UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Engineering

LOCAL THRESHOLD IDENTIFICATION AND GRAY LEVEL CLASSIFICATION OF BUTT JOINT WELDING IMPERFECTIONS USING ROBOT VISION SYSTEM

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A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

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DECLARATION

I declare that this thesis entitled "Local Threshold Identification and Gray Level Classification of Butt Joint Welding Imperfections Using Robot Vision System" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
Name	:	Hairol Nizam Bin Mohd Shah
Date	:	....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : ………………….…………..

Supervisor Name : Prof. Ir. Dr. Marizan Bin Sulaiman

Date : ………………………………

DEDICATION

Dear Allah

I devoted my life and death to You, Allah. May my life is within Your guidance.

Dear My Parent

Thank you for your sacrifice and love. No such compensate except from Allah.

Dear My Beloved Wife

Your support, patience and encouragement give me strength. May Allah bless us.

Dear Teachers

Thank you for all the knowledge. May your knowledge are useful for all humanity.

Dear My Siblings

Thank you for your support and love. May Allah forgive us.

Dear My Children

May Allah guide and protect us to be good Muslims.

ABSTRACT

This research is carried out be able to automatically identify the joint position and classify the quality level of imperfections for butt welding joint based on background subtraction, local thresholding and gray level approaches without any prior knowledge of the joint shapes. The background subtraction and local thresholding approaches consist of image pre-processing, noise reduction and butt welding representation algorithms. The approaches can automatically recognize and locate the butt joint position of the starting, middle, auxiliary and ending point according to the three different joint shapes; straight line, tooth saw and curved joint shapes. The welding process was done by implemented an automatic coordinate conversion between camera (pixels) and KUKA welding robot coordinate (millimeters) from the KUKA welding robot and camera coordinate ratio. The ratio was determined by a camera and three reference point (origin, x-direction and y-direction) taken around workpiece. Hence, the quality level of imperfection for butt welding joint was classified using Gaussian Mix Model (GMM), Multi-Layer Perceptron (MLP) and Support Vector Machine (SVM) classifiers according to their class of imperfection categories; good welds, excess welds, insufficient welds and no weld in each welding joint shape. These classifiers introduced 72 characteristics of feature values of gray pixels taken from co-occurrence matrix. The feature values consist of energy, correlation, homogeneity and contrast combine with gray absolute histogram of edge amplitude including additional characteristic features with scaled image factor by 0.5. The proposed approaches were validated through experiments with a KUKA welding robot in a realistic workshop environment. The results show that the approaches introduced in this research can detect, identify, recognize, locate the welding position and classify the quality level of imperfections for butt welding joint automatically without any prior knowledge of the joint shapes.

ABSTRAK

Penyelidikan ini dapat mengenalpasti kedudukan sambungan kimpalan dan mengelaskan tahap kualiti ketidaksempurnaan kimpalan untuk sambungan kimpalan temu berdasarkan pendekatan pengurangan latar belakang, ambang tempatan dan tahap kelabu tanpa pengetahuan sebelumnya tentang sambungan bentuk kimpalan. Pengurangan latar belakang dan ambang tempatan terdiri daripada pemprosesan imej, pengurangan hingar dan algoritma perwakilan kimpalan temu. Pendekatan in secara automatik dapat mengenali dan mencari kedudukan titik sambungan kimpalan temu samaada permulaan, pertengahan, persilangan dan pengakhiran mengikut tiga bentuk sambungan yang berbeza; garis lurus, gergaji gigi dan sambungan secara melengkung. Proses kimpalan dilakukan dengan melaksanakan penukaran koordinat antara kamera (piksel) dan kimpalan robot KUKA (milimeter) secara automatik dari nisbah antara kimpalan robot KUKA dan kamera yang diselaraskan. Nisbah itu diperolehi daripada kamera dan tiga titik rujukan (asal, arah x dan arah y) yang diambil di sekeliling benda kerja. Justeru itu, tahap kualiti ketidaksempurnaan untuk sambungan kimpalan temu akan diklasifikasikan menggunakan pengelas Gaussian Mix Model (GMM), Multi-Layer Perceptron (MLP) dan Support Vector Machine (SVM) mengikut kategori kelas ketidaksempurnaan mereka; kimpalan yang baik, kimpalan berlebihan, kimpalan yang tidak mencukupi dan tiada kimpalan di setiap sambungan kimpalan. Pengelas ini memperkenalkan 72 nilai ciri-ciri dalam piksel kelabu yang diambil dari matriks coocurrence. Nilai ciri-ciri tersebut terdiri daripada tenaga, hubung kait, serumpun dan pertentangan bergabung dengan histogram mutlak kelabu daripada pinggir amplitud termasuk tambahan ciri-ciri dengan meningkatkan faktor imej kepada 0.5. Pendekatan yang dicadangkan dibuktikan melalui percubaan dengan menggunakan kimpalan robot KUKA dalam persekitaran bengkel yang realistik. Keputusan menunjukkan bahawa pendekatan yang diperkenalkan dalam kajian ini dapat mengesan, mengenalpasti, mengenali, menyetempatkan kedudukan kimpalan dan mengelaskan tahap kualiti ketidaksempurnaan untuk sambungan kimpalan temu secara automatik tanpa pengetahuan sebelumnya tentang sambungan bentuk kimpalan.

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ACO	-	Ant colony optimization
ANFIS	-	Fuzzy inference system based adaptation
ANN	-	Artificial neural network
CCD	-	Charge coupled devices
CIR	-	Circular motion
CoD	-	Correction of defect
DEA	-	Differential evolutionary algorithm
DOGS	-	Degree of grey similarity
EM	-	Expectation maximization
GLCM	-	Gray level co-occurrence matrix
GMA	-	Gas metal arc
GMM	-	Gaussian mixture model
GTAW	-	Gas tungsten arc
KRL	-	KUKA robotic language
LED	-	Light emitting diode
LIN	-	Linear motion
MIG	-	Metal inert gas
MLP	-	Multi-layer perceptrons
NCC	-	Normalized cross correlation
NDT	-	Non-destructive testing