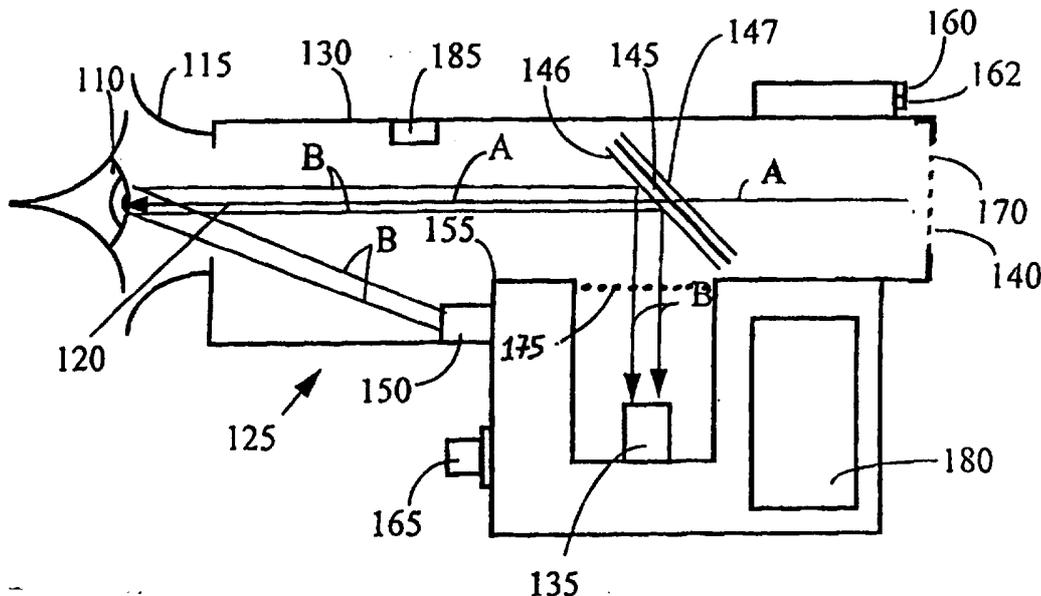




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<p>(21) International Application Number: PCT/GB97/01524 (22) International Filing Date: 6 June 1997 (06.06.97) (30) Priority Data: 9611787.4 6 June 1996 (06.06.96) GB 9621900.1 18 October 1996 (18.10.96) GB 97302580.2 15 April 1997 (15.04.97) EP (34) Countries for which the regional or international application was filed: AT et al. (71) Applicant (for all designated States except US): BRITISH TELECOMMUNICATIONS PUBLIC LIMITED COMPANY [GB/GB]; 81 Newgate Street, London EC1A 7AJ (GB). (72) Inventors; and (75) Inventors/Applicants (for US only): SEAL, Christopher, Henry [GB/GB]; 16 Hintlesham Close, Stowmarket, Suffolk, IP14 2PF (GB). GIFFORD, Maurice, Merrick [GB/GB]; 1 Dickinson Terrace, Kesgrave, Ipswich, Suffolk, IP5 7GR (GB). McCARTNEY, David, John [GB/GB]; 5 South Close, Ipswich, Suffolk IP4 2TH (GB).</p>	<p>(74) Agent: LLOYD, Barry, George, William; BT Group Legal Services, Intellectual Property Dept., 8th floor, 120 Holborn, London EC1N 2TE (GB). (81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	

(54) Title: PERSONAL IDENTIFICATION



(57) Abstract

A hand-held imaging apparatus (125) for capturing an image of an eye (110) comprises a housing (125) having an eye-cup (115) at a rear window (120) to position the eye. The housing (125) provides a line-of-sight through the apparatus to a front window (140). An angled, semi-reflecting mirror (145) in the line of sight directs an image of the eye to a camera (135) for the purposes of image capture. The apparatus also includes a transmitter (160) and a receiver (162) to transmit and receive data relating to iris image information to and from a remote apparatus.

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## PERSONAL IDENTIFICATION

The present invention relates to personal identification and apparatus, methods and uses therefor.

5 In today's world of electronic communication and commerce, the ability to identify a person for the purposes of security in remote transactions is paramount. A common form of security is a simple password which, for example, is entered when a user wishes to access a computer network. Another form of security, which is widely used in bank automatic teller machines (ATMs), is a personal  
10 identification card, which holds on a magnetic strip encoded information such as the owner's personal details and account number, which is used in combination with a personal identification number (PIN) entered by the user when the transaction is initiated.

Various ways have been demonstrated of fraudulently by-passing the  
15 above-described and other commonly used security measures to gain access to private information or resources. Such security problems are discussed in the article entitled "Industrial Cryptography" in the IEE Review dated May 1996. As the title suggests, this article focuses on how cryptography can be used effectively as a way of increasing security.

20 Another way of ensuring the identity of a person is to capture and encode a biometric from the person and compare the result with a previously-stored, or enrolled, result, for example stored on a remote database system. A biometric, for the present purposes, is a statistical or quantitative measure of a biological feature of a person. The most well-known biometric for humans, used for identification  
25 purposes, is the fingerprint. A 'robust' biometric, such as a fingerprint, is one which can be used reliably and repeatedly to identify a person.

Recently, the use of the iris of an eye as a robust biometric for  
identification purposes has been proposed. US patent number 5,291,560, dated 1  
March 1994, describes a method of encoding the image of an iris into a 256-byte  
30 iris code. It has been shown that such a code can be used as a very reliable personal identifier.

One proposed example of the use of an iris code is for identifying a customer attempting to withdraw cash from an ATM (automatic teller machine).

The proposed ATM includes an imaging system which comprises a window through which the customer looks and an auto-focusing camera. The camera is positioned directly in the line of sight of the customer. When the customer looks through the window and, for example, inserts his bank card into the ATM, the  
5 camera captures an image of his eye.

Once the system has captured a suitable representation of an eye, the representation is digitised (if not already in digital form) and encoded to form an iris code. This iris code can then be compared with a stored iris code of allegedly the same person. If the two codes are sufficiently similar, the identity of the customer  
10 is verified and cash withdrawal, for example, is permitted.

This system is designed to be non-intrusive and can be used by anyone wishing to withdraw money from the ATM.

A problem arises in relation to such systems in that the apparatus is fixed and the customer must move his head relative to it so that the apparatus can  
15 capture an image of his eye. He must position his head such that the captured image is in focus and contains sufficient detail of the iris. Hence, if a fixed focus image capture device is employed the customer must position himself at the correct distance from the apparatus. This makes use of the apparatus awkward. This problem can be alleviated to an extent by providing an image capture device  
20 having an auto-focus and auto-zoom facility, but that results in the apparatus being bulky and expensive to manufacture.

An alternative approach is disclosed in U.S. Patent 5,369,669. This patent discloses a mobile retinal scan identifier. Although the apparatus is easier to use than fixed apparatuses it uses scanning optics and is therefore both  
25 complex and expensive to manufacture.

