

WELDING INSPECTION SYSTEM

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

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Declaration

We Hereby Declare That This Thesis Is Our Own Work And Effort. Throughout This Documentation Wherever Contributions Of Others Are Involved, Every Endeavour Was Made To Acknowledge This Clearly With Due Reference To Literature. This Work Is Being Submitted For Meeting The Partial Fulfilment For The Degree Of Bachelor Of Technology In Industrial Design At National Institute Of Technology, Rourkela For The Academic Session 2011 – 2015.

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CERTIFICATE

*This is to certify that the thesis titled “**Laser Sensor Based Automatic Welding System**” submitted by **K.Tejeswar Rao (111ID0153)** in partial fulfillment of the requirements for the award of **BACHELOR OF TECHNOLOGY** in **INDUSTRIAL DESIGN** at **National Institute of Technology, Rourkela** is an original work carried out by him under my supervision and guidance.*

The matter embodied in the thesis has not been submitted to any University/ Institute for the award of any Degree.

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ABSTRACT

This Project aims at building an automated welding system that can track a weld seam, calculate its area and depth and accordingly do the welding and also consider to keep the defects to a minimum so that better quality of weld can be given as output. It consists of a laser sensor that illuminates the weld seam so that the CCD/CMOS camera used can get the image of the weld seam. Then this image is transferred to MATLAB for image processing where the image is converted to grey scale and the grey scale image is then divided into two parts first part consists of the seam section which is colored grey and have red dots and other sections is considered as white section which don't have any utilization till the welding starts. After the image processing the part is carried to the welding section where the welding can be done with the help of the data abstracted from the above methods and then it minimizes the defect of welding and produces the output.

Keywords: - Laser sensor, image processing, defects

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List of Symbols

CCD camera.....	Camera based on Charge Coupled Devices technology
CMOS.....	Complementary Metal Oxide Semiconductor
Flexcell controller.....	Servo Robot Inc automatic weld measure equipment
I-P2-P1.....	The weld sample used in all tests in this report
Kt-value.....	A measure of the tension concentration in the weld toe
Leg length.....	Figure 1 The image shows a fillet weld and explains the leg and throat of the weld
MATLAB (Matlab).....	The MathWorks software with Image processing toolbox
MIG/MAG welding.....	Metal Inert/Active Gas welding
Throat.....	Figure 1 The image shows a fillet weld and explains the leg and throat of the weld
Weld face.....	The surface of the weld
Weld toe.....	The junction of the base material and the weld face

CHAPTER 1

INTRODUCTION

Welding, as the most regularly utilized procedure for joining metals and plastic, is essential to the economy a nation on the grounds that up to 50% of the gross national item is identified with welding in somehow. Then again, welding is such a complex procedure, to the point that the outwardly unmistakable nature of the weld is influenced by various methodology variables. The potential weld abandons incredibly break down the mechanical properties of the welded structures weld quality and subsequently, the dangers of part exhaustion, disappointment considerably fiasco are essentially expanded. In this manner, so as to recognize the conceivable vicinity of distinctive weld deformities, fitting sensing, observing and examination techniques are essential for quality control. For the most part, there are two classes of techniques that are sought weld quality investigation: on-line routines and disconnected from the net strategies. As welding is such a complex procedure, there are various physical phenomena, for example, electromagnetic radiation, optical and acoustic discharge and plasma era that will happen. Alongside these phenomena, distinctive sorts of signs are created amid the welding procedure and typically these signs are nearly connected with the weld quality. Subsequently, diverse on-line sensing systems have been created to screen the weld quality and identify the weld deformities taking into account the marks of the signs procured amid the welding methodology.

1.1 HISTORY

Welding is seemingly the most complex assembling process and is every now and again the slightest caught on. An astounding number of organizations burn through a great many dollars to mechanize get together while overlooking the welding methodology. Manual welding is still the best process for some gatherings. On the other hand, numerous constructing agents are actualizing computerized welding frameworks to expand quality, profitability and gainfulness. Welding computerization can be separated into two essential classifications: self-loader and completely programmed. In self-loader welding, an administrator physically stacks the parts into the welding installation. A weld controller then keeps the welding procedure, movement of the light, and stillness of the parts to preset parameters. After the weld is finished, the administrator uproots the finished get together and the methodology starts once more.

In completely programmed welding, a custom machine, or arrangement of machines, loads the work piece, lists the part or light into position, fulfills the weld, screens the nature of the joint and empties the completed item. Extra "part set up" and last item quality checks might likewise be outlined into the machine if fundamental. Contingent upon the operation, a machine administrator may be essential.

1.2 Benefits of Automated Welding

Automated welding systems offer four main advantages: improved weld quality, increased output, decreased scrap and decreased variable labor costs.

- Weld quality comprises of two variables: weld uprightness and repeatability. Computerized welding frameworks guarantee weld respectability through electronic weld process controllers. Consolidating motorized light and part movements with electronic review of welding parameters brings about a higher quality weld than can be finished physically. This offers immediate quality control. Besides, on the grounds that a weld is made just once, deserts are promptly unmistakable and discernible. People have a tendency to "cover up" an error with the light, concealing absence of infiltration or a potentially defective weld. Now and again, release testing and vision frameworks can be incorporated into completely mechanized frameworks to give extra quality control.
- Repeatability is an element of the nature of the weld process controller and of the designing of the machine movements. Motorized welding gives repeatable info parameters to more repeatable yield. Accepting the controller is working legitimately, the inquiry gets to be: Can the systems of the machine position the parts or the light inside the predetermined resistances for welding? The response to this inquiry will authenticate the nature of framework bought. Computerizing the light or part movements, and part position, diminishes the likelihood of human lapse. A weld happens just when all prerequisites are fulfilled. With manual welding, reject welds regularly increment when welders get to be exhausted. Contingent upon the estimation of the parts when they land at the welding station, the expense investment funds in scrap alone may legitimize the buy of a robotized welding framework. Mechanization ought to additionally be considered when constructing agents need to minimize the danger of transportation an awful part to a client.
- Lost opportunity costs are also significant. If a skilled welder fails to report to work, the company's variable costs skyrocket. Eight hours of production time is lost. Availability of skilled labor for manual welding may also pose a challenge. Conversely, general machine operators are more readily available and more affordable than skilled labor

1.3 Types of Welding Process

The main Types of welding used in industry and by home engineers are commonly referred to as **Mig welding, Arc welding, Gas welding, Tig welding and Laser Welding.**

1. **GMAW or Gas Metal Arc Welding:** - More commonly called MIG welding this welding type is the most widely used and perhaps the most easily mastered type of welding for industry and home use. The GMAW process is suitable for fusing mild steel, stainless-steel as well as aluminum.
2. **GTAW or Tungsten Inert Gas:**-TIG welding is comparable to oxy acetylene gas welding and needs a lot more expertise from the operator. Employed for carrying out high-quality work when a superior standard of finish is needed without making use of excessive clean up by sanding or grinding.

