the communication subsystem for display on a local display device viewable from within the first field-of-view, wherein the codec and the tracking subsystem are disposed within a common housing to form a set top box, and wherein the set top box transmits the first signal from the camera to the communication subsystem.

19. The system of claim 16, wherein the communication subsystem receives a second video signal from the remote terminal, the system further comprising:

a local display device that displays the second video signal.

20. The system of claim 19, wherein the second video signal at least a subset of the visible component of the first video signal are displayed simultaneously.

21. The system of claim 1, further comprising:

a range finder that calculates a distance between the object and the camera.

22. The system of claim 21, wherein the first field-of-view has a magnification level, the system further comprising:

a zoom subsystem that adjusts the magnification level of the first field-of-view based on the calculated distance between the object and the camera.

23. The system of claim 1, wherein the first field-of-view has a magnification level, the system further comprising:

a zoom subsystem that maintains a ratio of object size to first field-of-view size substantially constant during motion of the object.

24. The system of claim 23, wherein the ratio of object size to first field-of-view size is user selectable.

25. The system of claim 1, wherein the camera comprises:

a wide frequency charge-coupled device (CCD) that generates the visible-light component and the invisible-light component of the first video signal.

26. The system of claim 1, wherein the camera comprises:

a first charge-coupled device (CCD) that generates the visible-light component of the first video signal; and

a second CCD that generates the invisible-light component of the first video signal.

27. A system for automatically tracking an object with a camera, the system comprising:

an camera, sensitive to invisible light, that captures a first video signal of an object having a reflector disposed thereon to reflect a target of invisible light, the first video signal having visible and invisible components; and

a tracking subsystem that utilizes the invisible component to orient a first field-of-view of the camera to center the target within the first field-of-view.

28. A system for automatically tracking an object with a camera, the system comprising:

a camera, sensitive to invisible light, that captures a first video signal of an object having a reflector disposed thereon to reflect a target of invisible light, the invisible light generated by an invisible light emitter, the first video signal having visible and invisible components; and

a tracking subsystem that utilizes the invisible component to orient a first field-of-view of the camera to center the target within the first field-of-view.

29. A system for automatically tracking an object with a camera, the system comprising:

an invisible-light emitter, disposed on an object to be tracked, for emitting a target of invisible light;

a camera, sensitive to invisible light, that captures a first video signal depicting the object, the first video signal having visible and invisible components; and

a tracking subsystem that utilizes the invisible component to orient a first field-of-view of the camera to center the target within the first field-of-view.

30. The system of claim 29, wherein the invisible light comprises infrared light.

31. The system of claim 29, wherein the invisible light comprises ultraviolet light.

32. The system of claim 29, wherein the invisible-light emitter comprises an emissive side and a non-emissive side, the non-emissive side comprising an adhesive for affixing the emitter to the object to be tracked.

33. The system of claim 29, wherein the emitter comprises:

a power source that provides electrical potential; and

an invisible light generator electrically-coupled to the power source to convert electrical potential into invisible light.

34. The system of claim 29, wherein the object to be tracked comprises a person engaged in video communication using the camera.

35. The system of claim 34, wherein the emitter is attached to an article worn by the person.

36. The system of claim 35, wherein the article is selected from the group consisting of a pair of glasses, a tie clip, and a piece of jewelry.

37. The system of claim 29, wherein the object to be tracked is selected from the group consisting of a remote control device and a set of keys.

38. A system for tracking an individual during video communication, the system comprising:

an infrared-sensitive camera that captures a first video signal depicting the individual, the first video signal having infrared and visible-light components;

a targeting subsystem that identifies a target comprising an area of infrared intensity within the infrared component of the first video signal; and

a tracking subsystem that utilizes the infrared component to orient a first field-of-view of the camera to center the target within the first field-of-view.

39. The system of claim 38, wherein the area of infrared intensity corresponds to at least a portion of a head of the individual.

40. The system of claim 38, wherein the targeting subsystem determines a magnitude of infrared intensity of the target to identify the target.

41. The system of claim 38, wherein the targeting subsystem determines a size of the target to identify the target.

42. The system of claim 38, wherein the targeting subsystem determines a wavelength of infrared radiation from the target to identify the target.

43. The system of claim 38, wherein the first field-of-view has a magnification level, the system further comprising:

a zoom subsystem that maintains a ratio of object size to first field-of-view size substantially constant during motion of the object.

44. The system of claim 43, wherein the zoom subsystem determines a size of the area of infrared intensity to obtain the ratio of object size to first field-of-view size.