In accordance with a first aspect of the present invention there is provided an apparatus for providing an information signal characteristic of an eye, said apparatus being arranged to be carried into an operative position by a user, said apparatus comprising:

- 30 a housing;  
- a wave source mounted on the housing, and operable to provide waves to be incident upon the surface of the eye over an area outside the pupil;

an image capture device mounted on the housing, and operable to provide an image signal representing one or more features of the anterior of the eye responsive to waves reflected from the eye; and

a transmission device operable to transmit said information derived from  
5 said image to a remote apparatus.

In known iris recognition apparatuses the information captured comprises an optical image of the eye. However, it is envisaged that other forms of information characteristic of the eye, for example reflected sound-wave patterns, could be used to uniquely identify different eyes. Thus, even though the following  
10 description refers in general to captured optical images, it will be appreciated that this is for convenience only, and that embodiments employing the capture of other types of information are intended to fall within the scope of the present invention. However, embodiments using optical image capture are preferred.

By providing an apparatus which captures an image of an anterior part of a  
15 person or animal's eye (e.g. iris, cornea, sclera, eyelids etc.) the need for scanning optics is removed. This results in the apparatus being less bulky and less expensive than known apparatuses. If the eye to be investigated is that of the user, then since the user carries the apparatus to an operative position, rather than moving his eye into a suitable position for the apparatus, the apparatus is easier to  
20 use. The apparatus might, for example, form part of a mobile phone, or it might be worn on the wrist or as part of a pair of glasses. The waves produced by the apparatus may be incident both on the pupil as well as an area outside the pupil.

It is, of course, possible that the apparatus will be used by one person to obtain an information signal characteristic of another person's eye. In this way the  
25 apparatus might be useful, for example, to a policeman who wishes to identify or verify the identity of a person he has apprehended. The embodiments set out below involve the user using the apparatus on his own eye. However, it is to be understood that the eye under investigation may be that of a person or animal other than the user.

30 Preferably, the apparatus is adapted to be held in the hand and can therefore be held by the user and brought towards his or another's eye in use. Being portable, the apparatus need not be associated with any one particular

system or remote apparatus and, indeed, may be used with various different types of remote apparatus.

The transmission device may comprise a cordless transmission device. This arrangement has the advantage that the user does not need to concern  
5 himself with physical cable connections, for example on the back of a PC. Also, a user is not so restricted in his position relative to the PC, or other remote equipment, during use of the apparatus. Various types of cordless link, for example an ultrasonic, optical or RF link might be used.

An alternative communications link between the apparatus and the remote  
10 apparatus might comprise a telephone line, or similar connection. In this case, the apparatus includes means to convert electrical iris code data to an audible signal to be transmitted along the telephone line. The means to convert between sound and electrical data might employ standard modem technology.

Preferably, the apparatus comprises a target object viewable by the person  
15 whose eye is being investigated.

In preferred embodiments, the target object comprises a second window which provides a "line-of-sight" for the user, through the first window, to allow the user to view the environment beyond the apparatus. The second window may be a simple opening in the housing or might possibly include a visual display.

20 Having a second window is particularly advantageous when combined with a cordless arrangement, since the user is able to see accurately where the apparatus is pointing whilst looking into the apparatus for the purpose of eye image capture: the user can direct the apparatus appropriately at the remote apparatus receiver. It is believed also that allowing the user to fixate on the  
25 remote equipment causes the pupil of the eye to contract thus providing a larger and clearer view of the iris. Also, to a large extent, the view through the second window can provide a means for aligning the eye correctly in relation to the imaging means. However, further means to aid alignment, for example cross-hairs, may be provided.

30 The second window may be employed to allow a user to view a remote screen on which one or more captured images of the eye are displayed. The benefit to the user in this case is that he can see on the screen substantially what the imaging means is seeing, and adjust his eye position for correct alignment if

necessary. In this case the imaging means might be a video camera which is capable of transmitting real time images of the eye to the screen.

In preferred embodiments, said image capture device is responsive to user light reflected from the user which differs in spectrum from light from said target  
5 object. This arrangement allows the use of wavelength dependent optical devices to interact differently with user light and light from the target object.

The apparatus preferably comprises an encoding means for encoding captured information prior to its transmission. This has the advantage that the signal transmitted from the apparatus requires less bandwidth (assuming the  
10 transmission is to be achieved in a given time) than would be required by the transmission of the image signal.

The encoding means is preferably arranged to encode at least the iris portion, or part thereof, of a captured image. The encoding means may also encode one or more further features of the eye or surrounding face. For example,  
15 the code might include details of the pupil, the cornea, the sclera, and/or the eyelids, etc.

In preferred embodiments, the imaging apparatus further comprises means to encrypt an encoded image.

Encryption makes the apparatus more secure in use. The encrypted image  
20 code data typically includes other encrypted data such as date, time, apparatus serial number and/or even a GPS (global positioning system) co-ordinate record. Such extra information, when held in encrypted form, further increases the security of the system. For example, an encrypted code including encrypted time and date information could be intercepted by an eavesdropper but could not easily  
25 be used again since the date and time combination would be unique.

The apparatus may further comprise receiver means to enable bi-directional communications with the remote apparatus. Preferably then optical communications can be utilised using, for example, infra-red transmitters and receivers (e.g. photo-diodes). Such a 'cordless' arrangement might be used with  
30 remote apparatus having a suitable optical transmitter and receiver arrangement.

The illumination means preferably provides substantially non-visible wavelengths of optical radiation, for example predominantly near-infra-red (NIR) or infra-red (IR) optical radiation. A substantially non-visible illumination source is

believed to be more comfortable to the user. Also, in a line-of-sight embodiment, a substantially non-visible illumination source detracts the user's attention less from the line-of-sight image of the surroundings than would a source of visible optical radiation. For convenience only, the term "light" is intended in this description to include non-visible wavelengths of optical radiation. For this reason, the terms "light" and "optical radiation" are interchangeable.

In embodiments of the invention, correct eye alignment may be achieved by providing an optical component having a major region which is relatively less transmissive to visible optical radiation than a minor region of the component. The minor region would preferably be situated near or at the centre of the window and would be sufficiently small to require the pupil of an eye to be positioned close to the entrance window, in alignment with the minor region, to see a reasonable field of view of, for example, the target equipment through the apparatus. Then, in use, the person looking through the window would be encouraged to align the pupil of their eye with the minor region of the window thereby ensuring that the iris of the eye would be substantially centrally positioned and thus correctly aligned with respect to the window for the purposes of image capture. Also, to some extent, appropriate sizing of the minor region would control the distance the user places his eye from the screen. This would be beneficial in terms of reducing or removing any need to focus the imaging means.

The minor region of the window may comprise a material having a different optical composition from the major region. The major region might be substantially transparent to visible optical radiation and comprise, for example, clear glass or plastics material. Alternatively, the minor region may simply be a hole appropriately positioned in the window material of the major region. The major region might comprise, for example, a gelatin filter which is transparent to IR and NIR radiation.