3. **Arc Welding or SMAW:**-Generally known as stick or arc welding. Arc welding is the most basic of all welding types, is easy to master in a home welding situation. Stick welding can be used for manufacturing, construction and repairs, very much well suited for heavy metal size 4 millimeters upwards. Thinner sheet metals and alloys are usually more suited to the mig welding types.

4. **Gas or Oxy Acetylene Welding:**-Not used as widely for general welding of mild steel. Consists of mixing oxygen and acetylene gas to great a flame capable of melting steels. Mostly used today for maintenance work and gas metal cutting. Also common for brazing softer metals such as copper and bronze. Can also be used for welding delicate aluminum parts such as refrigeration pipes. Gas Cutting equipment for metal construction and maintenance. The most accessible of thermal cutting gear is by oxy-acetylene gas cutting and plasma cutting machines. Other methods include the use of a thermal cutting electrode for use with the arc welder machine

5. **Laser beam welding or LBW:** - is a welding technique used to join multiple pieces of metal through the use of a laser. The beam provides a concentrated heat source, allowing for narrow, deep welds and high welding rates. The process is frequently used in high volume applications, such as in the automotive industry.

1.4 Types of Welding Defects

In MIG/MAG Metal Inert/Active Gas welding, a few discontinuities generally show up. The discontinuities are contrasted with the no doubt understood welding standard ISO 5817. There are three weld quality levels B, C and D. B is the most stringent level and is connected on aviation and weight vessel applications and it is not examined in this report. How the irregularity can happen is specified yet there can be a few different reasons.

- Root imperfection is the point at which the base material breaks around the weld. It is permitted in little degree in level C and D. Root imperfection is a more regular irregularity with MIG/MAG welding than with other welding techniques..

- Absence of combination is the point at which the base material is not combined with the weld, i.e. they don't liquefy together. This brokenness is likewise basic with MIG/MAG welding and other combination welding sorts. Absence of combination is not permitted at all in level C and in little degree in level D

- Hardening chunky coke is regularly surface softening laughs to point of tears the weld. On the off chance that the split is greater than smaller scale breaks (stature * length <math><1\text{mm}^2</math>) it is not acknowledged at all in any of the quality levels. This deformity is material depending and frequently happens if the material contains contamination

- Porosity is not a genuine weld irregularity unless there is an abnormal state of pores. Circular pores are permitted from 4% in level B to 16% in level D of the anticipated weld zone. Just level D acknowledges stretched pores. The pores can be surface breaking or non-surface breaking. Earth or lacking shield gas can bring about pores.
- Spatter is a surface discontinuity and is accepted in all three quality levels and it is application depending. Figure 3 shows a small amount of spatter.
- Undercut is a surface intermittence and is acknowledged in each of the three levels, the permitted profundity is reliant on the thickness of the base material. The move between the weld and the surface must be smooth. The application figures out whether the undercut is acknowledged or not. Figure 3 shows undercut in the weld.

The welding standard STD 181-0001 is utilized when welding as a part of steel sheets thicker than 3 mm. This standard partitions the combination welds into four welding classes A to D. The welding standard has one more level than the ISO welding standard however they have likenesses welding class An is the most stringent and not examined in this report in light of the fact that Volvo CE utilizes the C and D class, and sometimes the B class. Table 1 of the welding standard determines shape deviation and external absconds in fillet welds, which is most intriguing in this report. The weigh length in the tables is situated to 200 mm in longitude course. In the event that the weld length is shorter then 200 mm the necessity should be identified with the weld length. Table 1 determines the B to D classes from the table 2 in the STD 181-0001 standard, the external absconds and shape deviation.

Table 1 Classification of weld discontinuities

Type of defect	Welding class		
	D	C	B
Crack	Not permitted	Not permitted	Not permitted
Root defect	Locally permitted	Not permitted	Not permitted
End crater, a crater at the end of the weld	Permitted but no crack	Permitted but no crack	Not permitted
Arc strikes i.e. the arc ignite too close or fare from	Occasional but no crack	Not permitted	Not permitted
Spatter	Spatter is permitted if it is stuck	Occasional globular spatter is permitted if it's	Not permitted

Surface pores	Single pore extension $\leq 0,2t$ max 3 mm	Single pore extension $\leq 0,1t$, max 1,5 mm.	Single pore extension $\leq 0,1t$,
Undercut	Locally $A \leq 0,2t$ but max 2 mm.	Locally $A \leq 0,1t$ but max 1 mm.	Locally $A \leq 0,05t$ but max 0,5 mm.
Leg deviation	$A \leq 2 + 0,2a$ a = throat height	$A \leq 2 + 0,2a$	$A \leq 1,5 + 0,15a$
Throat deviation	Locally $-0,2a$ a = throat height	Locally $-0,1a$	Throat must not be less than specified.

1.5 Problem Statement

In the era of automation and technology, automated system plays a major role in making life of people easy and comfortable. As welding is the most commonly used process for joining in industries its automation is inevitable at large. For industries to increase cost effectiveness and repeatability of the process with precision automatic welding system is required. So I arrived at the problem statement of this project as **Laser Sensor Based Automatic Welding Process**.

1.6 Objective

Based on the problem statement mentioned above, here are the objectives of this research

- To develop an automatic welding system.
- To minimize the welding defects.
- To check its consistency with other similar processes.

CHAPTER 2

LITERATURE REVIEW

Based on the study we received literatures on different topics. Literature review is an important phenomenon for any research project. We gain different ideas and a very broad way of thinking about the project by reviewing numerous topics. The search for literature includes various websites, journals and books.

