Angle Extraction Using Digital Image Processing

Andrew Fratpietro *M. John D. Hayes*

Department of Mechanical & Aerospace Engineering, Carleton University
1125 Colonel By Drive, Ottawa, ON, Canada, K1S 5B6

1. INTRODUCTION

The process of extracting information from an image takes a human observer mere milliseconds. The human mind is conditioned to focus on, or to ignore certain aspects of an image based on the relevancy of these aspects to the task at hand. A task such as counting the number of lines in an image does not require information regarding the color of the lines in the image. A task such as determining the orientation of lines in an image does not require knowledge regarding the lengths of the lines in question. These are examples of human intuition. When computers are implemented for the purpose of emulating this intuition, the process of extracting information from an image must be broken down into a series of algorithms that can be tailored to the task at hand. The process of extracting information from a digital image refers to image processing. The associated algorithms that are used in this procedure form a library of digital image processing toolboxes from whence certain algorithms can be selected and used to extract specific information from digital images.

A long-term goal of the project outlined in this paper is the design and implementation of a digital image-processing library of toolboxes to be used for a specific robotic calibration procedure. This calibration procedure requires the extraction of linear equations from a digital image containing multiple straight lines. A short term by-product of developing this library is the application of several of the algorithms in the library to a digital image processing-based angular measurement system. This low-cost solution exploits the relative orientation between lines independently of the true size of the line segments being measured. As a practical example, this system is applied in the angular measurement of the corner-piece for a turbine blade Z-section.

2. EQUIPMENT AND SETUP

The angular measurement system uses an off-the-shelf digital web camera at a resolution of 352x288 pixels for producing the digital images. The camera can be purchased for under $100. The object being imaged is placed on a flat surface and illuminated using a standard 60-Watt household lamp placed 1-2 feet from the object. The camera can be located 6 inches above the object and aimed co-linear with the cross-product vector of any angle that is to be measured. Certain 3-D objects may be oriented in such a way that angles to be measured have cross-products that are not vertical in direction. A set of example images can be viewed in Figure 1. These images contain sets of lines that were measured by the system: one orthogonal pair and one pair set at an arbitrary angle. The orthogonal line pair was used as a test image in order to determine the error resulting from the digital image processing angle extraction. These images represent cropped portions of larger images, hence the full 352x288 pixel resolution is not used.

All image-processing software was implemented using MATLAB version 6.5.

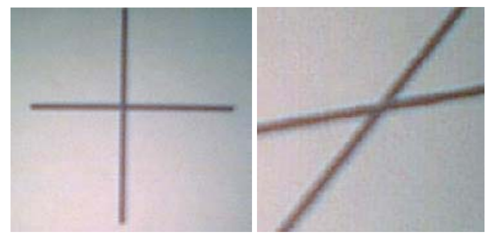

Figure 1. Digital images taken from a web-cam of line-segments at orthogonal and arbitrary angles.

3. ANGLE EXTRACTION ALGORITHM

The first step of the algorithm is the reading of an image into MATLAB (see Fig 1). All images are saved as type Joint Photographic Experts Group (JPEG), a file type that is compatible with the MATLAB software suite. These files are small in size due to a compression technique that eliminates details in the images that are undetectable to the human eye. Using images of smaller file size benefits this procedure by reducing processing time, but it also affects accuracy

The algorithm is equipped to process images of a gray-scale color-type. These images allow for direct comparison between neighboring pixels. The grey-scale image is also subjected to an inversion procedure where light pixels are set to darker shades and dark pixels are set to lighter shades. The comparison of neighboring pixels is slightly simplified when the pixels of greater importance have intensities that are given larger gray values.

A threshold technique is implemented in order to eliminate pixels of lesser importance and focus on pixels to be used in the measurement process. The technique involves computing the total range of pixel intensities that the image contains, and then setting all pixels with an intensity value below a certain percentage of this range to the shade black (gray-value = 0). Values in the range of 60-75% were determined through experimentation to provide maximum amounts of information.

The next step of the algorithm involves the use of a line-walking algorithm similar to that outlined in [1] for the purpose of extracting pixels of importance. The algorithm requires that lines have a tendency to be either more horizontal or vertical, but can be adapted to arbitrary orientations. Each pixel of importance is used as the center point in calculating the second moment in two directions relative to that location. This moment calculation at each pixel of importance attempts to locate a point to be used in a linear regression algorithm, allowing sub-pixel accuracy regarding the true location of the lines being measured.

