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A High Resolution Electronic Imaging System for Crime Scene Use

REFERENCE: Jackson, G. R., "**A High Resolution Electronic Imaging System for Crime Scene Use,**" *Journal of Forensic Sciences,* JFSCA, Vol. 39, No. 4, July 1994, pp. 912–919.

ABSTRACT: A portable high resolution electronic imaging system has been designed and built for recording laser or ultraviolet excited fluorescent marks at serious crime scenes. A 2048 × 2048 pixel Peltier cooled CCD camera and PC-based image capture system contained in two flight cases forms the basis of the system. The captured images can be viewed at the scene to ensure recording quality and returned to the Laboratory stored on magneto optical disks for hardcopy production or digital image processing.

KEYWORDS: criminalistics, electronic imaging, fingermarks, crime scene mark detection, fluorescence

Fluorescence techniques have been used in this laboratory for many years to detect and record physical marks, particularly fingerprints [*1*]. Typically lasers or ultraviolet lamps are used to excite the fluorescence. These methods have been very successful but, like all methods, they have limitations. High resolution electronic imaging offers a way to overcome some of the difficulties and provides a means to extend the range of casework applications.

Prints developed using reagents such as 1, 8-diazafluoren-9-one (DFO)[*2*] or Rhodamine 6G usually fluoresce brightly in the visible region of the spectrum and are relatively easy to record. To maximize the detection of marks in cases of serious crimes this laboratory uses a series of development techniques. These begin with with non destructive techniques such as examination for visual and and naturally fluorescing marks. Often this natural fluorescence is considerably weaker than that of the chemically developed marks and can cause recording problems when using conventional photography. This laboratory has found it common to use exposure times in excess of 15 minutes. These long exposures are caused by failure of the reciprocity law, the nonlinear response of photographic emulsions at low light levels [*3*].

This is a particular problem at scenes of crime where the light sources available for use have lower intensity than laboratory-based systems resulting in weaker fluorescence. The use of narrow band interference filters to reduce background noise becomes impossible using conventional photography. Also, under the pressures of a serious crime investigation, even very experienced photographers cannot be sure that usable images have been captured until the film has been developed. Searching for marks using other treatments, which may damage the marks in question, is undertaken immediately. The photographer will, therefore,

Received for publication 25 Oct. 1993; revised manuscript received 3 Jan. 1994; accepted for publication 4 Jan. 1994.

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use several different time consuming exposures to ensure the mark is recorded. To help solve these problems it was considered that a portable electronic imaging system for crime scene use would be very valuable.

In addition, electronic imaging offers new opportunities to use mathematical image processing techniques [*4*]. Contrast enhancement and removal of interfering backgrounds are two examples of mathematical processing that have been found by this laboratory to give useful image enhancement. The methods employed and results will be published separately. Furthermore, electronic images can be easily passed along communication links either for remote processing or for searching in modern AFR (automated fingerprint recognition) systems.

Resolution Requirements

The recent development of high resolution electronic imaging devices have enabled near photographic quality to be achieved using charge coupled device (CCD) array and linescan cameras. These can record very low light levels and can cover a greater spectral range than most photographic emulsions. At present, CCD array cameras are available with sensitivity from 180 nanometres to over 1000 nanometres. CCD linescan cameras are available to record even higher resolutions but are not usually ultraviolet sensitive or specifically designed for low light use. Furthermore unlike tube cameras, CCD imaging sensors consist of discrete photosites of known dimension and position, resulting in good geometrical stability.

To ascertain the minimum spatial resolution required for recording typical fingermarks, faint marks developed by cyanoacrylate adhesive (CNA) were imaged at a range of resolutions. In each case the sensor area was filled by the mark. Figure 1 illustrates the results. At 512 × 512 pixel resolution the resultant image was considerably blurred and the mark features indistinct. Using 1024 × 1024 pixel resolution the image quality was better but marks still had to fill the image sensor completely to attain a useable result. 2048 × 2048 pixel resolution gave images that were comparable to small format photography whilst at 4096 × 4096 pixel resolution the result obtained was visually comparable to that achieved using 5 × 4 inch film.

