

Vision Soil Analyzer

Product design of a vision based soil analyzer

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Foreword



Summary

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

The VSA takes a snapshot from a soil sample, which is placed under a microscope in an closed environment. This digital image is analysed using a multitude of computer vision algorithms. Statistical data is presented to the user in the form a Particle Size Distribution (PSD) and a histogram of the shape classification. The PSD is obtained by calculating the number of pixels for each individual particle, whilst shape classification is determined by describing the contour of each individual particle as mathematical function which undergoes a transformation to the frequency domain. This complex vector then serves as input for an Artificial Neural Network (ANN) where the output classifies each particle in a certain category.

The prototype developed during the minor EVD will serve as a basis for a graduation project of that same student, which initialized the project. This is done for his main course mechanical engineering at the HAN. This graduation project is done under the auspices of MTI Holland. The goal during this second stage is to develop a field ready prototype. In conjunction with the necessary documentation (Technical Dossier). Due to the scale of the project, several key problems are identified and separated from the main project. These problems can be tackled by separated student groups.



Contents

1	Introduction	11
----------	---------------------	-----------

I

Design

2	Functional Design	15
2.1	Global Input-Process-Output	15
2.2	Specifications	16
2.2.1	Functional requirements	16
2.2.2	Technical requirements	16
3	User Interface	19
3.1	Graphical User Interface	20
3.2	Hardware User Interface	20
4	Manuals	21
4.1	User manual	21
4.2	Administrator manual	21
5	Technical Design	23
5.1	Hierarchical structure	23
5.2	Architecture	23
5.3	Detailed Input-Process-Output schematics	23
5.3.1	Led driver	23
5.3.2	Global position unit	23

5.3.3	Controller	23
6	Vision design	25

II

Realization

7	Development Environment	29
7.0.4	Software development environment	29
7.0.5	Modeling development environment	31
7.0.6	Electronic development environment	31
8	Run Environment	33
9	Technical Realization	35
9.0.7	Electrical design	35
9.0.8	Design	35
10	Vision realization	37
10.1	Image acquisition	37
10.2	Image enhancement	38
10.3	Feature extraction	39
10.3.1	Shape features	39
10.3.2	CIE La*b* extraction	43
10.3.3	Fast Fourier Descriptors	43
10.3.4	Particle Size Distribution	43
10.4	Classification	44
10.4.1	Roundness using Hu-moments	44
10.4.2	Angularity using a Neural Network	44
10.4.3	Genetic Algorithm	44

III

Verification

11	Presenting Information	47
11.1	Table	47
11.2	Figure	47

IV

Addenda

Bibliography	51
Index	53
A Graphical User Interface	53
B Example Soil Report	57

C	RDM campus: Student project	63
D	Development Environment setup	65
E	Run Environment setup	71
F	Current project status	75
G	Soil and computer vision flyer	83
H	SoilMath Library	99
I	Hardware Library	153
J	Vision Library	209
K	Analyzer Library	265
L	QOpenCVQT Library	295
M	QParticleDisplay Library	299
N	QParticleSelector Library	305
O	QReportGenerator Library	311
P	Vision Soil Analyzer Program	325



1. Introduction

This project finds its roots in the minor Embedded Vision Design @ 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 gives an user information on color, texture and structure.

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

During the first period of the minor a basic prototype has been developed. This prototype ran in Matlab on a X64 desktop computer and was a first test case for the algorithms and idea's. In the second period this prototype is developed on an ARMv7 embedded Linux device and is compiled in C++. The goal of the software is to analyze soil samples and presenting the user with information regarding it's color, texture and structure.

Information regarding the color of a sample is presented to the user in the CIE Lab and Redness Index color-models. These color models show correlation between different soil properties, such as iron content and fertility. Conversion between different color-models

are CPU intensive, because each pixel will be transformed using multiple algorithms. It's therefore paramount that calculations are done with a minimum of machine instructions and with acceptable errors.

Texture information is presented to a user via a Particle Size Distribution, hereafter named PSD. This is a cumulative function representing the ratio of different particle sizes in the soil sample. Due to the nature of a two dimensional digital image numerous problems arise. These are overlap of smaller particles by bigger particles, this gives a distortion in the PSD results, because the smaller particle is registered as part of the bigger particle. And another problem is the fact that soil particles are three dimensional, but the image is two dimensional.

Information about the structure of the soil is extrapolated from the individual particles shapes. These shapes are described in the frequency domain, using a Fast Fourier Transform and fed into a Neural Network which classifies these shapes into standard soil categories. These are time consuming operations and therefore should be done with a minimum of machine instructions and efficient programming.

This wiki / product documentation gives the developer(s) and customers, namely MTI and IHC a tool to further the development of the VSA into a full fledged market ready product. The development environment and the used protocols are described in order to guard the quality of the work. The product itself is designed by determining a global IPO Input-Process-Output diagram. This leads to the functional specifications. To illustrate the working of the device further the User Interface will be designed which will be supplemented with a short manual. All the above design tools will come together in a detailed IPO. Correct working of the device is guaranteed with various testing protocols. The current working principles follows a set global workflow. The vision related algorithms are described in order to determine the most efficient working order. This results in the complete image processing steps

The following project setup is proposed for the release candidate. Future release will follow the roadmap



Design

2	Functional Design	15
2.1	Global Input-Process-Output	
2.2	Specifications	
3	User Interface	19
3.1	Graphical User Interface	
3.2	Hardware User Interface	
4	Manuals	21
4.1	User manual	
4.2	Administrator manual	
5	Technical Design	23
5.1	Hierarchical structure	
5.2	Architecture	
5.3	Detailed Input-Process-Output schematics	
6	Vision design	25



2. Functional Design

The idea to develop a vision based soil analyzer arose at the start of the minor embedded vision design. During the first period of this minor a strategy was developed to analyze soil using relevant optical characteristics of the individual particles. This first concept was tested in a Matlab environment and it was deemed a viable solution. At its current development stage a prototype is being developed. This chapter reports the functional design of this first generation prototype.

A functional design lays at the heart of a product. It is an abstract representation of the device and it illustrates its main function. In this chapter the workings of a vision based soil analyzer is laid out. It explains which role a vision based soil analyzer needs to fulfill in order to satisfy an user generated need. This main functionality and its output is visualized in an Input-Process-Output (IPO) diagram. This diagram aids in deciding the specification and setting up a user interface. These in turn dictate the interaction with the outside world.

2.1 Global Input-Process-Output

The main function of a vision based soil analyzer is evident from its name. The user can expect a device which performs an analysis of a soil sample. It does so by capturing and digitizing reflected light of the individual soil particles. This function is illustrated below in an Input-Process-Output (IPO) diagram, see figure 2.1. This is a so called black box approach. It shows an input, an output and a process, where the inner workings are not yet relevant. At this stage it isn't relevant to know what happens in this process.

Technical system

Prototype of an intelligent soil microscope

Main function

To analyses a dried soil sample, consisting of particle in the range of $0.02[\text{mm}] \leq P \leq 2.0[\text{mm}]$ and present a user with information regarding color, texture and structure.



Figure 2.1: Main Input-Process-Output diagram

2.2 Specifications

With the global Input-Process-Output in mind the functional specifications can be written. This is done by identifying requirements that lie at the heart of its main functionality. These are specification that define a product. It is important to note that there are two types of requirements: functional and technical requirements; Each requirement can either be constant or a variable. The constant requirements are the baseline. If the product doesn't fulfill these, it can't be called a soil analyzer. Whilst variable requirement determine how well a product performs.

Functional Requirements

Functional requirements describe the purpose of the product.

Technical Requirements

Technical requirements describe the functionality of the device with regards to its peripherals and its technical environment. They're described in such a way that they are either true or false.

2.2.1 Functional requirements

2.2.2 Technical requirements

Name Description

Word Definition

Comment Elaboration

ID	Description	Type
F1	Quantify color	
F1.1	Determine the color in a RGB color model, from all visually (by human eye) discernible particles	Const.
F1.2	Chromatic a* values must lie within 3σ	Const.
F1.3	Chromatic b* values must lie within 3σ	Const.
F2	Quantify texture	
F2.1	The result of an analyzed sample should fall within a probability of at least $P = 0.95\%$ when compared against the result of the same sample, but obtained using the established sieve method. These results are to be compared by Welch's t-test	Const.
F2.2	PSD bins should have the same range as the fractions used in the sieving method	
F3	Quantify structure	
F3.1	Roundness should be assigned in three categories	Const.
F3.2	Angularity should be assigned in six categories	Const.
F3.3	Predicted values should have at least a linear regression value of $R \geq 0.9$ when compared to expertly classified particles	Const.
F4	General specifications	
F4.1	Analyze particle with sizes within the range $200\mu m \leq P_{size} \leq 2mm$	Const.
F4.2	No more than 2% of the extracted blobs may be connected particles	Const.
F4.3	Analyzing a sample should take no longer than 1min (rearranging of sample between shot disregarded)	Const.
F5	Interaction	
F5.1	Show individual particles	Const.
F5.2	Show PSD graph with particle size in logarithmic scale	Const.
F5.3	Show Angularity in histogram	Const.
F5.4	Show Roundness in histogram	Const.
F5.5	Show probability distribution function in the histogram	
F5.6	Information can be shown on a screen	Const.
F5.7	Exporting to pdf file	Const.

Figure 2.2: Functional Requirements

ID	Description	Type
T1	Software environment	
T1.1	The software should run on an Linux device	Const.
T1.2	The software should be written in C++	Const.
T1.3	The software should be written as OOP and be reusable	Const.
T1.4	The software should be written with revision control	Const.
T1.5	Easily portable to Windows environment	Const.
T1.6	Easily portable to Android environment	Const.
T2	Hardware environment	
T2.1	Should run on an ARMv7 or higher device	Const.
T2.2	Should run on a x86 or x64 device	Const.
T2.3	At least 1GHz processing power	Const.
T2.4	At least 1GB memory	Const.
T3	Peripherals	
T3.1	USB connection	Const.
T3.2	Ethernet LAN and/or WAN connection	Const.
T3.3	GPS unit	Optional
T3.4	Light controller	Const.
T4	General specifications	
T5.8	Sample file size should not exceed 10mb	Const.
T4.1	Guard the maximum size of particles to 2mm	Const.

Figure 2.3: Technical Requirements



3. User Interface

Global 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 positioned, 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 thresholds separation. The color information is determined with various matrix calculations, translating the RGB pixel value to CIE Lab and Redness Index.

The texture information is determined by counting the number of discrete pixels for each individual article. 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 shown 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 be downloaded from the device using a LAN network device or optional Wi-Fi or Bluetooth. Basic human interaction can be performed via an on-board encoder, or optional USB keyboard and/or mouse.

3.1 Graphical User Interface

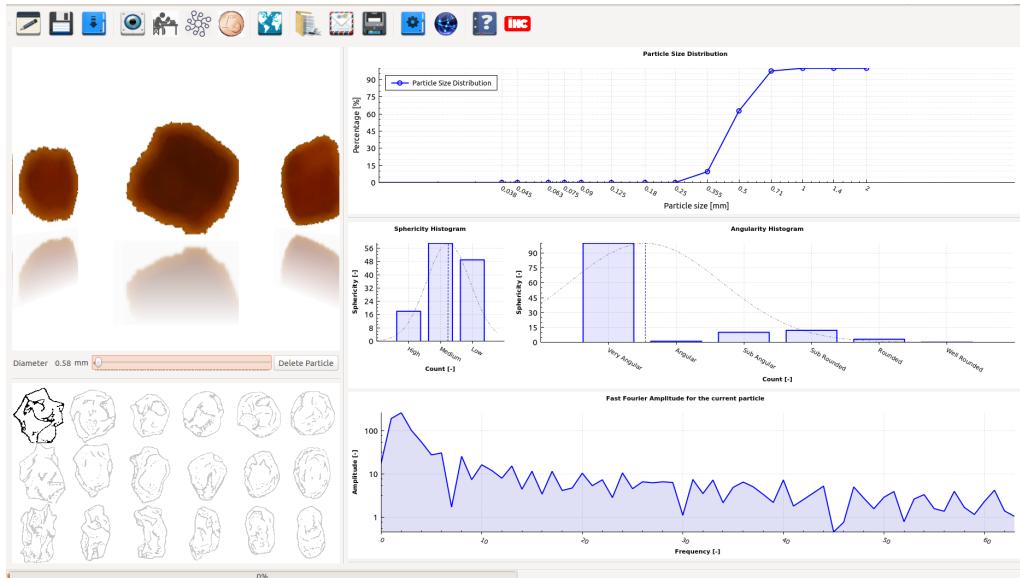


Figure 3.1: Main Graphical User Interface

3.2 Hardware User Interface



4. Manuals

4.1 User manual

4.2 Administrator manual



5. Technical Design

5.1 Hierarchical structure

This is an example of theorems.

5.2 Architecture

This is a theorem consisting of several equations.

5.3 Detailed Input-Process-Output schematics

This is a theorem consisting of just one line.

5.3.1 Led driver

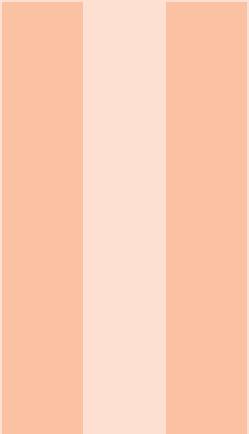
The light meter is connected to the 12-bit ADC (Analogue Digital Convertor)

5.3.2 Global position unit

5.3.3 Controller



6. Vision design



Realization

7	Development Environment	29
8	Run Environment	33
9	Technical Realization	35
10	Vision realization	37
10.1	Image acquisition	
10.2	Image enhancement	
10.3	Feature extraction	
10.4	Classification	

7. Development Environment

The project is developed using three major disciplines; These are mechanical, electrical and software engineering. Each of these disciplines require their own setup and tools. All three are described in their own section below. As indicated in previous chapters the current focus lies on the software development stage, electrical en mechanical systems are described, but with less detail.

At the basis of all three development environments lies the hardware. The specifications given below, describe the current development computer. It is guaranteed that the project can be recreated with a similar computer.

- Intel(R) Core(TM) i5-4210U CPU @ 1.70GHz
- 8gb memory
- Nvidia 820M
- SSD 128 gb
- HDD 500 gb
- Dual boot Ubuntu 15.04 / Windows 10

reference explain
of the project an
fases

7.0.4 Software development environment

The software for the VSA runs on an embedded Linux device. This environment is described in chapter 8. It is highly recommended that the software development environment mirrors this configuration. From the kernel and the operating system towards the package and libraries.

When development takes place in a Linux environment, a tight integration with the prototype is ensured. Eliminating the need to setup the environmental settings and script for multiple operating systems. This also adds the option to debug the software on the development computer.

Programming language

The software for the VSA is written in C++. This language was chosen because of its efficiency and high level of abstraction. Most image processing algorithms look at each individual pixel. Since the image obtained with the VSA microscope are in the order of

10×10^6 [Pixels] a lot of machine instructions can be eliminated by programming in C++. One of its main strength is, that it allows for direct memory access without type checking and error checking. As Bjarne Stroustrup, the creator of C++, puts it [3] :

C++ is a general-purpose programming language providing a direct and efficient model of hardware combined with facilities for defining lightweight abstractions.

Integrated Development Environment

Development is performed on a desktop computer running Linux 3.19.0-18-generic #. Ubuntu 15.04. The preferred Integrated Development Environment, or IDE is QT Creator Community edition. This is open-source IDE and available for Linux / Windows / Mac. Version control is handled using the services of Github the main project page is VisionSoilAnalyzer - project page (<http://peer23peer.github.io/VisionSoilAnalyzer/Webpage/index.html>). Access to the Github page requires collaboration privileges.

The basic list of installed packages is given below. The complete list of packages and installation steps are depicted in appendix D.

- Environment
 - Kernel Linux 3.19.0-18-generic
 - Ubuntu 15.04
- IDE-tools
 - Clang 3.6 compiler
 - C++ GNU compiler
 - QT Creator
 - Valgrind
 - Doxygen
 - Git
 - Cmake
- Libraries
 - OpenCV 3.0 beta
 - CUDA 7.0 SDK
 - ZLib
 - Boost 1.58
 - Video4Linux
 - GStreamer



It is a fact that computers and their environment evolve. New settings, packages and development changes are described in the project wiki. Which is actively maintained during the complete development phase. This wiki can be found at <https://github.com/peer23peer/VisionSoilAnalyzer/wiki>

Object Orientated

The software for the VSA is object orientated and written in such a way that external parties can work on section of the code while remaining unaware of the complete picture. This is achieved by writing classes, or so called shared libraries. These are individual projects, which are compiled individually and will be called from the main program during runtime. These classes can be reused with other projects.

Readability

It is common practice to document the routines and functions, explaining the code to third parties and improving the overall readability. These comments are scattered through out the source code and can be extracted with Doxygen into software references documentation.

Directory structure

When cloning the git the folder structure is automatically applied. This is not the case for the build folder. This folder hold the compiled source code and from here the program is executed. Since it is important that links between project are maintained, the directory structure as given in appendix D has to be obeyed.

Testing and benchmarking

Testing is done using the **QT unit test framework** results are verified against known results. Which are calculated via **Matlab**, **Mathematica** or **Python**. Benchmarks are done using the QT unit test framework and will test multiple solutions. Solutions that are deemed obsolete by the benchmark results will not be removed but be renamed with a `_` in front of the function name `_FunctionName`. **Valgrind** is used to determine memory leakages and function profiles. These profiles will be the guide which determine the priority of functions to be optimized.

7.0.5 Modeling development environment

7.0.6 Electronic development environment



8. Run Environment

Although the software is build to run on any Linux enable device, it is intended to be run on embedded ARM device. The choice for the basic run environment is made for the Beaglebone black

To steps which are set out in appendix E



9. Technical Realization

9.0.7 Electrical design

9.0.8 Design



10. Vision realization

This chapter describes the used vision processing techniques. The current prototype and work flow is developed to allow for different routines. The user has multiple options and strategies available to achieve optimum results. Each of these are explained in the sequential subsection below. It begins with the acquisition of image(s), which are then enhanced to allow for optimal segmentation of pixels related to sand particles. These pixels are used to determine the features of each particle, which serve as input for the classification algorithms.

10.1 Image acquisition

A thorough review of the current literature [2] identified three properties that can be used in vision based analyzing. These properties are structure (shape), color and texture (size). When looking closely at sand sample, you notice a multitude of shapes, colors and sizes, each particle is unique and differs from its neighbor. This diversity brings it own challenges. The shape of a particle determines how it will rest on the sample plate. The color and the translucency of the particle, determines how easily it can be segmented or identified from the background. Whilst the size determines the needed focus depth of the microscope.

R In samples, where the particles show a huge spread in size, compared to the mean size, there will be a noticeable difference in focus, between big and small particles.

Acquisition strategies

The first prototype is developed in such a way that multiple acquisition strategies can be implemented. Each of these tackle different challenges. The quality of the acquired image is the biggest factor in the successful extraction of a particle, but in order to make any valid claim about the sample, a certain amount of particles have to be examined. To determine the minimum sample size, the following equation can be derived:

Let the reliability be 95% $\therefore z = 1.96$, the probability be $P = 50\%$ and the accuracy be $\alpha = 5\%$; consider the function:

$$z\sqrt{\frac{p \times (1 - P)}{n}} \leq \alpha \rightarrow n \geq \frac{-p \times (P - 1) \times z^2}{\alpha^2} \quad (10.1)$$

This brings the minimum amount of particles to 384. With the predefined range of particle sizes ($0.2[\text{mm}] \leq P_{\text{size}} \leq 2[\text{mm}]$ where P defines a particle) and the limited work area under the microscope, multiple shots have to be taken. Where the sample is rearranged. Between fifteen and twenty shots are usually enough.



The process of rearranging the particles, will be automated in the future. Student of the minor Offshore & Construction taught at the University of Applied Sciences Rotterdam will work on this challenge. This is done on the RDM Campus. This minor starts in September 2015. Their product will serve as input for the second prototype. Their assignment is described in appendix C and will be executed under the auspice of MTI Holland and the author.

Acquisition

Each sample is placed in a light condition room, and laid out on a semitransparent white acrylate plate. The sample can be illuminated with a bright field light source, where the light is aimed directly at an object or the particle can be lit with back lighting. See the course notes [6] for a more in-depth description. The choice for back lighting can be made because translucent particle are harder to segment in a bright field light. The trade off is extra processing time.

After the sample is placed in the light condition room, the microscope takes a image with bright field illumination and, if the option is selected, another one with back lighting. Hereafter the sample is rearranged, this is a manual procedure. Once the sample is rearranged a new set of shots is taken. Each image that is acquired from the microscope is defined by a matrix were the values are triples for the RGB (red, green and blue) values and these are defined by an unsigned byte.

Each image is stored in a vector using a custom container. This container consists of a bright field image, back light image and a SI-conversion factor. Each time the height is changed, the microscope has to be calibrated so that the relation between pixel and [mm] can be determined. This is done by taking a shot of a disc with known dimensions. A single euro cent can serve for this purpose.



The image is stored in the OpenCV matrix (cv::Mat) container. This container is designed to handle image processing data and routines. It makes use of memory management and smart pointers to handle the data effectively.

10.2 Image enhancement

Image enhancement prepares the RGB image for conversion to a binary image. It eliminates noise and brings out wanted features, by using filters.

Intensity image

The first step in this process step is the conversion from the RGB color space to an scalar valued image which represent the luminosity, also known as a intensity image. This luminosity is calculated using a weighted average and is done for bright field and back lit images.

Let \mathbf{I} and $\mathbf{R}, \mathbf{G}, \mathbf{B}$ be a matrices with dimensions $n \times m$ derived from the color matrix \mathbf{RGB} with dimensions $n \times m \times 3$; The weighted average can be calculated with the following equation:

$$\mathbf{I} = 0.2126 \times \mathbf{R} + 0.7152 \times \mathbf{G} + 0.0722 \times \mathbf{B} \quad (10.2)$$

Adaptive contrast stretch

After the conversion from RGB to an intensity image, the user has the choice to apply an adaptive contrast stretch to the bright field images. This process is used to enhance the contrast of the intensity image. For every pixel and its surrounding area the mean and standard deviation are calculated. If the value of the pixel is above or below the mean than the following rule is used to determine the new value: $\mathbf{I}_{n,m} = \mathbf{I}_{n,m} \times \alpha \pm \sigma$, where α is a scaling factor and σ is the standard deviation of the old pixel value with it's neighboring kernel pixels.

Blur

As a second enhancement the user can apply a blurring operation to the bright field images, in essence the opposite of the contrast stretch. The blur operation also determines the mean for every pixels within a given area: the kernel. The mean value of the kernel is assigned to the pixel.

Cropping

The above operations described in the paragraph 10.2 and 10.2, leave the border pixels unaffected in their calculations. This offset is determined by half of the biggest kernel size. These pixels are discarded for the next step. The enhanced intensity matrix is used for particle segmentation, see section 10.3. Whilst the intensity matrix of the bright field image is used for the conversion to the CIE La*b* colorspace, as explained in section 10.3.2.

10.3 Feature extraction

The individual particles have to be identified and segmented from the background. These operations are performed on the enhanced intensity matrix. If the user opted to use back lit and bright field matrices, the enhanced intensity matrices where calculated from the back lit intensity matrices. Otherwise the bright field intensity matrices are used.

10.3.1 Shape features

One of the main features that are of interest are those that describe shape, be it the contour or area of a particle. The feature are extracted using the algorithms below.

Segmentation

The images are segmented by calculating a threshold value. This value is determined by using the Otsu threshold. Xu et al. [5] describe that the Otsu threshold is equal to the average of the mean levels of two classes partitioned by this threshold. This threshold value can be iteratively determined.

Let \vec{h} be a vector of dimension 256 which represent a count of values in the enhanced

intensity matrix $\mathbf{I} \subset \mathbb{Z}^n \rightarrow \{0, 255\}$ with dimensions $m \times n$

$$\frac{1}{t_o} \sum_{i=1}^{t_o} \vec{h}_i = t_o - \frac{1}{256-t_o} \sum_{i=t_o}^{256} \vec{h}_i \quad (10.3)$$

In order to get more control over the segmentation process, the normal Otsu's method, as shown above is altered. A user now has the option to choose whether bright or dark object are segmented and how much the intensity values may deviation from the mean value. The mean value obtained from equation 10.3 is modified with a scaling factor and the standard deviation, as shown in equation 10.4 and 10.5.

Let $t_o \subset \mathbb{Z}^n \rightarrow \{0 \leq t \leq 255\}$ be the threshold value obtained with the iteration algorithm used to solve equation 10.3, α be the a multiplication factor given by the user and let $\vec{h} \subset \mathbb{Z}^n$ be a vector of dimension 256 which represent a count of values in the enhanced intensity matrix $\mathbf{I} \subset \mathbb{Z}^n \rightarrow \{0, 255\}$ with dimensions $m \times n$

If dark objects are to be obtained

$$t = \frac{1}{t_o} \mu + \frac{1}{2} \alpha \sigma \text{ where } \sigma = \sqrt{\frac{1}{t_o} \sum_{i=1}^t (\vec{h}_i - \mu)^2}, \text{ and } \mu = \frac{1}{t_o} \sum_{i=1}^t \vec{h}_i \quad (10.4)$$

else

$$t = \frac{1}{t_o} \mu - \frac{1}{2} \alpha \sigma \text{ where } \sigma = \sqrt{\frac{1}{256-t_o} \sum_{i=t}^{256} (\vec{h}_i - \mu)^2}, \text{ and } \mu = \frac{1}{256-t_o} \sum_{i=t}^{256} \vec{h}_i \quad (10.5)$$

Binary Image

The binary image is calculated by using the previous obtained threshold value as illustrated in equation 10.6.

Let $\mathbf{B} \subset \mathbb{Z}^n \rightarrow \{0, 1\}$ and $\mathbf{I} \subset \mathbb{Z}^n \rightarrow \{0, 255\}$ both with dimensions $m \times n$ and let $t \subset \mathbb{Z}^n \rightarrow \{0 \leq t \leq 255\}$

$$\mathbf{B} = \begin{bmatrix} \mathbf{I} \\ t \end{bmatrix} \quad (10.6)$$

Labeled blobs

If the threshold value was correctly ascertained then the binary image will consist of zeros and ones. Particles are represented by islands of connected elements with a designated value of one in an ocean of zeros. The individual particles, which are dubbed "blobs" will be identified with a two-pass connected-component labeling algorithm.

