

# Target Location algorithm for Automation Assistance in Weld Industries

Ragesh Kumar R<sup>1</sup>, Vivek M Elayidom<sup>2</sup> and A P Sudheer<sup>3</sup>

Mechatronics /Robotics laboratory, NIT Calicut  
apsudheer@nitc.ac.in

<sup>1</sup>Undergraduate Student  
Department of Civil Engg.  
ragesh88@gmail.com

<sup>2</sup>Undergraduate Student  
Department of Mechanical Engg.  
3dsmaxvivek@gmail.com

<sup>3</sup> Assistant Professor  
Department of Mechanical Engg.  
apsudheer@nitc.ac.in

National Institute of Technology Calicut  
Calicut – 673 601, Kerala, India

## Abstract

*This paper proposes a new target locating algorithm for detecting the weld pattern from a digital photograph and thus providing the approximate location of the weld for robotic end effector to perform various operations like cleaning, grinding etc. This reduces the human intervention and improves the quality of the work. Implementing this algorithm reduces computational complexities and can be easily adapted to the generally available automation system. In the present work, camera captures the image and MATLAB image processing toolbox is used to perform auto segmentation. The output of this algorithm is the approximate position coordinates of the weld strip. Algorithm is found effective for rough terrained weld image strips where normal edge detection and enhancing techniques fail usually.*

**Keywords:** Weld, Machine vision, Pattern matching

## 1. Introduction

Welding is often one of the unavoidable joining processes in any of the fabricating industries. Normal welds done by humans in small scale industries need a lot of time in grinding of the parts and surface finishing the welded portions. Machine vision for target location of welds and machine vision for parameter measurements have been active areas of research. In several cases a radiographic photography is used [4] but in several others a more economical setup using simple digital camera is used [5]. Some projects are focusing on real time processing for control applications [6]. The target location can be effectively done with digital camera of considerable resolution. Human inspection cannot be fully efficient and is subjected to lot of factors like lose of attention, boredom, inaccuracy etc.

This particular work is mainly focusing on the development of a more specific approach for detecting and grinding of the weld deposits. More focus is given to the image processing part for locating the target of weld location autonomously. Weld samples using digital camera are analyzed. Iterations are done for 10 worse cases and 10 medium cases for inspecting the quality of algorithm.

## 2. Weld Target Location

Welded joints are sometime error prone without finish if it has made manually. When cooled welds are usually exposed, irregular projections are formed which needs to be grinded for getting good surface finish and appearance. The process requires a lot of time for transporting the half finished work piece to the grinding table and fixing it on the grinding table. The whole process can be automated for grinding the weld surface. The proposed target location automation system is given in figure-1.

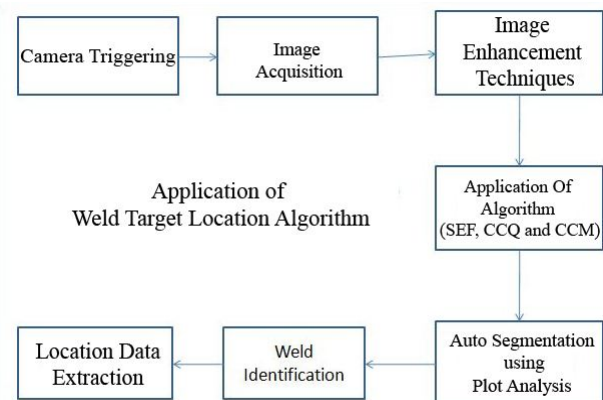


Fig.1.Target location automation system.

Keeping focus on the image processing part the whole sequence of actions are triggering Camera, image acquisition, image enhancement to develop better contrast

and auto segmentation, Weld Identification is done by using the dual axes analysis and location data extraction.

