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# Developing on Exact Quality and Classification System for Plant Improvement

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**Abstract:** On the field of potato research and breeding, there are several possibilities for the application of modern digital image processing and data collection/analysing techniques. One of the most obvious methods is the multi/hyper spectral analysis. In our experiments research were done in the visible as well as in the infra, near infra and thermal wavelength. For more advanced analysis we developed a multi/hyper-spectral analysis method (spectral fractal dimension measurement and application). In the following we summarize its basic elements and the developed integrated information system of potato research and breeding.

**Keywords:** image classification, fractal dimension, plant improvement, thermovision, potato breeding and qualification

**Categories:** I.4.8, J.3

## 1 Introduction - a Historical Background to Thermovision

The thermovision technology was developed for military purposes. Heat-following missiles or real 'night vision' tools use the same technology as those thermovision or FAR (FarInfraRed) cameras which identify the heat loss of the houses or which provide a heat map of the human body. The high cost, the inconvenience of cooled detector technology and the ban on export limited it comprehensive civil usage [Nagy, 2005a].

The 'ancient' tools that could be used in practice appeared in the early 1960's. In 1978 the first uncooled technology equipment followed these cooled detector technology Forward-Looking Infrared (FLIR) equipment. In the early 1980's, TEXAS INSTRUMENTS, HONEYWELL, developed the uncooled technology microbolometer sensor. The first serial equipments based on microbolometer were

launched in 1996. The excellent capacity/price amorphous Si technology microbolometer came out in 2000, [Nagy, 2005b].
Although no thermovision equipment had been produced in Hungary, and because of export bans and high prices, there were only a few appliances available for experts, a surprisingly high standard of application was achieved.

Professor Imre Benkő (BME) started and has supported the regular organization of thermogrammetry conferences since 1977, which makes it clear that there has become a very strong expert background in Hungary- engineers, doctors, physicians, chemical researchers, environment and agricultural experts.

The adequate equipment that was expensive even in the West of Europe was unaffordable in Hungary. The first instruments used to be cooled by liquid Nitrogen with adequately 'unintelligent' electronic solutions, with system technology and construction not compatible with any known technology. It was difficult to use them. They were incapable of permanent usage and too sensitive because of their moving parts.

With the development of technology, the extraordinarily expensive instruments with a closed cooling system appeared in Hungary too. They ensured a much more convenient use and came with a handheld camera as well. Unfortunately price and export bans limited the spreading of these instruments. Instead of the expected ease as NATO members, it became even more difficult to obtain these instruments after September 11, 2001.

Both in the European and Hungarian application technology there was a breakthrough when the French company, ULIS has launched its microbolometer-based FIR sensor appliances a few years ago, [Mottin, 2002], [Tissot, 2004]. An unbelievably high advantage is that they have excellent sensing capacity and resolution, and there is no need for cooling. Production technology is based on Si, a polysilicon-sensing layer is milled in a brilliant way to the carrier, more exactly a 'bridge' above it. Thus, complementary circuits can be placed on the same section making production more cost-effective.

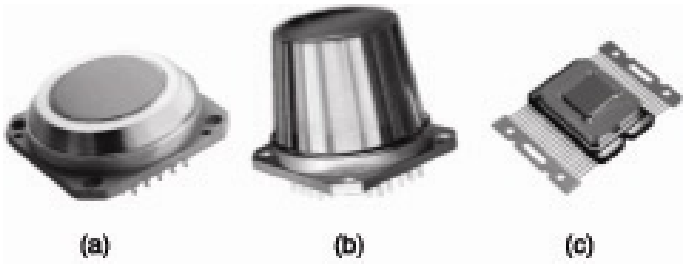


*Figure 1: Si technology microbolometer detectors manufactured by ULIS in different cases (photo of ULIS))*

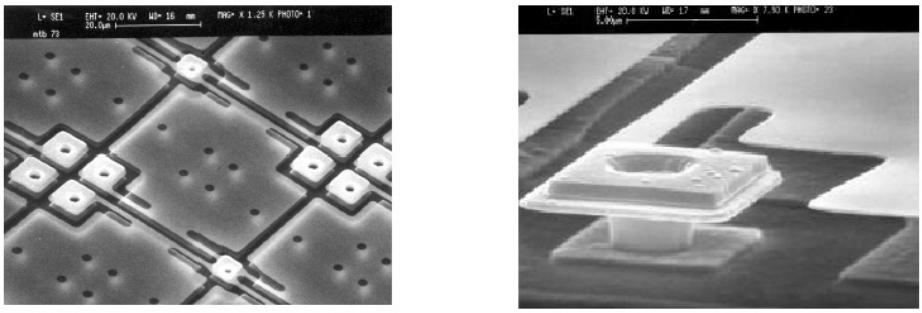

*Figure 2: Scanning Electron Microscopic picture of one part of the matrix microbolometer based on Si technology (photo of ULIS)*

The HEXIUM Mechanical Development Company (HEXIUM Műszaki Fejlesztő Kft) has developed special thermovision instruments between 2002 and 2004 with the financial support of OM (Ministry for Education) by the IKTA project. On the basis of K+F (Research & Development) project results the production of thermovision instruments in Hungary started in 2004, [Nagy-Fülöp, 2005].