This algorithm passes each element in a binary image in a consecutive manner. When the current element belongs to a particle, it will check if previously processed neighboring pixels belong to an earlier la-

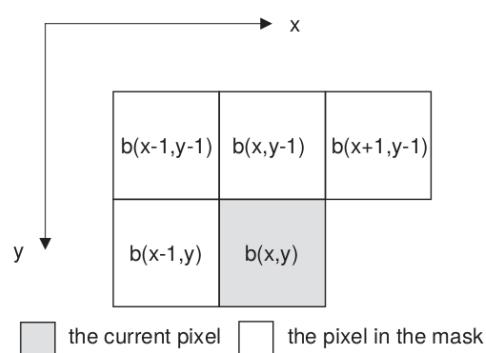


Figure 10.1: Neighboring elements Source: [1]

beled blob. If this is not the case it will assign a new label value to the current element. If it finds that one of the neighbors belong to one or more blobs, it assigns the lowest value and writes the other value to a queue. To store the connected labels.

In order to determine the lowest value of the connected component, a graphs matrix is generated, see figure 10.2. Each branch on these trees are followed till the lowest value is ascertained. All the leafs on the tree are then set to this value. These values are placed in a Look-Up-Table. With the second loop through the previously labeled image each value is replaced by looking up the lowest value in LUT.

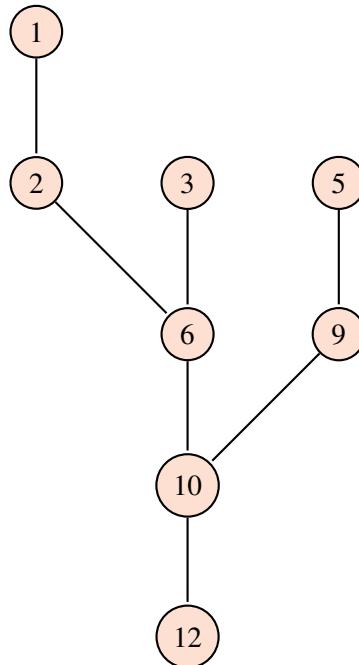


Figure 10.2: Connected Queue



A Look-Up-Table (LUT) is an array where a new value can be obtained with a simple array indexing operation. This is a very effective operation since looking up a value in memory cost less machine instructions then perform computation on each matrix element. A LUT consist of 256 elements for a unsigned byte, while a image matrix has roughly 5 million elements.

The numbering of the labels are made consecutive using an adapted quick sorting algorithm. These numbers are used to identify the individual particles in a sample. For each unique particle a type is created. This type is stored in vector and represent the sample.

For each particle a region of interest or ROI is obtained looking for the minimum and maximum value of the labeled blob within the labeled image. This ROI, is used to extract the same blob from the bright field RGB image.

Hu moments

The Hu moments are determined for the individual blobs. A Hu moment is a certain particular weighted average, or moment, of pixels in an image and can be defined as follows for a discrete image.

Let $\mathbf{B} \subset \mathbb{Z}^n \rightarrow \{0, 1\}$ with dimensions $m \times n$

$$M_{i,j} = \sum_m \sum_n m^i n^j B_{m,n} \quad (10.7)$$

The first order or raw moment gives the total area of the particle, while the second order gives the centroid. Which is used when describing complex contour. This will be explained later on. The second order can be used to determine the orientation of the particle. By constructing a covariance matrix the rotation can be extracted from the angle of the eigenvector associated with the largest eigenvalue.

$$\Theta = \frac{1}{2} \arctan \left(\frac{2(M_{11}/M_{00} - \bar{x}\bar{y})}{(M_{20}/M_{00} - \bar{x}^2) - (M_{02}/M_{00} - \bar{y}^2)} \right) \quad (10.8)$$

Particle rotation

When the above orientation deviates from a horizontal or vertical axis, the particle is rotated. This is done by expanding the matrix in all four directions. Padding the borders. And applying the rotation matrix. When old pixels don't completely fall within the new grid. The new pixel value is obtained with linear interpolation.



The orientation of a particle is relevant because it allows for easy determination of the smallest diameter. The VSA uses a equivalent diameter to calculate the Particle Size Distribution. Normally this equivalent diameter is calculated with the assumption that the particle is round. This gives a distortion when comparing against particles that are sieved. The mesh size of the sieve allows oval particle to pass by their smallest cross-section.

Particle edge

Using the binary image from the individual particle an edge is obtained. This is done by applying the morphological operation of erosion. With this algorithm the blobs are eroded using the following principle

$$\text{Let } \mathbf{B} \subset \mathbb{Z}^n \rightarrow \{0, 1\} \text{ and } \mathbf{K} = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

$$\mathbf{B} \ominus \mathbf{K} = \bigcap_{k \in \mathbf{K}} \mathbf{B}_{-k} \quad (10.9)$$

The previous obtained ROI is used to extract the edges from the individual particles. This edge is used in the Fast Fourier Transformation. In order to obtained a continuous function from the edge, a depth-first searching algorithm is applied.

Depth-first search

This starts at the top-left edge pixels and looks at its neighboring pixels. If it finds more then two neighboring pixels it stores the additional values in a queue and it moves to the first pixel new pixel. Here it performs the above decision process again. If it doesn't it only finds one neighboring pixel it know it's at a dead end. The algorithm will backtrack and start at the first branch in the queue. Subsequently storing the previously walked path, so it doesn't traverses again down this branch. This process is repeated until it find the

starting pixel. Each individual branch that is processed in this way is stored in a vector of coordinates.

Complex contour

These coordinate are stored as complex numbers where the real part is the row and the imaginary part is the column. Both are taken with respect to the center of gravity, which is obtained with the first order of the Hu-moments, see earlier paragraph. The shortest vector of connected coordinates that form a loop is determined to represent the edge of the particle.



By choosing the shortest path of neighboring edge pixels as a complex contour. The roughness of the edge is represented slightly less rough then the pixel suggest that is. This effect is negated, because of the discrete nature of the digital representative of a particle compared with continuous real curve of actual particle.

10.3.2 CIE La*b* extraction

In The bright field RGB images serve as the starting point

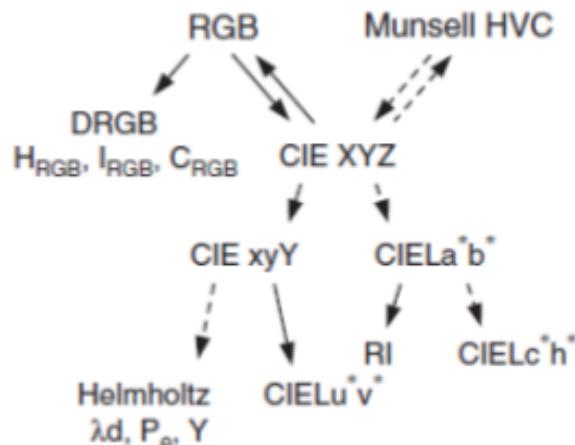


Figure 10.3: Conversion steps to different colormodels (Source: [4])

10.3.3 Fast Fourier Descriptors

10.3.4 Particle Size Distribution

The normal procedure for creating a Particle Size Distribution uses sieves and weights, to determine the volume of the the particle.

The Sieve mesh size can be perceived as a cross section of a particle, since the particle is only retained in a sieve when it passes through the top sieve but can't pass through the sieve below. The cross section of the particle is at minimum the sieve mesh size of the top sieve, but other dimensions of the particle can exceed the sieve mesh size at which it last passes.

Work this argument to explain why it is ok to use a 2 dimensional representation of a 3 dimensional particle

10.4 Classification

10.4.1 Roundness using Hu-moments

10.4.2 Angularity using a Neural Network

Angularity of particle can be described as

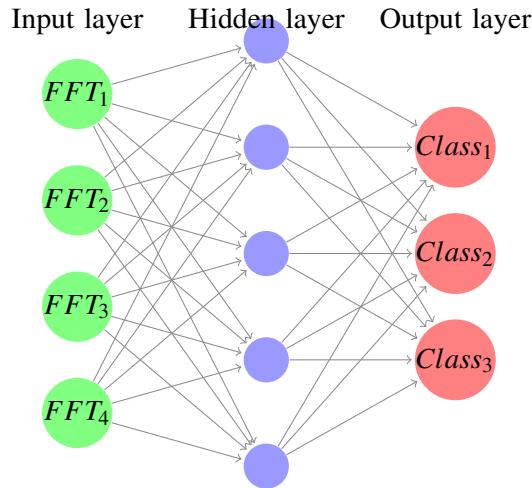
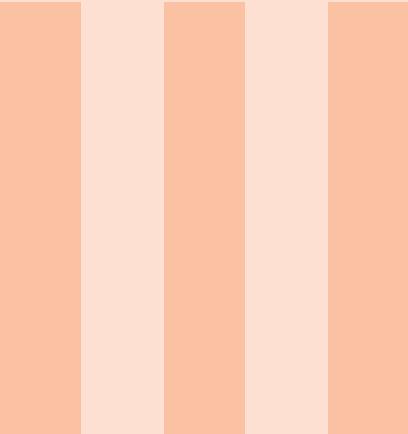


Figure 10.4: Neural Network

10.4.3 Genetic Algorithm

Viva la revolution!

This is an example of examples.



Verification



11. Presenting Information

11.1 Table

Treatments	Response 1	Response 2
Treatment 1	0.0003262	0.562
Treatment 2	0.0015681	0.910
Treatment 3	0.0009271	0.296

Table 11.1: Table caption

11.2 Figure

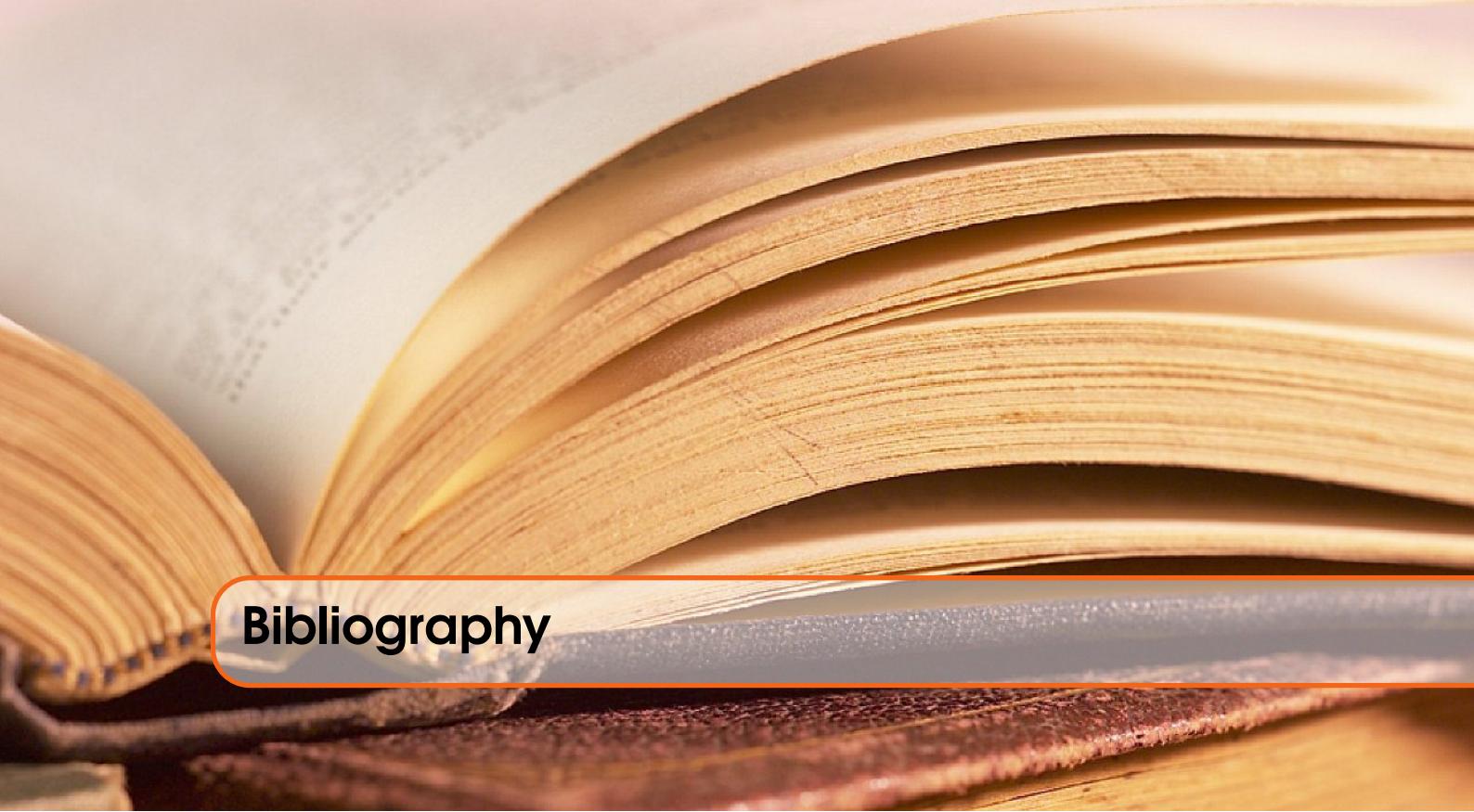


Figure 11.1: Figure caption

Addenda



	Bibliography	51
	Index	53
A	Graphical User Interface	53
B	Example Soil Report	57
C	RDM campus: Student project	63
D	Development Environment setup	65
E	Run Environment setup	71
F	Current project status	75
G	Soil and computer vision flyer	83
H	SoilMath Library	99
I	Hardware Library	153
J	Vision Library	209
K	Analyzer Library	265
L	QOpenCVQT Library	295
M	QParticleDisplay Library	299
N	QParticleSelector Library	305
O	QReportGenerator Library	311
P	Vision Soil Analyzer Program	325



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- [5] Xiangyang Xu et al. “Characteristic analysis of Otsu threshold and its applications”. In: *Pattern Recognition Letters* 32.7 (2011), pages 956 –961. ISSN: 0167-8655. DOI: <http://dx.doi.org/10.1016/j.patrec.2011.01.021>. URL: <http://www.sciencedirect.com/science/article/pii/S0167865511000365> (cited on page 39).