2.1 Robust sensor for automated weld-seam-tracking

Another laser stripe sensor framework for the mechanization of welding methodologies in overwhelming businesses is exhibited. Traditional laser stripe sensors use costly multiprocessor blocks with to six advanced sign processors (DSP) to adapt to the high information rate of 14 Mbyte/s conveyed by the sensor's CCD-cam. Another arrangement utilizing one and only profoundly incorporated rationale IC (FPGA) has been produced offering the same execution as multiprocessor arrangements at a radically lower value making laser stripe sensors alluring for expense delicate applications in the substantial businesses. Incorporating the FPGA in the sensor head encourages information transmission to the sensor PC as the information rate is diminished by an element of 700 and can accordingly be transmitted as a powerful RS485 serial flag over huge separations. For the identification of the area of the welding notch another strong fluffy calculation has been produced that ensures a fantastic following result notwithstanding when the welding hole geometry firmly shifts or is twisted by commotion. Utilizing this new strategy, examinations did on modern examples from the boat building industry demonstrated that the fluffy methodology had the capacity adapt to solid crease geometry varieties and ended up being better than ordinary methodologies

2.2 Laser Based Sensor

As shown in Figure 1(a), a typical laser triangulation vision sensor consists of a laser generator, a structured pattern generator, an image sensor, a focus lens and an optical filter.

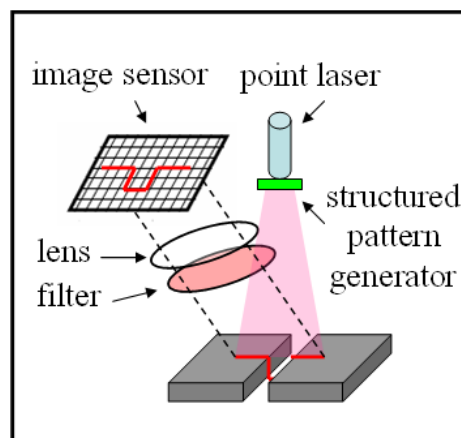


Figure 1 (a) Schematic of the sensor

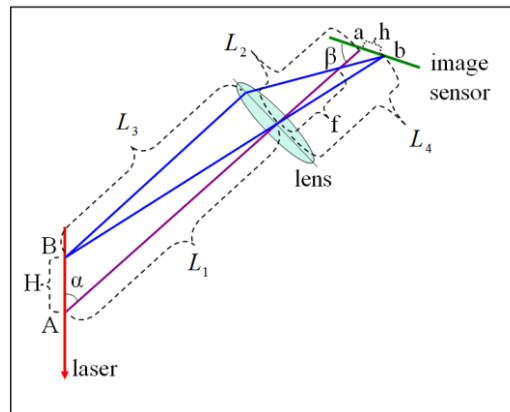


Figure 1 (b) Design of sensor parameters based on laser triangulation.

Another laser stripe sensor structure for the automation of welding techniques in overpowering organizations is shown. Customary laser stripe sensors utilize expensive multiprocessor obstructs with to six propelled sign processors (DSP) to adjust to the high data rate of 14 Mbyte/s passed on by the sensor's CCD-cam. Another game plan using unrivaled significantly fused basis IC (FPGA) has been delivered offering the same execution as multiprocessor courses of action at a fundamentally lower quality making laser stripe sensors charming for cost sensitive applications in the significant organizations. Consolidating the FPGA in the sensor head urges data transmission to the sensor PC as the data rate is decreased by a component of 700 and can in like manner be transmitted as an intense RS485 serial banner over gigantic partitions. For the ID of the territory of the welding score another solid cushioned estimation has been created that guarantees an incredible after result despite when the welding gap geometry solidly moves or is contorted by uproar. Using this new method, examinations did on advanced illustrations from the vessel building industry exhibited that the cushioned procedure had the limit adjust to strong wrinkle geometry assortments and wound up being superior to standard approaches point —all. α is the angle between the optical axis and the laser beam and β is the angle between the optical axis and the image sensor.

2.3 Image caption with camera and laser line projection

The camera is a ASUS A601f-HDR 656(H) x 491(W) pixel and the pixel size 9,9 x 9,9 μm . The laser is a 650 nm laser diode with ability to change the contour of the projection from a dot to a thin ellipse.

Error like commotion, and deviation from the first state of the laser line, are imperative to discover. The laser diode for the laser line projection, and the cam were fixed. Diverse separations from the laser diode to the weld surface were initially tried.

Table 2 The approximate distance from the weld to the laser and the camera

Distance from	To camera (B)	To laser line diode (H)	Angle α
Weld	295 mm	550 mm	45 to 60 degrees

