



COMPUTER IMAGE PROCESSING

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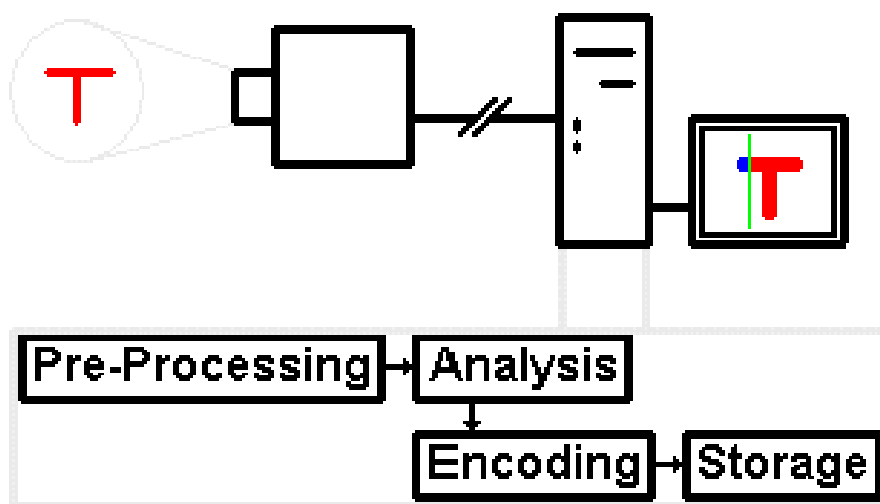


Introduction

Image processing is a growth field covering a wide range of techniques for the manipulation of digital images. With the low cost and high availability of CCD cameras, more companies than ever before are able to utilise image processing software and reliable hardware in their research, production and quality control environments, as well as in their products. This technical supplement briefly describes some of the principle techniques available for image processing and how they may be used.

Setup

Until recently, image acquisition and analysis was a costly procedure requiring specialist camera equipment, framestores and high specification computers with processing accelerators. Modern computer speeds, CCD cameras and a dramatic increase in storage capacity mean the cost of hardware has been significantly reduced, but with increased quality. A typical hardware and software solution for image processing is shown below:



Overview of Processing Methods

Image processing is a general term most often used to describe digital image manipulation in all forms, though it can be dissected into three main areas: Encoding, Transformation and Analysis.

Encoding describes the methods by which an image can be represented as a series of binary digits. They say that an image is worth a thousand words and in terms of storage space that can be a conservative estimate. Encoding concentrates on reducing the size of the data that represents an image, for transmission or storage.

Transformation is the process of altering the image to make it more suitable for the intended purpose. Many people use software programs such as PhotoShop to remove noise and correct light imbalances in their digital photos. Operations like these can also be performed in an automated environment to prepare an image for presentation or further analysis.

Analysis allows conclusions to be drawn from an image. Image analysis can take the form of identification of features, statistical analysis, classification, measurement or a combination of these. The methods used to analyse images vary greatly, some common examples are presented later.

Encoding

As images are information rich, they can take a large number of binary digits to describe them. For this reason, the main aim of encoding is size reduction, equating to higher speed of transmission and lower requirements for storage. Lossless methods concentrate on compacting the binary data using encoding algorithms - the most commonly used example is WinZip. Good levels of compression can be achieved in this way, with no loss of clarity when the image is decompressed. To achieve higher levels of compression there are 'Lossy' encoding techniques. 'Lossy' encoding methods (such as JPEG) are varied but tend to work on the principle of reducing the total amount of information in the image in ways that the human eye will not detect. Decoding an image encoded using a 'Lossy' algorithm will not return the original image but rather an approximation of it. The different methods of encoding are often best suited to certain types of image, some knowledge and skill may be required to choose appropriately.

Transformation

When processing an image, there are a variety of methods available to get the desired results. Broadly they can be broken down into Histogram Operations, Arithmetic and Logical Operations, Convolution Operations, Derivative Operations and Morphological Operations.

Histogram Operations allow the balance of colour or intensity within an image to be remapped. A histogram of a number of pixels against intensity is produced for an image (this describes, in graphical form, the probability distribution function (PDF) of the image). A function f is then generated to describe the mapping between the actual PDF of the image and the desired PDF. Each pixel is transformed by f to generate a new image.

Using this method, contrast can be ‘stretched’ to increase the definition of features within an image. Another common application of Histogram operations is that of Equalisation. This application sets all intensity levels to have an equal distribution and is used to compensate for differential lighting conditions on images before comparison.

Arithmetic and Logical Operations allow the combination of images by performing simple calculations on the values of corresponding pixels within two images. The resultant value of the calculation becomes the value of the pixel in the new image. The simplest operations of this sort are binary calculations with black and white images, such as those shown below:



Image A Image B AND(A,B) OR(A,B) XOR(A,B) SUB(A,B)

Convolution Operations are very powerful whilst being essentially simple, giving a means to remove noise and smooth an image. Convolution produces a new image based on the result of a convolution filter (also known as a kernel) being moved over the source image. The filter is a grid that is smaller than the source image. At the centre of the filter is the target pixel; the output value (O) of the pixel at the target position is the sum of the multiples of the filter values (K) by their corresponding source pixel values (I).

$$[h_x] = \frac{1}{3} \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$$

Prewitt Gradient Filter (x filter with y smooth).

$$[h_y] = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

Prewitt Gradient Filter (y filter with x smooth).