45. The system of claim 38, further comprising:

a local display device viewable from within the first field-of-view that displays at least a subset of the visible component of the first video signal.

46. The system of claim 38, further comprising:

a communication subsystem that transmits at least a subset of the visible component of the first video signal to a remote terminal for display.

47. The system of claim 46, wherein the communication subsystem is configured to use a network selected from the group consisting of a cable television network and a direct broadcast satellite network.

48. The system of claim 47, further comprising:

a codec that receives television programming from the communication subsystem for display on a local display device viewable from within the first field-of-view, wherein the codes and the tracking subsystem are disposed within a common housing to form a set top box, and wherein the set top box transmits the first signal from the camera to the communication subsystem.

49. The system of claim 46, wherein the communication subsystem receives a second video signal from the remote terminal, the system further comprising:

a local display device that displays the second video signal.

50. The system of claim 49, wherein the second video signal and at least a subset of the visible component of the first video signal are displayed simultaneously.

51. A method for automatically tracking an object with a camera, the method comprising:

reflecting a target of invisible light with a reflector disposed on an object to be tracked;

capturing a first video signal depicting the object with a camera sensitive to invisible light, the first video signal having visible and invisible components; and

utilizing the invisible component to orient a first field-of-view of the camera to center the target within the first field-of-view.

52. The method of claim 51, wherein the invisible light comprises infrared light.

53. The method of claim 51, wherein the invisible light comprises ultraviolet light.

54. The method of claim 51, further comprising:

calculating a vector from the camera to the reflector based on a location of the target within the first field-of-view.

55. The method of claim 54, wherein orienting the first field-of-view comprises physically aligning the camera along the calculated vector.

56. The method of claim 51, further comprising:

determining whether the target is centered within the first field-of-view and, if the target is not centered, moving the first field-of-view of the camera in a direction calculated to center the target within the first field-of-view until the target is centered.

57. The method of claim 51, further comprising analyzing motion of the object to determine a shape of the object.

58. The method of claim 51, wherein the first field-of-view is a cropped subset of a second field-of-view of the camera, and wherein orienting the first field-of-view comprises moving the first field-of-view to a location of the second field-of-view in which the target is centered.

59. The method of claim 51, further comprising affixing the reflector to the object to be tracked with an adhesive disposed on a non-reflective side of the reflector, the reflector further having a reflective side.

60. The method of claim 51, wherein the object to be tracked comprises a person engaged in video communication using the camera.

61. The method of claim 60, further comprising attaching the reflector to an article worn by the person.

62. The method of claim 61, wherein the article is selected from the group consisting of a pair of glasses, a tie clip, and a piece of jewelry.

63. The method of claim 60, further comprising applying a coating directly to skin of the person, wherein the coating reflects invisible light.

64. The method of claim 51, wherein the object to be tracked is selected from the group consisting of a remote control device and a set of keys.

65. The method of claim 51, further comprising:

displaying at least a subset of the visible component of the first video signal at a location viewable from within the first field-of-view.

66. The method of claim 51, further comprising:

transmitting at least a subset of the visible component of the first video signal to a remote terminal for display.

67. The method of claim 66, wherein at least a subset of the visible component of the first video signal is transmitted through a network selected from the group consisting of a cable television network and a direct broadcast satellite network.

68. The method of claim 67, further comprising:

receiving television programming from the network for display at a location viewable from within the first field-of-view, wherein orienting the first field-of-view and receiving the television programming are performed within a set top box, and wherein the set top box transmits the first signal from the camera to the network.

69. The method of claim 66, further comprising:

receiving a second video signal from the remote terminal; and

displaying the second video signal on a local display device.

70. The method of claim 69, wherein the second video signal and at least a subset of the visible component of the first video signal are displayed simultaneously.

71. The method of claim 51, further comprising:

calculating a distance between the object and the camera.

72. The method of claim 71, wherein the first field-of-view has a magnification level, the method further comprising:

adjusting the magnification level of the first field-of-view based on the calculated distance between the object and the camera.

73. The method of claim 51, wherein the first field-of-view has a magnification level, the method further comprising:

maintaining a ratio of object size to first field-of-view size substantially constant during motion of the object.

74. The method of claim 73, wherein the ratio of object size to first field-of-view size is user selectable.

75. The method of claim 51, wherein capturing the first video signal comprises:

exposing a wide frequency charge-coupled device (CCD) to visible light and to the invisible light to generate the visible and invisible components of the first video signal.

