

THROUGH HOLE SOLDERING SYSTEM WITH AUTOMATIC OPTICAL INSPECTION

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Declaration

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Abstract

Machine vision has been widely deployed in many applications in various sectors like industrial, medical, manufacturing, agricultural, surveillance etc. Such applications consist of numerous algorithms to fulfil the ultimate requirement of the end product. The role of automatic vision for classifying the quality of solder joints in the Electronics Manufacturing Services (EMS) industry has become significant because the increasing cost of labour, skill dependency, attitudes, time variance of human operators have narrowed down the quality of their service. Several major companies develop stand-alone Automatic Optical Inspection (AOI) systems with proprietary algorithms that contains multiple cameras operating inside a specific lighting environment for the inspection of Surface Mount Devices (SMD) and Through-Hole Technology (THT) components. However, the accuracy and maturity level for the automatic inspection of the quality of solder joints have yet to reach its ultimate goal due to the complex appearance of solder joint surface. Even though, many AOI systems are available, no vision system has been developed to integrate with a soldering robotic system to provide quality classification of solder joints in real time without prior teaching of individual joints and enclosed chambers with specific lighting to operate.

In this research, a THT soldering system with an AOI and Computer Aided Design (CAD) tool has been developed to classify the quality of THT solder joints without prior teaching and specific lighting requirements. The design consists of three main stages:

- AOI system for quality classification of THT solder joints (Major Research)
- CAD tool for extracting physical parameters of each component (Minor Research)
- THT Soldering system to perform automatic soldering (Minor Research)

The AOI system mainly operates in three stages. The first stage involves with precise alignment of the Printed Circuit Board (PCB) to the origin of the THT soldering system using feature extraction and template matching techniques. This approach provide a reliable and robust PCB verification and alignment capability compared to Hough transform based alignment method proposed by Nang Seng Siri Mar. Furthermore, this methodology rendered a better outcome even in distinguishing between vias, pads and test-points in addition to conventional fiducial markings. The identification of the solder pad and the verification of the component availability is performed prior to soldering in the second stage. The automatic identification of solder pad regardless of its plated colour and surrounding solder mask colour made a significant improvement over the methodology proposed by T. Y. Ong, Z. Samad and M. M. Ratnam, based on prior teaching of individual pads using artificial neural networks. In addition to that, the implemented methodology provides online positioning accuracy calibration which is not available in any commercial soldering robotic systems. The component availability is assured by precisely segmenting the component lead top from the identified solder pad. The developed algorithms could render a better outcome even for component leads which possess a minimum colour dissimilarity with their surrounding drill-hole region. No commercial soldering robotic system is capable of verifying component availability prior to soldering. Further, the segmented lead is used to establish a relationship between prior and post soldering stages of the solder pad in order to provide a robust solder quality classification capability. The classification of the soldering quality for short circuit (solder bridging), voids inside the drill-hole, voids on solder pad and excess solder, is carried out after soldering during the third stage. The implemented algorithms could render an improved recognition rate even with applied flux, illuminated pad regions, uneven illumination distribution and shadows on the solder joint surface. Such a widely distributed quality inspection capability is

not covered in any of the reported studies. Neither commercial AOI systems nor soldering robotic systems perform real time inspection of soldering quality just after the soldering of THT components. Moreover, the precise localization of defective areas inside the solder joint, enables the robotic system to perform automatic reworking on defective solder joints adhering to IPC regulations with minimum user interaction. Such automatic reworking capability is not available with any commercial soldering robotic system in the market today.

The CAD system extracts the geometrical information of components and their pads such as the component location, its orientation, size of the solder pad and drill hole, height of nearby components, the width of the connected PCB track to the solder pad from the respective CAD file and visualize the 2D view of the PCB to the user in a Graphical User Interface (GUI). This information enhances the intelligence and the situational awareness of both robotic system and AOI.

The THT soldering system is a four-axis robotic platform that performs soldering on selected solder pads through the CAD system GUI. Its operation is mainly controlled by the vision system and the information acquired from the CAD system. The implemented THT soldering system together with integrated AOI and CAD tool provides a new concept in the EMS industry by replacing the manual inspection of THT solder joints with automatic inspection and providing automatic rework capability on defective solder joints within a single platform.

