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Application of LASSIE to improve agricultural field experimentation

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Abstract

Topical information of vegetation is of great interest in agricultural field experimentation. In general observations and documentation of the experiments are performed by time consuming field inspections. By means of the ground based remote sensing system LASSIE present image information of the experiments can be gathered in almost real time. This system allows permanent, geocoded and standardised remote field inspections.

Key words: Field inspection, ground based remote sensing, LASSIE, field experimentation, dynamic maps

Zusammenfassung

Einsatz von LASSIE zur Unterstützung des landwirtschaftlichen Feldversuchswesens

Aktuelle Bestandesinformationen sind im landwirtschaftlichen Feldversuchswesen von großem Nutzen. Die Beobachtung und Dokumentation von Freilandversuchen wird in der Regel durch zeit- und personalintensive Bonituren durchgeführt. Mit Hilfe des bodengestützten Fernerkundungssystems LASSIE lassen sich aktuelle Bildinformationen über den Bestand in Echtzeit gewinnen. Damit können Feldversuche lagegenau und zeitlich lückenlos dokumentiert und Bonituren standardisiert werden.

Schlüsselwörter: Bonitur, bodengestützte Fernerkundung, LASSIE, Feldversuch, dynamische Karten

1 Problems of field experimentation

The aim of field experimentation, in contrast to applied agriculture, is the observation and understanding of variability in growth and development under different management conditions. Field experiments can also be used to test and refine new concepts and ideas, and to transfer new developments from research to the public. Especially three basic questions are of specific interest in field experiments:

1. Where are differences?
2. When do these differences occur?
3. How do differences develop during time?

In general differences will be evaluated by visual diagnosis. With field inspections variations in plant development or diseases can be mapped. This common assessment method requires much experience of the staff. In addition the main point of criticism for this kind of field evaluation is the incomparability of the results retrieved by different personnel since it concerns a subjective procedure.

Apart from the spatial structures the temporal component is of importance. The time, when a phenomenon arises, is hardly to cover by field inspections since it is dependent to the experiences of the staff. Nevertheless it occurs that an assessment is performed at the wrong time.

For example fungus infestation in cereals will be monitored at several dates during the vegetation period. The occurrence of infestation depends strongly on the weather situation. If the wrong time for assessment is selected, it can occur that infestation is recognized too late. On the other hand it can happen that no fungus is present at all, and the evaluator came in vain.

Remote sensing technologies like aerial photographs or satellite images offer the possibility of a fast mapping of agricultural areas, without getting in physical contact to the target. The visual appearance of agricultural fields and the dates for fieldwork vary from year to year and between crops (Kühbauch 2002). Agricultural monitoring by remote sensing requires repeating image acquisition by four to 14 days, depending on crop and management practice (Allan 1990).

Especially in Central Europe cloud coverage is a severe problem for the data availability of remote sensing data. Together with data pre-processing the time span of delivery for agricultural applications is too long. The multiplicity of technical and logistical problems led to the fact that in agriculture remote sensing is mainly used in scien-

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tific research and operational application for farm management is still not available (Moran 2000).

Remote sensing as a tool for farm management is only useful if the data is available in real time. Short term flight-campaigns with aeroplanes can be used as alternative to satellite images (Grenzdörffer 1999), but these flight campaigns require a high logistic effort, whereby apart from the tremendous costs, the problem of the cloud coverage remains existing.

A new concept for the agricultural remote sensing was developed at the *Institute of plant nutrition and soil science* at the Federal Agricultural Research Centre (FAL) and this might solve the past problems:

The so-called LASSIE (**L**ow **A**ltitude **S**tationary **S**urveillance **I**nstrumental **E**quipment) consists of digital cameras, which are set up at exposed positions in the landscape, operating below the cloud cover, so that the system is almost independent of any weather situation (Panten et al. 1998, Schnug et al. 2000, Lilienthal 2003).

