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Next in precision agriculture: detecting and correcting pixels with machinery track line within farms

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Abstract.

With more satellites orbiting the earth, monitoring of fields using satellite data has become easier and ubiquitous. Frequent observations of a field can provide vital cues about field health and management practices. However, farm analytical statistics derived from such datasets often need modification to create practical applications. This paper focuses on the detection and removal of field machinery track line pixels to reduce their effect on satellite-based agronomic recommendation and product development.

Two methodologies were tested for detection purposes using medium spatial resolution Sentinel-2 images. In the first method, the image was passed through various filters and mathematical operators to detect the track lines. This method is quick and requires low computational resources. However, the output is influenced by infield differences and other infield objects. Additionally, it is input resolution dependent thus limiting the application to medium resolution satellite image sources such as Sentinel-2. In the second method, the content of a sliding window is Fourier transformed into the frequency domain. Signals within a given frequency range are examined for improved accuracy and precision of the detected tracks. This method is most suited for precise detection of the machinery tracks despite the high computational demand. Additionally, this method can handle various resolutions and can therefore be used for a wide spectrum of remote sensing data, for example drone or satellite imagery.

Once the machinery tracks are detected, the data on the detected pixels can be modified using neighboring pixels. Three neighborhood filters, namely mean, median and weighted mean, were tested. The median filter was found to produce the best result in removing the track line effect and allowed field statistics that are free from the impact of the track lines present in the images.

Keywords.

Machinery tracks, field properties, farm management, remote sensing

Problem Space

Remote sensing in agriculture has become an essential tool to monitor changes and processes in the field. However, converting this data to real recommendation is often tricky. This paper highlights one such issue arising from the machinery tracks in the fields. While creating the variable fertilizer application rate, for high and medium resolution imagery, there are often pixels containing mixed information of the crop and these tracks (Fig 1). Such pixels cause an undesired change in the local application rate. The lower vegetation information in these pixels is not caused by a lower growth rate but by mixed information about crop area and machinery track. The issue of the mixed pixels or altered vegetation information due to tracks becomes more pronounced when moving from low to high spatial resolution images. It is desirable that variable application rates are created based on the in-field differences of the crop and not differences due to the machinery tracks. This requires detecting a field property, namely the field track lines, which depend on the type of machinery used on the field. They are caused by the adopted human management system.

Fig 1. True color images of fields with track lines, source Google Earth Engine (left) Sentinel-2 (on the right)

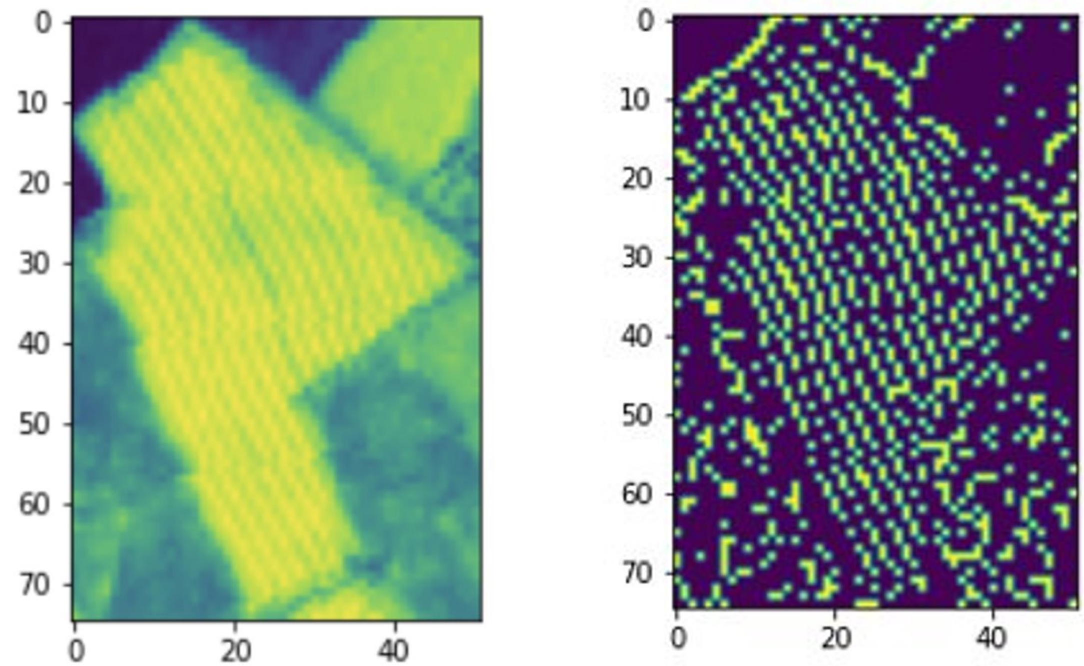
In the process of removing the effect of the track lines from the image, detection is the first step. The next step is to recreate an image where these tracks are removed without altering any other infield differences caused by variable crop growth and performance regions. In the following section, two methods developed to detect and compensate such track line pixels in satellite imagery are discussed.

