AN IMPROVED FRAMEWORK OF REGION SEGMENTATION FOR DIAGNOSING THERMAL CONDITION OF ELECTRICAL INSTALLATION BASED ON INFRARED IMAGE ANALYSIS

MOHD SHAWAL JADIN

UNIVERSITI SAINS MALAYSIA

2018

AN IMPROVED FRAMEWORK OF REGION SEGMENTATION FOR DIAGNOSING THERMAL CONDITION OF ELECTRICAL INSTALLATION BASED ON INFRARED IMAGE ANALYSIS

by

MOHD SHAWAL JADIN

Thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

July 2018

ACKNOWLEDGEMENT

First and foremost, I would like to express my utmost gratefulness to Allah (S.W.T) The Almighty and The Most Powerful for giving me the strength, wisdom and perseverance in successfully accomplishing my research. My deepest appreciation to my main supervisor, Associate Professor Ir. Dr. Dahaman Ishak and my co-supervisor Associate Professor Dr. Soib Taib, for their knowledgeable support, ideas, high tolerance, great patience and good leadership skill provide me a high spirit to face any difficulty throughout this research. This dissertation would not have been possible without his guidance and persistent supervision. Apart from that, special thanks to my field supervisor Prof. Ir. Dr. Hj. Kamarul Hawari Ghazali for his valuable opinions and guidance to further improve my research.

I would also like to acknowledge with much appreciation to the Ministry of Higher Education, Universiti Malaysia Pahang and Universiti Sains Malaysia, for their sponsorship and financial support as well as the facilities until the research completed.

Special thanks also I would like to dedicate to the lecturers, technicians and the entire staffs of School of Electrical and Electronic, University Sains Malaysia for their technical and motivational support.

Special thanks are due to my parents, wife and family, for their outstanding support and patience which giving me high motivation to complete this thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASTM	American Society for Testing & Materials
AUC	Area Under Curve
CTREM	Complexity Based Transition Region Extraction Method
DoG	Difference of Gaussians
EDISON	Edge Detection and Image Segmentation
FN	False-Negative
FP	False-Positive
FPR	False-Positive Rate
F	Fault Condition
GT	Ground Truth
NETA	International Electrical Testing Association
JSEG	J measure based SEGmentation
MSER	Maximally Stable Extremal Regions
MSE	Mean Squared Error
MLP	Multilayer Perceptron
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NF	No Fault Condition
RBF	Radial Basis Function
RANSAC	RANdom SAmple Consensus
SIFT	Scale Invariant Feature Transform
SI	Segmented Image
SVM	Support Vector Machine

TRE	Transition Region Extraction
TN	True-Negative
TP	True-Positive
TPR	True-Positive Rate

LIST OF SYMBOLS

α	Absorption of thermal radiation
$F(\bullet)$	Activation function
T_{amb}	Ambient temperature
θ_{co}	Angle of clusters matching
T_{mean}	Average temperature
T_{bg}	Background temperature
d_B	Bhattacharyya histogram distance between target and reference region
d_C	Canberra histogram distance between target and reference region
H_B	Classes of image background
H_F	Classes of image foreground
$d(\Omega_a, \Omega_b)$	Cluster dissimilarity function
α_{ent}	Coefficient of the maximal entropy
w_{ij}^1, w_{jk}^2	Connection weights between the hidden and the output layers
$P(T_g)$	Cumulative probability
T_{cut}	Dendrogram cutting threshold
E_{obj}	Energy emitted directly from the target object
E_{amb}	Energy reflected from other surrounding objects
R_i	Estimated absolute radius of region
d_E	Euclidean histogram distance between target and reference region
H_1, H_2	First and second histogram of a region
f_j, f_k	First and the second nearest neighbour
n_i	Frequency of gray level
Q_{obj}	Fuzzy objective function

i	Gray level of an image
k_1,k_2	Hamadani method's constants
I_n	Image brightness value
$\mathcal{R}_0$	Initial region clustering
I_{inv}	Inverted image
K	Kernel function parameter
λ_1, λ_2	Length of the first and second axis of the ellipse
F_{sift}	List of SIFT descriptors
A_{gb}	Local accumulated gradient of brightness
$E(\Omega_k)$	Local entropy of neighborhood
$\hat{x}$	Local extrema
T_{coef}	Local texture coefficient
X_{match}	Matching candidate coordinates
T_{match}	Matching threshold
d_M	Matusita histogram distance between target and reference region
Q_i	Maximally stable region
T_{max}	Maximum temperature of the selected region
T_{rmax}	Maximum temperature range of the image
μ	Mean
E_r	Mean squared error
μ_b	Mean values of the image background
μ_f	Mean values of the image foreground
$T_{component}$	Measured absolute temperature of the component
T_{rmin}	Minimum temperature range of the image
S	Multiplication factor of the scale-space image