LASSIEs are very suitable for monitoring of agricultural experimentation sites. The system can be operated like a conventional camera, and equipped with specialised optics zooming up to the resolution of a single leaf is possible. In that way field assessment is placed on an objective base and the experiment can be documented by real time imagery. Using LASSIE for field assessment a standardisation of the monitoring results can be achieved. By means of digital image processing the accurate proportion of fungus infestation per leaf can be evaluated. The schedule of field assessment can be planned on the base of the LASSIE results. Also the image data allows assess areas within the field which are hard to reach.

For researchers, which operate at spatially widespread test areas, LASSIE offers the possibility to gain information about the current condition of the field experiments. For example the regional phenological stage of different cultivars can be documented without assigning personnel for the assessment.

2 The LASSIE system

LASSIEs describe stationary scanner systems on elevated positions in the landscape (Schnug et al. 2000). The area covered by a LASSIE mainly depends on the height of the pylon the camera is mounted to. By means of a LASSIE real time images of crop and soil surfaces can be continuously recorded and automatically corrected of geometric distortion and geo-coded in a GIS (Geographical Information System). Thus changes in crop performance become easily visible and can be addressed either directly if a ground truth is not required or indirectly with accompanying ground truth.

The latest LASSIE consists of two sensors, one colour camera for the visible part and a second black and white camera for the near infrared part of the spectrum. Figure 1 shows the spectral sensitivity of the cameras compared to the reflection features of bare soil and vegetation.

The most important spectral features of soils and vegetation in the reflective spectral domain, like the pigment absorption (400 – 700 nm) and the strong reflection caused by the cell structure (700 – 1300 nm) are covered by the spectral layout of the LASSIE sensors. Changes in the colour of plants can easily be detected with LASSIE, but remote sensing has the general problem that differences in the spectral reflectance of the canopy can have more than one reason.

Changes in the "green" colour of crops, preferably identified by means of the reflectance of visible light are certainly most likely due to changes in the chlorophyll content and the nitrogen content of the plant. This is most often attributed to the nitrogen supply of the crop and thus claimed as a suitable information for the design of nitrogen dressings (Baret & Fourty 1997; Blackmer & Schepers 1996). But there are many more reasons why the canopy's green or infrared reflectance can change - for instance sulphur or other nutrient availability as well as from shortage/excess of water or from pests and diseases. Most recently, the sulphur supply of crops for instance, has become the major explanation for reasons of "green" colour intensity of crops in the northern hemisphere (Schnug & Haneklaus 1998).

A detailed description of the spectral properties of LASSIE is listed in table 1.

The system consist of four major components showed in figure 2. The sensor (1) is mounted on the stepping motors (2). The imagery acquired by the sensor will be digitised by the video server (3) and send to the processing unit (4) where the imagery will be rectified.

The rectification of the imagery requires additional information of the geometric conditions at image exposure. Figure 3 shows the constellation of the different angles affecting the geometry of the resulting image.

The rectification of the image data can be simplified and accelerated due to the stationary situation of the system. The cameras are installed on stepping motors, which can start pre-programmed positions with a high accuracy. Since the geometry of the images which were taken at different times but at the same position, are identical, the correction can be performed, if the parameters were defined before. The system needs to be calibrated once and afterwards can be automated.

Using techniques from photogrammetry allows the computation of pseudo-nadir images from the original oblique pictures. Figure 4 shows an example of an original and the corrected LASSIE image.

The area which can be observed with a LASSIE is dependent on the height of the position. Table 2 gives an overview.

With a 20 m pylon an area of around 100 ha can be observed in an open area. Terrain, trees and bushes can