The performance of the complete system was evaluated under different illumination levels, flux residues, different types of component leads, colour combinations of solder pads and solder mask colours, wide variety of solder pad neighbourhoods and a range of solder pad sizes. Each stage of the AOI was able to provide a significant improvement over the reported studies and commercial systems. The automatic identification of solder pad and the verification of component availability could provide nearly a 98% of recognition rate for both cases. However, the existence of highly illuminated pad regions and overheated solder joints surfaces degrades the performance of the classification of not soldered regions by 2% and excess solder detection by 5% respectively (subjected to a sample size of 200 solder joints). Even though, a slight performance reduction is there due to such extreme conditions, the proposed approach provides an automated solution for soldering and quality assurance within a single platform while solving several problems in the reported studies and commercial systems effectively.

Keywords:

Automatic Optical Inspection, Solder Quality Classification, Localization of Component Lead inside a THT Solder Joint for Solder Defects Classification, Fiducial Verification

To my parents, wife and sister

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Table of Contents

Declaration	I
Abstract	II
Dedication	IV
Acknowledgement	V
Table of Content	VI
List of Figures.....	X
List of Tables.....	XIX
List of Abbreviations	XXII
List of Appendices	XXIV
1. Introduction.....	1
1.1 Overview of Automatic Optical Inspection Systems	2
1.2 Overview of Soldering Robotic Systems.....	3
1.3 Recent Works.....	4
1.4 Original Contribution of the Research in Knowledge Gap and Industry	7
1.5 Automatic Optical Inspection System Architecture.....	10
1.6 THT Soldering System Architecture.....	12
2. Implementation of Automatic PCB Fiducial Alignment Process	14
2.1 PCB Fiducials and Importance of Localizing Them.....	14
2.2 The Distinctive Behaviour of the Proposed Fiducial Verification Process in the Automatic Optical Inspection System.....	16
2.3 Algorithms for Fiducial Verification.....	17
2.3.1 Scale Invariant Feature Transform	19
2.3.2 Speed-Up Robust Feature	25
2.3.3 Features from Accelerated Segment Test	34
2.4 Performance Evaluation of Feature Extraction Algorithms	36
2.5 Performance Evaluation of Template Matching Algorithms.....	45

3. Identification and Localization of Bare Solder Pad from PCB Surface	49
3.1 Overview on Colour Models.....	49
3.2 Performance Analysis of Colour Models for Solder Pad Identification	55
3.3 Image Type Verification for Image Segmentation.....	61
3.4 Solder Pad Segmentation.....	63
4. Identification and Localization of THT Component Lead	73
4.1 Importance of Identification and Localization of THT Component Lead Top inside a Solder Joint	73
4.2 Segmentation of THT Component Lead Top from Solder Pad Region	76
4.2.1 Automatic Computation of Drill-hole Region	77
4.2.2 Segmentation of Component Lead Top	84
4.3 Localization of THT Component Lead inside Solder Joint.....	89
5. Classification of the Quality of THT Solder Joints	96
5.1 Types of Soldering Defects on THT Solder Joints	96
5.2 Identification the Defect of Solder Bridging	98
5.3 Identification of Not Soldered Areas inside the Drill-Hole Region of a Solder Joint	99
5.4 Identification of Not Soldered Areas Across the Solder Pad Region of a Solder Joint	113
5.5 Computation of Solder Coverage on the Pad.....	118
5.6 Identification of Over Soldered Situation Applied on a Solder Joint	119
6. Computer Aided Design Tool	129
6.1 CAD System Implementation	129
6.2 Generating a Programme for a New PCB	134
7. Implementation of 4-Axis THT Soldering System	139
7.1 Electronics System Operation of THT Soldering System.....	139
7.1.1 System Main Controlling Unit	140
7.1.2 Vertical Direction Controlling Unit.....	142
7.1.3 Angular Direction Controlling Unit.....	144

