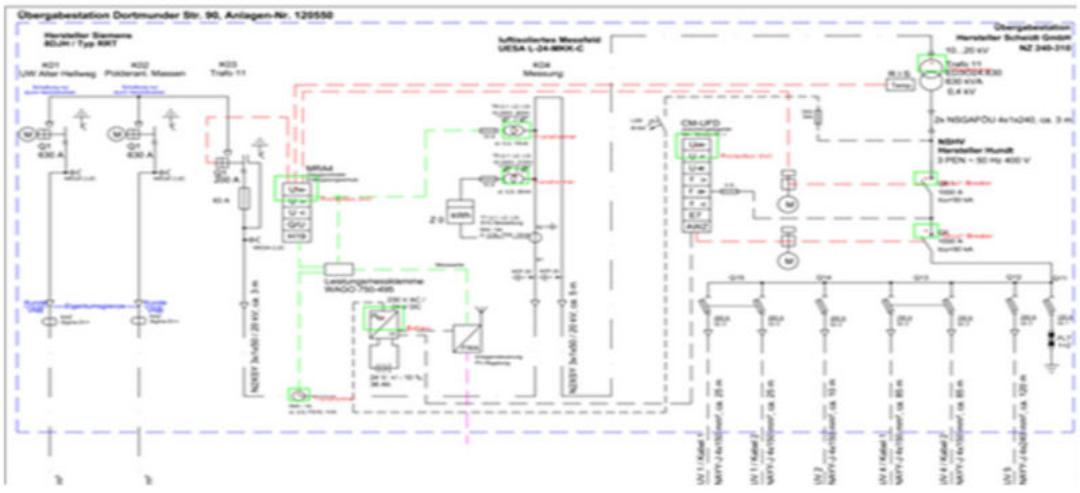
ANALYSIS OF SINGLE LINE DIAGRAMS USING AI

Artificial Intelligence has proven to be very critical when it comes to processing a humongous amount of data. In order to analyze this data manually, it takes an immense amount of resources that needs to be invested in order to complete the task. Additionally this kind of analysis is prone to human error and this error can be minimized through an iterative approach which is a very time consuming process. AI has proven its ability in the past decade in solving various challenging problems in various applications. One such application is the analysis and evaluation of single line diagrams using AI.

Before a power plant in Germany can be certified, a large number of documents must be evaluated for the relevant information, consistency and conformity to the standards. For a smaller number of customers this evaluation process by an engineer may require less time. However, as the customer database grows, the quantity of data that needs to be analyzed will increase. As a result more resources have to be invested to analyze this data which can lead to error-prone results. This is when AI will prove its efficiency. Gridcert, a browser based platform with the objective to speed up the certification process power plants, employs AI algorithms to extract the relevant data out of these documents and makes it easy for an engineer to validate the extracted information.

One such use case is done in the evaluation of a document called Single Line Diagram (SLD) which is an electrical schematic showing the main components, major control concept and protection concept components. An excerpt from such a document looks as follows:



The information of importance from such a document includes the number of transformers, circuit breakers, batteries, etc. along with the specifications of the respective components. This information is important for the evaluation report to check conformity against the given standard or grid operator requirements. In order to achieve this objective, various AI based approaches have been investigated.

Object Detection:

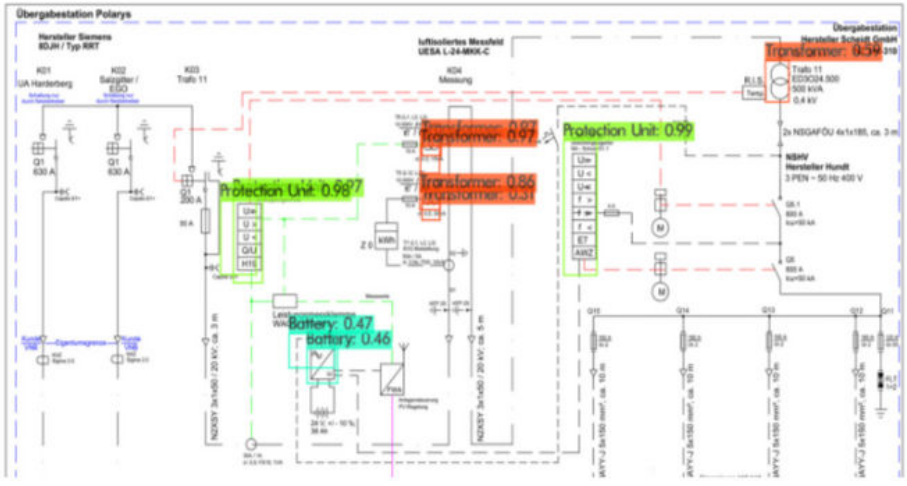
Object detection returns each object bounding box coordinates found in the image. The object detection applies tags based on the objects identified in the image. There are several ways that object detection can be achieved using machine learning approaches. Here two main methods are discussed.

Custom Object Detection:

In this method, the given datasets are initially labeled. In this process, bounding boxes are drawn around the objects of particular interest and corresponding tags are given to these objects. There are several tools that are available in order to label these datasets such as (CVAT, LabelImg, VoTT). Once the labeled data is prepared, the custom detection model and its necessary dependencies are installed. Next the model configuration file must be defined for the custom object detector. Using the configuration file, one can initialize the training procedure for the selected model. This configuration file contains the information regarding the number of layers in the neural network, image size, batch size required during the training, etc. During the training the model weights in the layers are updated. After certain iterations are completed, the model needs to be evaluated using various metrics such as Intersection over Union (IoU), Accuracy, Precision etc. Once the required performance is achieved on these metrics, the final model can be used to predict the required components in the Single Line Diagram. Various models that follow similar training procedure include YOLO variant models, RCNN based models, etc.

Disadvantages:

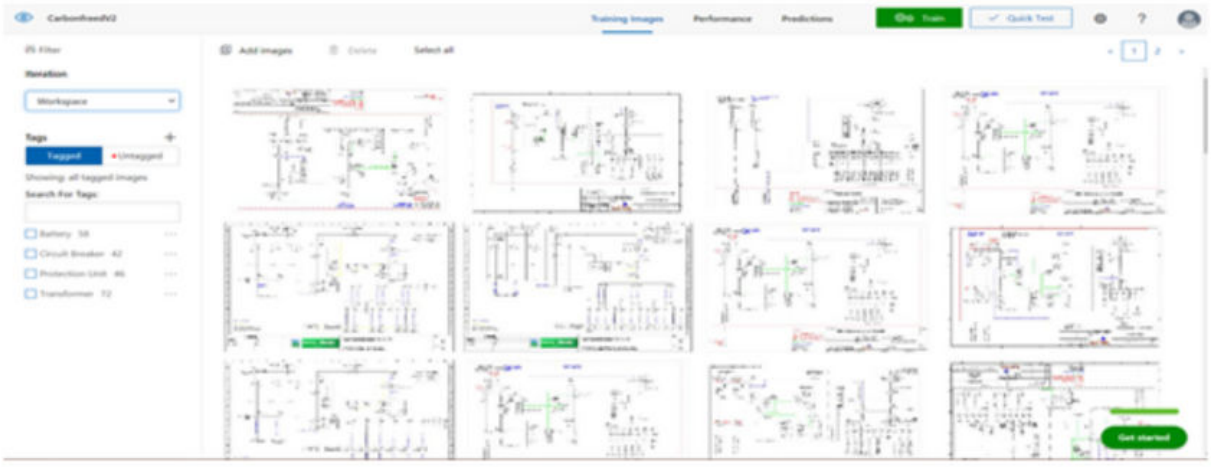
- Training such models requires vast amount of datasets in order to achieve high accuracy.
- The training time and computational requirements increase as the complexity of the models and size of training data enlarge.