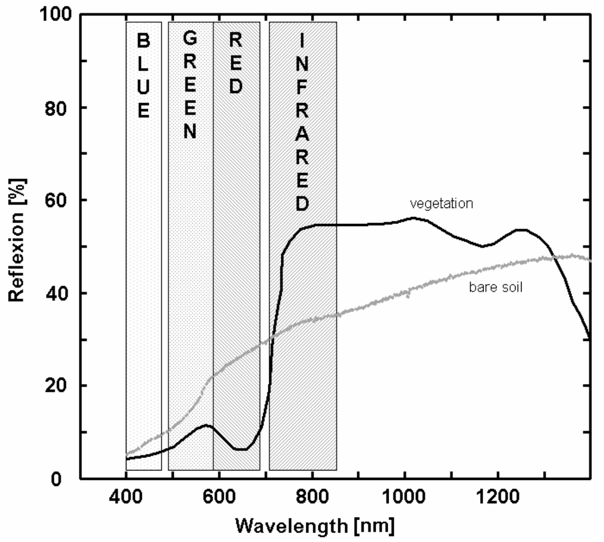

Fig. 1:
Spectral sensitivity of LASSIE compared with reflectance spectra of vegetation (black) and bare soil (grey)

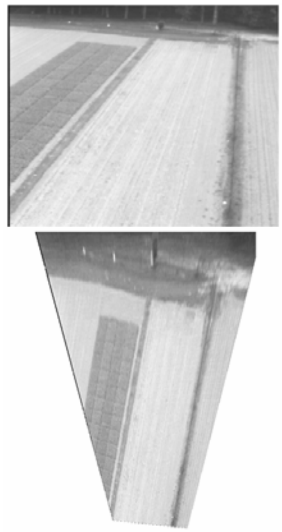

Fig. 4:
top: original oblique image
bottom: geocoded pseudo-nadir image

Fig. 2:
Components of LASSIE

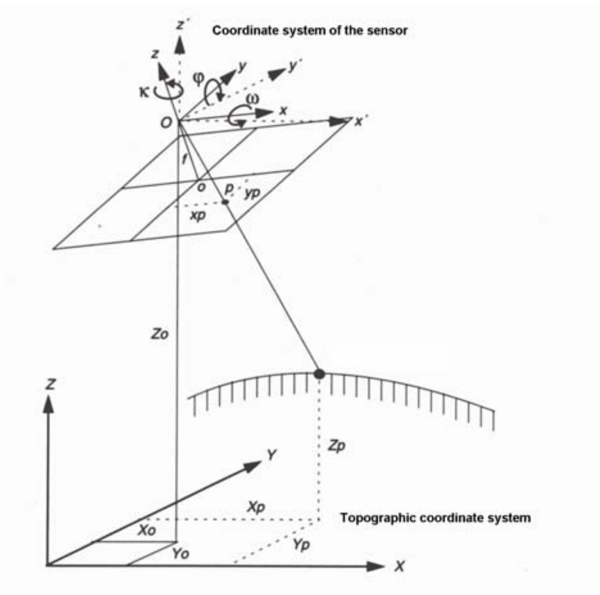

Fig. 3:
Geometric situation of LASSIE at image exposure (ERDAS 2001, modified)

hide parts of the area so that the effective area might be smaller.

The ground resolution that can be obtained is dependent on the incidence angle of the system, since the resolution deteriorates with the distance from near range to the far range. Figure 5 gives an impression of the geometric conditions.