Preferably, when using non-visible wavelengths of optical radiation, for example IR or NIR radiation, for the purposes of eye illumination and image capture, the window is substantially uniformly transparent over the window area to those wavelengths. Thus, while the window has only a minor region suitable for viewing, and thus aligning, purposes, the whole area of the window can be used for image capture purposes.

The apparatus preferably includes a trigger means. The trigger means may be operable by the user, by the apparatus itself or even, in a bi-directional embodiment, by the remote apparatus. Such arrangements allow the user, or one of the said apparatuses, to control exactly when image capture and/or when data  
5 transfer occurs. This feature finds particular application when using a cordless arrangement.

As well as being used to identify humans, the present apparatus can be used, in an appropriate form, to identify animals. Such an apparatus would typically need to be larger (depending on the size of the animal's eyes) and more  
10 robust. Suitable candidates for such a use are, for example, horses, and in particular expensive race-horses.

Embodiments of the present invention will now be described, by way of example only, with reference to the following drawings, of which:

Figure 1 is a schematic representation of an imaging apparatus;

15 Figure 2 is a schematic diagram which illustrates one possible hardware architecture for the imaging apparatus;

Figure 3 is a flow chart of an image capturing and encryption process;

Figure 4 is a diagram which illustrates possible configurations of illumination source;

20 Figures 5a and 5b are diagrams which illustrate correct and incorrect eye alignments respectively; and

Figure 6 is a diagram which illustrates an arrangement of apparatus to overcome the incorrect alignment illustrated in Figure 5b.

Figure 1 illustrates the imaging apparatus in use. The imaging apparatus is  
25 principally intended to be used by a single user and is thus designed to be intrusive, requiring a user to place his eye (and surrounding face) directly in contact with the apparatus. In the event it is intended that more than one user will use the apparatus, personal, replaceable eye-cups can be provided.

The apparatus is contained in a suitable housing 125. A user positions his  
30 eye 110 by placing his face appropriately against an eye-cup 115 at a rear window 120 of the housing 125. The eye-cup acts both as a means of minimising the amount of ambient light entering the apparatus and as the means for aligning the user's eye with the window.

The eye-cup 115 is attached to a barrel 130 formed in the housing 125 which provides a fixed separation between the eye 110 and a fixed-focus Charge Coupled Device (CCD) camera 135. The length, however, of the barrel 130 is adjustable to suit different users and is lockable once the correct length has been  
5 determined. The barrel 130 also provides a line-of-sight for the user, from the rear window 120 to a front window 140, through the housing 125. The adjustable barrel and fixed focus camera arrangement may be replaced by an auto-focusing camera arrangement. However, such an arrangement would increase the optical, electronic and mechanical apparatus complexity

10 The optical path between the eye 110 and the camera 135 subtends an angle of  $90^\circ$  due to a partially reflecting,  $45^\circ$  mirror 145 in the line-of-sight of the barrel 130.

An infra-red (IR) illumination source 150 is located between the mirror 145 and the eye 110 to illuminate the eye. The source has an associated screen 155  
15 to prevent light travelling directly from the source 150, via the mirror 145, to the camera 135.

An IR transmitter 160 and receiver 162 are located on the front of the housing 125, in line with the line-of-sight of the barrel 130, and a trigger button 165 is included on the housing for the user to control when the image is captured  
20 and/or transmitted to a remote apparatus (not shown).

As has already been mentioned, the connection between the apparatus and the remote apparatus might instead comprise a telephone line or similar connection, and the apparatus might then employ known modem technology to facilitate data transfer across the telephone line to and from the remote apparatus.

25 The front of the barrel 130 includes an IR filter 170 to minimise the amount of stray IR radiation that enters the apparatus. Additionally, the filter 170 might be useful to protect the user's eye from the accidental reflection of radiation emitted from the output of the transmitter 160. The CCD camera 135 is protected from stray visible light with a visible light filter 175 positioned between the camera  
30 and the barrel. The CCD camera is a standard black and white camera which is also sensitive to IR optical radiation. Other types of camera, for example a colour camera, could equally be used for image capture.

The apparatus also includes appropriate electronic circuitry 180 contained in the housing (described in more detail in relation to Figure 2.).

An optical indicator 185 is positioned in the barrel, in the field of view of the user. The indicator comprises one or more LEDs of varying colours which can  
5 be illuminated to indicate different apparatus statuses (as described below). Other indication systems which will be apparent to the skilled person may provide effective solutions. For example, these might include the use of display panels and/or sound.

In practice, the two filters 170 and 175 may be replaced by crossed  
10 polariser screens to prevent stray and unwanted light from outside the apparatus reaching the camera 135. The polarisers would be positioned in a similar fashion to the filters. The nature of the filters or polarisers depends on the type of illumination used. For example, if the imaging wavelength is near infra-red (NIR) or IR then an IR filter is required to prevent stray IR radiation from entering the apparatus  
15 through the front window 140. Alternatively, if the imaging wavelength(s) is that of visible light then crossed polarisers over the front window 140 and the camera 135 could be used. Other similar light blocking or filtering arrangements, which will be apparent to the skilled person, may provide equally effective solutions.

A 'hot mirror' 145 (for example, as sold under catalogue number 35-  
20 6681 by Ealing Optics of Greylaine Rd, Watford, U.K.) is located directly above the CCD camera 135. The mirror 145 slopes downwardly and forwardly at 45° to the longitudinal axis of the barrel 130. The mirror is formed from a glass slide having a coating of dielectric materials on its underside. The other side of the glass slide is coated with an anti-reflective coating 147. The coating 146 of dielectric material  
25 is effective to reflect approximately 80% of near infra-red light which falls upon it and to allow the passage of approximately 90% of visible light which falls upon it.

An advantage of this type of mirror is that, to some extent at least, the mirror also acts as a filter to IR radiation reaching the eye and to visible light reaching the camera. Other forms of lens, filter, beam splitter and/or prism  
30 arrangement could be used.

The overall size of the apparatus depends mainly on the size of the opening for the eye 120 and on the level of comfort and ease of use required by a user of the apparatus. The hardware for the apparatus is designed onto a single

application specific integrated circuit (ASIC) chip, the size of which is not a limiting factor to the size of the apparatus. Also, known CCD cameras can have dimensions in the order of millimetres and are not a limiting factor of the apparatus size.

5           Although Figure 1 shows the line-of-sight of the imaging apparatus as being directly through a barrel, it will be appreciated that the line-of-sight may instead be via path bending optics such as mirrors or prisms and may include lenses. Such arrangements may provide for an even more compact design and may enhance the image of the outside environment received by the user or the  
10 image of the eye received by the camera.

