Spatio-Temporal Analysis Of Remote Sensing And Field Measurements For Smart Farming

Customer

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EXECUTIVE SUMMARY

Spatio-Temporal Analysis Of Remote Sensing And Field Measurements For Smart Farming

Problem area

For the optimization of crop yield and quality, there is an ongoing development in improving crop management advice, in order to cope with the spatial variability of the growth process, caused by local variations in, amongst others, soil composition, moisture and nutrition content. To achieve this improvement, reliable information is required on the actual status of the vegetation and the expected development and yield given different management scenarios. Remote sensing observations form a valuable information source for assessing the location of suboptimal growth, but hardly ever provide the cause of the arrearage. In order to determine this cause, the observations must be combined with other observations and models and analyzed integrally.

Description of work

This article presents the followed approach and initial results of a pilot project Smart Farming carried out in the Dutch North East Polder. Observations and data from several sources have been

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This report is based on a poster presentation held at the spatial statistics conference in Avignon, June 9-12, 2015. The results are published in [1].

collected for a number of potato parcels in 2014. The collected data includes multi-temporal satellite and UAS observations, field based soil, vegetation and yield observations, soil type maps, height maps, historic parcel and crop information and meteorological data. A data driven approach was followed to determine the presence of relations between the various observations in order to couple location and probable cause of sub-optimal crop growth and determine temporal developments in series of observations. The available data was analyzed integrally using correlation, regression and histogram analysis techniques. All resulting spatial layers are visually presented in a GIS based web service environment.

Results and conclusions

Different methods for data pre-processing, analysis and visualization are investigated. Data from different sources and containing different types of information is collected. Some preliminary data analyses are performed. Visual analyses of the existence of a relationship between images are carried out using histogram analysis. Using simulated data the usefulness of cross-correlation techniques is investigated, these results are promising. Future work should focus on the collection of more data and extension of the data driven analysis in combination with existing models of biophysical properties.

Spatio-Temporal Analysis Of Remote Sensing And Field Measurements For Smart Farming

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Summary

For the optimization of crop yield and quality, there is an ongoing development in improving crop management advice, in order to cope with the spatial variability of the growth process, caused by local variations in, amongst others, soil composition, moisture and nutrition content. To achieve this improvement, reliable information is required on the actual status of the vegetation and the expected development and yield given different management scenarios. Remote sensing observations form a valuable information source for assessing the location of suboptimal growth, but hardly ever provide the cause of the arrearage. In order to determine this cause, the observations must be combined with other observations and models and analyzed integrally.

This article presents the followed approach and initial results of a pilot project Smart Farming carried out in the Dutch North East Polder. Observations and data from several sources have been collected for a number of potato parcels in 2014. The collected data includes multi-temporal satellite and UAS observations, field based soil, vegetation and yield observations, soil type maps, height maps, historic parcel and crop information and meteorological data. A data driven approach was followed to determine the presence of relations between the various observations in order to couple location and probable cause of sub-optimal crop growth and determine temporal developments in series of observations. The available data was analyzed integrally using correlation, regression and histogram analysis techniques. All resulting spatial layers are visually presented in a GIS based web service environment, so that the advisor or farmer can view the raw and derived information interactively and form his/her conclusions.


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Content

Abbreviations

Acronym	Description
GIS	Geographic Information System
NDVI	Normalized Difference Vegetation Index
UAS	Unmaned Areal System

1 Smart Farming

The agricultural sector in Flevoland (a province of the Netherlands) is both nationally and internationally famous for its cultivation of (seed)-potatoes. The province houses Emmeloord, also known as the “World Potato City”. The sector estimates it is the second largest exporter in the world and generates the highest yield per acre worldwide. Nevertheless, it is estimated that the yields can be increased with an additional 10 to 20 percent and the quality of the products can also be increased if the cultivation process is controlled better. An essential element in further improvement is information. Information on when and where which cultivation measures like fertilization, irrigation and pest and disease control measures must be applied.