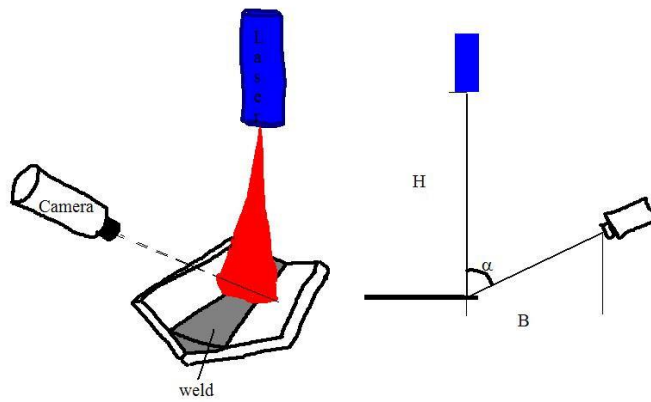


Fig.2 Position of camera and laser sensor over the weld

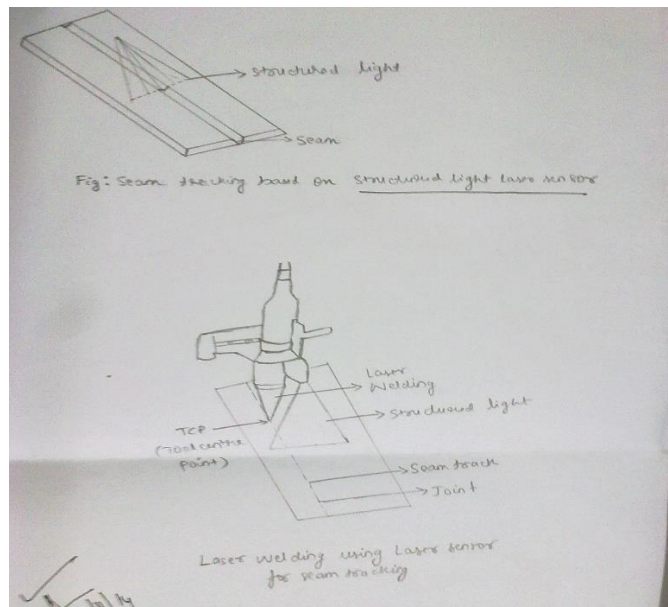


Figure 3 .G.Pristshow Concept

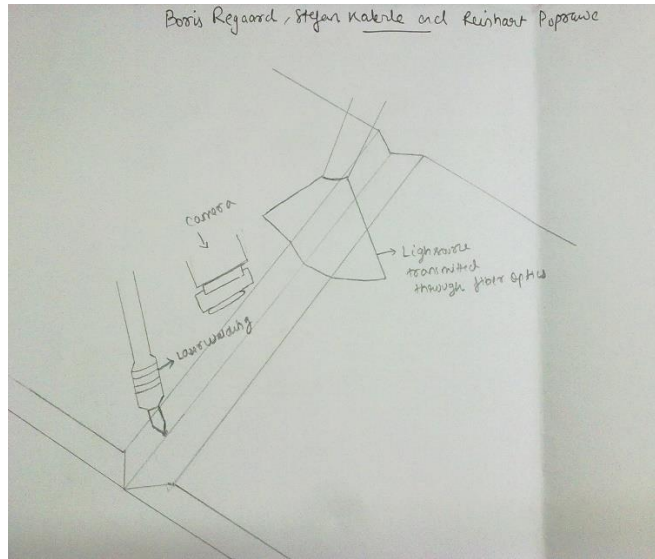


Figure 4. Boris Regaard, Stefan Kalerle and Reinhart Poprawe Concept

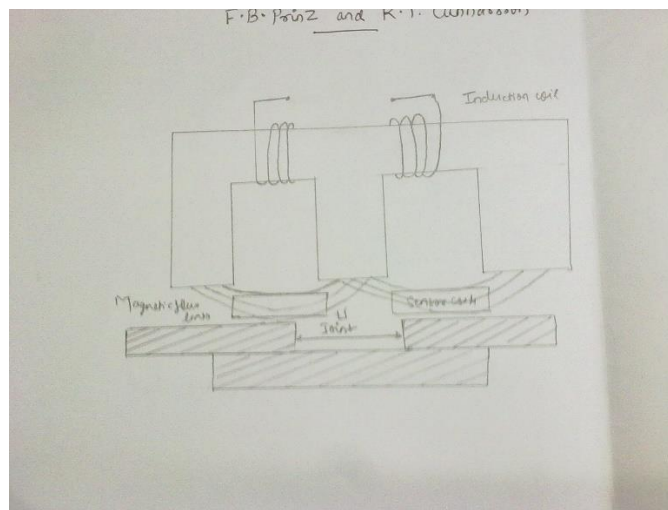
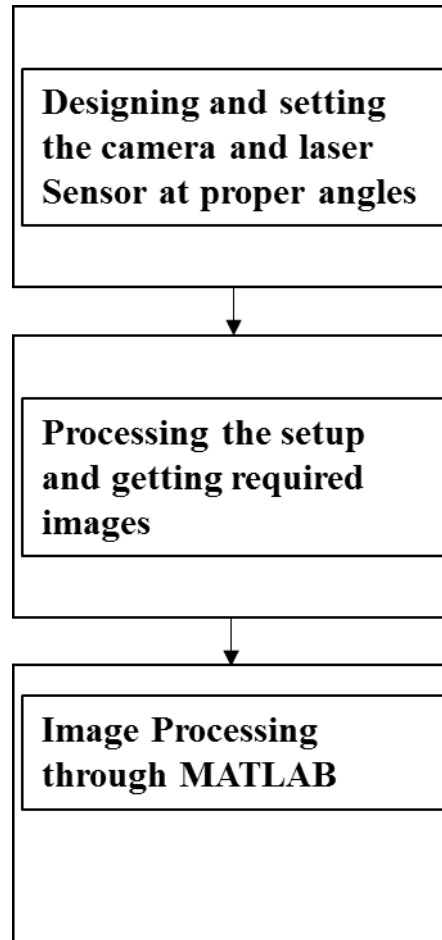


Figure 5. F.B. Prinz and K.T. Cunnarsson

CHAPTER 3

METHODOLOGY

The whole process of automatic welding process is divided into these broad categories:-



3.1 Setting up the camera and Laser sensor at proper angles

As indicated in Figure 2, the created vision sensor fuses an organized light laser generator, a GigE cam, a lens and an optical channel. The organized light laser generator oppositely extends laser plane with a wavelength of 657.9 nm onto the target weld. To gain the picture of the framed set stripe that takes after the profile of the target weld, a GigE cam with an inserted CMOS picture sensor is organized at the planned edge of β regarding the optical pivot of the lens and a separation of L concerning the lens. The strategy to guarantee the gathering precision of all the sensor parts is first to portray the predesign geometrical plan of the segments with taking thought of their geometric detail with CAD programming. At that point distinctive tooling machines are utilized to process the metal plates to frame the sensor lodging in view of the CAD sketch. With precise positions of screw gaps on the metal lodging, the sensor parts are then altered to the metal lodging in predefined points and position. The CMOS picture sensor is a monochromatic sensor chip with

a 659×494 exhibit of eight-bit pixels. It can be utilized to procure grayscale picture with a light force going from 0 to 255, while 0 speaks to the least light power, and 255 speaks to the most astounding light force. The edge rate of the GigE cam is dependent upon 196 edges every second, and the link length is dependent upon 100 m. Before the cam, the center lens with a central length f is likewise exactly organized at the planned separation of L concerning the crossing point between the laser pillar and the optical hub. The point between the optical hub and the laser stripe is orchestrated at the planned edge of a . Likewise, a slender band optical channel focused at 658 nm is set before the centering lens. This optical channel will shut out incidental light created amid the welding methodology.