Object Detection using Cloud Services:

AI and machine learning require higher computational resources in order to train and evaluate their algorithms on their datasets. To avail such resources, one must invest an immense amount of money. Cloud services provide a cheaper option for an individual or an enterprise. With cloud services, one can benefit from cloud computing, which offers a host of services to the user. These services range from server access, more storage for Big Data with better back-ups, ability to run high-end analytical tools for AI & BI – all over the Internet. Additionally, these services are far more reliable, faster, affordable, more flexible and scalable as per user needs. Users can optimize their costs through the efficient use of these services. The cloud services market is currently dominated by four major players: Google, Microsoft, Amazon and IBM, since they offer the required web services for machine learning. These are AWS (Amazon Web Services), Azure (Microsoft), Google Cloud and IBM Cloud. The Amazon Web Services platform includes products like Amazon SageMaker, Amazon Augmented AI, Amazon Forecast, Amazon Translate, Amazon Personalize, AWS Deep Learning AMI, and Amazon Polly for various Machine Learning requirements. Similarly, Microsoft Azure (2010) is quite a popular choice for machine learning and data analytics needs. This service includes products like Microsoft Azure Cognitive Service, Microsoft Azure Databricks, Microsoft Azure Bot Service, Microsoft Azure Cognitive Search, and Microsoft Azure Machine Learning for creating, training, and deploying machine learning models on the Cloud. Google Cloud offers various products for machine learning like Google Cloud AutoML, Google Cloud AI Platform, Google Cloud Speech-to-Text, Google Cloud Vision AI, Google Cloud Text-to-Speech, and Google Cloud Natural Language for all Individual and Enterprise level Machine Learning Projects. Finally, IBM Cloud service includes various cloud delivery models that are public, private and hybrid models. IBM Cloud offers various products for machine learning such as IBM Watson Studio, IBM Watson Speech-to-Text, IBM Watson Text-to-Speech, IBM Watson Natural Language Understanding, IBM Watson Visual Recognition and IBM Watson Assistant to assist all Machine Learning needs.

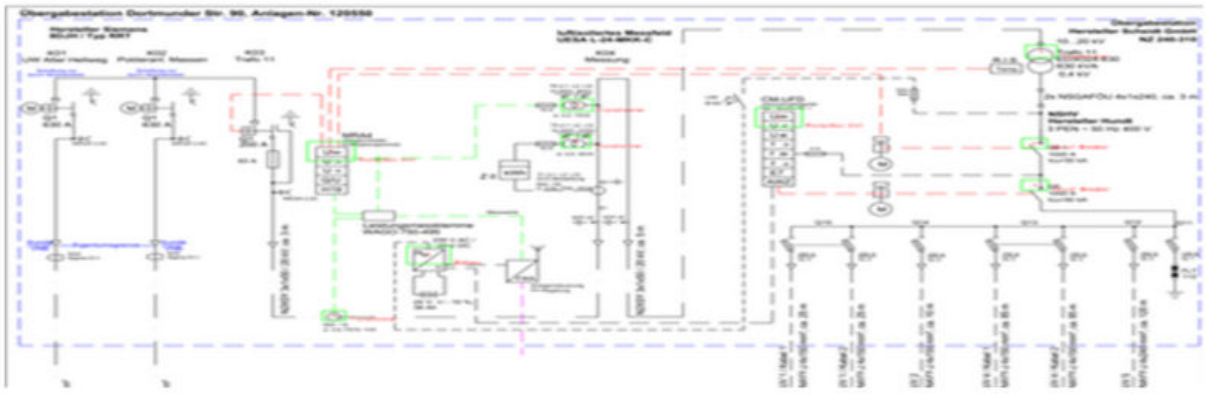
Object Detection on Cloud Service:



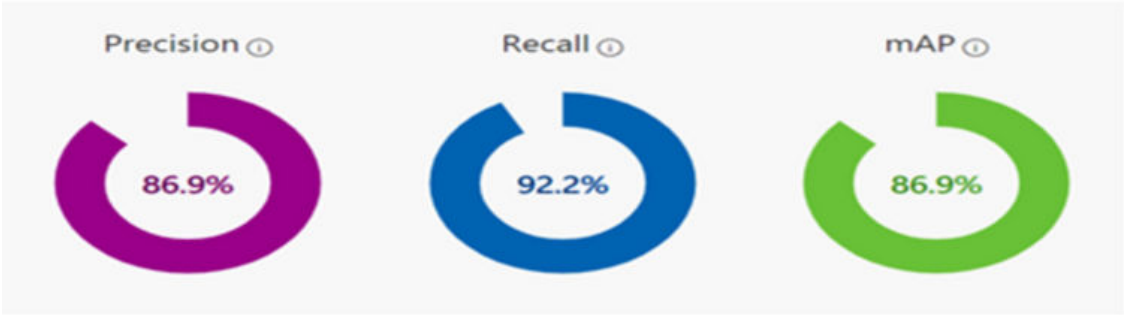
Initially the dataset is uploaded into a chosen cloud workspace in the corresponding Computer Vision Service. Once the dataset is uploaded, the corresponding tags that need to be identified in the image must be annotated. After the annotation process is completed, the training process must be initiated so that the service will train the object detection model. Next we can evaluate the performance on the model on the dataset using the standard metrics that are available in the cloud service.

Some of the metrics include precision, recall, accuracy and F1 score. Based on the model performance on these metrics, we can either decide to deploy the final model or train more datasets until the desired performance is reached.

Result of Object Detection using cloud services:



Evaluation Metrics on cloud service:



Performance Per Tag

Tag	Precision	Recall	A.P.	Image count
Protection Unit	94.1%	88.9%	93.4%	46
Battery	93.3%	97.7%	91.8%	58
Transformer	82.6%	95.0%	94.4%	72
Circuit Breaker	71.4%	71.4%	67.9%	42

Drawbacks of using cloud services:

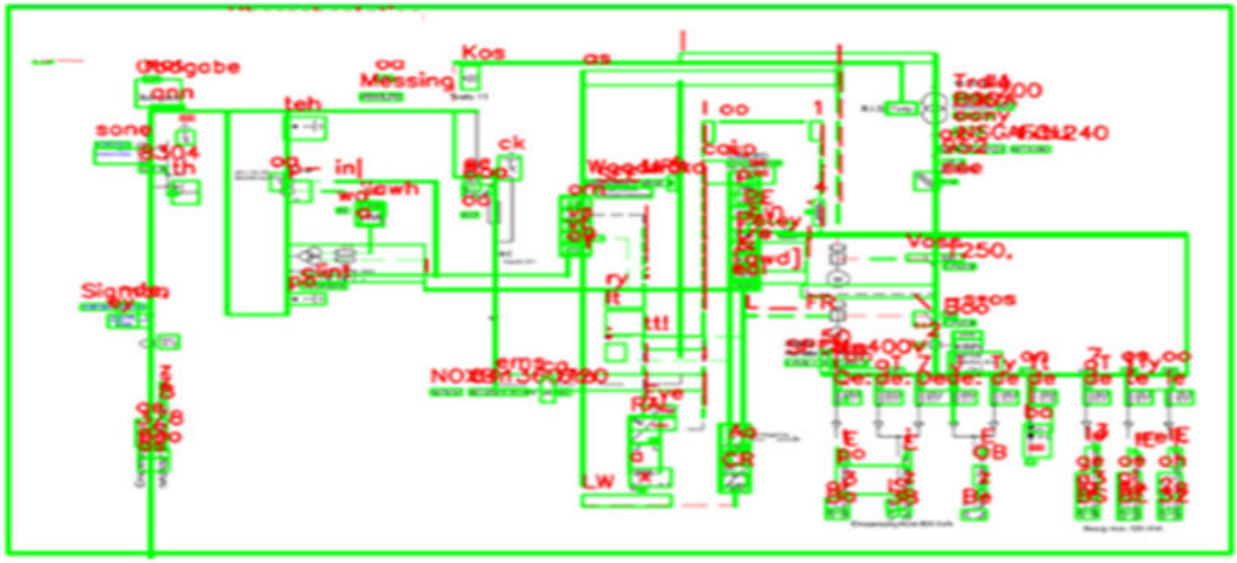
- Objects are generally not detected if they are small (less than 5% of the image).
- Objects are generally not detected if they are arranged closely together (a stack of plates, for example).
- Objects are not differentiated by brand or product names (different types of sodas on a store shelf, for example.