The goal of this project is the realization of “Task Map 2.0” and “AgroGIS”. A task map is a standardized digital instruction which can be used by a dedicated machine to automatically and independently perform different tasks on particular areas of the parcel. Tasks like planting, fertilizing, irrigating, spraying pesticides, etc. The addition “2.0” refers to the fact that in contrast to the current task maps, which are based on one or only a few information sources, “Task Map 2.0” is the result of a comprehensive analysis of as many as possible relevant parcel data, of which a large amount is obtained from open data sources, and biophysical properties; historical yield data, soil properties, crop processing data of the current growth season and observed data for the current growth season like crop scans, laboratory analyses, satellite images, aerial photos and meteorological data. All this data is collected, stored and integrally analyzed in a special information system: “AgroGIS”. The analysis consists of finding spatial and temporal relationships using all data layers to indicate sub-optimal crop growth. These relationships are partly established by automatic image optimization and interpretation algorithms and partly by visual inspection of the images by image analysis experts with a background in agriculture. Next specialized crop advisors interpret the information from “AgroGIS” and the found relationships to formulate an advice and construct “Task Map 2.0”. The farmer him/herself ultimately decides whether (s)he fully or partially accepts the recommendations of “Task Map 2.0”.

2 Project setup and data collection

The Smart Farming project is a collaboration between Dutch research institutes, Dutch industry and Dutch agricultural businesses. This collaboration led to the forming of the Smart Farming consortium: Aequator, BocaVista, Ecoflight, Infram, National Aerospace Laboratory, Profytodsd and Weevers Marknesse. This consortium was formed to investigate the possibility of using remote sensing solutions to gain better control of the cultivation process. Two farmers participated in the project. The parcels of these farmers which were investigated as part of this project are both located in the Dutch North East polder. During the growth season of 2014 one farmer cultivated seed-potatoes and the other farmer cultivated ware-potatoes.

The first steps of this project consisted of the collection of data. Different types of data were used to find relationships which indicate sub-optimal crop growth. The collected data can be divided into four groups:

- Soil: Electric conductivity of substrates, pH-values, organic matter content and lutum content.
- Vegetation: Remote sensing images; Images from Unmanned Aerial Systems (UAS) and satellites.
- Meteorological: Information about approximately 30 weather parameters.
- GIS: Parcel registration, elevation map, soil map and other thematic maps.

3 Data analysis

After the data is collected it is analyzed to find possible spatial and temporal relationships. When these relationships are found they can be visualized to gain more insight in the relationship.

3.1 Spatial relationships

As a first indication of a possible (linear) relationship between two images, which contain different types of information, the correlation coefficient between these images can be calculated. First the images are resampled such that the image with the largest resolution is left intact. The other image is resampled such that the overlapping area of the 2 images becomes a grid which is equal to the corresponding grid of the image which is left intact. This resampling is performed using interpolation according to the nearest neighbour principal. This form of interpolation is used to keep the original measured quantities intact.

The correlation coefficient provides an indication of the amount of noise and the direction of a linear relationship between the two images, but it does not provide the slope of this relationship or any information on the possible existence of a non-linear relationship between these images. The correlation coefficient for all possible pairs of available images is calculated.

The pairs of images which have a high indication of the existence of a linear relationship can be investigated further by performing a simple linear regression analysis. This can be used as a preliminary quantization of the linear relationship between the two images, or equivalently between the two variables contained in these images.

For the images in figures 1a and 1b such a preliminary quantization of the linear relationship performed. The result of this quantization is shown in figure 1c. Figure 1a shows an image of the electric conductivity measurements carried out on the parcel. The measurements are interpolated to obtain the shown raster data. Figure 1b shows the height map of the parcel.

The height map shows that the north side of the parcel is higher than the south side. This can be traced back to the presence of an old river dune on the north side of the parcel. This old river dune consists of finely sand with clay on top. This layer of clay becomes increasingly thicker to the south side of the parcel until eventually the soil can be classified as heavy sandy clay. The lowest conductivity is found in the old river dune, as can be seen in figure 1a. Here, the texture is different (coarser) and the ground is relatively high. As a result of this relative high position, and the coarser texture, this part of the field is relatively dryer. To further investigate the relation between the height map and the electric conductivity a simple linear regression between the electric conductivity and the freeboard is performed. The freeboard is the difference between the height map and the local surface water level in the polder. This resulted in a quantization of the linear relationship, see figure 1c. This quantization can be used to further analyze the relationship between the two images.