Derivative filters are used to pick features from images of 3D relief surfaces, such as stone carvings, where it is the gradient change that defines the image.

Morphological Operations are used to pre-process images for recognition and classification. Dilation and Erosion are basic operations used to ‘grow’ or ‘shrink’ entities within an image. They are used as the basis for the more useful operations Opening and Closing. Opening is used to separate joined entities within an image, Closing is used to join entities within an image. These two operations are very important in pre-processing for image analysis as they can be used to differentiate between entities. The construction of the Opening and Closing filters requires structuring elements to be defined. The structuring elements tend to be application specific and require *a priori* knowledge of the problem domain meaning there is no ‘perfect’ solution for all situations, rather requiring experimental development for each problem type. Additional morphological operations such as Skeletoning and Seeding can be used to define the underlying structures in images, providing a form of analysis in their own right.

Analysis

The Analysis that can be performed on an image is dependent on the type of image and the information it contains. As with Radio communication, the useful information in an image can be thought of as the Signal and the extra information as the Noise. To perform accurate analysis of the Image it is important to

remember that the image has been changed when carrying out pre-processing, therefore measurements recorded during the analysis may have to be adjusted to compensate.

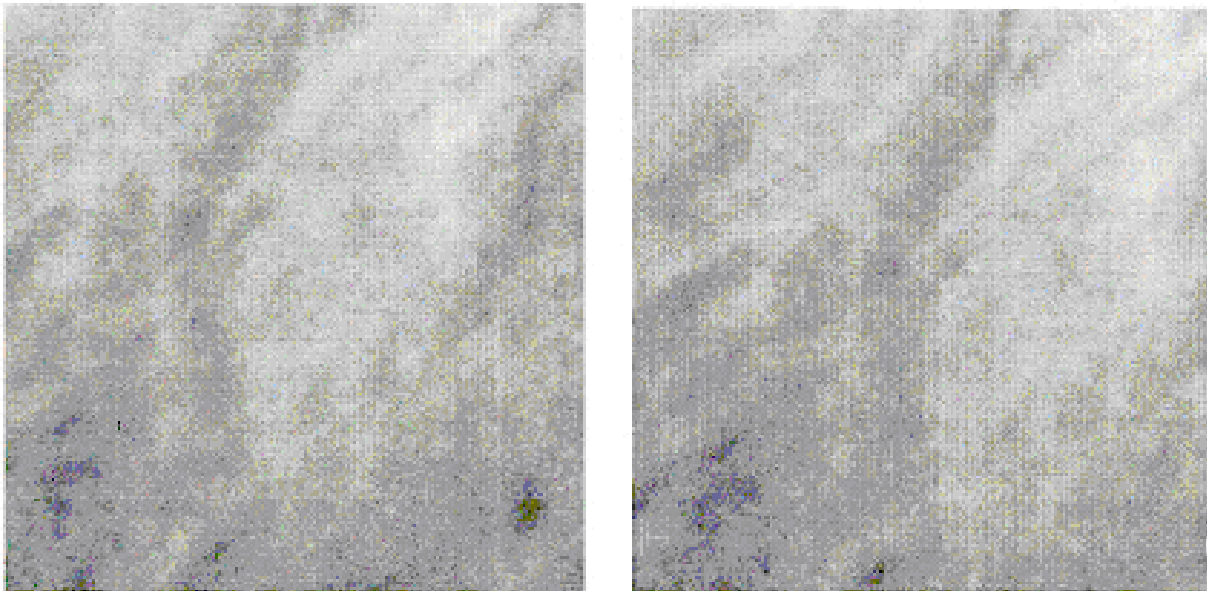
Region Identification provides an automated way to identify regions within an image by correlation or criteria matching. Correlation involves comparing collections of points on two images for similarities; a correlation of 1 would be a complete match. Setting up such automated systems often requires a significant 'training set' of data so that thresholds and compensation values can be set. Region identification has been used successfully in several fields, including tissue typing in medical images and environmental surveying from satellite images.

Counting and Measurement are widely used within the biological community to perform automated measurements of cell size and number of cells. Techniques such as Opening and Closing are used to identify the individual cells before a series of measurements are taken. By identifying the cells beforehand the problem becomes quite simple and measurements can be taken from a 'mask' of the cell. The proximal axis, total area, boundary size and orientation can all be determined from a simple binary mask of the cell. Additional measurement accuracy can be gained by considering an intensity mask to overcome the quantisation effect of using a digital image. An intensity mask considers the pixels neighbouring those on the edge of an entity and assigns a proportional value based on the intensity. Using an intensity mask is often problematic to set up, as the relationship between the intensity and the size is non-linear and direction dependant due to lighting. The problem can become much more complex in environments when overlapping occurs and segmentation is non-trivial.

