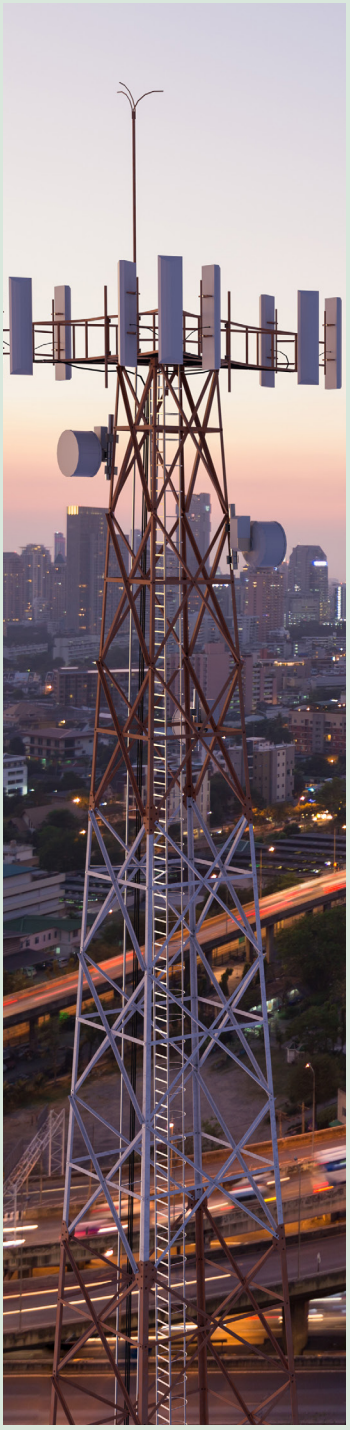
WHITE PAPER



INTELLIGENT IMAGE ANALYZER FOR TELECOM NETWORK

Abstract

Moving ahead in digital times, it is very crucial that we address various tedious and time-consuming manual efforts in Telecom industry where multiple use cases require rigorous visual inspection and verifications to validate, upgrade or replace the network elements on field at regular intervals. Moreover, this process is less accurate since it is primarily based on human experience and doesn't follow any specific rule base. This paper elaborates and explores the various practical use cases based on Image Analytics specifically in telecom domain ranging from usual brownfield use cases such as network inspection in case of upgrade of network (4G to 5G etc.), identifying and replacing various equipments to even complex scenarios such as address fallout management, drone-based image analytics for 5G small cell deployment, tower inspection etc. On the technical aspect, the solution leverages Deep learning-based object detection algorithms and advanced analytics to solve these multifaceted problems.

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1. Background

1.1. Cognitive Analytics & Computer Vision – A Quick glance

Cognitive Analytics allows users to deliver humanlike insights at machine scale. Even though Artificial Intelligence was around for the past 60 years, it has become so much of a buzz word recently mainly because of abundance of data, increased compute power and advancement of neural networks which is the heart of AI and ML. Cognitive Analytics is little bit more than just machine learning, such as Reasoning algorithms, Genetic Programming, Deep Learning [3] and Natural Language Processing (NLP) [4].

Computer Vision and Image Analytics are among the key Cognitive Analytics application areas. Specifically for Telecom, the advancement in computer vision techniques has led to a lot of recent developments including automated generation of network inventory, accelerated network acceptance through 3D model of the cell site with accurate dimensions and recognized equipments on-field etc. Other common areas of Telecom domain provide automation for the field technician, automatic detection of abnormalities such as material corrosion, incorrectly connected cables, or tilted antennas etc. This is getting increasingly important with the rollout of 5G networks, MEC, 6G Research, SDN and NFV and other recent next-generation telecom solutions.

1.2. Image Analytics – Researcher's Viewpoint

Image Analytics is the process of transformation of unstructured data in the form of images and videos, into machine readable parameters and variable and then extract valuable information and patterns out of it. This process will further help automate such scenarios and build an end-to-end actionable insights and decision system.

A lot of research that was performed in Image analytics was referred to exploration of various possibilities for automatically performing image recognition and tagging them with meaningful use cases in telecom domain. One such use case included an approach to perform Vehicle Detection from Satellite Images using Image Processing techniques [9]. In this scenario, Morphological Algorithms & Image Segmentation features for filtration and dilation was used where number of vehicles are recognized from the image in the form of bounding box.

Another reference paper [11] explains a practical approach on Principal Component Analysis and Independent Component Analysis Transforms in Digital Image Processing. For this, the extraction of the unique characteristic of the query image is performed using PCA, which distinguishes it from the other images used for unsupervised learning.

