On-line digital imaging

Ed Boyes looks at digital image processing — the technique which gleans quantitative data from pictures.

DIGITAL techniques are increasingly being used to enhance, standardize and sometimes replace conventional photographic recordings. This growing interest in digital analysis arises largely from the fact that image processing puts a quantitative value on an otherwise qualitative picture, making it possible to compare two photographs accurately, or to glean more detailed information from a single image.

The essential difference between conventional photographs and digitally-processed images is that in the latter the image is converted to a digital form and stored as numbers in a large semiconducter image memory, or "framestore" attached to a computer, rather than being exposed directly onto a piece of film or an instant film pack. With typical commercially available equipment this means that images of at least 512 × 512 picture points, or pixels, can be quantified and stored directly from virtually any input, such as a TV camera or an ultra-sound scanner. The picture can be analysed with 8-bit precision, by splitting the image into 2^8 (or 256) shades of grey or colour before it is stored, with a chance of "doctoring" the image both immediately after input and again before output. In this way the image can be changed before an actual picture is produced, so that areas of interest can be enhanced and the background subdued, or colours can be added to increase contrast. Image processing also provides the opportunity to present other physical values in a visual form.

Advantages

Image enhancement procedures are designed to produce the best possible image from the input, and to assist the analysis and communication of results. In doing so, digital techniques have three major advantages over conventional techniques. First, once the data have been in the computer, the images are available for processing in any order with random access to the memory, unlike conventional films which have to be analysed in sequence. Second, image sequences can be displayed on the video screen and frozen electronically at any time for closer inspection. Third, the original data is kept intact and can be repeatedly analysed without distortion. Furthermore, any analytical procedures used on the data can be explicitly defined and recorded.

Enhancement techniques

At the most simple, but nevertheless essential, level of data processing, the brightness and contrast of the image are enhanced so that features of special interest can be picked out more easily. More complicated imaging needs more advanced techniques. Many scientific signals are either very infrequent or very weak, coming complete with heavy background noise. To break these down requires long integration times, during which the image is built up in the memory store and controlled from the display on a video screen. Signal to noise ratios can be improved by averaging successive frames from a TV camera with a controlled output or by summing the data from adjacent pixels, which brings out the similarities in the data and hence the differences between the data and the background. When the noise level of the input is lower, a modified processing of adjacent pixels, for example in a 3 × 3 array, can be used to sharpen edge-detail by enhancing the differences rather than the similarities between the groups. Similarly, information about intensity may be made more meaningful by producing a non-linear output. An example of this would be in an experiment where the temperature was being increased from 0 to 1,000°C, but in which it was important to see the point at which 600°C was reached. This changeover would be made more obvious by representing, for example, all temperatures below 599°C by the colour green and all those above 600°C by the colour red.

Clearly, digital image processing is a useful analytical technique. It therefore seems curious that it has only become widely used in the last few years, even more so when you consider that analog electronic analysis has been in use far longer, despite the fact that it can only analyse serially and the information that it gives is much less useful. The problem with developing digital techniques has been that until recently, digital image processing has required a substantial mainframe computer, and, even then, there were only facilities for on-line analysis and control in very specialized applications. Now, however, laboratory-scale systems are available with typical image memories of 512×512 or 1,024×1,024 pixels. Each picture point from the input is mapped to an equivalent position on the computer video screen. If the input frequency is slow, the image processing can be carried out by computer alone. This gives a highly flexible system, but severely limits the rate at which data can be handled. To reach the 15 MHz required by a raster scan demands that some flexibility be sacrificed by the introducton of a piece of dedicated hardware, such as the recursive video processor, or RVP.

The RVP is essentially capable of doing three things — it can take the difference between adjacent frames, and it can sum or average incoming signals to improve the signal to noise ratio. Averaging the signal involves taking data from the store and comparing it with the incoming data, so that, for example, one eighth of the output comes from the input data, and seven eighths from the running average. In addition to controlling noise, it is important to avoid distortion of the image during processing. Any digital processing system is capable of generating a picture without an input, and so it is essential to make sure that interference is kept to a minimum.

It seems that in the future, digital imaging techniques will split into three main categories with cost being their main divider. First, there will be the simple units to store or compare single images in digital form with a TV output display. These are now becoming available as single computer cards, similar to those upon which the latest high-resolution colour VDUs are based. Second, when any significant level of processing becomes necessary, some kind of computer will have to be involved, and this in turn will require extensive software, suggesting that some kind of package system will be developed. At the third level will come the highly sophisticated, fully integrated sytems with powerful processors attached to multiple framestores and extensive processing, analysis and storage facilities.

Luckily, it is emerging that many image processing methods require very similar hardware and software. It appears that all that is needed to specialize the systems is a tailor-made sensor coupled to personalized software. □

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