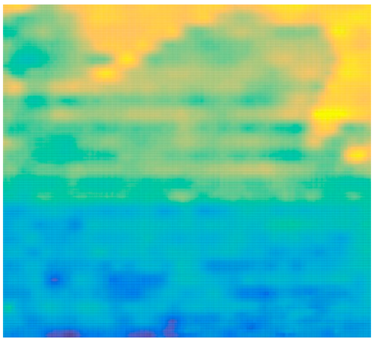

Figure 1a Electric conductivity measurements ranging from 10.1 mS/m in yellow to 41.9 mS/m in dark blue.

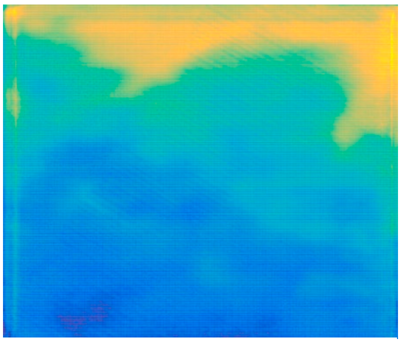

Figure 1b Height map ranging from 4.2m below sea level in dark blue to 3.1m below sea level in yellow.

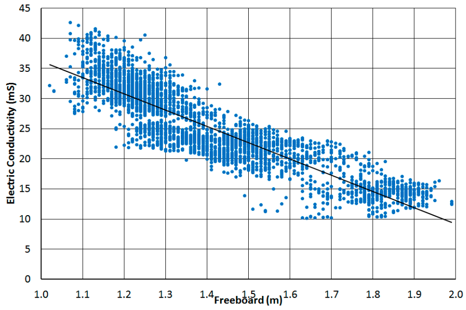

Figure 1c Scatterplot E.C. vs freeboard. Simple linear regression line y = -26 x + 63, R^2 = 0.79.

A different, more visual, technique to analyze the existence of relationships between different images is histogram analysis. With histogram analysis two images are spatially compared based on a classification. Each image is classified into three classes: 'High', 'Average' and 'Low'. The outer 10 percent of the histogram on both sides is classified as respectively 'Low' and 'High', the middle 80 percent is classified as 'Average'. This classification is based on the fact that the 'Average' values are of lower interest as they are less likely to indicate possible relationships between different images. After two images are classified in this way their classification can be combined such that 9 different class combinations can be identified. These combinations can be colored in such a way that combinations of interest can be distinguished.

Figures 2a and 2b show the classification of a near infrared image of a parcel and an image containing information about the organic matter on that same parcel respectively. To visually investigate the existence of a possible relationship between these two images a histogram analysis is performed. The outcome is shown in figure 2c. This figure can be used to visually identify possible spatial relationships.

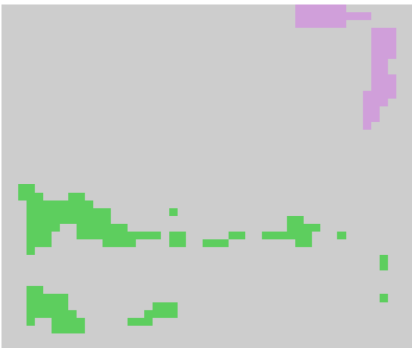

Figure 2a Near-infrared classification. Three classes: 'High' in green 'Average' in grey and 'Low' in pink.

Figure 2b Organic matter classification. Three classes: 'High' in green 'Average' in grey and 'Low' in pink.

Figure 2c Outcome of histogram analysis. Combinations 'NIR – OM': 'High-High' in dark green, 'High-Average' and 'Average-High' in green, 'Low-Average' and 'Average-Low' in pink, 'Low-Low' in dark pink and all other combinations in grey.

3.2 Temporal relationships

Temporal variables like hours of sunlight, temperature and rain have significant influence on the crop growth. Therefore the trend of these variables needs to be analyzed. Via the Royal Netherlands Meteorological Institute information about these variables can be retrieved. A historical analysis of these variables can be made and compared to the current weather to gain insight in the extent and manner in which the current growth season deviates (weather wise) from previous years.

From satellite images the Normalized Difference Vegetation Index (NDVI) values can be deduced. These values serve as an indication of the amount of photosynthetically active vegetation on the parcel. Using historical analysis a crop and even variety specific NDVI curve has to be established which can be used to monitor the vegetation development characteristics using satellite imaging. Also trend analysis must be performed on the NDVI data in combination with trend analysis on temporal variables. This analysis should focus on identifying relationships between the NDVI curves and temporal variables like sunlight, temperature and rain. Eventually these relationships are crucial in the formulation of data driven models used in the creation of "Task Map 2.0".