76. The method of claim 51, wherein capturing the first video signal comprises:

exposing a first charge-coupled device (CCD) to visible light to generate the visible-light component of the first video signal; and

exposing a second charge-coupled device to the invisible light to generate the invisible-light component of the first video signal.

77. A method for automatically tracking an object with a camera, the method comprising:

emitting invisible light;

capturing a first video signal depicting the object with a camera sensitive to invisible light, the object having a reflector disposed thereon to reflect a target of invisible light, the first video signal having visible and invisible components; and utilizing the invisible component to orient a first field-of-view of the camera to center the target within the first field-of-view.

78. A method for automatically tracking an object with a camera, the method comprising:

capturing a first video signal depicting the object with a camera sensitive to invisible light, the object having a reflector disposed thereon to reflect a target of invisible light, the invisible light generated by an invisible light emitter, the first video signal having visible and invisible components; and

utilizing the invisible component to orient a first field-of-view of the camera to center the target within the first field-of-view.

79. A method for automatically tracking an object with a camera, the method comprising:

emitting a target of invisible light with an invisible-light emitter disposed on an object to be tracked;

capturing a first video signal depicting the object with a camera sensitive to invisible light, the first video signal having visible and invisible components; and

utilizing the invisible component to orient a first field-of-view of the camera to center the target within the first field-of-view.

80. The method of claim 79, wherein the invisible light comprises infrared light.

81. The method of claim 79, wherein the invisible light comprises ultraviolet light.

82. The method of claim 79, further comprising affixing the emitter to the object to be tracked with an adhesive disposed on a non-emissive side of the reflector, the reflector further having an emissive side.

83. The method of claim 79, wherein the emitter comprises:

a power source that provides electrical potential; and

an invisible light generator electrically coupled to the power source to convert electrical potential into invisible light.

84. The method of claim 79, wherein the object to be tracked comprises a person engaged in video communication using the camera.

85. The method of claim 84, further comprising attaching the emitter to an article worn by the person.

86. The method of claim 85, wherein the article is selected from the group consisting of a pair of glasses, a tie clip, and a piece of jewelry.

87. The method of claim 79, wherein the object to be tracked is selected from the group consisting of a remote control device and a set of keys.

88. A method for tracking an individual during video communication, the method comprising:

capturing a first video signal of an individual with an infrared-sensitive camera, the first video signal having infrared and visible-light components;

identifying a target comprising an area of infrared intensity within the infrared component of the first video signal; and

utilizing the infrared component to orient a first field-of-view of the camera to center the target within the first field-of-view.

89. The method of claim 88, wherein the area of infrared intensity corresponds to at least a portion of a head of the individual.

90. The method of claim 88, further comprising determining a magnitude of infrared intensity of the target.

91. The method of claim 88, further comprising determining a size of the target.

92. The method of claim 88, further comprising determining a wavelength of infrared radiation from the target.

93. The method of claim 88, wherein the first field-6f-view has a magnification level, the method further comprising:

maintaining a ratio of object size to first field-of-view size substantially constant during motion of the object.

94. The method of claim 93, further comprising determining a size of the area of infrared intensity to obtain the ratio of object size to first field-of-view size.

95. The method of claim 88, further comprising:

displaying at least a subset of the visible component of the first video signal at a location viewable from within the first field-of-view.

96. The method of claim 88, further comprising:

transmitting at least a subset of the visible component of the first video signal to a remote terminal for display.

97. The method of claim 96, wherein at least a subset of the visible component of the first video signal is transmitted through a network selected from the group consisting of a cable television network and a direct broadcast satellite networks.

98. The method of claim 97, further comprising:

receiving television programs from the network for display at a location viewable from within the first field-of-view, wherein orienting the first field-of-view and receiving the television programming are performed within a set top box, and wherein the set top box transmits the first signal from the camera to the network.

99. The method of claim 96, further comprising:

receiving a second video signal from the remote terminal; and

displaying the second video signal on a local display device.

100. The method of claim 99, wherein the second video signal and at least a subset of the visible component of the first video signal are displayed simultaneously.

101. A system for automatically tracking an object with a camera, the system comprising:

means for emitting invisible-light;

means, disposed on an object to be tracked, for reflecting a target of invisible light;

a camera, sensitive to invisible light, that captures a first video signal depicting the object, the first video signal having visible and invisible components; and

means, utilizing the invisible component, for orienting a first field-of-view of the camera to center the target within the first field-of-view.

* * * * *