Thusly, just the reflected laser stripe in the wavelength of 657.9 nm can go through the optical channel to the picture sensor while light unsettling influence and commotion in different wavelengths will be separated out. By correctly orchestrating distinctive parts inside the vision-based sensor module at the composed optical parameters, the position data and the geometrical highlights of the target weld can be acquired taking into account the scientific relationship inferred previously. As demonstrated in Figure 2, the manufactured laser-construct vision sensor is mounted in light of a vertically versatile slide over the worktable of the numerous hub movement framework. With a specific end goal to perform weld quality examination, the movement framework is controlled to accomplish development in 3D space and the profile of the weld then can be examined along particular course. In this study, the pictures obtained by the vision sensor are exchanged to a PC through an Ethernet link. A created picture preparing module that will prepare the pictures and concentrate valuable quality data about the weld is point by point in the accompanying segment

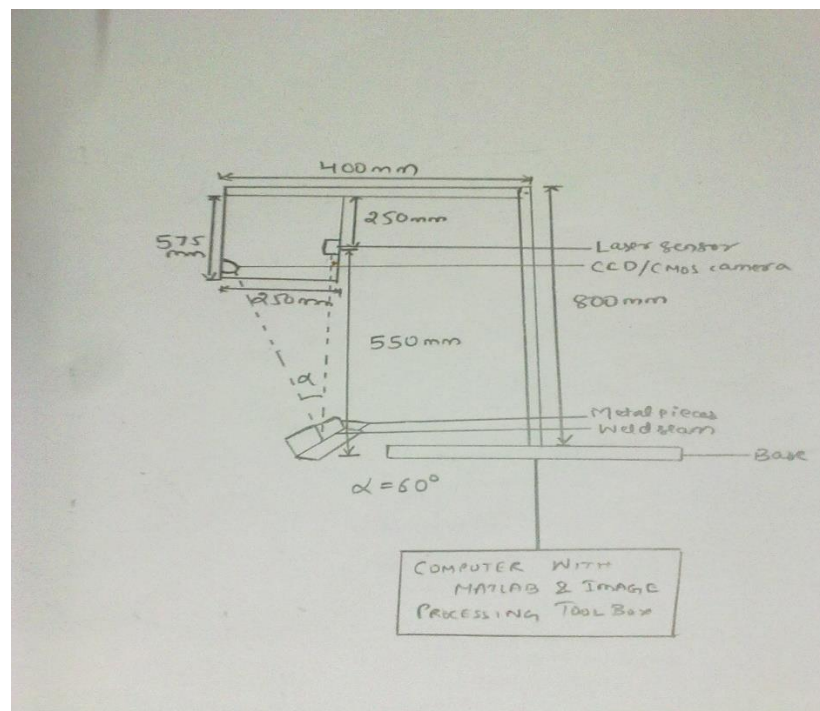


Figure 6. Position and angle of incidence camera and laser sensor

3.2 Processing the setup and getting required images

The separation between the laser diode and the weld is vital to make sufficiently long to guarantee that the projection covers the weld and a portion of the base material. It is vital keeping in mind the end goal to locate the cross-segment of the base material when the picture is examined. The cross-area of the lines speaking to the base material is then utilized as the new root of the projection from the weld. **Appendix 1**

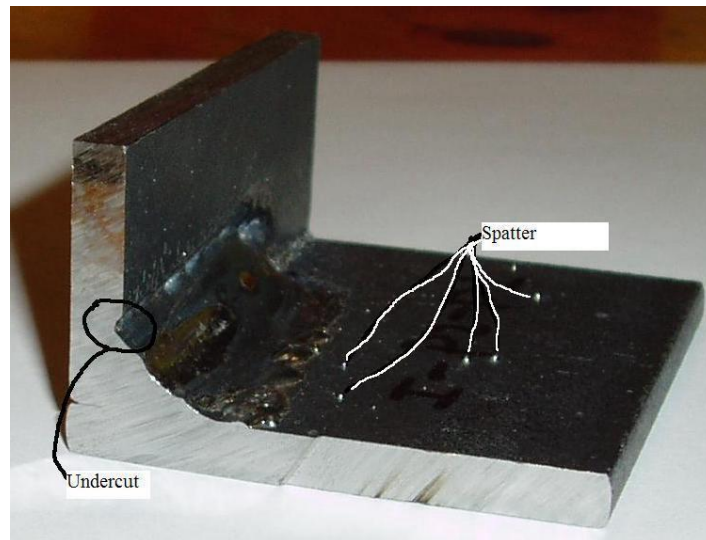


Figure 7. Two metal parts already welded and its defects

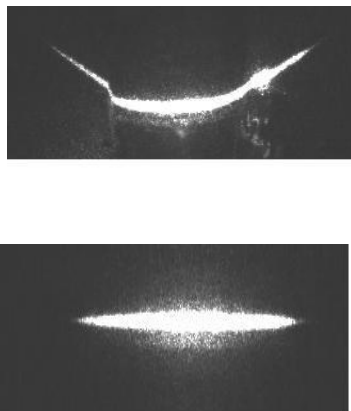


Figure 8. The image captured by the camera of the laser line projection on the weld surface, the right image show the projection on a plane surface.

3.3 Image Processing Through MATLAB

Matlab Image Processing Toolbox is utilized and imread opens the picture and harvests it with incrop to minimize information and after that the picture is dark scaled and Sobel sifted with the

edge identification capacity. Figure 5 demonstrates the consequence of a Sobel channel connected to the dark scaled picture, utilizing two diverse dim scale limits

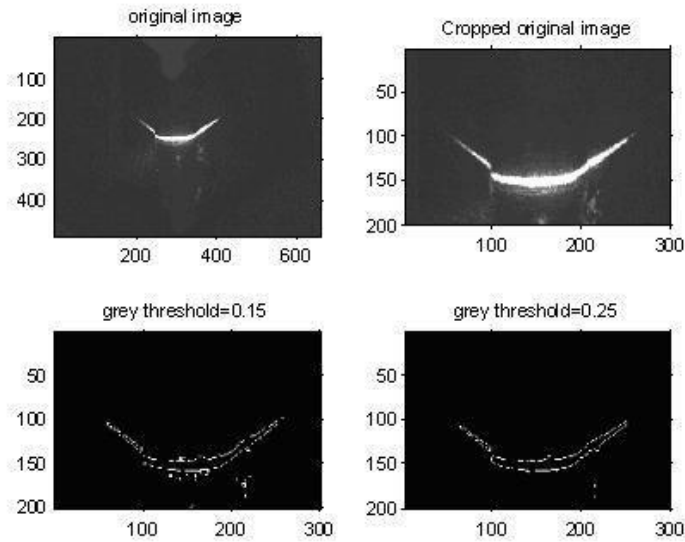


Figure 9. Different grey threshold and Sobel filter on the image

An endeavor to utilize edge identification with Canny channel was performed; the Canny channel gives smooth lines however further on it is unrealistic for the widening device to unite the adjacent items. The enlargement device grows the pixels in level and vertical bearing to consolidation pixels together. As opposed to utilizing vigilant channel all pictures are handled with Sobel channel.