7.1.4	Servo Driver Interface Module.....	145
7.2	Implementation of Robotic System.....	145
7.2.1	XY Positioning System.....	146
7.2.1.1	Real Time Calibration of Positioning Accuracy.....	147
7.2.1.2	Computation of Optimum Travelling Path.....	147
7.2.2	Implementation of Soldering Arm.....	150
8.	Results and Discussions.....	154
8.1	Discussion: Implementation of Automatic PCB Fiducial Alignment Process ..	154
8.1.1	Minimizing the effect of similarity between the defined fiducial points in different PCB types.....	155
8.1.2	Minimizing the effect of multiple appearances of the same fiducial point in different PCBs	158
8.2	Discussion: Implementation of Solder Pad and Component Lead Segmentation Process.....	158
8.2.1	The Accuracy of Localizing the Actual Pad to be Soldered by the Vision System as Defined in the Respective Programme for Soldering	159
8.2.2	The accuracy of localizing the drill-hole region of the solder pad	162
8.2.3	The accuracy of segmentation of the component lead from the solder pad	164
8.3	Discussion: The accuracy of solder quality classification of the solder joint....	166
8.3.1	The classification of voids inside the drill-hole	166
8.3.2	The classification of voids on the solder pad	168
8.3.3	The classification of excess solder	170
8.4	Discussion: The stability of the THT soldering system hardware	170
8.4.1	The stability of the soldering wire feeder	170
8.4.2	The stability of the soldering iron.....	171
9.	Conclusion	172
	Reference List.....	175

List of Figures

	Page
Figure 1.1	AOI system architecture 11
Figure 1.2	Robotic system architecture..... 13
Figure 2.1	Fiducial points defined by the PCB layout designer 14
Figure 2.2	Distinct objects on the PCB in addition to fiducial markings provided by layout designer..... 16
Figure 2.3	Best matching points detected by various template matching algorithms 18
Figure 2.4	Feature matched images using feature extraction algorithms 19
Figure 2.5	Few samples of scale space 21
Figure 2.6	Generation of scale space structure in SIFT 22
Figure 2.7	Detected key points on different objects using SIFT feature detector 25
Figure 2.8	Computation of integral image based on the pixel intensity values of a given I 27
Figure 2.9	Generation of $(i+1)^{th}$ level of box filter using i^{th} level of box filter inside o^{th} octave level in both y and xy directions respectively 30
Figure 2.10	Graphical representation of box filter size for three octaves 30
Figure 2.11	Detected key points on solder pads, vias and test pads on different colour PCBs 34
Figure 2.12	Selection of neighbouring pixels lie at candidate pixel P (Yellow Square) in FAST 35
Figure 2.13	Detected key points on solder pads, vias and test pads on different colour PCBs at $I_t = 30$ with non-maximum suppression using FAST corner detector. Here I_t is a user defined threshold value 36
Figure 2.14	Feature matching between images using SIFT together with distance measurement algorithms 40

Figure 2.15	Feature matching between images using SURF together with distance measurement algorithms	41
Figure 2.16	Feature matching between images using FAST together with distance measurement algorithms	42
Figure 2.17	Falsely detected areas of the model image inside the input image using homography matrix	44
Figure 2.18	Model image localization inside given input image using template matching algorithms	46
Figure 2.19	Results obtained from template matching algorithm over 2% scaled down images	47
Figure 2.20	Process flow chart of the proposed fiducial verification process	48
Figure 3.1	RGB colour model.....	50
Figure 3.2	HSV colour model.....	50
Figure 3.3	HSL colour model	50
Figure 3.4	Selected regions of a solder joint foreground and background regions...	55
Figure 3.5	Visual comparison between colour transformed images using modified $I_1I_2I_3$ colour model	57
Figure 3.6	Colour space transformation of a gold-plated solder joint on green PCB	58
Figure 3.7	Colour space transformation of a gold-plated solder joint on blue PCB	59
Figure 3.8	Colour space transformation of a tin-plated solder joint on green PCB	60
Figure 3.9	Colour space transformation of a tin-plated solder pad on red PCB	60
Figure 3.10	Colour space transformation of a tin-plated solder pad on black PCB	61
Figure 3.11	Channels of YIQ colour model	62
Figure 3.12	Structure for Image Segmentation Process	63
Figure 3.13	Noise filtered colour transformed images using median filter.....	64
Figure 3.14	Selection of centroid on a given data set in K-means clustering	65
Figure 3.15	Clustered data set in K-means clustering	65
Figure 3.16	Colour clustered images using k-means colour clustering algorithm	66
Figure 3.17	Thresholding of colour clustered images for solder pad segmentation	67

