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Real Time 3D Imaging and Processing

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Abstract: ***Over the past dozen years forensic and medical applications of technology first developed to record and transmit pictures from outer space have changed the way we see things here on earth, including Old English manuscripts. With their talents combined, an electronic camera designed for use with documents and a digital computer can now frequently enhance the legibility of formerly obscure or even invisible texts. The computer first converts the analog image, in this case a videotape, to a digital image by dividing it into a microscopic grid and numbering each part by its relative brightness. Specific image processing programs can then radically improve the contrast, for example by stretching the range of brightness throughout the grid from black to white, emphasizing edges, and suppressing random background noise that comes from the equipment rather than the document. Applied to some of the most illegible passages in the Beowulf manuscript, this new technology indeed shows us some things we had not seen before and forces us to reconsider some established readings.***

Keywords: Anti-Aliasing, Re-sampling, Replication, Raw Data, Picture Element, Image Functions.

1. Introduction

Pictures are the most common and convenient means of conveying or transmitting information. A picture is worth a thousand words. Pictures concisely convey information about positions, sizes and inter-relationships between objects. They portray spatial information that we can recognize as objects. Human beings are good at deriving information from such images, because of our innate visual and mental abilities. About 75% of the information received by human is in pictorial form. Vision allows humans to perceive and understand the world surrounding us.

In the present context, the analysis of pictures that employ an overhead perspective, including the radiation not visible to human eye are considered.

- Computer vision aims to duplicate the effect of human vision by electronically perceiving and understanding an image.
- Giving computers the ability to see is not an easy task - we live in a three dimensional (3D) world, and when computers try to analyze objects in 3D space, available visual sensors (e.g., TV cameras) usually give two dimensional (2D) images, and this projection to a lower number of dimensions incurs an enormous loss of information.
- In order to simplify the task of computer vision understanding, two levels are usually distinguished; low-level image processing and high level image understanding.
- Usually very little knowledge about the content of images
- High level processing is based on knowledge, goals, and plans of how to achieve those goals. Artificial intelligence (AI) methods are used in many cases. High-level computer vision tries to imitate human cognition and the ability to make decisions according to the information contained in the image.
- This course deals almost exclusively with low-level image processing, high level in which is a continuation of this course.
- Age processing is discussed in the course Image Analysis and Understanding, which is a continuation of this course.

2. Image Functions

The Image Functions:

- The image can be modeled by a continuous function of two or three variables;
- Arguments are co-ordinates x, y in a plane, while if images change in time a third variable t might be added.
- The image function values correspond to the brightness at image points.
- The function value can express other physical quantities as well (temperature, pressure distribution, distance from the observer, etc.).
- The brightness integrates different optical quantities - using brightness as a basic quantity allows us to avoid the description of the very complicated process of image formation.
- The image on the human eye retina or on a TV camera sensor is intrinsically 2D. We shall call such a 2D image bearing information about brightness points an intensity image.
- The real world, which surrounds us, is intrinsically 3D.
- The 2D intensity image is the result of a perspective projection of the 3D scene.

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- When 3D objects are mapped into the camera plane by perspective projection a lot of information disappears as such a transformation is not one-to-one.
- Recognizing or reconstructing objects in a 3D scene from one image is an ill-posed problem.

3. Image Representation

Any image refers to two-dimensional light intensity function f(x, y) where x and y are special co-ordinates with their origin at left top end of the image. The value of f at any point is proportional to the brightness of the image at that point. Thus any digital image can be considered as a matrix whose row and column indices represent a point in the image and the corresponding matrix element value represent the gray level at the point. The elements of such a digital image are called picture elements or PIXELS.

4. Color Composites

While displaying the different bands of a multispectral data set, images obtained in different bands are displayed in image planes (other than their own) the color composite is regarded as False Color Composite (FCC). High spectral resolution is important when producing color components. For a true color composite an image data used in red, green and blue spectral region must be assigned bits of red, green and blue image processor frame buffer memory. A color infrared composite 'standard false color composite' is displayed by placing the infrared, red, green in the red, green and blue frame buffer memory. In this healthy vegetation shows up in shades of red because vegetation absorbs most of green and red energy but reflects approximately half of incident Infrared energy. Urban areas reflect equal portions of NIR, R & G, and therefore they appear as steel grey.