Methodology

Open-source Sentinel-2 and one set of privately acquired drone images of various fields in Western Germany were used for the development and testing of the methods. All processes were performed using Python scripting tools and libraries, namely `rasterio`, `cv2`, `numpy` and `scipy`.

The first method applied traditional edge detection filters. Among the multitude of filters available, it was seen that the Laplacian filter performed best when it comes to highlighting infield differences. The Laplacian filter detects sudden intensity transitions caused by the tracks in the image and highlights it as an edge (Satish, 2018). The filter requires low computational resources and is easy to understand and apply. But there is a massive downside: There is no way of distinguishing infield differences caused by machinery tracks from those caused by other reasons. The use of filters and mathematical operators works well with fields known to be homogenous. However, in a heterogeneous field, additional measures need to be taken to distinguish the variability caused by the track lines from that of the crop growth. Additionally, this methodology is dependent on the input image resolution: The Laplacian filter can only work with medium resolution images. For high resolution images, the filter begins to highlight differences even within the track lines.

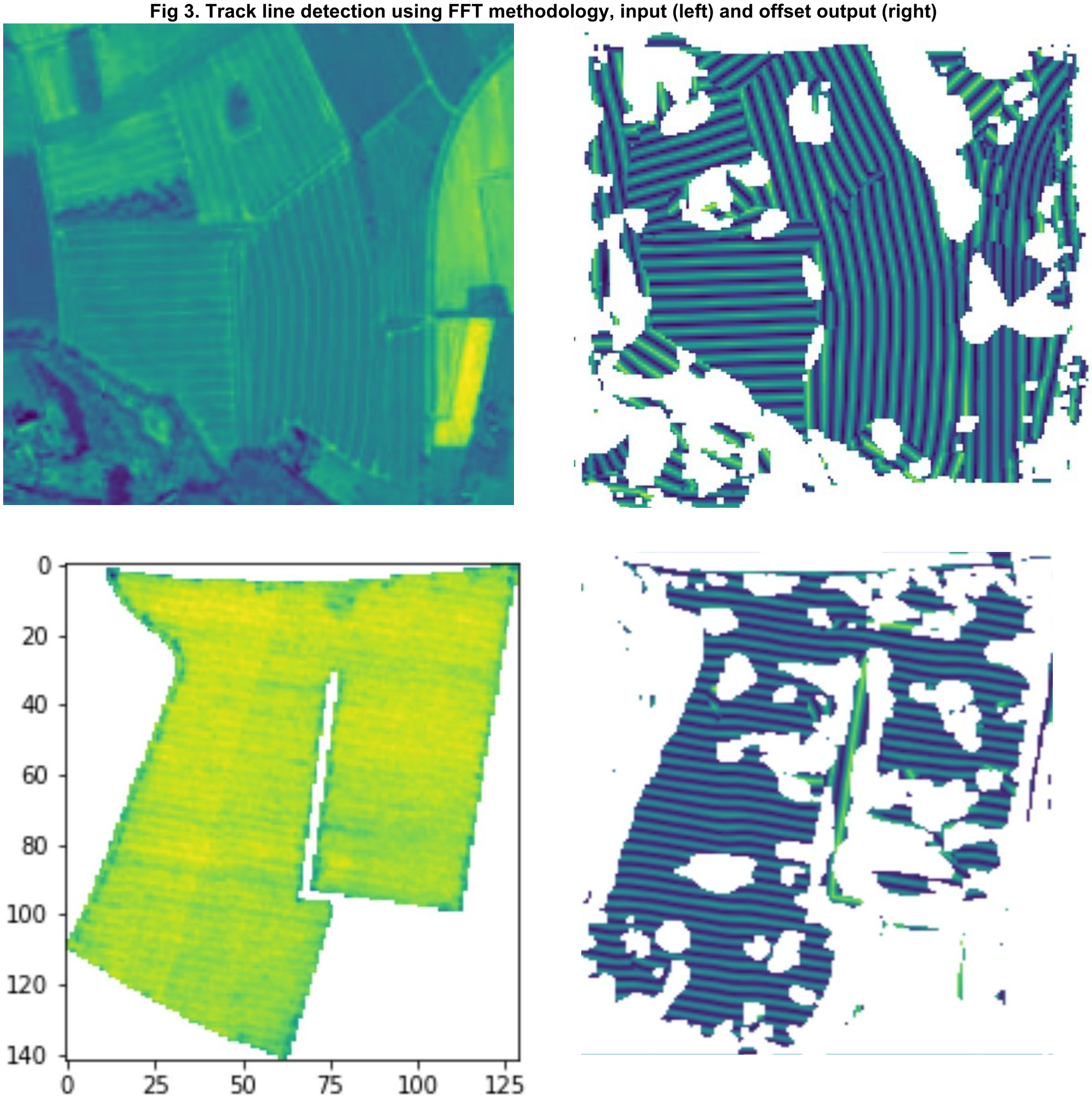
Fig 2. Track line detection using Laplacian filter (right) on NDVI Sentinel-2 image of the field (left)