Figure 3 shows some of the collected NDVI data. The shown curves are related to the growth of seed-potatoes on four different parcels. Between these parcels there are variations in location, soil composition, crop management and other biophysical properties. These variations contribute to the differences between the curves. But also some similarities between the curves can be seen, like the magnitude of the minimum and maximum values, the point in time at which the increase of the curves starts and the (location specific) point in time at which the decrease of the curves starts. This shows the viability of finding crop specific NDVI curves and identification of relationships between the NDVI data and temporal variables.

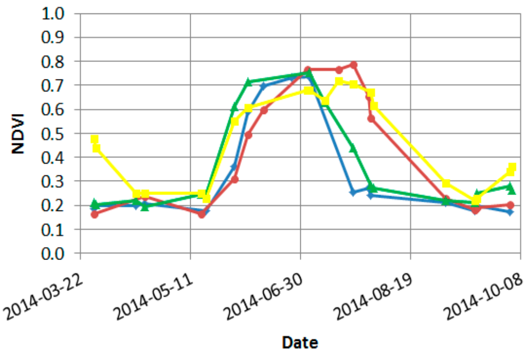

Figure 3 NDVI values for 4 parcels. 2 parcels in the North East Polder: blue and green curve. 2 parcels in South Flevoland: red and yellow curve. Source: Groenmonitor.

3.3 Visualization

To get an overview of and insight into the various datasets, a web application is built. In this environment data can be inserted and relations between different datasets can be visually inspected. The results of the analyses on the set of collected data are made available via: http://gis.nlr.nl/smartfarming. This application is still in development. At this point in time the various data layers are displayed with limited results of analysis, but these layers already give a good insight in possible relationships.

4 Future work

Another technique which can be used to analyze the data involves spatial cross-correlation techniques. First spatial anomalies on the parcel are visually identified and marked as patterns of interest. It is then investigated if these patterns of interest occur in other images. Spatial cross-correlation is robust in the sense that even when noise is present in the image, it is still able to determine if the patterns of interest are present in other images. This is a valuable property of this technique since noise in the images can severely influence the analysis and interpretation of the image. Until now, this technique is applied only to simulated data to get familiar with the technique and investigate the usefulness of it. The results look promising, therefore in future work this technique must be applied on obtained data and analyzed further.

Currently, more data is being collected such that more extensive analyses can be carried out. Especially more work with regards to NDVI curves and their relationships with temporal variables needs to be done. In a next step the found relations must be formulated in an empirical model and combined with a crop growth and weather forecast model to cover the predictive aspect. Also the web application needs to be further developed to give more insight in the found relationships. Eventually this must lead to the creation of “Task Map 2.0” and “AgroGIS”.


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5 Conclusion

The long-term focus of this project is the realization of “AgroGIS” which need to provide better and more complete information for crop management in a visual way, such that better advice, using “Task Map 2.0”, can be given, thereby increasing efficiency and improving quality in the agricultural sector.

Different methods for data preprocessing, analysis and visualization are investigated. Data from different sources and containing different types of information is collected. Some preliminary data analyses are performed. First the correlation coefficient between all pairs of available images is calculated. Images which have a high indication of the existence of a linear relationship are used in linear regression analyses. Visual analyses of the existence of a relationship between images are carried out using histogram analysis. Using simulated data the usefulness of cross-correlation techniques is investigated, these results are promising. Some of the analyses are already implemented in a web application. Future work should focus on the collection of more data and extension of the data driven analysis in combination with existing models of biophysical properties.

References

1. B. van de Kerkhof et al., *Spatio-Temporal Analysis Of Remote Sensing And Field Measurements For Smart Farming*, Procedia Environmental Sciences 27 (2015) 21 - 25

WHAT IS NLR?

The NLR is a Dutch organisation that identifies, develops and applies high-tech knowledge in the aerospace sector. The NLR's activities are socially relevant, market-orientated, and conducted not-for-profit. In this, the NLR serves to bolster the government's innovative capabilities, while also promoting the innovative and competitive capacities of its partner companies.

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