A. Graphical User Interface

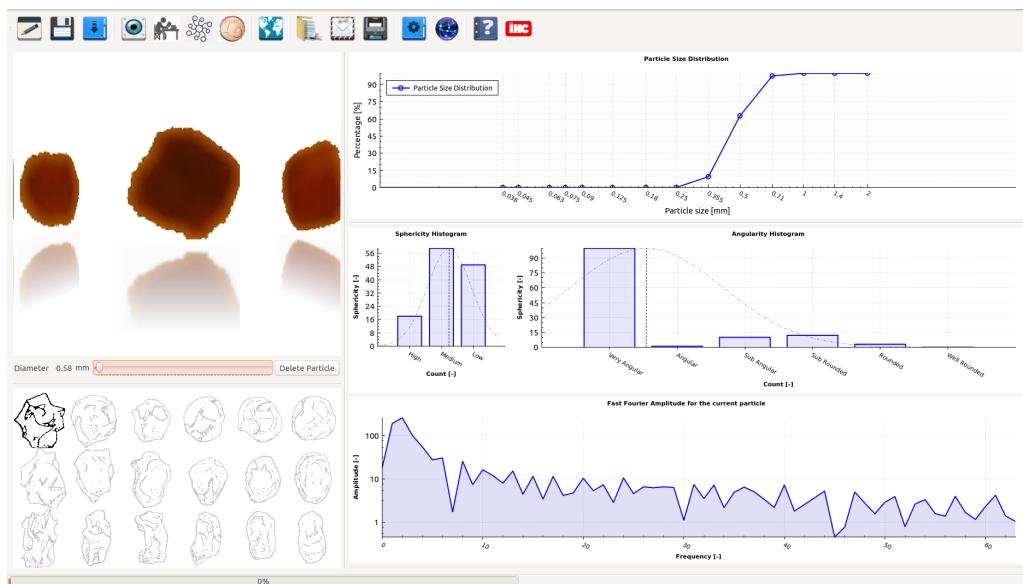


Figure A.1: Main Graphical User Interface

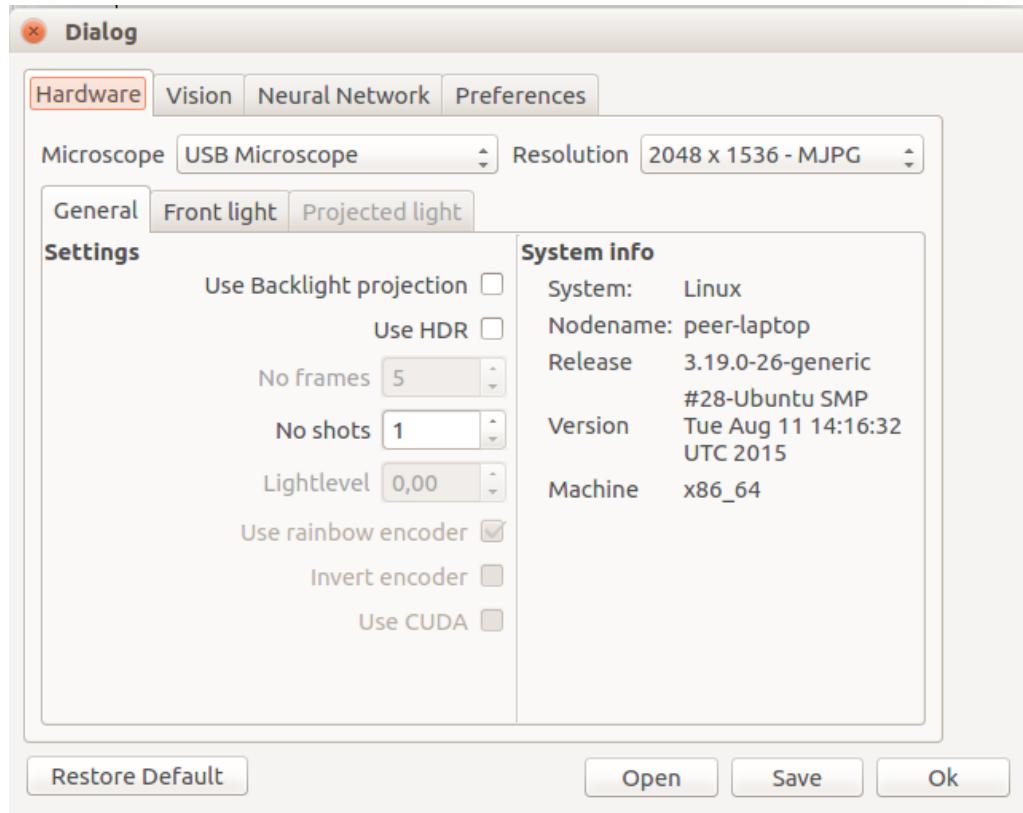


Figure A.2: Settings Hardware Interface

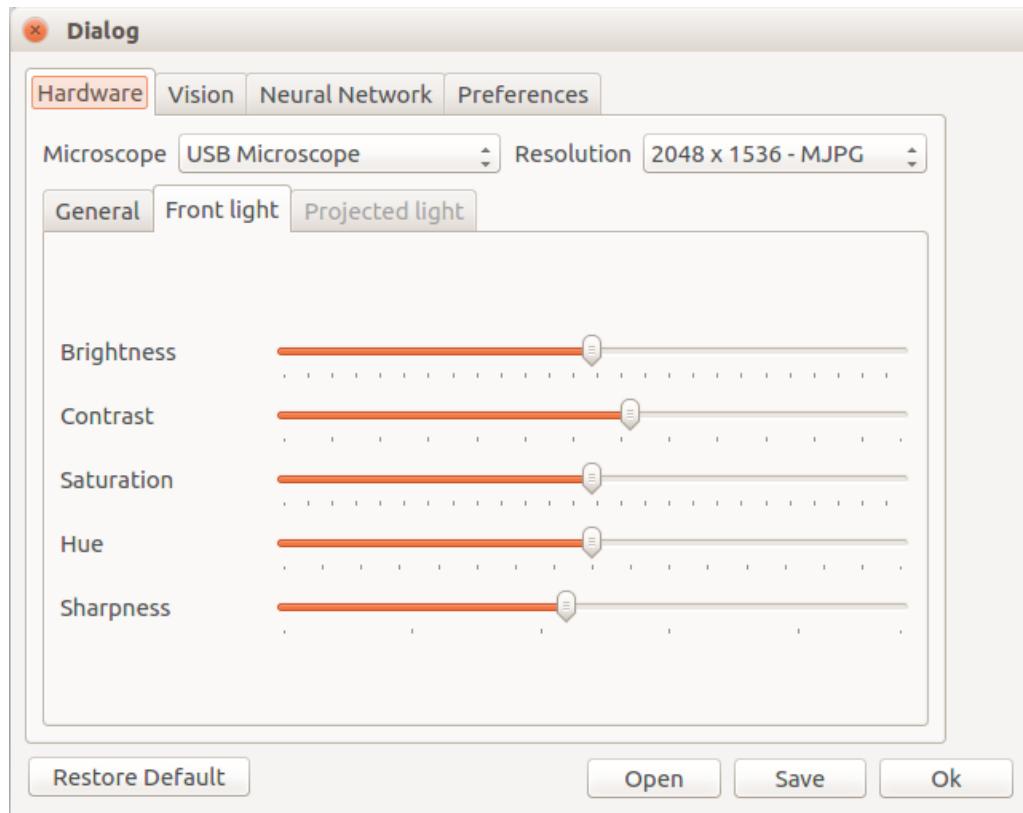


Figure A.3: Settings Hardware Cam Interface

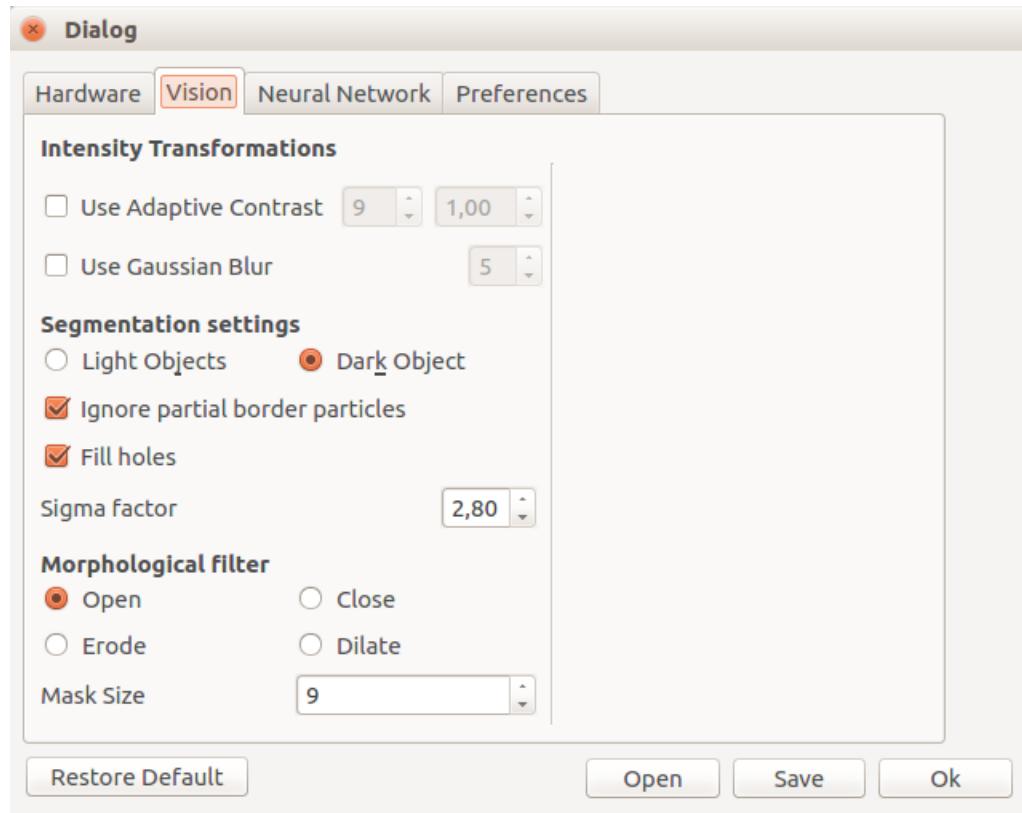


Figure A.4: Settings Vision Interface

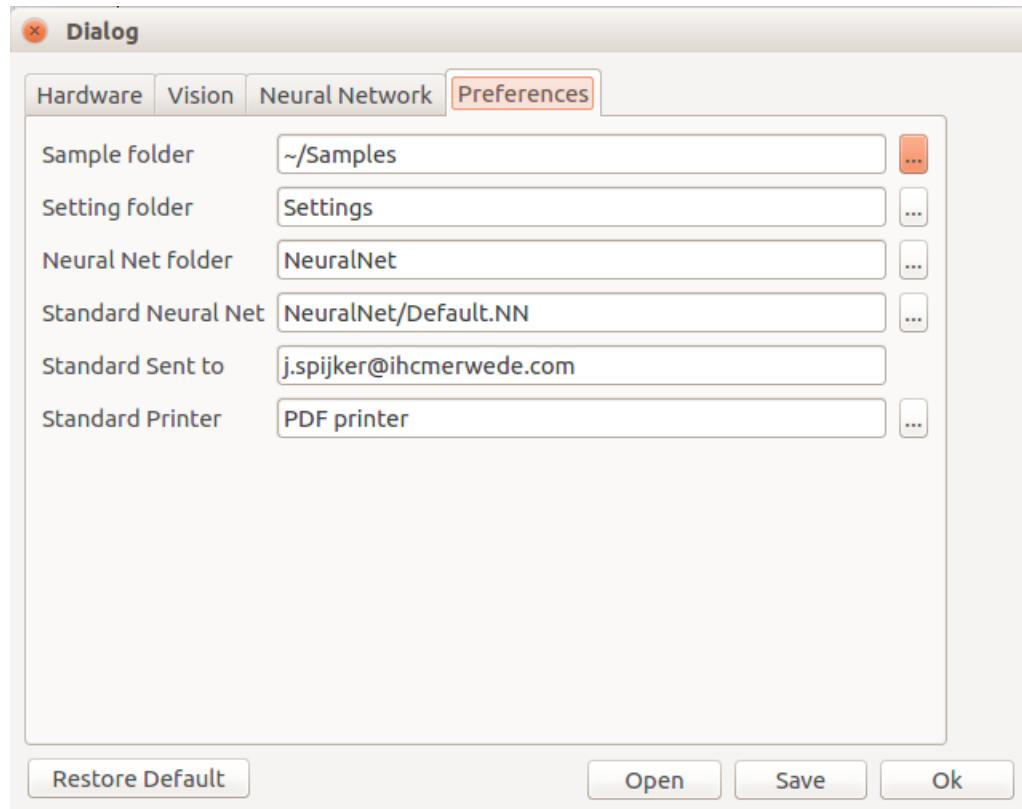


Figure A.5: Settings Preference Interface

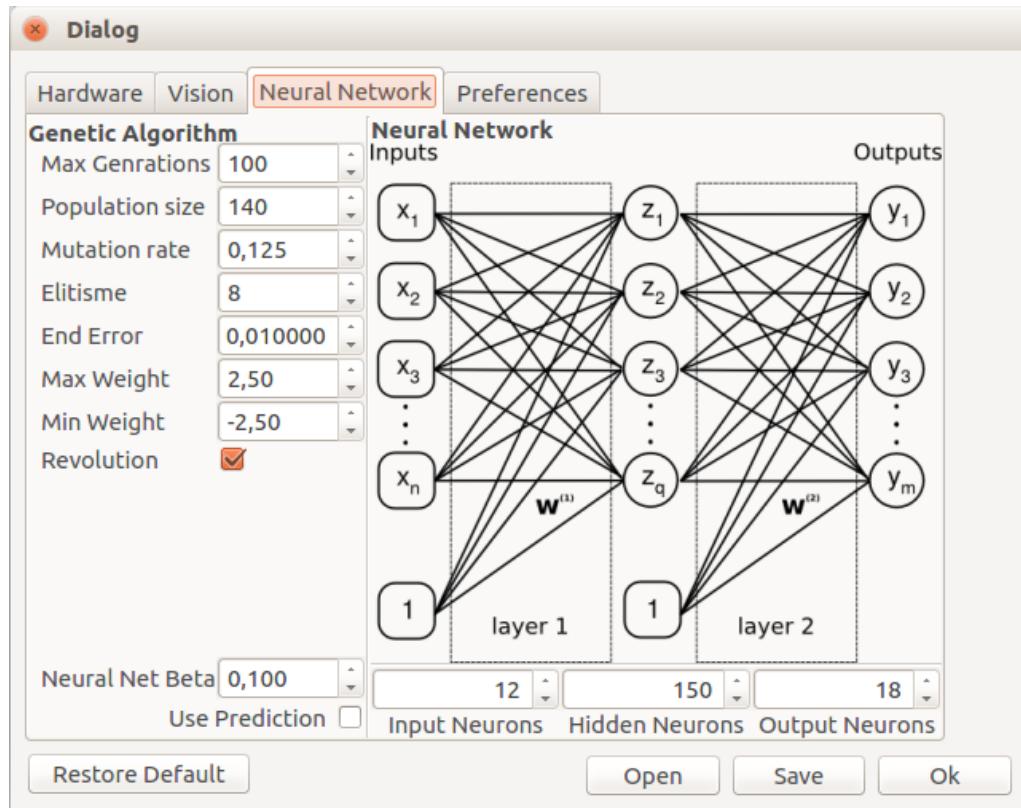


Figure A.6: Settings Neural Network Interface

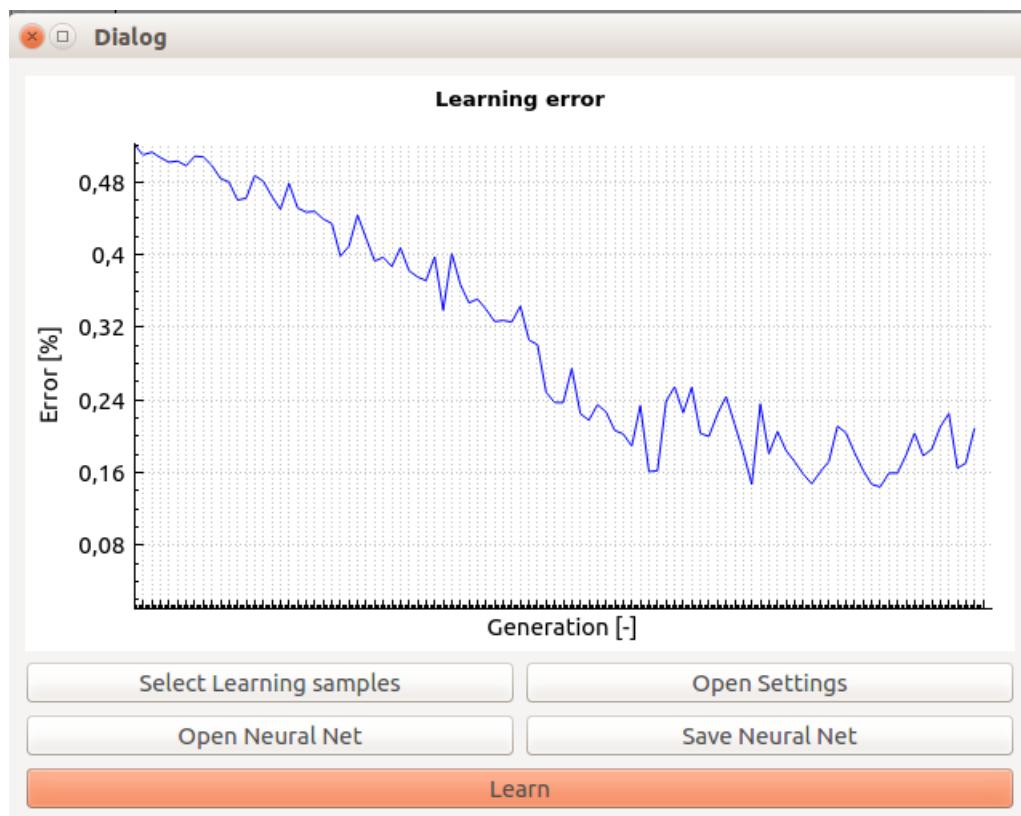
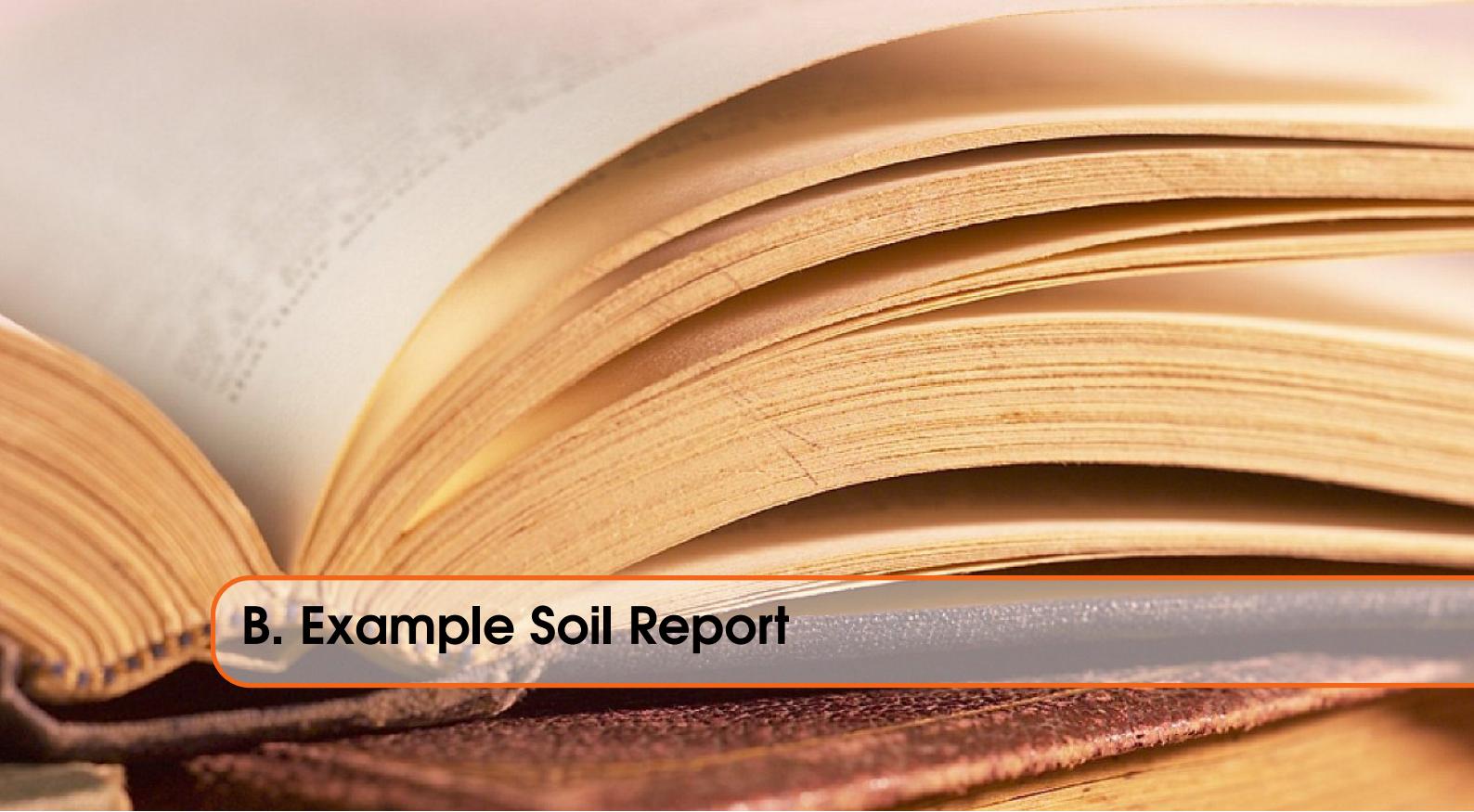


Figure A.7: Neural Network Learning Interface



B. Example Soil Report

Soil Report

Sample name:

Sample ID:

4084628568

Date:

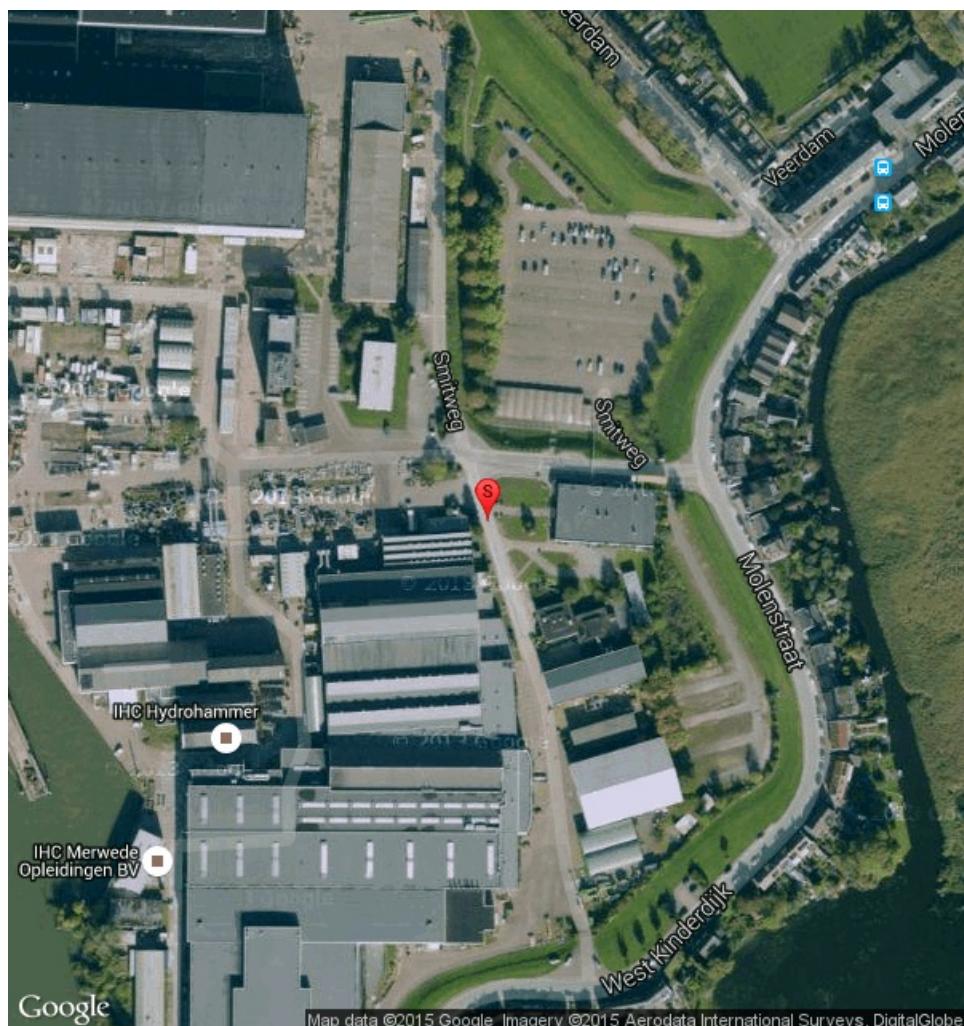
01-09-2015

Location:

51.8849, 4.62962

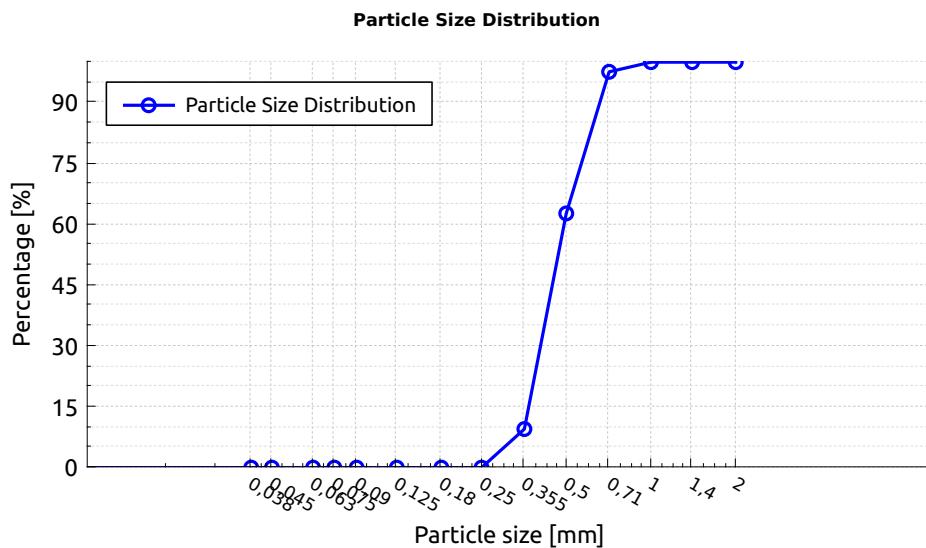
Sample depth:

0 [m]



Particle Size Distribution

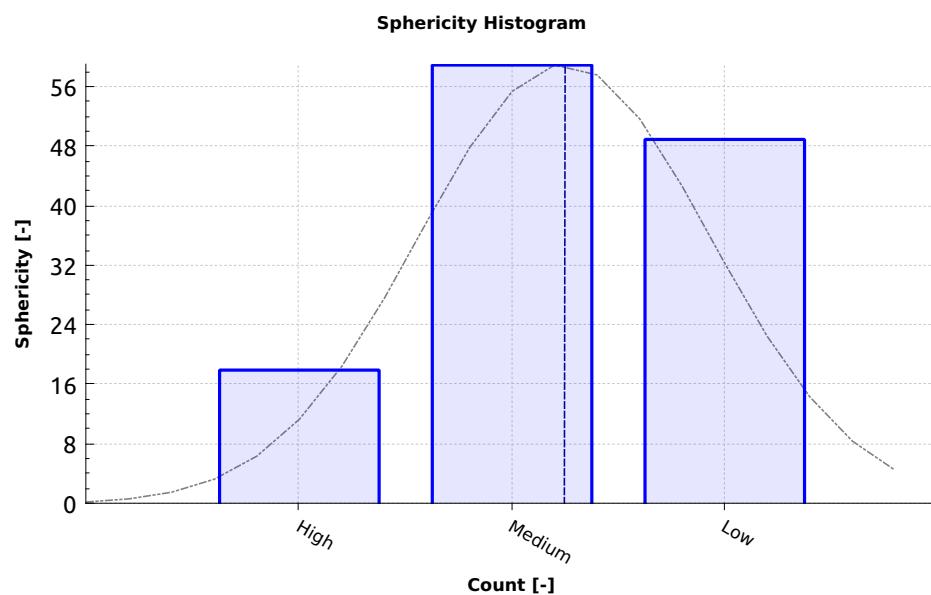
No of particles:	126
Mean:	0.673049
Minimum:	0.407876
Maximum:	1.14742
Range:	0.739541
Standard deviation:	0.142802



Mesh Size [mm]	Cummulatief [%]	Retained [-]
2	100	0
1.4	100	0
1	100	3
0.71	97.619	44
0.5	62.6984	67
0.355	9.52381	12
0.25	0	0
0.18	0	0
0.125	0	0
0.09	0	0
0.075	0	0
0.063	0	0
0.045	0	0
0.038	0	0
0	0	0

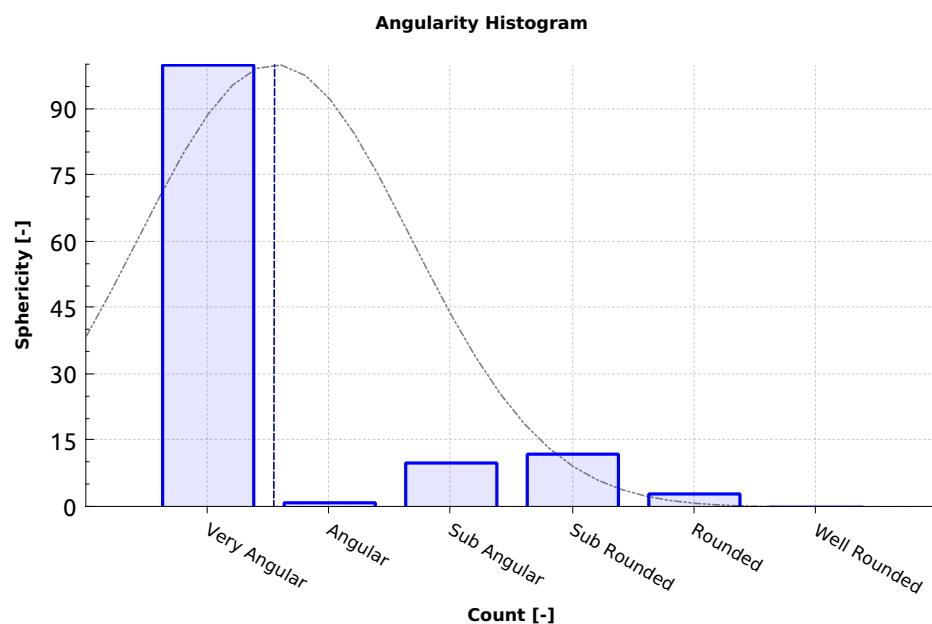
Sphericity Classification

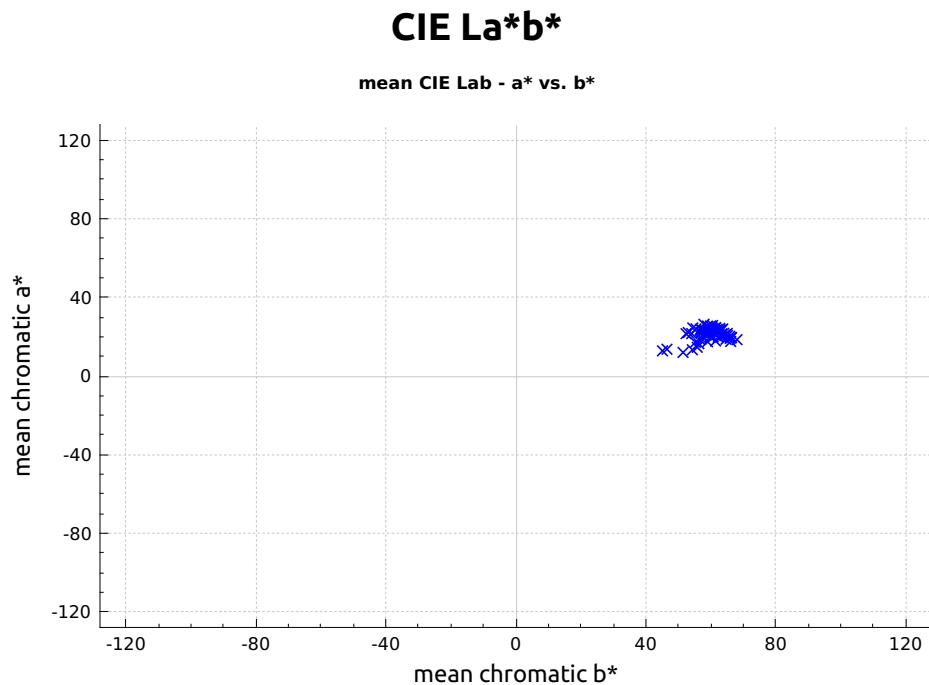
No of particles:	126
Mean:	2.24603
Minimum:	1
Maximum:	3
Range:	2
Standard deviation:	0.686451

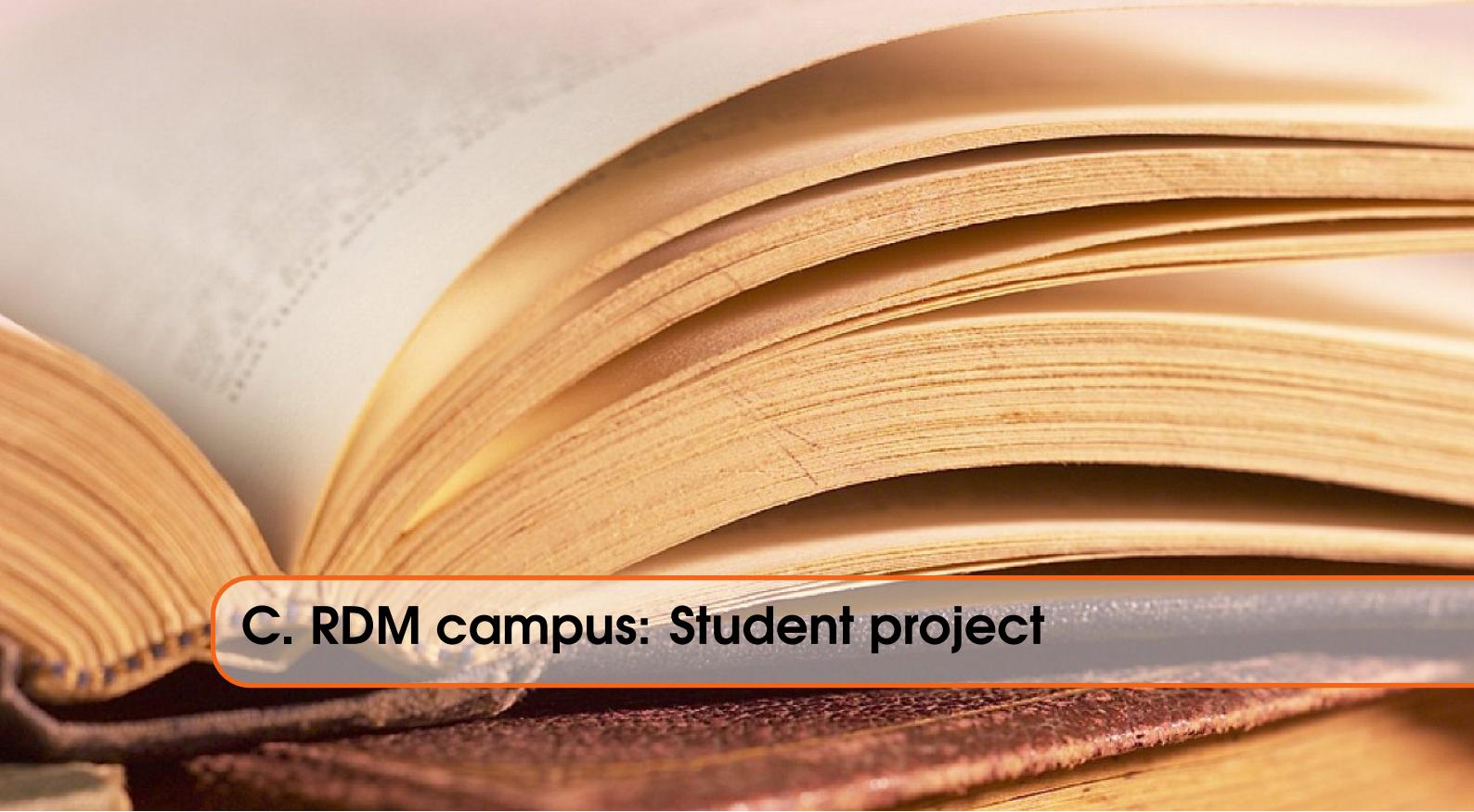


Angularity Classification

No of particles:	126
Mean:	1.54762
Minimum:	1
Maximum:	5
Range:	4
Standard deviation:	1.1241







C. RDM campus: Student project

Subject: RDM Student project
Author: Jelle Spijker

Introduction

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

The VSA takes a snapshot from a soil sample, which is placed under a microscope in an closed environment. This digital image is analysed using a multitude of computer vision algorithms. Statistical data is presented to the user in the form a Particle Size Distribution (PSD) and a histogram of the shape classification. The PSD is obtained by calculating the number of pixels for each individual particle, whilst shape classification is determined by describing the contour of each individual particle as mathematical function which undergoes a transformation to the frequency domain. This complex vector then serves as input for an Artificial Neural Network (ANN) where the output classifies each particle in a certain category.