Figure 7 demonstrates the picture prepared with Sobel channel and widening apparatus to join the parts of the item. Imfill is the apparatus that fills gaps in a dull range encompassed by lighter pixels and makes it to one article. The edge (Thres = 150) is utilized as a part of the capacity bwareopen for pixel bunches greater then 150, to be evacuated. **Appendix 2**



Figure 10 Two different dilation values, and the **imfill** tool

The plotted picture from the focuses caught in the picture demonstrates that the base material is not right-calculated. The cam position makes the edge between the computed base- materials don't harmonizes with the direction tomahawks.

There are too many points left and it is recommended to do some calculation to find the geometry among all the points-**Appendix 3**

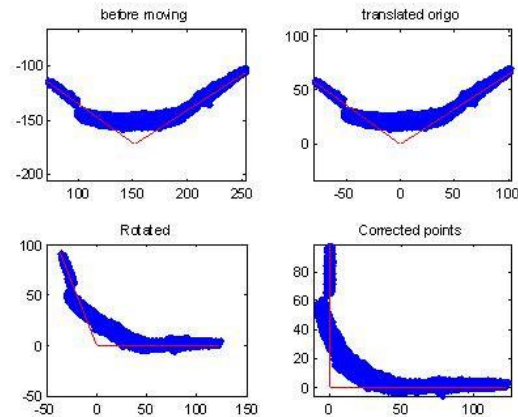


Figure 11 The points from the image translated and rotated

3.3.1 MATLAB Code

```
I=imread('C:\Weld.jpg'); weld = imcrop(I,[150 100 300 200]);
figure;
subplot(2,2,1);imshow(I, title('original image'));axis on
subplot(2,2,2);imshow(weld);title('Cropped original image');axis on

subplot(2,2,3);nnr = 0.15; Ws1=edge(weld,'sobel',(graythresh(weld)*nnr));
imshow(Ws1);title(['grey threshold=' num2str(nnr)]);axis on

subplot(2,2,4);nnr = 0.25; Ws=edge(weld,'sobel',(graythresh(weld)*nnr));
imshow(Ws);title(['grey threshold=' num2str(nnr)]);axis on

% Dilation, Binds nerby objects to eatchother Dv=3;Dh=3;
% Dv=3 Dh=3 best value for bright 187 se90=strel('line',Dv,90);
se0=strel('line',Dh,0);
th1=20; % threshold for small pixel groups r1=num2str(th1);
r20=num2str(Dh);
r21=num2str(Dv);
figure;set(gcf,'Name',['Dilated sobel. Removed pixel groups smaller then ' r1])
Wdareaopen = bwareaopen(Ws,th1); % removes noise smaller than "th" pixels
Wsdils=imdilate(Wdareaopen,[se90 se0]); subplot(2,2,1);imshow(Wsdils);axis off;title(['Dilated,
horiz ' r20 'vert ' r21 ])
se90b=strel('line',3,90); se0b=strel('line',3,90);
```

```

subplot(2,2,2);imshow(imdilate(Wdareaopen,[se90b se0b]));title('Dilated, horiz 3; vert 3')

Wdfill=imfill(Wsdils, 'holes');
subplot(2,2,3);imshow(Wdfill);axis off; title('Imfill tool')

th2 = 150;% th2 = 150;
r10=num2str(th2);
Wdareaopen = bwareaopen(Wdfill,th2);

% Remove extra thicknes dinum=0; % dinum=1; Best value seD=strel('diamond',dinum);
Wfinal=imerode(Wdareaopen,seD);

[L,num] = bwlabeln(Wfinal,8); % L label of objects found, num= how many objects

NUM=num2str(num)
subplot(2,2,4);imshow(L),title(['num obj=' NUM ' Thres= ' r10])

rall = [];call = [];
% figure;set(gcf,'Name',['R,c for the different objects found ' image])
for ii = 1 : num % for all objects found:
[r c] = find(bwlabel((L)==ii)); assignin('base',['r_' num2str(ii)],r); assignin('base',['c_'
num2str(ii)],c);
hold on; subplot(2,2,ii);plot(c,-r);title(['Object nr ' num2str(ii)]);
a = axis; axis([a(1) a(2) -a(4) -a(3)])
axis('equal')
subplot(2,2,ii);

end

rall = [rall; r]; % take hold of all values call = [call; c];

subplot(2,2,num+1);
axis off; text(0,0,'Must only be 1 object found - change threshold or other features otherwise')

% Now I start with the rightmost part and study the last 100 elements in r
% and c:
npr = 150; % number of points from right npl = 200; % number of points from left rright =
rall(end-npr:end,:);
cright = call(end-npr:end,:);
% the angle in the figure to the right
kright = (rright(end)-rright(1))/(cright(end)-cright(1));
theta_right = atan(kright); % in radians

% same with left part rleft = rall(1:npl,:); cleft = call(1:npl,:);
% the angle in the figure to the right