The apparent sharpness of linescan images were greater than that from an array camera. One reason for this is the way the image is blurred as the electron charge is moved across the photosites of an array chip to be read out at the edge. The linear chip is read directly and therefore does not exhibit this blurring. The linear chip photosites were also physically larger than those of the array chip therefore the absolute lens quality and focusing requirements were less. In an operational environment, the practical camera setup and sizing required to fill a 1024 × 1024 resolution image sensor would be time consuming and inconvenient at a crime scene. It was decided that 2048 × 2048 pixel resolution was the minimum required for recording scene marks fairly easily while still maintaining reasonable quality. As the use of a 2048 element chip does not require the mark to fill the sensor to achieve a useable image, the camera positioning is less critical and a scale and identity label can be included in the image.

Most systems investigated had been designed for laboratory use. To use the full potential of this type of imaging, a portable system that could be used at crime scenes was needed.

General Requirements

The following criteria for design were identified:

1. The system should be portable, rugged, and possible to decontaminate.
2. There should be minimal interconnections required on site and the system should be as user friendly as possible.

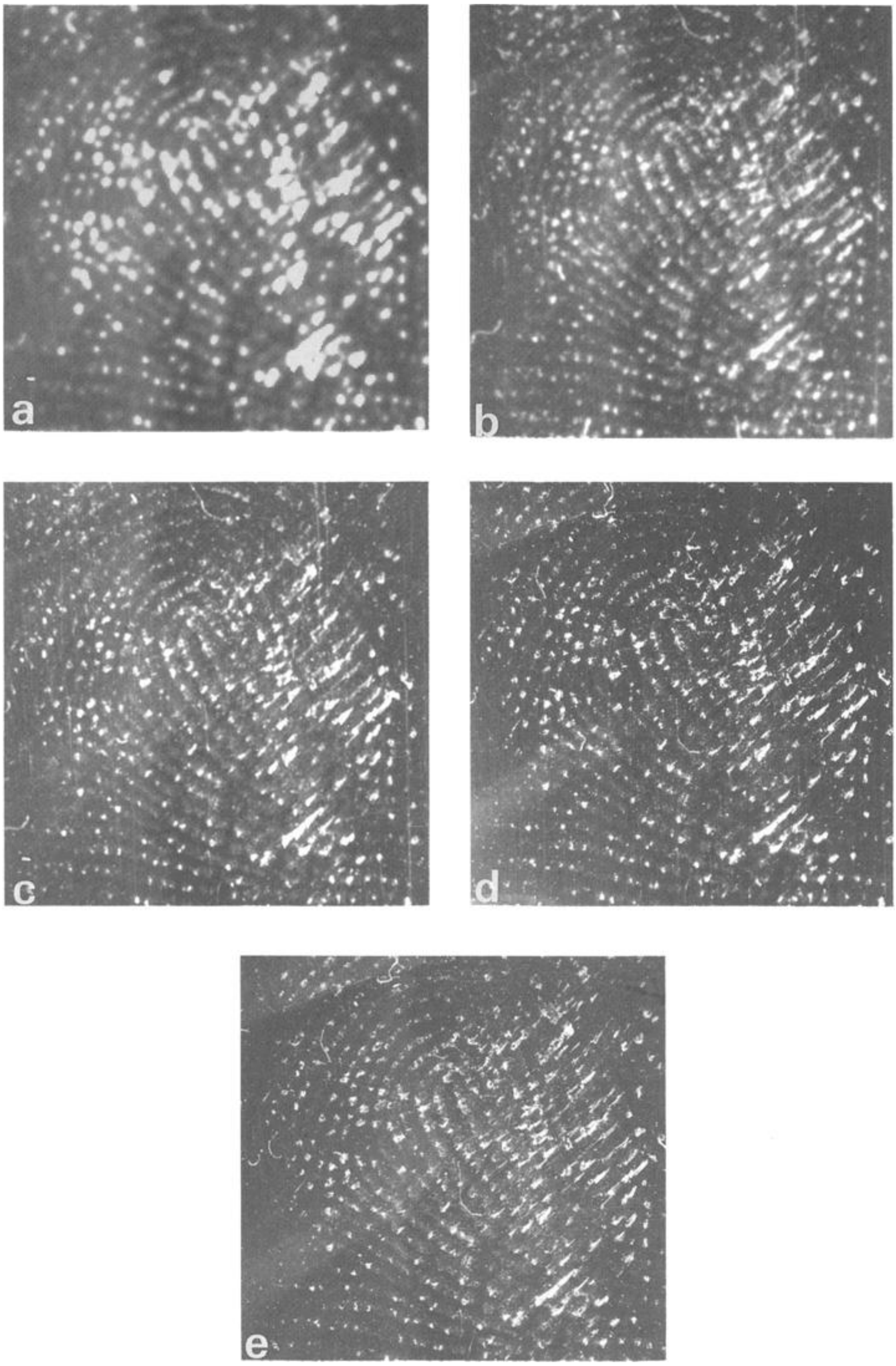

FIG. 1—*Fingermark image captured at* (a) *512 pixel resolution* (b) *1024 pixel resolution* (c) *2048 pixel resolution* (d) *4096 pixel resolution* (e) *conventional large format (5" × 4") photography.*

3. The image capture device should have at least 2048 × 2048 pixel resolution and should be easy to focus.