In Figure 1, the line of sight is an optical path through the barrel. It is envisaged, however, that the line of sight could be provided by a screened image of the environment beyond the apparatus, for example, on an liquid crystal display (LCD) screen. The image could be provided by a CCD camera mounted on the  
15 front of the apparatus. Thus, it would be possible to superimpose graphical indicators onto the image to aid the user in aligning the said apparatus with the remote apparatus. Alternatively, the LCD screen may be substantially transparent, to allow the user to see the actual environment beyond the apparatus, and the screen could be used purely for superimposing alignment, or other, information  
20 over the actual image. Correct alignment could be established by monitoring a series of signals being emitted by one of the imaging apparatus or the remote apparatus and being received and processed by the other. Although such an arrangement is technically more complex than a simple line-of-sight arrangement through a barrel, as electronic devices such as CCD cameras and LCD displays  
25 become smaller and cheaper, such a technically more complex arrangement might make more practical sense. The LCD might alternatively echo the image signal output by the image capture apparatus.

Figure 2 shows one possible hardware architecture arrangement for the apparatus. As already stated, the processing hardware is preferably engineered  
30 onto a single ASIC chip. The apparatus is controlled by a processor 200 which runs software held in read-only memory (ROM) 205. The processor 200 is connected via a bus 210 to the ROM 205, a block of random access memory (RAM) 215 and an input/output (I/O) controller 220. The RAM is large enough to

hold at least one captured image of an eye. The I/O controller 220 is connected by appropriate circuitry and drivers (not shown) to the IR transmitter 160 and receiver 162, the CCD camera 135, the trigger 165, the IR illumination source 150 and the optical indicator 185. The whole apparatus is powered by a suitable battery (not shown).

The processor 200 is sensitive to signals received from the trigger 165, the IR receiver 162 and the CCD camera 135. Also, the processor controls the IR transmitter 160, the IR illumination source, the CCD camera operation and the optical indicator 185.

The flow diagram in Figure 3 illustrates one possible process for the image capturing, processing and transmitting aspects of a user validation system. This procedure includes encryption to enhance the level of security. The encryption system uses a 'public key' to encipher data and a private key (known only to the recipient of the enciphered data) to decipher the data.

In step 300, the imaging apparatus is in a state where a trigger depression is awaited to start the process. When the user presses the trigger, the trigger generates a signal which is received by the processor. The processor then controls the IR transmitter to send a signal, in step 305, to the remote apparatus to initiate communications. In response, the remote apparatus sends a return message to the imaging apparatus.

In other embodiments, the trigger is substituted by the imaging apparatus, or the remote apparatus, monitoring for correct alignment. When correct alignment is established by the user, the capture, encoding and transmitting operations are initiated. Monitoring would involve one or other of the apparatuses emitting a signal which could be received and processed by the other apparatus to indicate correct alignment.

If the return message is not received by the imaging apparatus in step 315, for example as a result of the remote apparatus not receiving the first signal, the optical indicator lights up red in step 320 to indicate failure and inform the user to re-start the process by pressing the trigger again.

If the return message is received in step 315, the signal from the remote apparatus includes a selection of which public encryption key and which iris code format the imaging apparatus must use for successful transmission. A plurality of

public encryption keys and a plurality of iris code algorithms from which the selection can be made are stored in the RAM (or the ROM) in the imaging apparatus. The remote apparatus also transmits a date and time stamp to the imaging apparatus.

5           The information in the return signal, transmitted by the remote apparatus, is stored in the RAM in the imaging apparatus for subsequent access.

Next, in step 325, the processing means signals to the camera that one or more images should be captured. The images which are captured are stored in the RAM. In step 330, the processing means determines if the stored image, or which  
10 image, is suitable for encoding. If the, or none of the, images is/are suitable, the processor signals to the camera to re-capture the image(s).

The image capturing step includes control of the illumination source. The illumination source is connected in a control loop whereby the processor can vary the light intensity of the source depending on, for example, the colour of the user's  
15 iris: a light blue iris reflects far more light and needs less illumination than a dark brown iris. Several sequentially captured images, similar to a video sequence, might be required for the processor and software to determine the optimum illumination for the eye before a suitable image, or suitable images, is/are obtained.

It is suggested that pulsing the illumination source is more desirable than  
20 using a continuous source, although the image capture would need to be synchronised with a pulse of light to ensure suitable illumination. Pulsing light has the advantage that the user's eye is exposed, on average, to less optical radiation. Also, a pulsed source uses less energy.

Capturing multiple images can also overcome problems such as, for  
25 example, the user blinking at the point when one image is captured. Known digital signal processing techniques can be used to establish which image is the best and to reject unsuitable images.

When a suitable image is obtained, the image data is retrieved from the RAM and is processed to form an iris code, in step 335, using the iris code  
30 generating algorithm selected by the remote apparatus in step 315. An example algorithm is that described in US patent 5,291,560. The resulting iris code is stored in the RAM.

The processor then encrypts the iris code, in step 340, using the selected public key, along with the date and time stamp provided by the remote apparatus in step 315. The resulting data is stored in RAM. The coded and encrypted data is then transmitted to the remote apparatus by the IR transmitter in step 345.

5 It is feasible that the image capture, processing and encryption steps are completed without any intervening steps of storing data in RAM, that is to say processing is done "on-the-fly", to greatly increase the speed of operation of the apparatus. However, such processing would require more expensive and more complex electronics.

10 Finally, if the data is received successfully by the remote apparatus, the remote apparatus returns a 'success' signal to the imaging apparatus in step 350. The processing means, in response, causes the optical indicator to light up green to indicate to the user that the procedure has been successful in step 360. Repeated failure to transmit the data, for example after five attempts, causes the  
15 optical indicator to light up red in step 355 and results in the user needing to re-start the whole procedure.

A simpler process than that described above involves the imaging apparatus dictating which of the plurality of public encryption keys to use. The selection can be made using a pseudo-random number generator in the imaging  
20 apparatus. If each public key has an index reference, the respective reference can be included, obviously in non-encrypted form, with the encrypted data to indicate to the remote apparatus which public key has been used and, thus, which private key should be used for de-encryption. An extension to this arrangement is that a new set of public keys is down-loaded to the imaging apparatus, from the remote  
25 apparatus, each time a successful transaction occurs. Other, further encryption possibilities will be apparent to the skilled person.

In alternative embodiments, security may be further improved with the use of a personal identity card similar, for example, to a bank card which holds personal identity information on a magnetic strip. Alternatively, the personal  
30 identity card might be a smart-card which holds data in electronic form. The card, smart card, or an equivalent card or device, provides information in the form of magnetic or electronic data held on the card, which identifies a particular user. This information can be read by the imaging apparatus, when the card is inserted

into a suitable slot provided therein, and incorporated into the iris code along with, for example, other time stamp and apparatus identity information, further similar embodiments will become apparent to the skilled person.