### 3. System Design

The system is designed to have input from the conveyor belt system from the production line. The whole process line is designed to have an intermittent motion to bring a pause between image acquisition and processing as mentioned in short, above. Intermittent motion is being given with the help of appropriate mechanisms like Geneva wheel mechanism. The dimensions of Geneva wheel are set in coordination with processing time for weld target detection. The image is acquired at one end and image is processed before the weld is reached at the other end. The input drive is given via a DC motor with required torque specification. The required position of the weld is given as input coordinates for the grinding wheel drive and the weld surface is ground using a tool head with three degrees of freedom- the X, Y and a rotational axis. The final output from the image processing algorithm (target location) is the position co-ordinates for the grinding wheel. The whole process is automated and the processing time is reduced avoiding ineffective process like positioning of weld and setting the grind wheel using human control. The process can be modified to adapt to any end effectors like cutters, markers, paint heads or drillers. The image acquisition is done, specifically for this experiment, using a normal digital camera (make: Sony, Resolution: 7 Mega pixels), used without a frame grabber. A frame grabber can be adapted to the system, for real time processing.

### 4. Image Processing

The image processing module is the key part in automation of the whole system. It gives input to the grid wheel system and hence grinding is done. Image computations are done with the help of MATLAB Image Processing Toolbox (Ver. R14). The image processing system is split up into several sections as explained below:

#### 4.1 Smoothing and contrasting techniques.



a) Raw Image



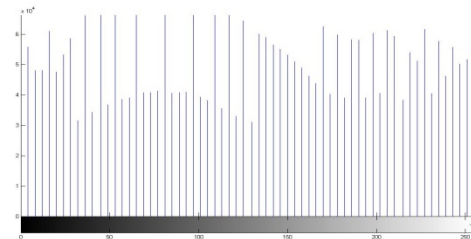
b) Histogram Equalised

The raw image taken here is highly worse case with bad lighting and a very unsteady pattern. Experimentation is done with this “risky” specimen using this algorithm. The raw image is processed initially for the algorithm to act on. The smoothing process helps in denoising the image and enhancing the image. More contrasting is also done. The processes performed here are:

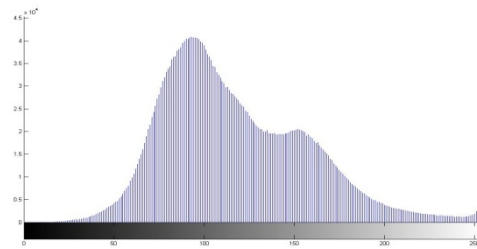
**4.1.1** First, the median filter is applied for smoothing the background metal pattern. This helps in better recognition of the pixel distribution.

**4.1.2** Second, Histogram equalization is also done for the image. This helps in even more contrast with the background.

The mathematical depiction of histogram equalization is given in figures 2,3 and 4.



i) Fig. 2 -Histogram Equalization for raw Image



ii) Fig.3 - Histogram Equalized Image



iii) Fig.4 - Image after the above two process.

Histogram equalization helps in improving the contrast making brighter regions brighter and darker regions darker.

### Segmentation Enhancement Function (SEF)

A function is taken here for enhancing the segmentation process. The SEF function is

$$f(x) = e^{\lambda \left( \frac{-(x-\mu)^2}{\sigma^2} \right)} \dots\dots (1)$$

Function adapted here is used for enhancing the segmentation process due to its certain unique features like,

1. Function reaches its maximum value at one at  $\mu$ .
2. The graph generated by the function is a bell shaped curve and the width is proportional to square of  $\sigma$ .
3. Function is continuous, differentiable and positive in the whole range of number line ( $-\infty$  to  $+\infty$ )

### 4.2 Traversing the Correlation Quantification Matrix (CQM)

A matrix as given below is used for traversing the whole of the pixel matrix representation and finding the correlation coefficients which have to be further plotted spatially with respect to the perpendicular inspection directions. Here we have taken a random square matrix of the order fifty. Each element in the matrix is given a value of unity for the easiness of computation.