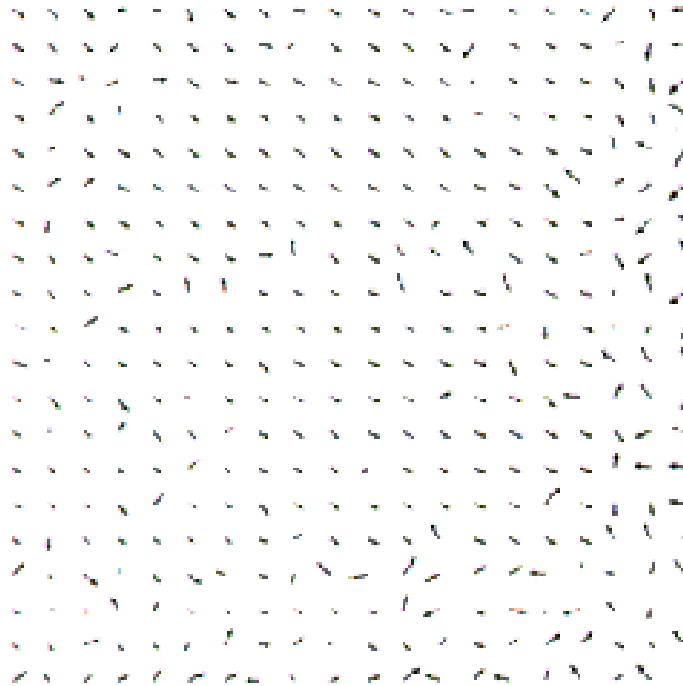
Object Classification is often used in combination with region identification to classify objects identified within an image. In simple cases the objects can be quite different, such as differentiating circles from squares - more complex tasks require the identification of defective goods or classification of very similar objects. Classification often involves identifying the unique features of a class and subjecting the image to analysis to look for those features, although there is another way. Neural networks (Artificial Intelligence) have been used to perform classification without specific identification of unique features but rather by 'training' with examples.

Meteorological Example

Satellite images can be analysed to determine cloud movements and hence wind velocities. The principle involved is the matching of sections of one image with different parts of another image over the same ground area at a later time. This is performed by calculating a correlation coefficient between the sections of the two images with different offsets. A good match, i.e., high correlation coefficient, is found when the parts of the images being compared contain the same cloud formations. The relative positions of the matching parts of the images show how far the clouds have moved and so the wind velocity can be calculated. By repeating the process at many points on the images a wind velocity map can be built up. This is illustrated by the following images and map:



Images corresponding to two different times



Calculated wind velocity map

There are areas in the velocity map in which the vectors are not aligned with the surrounding ones. This can occur because a corresponding region of the image has changed too much as well as being shifted - clouds can form and disappear - or because the region is featureless (or has moved out of the field of view). However, this relatively straightforward method has been generally successful in identifying the motion in the image.

Infrared Imaging Simulation

Tessella was asked by the DRA Farnborough to provide a simulation environment for determining the visibility of objects using infrared imaging. The system was based on AVS, a data visualization system, and in particular its Network Editor. This allows a user to control data processing by setting inputs and outputs of previously defined modules using a graphical interface. The initial system included modules to simulate the emission of IR radiation from objects, to simulate IR detection by sensors and to interface with an existing model of atmospheric transmission of IR radiation. The system was extended by the

addition of modules to generate various MTF (modulation transfer function) curves to describe various modifications to radiation, which would be caused by:

- Diffraction in finite sized detectors
- Geometric blur
- Image motion
- Various specific detectors
- Electronics
- Visual displays of various types
- Human eyes

The modelling environment allows these to be combined in arbitrary ways.

Printing Analysis Example

Tessella was asked to make recommendations on software suitable for analysis of a number of different types of printing on paper. A list of required measurements was drawn up:

- Halftone screen angles and frequencies
- Halftone dot shapes
- Photocopy/laser print line frequencies
- Photocopy/laser print dot separations
- Photocopy/laser print toner particle size and shape characterisation
- Ink colour measurements
- Paper fibre size and shape characterisation

From this list the required features of software packages were determined. These included:

- Segmentation and thresholding of colour and grey scale images.
- Identification of objects as regions of interest.
- Geometrical measurements of objects.
- Fourier transforms for spatial frequency measurements.
- Facilities for customisation.

It was recognised that none of the packages could carry out all of the required tasks so a means to add functionality was essential. The various packages on the market were assessed in view of the above requirements and in terms of what additional work would be required to complete the package. A recommendation could then be made on which system represented best value for money.

Tessella and Image Processing

Tessella has many years experience in building scientific/technical data analysis and visualization applications. Tessella employees have worked in meteorological image processing and in image analysis to interpret scenes by finding edges and surfaces within them. Tessella has also been involved in work to measure bands on electrophoresis plates in the analysis of DNA; creating specialist image processing tools to remove distortion and artefacts from biotech gel images; and in consultancy work in the area of security printing.

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