Figure 4a represents one possible configuration for illumination having a plurality of different wavelength sources 412, 414 and 416. The diagram represents the view through the first window 400 to the camera 405 (the diagram does not take account of the 45° mirror). At the bottom of the view area inside the body of the apparatus is provided an light-emitting diode (LED) array comprising three LEDs, each producing NIR optical radiation of a different wavelength band beyond about 700nm. For example, each band spreads over about 20nm and each band is separated from the next by about 200nm. One of the LEDs may instead provide visible light.

One reason for providing illumination sources having different wavelengths stems from the observation that different lighting conditions, to some extent, provide different images. This is a result of the iris of an eye being a three-dimensional object in which different wavelengths of light penetrate to, and reflect from, different depths. For example, IR optical radiation penetrates more deeply into the iris than visible light. Thus, a broadband light source creates a far richer, more complex, image of an iris than a narrow band light source can. An advantage of using a narrow band light source is that a simpler image is produced which can be captured using relatively cheap optics.

Another reason for providing illumination sources having different wavelengths is that the degree of absorption of, say, near infra-red light, by an iris is dependent on its colour. Therefore to obtain an image having the required brightness, different wavelength sources can be used for different colour eyes.

The applicants have determined that different narrow band light sources can be used to produce different iris images which as a group form a family of images for one iris. Thus, one or more of the images can be used to identify or validate a user. The choice of which image to use can be determined by the remote apparatus. This approach increases security by overcoming fraud which might be possible otherwise by substituting a user with a photograph of an eye. Since a photograph is only two-dimensional, there would be no, or at least a

different, wavelength dependence in the images produced, and the image would not vary regardless of which wavelength of source was used.

Other embodiments in which separate images resulting from different wavelengths of illumination are combined in different ways will be apparent to the  
5 skilled person.

In practice, the array, and each of the LEDs individually, is controlled by the processor (via suitable electrical circuitry which is not shown). The processor controls when and which LEDs light up to illuminate the eye, either in response to its own controlling software or in response to signals received from the remote  
10 equipment. The processor also determines when, and under which lighting conditions, the image capturing process occurs. Said lighting conditions depend on the image(s) required by the remote equipment and, as has already been described, may be pulsed.

Figure 4b is similar to Figure 4a, except four identical LED arrays are  
15 provided to produce a more even illumination of the eye.

Instead of different wavelength sources, one or more broadband sources may be used to illuminate the iris, with optical filters used to isolate the required, different wavelength bands.

The procedure relies on the remote apparatus being arranged to receive,  
20 transmit and react in a complementary fashion to the imaging apparatus. In one embodiment, the remote apparatus is a PC programmed with suitable software and having a suitable transmitter and receiver arrangement. Also, the PC is typically connected via a data network to other remote apparatus, for example a database server. In operation, once received by the PC, the encrypted iris code data is  
25 directed across the network to the database server. The database server decodes the data and accepts or rejects the user as a valid or an invalid user.

Figure 5a illustrates correct alignment of an eye 500 with respect the rear window 520 of the apparatus. Correct alignment in this example requires that the whole iris 530 of the eye 500 is in the field of view of the window 520.

30 Figure 5b, which uses the same reference numerals as Figure 5a, illustrates a potential problem with eye alignment with respect to the rear window 520 of the apparatus. As shown, it is possible that the pupil 510 of the eye 500 has a view through the window 520, but at the same time a significant portion of

the iris 530 is obscured from view through the window. Whilst the user might have a reasonable view through the apparatus of, for example, target equipment, the CCD camera 135 would be unable to capture a full iris image, which would prevent successful iris recognition.

5           Figure 6 illustrates one possible way of encouraging a user to align their eye correctly in relation to the rear window 620 of the apparatus. The rear window 620 of the apparatus incorporates a screen 625. The screen comprises a gelatin filter, for example a Kodak (TM) Wratten filter No. 89B, which is transparent to wavelengths greater than 700nm and opaque to lower, visible  
10 wavelengths. The screen has a hole 328 at or around its centre which allows all wavelengths of light to pass through the screen. The hole 328 is large enough to allow the pupil of the eye a view (indicated by solid projection lines) through the screen. This view is not interrupted by a 45° mirror 645 which is substantially transparent to visible wavelengths of optical radiation, but reflecting to IR and NIR  
15 wavelengths.

The major portion of the screen 625 is opaque to visible wavelengths of radiation, but transparent to IR and NIR wavelengths. Thus, with suitable IR or NIR illumination (not shown), an image of the iris 612 of the eye, visible through the screen 625 and projected via the mirror 645 to a camera (not shown), can be  
20 captured (as illustrated by the dashed projection lines).

Other appropriate compositions of screen will become apparent to the skilled person in view of the preceding description. Indeed, any variations of screen providing a similar advantage could be employed. For example, the major region may be translucent rather than opaque to visible light. Alternatively, the  
25 major region may simply be tinted with respect to the minor, pupil aligning region to encourage the user to adopt the correct alignment. Also, the screen may be reinforced with glass or plastics materials, covering the hole to prevent, for example, dust from entering the apparatus.

Clearly, an eye alignment technique employing a screen as described  
30 above has potentially broader application than use in conjunction with an apparatus according to the present invention. Indeed, such a screen could be incorporated into any device or apparatus requiring similar, correct eye alignment in relation to the respective apparatus.

As an alternative to the hot mirror used in the above embodiment, a cold-mirror may be used. The cold mirror has the same position and orientation as the hot mirror but has a different coating on its underside. The coating would be effective to reflect most visible light whilst allowing the passage of near infra-red light. The other alteration which is made in this alternative embodiment is to swap the CCD camera and the LCD display about.

Obviously, also, the imaging apparatus according to the invention has far wider application than database access user validation. For example, the apparatus could be used to identify the owner of a car to an engine immobiliser in the car: unless the user is the owner, the car cannot be started. Many other uses of the invention will become apparent to the skilled person on reading the present description.

CLAIMS

1. An apparatus for providing an information signal characteristic of an eye, said apparatus being arranged to be carried into an operative position by a user,  
5 said apparatus comprising:  
a housing;  
a wave source mounted on the housing, and operable to provide waves to be incident upon the surface of the eye over an area outside the pupil;  
an image capture device mounted on the housing, and operable to provide  
10 an image signal representing one or more features of the anterior of the eye responsive to waves reflected from the eye; and  
a transmission device operable to transmit said information signal derived from said image to a remote apparatus.
- 15 2. An apparatus according to claim 1 wherein:  
said housing has an entrance window;  
said wave source comprises an illumination source operable to illuminate the eye; and  
said image capture device is mounted within the housing and is in optical  
20 communication with said entrance window.
3. Apparatus according to claim 1 or 2, wherein the apparatus is adapted to be held in the hand.
- 25 4. Apparatus according to any preceding claim, wherein said transmission device comprises a cordless transmission means.
5. Apparatus according to any one of claims 2 to 4 further comprising a target object visible, in use, to the eye to facilitate alignment of the eye with said  
30 entrance window.

