Vision Soil Analyzer

Current status and fare sight

Client: Royal IHC – MTI Holland

Completion date: **15 juni 2015**

Jelle Spijker

Date 14 June 2015
Revision 20150614

Contact gegevens:

Jelle Spijker (495653) – 06-43272644 – Spijker.Jelle@gmail.com

Disclaimer HAN:

Door ondertekening van dit voorblad, bevestigen wij dat het – door ons ingeleverd(e) werkstuk/rapport/scriptie (verder te noemen "product") – zelfstandig en zonder enige externe hulp door ons is vervaardigd en dat wij op de hoogte zijn van de regels omtrent onregelmatigheden/fraude zoals die vermeld staan in het opleidingsstatuut.

In delen van het product, die letterlijk of bijna letterlijk zijn geciteerd uit externe bronnen (zoals internet, boeken, vakbladen enz.) is dit door ons via een verwijzing conform APA-norm (b.v. voetnoot) expliciet kenbaar gemaakt in het geciteerde tekstdeel (cursief gedrukt).

IHC Holland B.V.

P.O. Box 1, 2960 AA Kinderdijk
Smitweg 6, 2961 AW Kinderdijk

T +31 786 91 09 11
F +31 786 91 38 66
info@ihcmerwede.com
www.ihcmerwede.com

TABLE OF CONTENT

The technology innovator.

1   Introduction

BACKGROUND

This project finds its roots in the minor Embedded Vision Design taught at the university of applied sciences HAN, hereafter named EVD. During this minor an embedded device was developed which analyses soil samples using a microscope. This Vision Soil Analyzer hereafter referred to as VSA, analyzes samples using the optical properties. It's main function is: *Presenting quantifiable information to a user on the properties of soil such as colour, texture and structure.*

IHC & MTI

This device is developed in collaboration with Royal IHC and MTI Holland. Royal IHC is one of Holland major shipyard companies and specializes in dredging and offshore. MTI Holland BV is royal IHC dredging knowledge center. They're worldwide leading center of expertise in the area of translating knowledge of dredging, mining and deep-sea mining processes into the specification, design and application of equipment. Both companies have an interests in knowing the properties of soil, be it to advise their customers or to further facilitate their own research and services.

ANALYZED PROPERTIES

The properties that can be analyzed using a digital camera and the preferred methods where determined by investigating the current literature , regarding soil, computer vision and various algorithms needed to perform the calculations. The detailed study can be found at appendix I.

TIME CONSUMING ARCHAIC METHODS

Current methods, like the Particle Size Analysis using a sieve and hydrometer are time consuming and non-portable. To facilitate quick, accurate and on location soil research an embedded device has been developed. This VSA analyzes soil samples using a microscope and gives the user acceptable and quick results on the soil visual properties.

QUICK & ACCURATE

Quick and reliable results are a welcome addition into any laboratory, this combined with a device that is light and portable gives its users an added benefit of shortened logistical operations for their soil samples. This results in some serious time benefits.

CURRENT & FUTURE PLANS

The current beta project brought a couple of complications to light which should be overcome in order to have a working release candidate. The release candidate will be further developed with the help of MTI and RDM campus and various study groups. The release candidate will be separated into a smaller subset of engineering and project challenges which will result in a working release candidate.

The technology innovator.

IHC Holland B.V.

P.O. Box 1, 2960 AA Kinderdijk
Smitweg 6, 2961 AW Kinderdijk

T +31 786 91 09 11
F +31 786 91 38 66
info@ihcmerwede.com
www.ihcmerwede.com

This document has the following structure. At first the basic working principle of the device in general is explained in chapter two. Secondly the alpha stage is briefly described in chapter three. Thirdly the beta and current stage is described, indicating which problems are still to overcome for the release candidate. This can be found in chapter four. In chapter five the release candidate is described. Naming the preliminary requirements and describing the proposed project setup. In chapter six there will be a short roadmap to the future. Finally the conclusion is drawn in chapter seven.

