Enhancing Atmospheric Measurements and Site Monitoring with Camera Imagery and Machine Learning

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ARM Camera Images and Convolutional Neural Networks (CNN)

Fig. 1: Polar bear caught on camera at the NSA C1 site in Utqiagvik, Alaska

Visual Geometry Group (VGG) type Convolutional Neural Networks (CNNs) have shown to be effective models for classifying images and object detection. This is a particularly useful tool for more accurate motion detection monitoring necessary for ensuring the safety and security of ARM sites, as well as providing new high quality scientific data streams.

CNN models can be applied to various types of imagery, from RGB photography to hyperspectral imagery.

Fig. 2: The boat crane area crane area near the Aerosol Observing System (AOS) at the AMF1 site is monitored for motorized activities

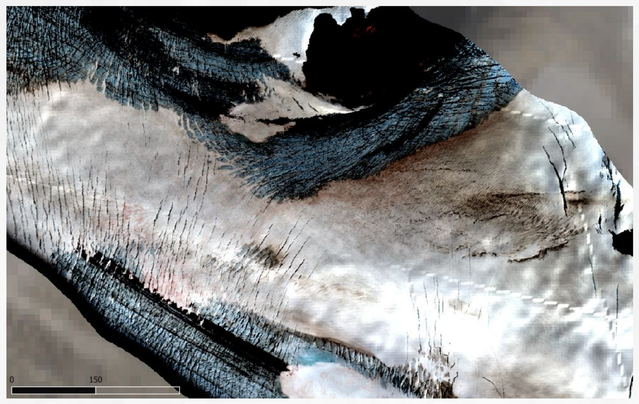
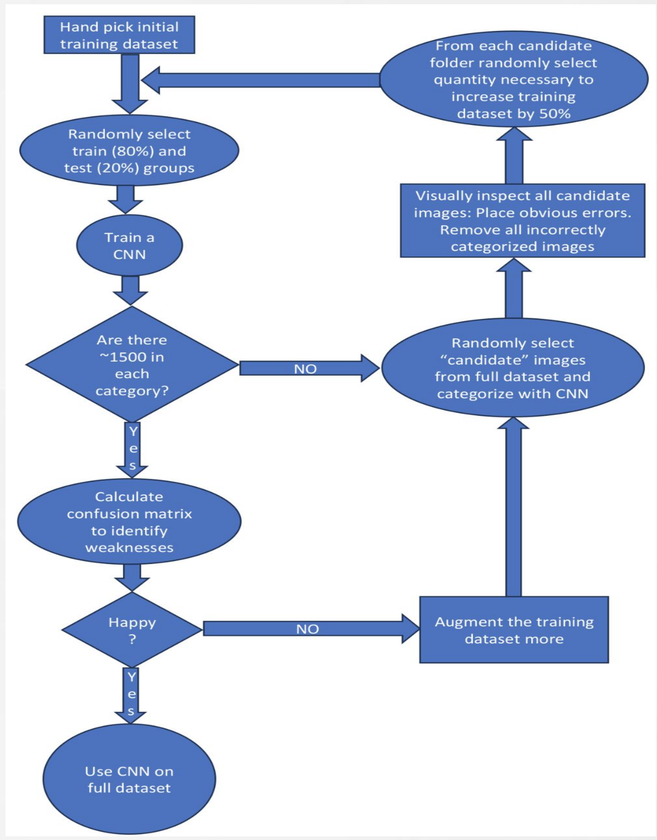


Fig. 3: Hyperspectral imagery from a flight over Grewingk Glacier, Alaska

CNN with Imagery Workflow



We have developed a workflow for efficiently conducting Machine Learning studies in a less biased way. In this chart, rectangles represent actions that the researcher must do manually. Diamonds represent decisions, and ovals represent actions where pre-written programs are ready to do the work.

The workflow balances objectivity with speed. With a number of categories, it becomes extremely tedious to hand pick 1500 images for each category. After initially hand selecting a much smaller dataset, a preliminary CNN is trained, then used to select candidate images from the full dataset. These candidate images must be individually scrutinized before they can be included in the training dataset for the next iteration. As the training dataset grows, each successive CNN becomes more accurate.

Once the desired accuracy is achieved, the full dataset can be analyzed.

Plume Detection and Cloud Type Analysis

A CNN-based study has been conducted to identify and differentiate between atmospheric conditions using panoramic camera images. Categories include cloudy, clear, ice fog, or snowing. A second CNN was developed for characterizing a powerplant plume. Camera images were collected every 10 minutes and were categorized using the VGG16 CNN (16 layers deep). Pre-selected data was correctly categorized better than 90% of the time. Some example images for dfferent categories are shown below as well as saliency maps that give confidence that the CNN is making decisions for the correct reasons.