The prototype developed during the minor EVD will serve as a basis for a graduation project of that same student, which initialized the project. This is done for his main course mechanical engineering at the HAN. This graduation project is done under the auspices of MTI Holland. The goal during this second stage is to develop a field ready prototype. In conjunction with the necessary documentation (Technical Dossier). Due to the scale of the project, several key problems are identified and separated from the main project. These problems can be tackled by separated student groups.

Problem description

Due to the transformation from 3D particles to a discrete 2D image certain data is lost. This degradation of data introduces errors in the statistical data. One of the forms of degradations is the overlap of bigger particle onto smaller particles. These particles are identified as a particle with at least the size and the contour of the biggest particles. Thus giving false negatives for the smaller particles and often false positives for the bigger particle.

A solution that will be explored during this stage is the execution of multiple analysis of the same discrete particle population. This will result in an accurate statistical representation of the soil sample placed under the microscope.

The project that the RDM students can tackle can be described as follow:

Design and build a prototype with which the placement of particles, relative to each other and ranging in sizes from 0.02 - 2 [mm] are randomly changed in a time span of 1 [sec], which is tightly integrated with the main prototype.

The prototype is to be CE compliant and should be build according to technical specifications. It should be described in a Technical Dossier, containing all necessary documents such as: technical drawings (according to mono system), bill of materials, calculation, analysis and design reports.



D. Development Environment setup

Below is a list of used libraries during and their installation instructions:

Common packages

```
sudo apt-get install build-essential cmake git libgtk2.0-dev pkg-config libavcodec-dev libavformat-dev libswscale-dev python-dev python-numpy libtbb2 libtbb-dev libjpeg-dev libpng-dev libtiff-dev libjasper-dev libdc1394-22-dev libv4l-dev v4l-utils libqt5multimediawidgets5 clang libboost-all-dev cheese cmake-qt-gui qt-sdk libgstreamer0.10-dev libgstreamer-plugins-base0.10-dev libv4l-dev libtbb-dev libqt4-dev libfaac-dev libmp3lame-dev libopencore-amrnb-dev libopencore-amrwb-dev libtheora-dev libvorbis-dev libxvidcore-dev x264 v4l-utils unzip libopencv-dev build-essential cmake git libgtk2.0-dev pkg-config python-dev python-numpy libdc1394-22 libdc1394-22-dev libjpeg-dev libpng12-dev libjasper-dev libavcodec-dev libavformat-dev libswscale-dev libxine2-dev libtiff5-dev libgstreamer0.10-dev libpython3-all-dev libpython-all-dev libbz2-dev valgrind python3-numpy
```

Nvidia driver (820M)

```
sudo apt-get purge nvidia*
sudo add-apt-repository ppa:graphics-drivers/ppa
sudo apt-get update
sudo apt-get install nvidia-355 nvidia-settings
sudo nvidia-xconfig
sudo apt-get install bumblebee bbswitch-dkms primus
sudo systemctl enable bumblebeed
sudo echo "i915" » /etc/modules-load.d/modules.conf && sudo echo "bbswitch" » /etc/modules-load.d/modules.conf
sudo ln -s /usr/lib/nvidia-current /usr/lib/nvidia-355
sudo ln -s /usr/lib32/nvidia-current /usr/lib32/nvidia-355
sudo nano /etc/bumblebee/bumblebee.conf
```

```
change the parameter 'Driver=' > 'Driver=nvidia
change the parameter 'KernelDriver=nvidia-current' > 'KernelDriver=nvidia-355
restart the computer
```

CUDA

```
wget http://developer.download.nvidia.com/compute/cuda/7_0/Prod/local_installers/rpmdeb/cuda-
repo-ubuntu1410-7-0-local_7.0-28_amd64.deb
sudo dpkg -i cuda-repo-ubuntu1410-7-0-local_7.0-28_amd64.deb
sudo apt-get update
sudo apt-get install cuda
export PATH=/usr/local/cuda-7.0/bin:$PATH
export LD_LIBRARY_PATH=/usr/local/cuda-7.0/lib64:$LD_LIBRARY_PATH
```

Qt and Qt Creator

```
wget http://download.qt.io/official_releases/online_installers/qt-unified-linux-x64-online.run
sudo chmod +x qt-unified-linux-x64-online.run
./qt-unified-linux-x64-online.run
```

OpenCV 3.0 beta

```
cd ~
git clone https://github.com/Itseez/opencv.git
cd opencv
mkdir release
cd release
```

Enter the following command for an NVIDIA CUDA enabled environment:

```
cmake -D CMAKE_BUILD_TYPE=RELEASE -D CMAKE_INSTALL_PREFIX=/usr/local
-D BUILD_CUDA_STUBS=ON -D BUILD_DOCS=OFF -D BUILD_JPEG=ON -D
BUILD_PNG=ON -D BUILD_TESTS=OFF -D BUILD_WITH_DEBUG_INFO=OFF
-D CUDA_FAST_MATH=ON -D ENABLE_FAST_MATH=ON -D WITH_CUBLAS=ON
WITH_OPENGL=ON WITH_QT=ON ..
```

Or the command below for a computer that has no NVIDIA CUDA capabilities:

```
cmake -D CMAKE_BUILD_TYPE=RELEASE -D CMAKE_INSTALL_PREFIX=/usr/local
-D WITH_CUDA=OFF -D BUILD_DOCS=OFF -D BUILD_JPEG=ON -D BUILD_PNG=ON
-D BUILD_TESTS=OFF -D BUILD_WITH_DEBUG_INFO=OFF -D ENABLE_FAST_MATH=ON
-D WITH_OPENGL=ON -D WITH_QT=ON ..
make -jnumber of processors
sudo make install
sudo /bin/bash -c 'echo "/usr/local/lib" > /etc/ld.so.conf.d/opencv.conf'
sudo ldconfig
```

ZLib

```
wget http://zlib.net/zlib-1.2.8.tar.gz
tar xf zlib-1.2.8.tar.gz
cd zlib-1.2.8
./configure
make -jnumber of processors
```

```
sudo make install
```

Folder structure

```
/  
  src  
    pictureflow-qt  
    qcustomplot  
    QOpenCVQT  
    QParticleDisplay  
    QReportGenerator  
    SoilAnalyzer  
    SoilHardware  
    SoilMath  
    SoilVision  
    Tests  
      ComparisionPictures  
      Microscope_Test  
      SoilMath_Test  
      Soil_Test  
      Vision_Test  
    tiscamera  
    VSA  
      Icons  
      Images  
      NeuralNet  
      Settings  
      Soilsamples  
      TestedSamples  
  build  
    debug  
      pictureflow-qt  
      qcustomplot  
      QOpenCVQT  
      QParticleDisplay  
      QReportGenerator  
      SoilAnalyzer  
      SoilHardware  
      SoilMath  
      SoilVision  
    install  
      pictureflow-qt  
      qcustomplot  
      QOpenCVQT  
      QParticleDisplay  
      QReportGenerator  
      SoilAnalyzer  
      SoilHardware  
      SoilMath  
      SoilVision  
    release  
      pictureflow-qt
```

```
    └── qcusomplot
    └── QOpenCVQT
    └── QParticleDisplay
    └── QReportGenerator
    └── SoilAnalyzer
    └── SoilHardware
    └── SoilMath
    └── SoilVision
    └── Tests
        └── ComparisionPictures
        └── Microscope_Test
        └── SoilMath_Test
        └── Soil_Test
        └── Vision_Test
    └── doxygen
        └── html
        └── latex
```




E. Run Environment setup

Building the Kernel

First setup the cross-compile environment on the development PC.

Linaro

```
wget -c https://releases.linaro.org/14.09/components/toolchain/binaries/gcc-linaro-arm-linux-gnueabihf-4.9-2014.09_linux.tar.xz
tar xf gcc-linaro-arm-linux-gnueabihf-4.9-2014.09_linux.tar.xz
export CC='pwd'/gcc-linaro-arm-linux-gnueabihf-4.9-2014.09_linux/bin/arm-linux-gnueabihf-
```

Bootloader: U-Boot

```
git clone git://git.denx.de/u-boot.git
cd u-boot/
git checkout v2015.10-rc2 -b tmp
```

Apply the Beaglebone patch against the cloned boot-loader, make sure you are in the ~/u-boot directory

```
git revert --no-edit 0a9e34056fcf86fb64e70bd281875eb7bbdbabde
wget -c https://rcn-ee.com/repos/git/u-boot-patches/v2015.10-rc2/0001-am335x_evm-uEnv.txt-bootz-n-fixes.patch
patch -p1 < 0001-am335x_evm-uEnv.txt-bootz-n-fixes.patch
```

OS ubuntu 14.04 Download the Ubuntu 14.04 OS

```
wget -c https://rcn-ee.com/rootfs/eewiki/minfs/ubuntu-14.04.2-minimal-armhf-2015-06-09.tar.xz tar xf ubuntu-14.04.2-minimal-armhf-2015-06-09.tar.xz
```

Setup the SD card

```
export DISK=/dev/mmcblk0
sudo dd if=/dev/zero of=${DISK} bs=1M count=10
sudo dd if=./u-boot/MLO of=${DISK} count=1 seek=1 bs=128k
sudo dd if=./u-boot/u-boot.img of=${DISK} count=2 seek=1 bs=384k
sudo sfdisk -in-order -Linux -unit M ${DISK} <-__EOF__
1,,0x83,*
__EOF__
sudo mkfs.ext4 /dev/mmcblk0p1 -L rootfs
```

Describe the process
for the BBB

remember that initial user and password are **ubuntu** and **temppwd**

Setup pinmuxing

Enable Beaglebone overlays for kernel 4.1.x by cloning Robert C. Nelson bb.org-overlays do this on the BBB. Check if the kernel has the CONFIG_BONE_CAPEMGR=y option

```
zcat /proc/config.gz | grep CONFIG_BONE_CAPEMGR
```

Update the kernel, not needed on a fresh build.

```
cd /opt/scripts/tools
git pull
sudo ./update_kernel.sh -lts --bone-channel
```

check if the DTC version is atleast Version: DTC 1.4.1-g2341721b

```
dtc --version
```

Install the overlays

```
git clone https://github.com/RobertCNelson/bb.org-overlays.git
cd bb.org-overlays
sudo ./dtc-overlay.sh
sudo ./install.sh
```

Install the universal IO device tree for easy PWM and GPIO acces

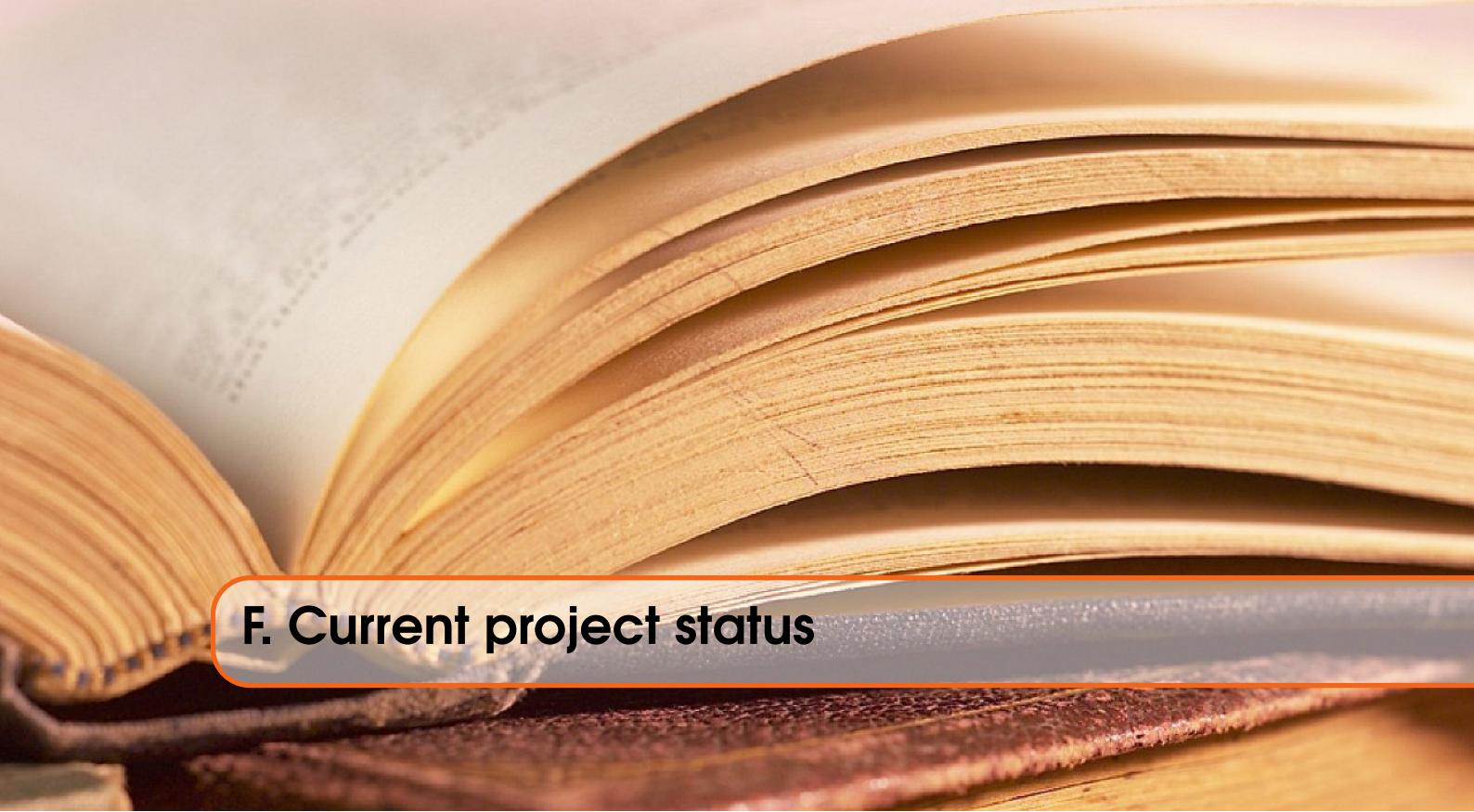
```
git clone https://github.com/cdsteinkuehler/beaglebone-universal-io.git
sudo sh -c "echo 'cape-universalm' > /sys/devices/platform/bone_capemgr/slots"
sudo cp config-pin /bin/
```

Setting up the software

The following software should be installed on the BBB

OpenCV

```
cmake -D CMAKE_BUILD_TYPE=RELEASE -D CMAKE_INSTALL_PREFIX=/usr/local  
-D WITH_CUDA=OFF -D WITH_CUFFT=OFF -D WITH_CUBLAS=OFF -D WITH_NVCUVID=OFF  
-D WITH_OPENCL=OFF -D WITH_OPENCLAMDFFT=OFF -D WITH_OPENCLAMDBLAS=OFF  
-D BUILD_opencv_apps=OFF -D BUILD_DOCS=OFF -D BUILD_PERF_TESTS=OFF  
-D BUILD_TESTS=OFF -D ENABLE_NEON=on ..
```

F. Current project status

Date
15 June 2015

Reference
xxxxxxx

Version
Rev. A

Status
Concept / Final

Name Author
Jelle Spijker

Vision Soil Analyzer

Current status and results



Contact gegevens:

Jelle Spijker (495653) – 06-43272644 – j.spijker@ihcmerwede.com

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Datum
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Reference
xxxxxxxx

Version
Rev. A

Pagina
2 van 7

Vision Soil Analyzer

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

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 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.

1.1 Goal

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 five minutes. The results are presented to the user using a generic HDMI monitor or can be download from the device in PDF format. These results fall in to a predefined and for a user acceptable error margin.

1.2 Presented information

The user gets information presented in the following formats:

- | | |
|--------------|---|
| Color | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • 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. |
|------------------|---|

Datum
5 juni 2015Reference
xxxxxxxxxVersion
Rev. APagina
3 van 7

2 First test results

The test setup was a X64 desktop computer running Matlab 2014a. The microscope was placed in an open environment. This setup 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.

Success	Challenges
Segmentation and identification of individual particle is possible for non-transparent particles. See figure 2	Segmentation of transparent particles is a challenge. This is critical to overcome, since systematic exclusion of a certain subset of particles gives inaccurate statistical results
Color model transformation can be strategically performed. Saving calculation time	Variations in color related results. Due to changing light conditions during the day. Test result relating to color could not be reproduced during the day.
Volume of the particles, could be roughly calculated, from a 2D image	Overlap of smaller particles by bigger particles. The combination of the two samples overlapping particles where registered as one bigger particle. This gives distorted PSD results.
Individual particles where identified, and the Fourier Descriptors could be calculated. The inverse of these descriptors translated to accurate results. See figure 1	No correlation between estimated shape classification and human shape classification. The Neural Network was fed an in perfect an small learning dataset.
	Calculation of image consisting of 5e6 pixels takes roughly 7 minutes

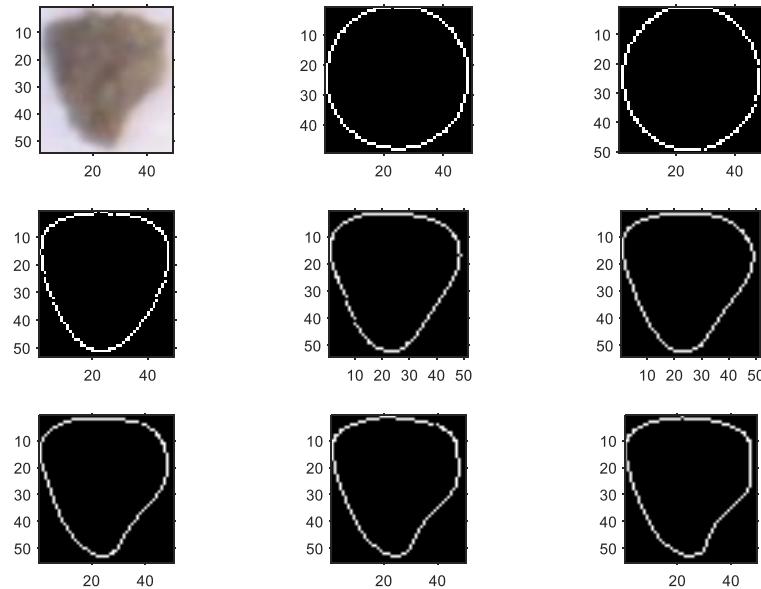


Figure 1 Fourier Descriptors of a soil particle

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Version
Rev. A

Pagina
4 van 7



Figure 2 Soil particles separated from the background

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Reference
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Version
Rev. A

Pagina
5 van 7

3 Second (current) stage

The second stage of this project consist of a transfer from Matlab to C++ running on an embedded Linux ARMv7 device. This consist of rewriting and designing all the algorithms from scratch. Implementing and unit testing them. Design and construction of a light condition case. Design and construction of a PCB for control of the light conditioning case and user interaction. See figure 3 and 4.

The source code currently consists of 7000+ lines. Although the code can be run from a Linux Desktop computer and can probably be ported to a Windows computer. The code and algorithms are designed and optimized for the ARM architecture.

Success	Challenges
Program can be run from a Linux Desktop computer and an ARM microcontroller	
Vision algorithms are performed with 0% error margin compared with their Matlab counterpart. Speed increase is 650% on average	Segmentation of transparent particles is a challenge. This is critical to overcome, since systematic exclusion of a certain subset of particles gives inaccurate statistical results
Statistical calculations are performed within an error margin of 0.0001% compared with their Matlab counterparts. The speed increase is 400%	Since this class is used throughout the project and still takes up to 9% of the total time be called upon. Further optimization is advised.
Fast Fourier Transformation are performed within an error margin of 0.001% compared with their Matlab counterparts. The speed increase is 230%.	Further optimization is needed. The current C++ code is compiled with X64 desktop optimization. ARM machine code can perform this process with less instructions. Rewrite the FFT function in assembler for a big speed increase
The Neural Net can learning multiple Logical AND OR NAND setups.	Creation of an accurately classified soil particle database to learn the neural net.
	Overlap of smaller particles by bigger particles. The combination of the two samples overlapping particles where registered as one bigger particle. This gives distorted PSD results
	Scaling of pixels to SI unit mm
Light conditions case results in better reproducible color test results. Error margin of 10%.	Creation of a better sample environment
PCB electronics interfaces correctly with the ARM microcontroller	



Datum
5 juni 2015

Reference
xxxxxxxx

Version
Rev. A

Pagina
6 van 7



Figure 3 Embedded Microcontroller

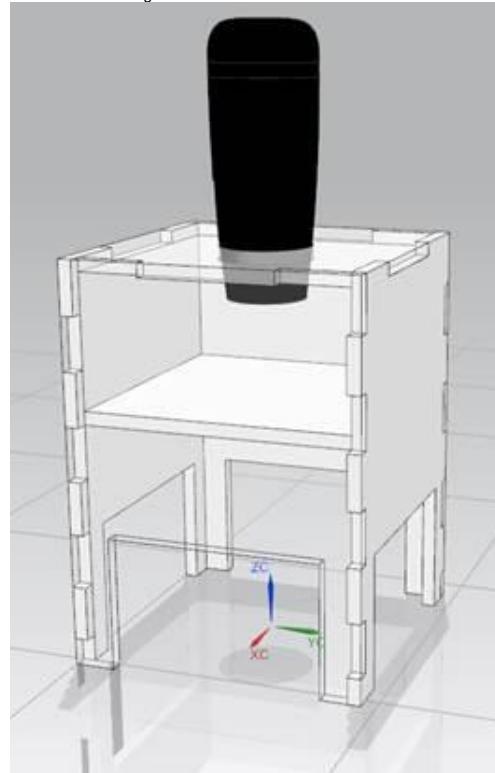


Figure 4 Light Environment Casing with Microscope

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Version
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Pagina
7 van 7

4 Release candidate

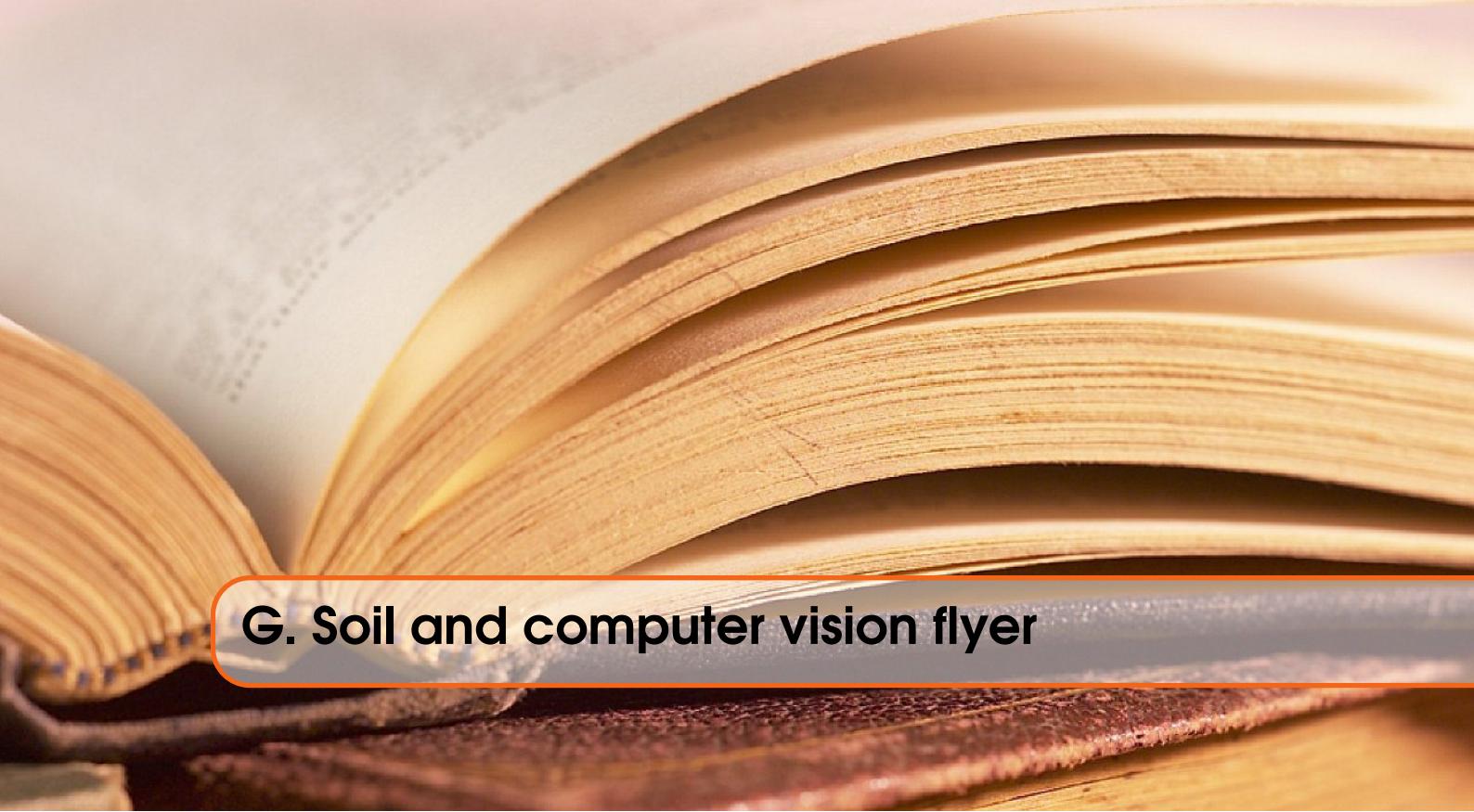
The goal of the future release candidate is to have a field ready device which is portable. The results are presented to the user using a generic HDMI monitor or can be download from the device in PDF format. These results fall in to a predefined and for a user acceptable error margin. The preliminary requirement below are an indication of possible requirements for a release candidate and are still subject to chance.

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 Distribution 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:

- 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.



