A smart quality monitoring system for the electric drives production.

- Electric motor mainly consists of rotor, stator and surrounding housing.

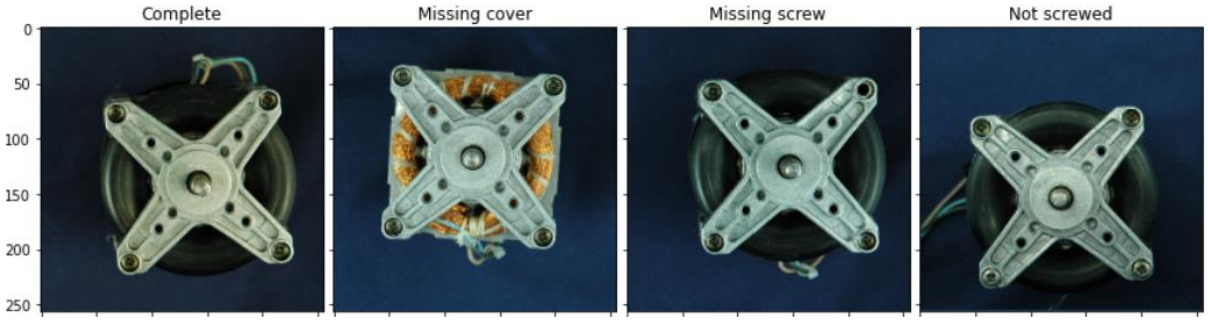


Figure 1: Top view of the images is considered and the target is to detect three defects, missing cover, missing screws and not screwed after assembly.

- OpenCV is an opensource computer vision and machine learning library used for image and video processing. By default, OpenCV reads the image in BGR format. The channels are converted to RGB form.
- Load the features and labels. Features are all the images as numpy arrays. Labels are the associated defect which is obtained from the title of the image (“Complete”, “Missing cover”, “Missing screw”, “Not Screwed”).
- Image processing:
- Resize: reduce the resolution of the image. Makes the training process faster and reduces the computational resources.
- Converting RGB images to BW images. Gray scale images have one channel when compared to RGB having three channels.
- Image shape: The image is flattened from 2.5D to 1D.

Class distribution:

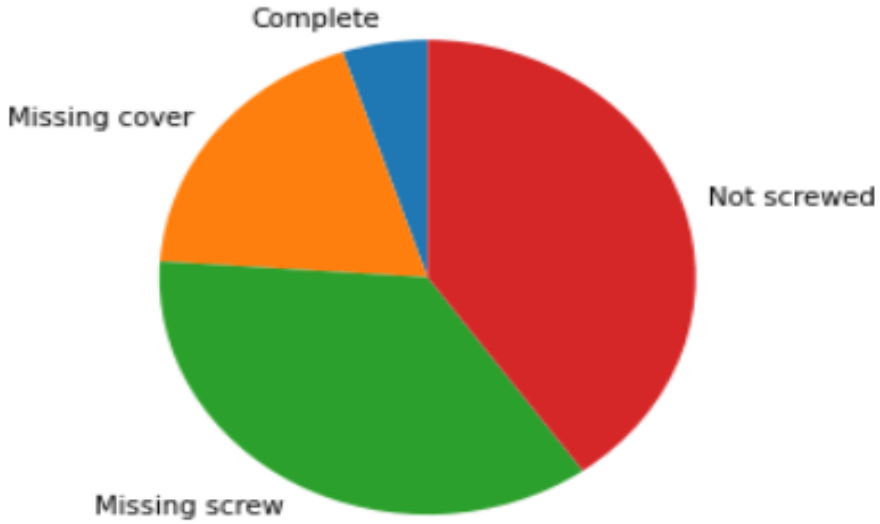
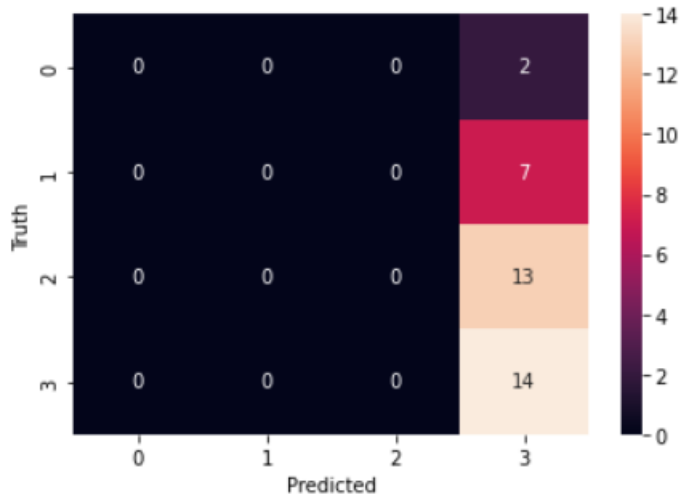