Figure 3.18	Segmented solder pads on different pad and PCB surface colours	68
Figure 3.19	Effect of offset issue on green colour PCBs with gold plated solder pads.....	69
Figure 3.20	Result of offset area removing algorithm	70
Figure 3.21	False detection of solder pad areas due to light colour PCB tracks on gold-plated solder pads on blue colour PCBs	70
Figure 3.22	Mapped colours of light colour PCB tracks during colour transformation and colour quantization processes for gold plated solder pads on blue colour PCBs	71
Figure 3.23	Accurate detection of solder pads after removing the effect of PCB tracks on blue colour PCBs with gold-plated solder pads	71
Figure 4.1	The implemented methodology to detect and localize lead top of a component	73
Figure 4.2	Importance of localizing the component lead top inside the solder joint	75
Figure 4.3	Impact of colour similarity between solder pad and component lead on segmentation accuracy	76
Figure 4.4	The offset between the computed size (based on CAD data) and the actual size of the drill-hole.....	77
Figure 4.5	Structure of the drill-hole segmentation algorithm	79
Figure 4.6	Results from colour transformation using several colour models over a segmented bare solder pad	80
Figure 4.7	Generation of a binary image to compute area covered by drill-hole.....	81
Figure 4.8	Automatic computation of the drill-hole.....	83
Figure 4.9	Results from a graph-cut based image segmentation algorithm.....	84
Figure 4.10	Resulted images from colour clustering algorithms for lead detection ...	86
Figure 4.11	Detected component lead top inside the drill-hole region of the solder pad	87
Figure 4.12	Application of feature extraction algorithms for lead top localization.....	90
Figure 4.13	Localized THT component lead top with higher colour dissimilarity to solder paste on several solder joints using SQDIFF template matching algorithm	91

Figure 4.14	Localized THT component lead top with lower colour dissimilarity to solder paste on several solder joints using SQDIFF template matching algorithm	92
Figure 4.15	Localized lead top using SQDIFF algorithm over several colour models	93
Figure 4.16	Detected THT component lead top on several HSL colour transformed solder joints using SQDIFF template matching algorithm	94
Figure 5.1	Different types of soldering defects	97
Figure 5.2	Identification of Solder bridging among different solder pads.....	99
Figure 5.3	Image size reduction for solder void detection inside drill-hole	100
Figure 5.4	Structure of the graph-cut image segmentation algorithm	103
Figure 5.5	Results from graph-cut based image segmentation over two solder joint types	105
Figure 5.6	Detected faults inside the drill-hole region for three solder joints types	106
Figure 5.7	Adjoining solder pad regions (blue colour) corresponding to detected voids inside drill –hole (red colour)	107
Figure 5.8	Intersection of line segments L_1 and L_2 (blue lines) with outer boundary of solder pad (red dash circle) and outer boundary of drill-hole (green dash circle)	108
Figure 5.9	Extracting adjoining solder pad region corresponding to detected voids inside the drill-hole region.....	109
Figure 5.10	Resulted images from colour clustering algorithms for adjoining solder pad verification.....	111
Figure 5.11	Detected voids inside the drill-hole region of a solder joint using the proposed algorithm	112
Figure 5.12	Image size reduction for solder void detection on solder pad	113
Figure 5.13	Imperfections on solder pad regions marked in red boundary. (a) Uneven illumination.....	114
Figure 5.14	Image segmentation using graph-cut algorithm (Blue highlighted regions represents the segmented regions)	114

Figure 5.15	Step wise illustration of proposed algorithm for void detection on solder pads	116
Figure 5.16	Detection of voids on tin and gold plated solder pad regions.....	118
Figure 5.17	Evaluation on the solder coverage for the solder joints with detected voids on the solder pads	119
Figure 5.18	Colour transformation from RGB to HSL and RGB to HSV colour models for the classification of excess solder	120
Figure 5.19	Boundary detection of segmented illuminated regions of a good (a) and excess soldered (b) solder joints	123
Figure 5.20	Selection of boundary pixels within the offset angle ϕ_R marked by red dash lines. Pink and green dots show the inner and outer boundary pixels inside ϕ_R respectively	124
Figure 5.21	Comparison of the size of the connected region inside the resulted binary image with respect to shape of the solder joint for excess solder detection.....	124
Figure 5.22	Connected regions and outer boundary pixels for excess solder detection	126
Figure 5.23	Performance of the AOI system for solder quality classification	127
Figure 6.1	Structure of the implemented CAD tool	130
Figure 6.2	GUI of the implemented CAD tool.....	131
Figure 6.3	The formatted geometrical information related to the pins of a particular component	131
Figure 6.4	Drawn PCB layout on the CAD system GUI based on the information acquired from the respective CAD file.....	132
Figure 6.5	Multiple orientations of the PCB layouts	133
Figure 6.6	Separate layers of the drawn PCB.....	134
Figure 6.7	User confirmation windows that accepts the user inputs to define PCB surface colour, solder pad colour and PCB access side.....	135
Figure 6.8	Defined fiducial point from the via layer.....	135
Figure 6.9	Illustration of selected components on the GUI of CAD tool	136
Figure 6.10	Generated programme for soldering	137