G. Soil and computer vision flyer

Vision Soil Analyzer

Current status and fare sight

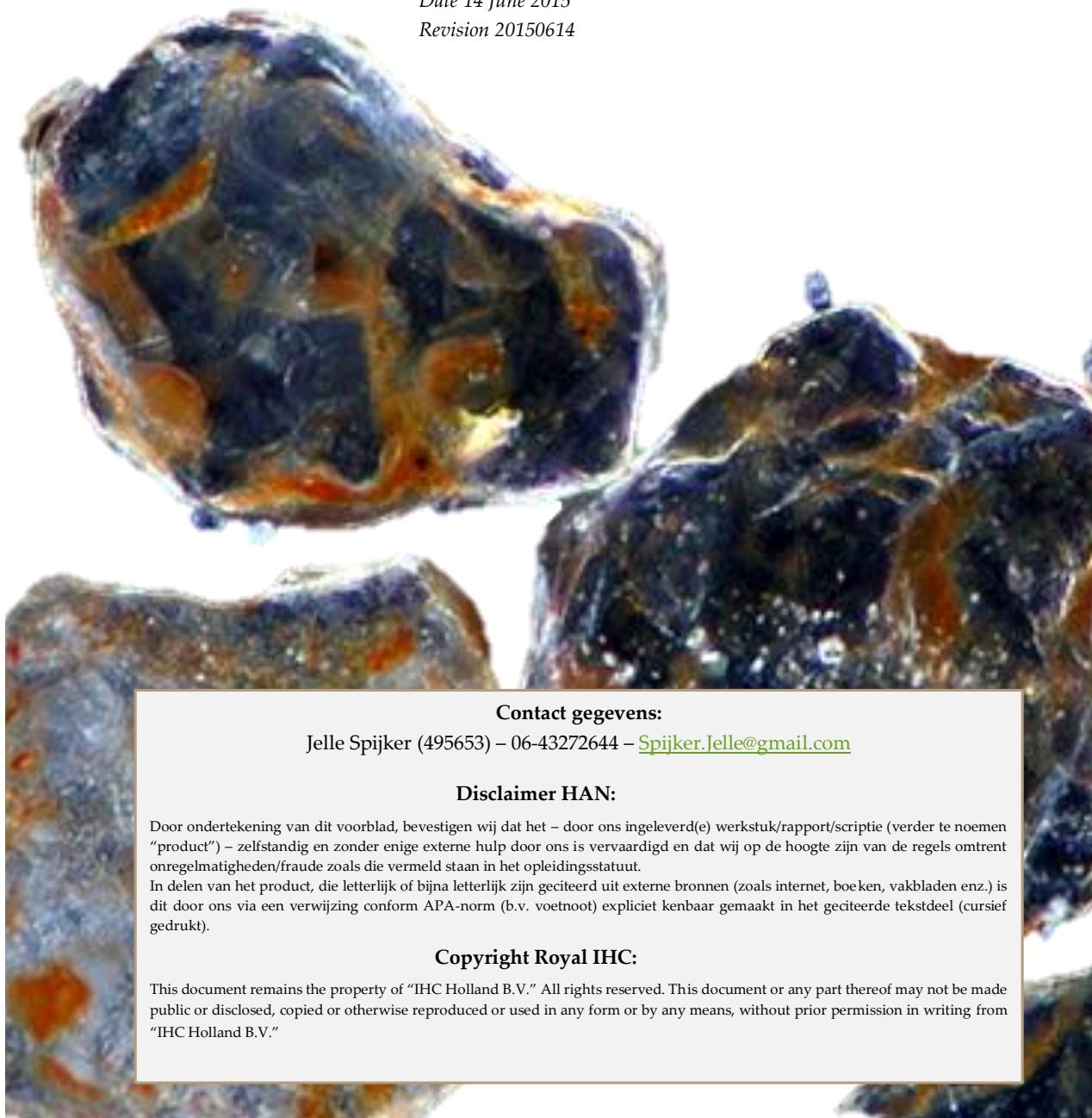
Client: Royal IHC – MTI Holland

Completion date: 15 juni 2015

Jelle Spijker

Date 14 June 2015

Revision 20150614



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TABLE OF CONTENT

TABLE OF CONTENT	2
1 INTRODUCTION.....	3
2 WORKING PRINCIPLE.....	5
3 VISION SOIL ANALYZER ALPHA.....	7
3.1 TECHNICAL SPECIFICATION	7
3.2 CHALLENGES TO OVERCOME.....	7
4 VISION SOIL ANALYZER BETA	8
4.1 TECHNICAL SPECIFICATION	8
4.2 CHALLENGES TO OVERCOME.....	8
5 THE RELEASE CANDIDATE.....	9
5.1 PRELIMINARY REQUIREMENTS.....	9
5.2 PROPOSED PROJECT SETUP	10
6 ROADMAP TO THE FUTURE.....	12
7 CONCLUSION.....	13
APPENDIX I. LITERATURE STUDY – SOIL AND IT'S OPTICAL PROPERTIES.....	14

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Page 2/14

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Soil and computer vision – Concept

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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.

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Page 3/14

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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.

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Page 4/14

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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

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.

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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 positioned, 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 thresholds separation.

The color information is determined with various matrix calculations, translating the RGB pixel value to 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 shown 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 be 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.

WORKFLOW

PARTICLE SEGMENTATION

COLOR

TEXTURE

STRUCTURE

USER INTERFACE

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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.



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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 and 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 to 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 Creator 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.

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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 or 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:

- Calculations are done in a time span of five minutes.
- Calculation are within an acceptable and predefined error margin
- Results of the Particle Size Distribution 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.



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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.

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- WTB
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.
 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.
- EI OR ESD

DIVISION OF LABOR

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.



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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

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Page 12/14

Revision 20150614

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7 Conclusion

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Page 13/14
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Appendix I. Literature study – Soil and it's optical properties

See external document

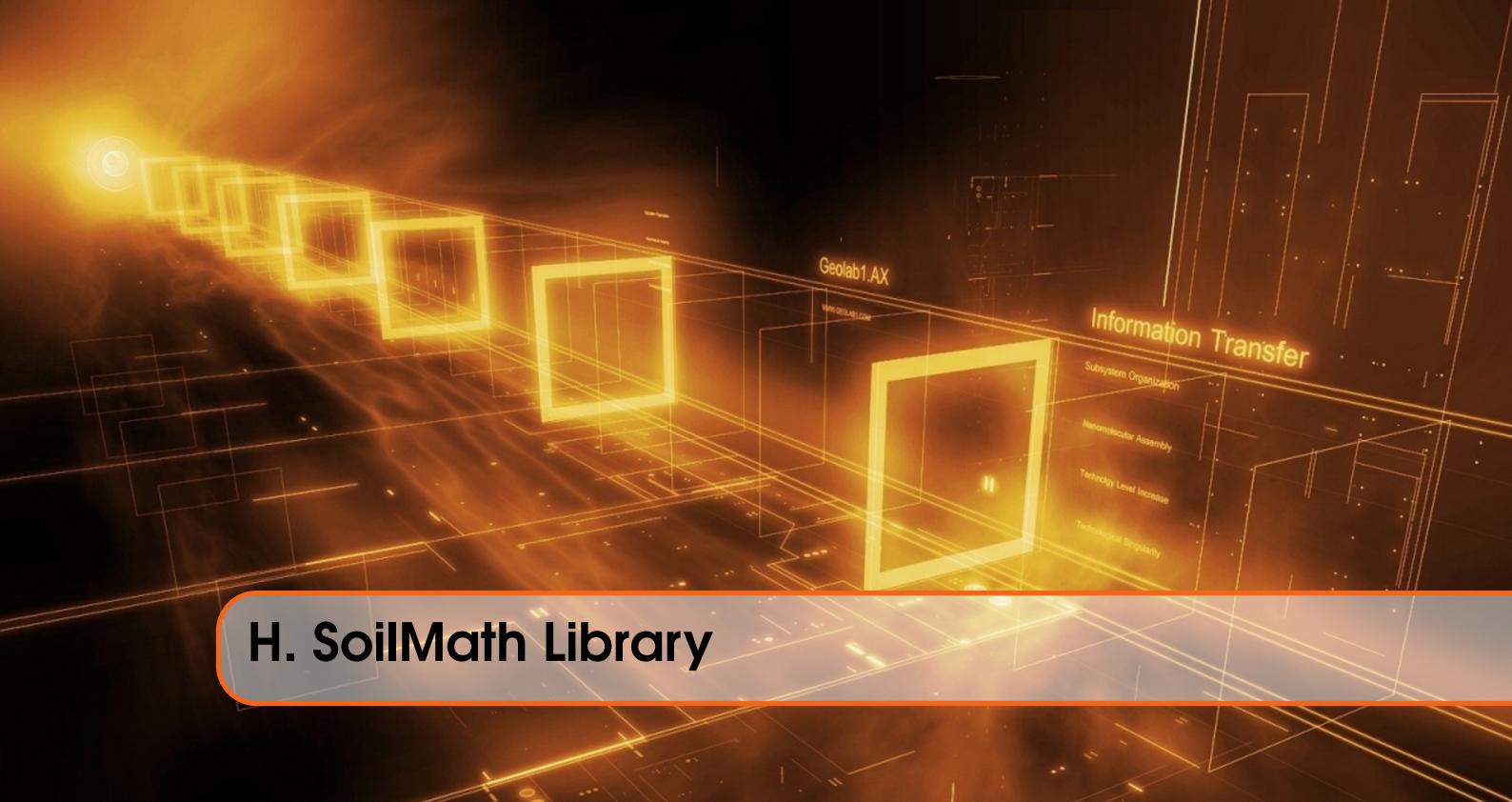
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Page 14/14

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H. SoilMath Library

Genetic Algorithm Class

```
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4   * and only allowed with the written consent of the author (
5   * Jelle Spijker)
6   * This software is proprietary and confidential
7   * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8   */
9
10  /**
11   * Use this class for optimization problems. It's currently
12   * optimized for
13   * Neural Network optimzation
14   */
15 #pragma once
16
17 #include <bitset>
18 #include <random>
19 #include <string>
20 #include <algorithm>
21 #include <chrono>
22 #include <math.h>
23 #include <list>
24
25 // #include "NN.h"
26 #include "SoilMathTypes.h"
27 #include "MathException.h"
28
29 #include <QtCore/QObject>
30 #include <QDebug>
```

```
29 #include <QThread>
30 #include <QtConcurrent>
31
32 #include <boost/bind.hpp>
33
34 namespace SoilMath {
35
36 class GA : public QObject {
37     Q_OBJECT
38
39 public:
40     float MutationRate = 0.075f; /*< mutation rate*/
41     uint32_t Elitisme = 4;           /*< total number of the
42                                     elite bastard*/
43     float EndError = 0.001f;         /*< acceptable error between
44                                     last itteration*/
45     bool Revolution = true;
46
47     /*!
48     * \brief GA Standard constructor
49     */
50     GA();
51
52     /*!
53     * \brief GA Construction with a Neural Network
54     * initializers
55     * \param nnfunction the Neural Network prediction
56     * function which results will
57     * be optimized
58     * \param inputneurons the number of input neurons in the
59     * Neural Network don't
60     * count the bias
61     * \param hiddenneurons the number of hidden neurons in
62     * the Neural Network
63     * don't count the bias
64     * \param outputneurons the number of output neurons in
65     * the Neural Network
66     */
67     GA(NNfunctionType nnfunction, uint32_t inputneurons,
68         uint32_t hiddenneurons,
69         uint32_t outputneurons);
70
71     /*!
72     * \brief GA standard de constructor
73     */
74     ~GA();
75
76     /*!
77     * \brief Evolve Darwin would be proud!!! This function
78     * creates a population
79     * and itterates
80     * through the generation till the maximum number off
81     * itterations has been
82     * reached of the
83     * error is acceptable
84     */
85 }
```

```

74     * \param inputValues complex vector with a reference to
75     * the inputvalues
76     * \param weights reference to the vector of weights which
77     * will be optimized
78     * \param rangeweights reference to the range of weights,
79     * currently it doesn't
80     * support individul ranges
81     * this is because of the crossing
82     * \param goal target value towards the Neural Network
83     * prediction function
84     * will be optimized
85     * \param maxGenerations maximum number of itterations
86     * default value is 200
87     * \param popSize maximum number of population, this
88     * should be an even number
89     */
90 void Evolve(const InputLearnVector_t &inputValues,
91             Weight_t &weights,
92             MinMaxWeight_t rangeweights,
93             OutputLearnVector_t &goal,
94             uint32_t maxGenerations = 200, uint32_t
95             popSize = 30);
96 signals:
97     void learnErrorUpdate(double newError);
98
99 private:
100    NNfunctionType NNfuction; /*< The Neural Net work
101        function*/
102    uint32_t inputneurons;    /*< the total number of input
103        neurons*/
104    uint32_t hiddenneurons;  /*< the total number of hidden
105        neurons*/
106    uint32_t outputneurons; /*< the total number of output
107        neurons*/
108
109    /*!
110     * \brief Genesis private function which is the spark of
111     * live, using a random
112     * seed
113     * \param weights a reference to the used Weight_t vector
114     * \param rangeweights pointer to the range of weights,
115     * currently it doesn't
116     * support individul ranges

```

```
114     * \param popSize maximum number of population, this
115     *      should be an even number
116     */
117 Population_t Genesis(const Weight_t &weights, uint32_t
118     popSize);
119 /**
120 * \brief CrossOver a private function where the partners
121 *      mate with each other
122 * The values or PopMember_t are expressed as bits or are
123 *      cut at the point
124 * Crossover
125 * the population members are paired with the nearest
126 *      neighbor and new members
127 * are
128 * created pairing the Genome_t of each other at the
129 *      crossover point.
130 * Afterwards all
131 * the top tiers partners are allowed to mate again.
132 * \param pop reference to the population
133 */
134 void CrossOver(Population_t &pop);
135 /**
136 * \brief Mutate a private function where individual bits
137 *      from the Genome_t
138 * are mutated
139 * at a random uniform distribution event defined by the
140 *      mutationrate
141 * \param pop reference to the population
142 */
143 void Mutate(Population_t &pop);
144 /**
145 * \brief GrowToAdulthood a private function where the new
146 *      population members
147 * serve as the
148 * the input for the Neural Network prediction function.
149 * The results are
150 * weight against
151 * the goal and this weight determine the fitness of the
152 *      population member
153 * \param pop reference to the population
154 * \param inputValues a InputLearnVector_t with a
155 *      reference to the inputvalues
156 * \param rangeweights pointer to the range of weights,
157 *      currently it doesn't
158 * support individual ranges
159 * \param goal a Predict_t type with the expected value
160 * \param totalFitness a reference to the total population
161 *      fitness
162 */
163 void GrowToAdulthood(Population_t &pop, float &
164     totalFitness);
```

```

155 	/*!
156 	* \brief SurvivalOfTheFittest a private function where a
157 	battle to the death
158 	* commences
159 	* The fittest population members have the best chance of
160 	survival. Death is
161 	* instigated
162 	* with a random uniform distribution. The elite members
163 	don't partake in this
164 	* destruction
165 	* The ELITISME rate indicate how many top tier members
166 	survive this
167 	* catastrophic event.
168 	* \param inputValues a InputLearnVector_t with a
169 	reference to the inputvalues
170 	* \param totalFitness a reference to the total population
171 	fitness
172 	* \return
173 	*\/
174 	bool SurvivalOfTheFittest(Population_t &pop, float &
175 	totalFitness);
176
177 	/*!
178 	* \brief PopMemberSort a private function where the
179 	members are sorted
180 	* according to
181 	* there fitness ranking
182 	* \param i left hand population member
183 	* \param j right hand population member
184 	* \return true if the left member is closer to the goal
185 	as the right member.
186 	*\/
187 	static bool PopMemberSort(PopMember_t i, PopMember_t j) {
188 	return (i.Fitness < j.Fitness);
189 }
190
191 	/*!
192 	* \brief Conversion of the value of type T to Genome_t
193 	* \details Usage: Use <tt>ConvertToGenome<Type>(type,
194 	range)</tt>
195 	* \param value The current value which should be converted
196 	to a Genome_t
197 	* \param range the range in which the value should fall,
198 	this is to have a
199 	* Genome_t
200 	* which utilizes the complete range 0000...n till 1111...
201 	n
202 	*\/
203 	template <typename T>
204 	inline Genome_t ConvertToGenome(T value, std::pair<T, T>
205 	range) {
206 	uint32_t intVal = static_cast<uint32_t>(
207 	(UINT32_MAX * (range.first + value)) / (range.second
208 	- range.first));
209 	Genome_t retVal(intVal);
210 	return retVal;
211 }
```

```

196     }
197
198     /*!
199      * \brief Conversion of the Genome to a value
200      * \details Usage: use <tt>ConvertToValue<Type>(genome,
201      * range)
202      * \param gen is the Genome which is to be converted
203      * \param range is the range in which the value should
204      * fall
205      */
206     template <typename T>
207     inline T ConvertToValue(Genome_t gen, std::pair<T, T>
208     range) {
209     T retVal =
210         range.first +
211         (((range.second - range.first) * static_cast<T>(gen.
212             to_ulong()))) /
213         (UINT32_MAX);
214     return retVal;
215 }
216 };
217 }
218 }



---


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3  * strictly prohibited
4  * and only allowed with the written consent of the author (
5  * Jelle Spijker)
6  * This software is proprietary and confidential
7  * Written by Jelle Spijker <spijkert.jelle@gmail.com>, 2015
8  */
9
8 #include "GA.h"
9
10 namespace SoilMath {
11 GA::GA() {}
12
13 GA::GA(NNfunctionType nnfunction, uint32_t inputneurons,
14         uint32_t hiddenneurons,
15         uint32_t outputneurons) {
16     this->NNfunction = nnfunction;
17     this->inputneurons = inputneurons;
18     this->hiddenneurons = hiddenneurons;
19     this->outputneurons = outputneurons;
20 }
21
21 GA::~GA() {}
22
23 void GA::Evolve(const InputLearnVector_t &inputValues,
24                   Weight_t &weights,
25                   MinMaxWeight_t rangeweights,
26                   OutputLearnVector_t &goal,
27                   uint32_t maxGenerations, uint32_t popSize) {
28     minOptim = goal[0].OutputNeurons.size();
29     minOptim = -minOptim;
30     maxOptim = 2 * goal[0].OutputNeurons.size();

```

```

29     oldElit = Elitisme;
30     oldMutation = MutationRate;
31     this->inputValues = inputValues;
32     this->rangeweights = rangeweights;
33     this->goal = goal;
34
35     // Create the population
36     Population_t pop = Genesis(weights, popSize);
37     float totalFitness = 0.0;
38     for (uint32_t i = 0; i < maxGenerations; i++) {
39         CrossOver(pop);
40         Mutate(pop);
41         totalFitness = 0.0;
42         GrowToAdulthood(pop, totalFitness);
43         if (SurvivalOfTheFittest(pop, totalFitness)) {
44             break;
45         }
46     }
47     weights = pop[0].weights;
48 }
49
50 Population_t GA::Genesis(const Weight_t &weights, uint32_t
51     popSize) {
52     if (popSize < 1)
53         return Population_t();
54
55     Population_t pop;
56     unsigned seed = std::chrono::system_clock::now().
57         time_since_epoch().count();
58     std::default_random_engine gen(seed);
59     std::uniform_real_distribution<float> dis(rangeweights.
60         first,
61                                         rangeweights.
62                                         second);
63
64     for (uint32_t i = 0; i < popSize; i++) {
65         PopMember_t I;
66         for (uint32_t j = 0; j < weights.size(); j++) {
67             I.weights.push_back(dis(gen));
68             I.weightsGen.push_back(
69                 ConvertToGenome<float>(I.weights[j], rangeweights)
70             );
71         }
72         pop.push_back(I);
73     }
74     return pop;
75 }
76
77 void GA::CrossOver(Population_t &pop) {
78     Population_t newPop; // create a new population
79     PopMember_t newPopMembers[2];
80     SplitGenome_t Split[2];
81
82     for (uint32_t i = 0; i < pop.size(); i += 2) {
83         for (uint32_t j = 0; j < pop[i].weights.size(); j++) {

```

```

80     // Split A
81     Split[0].first = std::bitset<CROSSOVER>(
82         pop[i].weightsGen[j].to_string().substr(0,
83             CROSSOVER));
83     Split[0].second = std::bitset<GENE_MAX - CROSSOVER>(
84         pop[i].weightsGen[j].to_string().substr(CROSSOVER,
85             GENE_MAX -
86
87             CROSSOVER
88             ));
89
90     // Split B
91     Split[1].first = std::bitset<CROSSOVER>(
92         pop[i + 1].weightsGen[j].to_string().substr(0,
93             CROSSOVER));
94     Split[1].second = std::bitset<GENE_MAX - CROSSOVER>(
95         pop[i + 1].weightsGen[j].to_string().substr(
96             CROSSOVER,
97             GENE_MAX -
98
99             CROSSOVER
100            ));
101
102     // Mate A and B to AB and BA
103     newPopMembers[0].weightsGen.push_back(
104         Genome_t(Split[0].first.to_string() + Split[1] .
105             second.to_string()));
106     newPopMembers[1].weightsGen.push_back(
107         Genome_t(Split[1].first.to_string() + Split[0] .
108             second.to_string()));
109
110     newPop.push_back(newPopMembers[0]);
111     newPop.push_back(newPopMembers[1]);
112     newPopMembers[0].weightsGen.clear();
113     newPopMembers[1].weightsGen.clear();
114 }
115
116     // Allow the top tiers population partners to mate again
117     uint32_t halfN = pop.size() / 2;
118     for (uint32_t i = 0; i < halfN; i++) {
119         for (uint32_t j = 0; j < pop[i].weights.size(); j++) {
120             Split[0].first = std::bitset<CROSSOVER>(
121                 pop[i].weightsGen[j].to_string().substr(0,
122                     CROSSOVER));
123             Split[0].second = std::bitset<GENE_MAX - CROSSOVER>(
124                 pop[i].weightsGen[j].to_string().substr(CROSSOVER,
125                     GENE_MAX -
126
127                     CROSSOVER
128                     ));
129
130             Split[1].first = std::bitset<CROSSOVER>(
131                 pop[i + 2].weightsGen[j].to_string().substr(0,
132                     CROSSOVER));
133             Split[1].second = std::bitset<GENE_MAX - CROSSOVER>(

```



```

161     Weight_t hWeight(P.weights.begin() + ((inputneurons + 1)
162                         * hiddenneurons),
163                         P.weights.end());
164
165     for (uint32_t j = 0; j < inputValues.size(); j++) {
166         Predict_t results = NNfunction(inputValues[j], iWeight,
167                                         hWeight,
168                                         inputneurons,
169                                         hiddenneurons,
170                                         outputneurons);
171
172         // See issue #85
173         bool allGood = true;
174         float fitness = 0.0;
175         for (uint32_t k = 0; k < results.OutputNeurons.size();
176              k++) {
177             bool resultSign = std::signbit(results.OutputNeurons
178                                           [k]);
179             bool goalSign = std::signbit(goal[j].OutputNeurons[k
180                                           ]);
181             fitness += results.OutputNeurons[k] / goal[j].
182                         OutputNeurons[k];
183             if (resultSign != goalSign) {
184                 allGood = false;
185             }
186         }
187         fitness += (allGood) ? results.OutputNeurons.size() :
188                         0;
189         P.Fitness += fitness;
190     }
191 }
192
193 for_each(pop.begin(), pop.end(), [&](PopMember_t &P) {
194     P.Fitness /= inputValues.size();
195     totalFitness += P.Fitness;
196 });
197
198 bool GA::SurvivalOfTheFittest(Population_t &pop, float &
199                                 totalFitness) {
200     bool retVal = false;
201     uint32_t decimationCount = pop.size() / 2;
202
203     unsigned seed = std::chrono::system_clock::now().
204                     time_since_epoch().count();
205     std::default_random_engine gen(seed);
206
207     std::sort(pop.begin(), pop.end(),
208               [](&const PopMember_t &L, &const PopMember_t &R) {
209                 return L.Fitness < R.Fitness;
210             });
211
212     float maxFitness = pop[pop.size() - 1].Fitness * pop.size
213                         ();
214     uint32_t i = Elitisme;
215     while (pop.size() > decimationCount) {
216         if (i == pop.size()) {

```

```

205         i = Elitisme;
206     }
207     std::uniform_real_distribution<float> dis(0, maxFitness)
208         ;
208     if (dis(gen) > pop[i].Fitness) {
209         totalFitness -= pop[i].Fitness;
210         pop.erase(pop.begin() + i);
211     }
212     i++;
213 }
214
215 std::sort(pop.begin(), pop.end(),
216           [](const PopMember_t &L, const PopMember_t &R) {
217               return L.Fitness > R.Fitness;
218           });
219
220 float learnError = 1 - ((pop[0].Fitness - minOptim) / (
221     maxOptim - minOptim));
221
222 // Viva la Revolution
223 if (currentGeneration > 9) {
224     double avg = 0;
225     for_each(last10Gen.begin(), last10Gen.end(), [&](double
226                 &G) { avg += G; });
226     avg /= 10;
227     double minMax[2] = {avg * 0.98, avg * 1.02};
228     if (learnError > minMax[0] && learnError < minMax[1]) {
229         if (!revolutionOngoing) {
230             qDebug() << "Viva la revolution!";
231             oldElit = Elitisme;
232             Elitisme = 0;
233             oldMutation = MutationRate;
234             MutationRate = 0.25;
235             revolutionOngoing = true;
236         }
237     } else if (revolutionOngoing) {
238         qDebug() << "Peace has been restart";
239         Elitisme = oldElit;
240         MutationRate = oldMutation;
241         revolutionOngoing = false;
242     }
243     last10Gen.pop_front();
244     last10Gen.push_back(learnError);
245 } else {
246     last10Gen.push_back(learnError);
247 }
248 currentGeneration++;
249 emit learnErrorUpdate(static_cast<double>(learnError));
250 if (learnError < EndError) {
251     retVal = true;
252 }
253 return retVal;
254 }
255 }

