HACETTEPE UNIVERSITY
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING ELE 401-402 GRADUATION PROJECT

Optical Inspection of Electronic Circuit Boards using Machine Learning

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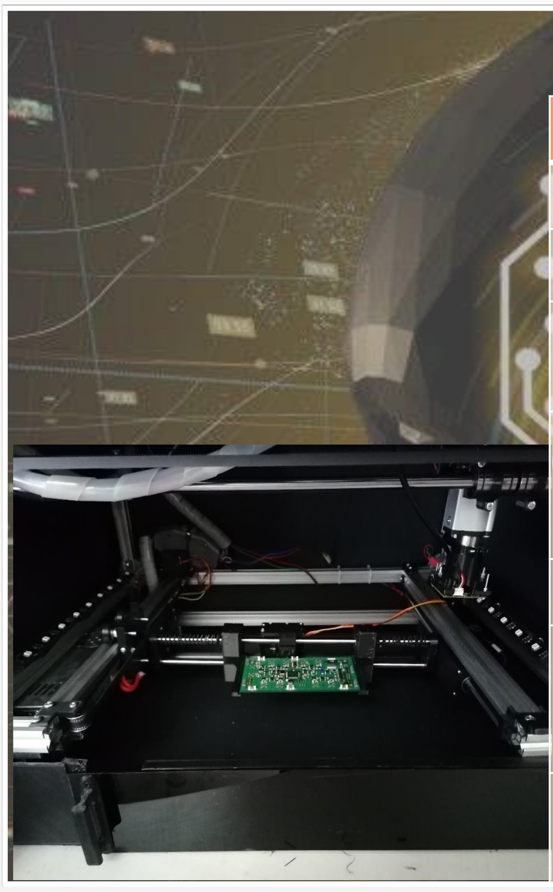
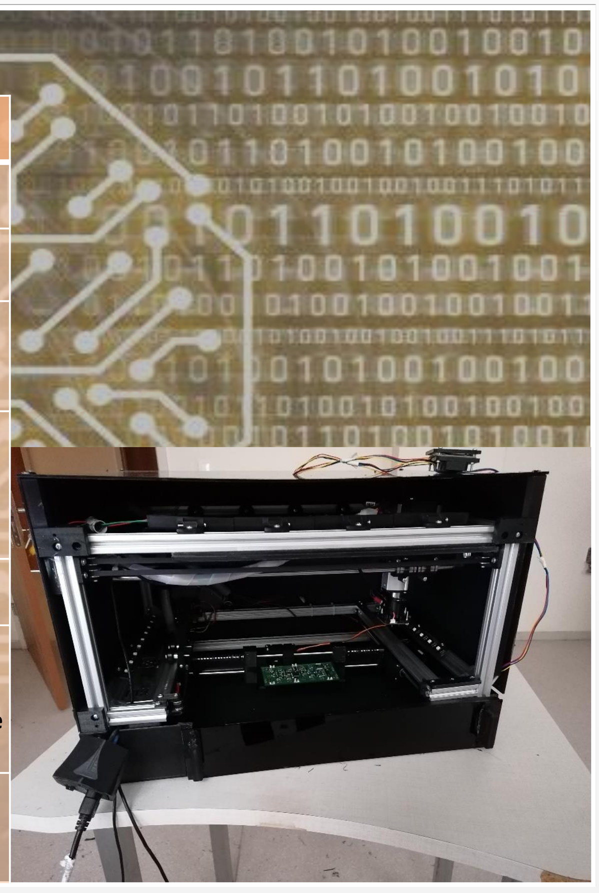
Introduction

Excellence in electronic system manufacturing begins with the defect-free fabrication of printed circuit boards (PCB). Identification of defects and errors related to fabrication and extensive use is of great challenge in the electronics industry. In this project, a machine learning software capable of identifying defects on PCBs was designed. This project was advanced using artificial intelligence.