6. Apparatus according to claim 5 wherein said target object comprises a further window, in optical communication with the first-mentioned window to provide a view beyond the housing to the eye.
- 5 7. Apparatus according to claim 5 or 6 wherein said target object comprises a visual display means which, in use, is visible to the eye.
8. Apparatus according to any one of claims 5 to 7 wherein said image capture device is responsive to light reflected from the eye which differs in  
10 spectrum from light from said target object.
9. Apparatus according to claim 8 wherein said image capture device is responsive to non-visible light.
- 15 10. Apparatus according to claim 9 wherein said image capture device is responsive to near infra red light.
11. Apparatus according to any one of claims 8 to 10 wherein:  
said apparatus further comprises a wavelength selective reflector effective  
20 to reflect either said visible light or said light of a different spectrum and to allow passage of the other;  
wherein, in use, visible light travels along a first optical path from the target object via the wavelength selective reflector to the eye and light travels along a second optical path from said illumination source via said wavelength  
25 selective reflector to said image capture apparatus.
12. An apparatus according to claim 9 or 10 further comprising an optical element interposed between said eye and said target object, said element being substantially transparent to non-visible radiation, and comprising a first region  
30 which is more transparent to visible optical radiation than a second region thereof.
13. An apparatus according to claim 12 wherein said first region is surrounded by said second region.

14. An apparatus according to any preceding claim further comprising an encoding means arranged in operation to encode at least part of said image signal to provide said information signal, whereby said information signal is of lesser  
5 extent than said image signal.
15. Apparatus according to claim 14, wherein the encoding means is arranged to encode at least an iris portion, or part thereof, of a captured image.
- 10 16. Apparatus according to claim 15, wherein the encoding means is arranged to encode one or more further features of the eye or surrounding face.
17. Apparatus according to any one of claims 14 to 16 wherein the means for encoding is controllable to select one or more of a plurality of encoding algorithms.  
15
18. Apparatus according to any preceding claim further comprising means to encrypt said encoded information.
19. Apparatus according to any one of claims 2 to 18, further comprising  
20 means to operate the illumination source in a pulsed manner.
20. Apparatus according to any one of claims 2 to 19 wherein said illumination source comprises a plurality of light sources emitting light in respective different wavelength bands.  
25
21. Apparatus according to claim 20 wherein said sources are controllable individually to illuminate an eye(s) for information capture.
22. Apparatus according to any one of the preceding claims, further  
30 comprising receiving means to enable bi-directional communications with said remote apparatus.

23. Apparatus according to claim 22, wherein one or more of the functions of the said apparatus is controllable by the remote apparatus.
24. Apparatus according to any preceding claim, further comprising means to  
5 select at least one image from a plurality of sequentially captured images for further processing.
25. Apparatus according to any one of the preceding claims, wherein said image capture device has a fixed focal length.
- 10 26. Apparatus according to any preceding claim further comprising means for locating an eye in predetermined relation to said entrance window.
27. Apparatus according to any preceding claim further comprising a trigger  
15 means operable by said remote apparatus.
28. Apparatus according to any one of the preceding claims, provided with means to read data from a personal identity card.
- 20 29. Use of an apparatus according to any one of the preceding claims to identify or verify a human.
30. Use of an apparatus according to any one of the preceding claims to identify or verify an animal.
- 25 31. A method of identifying a human or an animal, said method comprising:  
(a) capturing an image of an eye of the human or animal;  
(b) encoding said image to form a code of at least an iris portion, or part thereof, of the eye; and  
30 (c) transmitting said code to a remote apparatus in a cordless manner.
32. An imaging apparatus substantially as hereinbefore described with reference to any one or more of the accompanying drawings.

33. An apparatus for capturing information characteristic of one or both of a user's eyes, the apparatus comprising:

- a) a housing having a window; and
- 5 b) means for locating one or both of the user's eyes in predetermined relation to the window,

wherein the housing is provided with:

- d) means for illuminating the eye(s);
- f) means for capturing information characteristic of the eye(s); and
- 10 d) means for transmitting the information to remote apparatus.

34. Apparatus according to claim 33, wherein the housing is provided with a further window, in optical alignment with the first-mentioned window which provides to the user in use of the apparatus a view beyond the housing.