Figure 2: The classes are imbalanced. 'Not screwed: 47, 'Missing screw': 42, 'Missing cover': 22, 'Complete': 6.

SUPPORT VECTOR MACHINE (SVM):

Classification report:

	precision	recall	f1-score	support
Complete	0.00	0.00	0.00	2
Missing cover	0.00	0.00	0.00	7
Missing screw	0.00	0.00	0.00	13
Not screwed	0.39	1.00	0.56	14
accuracy			0.39	36
macro avg	0.10	0.25	0.14	36
weighted avg	0.15	0.39	0.22	36



- The classification report provides a summary of the performance metrics for a multi-class classification problem.
- Precision (Horizontal columns in the matrix) for the class “Complete”, “Missing cover” and “Missing screw” is 0.00, indicating that there were no true positive predicted for these classes. Precision for the class “Not screwed” is 0.39, indicating that when the model predicts “Missing screw”, it is correct about 39% of the time.
- Recall (Diagonal in the matrix) for the class "Not screwed" is 1.00, implying that the model is successfully capturing all instances of "Missing screw”.
- Support indicates the number of actual occurrences of each class in the dataset. The class “Complete” has a support of 2, “Missing cover” has a support of 6, “Missing screw” has support of 13 and “Not screwed” has support of 14.
- The accuracy of the model is 39%.
- In summary the model performs poorly on classes “Complete”, “Missing cover”, “Missing screw” but reasonably well on the “Not screwed”.

ARTIFICIAL NEURAL NETWORK:

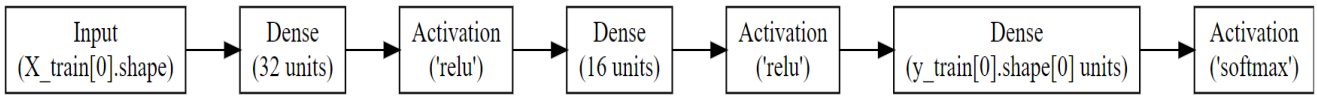
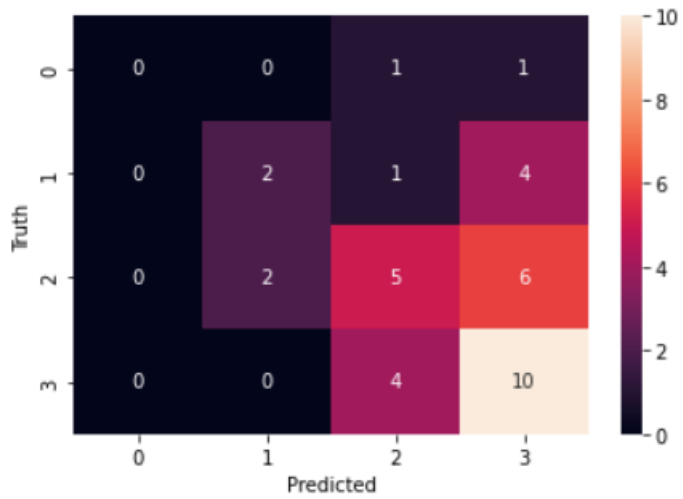