DOCUMENT STRUCTURE

The technology innovator.

IHC Holland B.V.

P.O. Box 1, 2960 AA Kinderdijk
Smitweg 6, 2961 AW Kinderdijk

T +31 786 91 09 11
F +31 786 91 38 66
info@ihcmerwede.com
www.ihcmerwede.com

2   Working principle

GOAL

As stated in the introduction, the goal is to develop a device which analyzes Soil samples using a digital microscopic camera connected to a microcontroller. The properties that are deemed possible to analyze using this technique are, color, texture and structure. The goal is to perform the calculation within a time span of a minute.

ANALYZED PROPERTIES

The user gets information presented in the following formats:

Color
- CIE La*b* color model presented as scatterplot with the mean values of each individual particle set out against the chromatic a* and b* axis. Studies indicate a correlation between organic carbon and the values in CIE La*b* color model
- Redness Index is presented as statistical data for each individual particle, such as mean, min, max, range, standard deviation etc. Welch tests anova can be executed in order to determine which particle deviates from the rest

Texture
- Particle Size Distribution Presented as a cumulative function. These properties show a correlation on water infiltration, pH buffering, buffering of organic materials and much more.

Structure
- Shape classification regarding each individual particle presented as histogram. The roundness and the angularity are determined and presented as sixteen individual classes. Ranging from high sphericity / well rounded to low sphericity / very angular. These properties show a correlation between erosion, biochemical and physical properties including tool degradation.

DEVICE DESCRIPTION

The program runs on an embedded Linux device. The algorithms which translate a digital snapshot of the magnified soil sample to the user preferred information are written in C++. They're by my own design and optimized to run on ARMv7 device running embed Linux. These algorithms can also be run from an X64 desktop computer, albeit optimization is not done for this environment. The performance is still better , because the average desktop computer has more system resources available.

The technology innovator.

Analyzing of the soil sample is done using the following workflow:

The soil sample is dried and the user makes sure the particle don't bond together. A small portion of the sample is placed on a sample plate. Taking care to separate the individual particles as much as possible. The cover is closed and a microscopic camera is positions, in an environment where the light conditions are controlled.

The embedded Linux device takes a snapshot which is analyzed using the following computer algorithms:

First the individual soil particles are identified in the image, using various algorithms, such as adaptive contrast stretch, Gaussian blurring, OTSU – optimal tressholds separation.

The color information is determined with various matrix calculations, translating the RGB pixel value tot CIE La*b* and Redness Index.

The texture information is determined by counting the number of discrete pixels for each individual particle. From this the volume is determined. If the scale of each pixel is known, the volume can be given in SI units.

The structure of an individual particle is determined by getting the edge of the pixels. This is done by creating a mask with a morphological erosion algorithm this mask is subtracted of the original image. The contour is translated to a function using the Dijkstra shortest path algorithm. Where each pixel is described as an imaginary complex number representing the radius towards the center of the particle. The vector holding these values are transformed to the frequency space using the Fast Fourier Transformation. The describing complex numbers gained during this transformation are fed into a feedforward Neural Network, which is optimized using Genetic Algorithms and a previously determined learning data set. The output is presented as probability that a certain particle belongs to a predefined category.

The results are presented to the user via a graphical user interface which are show when the device is hooked to a monitor carrying a HDMI input. It's also possible to present a report in pdf or a native format which can downloaded from the device using a LAN network device or optional Wi-Fi or Bluetooth. Basic human interaction can be performed via an onboard encoder, or optional USB keyboard and/or mouse.

The technology innovator.

IHC Holland B.V.

P.O. Box 1, 2960 AA Kinderdijk
Smitweg 6, 2961 AW Kinderdijk

T +31 786 91 09 11
F +31 786 91 38 66
info@ihcmerwede.com
www.ihcmerwede.com

3 Vision Soil Analyzer Alpha

This device was developed during the first part of the minor EVD. It served as a testing ground for the various algorithms. The goal was to develop a test setup with which to test the various computer algorithms and validate the theory.