The second method transforms a high contrasting band, or an index derived from the satellite imagery into the frequency domain and looks for the signal caused by the repetitive pattern of the track lines. The Fourier transformation decomposes the input signal (in this case spatial reflectance or index values) into separate signals at different frequencies. The peaks found are then filtered using two key criteria qualifying them to be signals from the track lines as described below.

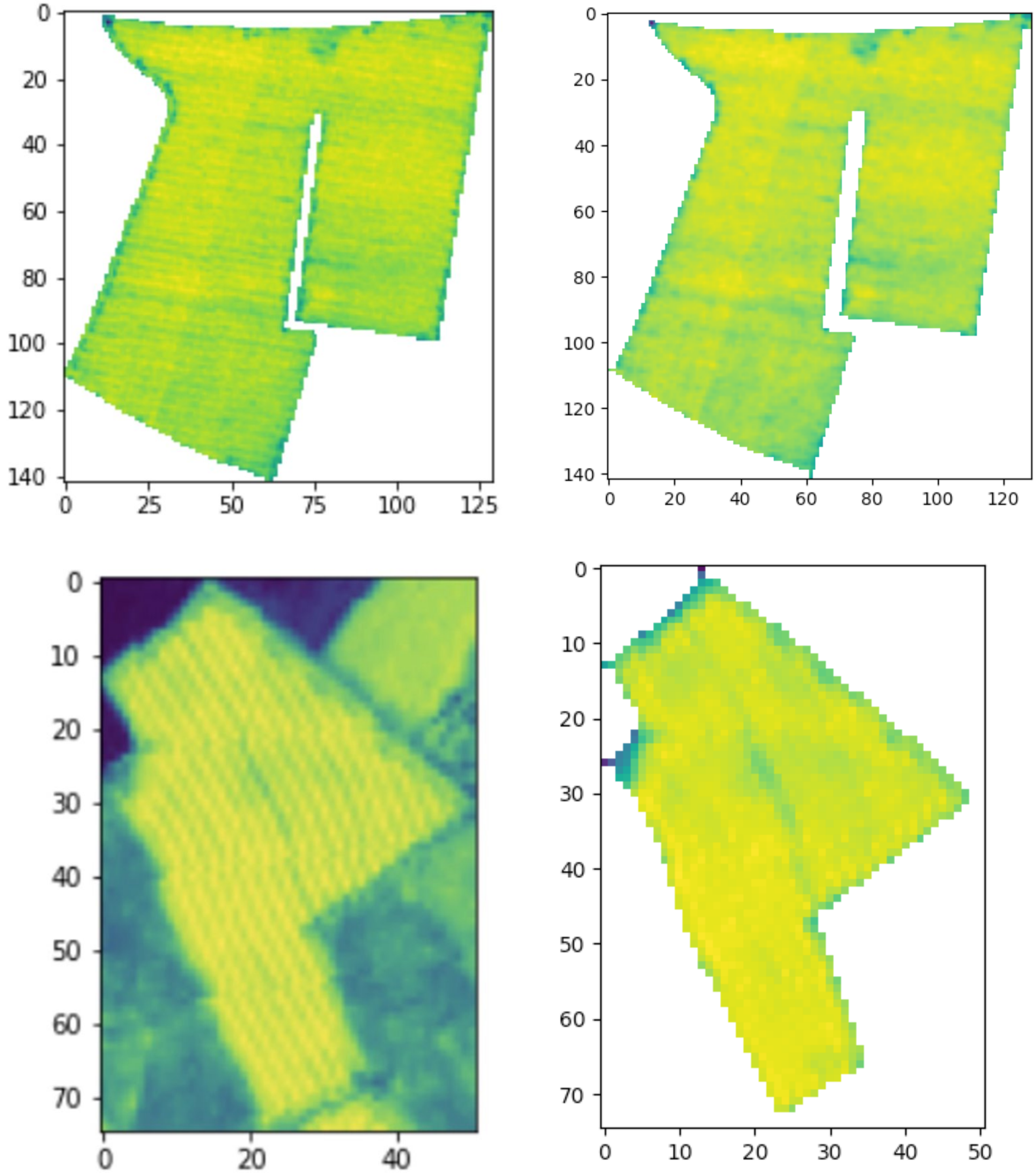
A Fast Fourier Transformation (FFT) is applied to the content of a sliding window on the image. The size of this window is constrained by the expected range of track line distances. It should be such that it contains at least 4 to 5 track lines. This enables the FFT to show the track line frequency signal which appears as a peak within a predetermined frequency range. The range is calculated using the expected minimum and maximum track line distance. It acts as a first filter to only find peaks caused by track lines and to remove signals representing infield crop growth differences, field boundaries, etc. The position of the highest peak found gives a first, coarse estimate of the frequency and direction of the track lines. Due to the FFT window function used, the peak is expected to have a certain shape. This allows a second, analytical estimation of the peak position with sub-pixel precision by looking at the values of pixels adjacent to the peak (Smith, 2011). If this calculated position is not within the peak pixel, the pixel is rejected as not being part of a track line system. Otherwise, the computed peak position provides a precise estimation of direction and distance of track lines around that pixel. The phase angle of the complex value at the peak provides the distance of the pixel from the next track line. This information, the “offset value,” can be used to recreate track lines. Low values signifying the pixel is within or contains a track line, higher values signifying that the pixel is farther away from a track line and hence pure vegetation. Fig 3 shows this distance as the result of FFT based track line detection.