To summarize, Image Analytics using deep neural networks with several layers have been widely studied during the past years and has become a highly successful and popular research topic in machine learning due to their excellent performance in many benchmark problems and applications. This learning has been leveraged and applied to Telecom network to solve some of the most useful use cases.

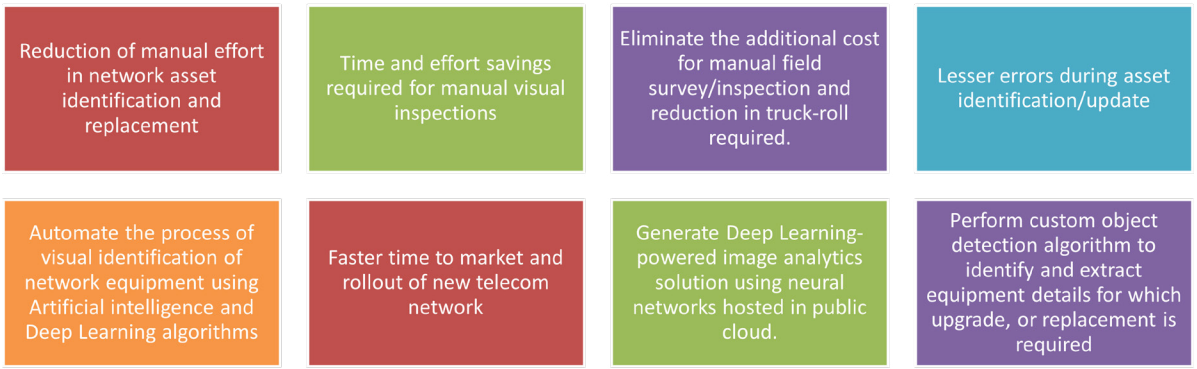
With the continued roll-out of 5G around the world, we are heading towards an ever-growing data revolution. Optimizing the networks to withstand such massive data volume is going to be one of the key strategic drivers for Telecommunications sector.

1.3. Current Industry Challenges

One of the key challenges currently faced by Telecom Industry during Network Rollout and network migration is the identification of the existing structure which can be reused or require any augmentation or replacement etc. The existing on-field inspection is very challenging and tedious manual effort is required to send a technician to the field and identify the tower or network asset for any failure or fault which is highly costly. This involves monotonous manual visual inspections and inventory update which will lead to delay in network roll-out and its services. There are also additional chances of human errors during inspection, and this may result in incurring higher cost with respect to manual field survey and inspection and thus increased truck roll cost for its relevant fixes.

With current manual and operator centric approach there is huge task of efficiently managing a large workforce across all service domains including mobile and fixed networks. Technicians carrying multiple devices to sites, error prone manual data entry by technicians, frequent handovers with unclear accountability etc. has caused incorrect network inventory.

This necessitates the need to develop an approach to identify the various telecom business cases that can leverage visual analytics for improving the network quality. To develop such an approach, the first step was to identify the key objectives and solution highlights as given in Figure 1



Key Objectives and Solution Highlights

2. Solution - The AI Approach

Across Telco industry, the Network Planning and Deployment Management must be re-imagined supporting the next generation network planning goals moving beyond reactive to provide proactive, predictive network plan and build across network. The business problem identified to be solved is digitizing the network field survey and inventory update (Figure 3)

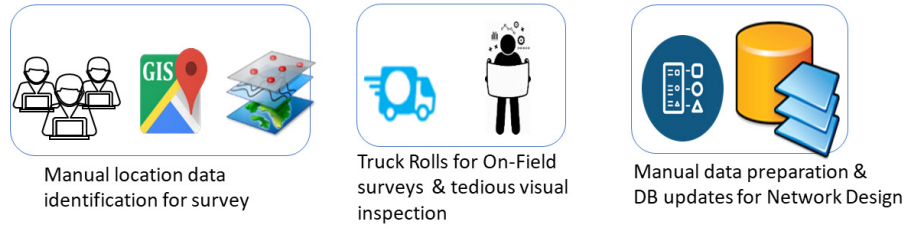


Figure 2: Business problem – Manual On-field survey and network inventory update

In the aforementioned scenario of Network Field operations, below are the few challenges that need to be addressed:

- Manual location data identification for survey
- Truck Rolls for On-Field surveys & tedious visual inspection
- Manual data preparation & inventory updates for Network Design
- Address/Location fallout in case of manual address verifications

To address this Usecase, the existing systems could be potentially uplifted with more advanced AI features for real-time on-field network planning and survey. With the introduction of Image Analytics into this scenario, the entire outcome was revolutionized. Below section provides few key solution insights:

- Deep Learning-powered cognitive intelligence & Artificial Neural Networks.
- Automated Self-learning based on processed images backed up with cloud native solution
- Automated extraction of network objects and identification of issues to be addressed in network.
- Business Locations mapping to service business premises using Optical Character Recognition (OCR) leveraging analytics services.