3.1 Technical Specification

Hardware environment

- Pentium i3 2.3Ghz 4 cores
- 8 gb DDR2 memory
- Radeon HD mobility video card with 512gb dedicated memory
- SSD 128GB hard disk
- Generic 5 mp microscopic USB camera capable of 300X optical zoom

Software environment

- Windows 8.1
- Matlab 2014a

3.2 Challenges to overcome

- Calculations take a long time
  - Overcome by changing the programming language from Matlab to C++.
- Changing light conditions
  - Created a light condition environment.
- Segmentation of individual particle from the background
  - Partly overcome with vision enhancement algorithms
  - Still problems with translucent particles
- Overlap of smaller particles with bigger particles
  - By manual changing the configuration and analyze the soil sample multiple times a more accurate results can be determined.
- No learning data set available to feed the neural net with known structure values.
  - No obvious correlation could be determined.

The technology innovator.

4 Vision Soil Analyzer Beta

During this project phase the switch was made from Matlab on a desktop environment to an embedded ARMv7 device running Linux. The algorithms are translated to the OOP – Object Orientated Programming language C++. Which is known for its speed an efficient handling of memory resources. Since each image consists of a matrix with around 5 million pixels in three color values. C++ was the logical choice. Due the scale of the project (7000 lines of source and counting) this phase is still ongoing.

4.1 Technical Specification

Development environment
- Desktop computer running a Debian based Linux distribution
- Qt Creater IDE
- Various debugging tools

Runtime device
- ARMv7 based device Beaglebone black
- Generic USB microscopic digital camera
- Linux Ubuntu
- Various C++ development libraries
- Various Linux tools to facilitate optional specifications

4.2 Challenges to overcome
- Interfacing the camera with USB mode
  - Beaglebone specific problem. Overcome by reading the data from the webcam serial instead of parallel.
- Segmentation of individual particle from the background
  - Partly overcome with vision enhancement algorithms
  - Still problems with translucent particles
- Overlap of smaller particles with bigger particles
  - By manual changing the configuration and analyze the soil sample multiple times a more accurate results can be determined.
- No learning data set available to feed the neural net with known structure values.
  - Testing and learning of the neural net will be performed using synthetic pictures.

The technology innovator.

5 The release candidate

GOAL

The goal of this release candidate is to have a field ready device which is portable. The results are presented to the user using a generic HDMI monitor of can be download from the device in PDF format. These results fall in to a predefined and for a user acceptable error margin.

5.1 Preliminary requirements

Since this project phase has yet to commence the requirements below are preliminary and subject to chance.

FUNCTIONAL REQ.

Functional:
- Calculations are done in a time span of five minutes.
- Calculation are within an acceptable and predefined error margin
- Results of the Particle Size Distibution are conforming NEN and ISO norms, such as but limited to NEN-ISO 9276-1 till 6.
- The device weighs less than 10 kg.
- The device can be lifted and carried by an adult human.
- The device can be used on a table with an max. level offset of 5°.
- The device complies at least with IP54 specifications.
- The device works at temperatures, ranging between -10°C / 40°C.
- Light conditions under the microscope are controlled.
- Results can be shared with other user or send to centralized database for further analysis.

FABRICATION REQ.

Fabrication:
- The firm- and software can be updated remotely.
- The firm- and software can be easily maintained and should be well documented.
- Standardized internal hardware components are preferred.
- The casing and the internal mounting system can be manufactured using prototyping techniques, such as laser cutting and 3D printing.
- Each individual part is dismountable using standardized tools, such as Philips or cross screwdrivers.
- Costs of the used materials will be as low as possible.
- The device can be made as a small series with a max. of 50 devices.
- Further development with upscaling fabrication numbers will be taken in to account.
- A cradle to crate philosophy will be used in design and fabrication.