These instruments are based on the most modern sensors using microbolometer (polycrystal Si) technology that need no cooling. The resolution is 320x240 pixels, and a 0.05$^{o}$C thermal resolution can be obtained (NETD<50mK, f/0.68, 300K).

The easier access, cost-effective price, the uncooled technology and the Hungarian research background can open up new fields for the professionals.

## 2 Possibility of Multispectral Sensing under Laboratory Conditions in the Agriculture

On the field of potato research and qualification there are several possibilities for the application of modern digital image processing and data acquisition/analysing techniques [Kim-Lee, 2004]. One of the most obvious methods is the digital spectroscopy. In this paper we presents results of two independent experiments where research were done in the visible as well as in the infra, near infra and thermal infra wavelength spectrum of the light by the application of equipments seen on Figure 3., [Polgár-Wolf, 2005], [Berke-Wolf, 2004].

1. In experiments I. using visible spectrum our research focused on developing methods that will be able to substitute those less precise, difficult to use data acquisition methods that are based on the traditional subjective decision-making. We applied the technique for the precise measurement of the leaf area affected by the pathogen of potato late blight (*P. infestans*) in a resistance test and for the exact determination of the quality and classification of processed potato products (chips and crisps) based their final colour. In our experiments, we dealt with the determination of resistance level of different potato genotypes to one of the most important fungal diseases, Potato late blight is the most important fungal disease of potato. Digital images were taken from the leaves of several potato genotypes after artificial infection with the pathogen. The leaf area affected by the fungus

was measured by the traditional manual way and by using digital techniques. Comparison of the two method for reliability, precision, and effectiveness for time consumption was conducted. Based on the results leaf are measurement by digital data acquisition is more precise, less subjective and for longer there offers the possibility for automatization (Figure 4).

The spectroscopy, colour intensity analysis in case of the potato can be applied to a reliable determination of such important quality parameters like skin and flesh colour of tuber and the determination of potato chips and crisps quality classes as well.

In our experiments numerous potato genotypes were classified based on the colour determination of their chips and crisps colour. For the classification digital images were taken under standardised conditions and digitally analysed while compared to classical photo based colour determination scale. In this case the new technique eliminates the subjectivity from the classification process and also offers a chance for automatization in the future.

*Figure 3: Instruments used in visible, near infra, and thermal infra spectral analyses of potato resistance test and images of a potato leaf taken in visible, near infra and thermal infra spectrum*

2. In experiments II. the infra and near infra wavelength was used for the investigation of the mechanism of plant defence reaction leading to resistance or susceptibility. Basically two types of resistance exist against potato late blight. The horizontal or polygenic type of resistance and the vertical or monogenic type

one. The former non-race specific type of resistance does not provide total resistance to the plant against the infection of the pathogen. It decreases of its extent only. In case of monogenic type of resistance the plant defence reaction is based on the hypersensitive death of a few plant cells providing total resistance. However this type of resistance is valid against certain races of the pathogen only.