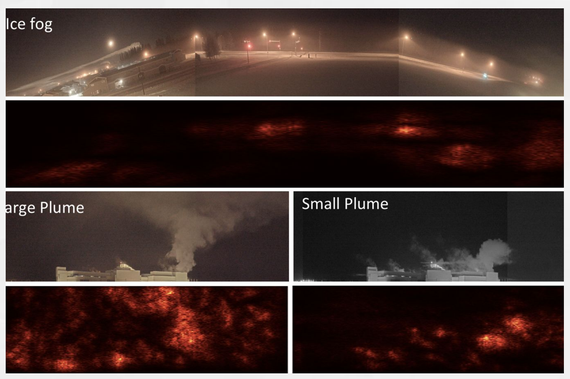


Fig. 4: Saliency maps for CNN studies identify which areas of the photos are more heavily weighted by the model for classification.

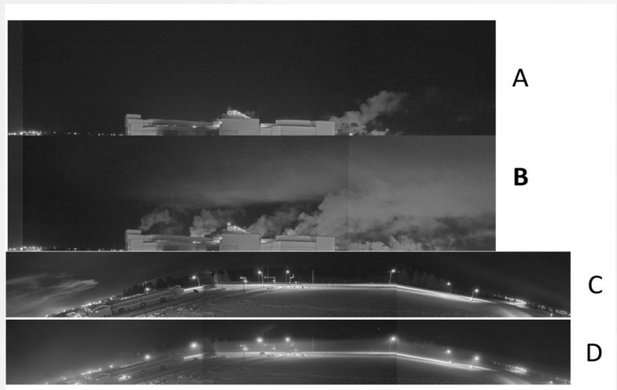


Fig. 5: Around the clock panoramic images monitoring the condition of the powerplant plume (A and B), cloudiness (C), and ice fog (D).

Pairing Imagery and Instrumentation

Combining classified sky and plume characteristics with data from co-located instrumentation enables us to develop a better understanding of the boundary layer. The MTP-5 Meteorological Temperature Profiler (from ATTEX) is one such instrument that has collected data in Fairbanks and the NSA C1 site. Conditions classified by the camera CNN are associated with different atmospheric temperature profiles.

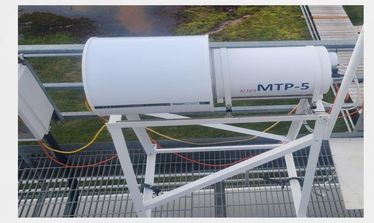


Figure 6: The MTP-5 Profiler installed at the NSA C1 site in Utqiagvik, Alaska.

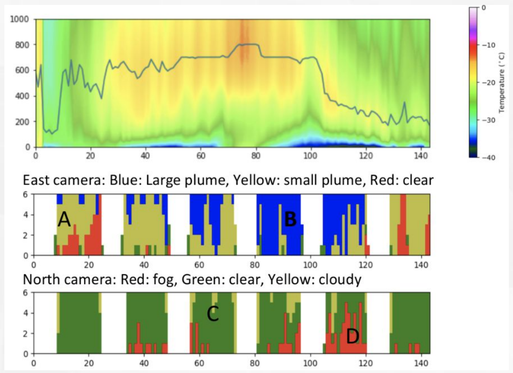


Figure 7: Temperature data from the MTP-5 during the cold event from January 3-9, 2022. Figure 5 shows panoramic images from this same time frame. CNN results are shown in the lower panels.

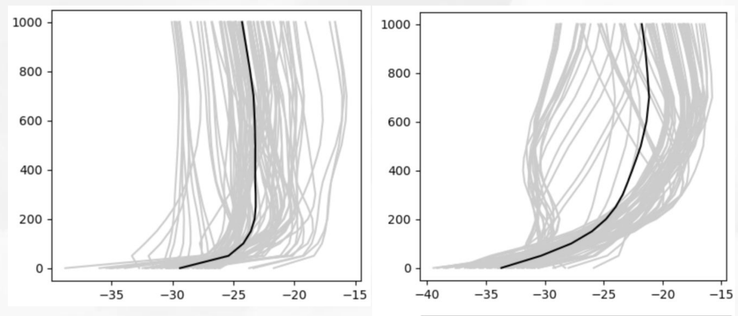


Figure 8 : Left, the measured temperature from the MTP-5 when little or no plume was detected. Right, the temperature profiles when a strong plume was detected.

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