```



```
kleft = (rleft(end)-rleft(1))/(cleft(end)-cleft(1));theta_left = atan(kleft); % in radians
```

```
% subplot(2,2,1);hold on  
pr = polyfit(cright,rright,1);  
k_right = pr(1);  
y_right = k_right*cright + pr(2);  
% plot(cright,-y_right,'g','LineWidth',3)  
t_theta_right=atan(k_right);
```

```
pl = polyfit(cleft,rleft,1);  
k_left = pl(1);  
y_left = k_left*cleft + pl(2);  
% plot(cleft,-y_left,'g','LineWidth',3)  
t_theta_left=atan(k_left);
```

```
% find origo where the left and right "axis" cross; sholud be approx c =  
% 190; r = 155;
```

```
A=[1 -k_left; 1 -k_right];  
y=[rleft(1)-k_left*cleft(1);r(end)-k_right*c(end)];  
x= A\y;
```

```
% No move all points to with the offset of this "x" to find a more suitable  
% origo:  
cnew = call - x(2);  
rnew = rall - x(1);
```

```
% Now rotate also to obtain x- and y-values - rotate right with  
% theta_right:  
points = cnew + j*rnew; % these are same as above but in complex writing.  
% rotated_points = points*exp(-j*theta_right);  
rotated_points = points*exp(-j*t_theta_right);  
xr = real(rotated_points);  
yr = -imag(rotated_points);
```

```
% Correction the ponts to the slope of the base material
```

```
[XR,YR]=adjustPoints(xr,yr); % sending points to rotation function  
plotGraf(XR,YR,xr,yr,x,call,rall,cnew,rnew,image)
```

```
function [XR, YR]=adjustPoints(xr,yr)  
% Input rotated points xr,yr  
% output adjusted points to x,y coordinate  
%  
% Called by imageTranslation.m  
% 2008-04-25 Inger Eriksson
```

```

V=atan2(yr(1),xr(1)); dV=V-pi/2; v=atan2(yr,xr);
dv=-v/V*dV; Z=[]; F=size(dv); for i=1:F
M=[cos(dv(i)) -sin(dv(i));sin(dv(i)) cos(dv(i))];
Z(:,i)=M*[xr(i);yr(i)];
end
XR=Z(1,:);
YR=Z(2,:);

```

3.3.2 MATLAB Graphical Interface

The interface was intended to choose one area of focuses from the 3D filtered picture, at the time. The weld utilized as a part of the previous undertaking did not have any scatter or undercut so the interface did not identify these deviations. Figure 13 demonstrates the first graphical interface made in Matlab. **Appendix 4,5**

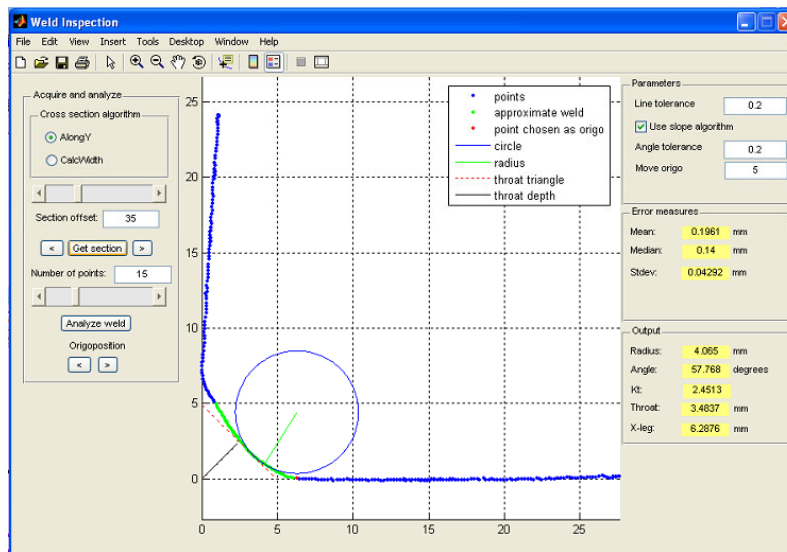


Figure 12 The original graphical interface made in MATLAB

In this form the test designer picks a cross segment from the 3D picture and the project then presents information figurings of the weld in the x-bearing. The "Get area" catch attracts the bend the window. The interface presents [2]:

- A figure on the chosen weld section
- The radius and angle of a circle drawn at the weld toe
- The weld throat
- The x-leg length of the weld
- The Kt-value

The Kt-quality is a measure of the strain fixation and can be assessed from the range and the edge at the weld toe. Kt ought not be under 2,5 and the worth is subject to the point and the sweep of the weld, see Appendix G (Calculation of the Kt-esteem). In the interface it is workable for the test architect to adjust the line resilience, and number of focuses in the estimation of the range and point of the weld toe. It is additionally conceivable to pick the purpose of the weld begin.

CHAPTER 4

RESULTS AND DISCUSSIONS

Results from the measuring of the gauge block, presented in Section 3.2.3 (Accuracy), gives that objects as small as 0,2 mm in the z-direction are possible to find. In the technical data of the scanCONTROL the resolution in the z-direction is 0,04 mm. There was no filter used in the test occasion and only one threshold.

The information from the picture tackled the anticipated laser line, from the laser diode, was just transformed until the focuses were acclimated to the x- and y- hub in the direction framework. The choice to that was the time furthest reaches of the task and that the output CONTROL framework had arrived. **Appendix 6**

The graphical interface made in Matlab, portrayed in the past section, was altered to allow the information from the scanCONTROL. The changes that was done from the previous version:

- Select what data file to open
- Indicate which points that differ from line tolerance
- Find the y-leg of the weld
- Indicate the weld start on the y-leg
- Find spatter
- Calculate the theoretical leg length

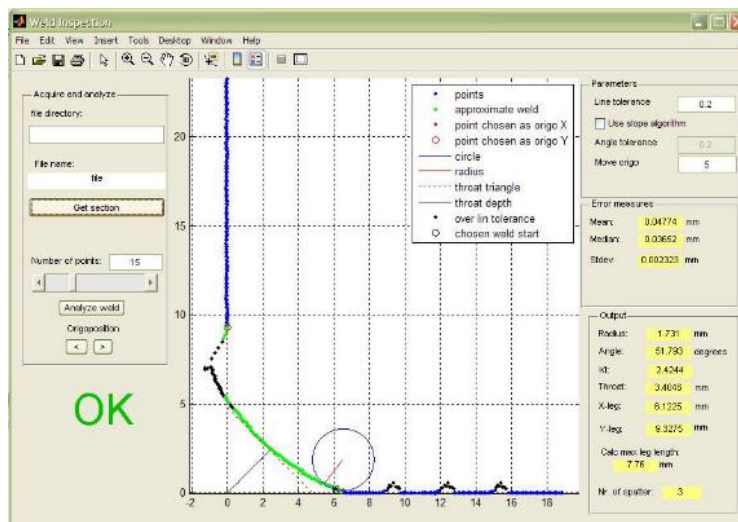


Figure 13 The revision of the graphical interface made in Matlab

CHAPTER 5

CONCLUSIONS AND FURTHER WORK

The begin of this undertaking was finished with the investigation of different programmed welding machines accessible in the business sector and subsequently we set forward the issue explanation.