The linear regression technique solves for two linear equations. The slopes of these linear equations are used to produce the resulting angle between the lines.

4. EXPERIMENTAL ANALYSIS

Three sets of results were produced for display in this summary paper. Figure 2 shows a picture that was generated using a computer graphics program and then printed to a white sheet of paper. The image is a set of specified perpendicular lines. Overlaid onto this image are the two lines that are estimated by the angular measurement system to represent the lines in the image. The output includes the equations of both lines and the angle between them.

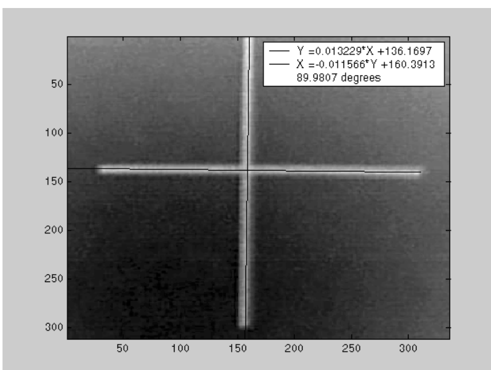

Figure 2. Angle between orthogonal lines.

The system produces a measurement of 89.9807 degrees. This measurement appears to have an error of 0.02%. Further analysis of the significant digits in this calculation will produce a more realistic error value. Figure 3 shows an angular measurement made on lines inclined at arbitrary orientations.

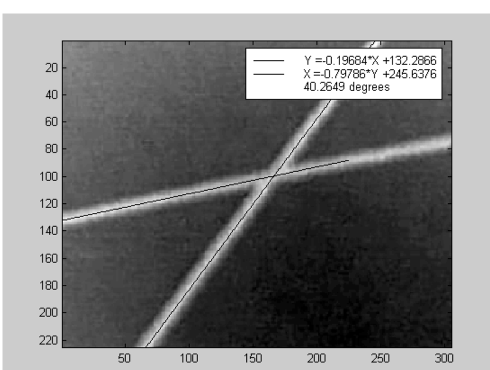

Figure 3. Lines at arbitrary angle.

The system is used in the measurement of the corner-piece of the turbine blade Z-section of Figure 4.

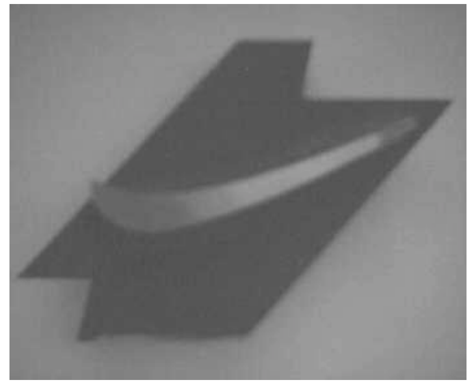

Figure 4. Turbine blade Z-section

The results of this measurement can be viewed in Figure 5. It was determined that the corner piece had an angular value of 75.6927 degrees. The two lines that were used to determine this angular value can also be viewed in Figure 5.

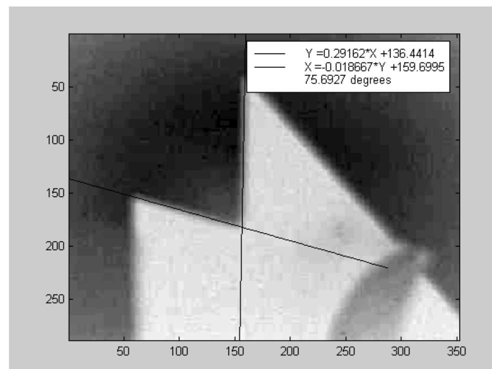

Figure 5. Z-section measurement

5. CONCLUSIONS & FUTURE WORK

From these results we conclude that this algorithm has the ability to extract the angle between two lines. The algorithm was applied to lines of several different orientations and separation angles resulting in angular measurements that were plausible. The application of such a system might be used in the area of quick camera-aided angular measurement in industry.

The future work on this project will involve the evaluation of the confidence interval of the data points used in the linear regression. All calculations are carried through with two decimal places, but the actual significant digits of the angular measurement have yet to be determined. In addition, an analysis of the system using singular value decomposition will be performed.

REFERENCES

[1] Ofner, R., O'Leary, P., Leitner, M., 2000, "A Collection of Algorithms for the Determination of Construction Points in the Measurement of 3D Geometries Via Light-Sectioning", Institute for Automation, University of Leoben, Austria.