The process and application of image analysis

Design, Photography

Image is a visual representation of a person or a thing. Images may be two-dimensional, such as a photograph or screen display, or three-dimensional, such as a statue. They may be captured by optical devices, such as cameras, telescopes, microscopes, etc. and natural objects and phenomena, such as the human eye or water.

An image is a representation of two-dimensional functions, where x and y are represented as spatial (plane) coordinates, and the amplitude off at any pair of coordinates (x, y) is referred to as the gray level of the image at that point.

A digital image can also be defined as a discrete representation of data that possesses both spatial (layout) and intensity (color) information.

Image analysis is the process of extracting significant information from images; mainly from digital images by means of digital image processing techniques. Image analysis is a computer-based process of extracting measurable information from images. The process starts with using image as an input and ends with the output of numerical data. This differentiates image analysis from image processing where both input and output are in the form of an image.

Image processing is a phenomenon whereby the input image is modified by one or more mathematical algorithms to produce an enhanced output image. For example, the noise in an image can be reduced.

Image analysis is best understood as a process consisting of a combination of steps. Not all steps are performed in all image analysis algorithms, and some steps may be explicit as multiple steps in one algorithm and form a combined step in another, different algorithm, but the steps described below are typical.

Preprocessing

The purpose of preprocessing is to remove as much variation as possible from the image without losing essential information. There are many sources of variation during image acquisition. Image device manufacturer and type, different sizes of field of view, variations in flash illumination, exposure duration are all examples of variation between images taken for the same purpose. These variations do not contribute to the understanding of the image, but they may alter further image analysis steps.

Preprocessing attempts to eliminate some or all of these sources of variation, as much as possible. A simple example is field of view: by scaling the image, and subtracting unexposed areas of the image, images from different cameras are normalized to a “ standard fundus image.”

Detection

The purpose of detection is to locate, typically in a preprocessed image, the specific structures of interest, or features, without yet determining their exact boundaries. Examples of such features can be edges, dark or bright spots, oriented lines, and dark–bright transitions in OCT images. Other terms in use for the concept “ structure of interest” are wavelets, textures, or filters. Typically, each individual pixel in the image is examined for the presence of one feature or more, and usually the surrounding area, or context, of each pixel is included in this examination. The output of the matching process indicates if and where the features were detected in the image. In some image analysis systems, this output is interpreted directly, while in others, a segmentation step (see below) is used to determine the exact boundaries of the object represented by the features.

Segmentation

The purpose of segmentation is to determine the precise boundaries of objects in the image, when the presence of specific object features has been determined in the detection step. For example, if the ganglion cell layer in an OCT image is detected but still has disjoint boundaries, the segmentation step connects these into a connected boundary. Commonly used segmentation techniques are graph search and dynamic programming, both of which try to find the mathematically best-fitting boundary, given the specific detection output(s). The output of the segmentation step can be used directly for assessment, for example when showing the different layers on a macular OCT scan, or can be the input for an interpretation step.

Registration

The purpose of registration is to find similar regions in two or more images so they can be localized. Registration is often used to overlay an angiogram on an OCT image, compare images from the same patient from two different visits, to detect improvement or worsening of the patient's condition between visits, where several fundus images are stitched together into one image covering a larger area of the retina. The registration step often utilizes similar functions as the detection step.

Interpretation

Usually, when the preceding steps have been completed an interpretation step is used to output relevant information. If the boundaries have been segmented, interpretation involves calculating the distance between the boundaries, so the user can see the thickness of the different layers at specific locations.

Applications of image analysis

Image analysis is advancing, and it has been applied in several fields of life. To broaden our knowledge on the research area, we need to examine the significance of image analysis in some specific areas.

In 2003, Honglu Yu and John MacGregor developed an online digital imaging systems for process monitoring and control is illustrated through two industrial applications: i) the control of coating concentration and distribution on snack food products, and ii) the monitoring of boiler systems through imaging of the combustion processes. Feature information extracted from images using Multivariate Image Analysis (MIA) based on Principal Component Analysis (PCA), is used to develop models to predict product quality and process property variables. The imaging systems are used to monitor this product quality and process property variables, to detect and diagnose operational problems in the plants, and to directly implement closed loop feedback control.