### 4.4 Correlation Process

- Pre processing:** The pixel matrix (raw image after histogram equalization) acquired is row wise multiplied with (element to element multiplication) the corresponding values of the segmentation enhancement function (from start to the end of the number of columns) with  $\mu = (\text{no. of columns} / 2)$  and  $\sigma = \text{a value such that the bell portion lies in 75 percent of the image matrix. i.e. three fourth of the image distributed equally from } \mu \text{ is accommodated.}$  This is done so that intensity of pixels of the tapered regions of the image matrix is suppressed as the value of the bell curve at those regions is nearly zero. This process also helps in smoothening the pixel intensity variation and hence is an intelligent function. The function makes smooth regions smoother and rough regions contrasted.
- Assumption:** The above process is done with the assumption that the weld is not present at the extreme side points. The planar image captured

should always be in conjunction with the above assumption. This is usually true in almost all of the practical cases.

- CQM Shifting:** The CQM mentioned above is assumed as a square matrix of order 50 and the CQM is shifted from one column to other in steps of unity through a single row. From this the correlation coefficient matrix (CCM) is created. For each shift we get a unique coefficient entry in the correlation coefficient matrix (CCM). The process is depicted mathematically below:

$f(x, y)$  == gives the pixel intensity at the coordinates  
 $x$  ( column number) ,  $y$  ( row number)

$0 < x < M$  and  $0 < y < N$

$M$  = maximum number of columns

$N$  = maximum number of rows

SEF is given by

$$g(x) = e^{\lambda \left( \frac{-(x-\mu)^2}{\sigma^2} \right)} \dots\dots\dots (2)$$

Let  $U = M/2$

And  $\sigma^2 = 200000$

$$h(x, y) = \sum_{y=1}^N \sum_{x=1}^M g(x) * f(x, y)$$

Let the Correlation Quantification Matrix (CQM) be as follows:

$$\text{CQM} = \begin{bmatrix} 1 & \dots & 1 \\ \vdots & \ddots & \vdots \\ 1 & \dots & 1 \end{bmatrix} \text{ 50 X 50 matrix}$$

CQM is traversed for each of the pixel position of  $f(x, y)$  and multiplied with each of the corresponding elements in  $f(x, y)$  and added. So there will be a unique value for each position of CQM matrix which gives us a row vector for each strip in CCM matrix.

- CCM Plotting:** The CCM values are plotted for each element in the image matrix corresponding to the CQM and for each strip of traverse, get a single plot. If we are going row wise with 2500 pixels in the image matrix we get 50 plots for a 50 order matrix.
- Plot Analysis:** From CCM plots obtained, necessary plots are analyzed to get an approximate position of the weld. At the weld region in the matrix (row image) we observe a corresponding peak rise and fall. The fall is followed by rise and can be effectively distinguished from the plot and analyzing the function. The plots for row wise analysis and column wise analysis of the image are given in figures 6 and 7. The raw image is shown in figure 5. The same process is repeated for vertical grids and the weld centre is hence identified.