```

Fast Fourier Transform Class

```

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6   * This software is proprietary and confidential
7   * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8   */
9
10 #pragma once
11
12 #include <vector>
13 #include <complex>
14 #include <cmath>
15 #include <valarray>
16 #include <array>
17 #include <deque>
18 #include <queue>
19 #include <iterator>
20 #include <algorithm>
21 #include <stdint.h>
22 #include <opencv2/core.hpp>
23 #include "SoilMathTypes.h"
24 #include "MathException.h"
25
26 namespace SoilMath {
27 /*!
28  * \brief Fast Fourier Transform class
29  * \details Use this class to transform a black and white
30  * blob presented as a
31  * cv::Mat with values 0 or 1 to a vector of complex values
32  * representing the Fourier
33  * Descriptors.
34  */
35
36 class FFT {
37 public:
38 /*!
39  * \brief Standard constructor
40  */
41 FFT();
42
43 /*!
44  * \brief Transforming the img to the frequency domain and
45  * returning the
46  * Fourier Descriptors
47  * \param img contour in the form of a cv::Mat type
48  * CV_8UC1. Which should
49  * consist of a continous contour. \f$ \{ img \in \mathbb{Z} \} | 0 \leq img \leq

```

```

48     * 1 \} \f$  

49     * \return a vector with complex values, represing the  

50     * contour in the  

51     * frequency domain, expressed as Fourier Descriptors  

52     */  

53     ComplexVect_t GetDescriptors(const cv::Mat &img);  

54  

55     private:  

56     ComplexVect_t  

57     fftDescriptors; /*< Vector with complex values which  

58     * represent the  

59     * descriptors*/  

60     ComplexVect_t  

61     complexcontour; /*< Vector with complex values which  

62     * represent the  

63     * contour*/  

64     cv::Mat Img;           /*< Img which will be analysed*/  

65  

66     /*!  

67     * \brief Contour2Complex a private function which  

68     * translates a continous  

69     * contour image  

70     * to a vector of complex values. The contour is found  

71     * using a depth first  

72     * search with  

73     * extension list. The alghorithm is based upon <a  

74     * href="http://ocw.mit.edu/courses/electrical-engineering  

75     -and-computer-science/6-034-artificial-intelligence-  

76     -fall-2010/lecture-videos/lecture-4-search-depth-first-  

77     hill-climbing-beam/">MIT  

78     * opencourseware  

79     * 6-034-artificial-intelligence lecture 4</a>  

80     * \param img contour in the form of a cv::Mat type  

81     * CV_8UC1. Which should  

82     * consist of a continous contour. \f$ \{ img \in \mathbb{C} :  

83     * |Z| \leq 0 \leq img \leq  

84     * 1 \} \f$  

85     * \param centerCol centre of the contour X value  

86     * \param centerRow centre of the contour Y value  

87     * \return a vector with complex values, represing the  

88     * contour as a function  

89     */  

90     ComplexVect_t Contour2Complex(const cv::Mat &img, float  

91     centerCol,  

92     centerRow);  

93  

94     /*!  

95     * \brief Neighbors a private function returning the  

96     * neighboring pixels which  

97     * belong to a contour  

98     * \param 0 uchar pointer to the data  

99     * \param pixel current counter  

100    * \param columns total number of columns  

101    * \param rows total number of rows  

102    * \return  

103    */  


```

```

90     iContour_t Neighbors(uchar *0, int pixel, uint32_t columns
91                         , uint32_t rows);
92
93     /*!
94      * \brief fft a private function calculating the Fast
95      * Fourier Transform
96      * let \f$ m \f$ be an integer and let \f$ N=2^m \f$ also
97      * \f$ CA=[x_0,\ldots,x_{N-1}] \f$ is an \f$ N \f$-
98      * dimensional complex vector
99      * let \f$ \omega=\exp(-2\pi i/N) \f$ and \f$ c_k=\sum_{j=0}^{N-1} CA_j \omega^{jk} \f$-
100     * then \f$ c_k=\frac{1}{N} \sum_{j=0}^{N-1} CA_j \omega^{jk} \f$-
101     * \param CA a \f$ CA=[x_0,\ldots,x_{N-1}] \f$ is an \f$ N \f$-
102     * dimensional
103     * complex vector
104     */
105     void fft(ComplexArray_t &CA);
106
107     /*!
108      * \brief ifft
109      * \param CA
110      */
111     void ifft(ComplexArray_t &CA);
112 };
113 }
```

```

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7  * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8  */
9
10 #include "FFT.h"
11
12 namespace SoilMath {
13 FFT::FFT() {}
14 FFT::~FFT() {}
15 ComplexVect_t FFT::GetDescriptors(const cv::Mat &img) {
16     if (!fftDescriptors.empty()) {
17         return fftDescriptors;
18     }
19
20     complexcontour = Contour2Complex(img, img.cols / 2, img.
21                                     rows / 2);
22
23     // Supplement the vector of complex numbers so that N = 2^
24     // m
25     uint32_t N = complexcontour.size();
26     double logN = log(static_cast<double>(N)) / log(2.0);
27     if (floor(logN) != logN) {
28         // Get the next power of 2
29     }
30 }
```

```

27     double nextLogN = floor(logN + 1.0);
28     N = static_cast<uint32_t>(pow(2, nextLogN));
29
30     uint32_t i = complexcontour.size();
31     // Append the vector with zeros
32     while (i++ < N) {
33         complexcontour.push_back(Complex_t(0.0, 0.0));
34     }
35 }
36
37 ComplexArray_t ca(complexcontour.data(), complexcontour.
38     size());
39 fft(ca);
40 fftDescriptors.assign(std::begin(ca), std::end(ca));
41 return fftDescriptors;
42
43 iContour_t FFT::Neighbors(uchar *0, int pixel, uint32_t
44     columns,
45     uint32_t rows) {
46     long int LUT_nBore[8] = {-columns + 1, -columns, -columns
47     - 1, -1,
48     columns - 1, columns, 1 +
49     columns, 1};
50     iContour_t neighbors;
51     uint32_t pEnd = rows * columns;
52     uint32_t count = 0;
53     for (uint32_t i = 0; i < 8; i++) {
54         count = pixel + LUT_nBore[i];
55         while (count >= pEnd && i < 8) {
56             count = pixel + LUT_nBore[++i];
57         }
58         if (i >= 8) {
59             break;
60         }
61         if (0[count] == 1)
62             neighbors.push_back(count);
63     }
64     return neighbors;
65 }
66
67 ComplexVect_t FFT::Contour2Complex(const cv::Mat &img, float
68     centerCol,
69     float centerRow) {
70     uchar *0 = img.data;
71     uint32_t pEnd = img.cols * img.rows;
72
73     std::deque<std::deque<uint32_t>> sCont;
74     std::deque<uint32_t> eList;
75
76     // Initialize the queue
77     for (uint32_t i = 0; i < pEnd; i++) {
78         if (0[i] == 1) {
79             std::deque<uint32_t> tmpQ;
80             tmpQ.push_back(i);
81             sCont.push_back(tmpQ);
82         }
83     }
84
85     while (!sCont.empty()) {
86         std::deque<uint32_t> &tmpQ = sCont.front();
87         uint32_t i = tmpQ.back();
88         sCont.pop_front();
89
90         for (int j = 0; j < 8; j++) {
91             int n = i + LUT_nBore[j];
92             if (n < 0 || n >= pEnd)
93                 continue;
94             if (0[n] == 1) {
95                 0[n] = 0;
96                 eList.push_back(n);
97             }
98         }
99     }
100
101    std::swap(sCont, eList);
102
103    ComplexVect_t result;
104    result.reserve(eList.size());
105    for (uint32_t i : eList)
106        result.push_back(Complex_t((centerCol - centerRow) * i));
107
108    return result;
109 }

```

```

78         break;
79     }
80 }
81
82 if (sCont.front().size() < 1) {
83     throw Exception::MathException(
84         EXCEPTION_NO_CONTOUR_FOUND,
85         EXCEPTION_NO_CONTOUR_FOUND_NR
86     );
87 } // Exception handling
88
89 uint32_t prev = -1;
90
91 // Extend path on queue
92 for (uint32_t i = sCont.front().front(); i < pEnd;) {
93     iContour_t nBors =
94         Neighbors(0, i, img.cols, img.rows); // find
95         neighboring pixels
96     std::deque<uint32_t> cQ = sCont.front(); // store first
97         queue;
98     sCont.erase(sCont.begin()); // erase first
99         queue from beginning
100    if (cQ.size() > 1) {
101        prev = cQ.size() - 2;
102    } else {
103        prev = 0;
104    }
105    // Loop through each neighbor
106    for (uint32_t j = 0; j < nBors.size(); j++) {
107        if (nBors[j] != cQ[prev]) // No backtracking
108        {
109            if (nBors[j] == cQ.front() && cQ.size() > 8) {
110                i = pEnd;
111            } // Back at first node
112            if (std::find(eList.begin(), eList.end(), nBors[j]) ==
113                eList.end()) // Check if this current route is
114                extended elsewhere
115            {
116                std::deque<uint32_t> nQ = cQ;
117                nQ.push_back(nBors[j]); // Add the neighbor to the
118                queue
119                sCont.push_front(nQ); // add the sequence to the
120                front of the queue
121            }
122        }
123    }
124 }
125
126 if (nBors.size() > 2) {
127     eList.push_back(i);
128 } // if there are multiple choices put current node in
129     extension List
130 if (i != pEnd) {
131     i = sCont.front().back();
132 } // If it isn't the end set i to the last node of the
133     first queue
134 if (sCont.size() == 0) {

```

```

123     throw Exception::MathException(
124         EXCEPTION_NO_CONTOUR_FOUND,
125         EXCEPTION_NO_CONTOUR_FOUND_NR
126     );
127 }
128 // convert the first queue to a complex normalized vector
129 Complex_t cPoint;
130 ComplexVect_t contour;
131 float col = 0.0;
132 // Normalize and convert the complex function
133 for_each(
134     sCont.front().begin(), sCont.front().end(),
135     [&img, &cPoint, &contour, &centerCol, &centerRow, &col
136         ](uint32_t &e) {
137     col = (float)((e % img.cols) - centerCol);
138     if (col == 0.0) {
139         cPoint.real(1.0);
140     } else {
141         cPoint.real((float)(col / centerCol));
142     }
143     cPoint.imag((float)((floorf(e / img.cols) -
144         centerRow) / centerRow));
145     contour.push_back(cPoint);
146 });
147 }
148
149 void FFT::fft(ComplexArray_t &CA) {
150     const size_t N = CA.size();
151     if (N <= 1) {
152         return;
153     }
154
155     //!< Divide and conquer
156     ComplexArray_t even = CA[std::slice(0, N / 2, 2)];
157     ComplexArray_t odd = CA[std::slice(1, N / 2, 2)];
158
159     fft(even);
160     fft(odd);
161
162     for (size_t k = 0; k < N / 2; ++k) {
163         Complex_t ct = std::polar(1.0, -2 * M_PI * k / N) * odd[
164             k];
165         CA[k] = even[k] + ct;
166         CA[k + N / 2] = even[k] - ct;
167     }
168
169 void FFT::ifft(ComplexArray_t &CA) {
170     CA = CA.apply(std::conj);
171     fft(CA);
172     CA = CA.apply(std::conj);
173     CA /= CA.size();

```

```
174  }
175  }
```

Neural Network Class

```

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8   */
9
10 #pragma once
11
12 #include <stdint.h>
13 #include <vector>
14 #include <string>
15 #include <fstream>
16 #include <boost/archive/xml_iarchive.hpp>
17 #include <boost/archive/xml_oarchive.hpp>
18 #include <boost/serialization/vector.hpp>
19 #include <boost/serialization/version.hpp>
20
21 #include "GA.h"
22 #include "MathException.h"
23 #include "SoilMathTypes.h"
24 #include "FFT.h"
25
26 #include <QtCore/QObject>
27
28 namespace SoilMath {
29 /*!
30  * \brief The Neural Network class
31  * \details This class is used to make prediction on large
32  * data set. Using self
33  * learning algoritmes
34  */
35 class NN : public QObject {
36     Q_OBJECT
37
38 public:
39 /*!
40  * \brief NN constructor for the Neural Net
41  * \param inputneurons number of input neurons
42  * \param hiddenneurons number of hidden neurons
43  * \param outputneurons number of output neurons
44  */
45     NN(uint32_t inputneurons, uint32_t hiddenneurons, uint32_t
46         outputneurons);
47
48     NN();
49
50 /*!

```

```

51     * \brief ~NN virtual deconstructor for the Neural Net
52     */
53     virtual ~NN();
54
55     /*!
56     * \brief Predict The prediction function.
57     * \details In this function the neural net is setup and
58     * the input which are
59     * the complex values descriping the contour in the
60     * frequency domein serve as
61     * input. The absolute value of these im. number because I
62     * 'm not interrested
63     * in the orrientation of the particle but more in the
64     * degree of variations.
65     * \param input vector of complex input values, these're
66     * the Fourier
67     * descriptors
68     * \return a real valued vector of the output neurons
69     */
70     Predict_t Predict(ComplexVect_t input);
71
72     /*!
73     * \brief PredictLearn a static function used in learning
74     * of the weights
75     * \details It starts a new Neural Network object and
76     * passes all the
77     * paramaters in to this newly created object. After this
78     * the predict function
79     * is called and the value is returned. This work around
80     * was needed to pass
81     * the neural network to the Genetic Algorithm class.
82     * \param input a complex vector of input values
83     * \param inputweights the input weights
84     * \param hiddenweights the hidden weights
85     * \param inputneurons the input neurons
86     * \param hiddenneurons the hidden neurons
87     * \param outputneurons the output neurons
88     * \return
89     */
90     static Predict_t PredictLearn(ComplexVect_t input,
91         Weight_t inputweights,
92                     Weight_t hiddenweights,
93                     uint32_t inputneurons,
94                     uint32_t hiddenneurons,
95                     uint32_t outputneurons);
96
97     /*!
98     * \brief SetInputWeights a function to set the input
99     * weights
100    * \param value the real valued vector with the values
101    */
102    void SetInputWeights(Weight_t value) { iWeights = value; }
103
104    /*!
105     * \brief SetHiddenWeights a function to set the hidden
106     * weights

```

```

93     * \param value the real valued vector with the values
94     */
95     void SetHiddenWeights(Weight_t value) { hWeights = value;
96     }
97 /**
98     * \brief SetBeta a function to set the beta value
99     * \param value a floating value usually between 0.5 and
100    1.5
101   */
102  void SetBeta(float value) { beta = value; }
103  float GetBeta() { return beta; }
104 /**
105  * \brief Learn the learning function
106  * \param input a vector of vectors with complex input
107  values
108  * \param cat a vector of vectors with the know output
109  values
110  * \param noOfDescriptorsUsed the total number of
111  descriptors which should be
112  * used
113  */
114  void Learn(InputLearnVector_t input, OutputLearnVector_t
115  cat,
116  uint32_t noOfDescriptorsUsed);
117 /**
118  * \brief SaveState Serialize and save the values of the
119  Neural Net to disk
120  * \details Save the Neural Net in XML valued text file to
121  disk so that a
122  * object can
123  * be reconstructed on a latter stadia.
124  * \param filename a string indicating the file location
125  and name
126  */
127  void SaveState(std::string filename);
128 /**
129  * \brief LoadState Loads the previous saved Neural Net
130  from disk
131  * \param filename a string indicating the file location
132  and name
133  */
134  void LoadState(std::string filename);
135
136 Weight_t iWeights; /**< a vector of real valued floating
137  point input weights*/
138 Weight_t hWeights; /**< a vector of real valued floating
139  point hidden weight*/
140
141 uint32_t MaxGenUsedByGA = 200;
142 uint32_t PopulationSizeUsedByGA = 30;
143 float MutationrateUsedByGA = 0.075f;
144 uint32_t ElitismeUsedByGA = 4;

```

```

136     float EndErrorUsedByGA = 0.001;
137     float MaxWeightUsedByGA = 50;
138     float MinWeightUsedByGA = -50;
139
140     uint32_t GetInputNeurons() { return inputNeurons; }
141     void SetInputNeurons(uint32_t value);
142
143     uint32_t GetHiddenNeurons() { return hiddenNeurons; }
144     void SetHiddenNeurons(uint32_t value);
145
146     uint32_t GetOutputNeurons() { return outputNeurons; }
147     void SetOutputNeurons(uint32_t value);
148
149     bool studied =
150         false; /*< a value indicating if the weights are a
151             results of a
152                 learning curve*/
153
154     signals:
155         void learnErrorUpdate(double newError);
156
157     private:
158         GA *optim = nullptr;
159         std::vector<float> iNeurons; /*< a vector of input values
160             , the bias is
161                 included, the bias is
162                     included and
163                         is the first value*/
164         std::vector<float>
165             hNeurons; /*< a vector of hidden values, the bias is
166                 included and
167                     is the first value*/
168         std::vector<float> oNeurons; /*< a vector of output
169             values*/
170
171         uint32_t hiddenNeurons = 50; /*< number of hidden neurons
172             minus bias*/
173         uint32_t inputNeurons = 20; /*< number of input neurons
174             minus bias*/
175         uint32_t outputNeurons = 18; /*< number of output neurons
176             */
177         float beta; /*< the beta value, this indicates the
178             steepness of the sigmoid
179                 function*/
180
181     friend class boost::serialization::access; /*< a private
182             friend class so the
183                 serialization
184                     can
185                         access
186                             all
187                                 the needed
188                                     functions
189                                     */
190
191     /*!
192     * \brief serialization function

```

```

177     * \param ar the object
178     * \param version the version of the class
179     */
180     template <class Archive>
181     void serialize(Archive &ar, const unsigned int version) {
182         if (version == 0) {
183             ar &BOOST_SERIALIZATION_NVP(inputNeurons);
184             ar &BOOST_SERIALIZATION_NVP(hiddenNeurons);
185             ar &BOOST_SERIALIZATION_NVP(outputNeurons);
186             ar &BOOST_SERIALIZATION_NVP(iWeights);
187             ar &BOOST_SERIALIZATION_NVP(hWeights);
188             ar &BOOST_SERIALIZATION_NVP(beta);
189             ar &BOOST_SERIALIZATION_NVP(studied);
190             ar &BOOST_SERIALIZATION_NVP(MaxGenUsedByGA);
191             ar &BOOST_SERIALIZATION_NVP(PopulationSizeUsedByGA);
192             ar &BOOST_SERIALIZATION_NVP(MutationrateUsedByGA);
193             ar &BOOST_SERIALIZATION_NVP(ElitismeUsedByGA);
194             ar &BOOST_SERIALIZATION_NVP(EndErrorUsedByGA);
195             ar &BOOST_SERIALIZATION_NVP(MaxWeightUsedByGA);
196             ar &BOOST_SERIALIZATION_NVP(MinWeightUsedByGA);
197         }
198     }
199 }
200 }
201 BOOST_CLASS_VERSION(SoilMath::NN, 0)

```

```

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8  */
9
10
11 #include "NN.h"
12 using namespace std;
13
14 namespace SoilMath {
15 NN::NN() { beta = 0.666; }
16
17 NN::NN(uint32_t inputneurons, uint32_t hiddenneurons,
18         uint32_t outputneurons) {
19     // Set the number of neurons in the network
20     inputNeurons = inputneurons;
21     hiddenNeurons = hiddenneurons;
22     outputNeurons = outputneurons;
23     // Reserve the vector space
24     iNeurons.reserve(inputNeurons + 1); // input neurons +
25     bias
26     hNeurons.reserve(hiddenNeurons + 1); // hidden neurons +
27     bias
28     oNeurons.reserve(outputNeurons); // output neurons
29
30     beta = 0.666;
31 }

```



```

74     Predict_t retVal;
75     uint32_t wCount = 0;
76
77     // Init the network
78     for (uint32_t i = 0; i < inputNeurons; i++) {
79         iNeurons.push_back(static_cast<float>(abs(input[i])));
80     }
81     for (uint32_t i = 0; i < hiddenNeurons; i++) {
82         hNeurons.push_back(0.0f);
83     }
84     for (uint32_t i = 0; i < outputNeurons; i++) {
85         oNeurons.push_back(0.0f);
86     }
87
88     for (uint32_t i = 1; i < hNeurons.size(); i++) {
89         wCount = i - 1;
90         for (uint32_t j = 0; j < iNeurons.size(); j++) {
91             hNeurons[i] += iNeurons[j] * iWeights[wCount];
92             wCount += hNeurons.size() - 1;
93         }
94         hNeurons[i] = 1 / (1 + pow(2.71828f, (-hNeurons[i] *
95             beta)));
96     }
97
98     for (uint32_t i = 0; i < oNeurons.size(); i++) {
99         wCount = i;
100        for (uint32_t j = 0; j < hNeurons.size(); j++) {
101            oNeurons[i] += hNeurons[j] * hWeights[wCount];
102            wCount += oNeurons.size();
103        }
104        oNeurons[i] =
105            (2 / (1.0f + pow(2.71828f, (-oNeurons[i] * beta)))
106            -
107            1; // Shift plus scale so the learning function can
108            be calculated
109    }
110
111    retVal.OutputNeurons = oNeurons;
112    retVal.ManualSet = false;
113    return retVal;
114 }
115
116 void NN::Learn(InputLearnVector_t input, OutputLearnVector_t
117                 cat,
118                 uint32_t noOfDescriptorsUsed __attribute__((
119                 unused))) {
120     if (optim == nullptr) {
121         optim = new SoilMath::GA(PredictLearn, inputNeurons,
122             hiddenNeurons, outputNeurons);
123     }
124     connect(optim, SIGNAL(learnErrorUpdate(double)), this,
125             SIGNAL(learnErrorUpdate(double)));
126
127     optim->Elitisme = ElitismeUsedByGA;
128     optim->EndError = EndErrorUsedByGA;
129     optim->MutationRate = MutationrateUsedByGA;

```

```
123
124     ComplexVect_t inputTest;
125     std::vector<Weight_t> weights;
126     Weight_t weight(((inputNeurons + 1) * hiddenNeurons) +
127                         ((hiddenNeurons + 1) * outputNeurons),
128                         0);
129     // loop through each case and adjust the weights
130     optim->Evolve(input, weight,
131                     MinMaxWeight_t(MinWeightUSedByGa,
132                                     MaxWeightUsedByGA), cat,
133                                     MaxGenUsedByGA, PopulationSizeUsedByGA);
134
135     this->iWeights = Weight_t(
136         weight.begin(), weight.begin() + ((inputNeurons + 1) *
137             hiddenNeurons));
138     this->hWeights = Weight_t(
139         weight.begin() + ((inputNeurons + 1) * hiddenNeurons),
140         weight.end());
141     studied = true;
142 }
143
144 void NN::SetInputNeurons(uint32_t value) {
145     if (value != inputNeurons) {
146         inputNeurons = value;
147         iNeurons.clear();
148         iNeurons.reserve(inputNeurons + 1);
149         studied = false;
150     }
151 }
152
153 void NN::SetHiddenNeurons(uint32_t value) {
154     if (value != hiddenNeurons) {
155         hiddenNeurons = value;
156         hNeurons.clear();
157         hNeurons.reserve(hiddenNeurons + 1);
158         studied = false;
159     }
160 }
161
162 void NN::SetOutputNeurons(uint32_t value) {
163     if (value != outputNeurons) {
164         outputNeurons = value;
165         oNeurons.clear();
166         oNeurons.reserve(outputNeurons);
167         studied = false;
168     }
169 }
```

Statistical Class

```

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8   */
9
10 #pragma once
11 #define MAX_UINT8_VALUE 256
12 #define VECTOR_CALC 1
13
14 #include <stdint.h>
15 #include <utility>
16 #include <vector>
17 #include <cstdlib>
18 #include <cmath>
19 #include <limits>
20 #include <typeinfo>
21 #include <string>
22
23 #include <boost/archive/binary_iarchive.hpp>
24 #include <boost/archive/binary_oarchive.hpp>
25 #include <boost/serialization/version.hpp>
26 #include <boost/math/distributions/students_t.hpp>
27
28 #include "MathException.h"
29 #include "SoilMathTypes.h"
30 #include "CommonOperations.h"
31
32 namespace SoilMath {
33
34 /*!
35  * \brief Stats class
36  * \details Usage Stats<type1, type2, type3>Stats() type 1,
37  * 2 and 3 shoudl be of
38  * the same value and concecutive in size
39  */
40 template <typename T1, typename T2, typename T3> class Stats
41 {
42 public:
43     bool isDiscrete = true; /*< indicates if the data is
44                             discrete or real*/
45     T1 *Data = nullptr;      /*< Pointer the data*/
46     uint32_t *bins = nullptr; /*< the histogram*/
47     double *CFD = nullptr;   /*< the CFD*/
48     bool Calculated = false; /*< indication if the data has
49                             been calculated*/
50     float Mean = 0.0;       /*< the mean value of the data
51                             */
52 }
```

```

48     uint32_t n = 0;           /**< number of data points*/
49     uint32_t noBins = 0;      /**< number of bins*/
50     T1 Range = 0;           /**< range of the data*/
51     T1 min = 0;             /**< minimum value*/
52     T1 max = 0;             /**< maximum value*/
53     T1 Startbin = 0;        /**< First bin value*/
54     T1 EndBin = 0;          /**< End bin value*/
55     T1 binRange = 0;        /**< the range of a single bin*/
56     float Std = 0.0;        /**< standard deviation*/
57     T3 Sum = 0;             /**< total sum of all the data
58     values*/
58     uint16_t Rows = 0;       /**< number of rows from the
59     data matrix*/
59     uint16_t Cols = 0;       /**< number of cols from the
60     data matrix*/
60     bool StartAtZero = true; /**< indication of the minimum
61     value starts at zero
61                         or could be less*/
62     double *BinRanges = nullptr;
63     double HighestPDF = 0.;
64
65     uint32_t *begin() { return &bins[0]; }      /**< pointer to
66     the first bin*/
66     uint32_t *end() { return &bins[noBins]; } /**< pointer to
67     the last + 1 bin*/
67
68 /*!
69  * \brief WelchTest Compare the sample using the Welch's
70  * Test
71  * \details (source:
72  *   \url{http://www.boost.org/doc/libs/1_57_0/libs/math/doc/html
73  *     /math_toolkit/stat_tut/weg/st_eg/two_sample_students_t
74  *     .html})
75  * \param statComp Statiscs Results of which it should be
76  *     tested against
77  * \return
78 */
79 bool WelchTest(SoilMath::Stats<T1, T2, T3> &statComp) {
80     double alpha = 0.05;
81     // Degrees of freedom:
82     double v = statComp.Std * statComp.Std / statComp.n +
83             this->Std * this->Std / this->n;
84     v *= v;
85     double t1 = statComp.Std * statComp.Std / statComp.n;
86     t1 *= t1;
87     t1 /= (statComp.n - 1);
88     double t2 = this->Std * this->Std / this->n;
89     t2 *= t2;
90     t2 /= (this->n - 1);
91     v /= (t1 + t2);
92     // t-statistic:
93     double t_stat = (statComp.Mean - this->Mean) /
94             sqrt(statComp.Std * statComp.Std /
95                 statComp.n +
96                 this->Std * this->Std / this->n);
97
98