v_i	Neurons in the input layer
C_l	Number of clusters
n_h	Number of hidden nodes
n_i	Number of input nodes
n	Number of samples
g_j	Number of pixels in the neighbourhood of grayscale image
θ	Orientation
C	Penalty parameter of error (Cost)
T_{gray}	Pixel intensity value at a certain point in the grayscale image
d_k	Predicted output
$p(i)$	Probability distribution of the image histogram
$p(j)$	Probability distribution local entropy of neighbourhood
γ	RBF kernel function parameter
T_r	Real temperature value
T_{ref}	Reference temperature
ρ	Reflection of thermal radiation
DT_{bg}	Relative to ambient temperature
S_f	Scaling factor of the image scale
T_h	Segmentation threshold
f	SIFT feature descriptor
ζ	Slack variable
Ω_k	Small neighbourhood window of image
q_R	Stability criterion of region
σ_{sd}	Standard deviation of image intensity
σ_b	Standard deviation of image background

σ_f	Standard deviation of image foreground
y_k	Target output in the output layer
ΔT_{phase}	Temperature difference between phases
T_{delta}	Temperature difference between target equipment and reference region
T_{kurt}	Temperature kurtosis
T_σ	Temperature standard deviation
T_{skew}	Temperature skewness
T_{var}	Temperature variance
T_{mgv}	The highest grayscale value of the image
L	The highest pixel intensity in the image
T_{L1}	The hot spot temperature of the measured object
T_{L2}	The hotspot temperature of the reference object
b_j	Threshold in the hidden nodes
T_g	Threshold value to divide the class variance
E_{cam}	Total energy sensed by an infrared camera
N_{pixel}	Total number of image pixels
τ	Transmission of thermal radiation
E_{bg}	Transmitted energy through the target object by other surrounding objects
v_p	Voted cluster pair
I_h	Warm region enhancement
m	Weighting exponent parameter
σ	Width of Gaussian filter
d_X	χ^2 histogram distance between target and reference region
w_0 , w_1	Zero-order cumulative moment

SATU RANGKA PENINGKATAN SEGMENTASI RANTAU UNTUK DIAGNOSIS KEADAAN TERMA PEMASANGAN ELEKTRIK BERDASARKAN ANALISIS IMEJ INFRAMERAH

ABSTRAK

Keadaan yang tidak normal bagi peralatan elektrik akan berlaku apabila suhunya melebihi had yang dibenarkan, yang boleh mengakibatkan kegagalan peralatan tersebut. Oleh itu, pencegahan awal amat penting untuk mengelakkan perkara ini berlaku disamping meningkatkan kebolehpercayaan peralatan tersebut. Kajian ini mencadangkan satu teknik baharu bagi segmentasi kawasan imej dan kaedah untuk mendiagnosis keadaan haba bagi peralatan elektrik dengan mengambilkira analisa imej inframerah secara kualitatif dan kuantitatif. Memandangkan kebanyakan pemasangan elektrik kebiasaannya disusun secara tetap dengan struktur yang berulang-ulang, satu kaedah baharu dicadangkan bagi mengesan semua struktur peranti elektrik yang serupa dalam satu imej inframerah. Kaedah ini menggunakan gabungan dua algoritma pengesan titik utama iaitu algoritma transformasi ciri-ciri invarian skala (SIFT) dan kawasan ekstrem yang stabil (MSER) bagi meningkatkan bilangan pengesanan titik utama. Satu kaedah baharu untuk memadan dan menterjemahkan kluster telah dicadangkan dengan memperkenalkan prosedur pengundian bagi menentukan padanan kluster. Pengesanan rantau dicapai dengan menggunakan kaedah grid di mana ia membahagikan kelompok-kelompok berulang sebelum keseluruhan objek yang disasarkan itu disegmentasi dengan sempurna. Untuk menilai keadaan pemasangan peralatan elektrik, keberkesanan menggunakan tiga jenis ciri input yang berbeza telah diselidiki. Pendekatan model ‘wrapper’ digunakan untuk memilih ciri yang sesuai di mana perseptron berbilang lapisan (MLP) rangkaian neural tiruan dan mesin vektor sokongan (SVM) digunakan untuk menilai setiap set gabungan ciri. Berdasarkan hasil kajian terhadap kaedah segmentasi yang dicadangkan, kira-kira 94.27% dari rantau telah dikesan dengan betul dengan purata nilai kawasan di bawah lengkung (AUC) sebanyak 0.79 telah dicapai. Semasa menentukan keadaan terma, didapati bahawa gabungan ciri input T_{delta}, T_{skew}, T_{kurt}, T_{σ} dan d_B menghasilkan ketepatan terbaik bagi mengesan kerosakan haba yang diklasifikasikan oleh SVM menggunakan fungsi kernel asas jejarian. Kadar prestasi tertinggi dicapai pada 99.46% dan 97.78% berdasarkan ketepatan dan nilai *f-score*.