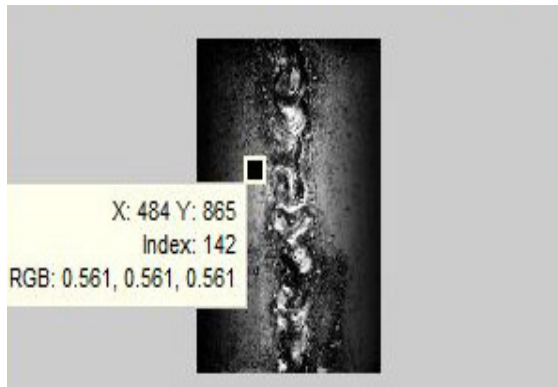


Fig .5 -Data plot on the image using MATLAB

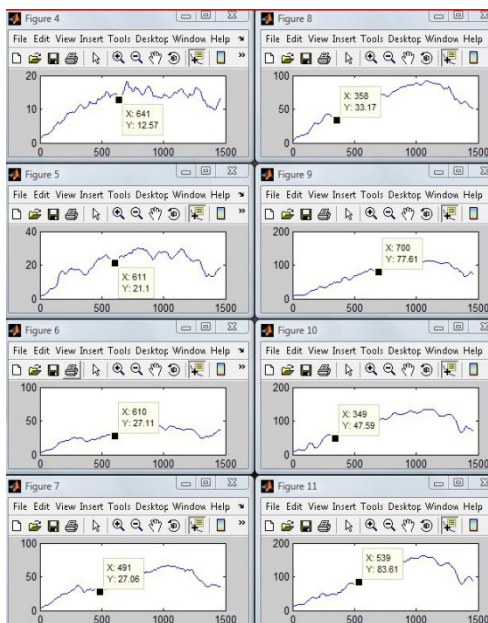


Fig. 6 Data plot (Horizontal) after CCM Plot Analysis

#### f) Inference from the figure :

The average of above peak values from Figure 6 gives a value = 537.00  

$$= (641+611+610+491+356+700+349+539)/8;$$

Approximate value from data plot from Figure 5 is 484. The difference is 53. Therefore percentage error is about 10.95 %. Since only the peak values (the start of weld) is only analyzed still lower values can be achieved if the whole pixel averaging from raw image is used. In figure 5 only a random point is selected, to show the effectiveness.

## 5. Analysis in both axes

The analysis is continued with Y axis and the results observed are shown below. The raw image corresponding to the plot is in figure 5. The variation observed here is studied. The pixel intensity variation increases in the figure 6 and 7 and decreases as the strip moves past the weld. These plots both x and y, are computed simultaneously to approximately judge the pixel area.

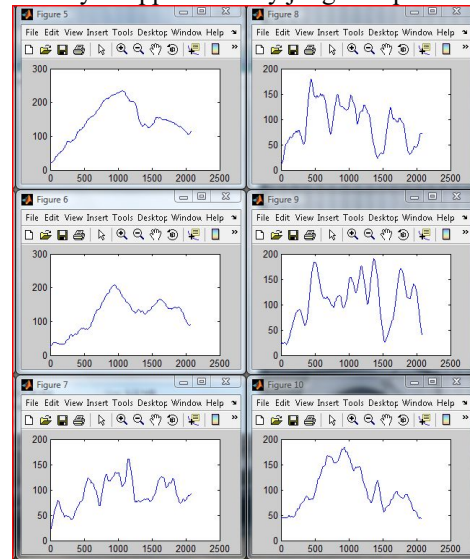


Fig.7 Plot analysis – Y axes

This algorithm is found effective with rough textured weld distribution which happens particularly with human operated weld pieces. In usual cases the edge transformation is adapted to find the edges as weld. In rough textured welds many noise elements can be identified as weld edges. Thus using this algorithm will be an effective substitute for edge detection for welds. Another weld piece analyzed is shown in figure 8(a),(b) and 8(c).