5. Digital Image Properties

Metric properties of digital images:

- Distance is an important example.
- The distance between two pixels in a digital image is a significant quantitative measure.
- The Euclidean distance is defined by Eq. 2.42
- Pixel adjacency is another important concept in digital images.
- 4-neighborhood
- 8-neighborhood

6. Spatial Filtering

A characteristic of remotely sensed images is a parameter called spatial frequency defined as number of changes in Brightness Value per unit distance for any particular part of an image. If there are very few changes in Brightness Value once a given area in an image, this is referred to as low frequency area. Conversely, if the Brightness Value changes dramatically over short distances, this is an area of high frequency. Spatial filtering is the process of dividing the image into its constituent spatial frequencies, and selectively altering certain spatial frequencies to emphasize some image features. This technique increases the analyst's ability to discriminate detail. The three types of spatial filters used in remote sensor data processing are: Low pass filters, Band pass filters and High pass filters.

7. Interpolation

This process is also called as "re-sampling" or "anti-aliasing". This is far different from the pixel "replication". In image replication the value of a pixel is just sent to the neighborhood cells as shown below;

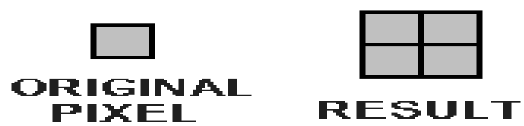

Figure 1

The result is the bigger version of the original image. This replicated data is called as "raw data". Interpolation is an entirely different process. Each pixel, or "Picture Element" has a grayscale value for the all the details in the area it covers. The area of a single pixel in the MGS Face image is about 18.67 square feet (it is somewhat better in the subsequent images).

In a camera like the one on MGS space craft all the details in a given area - in this case the square pixel - are derived from the *average* shade or "value" in the 18.67 square foot area.. Each pixel is derived from an eight-digit binary number representing a shade of gray from total black to total white in 256 gradations (extrapolated from an original 128 gray levels recorded by the camera.) The human eye can detect only about 32 different levels of gray, so the digital imaging and subsequent processing constitutes at least a fourfold improvement over visual seeing, especially when enhancement techniques are applied in the computer, which can integrate over these 128 levels. In other words, there is more data in a single pixel than is displayed by that pixel in a raw image.

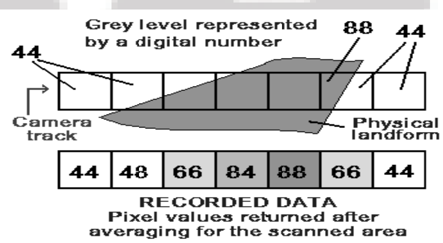

Figure 2

The above figure explains as to what happens as the camera passes over the edge of a land form .If one darker area has a value of 88, and the lighter area to the right has a grayscale value of 44, then the optics will record an integrated or averaged value of 66 for the shared pixels. The result of this,

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that the edges and fine details may be lost and unrecognizable in a "raw" transmitted image.

What interpolation does is to take the data in the individual pixels and use their relationships to each other to determine the best solution. These relational values contain more information than is visible to the eye (which can only see about 32 shades of gray) and depending on the algorithm used can recover much of the "lost" (averaged) data concerning the original shape of the object.

8. Algorithm

Step1: The original large pixel is divided into number of smaller pixels
Step2: The individual pixel of the raw data, queries and the proscribed number of surrounding pixels, which contribute to the appropriate values for the new pixel. i.e. The value of the new pixel is derived from the shared values of the original pixel.

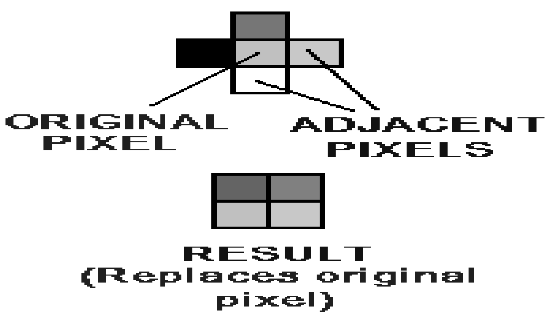


Figure 3

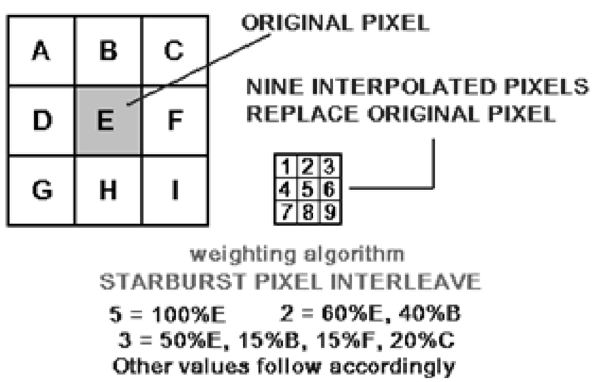


Figure 4

The above figure is a result of bilinear interpolation, which multiplies the original pixel into four. The adjacent figure, multiplies the original pixel into nine.