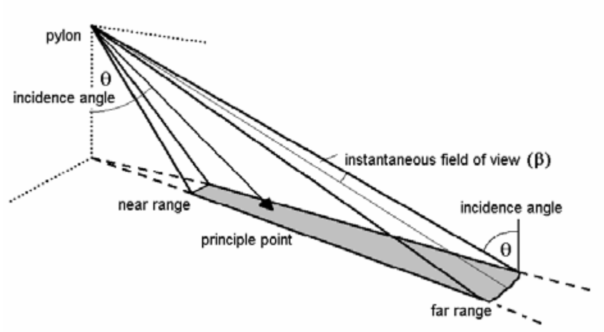

Fig. 5:
Geometric conditions

Table 1:
Technical specifications of LASSIE

Sensor	**LASSIE**	
Camera	JAI M90	Hitachi KP200
	3 x 1/3″ CCD	1 x 1/2″ CCD
Principle point x / y	2.450 mm 1.850 mm	3.225 mm 4.420 mm
Physical pixel size x / y	6.50 µm 6.25 µm	8.60 µm 8.30 µm
Effective size	4.90 x 3.70 mm	6.45 x 4.84 mm
Spectral sensitivity (blue)	397 – 522 nm (λ_{max} = 456 nm)	- -
Spectral sensitivity (green)	461 – 646 nm (λ_{max} = 538 nm)	- -
Spectral sensitivity (red)	539 – 729 nm (λ_{max} = 699 nm)	- -
Spectral sensitivity (near IR)	- -	403 – 1065 nm (λ_{max} = 610 nm)
Optics Focal length	remote controlled zoom/focus 8 – 120 mm	
Instantaneous field of view (IFOV)	3,0° - 43,6°	
Filters	Hama Sky 1 B	Colour filter Type 1013
Spectral range (b) Spectral range (g)	400 – 475 nm 490 – 588 nm	- -
Spectral range (r) Spectral range (IR)	586 – 688 nm -	- 708 – 852 nm
Positioning device		
Pan /Tilt horiz. / vert. backlash	eneo VPT-41/RS ± 180° / ± 90° < 0.2°	
Data capture		
Video server Pixel resolution	Axis 2400 704 x 576	
Processing unit		
Software	*Seetec* Viewpoint, *ERDAS* Imagine® Orthobase™	
Personal computer	State of the art	

In the case of a 20 m high pylon a ground resolution of 0,5 m (far range) for the complete area can be achieved.

The more or less unlimited temporal resolution of LASSIE (an image acquisition of 360° takes about 5 min) will enable the utilisation of time series in a new quality. For example with an hourly image acquisition physiological conditions of plants e.g. water stress of sugar beet during the day will become visible and irrigation can be optimised accordingly.

Table. 2:
Simulated ground coverage for different pylon heights

Height [m]	**Coverage** [ha]
10	25.6
20	102.5
50	640.8
100	2563.2

Remote sensing allows to detect variations in the spectral reflectance without giving a causal reason, so ground truth is still required for the evaluation of the variation of physical and chemical soil parameters (Haneklaus et al. 2000) or the nutritional status of crops (Lilienthal et al. 2000). Information about spatially variable plant features that can be gathered from LASSIE images without ground truth is water and heat stress as well as weed patches in the field LASSIE will provide a consistent collection of real time images so that crop growth variability and causal factors can be determined throughout the vegetation period.

3 Examples

In the vegetation periods 2002 and 2003 a LASSIE prototype has been tested on the test site of the FAL.

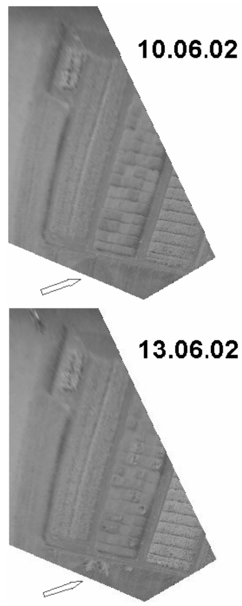

Fig. 6a:
Sample of a dynamic map of a fertilisation trial

3.1 Dynamic Maps

The good data availability with the LASSIE system makes it possible to generate dynamic maps. The geometrically corrected daily images can be mounted to a sequential film. This printed manuscript does not permit a presentation of these dynamic maps. For demonstration single frames of the film are shown in figure 6 in order to show the potential of dynamic maps. An example of a dynamic map can be found in the internet (www.pb.fal.de).

The dynamic maps permit the observation and documentation of growth processes. In figure 6a the exact date