Specifications and Design Requirements



Automated Optical Inspection Specifications	
Device Dimensions	582x467x336 mm
Displayable PCB Dimensions	350x250x70 mm
Camera Resolution	1280x720, 1920x1080, 20148x1536, 2592x1944, 3264x2448, 4192x3104
LED Color Scale and Intensity	Device LED options work according to RGB color codes, and the light intensity is adjustable.
Interface	Touch screen and Computer
System Equipment Requirements	A computer connection is required for the control of the device and the recording of the images taken with the camera.
Other	Automatic card feeding, Angle the card, Field portability



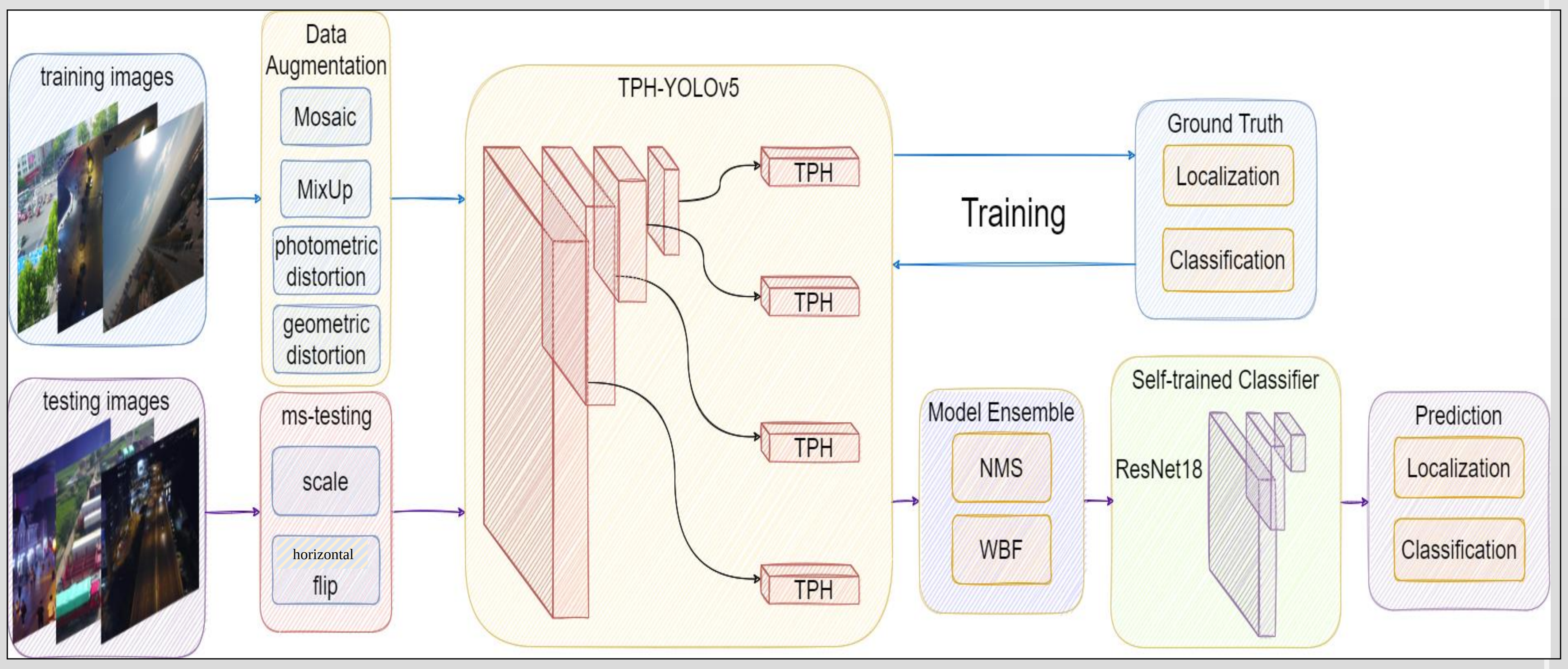
Automated Optical Inspection (AOI) was designed for the project to acquire card images.