4. Exposure times for weak fluorescent marks should be short (seconds rather than minutes). The camera should be capable of long exposures without build up of unacceptable background noise.

5. The camera should have spectral sensitivity from 180 nm to 1000 nm to allow use of Ultraviolet absorption and Infra red luminescence techniques.

6. It should be possible to display an image on the screen with good resolution to aid quality evaluation.

7. The image files should be saved onto removable data storage devices to preserve continuity of evidence.

Design

The criteria described have led to the use of a Photometrics CH 250 (Photometrics Ltd., Tucson, AZ) camera as the image capture device. This camera is fitted with a Kodak KAF 4200 CCD chip capable of 2048 × 2048 pixels and 4096 grey levels and has extended ultraviolet sensitivity (Fig. 2). The chip is Peltier cooled to −34°C to reduce background noise. Without cooling the use of charge integration times greater than 500 milliseconds could produce a high background noise level. The camera is supplied with Photometrics PMIS imaging software, which includes image processing as well as the image capture functions. The complete Photometrics imaging system includes the camera head, peltier cooler, camera controller, computer interface board, cables and coolant leads (Fig. 3).

The standard focusing method used by the image capture software is continuous image grab and display on a monitor while the camera lens is focused. It was found in practice that the critical focusing required for the large array chip was difficult using this method and for this reason an optical viewfinder was developed. An optical viewfinder system enables the camera to be quickly and easily maneuvered into position and also aids precise focusing. The viewfinder incorporates a mirror that can be removed from the optical path