Figure 3: ANN architecture

Classification report:

	precision	recall	f1-score	support
Complete	0.00	0.00	0.00	2
Missing cover	0.50	0.29	0.36	7
Missing screw	0.45	0.38	0.42	13
Not screwed	0.48	0.71	0.57	14
accuracy			0.47	36
macro avg	0.36	0.35	0.34	36
weighted avg	0.45	0.47	0.44	36



- 48 % of the time when “Not screwed” is Predicted it is predicted correctly.
- 71% of the total “Not screwed” instances are predicted correctly.
- The overall accuracy of the model on the entire dataset is 47%.
- Unlike SVM the ANN model is performing better in predicting the classes “Missing cover” and “Missing screw”. But ANN model does not perform as well as SVM for “Not screwed” as the recall of “Not screwed” in SVM is 1.00.

CONVOLUTION NEURAL NETWORK (CNN):

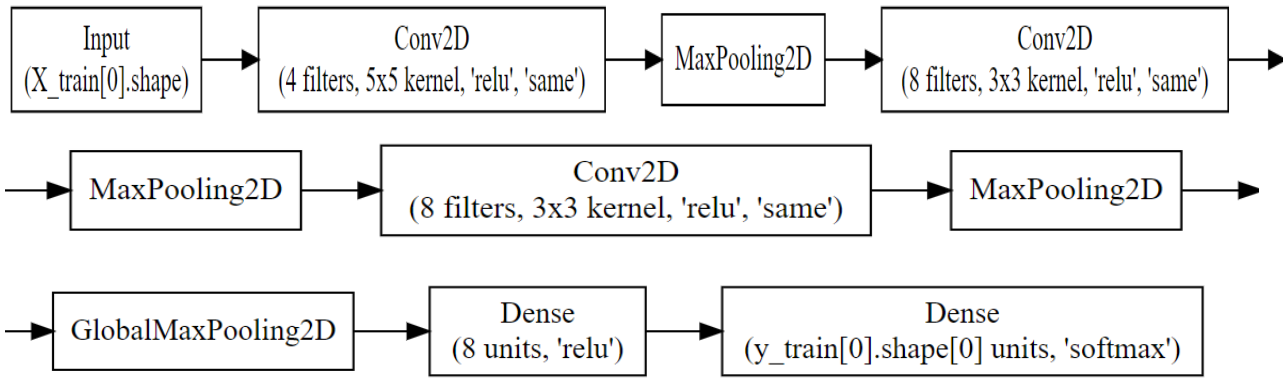
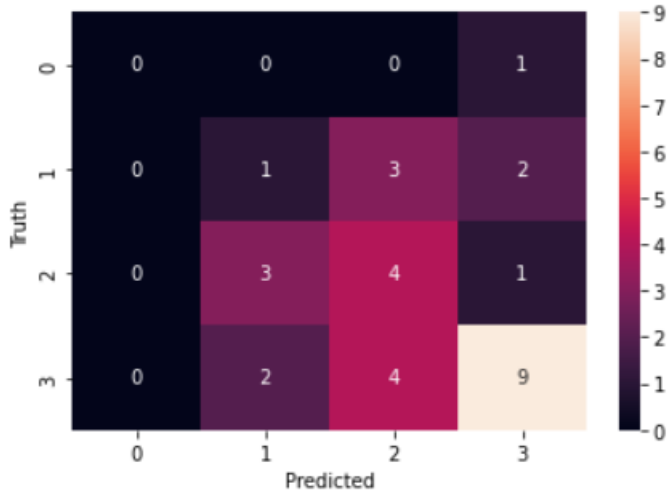


Figure 4: CNN architecture

Classification report:

	precision	recall	f1-score	support
Complete	0.00	0.00	0.00	1
Missing cover	0.17	0.17	0.17	6
Missing screw	0.36	0.50	0.42	8
Not screwed	0.69	0.60	0.64	15
accuracy			0.47	30
macro avg	0.31	0.32	0.31	30
weighted avg	0.48	0.47	0.47	30



- The overall accuracy of the model on the entire dataset is 47%.
- The model performs similarly to an artificial neural network.