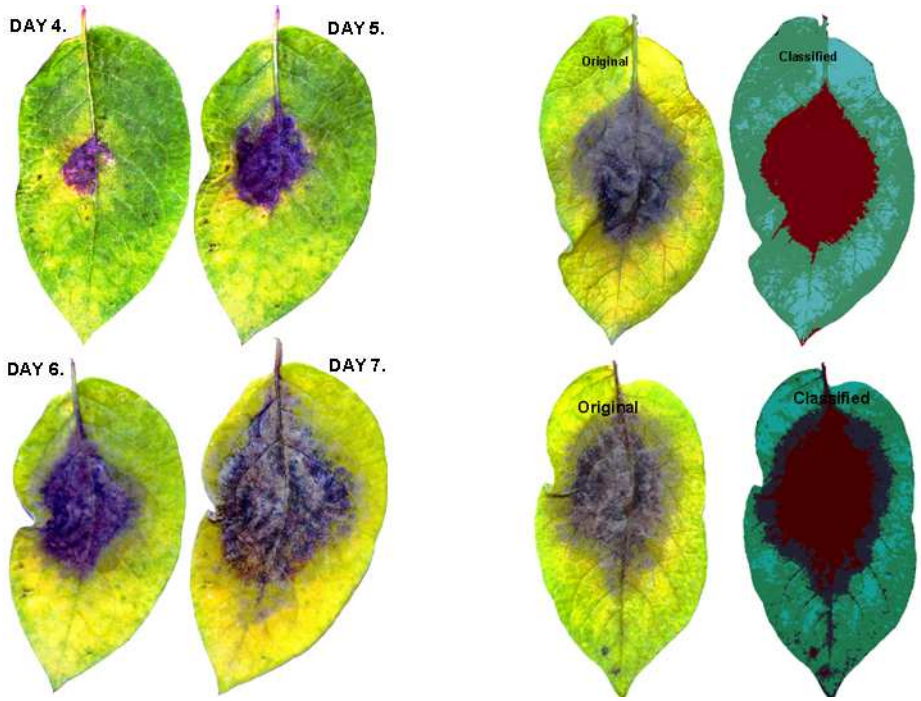


*Figure 4: In time leaf area affected by the fungus (left) was measured by visible images using digital image classification (right)*

In our experiments detached leaves of potato genotypes having different type of resistance were artificially infected with the late blight causing agent *P. infestans* under standardised laboratory conditions. The two kind of defence reaction to the pathogen, the start of metabolic processes in connection to the infection was investigated by the analyses of images taken in the visible, near infra and thermal infra spectrum. Distinction between the two kind of defence reaction was possible at the early stage (several days after infection) using far infra wave length analysis.

The above mentioned experiments were directly linked to the project EMOR (Development of an exact qualification and classification system for plant breeding and plant pathology applications by the use of digital image processing – IKTA-00101/2003, sponsored by National Research and Technology Office) having the goal to develop such a potato qualification system where common subjective decision making is minimised and fits the national and EU regulations. The system needs to be improved to make more precise the value determination of variety candidates by the

partial substitution of traditional scoring methods by more advanced ones. For efficient storing, handling and evaluation of all kind of information generated during the evaluation of variety candidates and breeding lines we developed a special complex information system (Integrated Information System - EMOR IIS, image processing measurement and evaluation methods, measurement database) [Berke, 2004], [Berke-Sisák, 2004].

During the processing of the images in all of the three spectrums we performed the preliminary processing of the images and later did their morphological and morphometric measurements like (Figure 5):

- histogram based threshold,
- determination of absolute and relative area of object,
- statistical data of the RGB layers.

For the more advanced analysis, we developed a multi/hyper-spectral analysis method as well (spectral fractal dimension measurement and application). In the next two chapters we summarize its basic elements and the developed integrated information system.

## 3 An Integrated IT System

For achieving the aforementioned purposes, development of an integrated IT system was essential. The integrated IT system for potato breeding and qualification consists of the following parts [Csák-Hegedűs, 2005]:

- setting up a database including genotype registration, pedigree data, and enlargement interface. First a standardised data structure was set up to store all the information on stock data and important supplementary data for the already released varieties.

The most widespread pieces of information are to be stored that can be of interest for the growers and all the experts who wish to obtain help through the system. Let us take a look at what kind of information can be stored and how it can be done. Stock data are the characteristics of certain genotypes (Figure 6). These can be basic images, characters or any other kind of information.

- Recording epithet data, synthesis and qualification as varieties. One of the most important pieces of information for breeders and researchers is to know the parentage of a given genotype .
- Recording and analysis of the basic data of experimental set up, like planting plan, different dates, fertilisation, weather data, etc. is also important.
- The elements of the standardised qualification process: subjective examination (based on senses), objective examination (measurement), non-IT measurements (weight, relative density, starch content), digital image analysis including morphometric examination and morphological examination. The program ensures possibility to record subjective evaluation points, sensual (taste) and objective measurement data (e.g. average tuber size) and to store picture information. We tried to do our best to define qualification process so that it contains the most possible objective data. That is why we applied automatic image analysis solutions during tuber shape, skin and flesh colour determination [Berke-Busznyák, 2004].