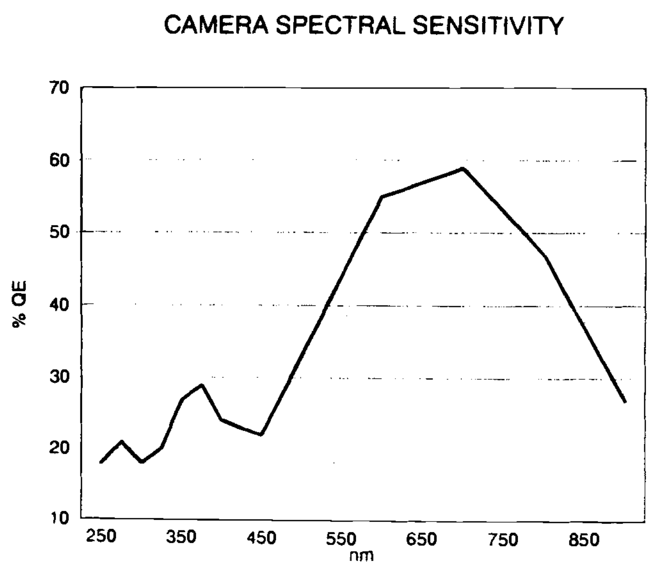

FIG. 2—*Spectral response of camera.*

FIG. 3—*Photometrics camera system as supplied to the laboratory.*

to ensure no degradation of the image and maximum light transmission to the sensor. A shutter was fitted to the eyepiece to prevent unwanted light from entering the camera (Fig. 4).

The camera head is connected to the peltier cooler by two hoses and to the camera controller by a multicore cable terminating with a 37-pin D connector. These leads could easily sustain damage and therefore a 35 mm diameter protective umbilical cord has been used for protection. A strong aluminum plate secures this to the base of the camera. The other end of the protective cord, the camera controller and the Peltier cooler have been permanently installed in the lower part of a flight case which has been fitted with filtered heat extraction fans.

The camera head, lenses, optical filters, coiled umbilical cord and computer interface cable fit into the upper part of this flight case for transportation. The camera, therefore,

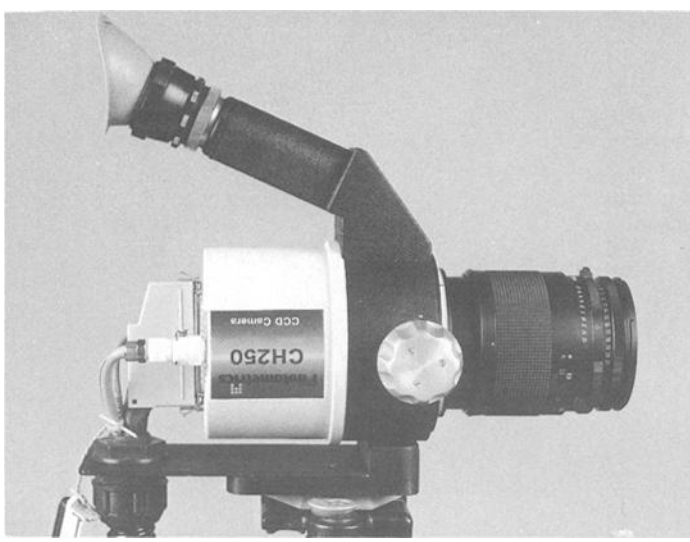

FIG. 4—*Modified camera head with optical viewfinder.*

can remain connected to the controller at all times reducing any possibility of damage to the imaging sensor. A side cable outlet port has been provided to enable the case to be closed during operation and used as a worktop or camera platform. The camera head can be used up to ten feet from its control case. This allows easy access to those areas where marks could be found at most scenes.

The computer used to control the system is a Hi Spectra Intel 80486-66MHz (Hi Spectra Ltd., Romsey, Hampshire, England) based PC containing the Photometrics interface card. It is loaded with the Microsoft Windows compatible PMIS software. This computer has been installed in another flight case using anti shock mounts and is operated within the case. A built in 10-inch SVGA monitor has been covered by a touch screen to enable operation without a mouse. A wipe-clean membrane keyboard has been fitted into the lid of the case together with a 3.25 inch 128Mbyte magneto-optical disk. A 25 pin locking bayonet socket has been provided on the outside of the case for connection to the camera controller. This and the electrical supply cables only are required to be connected on site. The computer has a network card allowing direct access to the image processing workstation if necessary. Both flight cases have been fitted with locking wheels for maneuverability (Fig. 5).