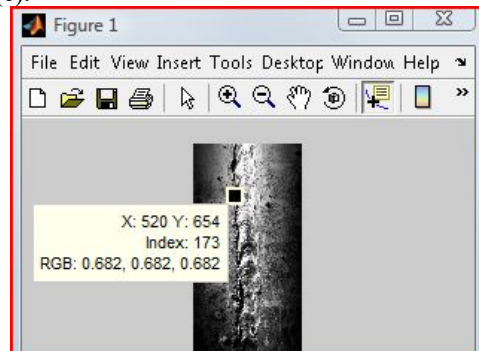


Fig.8 (a) Data plot on the raw image using Matlab



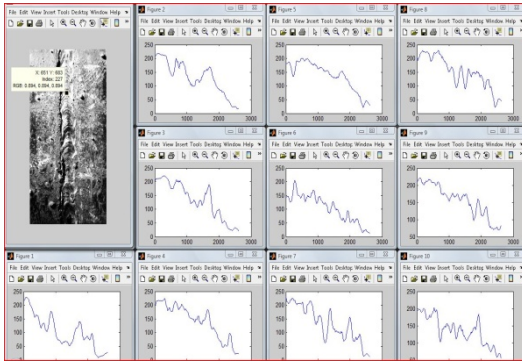


Fig.8 (b) Horizontal Variation

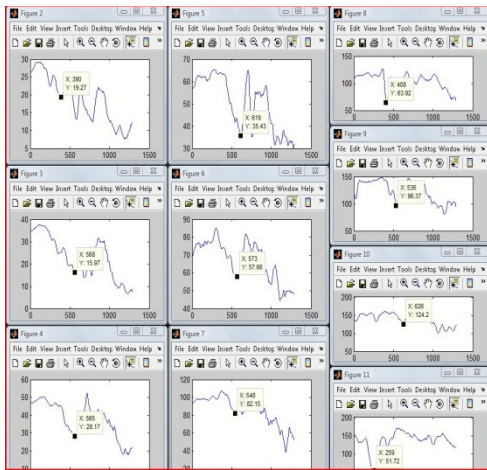


Fig.8 (c) Vertical Variation

Using these plots a bounding box with approximate probability of finding the weld was developed. The algorithm was tested for 20 other samples and approximate bounding box were generated for reasonably non uniform pixel distribution which were acquired using ordinary camera and normal lighting condition.

## 6. Step wise description

The whole sequence of process can be summarized as:

1. **Image acquisition** – using digital camera
2. **Image pre processing**
  - 2.1 Image Enhancement using Median filter
  - 2.2 Image Enhancement using Histogram Equalization
3. **Image Analysis**
  - 3.1 Multiplying SEF for Segmentation Enhancement
  - 3.2 Selecting CQM and traversing in X direction. (for column wise analysis)

3.3 Summing up for each step of traversing gives CCM.

## 4. Image analysis

4.1 CCM is plotted for X and Y axes after above Image Analysis steps were repeated in Y axis too.

4.2 CCM plots are analyzed to find the average of X coordinates.

4.3 Average position of weld is obtained.

## 7. Conclusion and outlook

The algorithm developed is tested for considerable amount of samples and expected results were found out. These included lateral displacement of weld from the mean position and welds at angles less than 50 degrees from the horizontal. Computational complexities are removed without much training algorithms and other prediction tools. The algorithm sticks to the basics of image processing and is found good for unusually rough visual terrain mapped on to the image.

This algorithm can be further improved using wavelet techniques and can also be trained using ANN (Artificial Neural Network). Faster processing can be achieved through hardware acceleration techniques for implementing algorithms in real time.

## 8. References

- [1] Gaohua Liao, Junmei Xi, (2009), “Image processing technology for pipe weld visual inspection”, 2009 WASE International Conference on Information Engineering, , Nanchang Institute of Technology Nanchang, China.
- [2] V.D.Makarenko and S.P.Shatilo, “Welding Nonrotating Joints in Petroleum Pipelines,” Chemical and Petroleum Engineering, Vol.40,No.5,2004,pp.5-6.
- [3] Li kai, “research on vision-based tracking system for pipeline,” HARBIN: Harbin Institute of Technology, 2007.
- [4] H.I. Shafeeka, E.S. Gadelmawlab, A.A. Abdel-Shafy, I.M. Elewab, (October 2003), “Assessment of welding defects for gas pipeline radiographs using computer vision”, NDT&E International 37 (2004) ,291–299.
- [5] Cae-Cheol Lim and Cae-Gab Gweon, (1999), “In-Process Joint Strength Estimation in Pulsed Laser Spot Welding Using Artificial Neural Networks”, Journal of Manufacturing Processes, Elsevier, Korea Advanced Institute of Science and Technology (KAIST),TaeJon, Korea, Vol I/No I .
- [6] J. Mirapeix, P.B. Garcí a-Allende, A. Cobo, O.M. Conde, J.M. Lo’ pez-Higuera, (2007), “Real-time arc-welding defect detection and classification with principal component analysis and artificial neural networks”, NDT&E International , 40 (2007) 315–323.