Text Recognition:

Optical Character Recognition (OCR) transforms a two-dimensional image of text into machine readable text. OCR process consists of generally following steps:

- Preprocessing the image
- Text Localization
- Character Segmentation
- Character Recognition
- Post Processing

The main objective of OCR is to identify and capture all the unique words using different languages from written text characters. There are several open source OCR tools that are available, for example Tesseract, OCRopus, Ocular, etc. As sample text recognition from the open source OCR model is as follows:



Drawbacks of open source tools:

1. The main drawbacks of open source models include insufficient accuracy. This leads to incomplete text recognition.
2. Also, when the text is smaller than a threshold size, the models fail to recognize such type of smaller text.

Text Recognition Using Cloud Services:

Text recognition on a cloud service applies advanced machine learning algorithms to extract text, key-value pairs, tables, and structures from documents automatically and accurately. This information is automatically and accurately extracted via optical character recognition (OCR) representing the industry standard for text-based feature extraction from documents. Cloud services provide a platform for the individual or enterprise to experiment with the different machine learning models and sample their returned data in an interactive manner without the need to write code. Once the dataset is uploaded on

the cloud, the pre-built text recognition model identifies the text from the given data and output is given as a JSON file. The relevant text is filtered out from the identified text using standard keywords that are quite commonly found in the single line diagrams. Some of the keywords are 'KVA', 'uk', '20kV', '20/0','4 kV', '10kV', '10/0', 'Stufe', 'Trafo', '/1A', '5P20', '20000V', '100V' etc. To match the identified text to the relevant component, a sample matching algorithm based on the simple Euclidean distance between the identified component bounding box centroid and text bounding box centroid has been proposed. The bounding boxes which are closer and less than a specified threshold distance have been assigned the relevant text to the component. The sample output contains information regarding the component location in the single line diagram and the relevant text that corresponds to that component.

Sample text detected around the component:

The detections in the file:
{'Battery detections': [{'Battery(1006, 1271)': ['fernwirktechnik', 'meteocontrol bluelog', 'enso', 'für die leistungsreduzierung sowie', 'wirk- und blindleistungsregelung']}]}
The Number of Battery detections are: 1

{'Circuit Breaker detections': [{'Circuit Breaker(2539, 1030)': []}]}
The Number of Circuit Breaker detections are: 1

{'Protection Unit detections': [{'Protection Unit(818, 816)': ['3', '-t3l1 p2', '-t3l2', '-t3l3 p1 l', '-t2l1 p2 l 3', '-t2l2', '-t2l3 p1', 'n2xsy 3x1x50mm2 / 3m']}, {'Protection Unit(2183, 692)': ['d', 'e', 'onh2']}]}
The Number of Protection Unit detections are: 2

{'Transformer detections': [{'Transformer(1457, 817)': ['w 225a', 'w 225a w 225a']}, {'Transformer(2549, 350)': []}, {'Transformer(1598, 612)': ['dc/24v.', '_ac/230v', 'q1', 'trafoschutz', '1250 a', 't7/pr232', 'dc/24y -', 'dc124y - ein', 'q2', 'von f30', 'ac/230v', 'm -- eb-']}]}
The Number of Transformer detections are: 3

Conclusion:

The rapid increase of datasets and complexity of machine learning models that are involved in analyzing these datasets results in an increase in the demand for higher computational requirements. In order to meet these requirements the individual or enterprise have to invest a higher price. Cloud services offer a cheaper solution to evaluate various machine learning models on various category of datasets. With the help of these cloud solutions, the task of object detection and text recognition has been simplified and one can obtain models with reliable performance on the standard metrics. Currently few components are being detected in the single line diagram and the corresponding text is being matched using basic algorithm. In the next steps, additional components need to be detected in the single line diagrams and efficient algorithms need to be developed to match the corresponding text to the detected components.