The technology innovator.

5.2 Proposed project setup

In order to have manageable amount of work the following division is proposed:

1. Project oversight   WTB
   o Compiling Technical Dossier for CE marking.
     ▪ Machinery directive.
     ▪ Determine harmonized norms.
     ▪ Determining final requirements (market research, norms, laws).
     ▪ Writing test protocols.
     ▪ Analyzing report (FMEA, DFA, RPA, etc.).
     ▪ Gathering test results.
     ▪ Protection of knowledge (patents).
     ▪ Collecting and filing of output of individual projects.
     ▪ Writing user manuals
   o Determine and ensuring implementation of solutions for the problem of:
     ▪ Overlapping particles.
     ▪ Segmentation of translucent particles.
   o Determine camera to be used and light conditions.
   o Determine technical specification for other individual projects.
   o Guarding individual project results.
2. Updating software to work with new device.   ESD OR ICA
   o Document the source code.
   o Rewrite source code to work with new peripheral.
   o Write camera driver.
   o Write light environment driver
   o Write Sample plate driver
   o Write unit tests
3. Development of the casing and internal mounting.   IPO OR WTB
   o Translate technical specifications to requirements.
   o Determine the design in accordance with the requirements
   o Draw the design output as mono drawings.
   o Generate a BOM
   o Manufacture a prototype of the device in accordance with requirements and drawings.

Revision 20150614
Soil and computer vision – Concept

The technology innovator.

<u>WTB</u>

4. Development of the sample plate.
   o Translate technical specifications to requirements.
   o Determine the design in accordance with the requirements
   o Draw the design output as mono drawings.
   o Write calculation report.
   o Generate a BOM.
   o Manufacture a prototype of the device in accordance with requirements and drawings.

<u>EI OR ESD</u>

5. Development of PCB and interface with the peripheral.
   o Translate technical specifications to requirements.
   o Determine the design in accordance with requirements.
   o Draw the PCB.
   o Generate a BOM.
   o Write calculation report.
   o Manufacture a prototype of the dive in accordance with requirements and design.

<u>DIVISION OF LABOR</u>

It is advised that project oversight and software updating are kept under supervision by the original process owner, Jelle Spijker. The project for the sample plate and the casing can be executed with the regular HRO (university of applied sciences Rotterdam) WTB students at the RDM campus. Development of the PCB can be performed via a third party or by electrical / embedded system design students from university of applied sciences HAN.

The technology innovator.

IHC Holland B.V.

P.O. Box 1, 2960 AA Kinderdijk
Smitweg 6, 2961 AW Kinderdijk

T +31 786 91 09 11
F +31 786 91 38 66
info@ihcmerwede.com
www.ihcmerwede.com

6 Roadmap to the future

If results from the release candidate are successful, this can serve as a basis for a consumer ready device. A device which has a place in any soil related laboratory, whether it's a stationary lab, field tent or a trailing suction hopper dredger.

The next challenge will be create a device which has a professional look, robust inner working, is economical priced and which will be easily maintained and upgraded.

But the biggest asset will be that its part of the IoT internet of things. Data gathered from this device can be uploaded to a centralized server. Trends can be spotted using this data, helping geo-engineers with their work all over the world. Offsite help can be given to users with questions, who want advise. And finally due to the use of self-learning Neural Networks it can optimize its results, learning from different devices and users.

CONSUMER READY DEVICE

INTERNET OF THINGS

The technology innovator.

7 Conclusion

The technology innovator.

IHC Holland B.V.

P.O. Box 1, 2960 AA Kinderdijk
Smitweg 6, 2961 AW Kinderdijk

T +31 786 91 09 11
F +31 786 91 38 66
info@ihcmerwede.com
www.ihcmerwede.com

Appendix I. Literature study – Soil and it's optical properties

See external document

The technology innovator.