Solution Methodology

No	Error Type
1	Exposed Base Material (Insufficient Solder)
2	Poor Adhesion (Insufficient solder)
3	Reflow of Pasta Solder - Cold Solder
4	Deteriorated Solder (Rotten Solder)
5	Non-adhesion
6	Solder Bridge (Short circuit)
7	Solder in Network Image - Solder Splash (Short circuit)
8	Solder Creep
9	Solder Balls / Solder Crumbs
10	Cracked Solder
11	Air Holes
12	Lead-Free Solder Filler Removal
13	Tear/Pull in Lead-Free Solder
14	Tombstone
15	Missing Material
16	Wrong Material
17	Slipped Material
18	Upturned Leg
19	Damaged Material
20	Directional Material
21	Where there should be no material; Material, Burrs, Solder Ball etc. existence

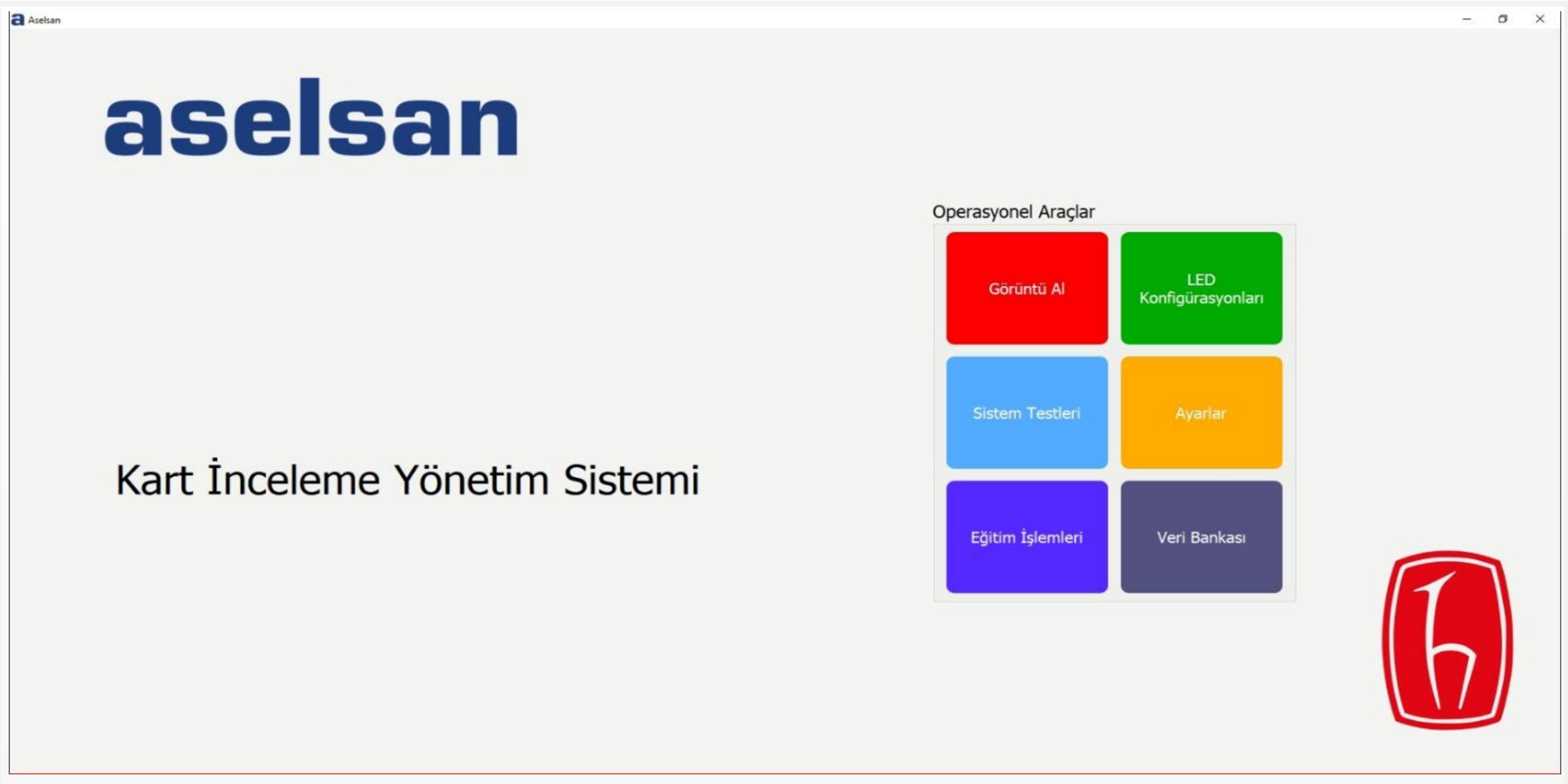
Rows 1–4 → Missing Solder
Rows 6–7 → Short Circuit
Rows 14–15 → Raised Component
Row 17 → Slipped Component

Within the scope of the project, 21 error classes that can be observed on the PCB were determined. Depending on whether the errors are encountered in practice, errors were grouped and assigned to classes.