Step3 - The process then moves on to the next raw pixel and this repeated until the image is complete.
Step4 - If the process has been tested against actual objects for accuracy - which all-Interpolative methods used, have - then the result can be considered highly reliable.

The result is illustrated in the following figure;

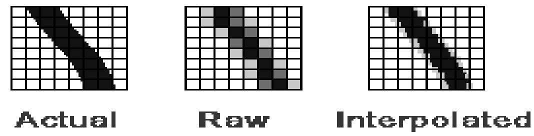


Figure 5

Usually bi cubic interpolation is used wherein the value of every pixel is shared by surrounding twelve pixels.

9. Image Enhancement Techniques

Image enhancement techniques improve the quality of an image as perceived by a human. These techniques are most useful because many satellite images when examined on a colour display give inadequate information for image interpretation. There is no conscious effort to improve the fidelity of the image with regard to some ideal form of the image. There exists a wide variety of techniques for improving image quality. The contrast stretch, density slicing, edge enhancement, and spatial filtering are the more commonly used techniques. Image enhancement is attempted after the image is corrected for geometric and radiometric distortions. Image enhancement methods are applied separately to each band of a multispectral image. Digital techniques have been found to be most satisfactory than the photographic technique for image enhancement, because of the precision and wide variety of digital processes.

A. Contrast

Contrast generally refers to the difference in luminance or grey level values in an image and is an important characteristic. It can be defined as the ratio of the maximum intensity to the minimum intensity over an image. Contrast ratio has a strong bearing on the resolving power and detectability of an image. Larger this ratio, more easy it is to interpret the image. Satellite images lack adequate contrast and require contrast improvement.

B. Contrast Enhancement

Contrast enhancement techniques expand the range of brightness values in an image so that the image can be efficiently displayed in a manner desired by the analyst. The density values in a scene are literally pulled farther apart, that is, expanded over a greater range. The effect is to increase the visual contrast between two areas of different uniform densities. This enables the analyst to discriminate easily between areas initially having a small difference in density.

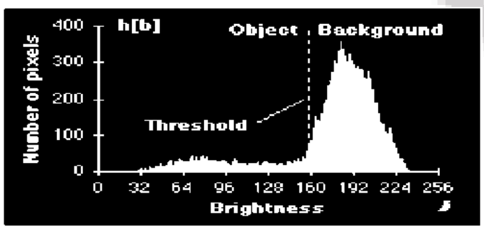
C. Linear Contrast Stretch

This is the simplest contrast stretch algorithm. The grey values in the original image and the modified image follow a linear relation in this algorithm. A density number in the low range of the original histogram is assigned to extremely black and a value at the high end is assigned to extremely white. The remaining pixel values are distributed linearly between these extremes. The features or details that were obscure on the original image will be clear in the contrast stretched image. To provide optimal contrast and color variation in color composites the small range of grey values in each band is stretched to the full brightness range of the output or display unit.

10. Enhancement of Fine Structures in the Face

Having discussed downsizing and interpolation techniques we now deal with the enhancement of fine structures. The raw imagery contained a great deal of "salt-and-pepper" noise caused by data transmission errors.

Step 1: The first processing step is to "clean up" the imagery. A 3x3 pixel Laplacian filter is used first to detect outliers (i.e., pixels whose values differ from the local mean by more than a specified threshold). The values of these pixels are then replaced by the local median value computed in a 3x3 window centered about the pixel to maintain the edge structure. The threshold value is selected to reduce the magnitude of the noise without significantly distorting the fine-scale detail in the image.



Step 2: Contrast stretch is done to remove shading variations due to illumination and albedo variations across the imagery, and increase the local contrast while maintaining the overall tonal balance of the imagery. Over small areas and for isolated features the contrast is enhanced using a global "clip-and-stretch" which assigns pixels below a minimum value to zero, pixels above a maximum value to 255, and pixels in between to the range 1-254.

Step 3: The image at this stage contains several thin lines that intersect above the eyes, four broad stripes across the face, and fine structure in the mouth area that appear to some as teeth. Each is discussed below.

11. Conclusion

Thus the above techniques mentioned in this paper are extensively used to enhance not only space images but also to explore other hidden details from images, which are of great importance to enrich man's knowledge about our UNIVERSE.

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