Figure 7.1	Robotic system operational block diagram.....	140
Figure 7.2	PCB layout of the main controlling unit.....	141
Figure 7.3	Operational block diagram of the main controlling unit.....	142
Figure 7.4	Speed control profile for servo drivers	142
Figure 7.5	Operational block diagram of the vertical direction controller	143
Figure 7.6	Speed loop for stepper motor control.....	144
Figure 7.7	PCB layout of vertical direction controlling unit.....	144
Figure 7.8	PCB layout of angular direction controlling unit.....	145
Figure 7.9	Operational block diagram of the angular direction controller	145
Figure 7.10	PCB layout of servo driver interface module	146
Figure 7.11	THT Soldering System.....	147
Figure 7.12	XY Positioning system	147
Figure 7.13	Real time correction of positioning offsets.....	148
Figure 7.14	Reorganized component pads according to the computed optimum travelling path.....	150
Figure 7.15	Implemented soldering arm.....	151
Figure 7.16	Kinematic diagram of soldering arm.....	150
Figure 7.17	Forward projection of coordinate frames between real world and image coordinate systems	153
Figure 7.18	Projection of an image inside camera at a focal length, f	153
Figure 7.19	Deformations occurred on solder joints due to the wrong angle between soldering iron and vertical plane.....	154
Figure 7.20	The angle which the soldering iron and wire feeder points to particular solder pad.....	155
Figure 7.21	Solder joints performed by the THT soldering system	155
Figure 7.22	Structure of the soldering arm	156
Figure 8.1	Fiducial verification process carried using the implemented AOI.....	157
Figure 8.2	The impact of slight PCB layout changes over the robustness of the fiducial verification process	158

Figure 8.3	Definition of subsequent images in different shapes and sizes.....	159
Figure 8.4	Definition of multiple subsequent images for a fiducial point	159
Figure 8.5	Verification of the existence of fiducial point using background subtraction method.....	160
Figure 8.6	Existence of the objects with similar dimensions inside the camera FOV	162
Figure 8.7	Executing diagnostic programme for solder pads to perform a precise real time calibration process	163
Figure 8.8	Identified objects inside the camera FOV	163
Figure 8.9	Defined solder pad by the user during the operation of diagnostic process	164
Figure 8.10	Selected candidate objects (highlighted in brown colour) and defined solder pad (highlighted in purple colour)	164
Figure 8.11	The erroneous computation of drill-hole region	166
Figure 8.12	The computation of drill-hole and identification of component lead.....	167
Figure 8.13	Different shapes of component leads	168
Figure 8.14	User confirmation for the pads with distributed shapes.....	168
Figure 8.15	The impact of illuminated areas on the solder pad for the stability of classifying voids inside the drill-hole	169
Figure 8.16	The removal of illuminated regions on the adjoining solder pad corresponding to a detected void inside the drill-hole	170
Figure 8.17	The soldering defects classification of voids inside the drill-hole, with the integration of the removal of illuminated pad regions	171
Figure 8.18	Effect of illuminated region removal on voids detection on the solder pad	172
Figure 8.19	Impact of longer pre-heat time required for pads connected to large copper planes on the accuracy of voids detection on solder pad.....	172
Figure 8.20	Impact of longer pre-heat time required by the solder pad on the distribution of light on the solder joint surface.....	173