```

```

93     // Define our distribution, and get the probability:
94     //
95     boost::math::students_t dist(v);
96     double q = cdf(complement(dist, fabs(t_stat)));
97
98     bool rejected = false;
99     // Sample 1 Mean == Sample 2 Mean test the NULL
100    // hypothesis, the two means
101    // are the same
102    if (q < alpha / 2)
103        rejected = false;
104    else
105        rejected = true;
106    return rejected;
107 }
108 */
109 * \brief Stats Constructor
110 * \param rhs Right hand side
111 */
112 Stats(const Stats &rhs)
113     : bins{new uint32_t[rhs.noBins]{0}}, CFD{new double[
114         rhs.noBins]{}}, 
115         BinRanges{new double[rhs.noBins]{}} {
116     this->binRange = rhs.binRange;
117     this->Calculated = rhs.Calculated;
118     this->Cols = rhs.Cols;
119     this->EndBin = rhs.EndBin;
120     this->isDiscrete = rhs.isDiscrete;
121     this->max = rhs.max;
122     this->Mean = rhs.Mean;
123     this->min = rhs.min;
124     this->n = rhs.n;
125     this->noBins = rhs.noBins;
126     this->n_end = rhs.n_end;
127     this->Range = rhs.Range;
128     this->Rows = rhs.Rows;
129     this->Startbin = rhs.Startbin;
130     this->Std = rhs.Std;
131     this->Sum = rhs.Sum;
132     std::copy(rhs.bins, rhs.bins + rhs.noBins, this->bins);
133     std::copy(rhs.CFD, rhs.CFD + rhs.noBins, this->CFD);
134     std::copy(rhs.BinRanges, rhs.BinRanges + rhs.noBins,
135             this->BinRanges);
136     this->Data = rhs.Data;
137     this->StartAtZero = rhs.StartAtZero;
138     this->HighestPDF = rhs.HighestPDF;
139 }
140 */
141 * \brief operator = Assigment operator
142 * \param rhs right hand side
143 * \return returns the right hand side
144 */
145 Stats &operator=(Stats const &rhs) {
146     if (&rhs != this) {

```

```

146     Data = rhs.Data;
147
148     if (bins != nullptr) {
149         delete[] bins;
150         bins = nullptr;
151     }
152     if (CFD != nullptr) {
153         delete[] CFD;
154         CFD = nullptr;
155     }
156     if (BinRanges != nullptr) {
157         delete[] BinRanges;
158         BinRanges = nullptr;
159     }
160
161     bins = new uint32_t[rhs.noBins];      // leak
162     CFD = new double[rhs.noBins];        // leak
163     BinRanges = new double[rhs.noBins];   // leak
164     this->binRange = rhs.binRange;
165     this->Calculated = rhs.Calculated;
166     this->Cols = rhs.Cols;
167     this->EndBin = rhs.EndBin;
168     this->isDiscrete = rhs.isDiscrete;
169     this->max = rhs.max;
170     this->Mean = rhs.Mean;
171     this->min = rhs.min;
172     this->n = rhs.n;
173     this->noBins = rhs.noBins;
174     this->n_end = rhs.n_end;
175     this->Range = rhs.Range;
176     this->Rows = rhs.Rows;
177     this->Startbin = rhs.Startbin;
178     this->Std = rhs.Std;
179     this->Sum = rhs.Sum;
180     this->Data = &rhs.Data[0];
181     std::copy(rhs.bins, rhs.bins + rhs.noBins, this->bins)
182         ;
183     std::copy(rhs.CFD, rhs.CFD + rhs.noBins, this->CFD);
184     std::copy(rhs.BinRanges, rhs.BinRanges + rhs.noBins,
185               this->BinRanges);
186     this->StartAtZero = rhs.StartAtZero;
187     this->HighestPDF = rhs.HighestPDF;
188 }
189
190 */
191 * \brief Stats Constructor
192 * \param noBins number of bins with which to build the
193 * histogram
194 * \param startBin starting value of the first bin
195 * \param endBin end value of the second bin
196 Stats(int noBins = 256, T1 startBin = 0, T1 endBin = 255)
197 {
198     min = std::numeric_limits<T1>::max();

```

```

198     max = std::numeric_limits<T1>::min();
199     Range = std::numeric_limits<T1>::max();
200     Startbin = startBin;
201     EndBin = endBin;
202     this->noBins = noBins;
203     bins = new uint32_t[noBins]{0};      // leak
204     CFD = new double[noBins]{};        // leak
205     BinRanges = new double[noBins]{}; // leak
206
207     if (typeid(T1) == typeid(float) || typeid(T1) == typeid(
208         double) ||
209         typeid(T1) == typeid(long double)) {
210         isDiscrete = false;
211         binRange = static_cast<T1>((EndBin - Startbin) /
212             noBins);
213     } else {
214         isDiscrete = true;
215         binRange = static_cast<T1>(round((EndBin - Startbin) /
216             noBins));
217     }
218
219     /*!
220      * \brief Stats constructor
221      * \param data Pointer to the data
222      * \param rows Number of rows
223      * \param cols Number of Columns
224      * \param noBins Number of bins
225      * \param startBin Value of the start bin
226      * \param startatzero bool indicating if the bins should
227      *   be shifted from zero
228      */
229     Stats(T1 *data, uint16_t rows, uint16_t cols, int noBins =
230           256,
231           T1 startBin = 0, bool startatzero = true) {
232     min = std::numeric_limits<T1>::max();
233     max = std::numeric_limits<T1>::min();
234     Range = max - min;
235
236     Startbin = startBin;
237     EndBin = startBin + noBins;
238     StartAtZero = startatzero;
239
240     if (typeid(T1) == typeid(float) || typeid(T1) == typeid(
241         double) ||
242         typeid(T1) == typeid(long double)) {
243         isDiscrete = false;
244     } else {
245         isDiscrete = true;
246     }
247
248     Data = data;
249     Rows = rows;
250     Cols = cols;
251     bins = new uint32_t[noBins]{0};
252     CFD = new double[noBins]{};

```

```

248     BinRanges = new double[noBins]{};
249     this->noBins = noBins;
250     if (isDiscrete) {
251         BasicCalculate();
252     } else {
253         BasicCalculateFloat();
254     }
255 }
256
257 /*!
258 * \brief Stats Constructor
259 * \param data Pointer the data
260 * \param rows Number of rows
261 * \param cols Number of Columns
262 * \param mask the mask should have the same size as the
263 *   data a value of zero
264 * indicates that the data pointer doesn't exist. A 1
265 *   indicates that the data
266 * pointer is to be used
267 * \param noBins Number of bins
268 * \param startBin Value of the start bin
269 * \param startatzero indicating if the bins should be
270 *   shifted from zero
271 */
272 Stats(T1 *data, uint16_t rows, uint16_t cols, uchar *mask,
273       int noBins = 256,
274       T1 startBin = 0, bool startatzero = true) {
275     min = std::numeric_limits<T1>::max();
276     max = std::numeric_limits<T1>::min();
277     Range = max - min;
278
279     Startbin = startBin;
280     EndBin = startBin + noBins;
281     StartAtZero = startatzero;
282
283     if (typeid(T1) == typeid(float) || typeid(T1) == typeid(
284         double) ||
285         typeid(T1) == typeid(long double)) {
286         isDiscrete = false;
287     } else {
288         isDiscrete = true;
289     }
290
291     Data = data;
292     Rows = rows;
293     Cols = cols;
294     bins = new uint32_t[noBins]{0};
295     CFD = new double[noBins]{};
296     BinRanges = new double[noBins]{};
297     this->noBins = noBins;
298     if (isDiscrete) {
299         BasicCalculate(mask);
300     } else {
301         BasicCalculateFloat(mask);
302     }
303 }

```

```

299
300  /*!
301  * \brief Stats Constructor
302  * \param binData The histogram data
303  * \param startC start counter
304  * \param endC end counter
305  */
306  Stats(T2 *binData, uint16_t startC, uint16_t endC) {
307      noBins = endC - startC;
308      Startbin = startC;
309      EndBin = endC;
310      uint32_t i = noBins;
311
312      if (typeid(T1) == typeid(float) || typeid(T1) == typeid(
313          double) ||
314          typeid(T1) == typeid(long double)) {
315          isDiscrete = false;
316          throw Exception::MathException(
317              EXCEPTION_TYPE_NOT_SUPPORTED,
318              EXCEPTION_TYPE_NOT_SUPPORTED_NR
319          );
320
321          bins = new uint32_t[noBins]{0};
322          CFD = new double[noBins]{};
323          BinRanges = new double[noBins]{};
324          while (i-- > 0) {
325              bins[i] = binData[i];
326              n += binData[i];
327          }
328          BinCalculations(startC, endC);
329      }
330
331      ~Stats() {
332          Data == nullptr;
333          if (bins != nullptr) {
334              delete[] bins;
335              bins = nullptr;
336          }
337          if (CFD != nullptr) {
338              delete[] CFD;
339              CFD = nullptr;
340          }
341          if (BinRanges != nullptr) {
342              delete[] BinRanges;
343              BinRanges = nullptr;
344          }
345      }
346
347  /*!
348  * \brief BasicCalculateFloat execute the basic float data
349  * calculations
350  */
void BasicCalculateFloat() {

```

```

351     float sum_dev = 0.0;
352     n = Rows * Cols;
353     for (uint32_t i = 0; i < n; i++) {
354         if (Data[i] > max) {
355             max = Data[i];
356         }
357         if (Data[i] < min) {
358             min = Data[i];
359         }
360         Sum += Data[i];
361     }
362     binRange = (max - min) / noBins;
363     uint32_t index = 0;
364     Mean = Sum / (float)n;
365     Range = max - min;
366
367     if (StartAtZero) {
368         for (uint32_t i = 0; i < n; i++) {
369             index = static_cast<uint32_t>(Data[i] / binRange);
370             if (index == noBins) {
371                 index -= 1;
372             }
373             bins[index]++;
374             sum_dev += pow((Data[i] - Mean), 2);
375         }
376     } else {
377         for (uint32_t i = 0; i < n; i++) {
378             index = static_cast<uint32_t>((Data[i] - min) /
379                                         binRange);
380             if (index == noBins) {
381                 index -= 1;
382             }
383             bins[index]++;
384             sum_dev += pow((Data[i] - Mean), 2);
385         }
386     }
387     Std = sqrt((float)(sum_dev / n));
388     getCFD();
389     Calculated = true;
390 }
391 /**
392 * \brief BasicCalculateFloat execute the basic float data
393 * calculations with a
394 * mask
395 * \param mask uchar mask type 0 don't calculate, 1
396 * calculate
397 */
398 void BasicCalculateFloat(uchar *mask) {
399     float sum_dev = 0.0;
400     n = Rows * Cols;
401     uint32_t nmask = 0;
402     for (uint32_t i = 0; i < n; i++) {
403         if (mask[i] != 0) {
404             if (Data[i] > max) {
405                 max = Data[i];
406             }
407             sum_dev += Data[i];
408         }
409     }
410     Mean = sum_dev / n;
411     Std = sqrt((float)(sum_dev / n));
412     getCFD();
413     Calculated = true;
414 }
```

```

404         }
405         if (Data[i] < min) {
406             min = Data[i];
407         }
408         Sum += Data[i];
409         nmask++;
410     }
411 }
412 binRange = (max - min) / noBins;
413 uint32_t index = 0;
414 Mean = Sum / (float)nmask;
415 Range = max - min;
416 if (StartAtZero) {
417     for (uint32_t i = 0; i < n; i++) {
418         if (mask[i] != 0) {
419             index = static_cast<uint32_t>(Data[i] / binRange);
420             if (index == noBins) {
421                 index -= 1;
422             }
423             bins[index]++;
424             sum_dev += pow((Data[i] - Mean), 2);
425         }
426     }
427 } else {
428     for (uint32_t i = 0; i < n; i++) {
429         if (mask[i] != 0) {
430             index = static_cast<uint32_t>((Data[i] - min) /
431                 binRange);
432             if (index == noBins) {
433                 index -= 1;
434             }
435             bins[index]++;
436             sum_dev += pow((Data[i] - Mean), 2);
437         }
438     }
439     Std = sqrt((float)(sum_dev / nmask));
440     getCFD();
441     Calculated = true;
442 }
443
444 /**
445  * \brief BasicCalculate execute the basic discrete data
446  *        calculations
447  */
448 void BasicCalculate() {
449     double sum_dev = 0.0;
450     n = Rows * Cols;
451     for (uint32_t i = 0; i < n; i++) {
452         if (Data[i] > max) {
453             max = Data[i];
454         }
455         if (Data[i] < min) {
456             min = Data[i];
457         }
458         Sum += Data[i];

```

```

458     }
459     binRange = static_cast<T1>(ceil((max - min) /
460         static_cast<float>(noBins)));
460     if (binRange == 0) {
461         binRange = 1;
462     }
463     Mean = Sum / (float)n;
464     Range = max - min;
465
466     uint32_t index;
467     if (StartAtZero) {
468         std::for_each(Data, Data + n, [&](T1 &d) {
469             index = static_cast<uint32_t>(d / binRange);
470             if (index == noBins) {
471                 index -= 1;
472             }
473             bins[index]++;
474             sum_dev += pow((d - Mean), 2);
475         });
476     } else {
477         std::for_each(Data, Data + n, [&](T1 &d) {
478             index = static_cast<uint32_t>((d - min) / binRange);
479             if (index == noBins) {
480                 index -= 1;
481             }
482             bins[index]++;
483             sum_dev += pow((d - Mean), 2);
484         });
485     }
486     Std = sqrt((float)(sum_dev / n));
487     getCFD();
488     Calculated = true;
489 }
490
491 /**
492 * \brief BasicCalculate execute the basic discrete data
493 * calculations with
494 * mask
495 * \param mask uchar mask type 0 don't calculate, 1
496 * calculate
497 */
498 void BasicCalculate(uchar *mask) {
499     double sum_dev = 0.0;
500     n = Rows * Cols;
501     uint32_t nmask = 0;
502     uint32_t i = 0;
503     std::for_each(Data, Data + n, [&](T1 &d) {
504         if (mask[i++] != 0) {
505             if (d > max) {
506                 max = d;
507             }
508             if (d < min) {
509                 min = d;
510             }
511             Sum += d;
512             nmask++;
513         }
514     });
515 }
```

```

511         }
512     );
513     binRange = static_cast<T1>(ceil((max - min) /
514         static_cast<float>(noBins)));
514     Mean = Sum / (float)nmask;
515     Range = max - min;
516
517     uint32_t index;
518     if (StartAtZero) {
519         i = 0;
520         std::for_each(Data, Data + n, [&](T1 &d) {
521             if (mask[i++] != 0) {
522                 index = static_cast<uint32_t>(d / binRange);
523                 if (index == noBins) {
524                     index -= 1;
525                 }
526                 bins[index]++;
527                 sum_dev += pow((d - Mean), 2);
528             }
529         });
530     } else {
531         i = 0;
532         std::for_each(Data, Data + n, [&](T1 &d) {
533             if (mask[i++] != 0) {
534                 index = static_cast<uint32_t>((d - min) / binRange
535                     );
536                 if (index == noBins) {
537                     index -= 1;
538                 }
539                 bins[index]++;
540                 sum_dev += pow((d - Mean), 2);
541             }
542         });
543         Std = sqrt((float)(sum_dev / nmask));
544         getCFD();
545         Calculated = true;
546     }
547
548 /**
549  * \brief BinCalculations execute the calculations with the
550  * histogram
551  * \param startC start counter
552  * \param endC end counter
553  */
554 void BinCalculations(uint16_t startC, uint16_t endC
555     __attribute__((unused))) {
556     float sum_dev = 0.0;
557     // Get the Sum
558     uint32_t i = 0;
559     for_each(begin(), end(), [&](uint32_t &b) { Sum += b * (
560         startC + i++); });
561
562     // Get Mean
563     Mean = Sum / (float)n;
564
565     // Get Std Dev
566     Std = sqrt((float)(sum_dev / nmask));
567
568     // Get CDF
569     getCFD();
570
571     Calculated = true;
572 }

```

```

562     // Get max
563     for (int i = noBins - 1; i >= 0; i--) {
564         if (bins[i] != 0) {
565             max = i + startC;
566             break;
567         }
568     }
569
570     // Get min
571     for (uint32_t i = 0; i < noBins; i++) {
572         if (bins[i] != 0) {
573             min = i + startC;
574             break;
575         }
576     }
577
578     // Get Range;
579     Range = max - min;
580
581     // Calculate Standard Deviation
582     i = 0;
583     for_each(begin(), end(), [&](uint32_t &b) {
584         sum_dev += b * pow(((i++ + startC) - Mean), 2);
585     });
586     Std = sqrt((float)(sum_dev / n));
587     getCFD();
588     Calculated = true;
589 }
590
591     uint32_t HighestFrequency() {
592         uint32_t freq = 0;
593         std::for_each(begin(), end(), [&](uint32_t &B) {
594             if (B > freq) {
595                 freq = B;
596             }
597         });
598         return freq;
599     }
600
601     void GetPDFfunction(std::vector<double> &xAxis, std::
602         vector<double> &yAxis,
603             double Step, double start = 0, double
604             stop = 7) {
605
606         uint32_t resolution;
607         resolution = static_cast<uint32_t>(((stop - start) /
608             Step) + 0.5);
609
610         xAxis.push_back(start);
611         double yVal0 = (1 / (Std * 2.506628274631)) *
612             exp(-(pow((start - Mean), 2) / (2 * pow(
613                 Std, 2))));
614         yAxis.push_back(yVal0);
615         HighestPDF = yVal0;
616         for (uint32_t i = 1; i < resolution; i++) {
617             double xVal = xAxis[xAxis.size() - 1] + Step;
618             xAxis.push_back(xVal);

```

```

614     double yVal = (1 / (Std * 2.506628274631)) *
615         exp(-(pow((xVal - Mean), 2) / (2 * pow(
616             Std, 2))));;
617     yAxis.push_back(yVal);
618     if (yVal > HighestPDF) {
619         HighestPDF = yVal;
620     }
621 }
622
623 protected:
624     uint32_t n_end = 0; /*< data end counter used with mask*/
625
626 /**
627  * \brief getCFD get the CFD matrix;
628  */
629 void getCFD() {
630     uint32_t *sumBin = new uint32_t[noBins];
631     sumBin[0] = bins[0];
632     CFD[0] = (static_cast<double>(sumBin[0]) / static_cast<
633         double>(n)) * 100.;
634     for (uint32_t i = 1; i < noBins; i++) {
635         sumBin[i] = (sumBin[i - 1] + bins[i]);
636         CFD[i] = (static_cast<double>(sumBin[i]) / static_cast
637             <double>(n)) * 100.;
638         if (CFD[i] > HighestPDF) {
639             HighestPDF = CFD[i];
640         }
641     }
642     delete[] sumBin;
643 }
644
645 friend class boost::serialization::access; /*<
646     Serialization class*/
647
648 /**
649  * \brief serialize the object
650  * \param ar argument
651  * \param version
652  */
653 template <class Archive>
654 void serialize(Archive &ar, const unsigned int version) {
655     if (version == 0) {
656         ar &isDiscrete;
657         ar &n;
658         ar &noBins;
659         for (size_t dc = 0; dc < noBins; dc++) {
660             ar &bins[dc];
661         }
662         for (size_t dc = 0; dc < noBins; dc++) {
663             ar &CFD[dc];
664         }
665         for (size_t dc = 0; dc < noBins; dc++) {
666             ar &BinRanges[dc];
667         }
668         ar &Calculated;

```

```

666     ar &Mean;
667     ar &Range;
668     ar &min;
669     ar &max;
670     ar &Startbin;
671     ar &EndBin;
672     ar &binRange;
673     ar &Std;
674     ar &Sum;
675     ar &Rows;
676     ar &Cols;
677     ar &StartAtZero;
678     ar &HighestPDF;
679 }
680 }
681 };
682 }
683
684 typedef SoilMath::Stats<float, double, long double>
685     floatStat_t; /*< floating Stat type*/
686 typedef SoilMath::Stats<uchar, uint32_t, uint64_t>
687     ucharStat_t; /*< uchar Stat type*/
688 typedef SoilMath::Stats<uint16_t, uint32_t, uint64_t>
689     uint16Stat_t; /*< uint16 Stat type*/
690 typedef SoilMath::Stats<uint32_t, uint32_t, uint64_t>
691     uint32Stat_t; /*< uint32 Stat type*/
692 BOOST_CLASS_VERSION(floatStat_t, 0)
693 BOOST_CLASS_VERSION(ucharStat_t, 0)
694 BOOST_CLASS_VERSION(uint16Stat_t, 0)
695 BOOST_CLASS_VERSION(uint32Stat_t, 0)



---


1 /* Copyright (C) Jelle Spijker - All Rights Reserved
2  * Unauthorized copying of this file, via any medium is
 * strictly prohibited
3  * and only allowed with the written consent of the author (
 * Jelle Spijker)
4  * This software is proprietary and confidential
5  * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
6  */
7
8 #pragma once
9
10 #include "Stats.h"
11 #include <boost/serialization/base_object.hpp>
12
13 namespace SoilMath {
14 class PSD : public SoilMath::Stats<double, double, long
15     double> {
16     private:
17     uint32_t DetBin(float value) {
18         uint32_t i = noBins - 1;
19         while (i > 0) {
20             if (value > BinRanges[i]) {
21                 return i;
22             }
23             i--;

```

```

23     }
24     return 0;
25 }
26
27 void BasicCalculatePSD() {
28     float sum_dev = 0.0;
29     n = Rows * Cols;
30     for (uint32_t i = 0; i < n; i++) {
31         if (Data[i] > max) {
32             max = Data[i];
33         }
34         if (Data[i] < min) {
35             min = Data[i];
36         }
37         Sum += Data[i];
38     }
39     uint32_t index = 0;
40     Mean = Sum / (float)n;
41     Range = max - min;
42     for (uint32_t i = 0; i < n; i++) {
43         index = DetBin(Data[i]);
44         bins[index]++;
45         sum_dev += pow((Data[i] - Mean), 2);
46     }
47     Std = sqrt((float)(sum_dev / n));
48     getCFD();
49     Calculated = true;
50 }
51 friend class boost::serialization::access;
52
53 template <class Archive>
54 void serialize(Archive &ar, const unsigned int version) {
55     if (version == 0) {
56         ar &boost::serialization::base_object<
57             SoilMath::Stats<double, double, long double>(*
58             this);
59     }
60 }
61 public:
62 PSD() : SoilMath::Stats<double, double, long double>(){}
63
64 PSD(double *data, uint32_t nodata, double *binranges,
65      uint32_t nobins,
66      uint32_t endbin)
67      : SoilMath::Stats<double, double, long double>(nobins,
68          0, endbin) {
69     std::copy(binranges, binranges + nobins, BinRanges);
70     Data = data;
71     Rows = nodata;
72     Cols = 1;
73     BasicCalculatePSD();
74 }
75 }

```

```
76 BOOST_CLASS_VERSION(SoilMath::PSD, 0)
```

General project files

```

1  #-----
2  #
3  # Project created by QtCreator 2015-06-06T11:59:21
4  #
5  #-----
6
7  QT      += core gui concurrent
8  greaterThan(QT_MAJOR_VERSION, 4): QT += widgets
9
10 TARGET = SoilMath
11 TEMPLATE = lib
12 VERSION = 0.9.8
13
14 DEFINES += SOILMATH_LIBRARY
15 QMAKE_CXXFLAGS += -std=c++11
16 unix:!macx: QMAKE_RPATHDIR += $$PWD/../../../../../build/install/
17
18 @
19 CONFIG(release, debug|release):DEFINES += QT_NO_DEBUG_OUTPUT
20 @
21
22 SOURCES += \
23     NN.cpp \
24     GA.cpp \
25     FFT.cpp
26
27 HEADERS += \
28     Stats.h \
29     Sort.h \
30     SoilMathTypes.h \
31     SoilMath.h \
32     NN.h \
33     MathException.h \
34     GA.h \
35     FFT.h \
36     CommonOperations.h \
37     predict_t_archive.h \
38     Mat_archive.h \
39     psd.h
40
41 #opencv
42 LIBS += -L/usr/local/lib -lopencv_core -lopencv_highgui
43 INCLUDEPATH += /usr/local/include/opencv
44 INCLUDEPATH += /usr/local/include
45
46 #boost
47 DEFINES += BOOST_ALL_DYN_LINK
48 INCLUDEPATH += /usr/include/boost
49 LIBS += -L/usr/lib/x86_64-linux-gnu/ -lboost_serialization -lboost_iostreams
50
51 #Zlib
52 LIBS += -L/usr/local/lib -lz
53 INCLUDEPATH += /usr/local/include