Data Augmentation:

Data augmentation is a technique used in machine learning and computer vision to artificially increase the diversity of a training dataset by applying various transformations to the existing data.

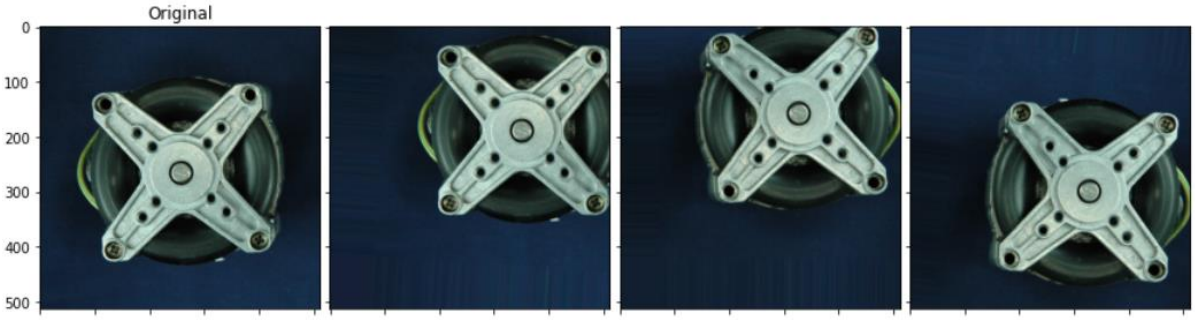
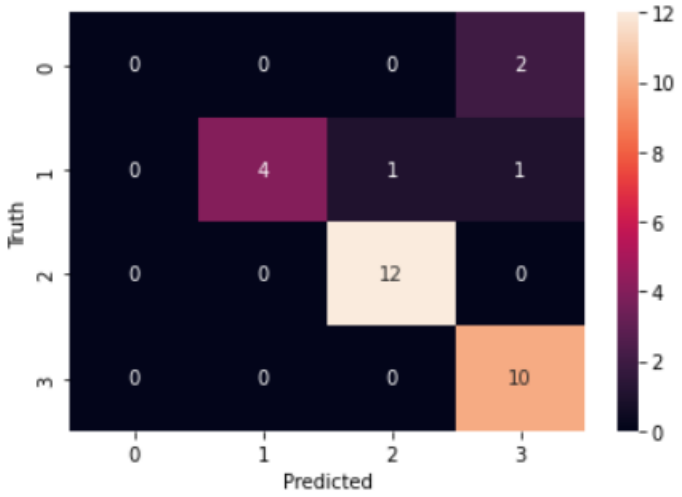


Figure 5: Data augmented images

By applying these transformations to the training data, the model learns to recognize patterns under various conditions, making it more robust and less sensitive to variations in the input. Data augmentation is particularly useful when the size of the training dataset is limited, as it helps prevent overfitting and enhances the model's ability to generalize to unseen data.

Classification report:

	precision	recall	f1-score	support
Complete	0.00	0.00	0.00	2
Missing cover	1.00	0.67	0.80	6
Missing screw	0.92	1.00	0.96	12
Not screwed	0.77	1.00	0.87	10
accuracy			0.87	30
macro avg	0.67	0.67	0.66	30
weighted avg	0.83	0.87	0.83	30



- The overall accuracy of the model is 87%.
- The model performs poorly on “complete” class.
- When “Missing cover” is predicted, 100% of the time it is predicted correctly.
- Recall for “Missing screw” and “Not screwed” is 1.00, indicating almost all of the class “Missing screw” and “Not screwed” are predicted correctly.

Conclusion:

- The CNN model with data augmentation is improved the overall accuracy of the model to large extent. But yet the model the model is not able to predict the class “Complete”.
- The dataset is imbalanced. The images belonging to class “Complete” must be added to the dataset so that the model would perform exceptionally well in predicting all classes.
- The overall accuracy achieved is 87%.