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MACHINE VISION SYSTEM FOR SEAM WELD DETECTION IN LONGITUDINALLY WELDED PIPES

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Abstract: *This paper presents the development of machine vision system for seam weld detection in longitudinally welded pipes. The system is to be used for positioning operations prior to mechanical working of such parts. Application which uses several different approaches is developed for this purpose. Experimental results show that robust seam weld detection system can be achieved using simple algorithms with low computational cost.*
Key words: *machine vision, seam weld detection, edge detection, Hough transform*

1. INTRODUCTION

Prior to mechanical working of longitudinally welded pipes (LWP), it is often necessary to determine exact position of seam weld. Reason for this is mostly due to inadequate mechanical properties of weld zone. Pipes must thus often be properly oriented with respect to seam weld position, in order to reduce strain during bending or avoid machining of weld zone.

Various seam weld detection systems, based on X-ray imaging, ultrasonic testing, or eddy currents exist today in industry, but these systems are primarily designed for non-destructive testing. Although most of these systems can be applied for indexing operations, their cost, processing and setup time, as well as often required human supervision are usually limiting factors.

Based on material, making technology and various other parameters, LWPs can have different properties. In order to develop practical machine vision (MV) based solution, which could be used regardless of material or making technology used, this paper is focused on common properties of LWPs such as changes in geometrical or optical surface characteristics of weld zone. Robustness to various forms of noise, such as corrosion of surfaces, presence of holes and other features is considered as most important factor, as these features can significantly influence success rate of detection algorithms.

Main goal behind this work is to develop compact and reliable MV based indexing system for orienting these parts. Motivation for this work is found in fact that MV approach has advantages as easily configurable versatile non-contact method for this task.

2. TASK ANALYSIS

Indexing system is briefly described as follows: Pipe is first placed in clamping device of indexing system by robot or some other machine attendance system. After clamping, camera is placed in the center axis of the pipe, which is then continuously rotated in steps for a given rotation angle.

After each rotation step, MV system is triggered, which executes weld detection algorithms within region of interest (RoI). Process completes upon successful detection of seam, with confirmation signal sent back.

Several samples of LWP with different characteristics were obtained, as shown in Fig.1. In some samples, seam weld is optically visible. Some of selected pipes also have holes present. In second case, there is very low contrast between weld and rest of material due to corrosion, but seam weld is still detectable as geometric feature.

Fig. 1. Two sets of LWPs obtained for testing

3. RECOGNITION ALGORITHMS

Approach used in case of optically visible longitudinal seam welds, consists of two steps: Canny’s algorithm followed by Hough transform (HT).

Using Canny’s algorithm (Canny, 1986), edge extraction is performed on greyscale image of RoI for each rotation step. In this technique, greyscale images are sequentially transformed into edge images using Gaussian smoothing, Sobel edge detection, thinning (non-maxima suppression) and finally, hysteresis thresholding. End result of this algorithm is binary image with edges extracted as single pixel thickness lines. Edge detection parameters can easily be adjusted in order to match sensitivity for specific pipe being indexed. These parameters include low and high hysteresis thresholds, as well as size of Gaussian convolution mask.

If seam weld exists for the given rotation step, it will be visible as straight vertical line in binary edge image. Such lines are easily detected using the simplest form of HT (Shapiro and Stockman, 2001), which is the second step of detection process.

This algorithm can be described as evidence gathering process in which edge pixels of image space are mapped to Hough space (accumulator array) and vice versa. In this case, polar representation of lines i.e. $r(\theta)=x0\cdot\cos(\theta)+y0\cdot\sin(\theta)$ was used for transformation. Each collinear point increases accumulator value at corresponding coordinates (r,θ). Maximum values of accumulator space after transformation indicate edges with maximum lengths. Sensitivity is again adjusted to match specific pipe being indexed, by taking into account only values exceeding adjusted threshold of accumulator array. Main advantages of this algorithm are robustness to noise with relatively low computational cost.

For detection of seam weld in second case, previously described approach is not suitable, since heavy surface corrosion causes low contrast between weld zone and base material. Even tough, seam weld is still possible to detect as there are changes in surface topology of weld zone.

These changes are easily expressed by illuminating seam topology using LED laser with line generating optics, oriented at low axial angle and normal to inner surface of LWP.

Orienting Laser in such way, beam will be projected as straight line on smooth surfaces, while on the other hand, broken line will be projected collinear with weld face reinforcement. It was experimentally determined that Hough transform is not suitable with this type of illumination, since it is difficult to adjust accumulator threshold for different batches and thus, achieve sufficient robustness. Number of visible pixels within RoI is therefore used to determine weather the seam weld is present for the given pipe orientation.

4. RESULTS

Two experimental systems were used for testing different sets of samples (Fig. 1). Mimas MV library is used as basis for application development in both setups. In this paper, only two images are shown for each setup. Results of more extensive testing can be found in (Mihljevic, 2008).

In the first case, a small mirror is placed in the center of the pipe, which is used to reflect inner surface of LWPs to camera placed above, as shown in Fig.2. Seam weld is visible within RoI of the second image, obtained after rotation step.