Among all the diverse programmed welding frameworks we picked the welding framework which is in view of laser sensor and CMOS Camera for precise area of the crease. The correct edge and plan for the setup was done and the picture accumulated from the subsequent setup was placed in the picture preparing strategy utilized for crease following and subsequently the crease was followed and the welding was finished. After this the setup was contrasted with the most usually utilized programmed welding machine as a part of the business scanCONTROL and their highlights were recognized.

The principal investigation, with the cam and laser diode, was an experience to realize a percentage of the settings of the cam, and to comprehend the impact of the edge between the cam and anticipated line. The examination of the information from the pictures ceased then the focuses were conformed to the direction framework, further examination obliges line fitting to discover one bend among all focuses. The cam and laser diode framework obliges a great deal of work push to concentrate and discover the geometry of the weld and conceivable imperfections. For this situation the anticipated line was somewhat short so it just secured the weld and a short separation of the base material. Keeping in mind the end goal to discover splash the laser line projection must be more extensive to cover a greater amount of the base material.

The obtained ScanCONTROL framework has manufactured in programming in the sensor head that concentrates the focuses from the projection of the laser line. The work that was performed on the first trial, to concentrate focuses, is as of now done in this framework, and the further work was to dissect the information. In the Matlab program that was audited and altered it was anything but difficult to discover scatter, undercut, leg-length and toe edge.

So as to robotize the investigation of the weld geometry it is presumably a smart thought to utilize another methodology. As opposed to ascertaining each bend in the examination programming, one can utilize a database with put away bends for correlation. Neural system is perhaps an approach to comprehend it, the neural system use calculations for example acknowledgment, and it figures out how to perceive particular examples.

It is conceivable to discover the geometry of the weld and it is conceivable to discover imperfections with laser line projection and cam. The gear is imperative keeping in mind the end goal to concentrate information helpful for investigation. I need to suggest a buy of the

ScanCONTROL since it is now part of the way through the work. The focuses from the laser projection are prepared to utilize either in the product acquired along the sensor, or created suitable for the event. It should however be tried to be sufficiently hearty in the event that it might be utilized on – line amid welding

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APPENDIX

1. Otsu' method in MATLAB

```
clc
clear all I=imread('C:/weld.jpg');
subplot(1,2,1),imshow(I);
title('initial image')
level=graythresh(I);    % setting grey thresholding value
BW=im2bw(I,level);
subplot(1,2,2),imshow(BW);
title('Otsu' method segmentation ');
```

2. Histogram thresholding in MATLAB

```
I=imread('C:/weld.jpg');
I1=rgb2gray(I); figure;
subplot(2,2,1);
imshow(I1);
title('greyscaled image')
[m,n]=size(I1);
GP=zeros(1,256);
for k=0:255
GP(k+1)=length(find(I1==k))/(m*n);
end
subplot(2,2,2),bar(0:255,GP,'g')    % display histogram diagram title('
Greyscaled histogram diagram ')
xlabel(' Grey value')
ylabel(' Probability of occurrence ')
I2=im2bw(I,45/255);
subplot(2,2,3),imshow(I2);
title('segmented image of thresholding value 45')
I3=im2bw(I,65/255);
subplot(2,2,4),imshow(I3);
title(' segmented image of thresholding value 65')
```

3. K-means clustering in MATLAB I_rgb =

```
imread('C:/weld.jpg');
subplot(1,2,1),imshow(I_rgb);
title(' initial image ');
C = makecform('srgb2lab'); I_lab =
applycform(I_rgb, C); ab =
double(I_lab(:, :, 2:3)); nrows =
size(ab,1);
ncols = size(ab,2);
ab = reshape(ab,nrows*ncols,2);
nColors = 3;    % initial cluster centers
```

```
[cluster_idx cluster_center] = K-
means(ab,nColors,'distance','sqEuclidean','Replicates',3);
% iteration loops
pixel_labels = reshape(cluster_idx,nrows,ncols); subplot(1,2,2),imshow(pixel_labels,[]),
title('K-means clustering segmentation');
imwrite(pixel_labels,'KC:/weld.jpg','quality',100);
```

5. Edge detection in MATLAB

```
I=imread('C:/weld.jpg'); subplot(2,3,1);
imshow(I); title('initial
image'); I1=im2bw(I);
I2=edge(I1,'roberts');
subplot(2,3,2); imshow(I2);
title(' detection by roberts operator ');
I3=edge(I1,'sobel');
subplot(2,3,3);
imshow(I3);
title(' detection by sobel operator ');
I4=edge(I1,'Prewitt'); subplot(2,3,4);
imshow(I4);
title(' detection by Prewitt operator ');
I5=rgb2gray(I);
I6=edge(I5,'canny');
subplot(2,3,6); imshow(I6);
title(' detection by canny operator ');
```

6. Image evaluation in MATLAB

```
file_name='1';
a=double(imread(file_name));
M=size(a,1);
file_name='O1';
b=double(imread(file_name));
N=size(b,2);
sum1=0;
for i=1:M;
    for j=1:N;
        sum1=sum1+(a(i,j)b(i,j))^2;
    end;
end;
mseValue=sum1/(M*N);           % calculate MSE
sum2=0;
for i=1:M;
    for j=1:N;
        sum2=sum2+(a(i,j))^2;
    end; end;
P=sum2;
```

```

snrValue=10*log10(P/mseValue);    % calculate SNR
psnrValue=10*log10(255^2/mseValue); % calculate PSNR
sum3=0;
for i=1:M;
    for j=1:N;
        sum3=sum3+abs(a(i,j)-b(i,j));
    end; end;
Q=sum3;
maeValue=Q/(M*N);% calculate MSE
fprintf('\n MSE/SNR/PSNR/MAE of comparative image are %f / %f / %f / %f
separately.\n',mseValue,snrValue,psnrValue,maeValue);
%display the MSE/SNR/PSNR/MAE

```

7. Image enhancement in MATLAB

```

I=imread('C:/weld.jpg');
subplot(1,2,1),imshow(I);
title('initial image') I1=rgb2gray(I);
J=imadjust(I1,[0.1 0.5],[0.1]);
% transform the range of grey value from [0.1 0.5]to[0 1]
k2=medfilt2(J,[5,5]); % median filtering in 5*5
I2=histeq(k2); % image equalization
subplot(1,2,2),imshow(I2);
title('image enhancement');

```