List of Tables

	Page
Table 2.1	Average percentage of keypoints detected in foreground region and repeatability of detection using SIFT, SURF and FAST feature detectors 37
Table 2.2	Percentage of erroneous matching between given model images and located images at (250-750) lux 39
Table 2.3	Percentage of erroneous matching between given model images and located images at (75-200) lux 39
Table 2.4	Percentage of erroneous matching between given model images and located images at (1000-1500) lux 39
Table 2.5	Percentage of successful matching between given model images and located images at (250-750) lux 43
Table 2.6	Percentage of successful matching between given model images and located images at (75-200) lux 43
Table 2.7	Percentage of successful matching between given model images and located images at (1000-1500) lux 43
Table 2.8	Successful detection rate of template matching algorithms over the feature matched located images..... 46
Table 2.9	Successful detection rate of template matching algorithms over the scaled down located images by a percentage of 2% 47
Table 3.1	Data Analysis for Different Combinations of Solder Mask and Solder Pad Colours 56
Table 3.2	Acquired results for average and standard deviation for separate channels of gray scale images and for a colour image of solder pads on green PCB gold-plated 62
Table 3.3	Successful detection rate of colour image segmentation process on selected colour models over different PCB types at different controlled conditions 68

Table 3.4	Experimentally obtained colour vector distances for quantized colours on the detected object area	69
Table 3.5	Successful detection rate after removing the effect of pad offsets and tracks	72
Table 4.1	Successful detection of drill-hole region of a solder pad.....	84
Table 4.2	Average euclidean distance of clustered colours inside lead top and drill-hole region for gold-plated component leads with reference to the origin of RGB colour cube	85
Table 4.3	Successful and erroneous detection rate of lead top inside the solder joint using template matching algorithms with respective average computation time	90
Table 4.4	Successful detection rate of lead top inside the solder joint using template matching algorithms over different colour models	92
Table 5.1	Mean (μ) and standard deviation (σ) of the vector distance between the foreground and background of the soldered joint for nine different colour models and four different solder mask colours.....	98
Table 5.2	Performance evaluation of clustering algorithms for solder void confirmation on adjoining solder pad to a detected void in drill-hole region.....	110
Table 5.3	Successful and Erroneous detection rate of void detection algorithm inside drill-hole region of the solder joint	112
Table 5.4	Successful and erroneous detection rate in identifying voids inside the solder pad region of a solder joint over gold-plated and tin-plated solder pads	117
Table 5.5	Successful and erroneous detection rate of proposed algorithm for the detection of excess solder on a solder joint	125
Table 7.1	DH Parameters for Soldering Arm.....	152
Table 7.2	DH Parameters for Camera.....	152

Table 8.1 Performance evaluation of the fiducial verification process along with the background verification methodology 161

Table 8.2 Performance evaluation of the size comparison method and the background learning methodology for identifying the exact solder pad to be soldered..... 165

Table 8.3 Performance evaluation of automatic drill-hole computation algorithm during the operation of the THT soldering system 166

Table 8.4 Performance evaluation of the algorithm for classifying voids inside the drill-hole region of the solder joint 170

List of Abbreviations

AOI	Automatic Optical Inspection
BRIEF	Binary Robust Independent Elementary Features
CAD	Computer Aided Design
CCOEFF	Correlation Coefficient
CIE	Commission Internationale de l'Éclairage
CV	Connection Validation
DCT	Discrete Cosine Transform
DMA	Direct Memory Access
DoG	Difference of Gaussian
DWT	Discrete Wavelet Transform
EDA	Electronic Design Automation
EMS	Electronics Manufacturing Services
FAST	Feature Accelerated Segment Test
FCM	Fuzzy C-Means
FLANN	Fast Library for Approximate Nearest Neighbour
FOV	Field of View
GPU	Graphical Processing Unit
GUI	Graphical User Interface
ICA	Independent Component Analysis
IPC	Institute for Interconnecting and Packaging Electronics Circuits
LoG	Laplacian of Gaussian
MCU	Module Control Unit
MST	Minimum Spanning Tree
NPI	New Product Industrialization
OCP	Over Current Protection
PC	Principle Curvatures

PCA	Principle Component Analysis
PCB	Printed Circuit Board
PUS	PCB Under Solder
ROI	Region of Interest
SD	Standard Deviation
SIFT	Surface Invariant Feature Transform
SMD	Surface Mount Devices
SMT	Surface Mount Technology
SPI	Serial Peripheral Interface
SQDIFF	Squared Difference
SURF	Speed-Up Robust Features
THT	Through Hole Technology