In one of the business scenarios – Pole Data cleansing, the network operators need to perform on-field survey for each location, and update the asset inventory based on the finding. This whole process was done manually thus impacting a huge truck roll as well as technician cost associated.

This manual process was automated by initially introducing desktop-based survey using Google Street view and manually verifying the asset details using google map. As the next step, an advanced layer of automation using deep learning and Google Street view APIs were leveraged to build a system of Artificial neutral network (ANN) which helped in solving this complex multilayered computational problem using Classification and Prediction methods.

Intelligent Image Analyzer solution provides an automated platform for users to analyze and identify any network related faults or maintenance required thus eliminating the requirement for the field engineer to perform on-field inspections.

The following segments provides more insights into the solution side.

2.1. Deep Learning powered Object Detection

Even though there are multifold solution possibilities for object detection, deep learning-based solution is most effective, since it is easy to construct, train and deploy the object detection models with the advent of Deep learning platforms such as TensorFlow and Object Detection APIs. This is the most critical module built in the entire solution where the training phase of creating deep neural network model that learns to associate images and label, classify images and setup layers need to build with the highest possible accuracy and precision.

This solution uses Convolutional Neural Networks (CNN) [5] as key base algorithm and Fast - RCNN [2] i.e., regions with CNN feature as a feature extractor logic.

The Object Detection API provides a collection of detection models, which can be pre-trained on the COCO Dataset. The final output of the object detection model is Frozen Inference Graph.

For this telecom use case of network device identification as there was only minimal pre-trained data set readily available, the newly built model was trained using a custom dataset of nearly 1000 images (poles and its cable specifications) for which bounding boxes were drawn to train the system to identify the required objects.

2.2. Implementation Approach

The Intelligent Image Analyzer solution can be classified as three key modules:

- Model Definer
- Network Dataset Trainer
- Telco Asset Object Detection

The below diagram provides detailed steps as part of each stage of the solution.

The various custom images were gathered using google street view and annotated for identifying the poles in each image, and training data set was created. This was used to train the object(pole) identification model and predict the presence of pole and its details from any new google coordinates provided. Using Google APIs, the solution will take snapshots from the Google Street View (GSV) APIs and then run the object detection model to identify the pre-trained object.

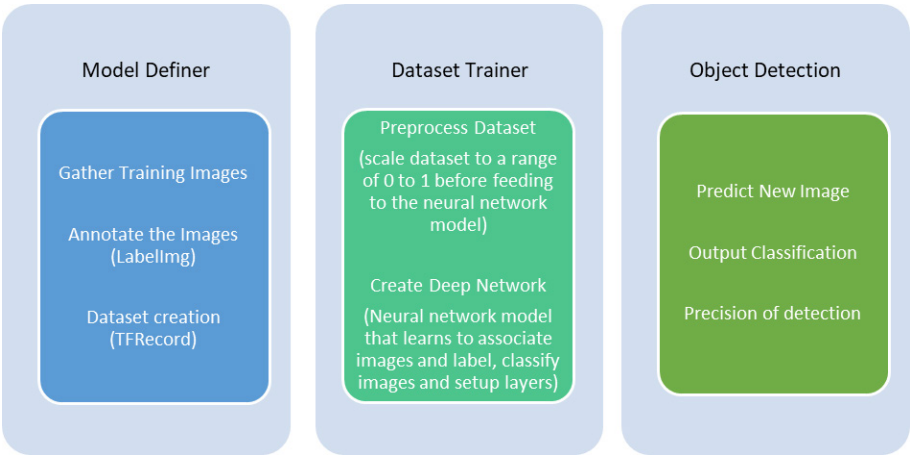


Figure 3: Solution Modules

2.3. The Outcome Derived

Once the model training is completed and deployed, it model will start to recognize the pre-trained network asset patterns present in the image and starts building its own cognition and neural network layer.