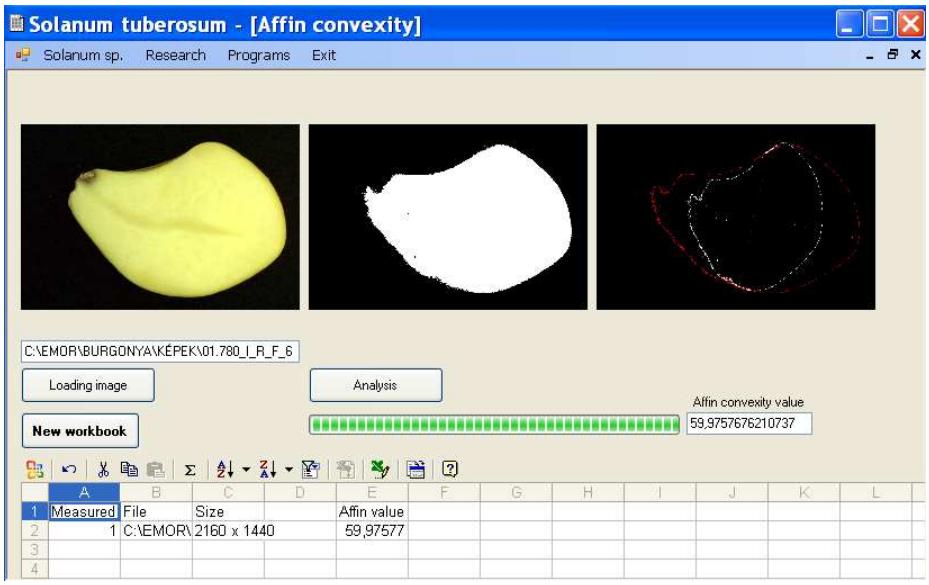


*Figure 5: Morphological and morphometric measurements of the images*

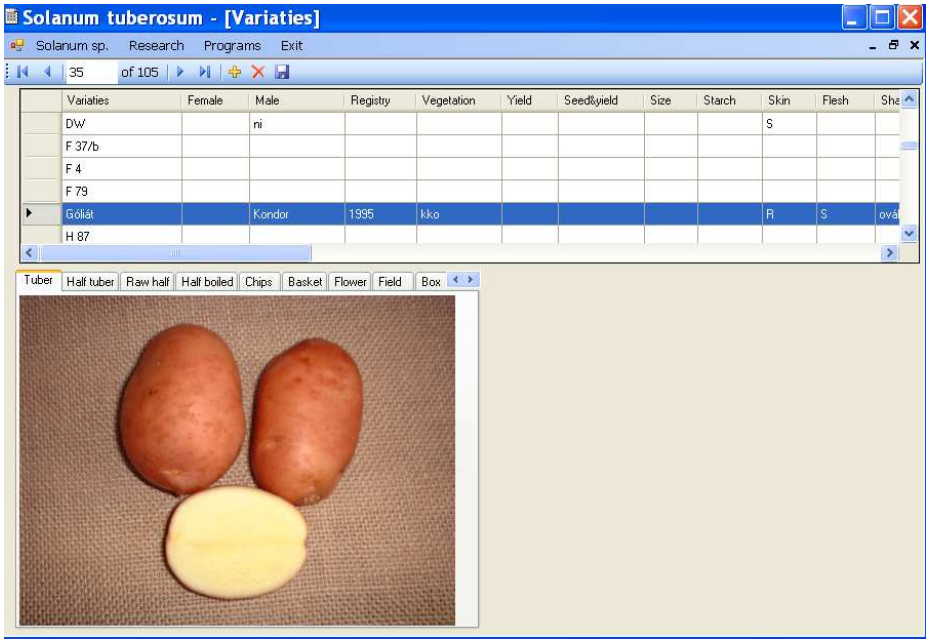


*Figure 6: User interface of IT system*

Applying workstations in a network, supporting organized processing with the information technology, using digital documents new solutions, new individual and group work methods came to being [Berke, 2005a]. In the present case, the research project demanded the launch of a system in which the participants of the projects were able to maintain continuous contact [Busznyák, 2004]. The most suitable tool for a contact like this was the Internet, to which all the members of the consortium had an access. Another need was to share information as easily as possible because not every partaker was a professional IT expert and used the system as a beginner. A teamwork system came to existence that makes it easier to use and to access the required information. The leadership of the project agreed on applying Microsoft's SharePoint Service product, of the application of which they had had previous experience for several years.

Windows SharePoint Service (WSS) is a teamwork system supported by Windows Server 2003 operation system and it is free to use. For its usage it is essential an SQL database *manager* program, which is an Internet Information Server responsible for information content and a .NET Framework with Windows Server 2003 operation system. The database *manager* can be a free database *manager* program belonging to the installation pack or Microsoft's SQL Server. Further components can become important because of the running ASP .NET environment where all the content appears to the user in ASP.NET format. Running the system, installing the settings, uploading and downloading data requires a simple Internet browser that is an essential part of nearly every operation system [Csák, 2004].