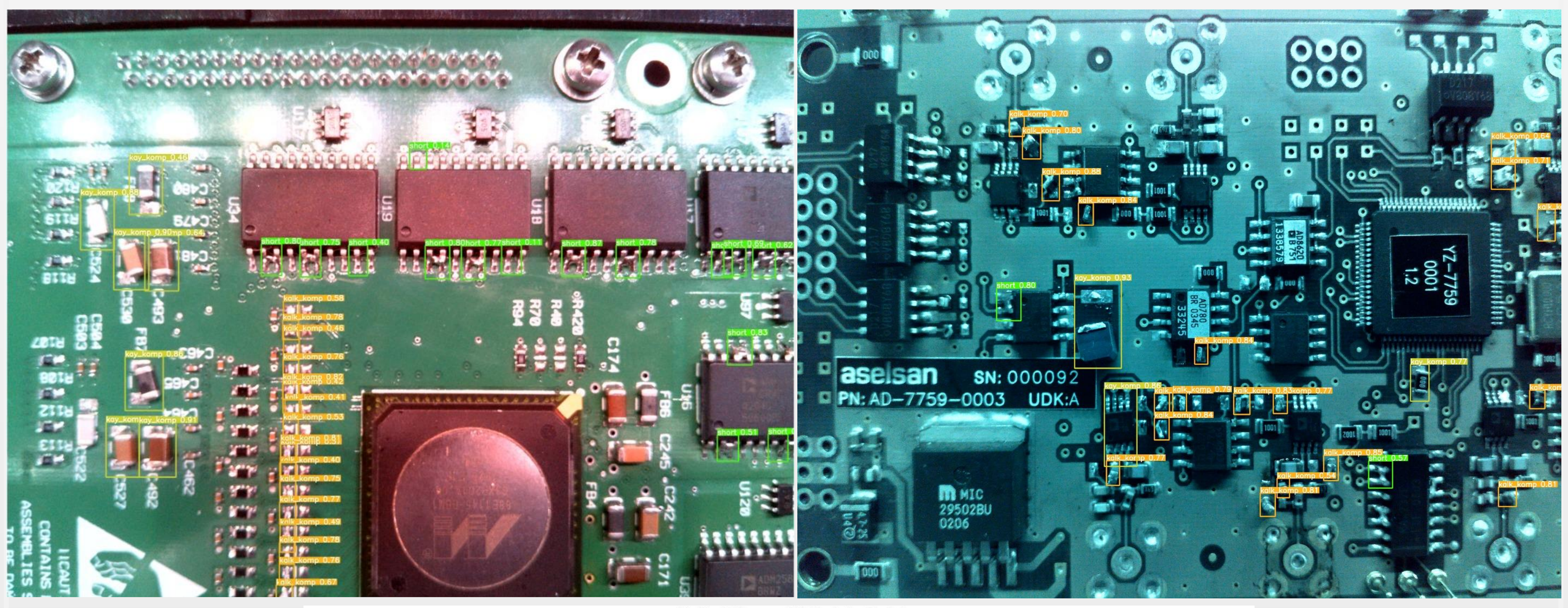
A data set, with the images collected from the AOI device, was created, and was divided into training, validation and test data. In order to achieve more successful results in classification, data augmentation was performed to increase the training data. Yolo v5 algorithm was used in the project. Reason for using yolov5.Reason for using yolov 5 YOLO v5 is different from all other prior releases, as this is a PyTorch implementation rather than a fork from original Darknet. Same as YOLO v4, the YOLO v5 has a CSP backbone and PA-NET neck. The major improvements includes mosaic data augmentation and auto learning bounding box anchors.