Open-Source Deep Learning framework based on Python ML libraries and Google APIs have been leveraged to generate the object detection model. The Convolutional Neural Network (CNN) [5] algorithm helped to avoid inputting the entire image as an array of numbers, instead the images were broken into several tiles and then predict what each tile is. This eventually let the system make out and predict what is in the overall image based on the prediction of the individual tiles. Google Open source Tensorflow based DL algorithm APIs helped in training the model faster.

Few challenges as well arised as part of the solution such as identifying different criteria of network assets, and look for the right object which would come at ease out of a manual operators inspection experience. However, for the designed model to operate with higher level of accuracy, the model need to be capable enough to identify complex scenarios as well, for example to distinguish between a tree trunk and a pole which are placed at the same distance in the image and seems very similar. The precision and accuracy of model depends on the % rate of prediction success rate and these kinds of complex scenarios need special attention to be thought through and tested properly so the model will have good level of accuracy.

The final model was able to detect the pole, its loops, and other characteristics with overall up to 80% accuracy. The below picture shows the object detection for pole data. These details are captured in the backend and relevant network inventory gets automatically updated.

Figure 5: Sample output using Object detection model

3. Implementing Advanced Telco Use cases

3.1. Location Fallout Management using Image Analytics and Object Character Recognition (OCR)

This particular use case handles the end user location data corrections required for Telecom service providers without any field re-visits. This solution along with Image Analytics also used, Text Analytics and Object Character Recognition (OCR)

In Telecom network, consolidating the physical and logical locations of network elements and address management is very crucial. This has required to have advanced Address management and fallout management in place for better location based mobile and fixed services.

The key solution highlights include

- In case of business address verification, advanced fallout scenarios to be identified using image analytics and OCR and verify the address.
- The solution performs automated business address verification and fallout identification
- Leverages public cloud services and performs automated address verification using Google Places API

The images of business locations can be downloaded using Google APIs and specific objects (business logos) decoded using Image Analytics and Text analytics/ OCR technologies. A sample is provided in the below figure.

Figure 6: OCR based Image Analytics for business logo detection

3.2. NextGen Telco Usecase – Drone based site surveys and asset digitalization

NextGen RF planning would leverage the use of Drones/ UAV (Unmanned Automated Vehicle) with Telcos enhancing internal efficiencies in their own operations, and new revenues from a wide array of drone-related services such as:

- Autonomous Network Planning and Optimization
- Automated Asset Inventory reconciliation and Preventive Maintenance of Operators' Infrastructure
- Automated Field Inspection, improving safety and efficiency of Field Technicians
- Structure Inspection including Bird Nest Monitoring, Cell Tower Monitoring

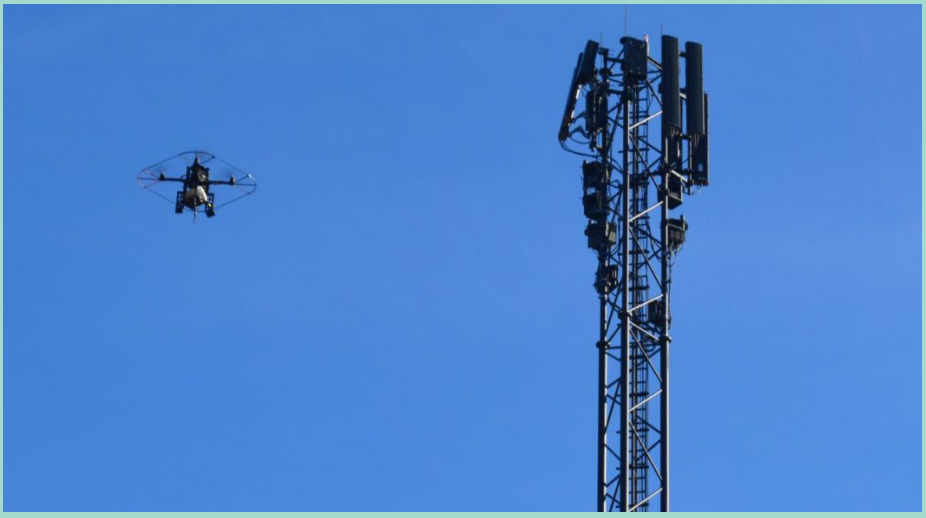


Figure 7: Drone based Field survey (Source: Google)

5G Network planning including Small Cell design involves high complexity and prolonged procedure to identify site logistical issues including placement locations, and planning issues. These Small Cells can be deployed in existing structure/Non-standard address traffic islands, advertisement boards, tall buildings etc. which can be easily identified using the Intelligent Image Analyzer solution.