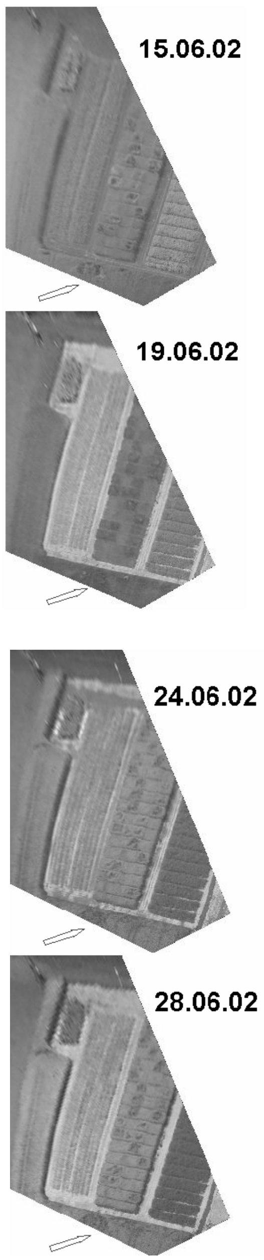

Fig. 6b:
Sample of a dynamic map of a fertilisation trial (cont.)

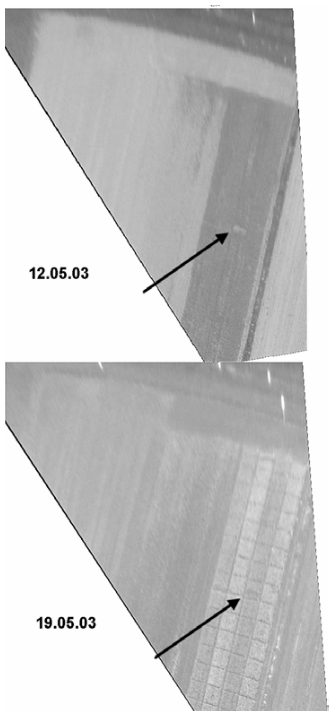

Fig. 7:
Problems in the seed emergence of oilseed rape

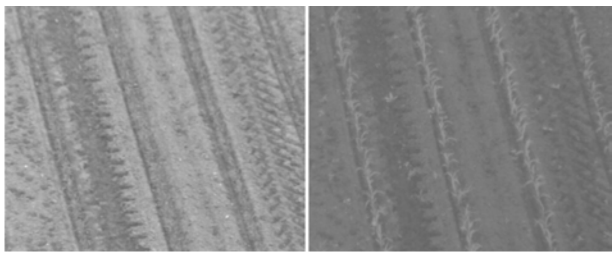

Fig. 8:
Maize in an early development stage.
Left: Image in the visible part of the spectrum
Right: Infrared image. Acquired at 23 May 2003.

(13.06.02) of the occurrence of lodging (marked with an arrow), due to partial over fertilisation with nitrogen can be defined.

The permanent availability of LASSIE images allows the provision of dynamic maps. These dynamic maps offer a new tool for the observation and documentation for the development of vegetation, and also give an information of the available the water content in the soil.

3.2 Phenology

Apart from the documentation of the entire vegetation period also phenological events can be documented as for example the beginning of the flowering. In particular in the early vegetation period the LASSIE system is suitable to observe errors for example in the seed emergence. Figure 7 shows a problem in seed emergence in oilseed rape.

For the observation of single plants and sparse vegetation stands the use of a infrared-sensitive camera, which can easily dissolve the reflection differences of vegetation and soil in comparison to a camera from the visible spectral range, is suitable (fig. 8).

Summary

The innovative concept of the ground based sensor LASSIE (Low Altitude Stationary Surveillance Instrumental Equipment) offers new possibilities of a continuous data acquisition for agricultural field experimentation. Image acquisition is possible in real time and almost any time, even under diffuse radiation conditions.

An accurate correction of several distortions and geocoding of the imagery acquired by LASSIE can be performed. The geometric resolution of the LASSIE-System used at the FAL was 0,5 m for the complete test area, and in the near range 0,1 m.

With LASSIE crop parameters can be assessed during the vegetation period. For instance differences in crop growth caused by different application of fertilization, irrigation and agro chemicals can be detected by the system. The total number of field inspections can be reduced and the schedule for inspections can be optimised, based on the LASSIE images.

A completely new source of information becomes available with LASSIE. Dynamic maps showing processes in plant development can be produced using LASSIE. Spatial processes can be observed in their temporal behaviour. By analysing dynamic maps, effects of the experimental design can be developed or evaluated.

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