15

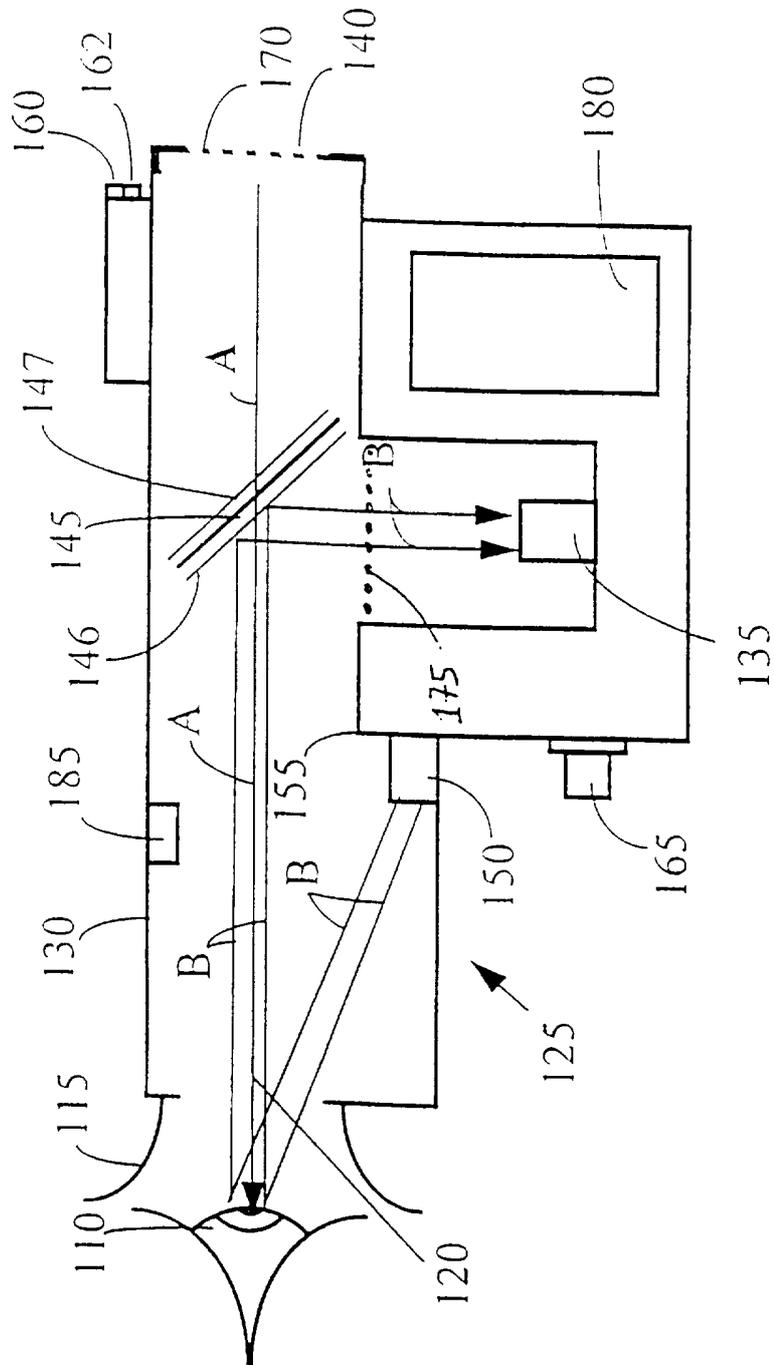


FIG. 1

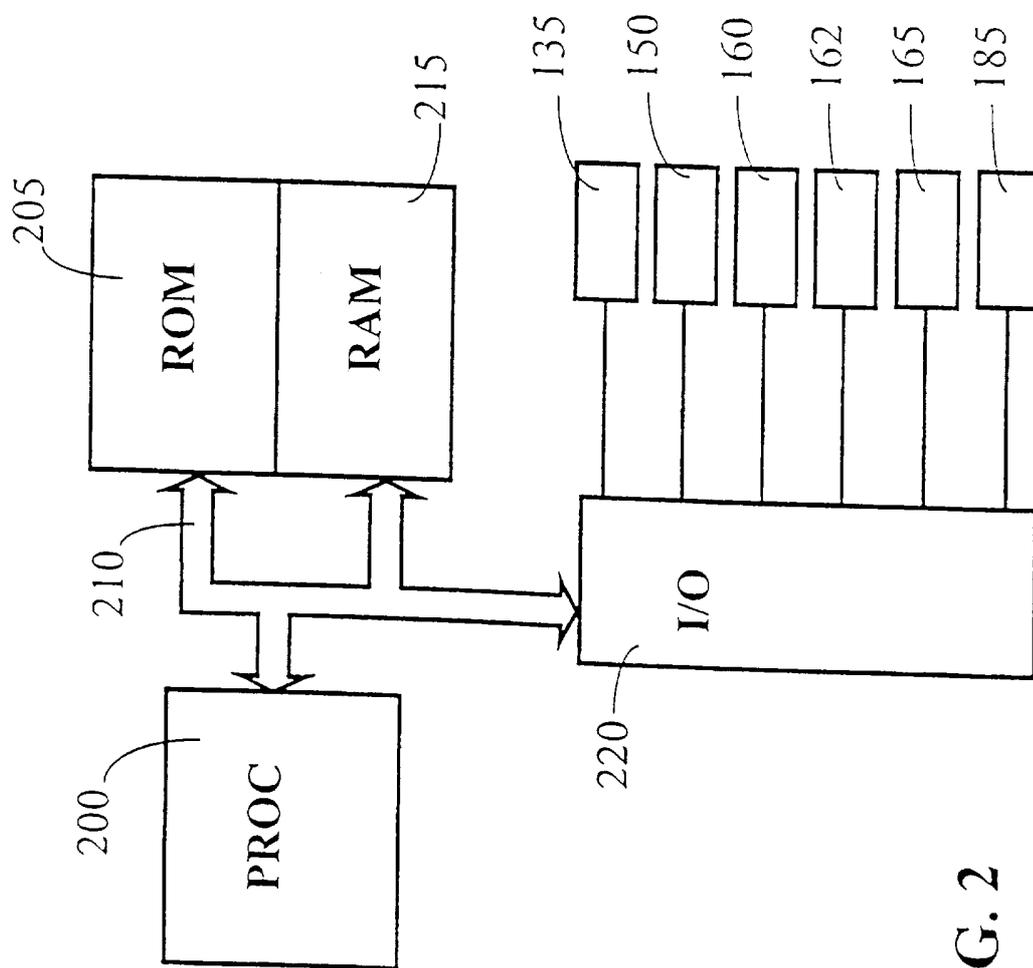
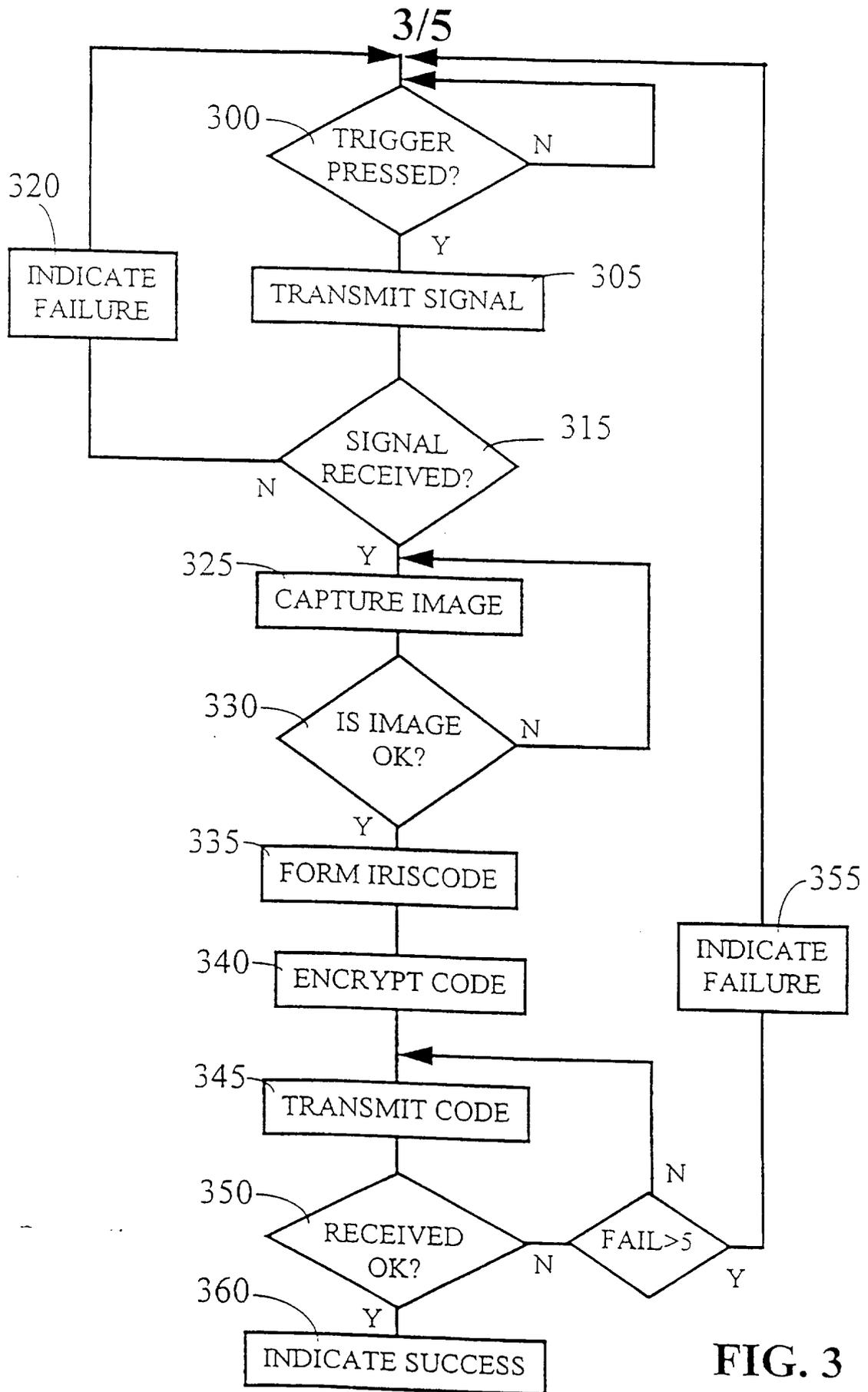