Caseworking Protocols

The correct operation of the camera system is checked at regular intervals using a standard test card comprising a registration chart and an inked fingerprint. This test card is imaged at full resolution. The resultant image is checked visually and stored using a unique filename. It is subsequently printed and the resultant hardcopy is filed in date order for subsequent examination. The equipment must not be used for operational work unless this test has been satisfactorily carried out.

If operating correctly the system may be used to record images, which are stored on the users numbered optical disk. Each image is given a unique filename. After use the optical disk is removed from the computer and kept in the possession of the user. On return to the laboratory the user transfers the image onto the image processing workstation where

FIG. 5—*Complete portable imaging system.*

the image can be either enhanced or printed directly onto conventional photographic emulsion using a filmwriter.

The optical disk bearing the original image is kept by the user until full when it can be signature sealed and stored for future reference or court use in a similar way to any other exhibit. The working copy of the image is archived to another optical disk after completion of work. This can then be stored remotely for additional security of backup data.

Filmwriter Hardcopy Devices

Filmwriters are mainly used in the computer graphics environment and allow very high resolution recording of an image onto standard photographic film. The resultant negative can then be printed onto conventional photographic paper at any magnification required with virtually no loss of spatial resolution. The Agfa FORTE Plus filmwriter in use at this laboratory is capable of 8000 lines resolution (Miles Inc., Orangeburg, NY). Most other grey level hardcopy devices give a maximum of 500 dpi (dots per inch) resolution. In the case of fingermarks where lifesize prints are normally required, assuming an average mark is 1″ square these devices would give hard copy from a 2048 pixel image as only 500 pixels whereas the filmwriter would maintain the full 2048 pixels.

Results

Ultraviolet-excited fluorescent marks illuminated using a Rofin Sinar Polilight (Rofin Australia Pty. Ltd., Mordialloc, Victoria, Australia) have been recorded using an exposure time of between 10 and 20 seconds. In comparison, conventional photographic exposures were over 10 minutes. Marks visualized using an Omnichrome Laserprint 1000 (Omnichrome Inc., Chino, CA) laser have been recorded using even shorter exposures. The ability to see the image at the time of capture can help ensure that the best image is obtained. The use of the PMIS software to improve the contrast and brightness of the screen image can allow the fingerprint expert to better ascertain whether sufficient detail exists for comparison purposes or to eliminate a mark.

Future

A 5000 $\times$ 7000 pixel, 3 $\times$ 256 intensity level color linescan camera is also in use at the laboratory. The higher spatial resolution of this device allows larger areas, such as shoemarks, to be recorded. It is envisaged that this type of device can be later integrated into the portable system to extend the range of uses.

Image data compression techniques are not used for casework at present but the use of lossless compression is being investigated. Tests made to date, using fingermark images, have shown that compression ratios better than 2:1 can be achieved by run length encoding, halving the storage space or transmission time required. Instead of using one byte of data per pixel, adjacent pixels of similar value can be stored as a sequence of pairs (n_1,v_1) where n denotes the number of pixels and v the intensity value.

Conclusion

The camera system has been taken to crime scenes for evaluation and is now well into its operational trials. It is already clear that cutting exposure times from several minutes to seconds will save considerable time at a scene where many fluorescent marks have been found. The high sensitivity of the camera extends the range of imaging techniques that can be used at crime scenes, for example the use of narrow band interference filters to reduce background interference in circumstances where low light levels made this impossible. The ability to display an real-time visual image is useful for immediate evaluation of a mark.

The imaging system discribed has been designed to have the potential to both search for and record latent marks outside the visible area of the spectrum. It has proved possible, using the system in an experimental environment, to detect marks both in the ultraviolet and near infrared regions of the spectrum. Work is ongoing to develop the full potential of the system and provide a usable caseworking method for the detection of these marks. The system described is not designed to replace conventional photography, which in many cases can be quick, inexpensive and efficient, but to supplement its use to improve the detection of evidence. Although the portable system is expensive costing approximately £60,000, improved detection of marks could lead to the early identification of a suspect, which in turn could lead to substantial savings of time and manpower.

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