## 4 Bases of Multispectral Examinations - Spectral Fractal Dimension

Fractal dimension is a mathematical concept belonging to fraction dimension. With the help of fractal dimension, the irregularity of a fractal curve can be defined. Generally, lines are considered to be one dimensioned, surfaces are of two dimensions and solid bodies are of three. There are several complex curves in practice: roots of plants, branches of trees, the branching system of blood vessels or the lymphatic system in the human body, a network of roads etc. Thus, irregularity can be considered as the extension of the concept of dimension. The dimension of an irregular curve is between 1 and 2 that of an irregular surface is between 2 and 3. The dimension of a fractal curve is a figure that describes how the distance grows between two of its points while increasing resolution. While the topological dimension of a line is always 1, and that of a surface is always 2, fractal dimension can be a figure between the two as well. Curves and surfaces in the real world are not real fractals, processes have formed them that can form formations lying only in a given dimension scale. Thus D can change according to resolution. This change can be of help when characterising the processes forming them.

Fractal dimension in practice can be computed applying the Box counting method, and can be a characteristic measurement of the structure of an object in a digital image [SFD, 2005].

Another important characteristic is the definition of the colour structure of spectral bands, for which the name and practical use of Spectral Fractal Dimension

(SFD) has been applied [Berke, 2004], [Berke, 2005b]. When examining digital images where scales can be of great importance (image compressing, classification of natural objects, qualification of potato seeds, resistance of potato by multispectral and multitemporal images) SFD is suggested to be taken among the so far usual (eg. sign/noise, intensity, size, resolution) types of parameters (eg. compression, general characterization of images). Useful information on structure as well as shades can be obtained applying the two (SFD and FD - [Berke, 2005b]) parameters together.

## 5 Conclusions

The intended qualification system contains no or only a minimal amount of subjective judgement. Thus qualification can be judged on the basis of exact information.

The applied multispectral imaging and the developed multi/hyper-band processing method can lead to results unexpected before (Figure 7), not only within laboratory measurements but in processing aerial and satellite images as well.

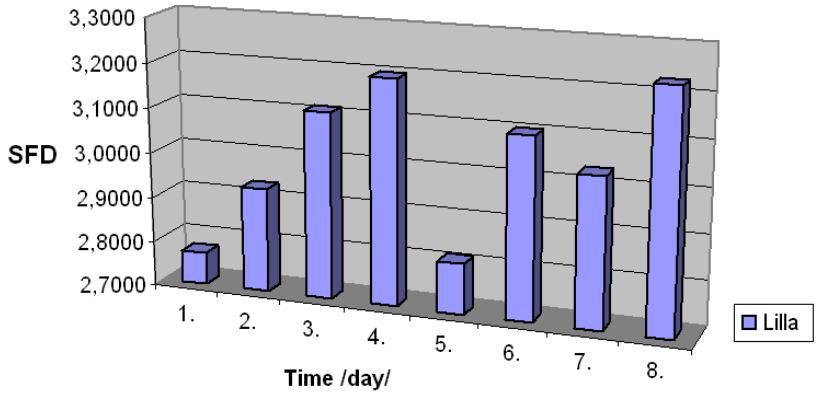


*Figure 7: Typical SFD values of the reaction of a late blight susceptible potato variety evaluated by multispectral (visual - 3 layers, infra – 1 layer and thermal – 1 layer) and multitemporal (1-8 days) images at different days after infection.*

The image processing method was successfully applied for a more more accurate measurement of pathogen affected area of potato leaf tissue in detached leaves tests compared to common method where affected area is calculated from the largest length and with of the lesion with the help of a formula. This result can lead to more precise determination of level of resistance/susceptibility of certain potato genotypes to the tested pathogen. Similarly in case of scoring of quality of chips or crisps of potato genotypes the digital method gave more consistent results compared to the eyes of breeders and use of standard colour scales. In both cases the data analyses as part of the evaluation process can be automated that enables to test of large sets of data in a relatively less period of time also with less efforts.

It was proved that by the measurements in three wave length spectra of the light it is possible to follow the initiation and further development of the process of plant

defence reaction to *P. infestans*. Using this technique the distinction of the two type of plant resistance (horizontal or vertical) was successful.

Finally for promotion the qualification work with variety candidates and breeding lines we developed a complex IT system that enables to store and efficiently handle all kind of relevant information for breeders, researchers or potato growers.

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