Grounded on Drone Automation, GIS data & Image analytics the solution should be able to identify and predict the locations where small cell deployments can be proposed as part of 5G RF Planning. The solution will have custom built algorithms to increase the coverage and quality and provide a 3D visualization layer for faster Network Planning.

Drone/UAV equipped with sensors will automatically detect the small cell deployment spots within the area. Required data can be acquired and images analytics performed with cost-effectively using inbuilt intelligent algorithm will measure the coverage area of the Small Cell using photogrammetry. This will provide a full view for Network Planner to gain very accurate 3D models and integrated with CAD software for final analysis at a remote location.

Figure 8: RF Tower/Small Cell (Source: Wikipedia)

With 5G and advanced Telecom technologies are expanding, good amount of research is being done to explore ways to incorporate AI and deep learning for the analysis of video data captured by drones for technical support and infrastructure maintenance of cell towers. In certain cases, these AI-powered systems can restart cell sites or towers based on their behavior such as connection disruption. Other use cases include optimizing the behavior of the network based on weather data, real-time usage data etc., enhancing network utilization and customer satisfaction through dynamic resource allocation to name a few.

3.3. Future and Extensions

Intelligent Image Analyzer solution has immense potential in many areas and as described in this technical paper, for Telecom domain, AI-enabled networks are capable of self-analysis and self-optimization, resulting in greater agility and precision. This solution has got massive potential for dramatically accelerating the development of diverse computer vision applications for the 5G network rollout and beyond.

This diagram summarizes the potential Telecom specific areas where Intelligent Image Analytics solution can make a remarkable impact and research are ongoing.

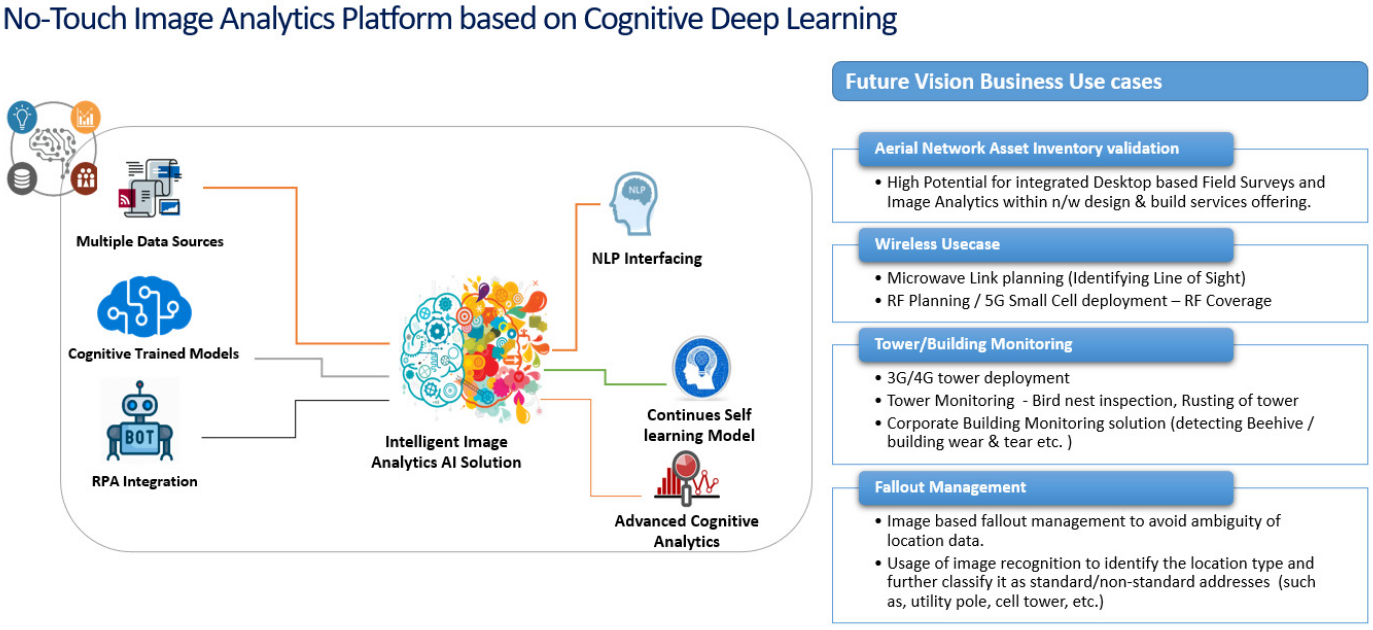


Figure 10: Summary of Potential Use cases in Telco using Image Analytics

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