Scanner Image Sensors

This issue of GIM International presents a Product Survey on Large-format Scanners. Scanners are essential for entering data in hardcopy format, such as maps and images, into the computer. But how does the conversion from hardcopy to bits and bytes (softcopy) take place? Scanning: <i>I know what it is, I know what it does, but how does it work</i>?

Scanners enable the transfer of hardcopy documents, such as images, drawings, maps and (written) text to digital format for further processing by computer. The essential component in all of this is the image sensor, which basically scans the document along two perpendicular axes and â€˜readsâ€™ the hardcopy. Using the sensor movement along the two axes as a decisive feature, scanners can be categorised into four main groups, as summarised in the Table. We shall now investigate how the scanner reads the document.

Electrical Current
Image sensors are based on two semiconductor technologies:

- Charge Coupled Devices (CCDs)
- Complementary Metal-Oxide-Semiconductors (CMOS).

The focus here is on CCDs, because these are what are used in large-format scanners. In terms of conducting electrical currents (EC), materials may be subdivided into three groups:

- insulators (no EC conduction)
- metals (easy EC conduction)
- semiconductors (EC conduction under constraints).

Examples of semiconductors are Silicon (Si) and Germanium (Ge). Basically, imaging semiconductors are able to generate an electrical current in the presence of electromagnetic energy (photons), provided that the energy content of the photons is high enough. Light with wavelengths shorter than 1,100nm - basically the visible and near-infrared part of the electromagnetic spectrum - is capable of generating an electrical current in a Si-semiconductor. In order to construct an imaging device from semiconductors a set of semiconductor elements (pixels) has to be charge-coupled. The simplest arrangement of pixels is in a single line; linear sensors are today by far in the majority. Frequently, 7,500 elements are put in line, although 10,680 pixels are also used. Another arrangement of pixels is in an array. The size of the pixels in combination with the optics determines the resolution of the scanner, which is usually given in pixels per inch (ppi) or, identically, dots per inch (dpi).

Shift Register
To read out the electrical current generated by the captured photons over a certain time interval (integration period), a CCD shift register is mounted next to the line of pixels. While the packets of charge are transferred through the CCD shift register towards the output stage, a new integration period begins. This production line enables continuous imaging. At the output stage the electrical current is sampled with clock frequency corresponding to the size of the pixels. In this way, a grey-level measure corresponding to the volume of captured photons is assigned to each individual pixel. This measure is digitally stored in the form of bits. The number of bits used lies between 8 bits (256 grey levels) to 16 bits (65,536 grey levels). Since almost all software and hardware supports only 8-bit per pixel, data is usually reduced to 8-bit. Often the user can influence the conversion through a Look-up Table (LUT).

Colour
The above CCD configuration produces a grey-level (monochrome) image. The additive colour model, in which Red, Green, and Blue (RGB) light is combined in various ways, enables the creation of colour images. Using filters, the image is decomposed into the three basic RGB components. There are several ways of implementing the filters. First, the pixels themselves may be provided with filters. Because three device pixels (one for capturing each of the three RGB components) are necessary for generating one output pixel, this solution reduces spatial resolution. Another approach is to place filters sequentially in front of the optics and this solution requires three scans. The most widely used solution is the trilinear CCD: one linear CCD for each of the three (RGB) colours.

Light
To generate photons an artificial light source is necessary. The position of the light source depends on whether the document is transparent or opaque. The higher the scan speed, the higher the illumination, since integration period is directly proportional to scan speed. A proper balance of colours present in the light source is also a critical factor for arriving at good results.