FIG. 2



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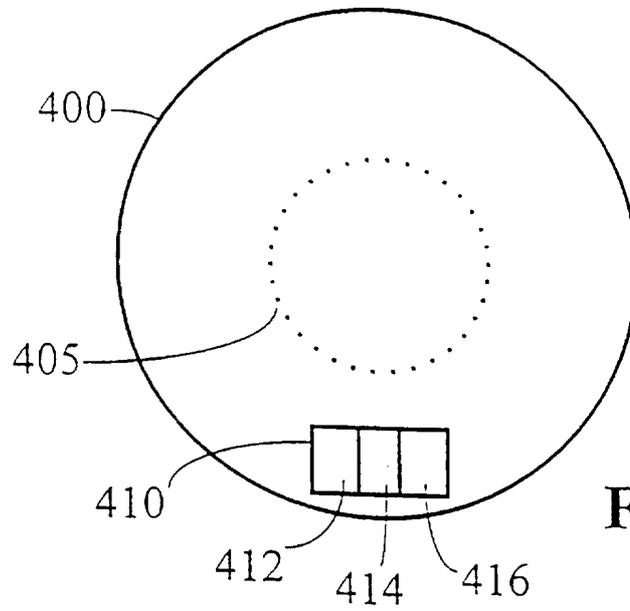


FIG. 4a

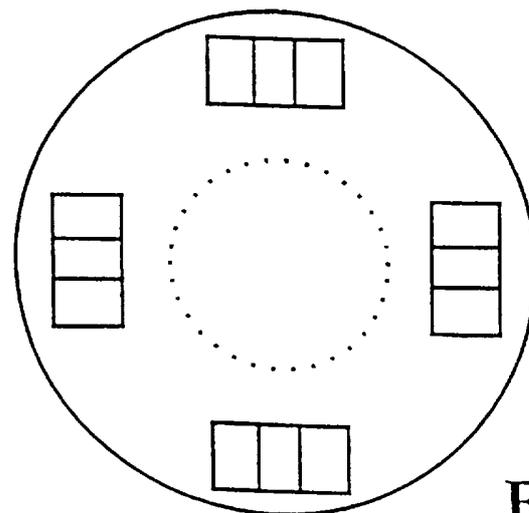


FIG. 4b

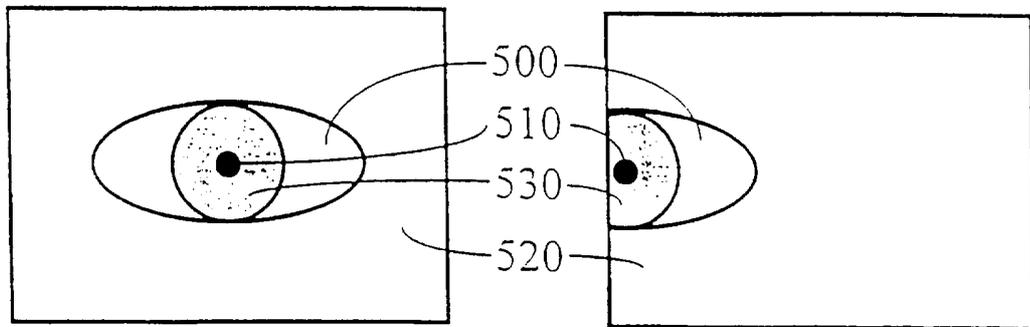


Fig. 5a

Fig. 5b

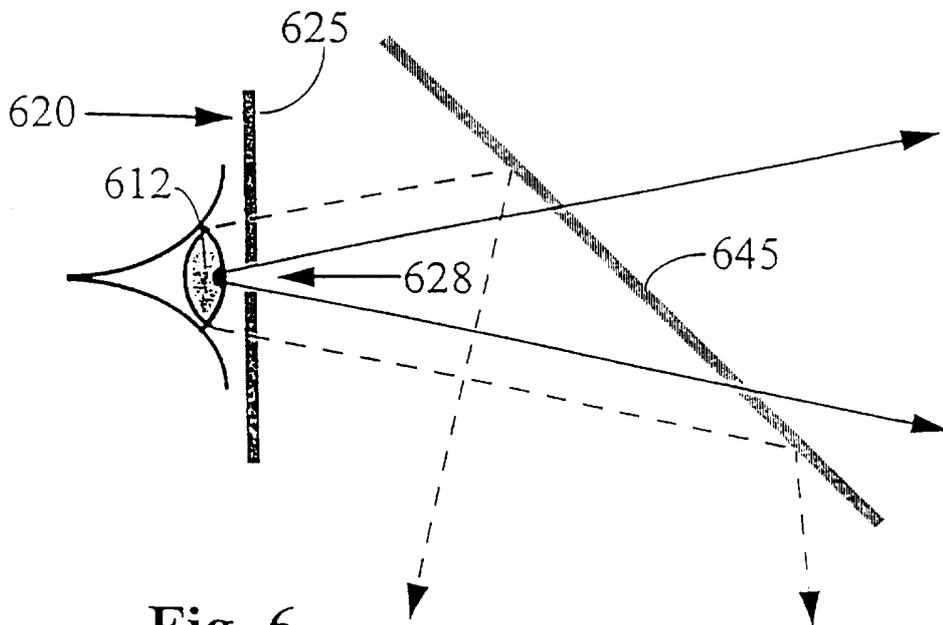


Fig. 6

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 97/01524

**A. CLASSIFICATION OF SUBJECT MATTER**  
 IPC 6 G07C9/00 A61B3/12

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

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G07C A61B

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

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

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 92 05736 A (FAIRVILLE MEDICAL OPTICS INC) 16 April 1992  see abstract; claims; figures see page 13, line 4 - page 18, line 35	1,2,5, 7-11, 19-21,26
A	---	3,4,6, 31-34
X	US 5 359 669 A (SHANLEY CHARLES W ET AL) 25 October 1994 see abstract; claims; figures see column 1, line 21 - column 2, line 40 see column 3, line 62 - column 5, line 26	1-4, 29-33
Y	---	6,14,15, 18,28,34
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Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

\* Special categories of cited documents :

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Date of the actual completion of the international search

2 October 1997

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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