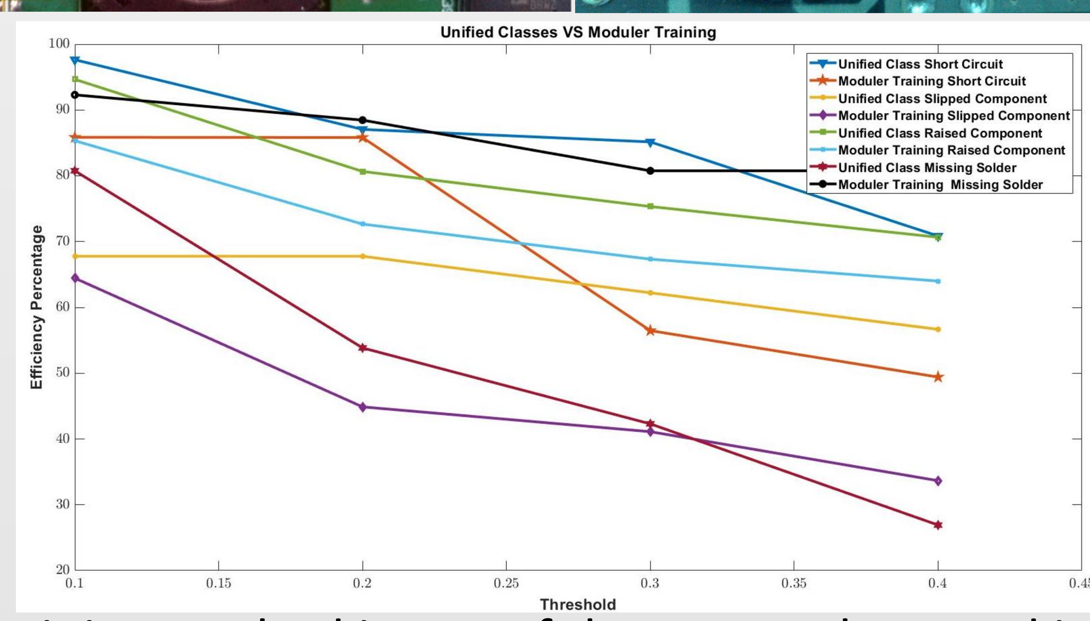
User Interface



A comfortable and user-friendly interface was designed, in which the user can control all the features and perform the operations.

Results and Discussion





The unified training method is one of the approaches used in the training of artificial intelligence algorithms. In this approach, datasets obtained with hardware and labeled and classified with deep learning applications are trained collectively and from a single item.

In the modular training method, the class files created during artificial intelligence training are separated within themselves, that is, they are grouped. Groups as many as the number of classes are obtained. Each group is trained separately.

Threshold 0.4	Unified method			Modular method		
Error Type	T.P	F.P	B.O	T.P	F.P	B.O
Short Circuit	60	0	%70.58	43	0	%50.58
Slipped Component	51	1	%56.66	58	0	%64.44
Raised Component	106	4	%70.66	96	0	%64.00
Missing Solder	15	0	%61.53	21	0	%80.76

Threshold 0.1	Unified method			Modular method		
Error Type	T.P	F.P	B.O	T.P	F.P	B.O
Short Circuit	83	5	%97.64	61	17	%71.76
Slipped Component	61	13	%67.77	70	23	%77.77
Raised Component	142	18	%94.66	128	17	%85.33
Missing Solder	22	2	%84.61	24	17	%92.30

The success rates seen in the table will increase as data is added to the database. At the same time, when a new error type is encountered, you can directly enter the system and add a database. As the threshold value increases, FP rates and success rates decrease. At low threshold values, along with success rates, false-positive rates also increase. The success percentages of short-circuit and raised element defects of modular training remained below the percentages of unified training. But the percentage of success increased in modular training with missing solder and slipped element defects. In the light of these results, it is understood that it would be beneficial to train some defects separately and to participate in the classifier setup with a hybrid system, considering the situation of the defects with a high probability of confusion.

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Publications:

❖ **Defect Classification from Electronic Card Images by Deep Learning-SIU2022(IEEE)-16/05/2022**