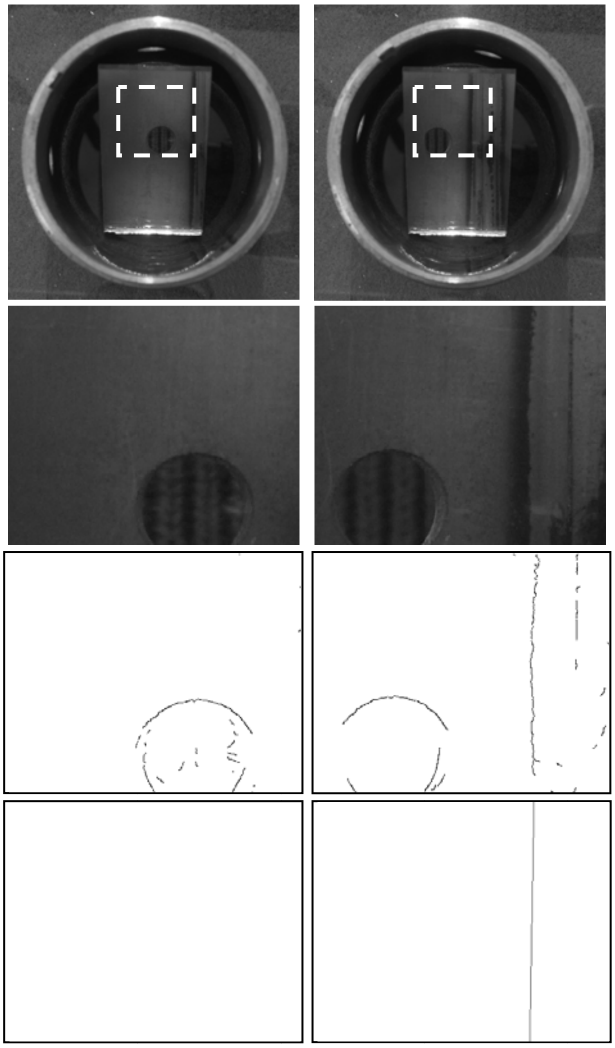

Fig. 2. Results of weld detection for two sequential rotation steps. Original images are shown in first row, followed by grayscale images of RoI, results of edge detection and finaly, Hough transform.

LWPs from second group are illuminated using LED Laser with line generating optics, as described in previous section. Images in Fig.3 show inner surface of LWP illuminated in such way. In the first case, smooth surface is illuminated, while second case shows illumination of weld face reinforcement. It can be seen that there is lesser number of pixels present in second case, indicating presence of seam weld at given rotation step.

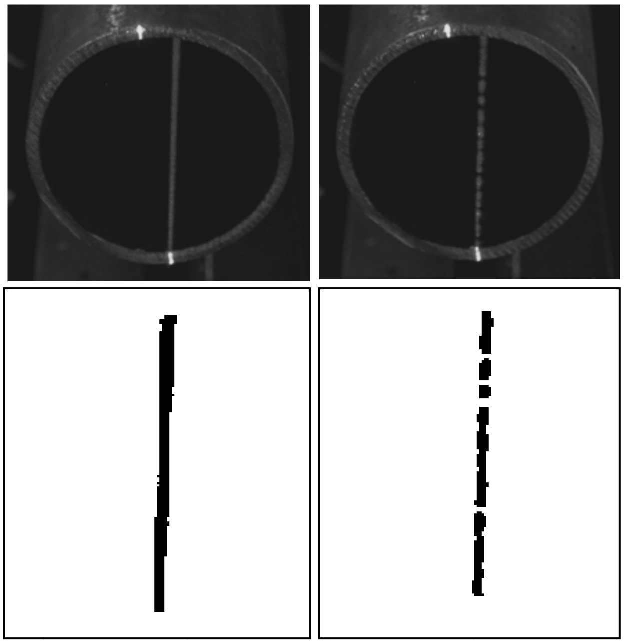

Fig. 3. Results of weld detection for two sequential rotation steps. Bitmap images of RoI after thresholding are shown in second row.

5. CONCLUSION

This paper presents practical MV based solution for indexing of LWPs, which is a common problem in modern production systems.

In this paper, only longitudinal seam welds are considered as features, but technique presented here can be easily expanded for detection of arbitrary shapes, i.e. by using generalized form of Hough transform algorithm (Ballard, 1981).

Although this work is still in early stage, overall repeatability of the process as well as robustness to noise shows promising results.

Future work will be conducted on expanding currently implemented algorithms for detection of objects with different features and will include investigations of other methods and algorithms for similar applications.

6. REFERENCES

Canny, J., (1986). A computational approach to edge detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence* 8(6), pp. 679–698.

Shapiro, L & Stockman, G. (2001). *Computer Vision*, Prentice-Hall, Inc., 0130307963, Upper Saddle River, NJ, USA.

Mimas C++ Real-time Computer Vision Library, *Available from:* http://vision.eng.shu.ac.uk/mmvlwiki/index.php *Accessed:* 2008-07-01

Mihljevic, V. (2007). Methods for seam weld detection in longitudinally welded pipes, *Diploma thesis*, University of Zagreb

Ballard, D. (1981). Generalizing the Hough transform to detect arbitrary shapes. *Pattern Recognition* 13(2), pp. 111–122.