Fig 3. Track line detection using FFT methodology, input (left) and offset output (right)



To remove the track line distortions, all pixels within the distance of one track-line width (which is a machinery dependent value) plus one extra pixel to accommodate for any shifts, are marked as track line pixels. The rest of the pixels are marked as field pixels. A mask of 0 and 1 is created with 0 indicating the track line pixels and 1 indicating field pixels. Once this information is available, the track line pixels are iteratively filled using the mean values of field pixels within a 3 by 3 moving window. Two other approaches, namely median and weighted mean for filling were also tested. The median approach works like the mean approach. In the first iteration, no track line pixels are used in the mean value calculation but in the later iterations all pixels not marked as track line are used to calculate the values of the pixels in the track line. For weighted mean approach, the offset value is used as the weight of the value and the weighted mean is also calculated within a 3 by 3 window size.

Fig 4. Field NDVI image (left) after compensating for the track lines using median filter(right)



Conclusion

It is possible to detect track lines within satellite images at a subpixel level precision. The most accurate methodology requires to transform highly contrasting band or a derived index into the frequency domain. This method adds additional information layers to the image such as direction and spacing of surrounding track lines and the distance to the closest estimated track line. Using that information, a simple threshold can be used to mark pixels within a given distance from a track line as such. This track line mask can then be used to revise data using a moving window median function for masked pixels. The resulting output is free of the track line distortions while still containing the infield differences arising from the vegetation growth (Fig. 4).

References

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