```

```
54
55 unix {
56     target.path = $PWD/../../build/install
57     INSTALLS += target
58 }


---


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8 */
9
8 /*! \brief Collection of the public SoilMath headers
9  * Common practice is to include this header when you want to
10 * add Soilmath
11 */
12 #pragma once
13
14 #include "Stats.h"
15 #include "Sort.h"
16 #include "FFT.h"
17 #include "NN.h"
18 #include "GA.h"
19 #include "CommonOperations.h"
20 #include "SoilMathTypes.h"
21 #include "psd.h"
22 #include "Mat_archive.h"
23 #include "predict_t_archive.h"


---


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8 */
8 #pragma once
9 #define COMMONOPERATIONS_VERSION 1
10
11 #include <algorithm>
12 #include <stdint.h>
13 #include <math.h>
14 #include <vector>
15
16 namespace SoilMath {
17 inline uint16_t MinNotZero(uint16_t a, uint16_t b) {
18     if (a != 0 && b != 0) {
19         return (a < b) ? a : b;
20     } else {
21         return (a > b) ? a : b;
```

```

22     }
23 }
24
25 inline uint16_t Max(uint16_t a, uint16_t b) { return (a > b)
26     ? a : b; }
27
28 inline uint16_t Max(uint16_t a, uint16_t b, uint16_t c,
29     uint16_t d) {
30     return (Max(a, b) > Max(c, d)) ? Max(a, b) : Max(c, d);
31 }
32
33 inline uint16_t Min(uint16_t a, uint16_t b) { return (a < b)
34     ? a : b; }
35
36
37 static inline double quick_pow10(int n) {
38     static double pow10[19] = {1, 10, 100, 1000, 10000,
39     100000, 1000000, 10000000,
40     100000000, 1000000000, 10000000000,
41     100000000000, 1000000000000,
42     10000000000000, 100000000000000,
43     1000000000000000, 10000000000000000};
44 }
45
46
47 // Source:
48 // http://martin.ankerl.com/2012/01/25/optimized-
49 // approximative-pow-in-c-and-cpp/
50 static inline double fastPow(double a, double b) {
51     union {
52         double d;
53         int x[2];
54     } u = {a};
55     u.x[1] = (int)(b * (u.x[1] - 1072632447) + 1072632447);
56     u.x[0] = 0;
57     return u.d;
58 }
59
60 static inline double quick_pow2(int n) {
61     static double pow2[256] = {
62         0,      1,      4,      9,      16,      25,      36,      49,
63         64,     81,     100,    121,    144,    169,    196,    225,    256,    289,
64         324,    361,    400,    441,    484,    529,    576,    625,    676,    729,
65         784,    841,
66     }
67 }
```

```
64      900,    961,    1024,    1089,    1156,    1225,    1296,    1369,
65      1444,    1521,
66      1600,    1681,    1764,    1849,    1936,    2025,    2116,    2209,
67      2304,    2401,
68      2500,    2601,    2704,    2809,    2916,    3025,    3136,    3249,
69      3364,    3481,
70      3600,    3721,    3844,    3969,    4096,    4225,    4356,    4489,
71      4624,    4761,
72      4900,    5041,    5184,    5329,    5476,    5625,    5776,    5929,
73      6084,    6241,
74      6400,    6561,    6724,    6889,    7056,    7225,    7396,    7569,
75      7744,    7921,
76      8100,    8281,    8464,    8649,    8836,    9025,    9216,    9409,
77      9604,    9801,
78      10000,   10201,   10404,   10609,   10816,   11025,   11236,
79      11449,   11664,   11881,
80      12100,   12321,   12544,   12769,   12996,   13225,   13456,
81      13689,   13924,   14161,
82      14400,   14641,   14884,   15129,   15376,   15625,   15876,
83      16129,   16384,   16641,
84      16900,   17161,   17424,   17689,   17956,   18225,   18496,
85      18769,   19044,   19321,
86      19600,   19881,   20164,   20449,   20736,   21025,   21316,
87      21609,   21904,   22201,
88      22500,   22801,   23104,   23409,   23716,   24025,   24336,
89      24649,   24964,   25281,
90      25600,   25921,   26244,   26569,   26896,   27225,   27556,
91      27889,   28224,   28561,
92      28900,   29241,   29584,   29929,   30276,   30625,   30976,
93      31329,   31684,   32041,
94      32400,   32761,   33124,   33489,   33856,   34225,   34596,
95      34969,   35344,   35721,
96      36100,   36481,   36864,   37249,   37636,   38025,   38416,
97      38809,   39204,   39601,
```

86 40000, 40401, 40804, 41209, 41616, 42025, 42436,
87 42849, 43264, 43681,
88 44100, 44521, 44944, 45369, 45796, 46225, 46656,
89 47089, 47524, 47961,
90 48400, 48841, 49284, 49729, 50176, 50625, 51076,
91 51529, 51984, 52441,
92 52900, 53361, 53824, 54289, 54756, 55225, 55696,
93 56169, 56644, 57121,
94 57600, 58081, 58564, 59049, 59536, 60025, 60516,
95 61009, 61504, 62001,
96 62500, 63001, 63504, 64009, 64516, 65025};
97 **return** pow2[(n >= 0) ? n : -n];

88 }

89

90 **static inline long** float2intRound(**double** d) {

91 d += 6755399441055744.0;

92 **return** **reinterpret_cast**<**int** &>(d);

93 }

94

95 **/*!**

96 * \brief calcVolume according to ISO 9276-6

97 * \param A

```

98  * \return
99  */
100 static inline float calcVolume(float A) {
101     return (pow(A, 1.5)) / 10.6347f;
102 }
103
104 static inline std::vector<float> makeOutput(uint8_t value,
105     uint32_t noNeurons) {
106     std::vector<float> retVal(noNeurons, -1);
107     retVal[value - 1] = 1;
108     return retVal;
109 }
110 */
111 * \brief calcDiameter according to ISO 9276-6
112 * \param A
113 * \return
114 */
115 static inline float calcDiameter(float A) {
116     //return sqrt((4 * A) / M_PI);
117     return 1.1283791670955 * sqrt(A);
118 }
119 }



---


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8  */
9 #pragma once
10
11 #define GENE_MAX 32 /*< maximum number of genes*/
12 #define CROSSOVER 16 /*< crossover location*/
13
14 #include <stdint.h>
15 #include <bitset>
16 #include <vector>
17 #include <complex>
18 #include <valarray>
19 #include <array>
20
21 typedef unsigned char uchar; /*< unsigned char*/
22 typedef unsigned short ushort; /*< unsigned short*/
23 typedef unsigned int uint32_t;
24
25 typedef std::complex<double> Complex_t; /*< complex
26  * vector of doubles*/
27 typedef std::vector<Complex_t> ComplexVect_t; /*< vector of
28  * Complex_t*/
29 typedef std::valarray<Complex_t> ComplexArray_t; /*<
30  * valarray of Complex_t*/
31 typedef std::vector<uint32_t> iContour_t; /*< vector
32  * of uint32_t*/

```

```

27 typedef std::bitset<GENE_MAX> Genome_t; /*< Bitset
   representing a genome*/
28 typedef std::pair<std::bitset<CROSSOVER>, std::bitset<
   GENE_MAX - CROSSOVER>>
29     SplitGenome_t; /*< a matted genome*/
30
31 typedef std::vector<float> Weight_t; /*< a float vector
   */
32 typedef std::vector<Genome_t> GenVect_t; /*< a vector of
   genomes*/
33 typedef struct PopMemberStruct {
34     Weight_t weights; /*< the weights the core of a
   population member*/
35     GenVect_t weightsGen; /*< the weights as genomes*/
36     float Calculated = 0.0; /*< the calculated value*/
37     float Fitness = 0.0; /*< the fitness of the population
   member*/
38 } PopMember_t; /*< a population member*/
39 typedef std::vector<PopMember_t> Population_t; /*< Vector
   with PopMember_t*/
40 typedef std::pair<float, float>
41     MinMaxWeight_t; /*< floating pair weight range*/
42
43 typedef struct Predict_struct {
44     uint8_t Category = 1; /*< the category number */
45     float RealValue = 1.; /*< category number as float in
   order to estimate how
   precise to outcome is*/
46     float Accuracy = 1.; /*< the accuracy of the category*/
47     std::vector<float> OutputNeurons; /*< the output Neurons
   */
48     bool ManualSet = true;
49 } Predict_t; /*< The prediction
   results*/
50 typedef Predict_t (*NNfunctionType)(
51     ComplexVect_t, Weight_t, Weight_t, uint32_t, uint32_t,
52     uint32_t); /*< The prediction function from the Neural
   Net*/
53
54 typedef std::vector<ComplexVect_t>
55     InputLearnVector_t; /*< Vector of a vector with complex
   values*/
56 typedef std::vector<Predict_t> OutputLearnVector_t; /*<
   vector with results*/

```

```

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6  */
7
8 // Source:

```

```

9 // http://stackoverflow.com/questions/16125574/how-to-
10 // serialize-opencv-mat-with-boost-xml-archive
11 #pragma once
12
13 #include <boost/archive/binary_iarchive.hpp>
14 #include <boost/archive/binary_oarchive.hpp>
15 #include <boost/serialization/access.hpp>
16 #include <opencv/cv.h>
17 #include <opencv2/core.hpp>
18
19 namespace boost {
20 namespace serialization {
21 /*!
22 * \brief serialize Serialize the openCV mat to disk
23 */
24 template <class Archive>
25 inline void serialize(Archive &ar, cv::Mat &m, const
26 unsigned int version __attribute__((unused))) {
27 int cols = m.cols;
28 int rows = m.rows;
29 int elemSize = m.elemSize();
30 int elemType = m.type();
31
32 ar &cols;
33 ar &rows;
34 ar &elemSize;
35 ar &elemType; // element type.
36
37 if (m.type() != elemType || m.rows != rows || m.cols !=
38 cols) {
39 m = cv::Mat(rows, cols, elemType, cv::Scalar(0));
40 }
41
42 size_t dataSize = cols * rows * elemSize;
43 for (size_t dc = 0; dc < dataSize; dc++) {
44 ar &m.data[dc];
45 }
46 }
47
48 */
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55 * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
56 */
57
58 // Source:
59 // http://stackoverflow.com/questions/16125574/how-to-
60 // serialize-opencv-mat-with-boost-xml-archive
61 #pragma once
62

```

```

12 #include <boost/archive/binary_iarchive.hpp>
13 #include <boost/archive/binary_oarchive.hpp>
14 #include <boost/serialization/access.hpp>
15 #include <boost/serialization/vector.hpp>
16 #include <boost/serialization/complex.hpp>
17 #include "SoilMathTypes.h"
18
19 namespace boost {
20 namespace serialization {
21 /*!
22 * \brief serialize Serialize the openCV mat to disk
23 */
24 template <class Archive>
25 inline void serialize(Archive &ar, Predict_t &P, const
26 unsigned int version __attribute__((unused))) {
27 ar &P.Accuracy;
28 ar &P.Category;
29 ar &P.OutputNeurons;
30 ar &P.RealValue;
31 }
32 }

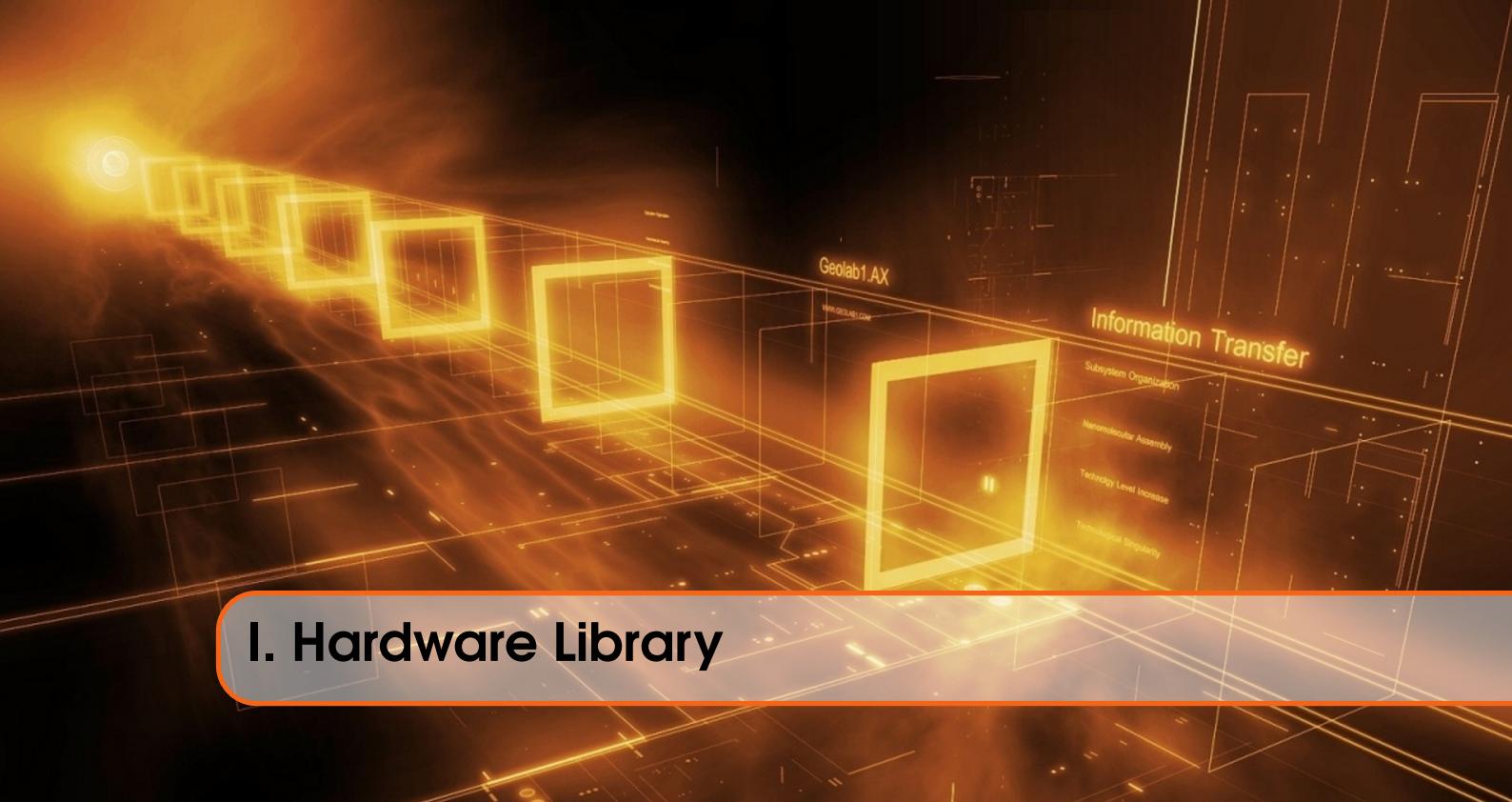
/*
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strictly prohibited
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*/
7
8 #define EXCEPTION_MATH "Math Exception!"
9 #define EXCEPTION_MATH_NR 0
10 #define EXCEPTION_NO_CONTOUR_FOUND
11 "No continuous contour found, or less than 8 pixels long!"
12 #define EXCEPTION_NO_CONTOUR_FOUND_NR 1
13 #define EXCEPTION_SIZE_OF_INPUT_NEURONS
14 "Size of input unequal to input neurons exception!"
15 #define EXCEPTION_SIZE_OF_INPUT_NEURONS_NR 2
16 #define EXCEPTION_NEURAL_NET_NOT_STUDIED "Neural net didn't
study exception!"
17 #define EXCEPTION_NEURAL_NET_NOT_STUDIED_NR 3
18 #define EXCEPTION_TYPE_NOT_SUPPORTED
19 "Type not supported for operation exception!"
20 #define EXCEPTION_TYPE_NOT_SUPPORTED_NR 4
21
22 #pragma once
23 #include <exception>
24 #include <string>
25
26 namespace SoilMath {
27 namespace Exception {

```



```
35         l++;
36     } else if (*r > p) {
37         r--;
38     } else {
39         T t = *l;
40         *l = *r;
41         *r = t;
42         l++;
43         r--;
44     }
45 }
46 Sort::QuickSort<T>(arr, r - arr + 1);
47 Sort::QuickSort<T>(l, arr + i - 1);
48 }
49
50 /**
51 * \brief QuickSort a static sort a Type T array with i
52 *        values where the key
53 *        are also changed accordingly
54 * \details Usage: QuickSort<type>(*type *type , i)
55 * \param arr an array of Type T
56 * \param key an array of 0..i-1 representing the index
57 * \param i the number of elements
58 */
59 template <typename T> static void QuickSort(T *arr, T *key
60     , int i) {
61     if (i < 2)
62         return;
63
64     T p = arr[i / 2];
65
66     T *l = arr;
67     T *r = arr + i - 1;
68
69     T *lkey = key;
70     T *rkey = key + i - 1;
71
72     while (l <= r) {
73         if (*l < p) {
74             l++;
75             lkey++;
76         } else if (*r > p) {
77             r--;
78             rkey--;
79         } else {
80             if (*l != *r) {
81                 T t = *l;
82                 *l = *r;
83                 *r = t;
84
85                 T tkey = *lkey;
86                 *lkey = *rkey;
87                 *rkey = tkey;
88             }
89             l++;
90         }
91     }
92 }
```

```
89         r--;
90
91         lkey++;
92         rkey--;
93     }
94 }
95 Sort::QuickSort<T>(arr, key, r - arr + 1);
96 Sort::QuickSort<T>(l, lkey, arr + i - 1);
97 }
98 };
99 }
```



I. Hardware Library

Microscope Class

```
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8   */
9
10 /*! \class Microscope
11 Interaction with the microscope
12 */
13
14 #pragma once
15
16 #include <stdint.h>
17 #include <vector>
18 #include <string>
19 #include <utility>
20 #include <algorithm>
21
22 #include <sys/stat.h>
23 #include <sys/utsname.h>
24 #include <sys/ioctl.h>
25 #include <fstream>
26 #include <fcntl.h>
27
28 #include <linux/videodev2.h>
29 #include <linux/v4l2-controls.h>
30 #include <linux/v4l2-common.h>
```

```
30 #include <boost/filesystem.hpp>
31 #include <boost/regex.hpp>
32
33 #include <opencv2/photo.hpp>
34 #include <opencv2/imgcodecs.hpp>
35 #include <opencv2/opencv.hpp>
36 #include <opencv2/core.hpp>
37
38 #include <gst/gst.h>
39 #include <gst/app/gstappsink.h>
40
41 #include <QtCore/QObject>
42 #include <QEventLoop>
43 #include <QDebug>
44
45 #include "MicroscopeNotFoundException.h"
46 #include "CouldNotGrabImageException.h"
47
48 namespace Hardware {
49 class Microscope : public QObject {
50     Q_OBJECT
51
52 public:
53     enum Arch { ARM, X64 };
54
55     enum PixelFormat { YUYV, MJPG, GREY };
56
57     struct Resolution_t {
58         uint16_t Width = 2048;
59         uint16_t Height = 1536;
60         PixelFormat format = PixelFormat::MJPEG;
61         std::string to_string() {
62             std::string retVal = std::to_string(Width);
63             retVal.append(" x ");
64             retVal.append(std::to_string(Height));
65             if (format == PixelFormat::MJPEG) {
66                 retVal.append(" - MJPG");
67             }
68             else if (format == PixelFormat::YUYV){
69                 retVal.append(" - YUYV");
70             }
71             else {
72                 retVal.append(" - GREY");
73             }
74             return retVal;
75         }
76         uint32_t ID;
77     };
78
79     struct Control_t {
80         std::string name;
81         int minimum;
82         int maximum;
83         int step;
84         int default_value;
85         int current_value;
```

```

86     uint32_t ID = V4L2_CID_BASE;
87     bool operator==(Control_t &rhs) {
88         if (this->name.compare(rhs.name) == 0) {
89             return true;
90         } else {
91             return false;
92         }
93     }
94     bool operator!=(Control_t &rhs) {
95         if (this->name.compare(rhs.name) != 0) {
96             return true;
97         } else {
98             return false;
99         }
100    }
101 };
102
103 typedef std::vector<Control_t> Controls_t;
104
105 typedef struct _CustomData {
106     GMainLoop *main_loop;
107     GstElement *pipeline;
108     GstElement *source;
109     GstElement *capsfilter;
110     GstElement *tisvideobuffer;
111     GstElement *tiscolorize;
112     GstElement *bayer;
113     GstElement *queue;
114     GstElement *colorspace;
115     GstElement *convert;
116     GstElement *sink;
117     GstBus *bus;
118     GstCaps *caps;
119     Hardware::Microscope *currentMicroscope;
120 } CustomData;
121
122 struct Cam_t {
123     std::string Name;
124     std::string devString;
125     uint32_t ID;
126     std::vector<Resolution_t> Resolutions;
127     uint32_t delaytrigger = 1;
128     Resolution_t *SelectedResolution = nullptr;
129     Controls_t Controls;
130     CustomData Pipe;
131     int fd;
132     bool operator==(Cam_t const &rhs) {
133         if (this->ID == rhs.ID || this->Name == rhs.Name) {
134             return true;
135         } else {
136             return false;
137         }
138     }
139     bool operator!=(Cam_t const &rhs) {
140         if (this->ID != rhs.ID && this->Name != rhs.Name) {
141             return true;

```

```
142         } else {
143             return false;
144         }
145     }
146 };
147
148 std::vector<Cam_t> AvailableCams;
149 Cam_t *SelectedCam = nullptr;
150 Arch RunEnv;
151
152 Microscope();
153 Microscope(const Microscope &rhs);
154
155 ~Microscope();
156
157 Microscope operator=(Microscope const &rhs);
158
159     bool IsOpened();
160     bool openCam(Cam_t *cam);
161     bool openCam(int &cam);
162     bool openCam(std::string &cam);
163
164     bool closeCam(Cam_t *cam);
165
166     void GetFrame(cv::Mat &dst);
167     void GetGstreamFrame(cv::Mat &dst);
168     void GetHDRFrame(cv::Mat &dst, uint32_t noframes = 3);
169
170     Control_t *GetControl(const std::string name);
171     void SetControl(Control_t *control);
172
173     Cam_t *FindCam(std::string cam);
174     Cam_t *FindCam(int cam);
175     cv::Mat lastFrame;
176
177     void SendImageRetrieved();
178
179 public slots:
180     void on_imageretrieved();
181
182 signals:
183     void imageretrieved();
184
185 private:
186     static void new_buffer(GstElement *sink, CustomData *data)
187         ;
188     void getResolutions(Cam_t &currentCam, int FormatType);
189     bool openedUpTheCam = false;
190     cv::VideoCapture *cap = nullptr;
191
192     std::vector<cv::Mat> HDRframes;
193
194     std::vector<Cam_t> GetAvailableCams();
195     Arch GetCurrentArchitecture();
196     int fd;
197 }
```

```
197 }

---



```
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3 * strictly prohibited
4 * and only allowed with the written consent of the author (Jelle Spijker)
5 * This software is proprietary and confidential
6 * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
7 */
8 #include "Microscope.h"
9
10 namespace Hardware {
11
12 Microscope::Microscope() {
13 RunEnv = GetCurrentArchitecture();
14 AvailableCams = GetAvailableCams();
15 for_each(AvailableCams.begin(), AvailableCams.end(), [](
16 Cam_t &C) {
17 C.SelectedResolution = &C.Resolutions[C.Resolutions.size()
18 () - 1];
19 });
20 connect(this, SIGNAL(imageretrieved()), this, SLOT(
21 on_imageretrieved()));
22 }
23 Microscope::Microscope(const Microscope &rhs) {
24 std::copy(rhs.AvailableCams.begin(), rhs.AvailableCams.end()
25 (),
26 this->AvailableCams.begin());
27 this->RunEnv = rhs.RunEnv;
28 this->SelectedCam = rhs.SelectedCam;
29 this->cap = rhs.cap;
30 this->fd = rhs.fd;
31 this->HDRframes = rhs.HDRframes;
32 connect(this, SIGNAL(imageretrieved()), this, SLOT(
33 on_imageretrieved()));
34 }
35 Microscope::~Microscope() { delete cap; }
36
37 Microscope::Arch Microscope::GetCurrentArchitecture() {
38 struct utsname unameData;
39 Arch retVal;
40 uname(&unameData);
41 std::string archString = static_cast<std::string>(
42 unameData.machine);
43 if (archString.find("armv7l") != string::npos) {
44 retVal = Arch::ARM;
45 } else {
46 retVal = Arch::X64;
47 }
48 return retVal;
49 }
```


```

```

47 std::vector<Microscope::Cam_t> Microscope::GetAvailableCams
48     () {
49     const string path_ss = "/sys/class/video4linux";
50     const string path_ss_dev = "/dev/video";
51     std::vector<Cam_t> retVal;
52     struct v4l2_queryctrl queryctrl;
53     struct v4l2_control controlctrl;
54
55     // Check if there're videodevices installed
56     // Iterate through the cams
57     for (boost::filesystem::directory_iterator itr(path_ss);
58          itr != boost::filesystem::directory_iterator(); ++itr
59          ) {
60         string videoln = itr->path().string();
61         videoln.append("/name");
62         if (boost::filesystem::exists(videoln)) {
63             Cam_t currentCam;
64             std::ifstream camName;
65             camName.open(videoln);
66             std::getline(camName, currentCam.Name);
67             camName.close();
68             currentCam.ID =
69                 std::atoi(itr->path().string().substr(28, std::
70                           string::npos).c_str());
71
72             // Open Cam
73             currentCam.devString = path_ss_dev + std::to_string(
74                 currentCam.ID);
75             if ((currentCam.fd = open(currentCam.devString.c_str()
76                 , O_RDWR)) == -1) {
77                 throw Exception::MicroscopeException(
78                     EXCEPTION_NOCAMS,
79                     EXCEPTION_NOCAMS_NR
80                     );
81             }
82
83             // Get controls
84             memset(&queryctrl, 0, sizeof(queryctrl));
85             memset(&controlctrl, 0, sizeof(controlctrl));
86             for (queryctrl.id = V4L2_CID_BASE; queryctrl.id <
87                 V4L2_CID_LASTP1;
88                 queryctrl.id++) {
89
90                 if (ioctl(currentCam.fd, VIDIOC_QUERYCTRL, &
91                     queryctrl) == 0) {
92                     if (!(queryctrl.flags & V4L2_CTRL_FLAG_DISABLED))
93                     {
94                         Control_t currentControl;
95                         currentControl.ID = queryctrl.id;
96                         currentControl.name = (char *)queryctrl.name;
97                         currentControl.minimum = queryctrl.minimum;
98                         currentControl.maximum = queryctrl.maximum;
99                         currentControl.default_value = queryctrl.
100                           default_value;
101                         currentControl.step = queryctrl.step;
102                         controlctrl.id = queryctrl.id;
103                     }
104                 }
105             }
106         }
107     }
108 }

```

```

92         if (ioctl(currentCam.fd, VIDIOC_G_CTRL, &
93             controlctrl) == 0) {
94             currentControl.current_value = controlctrl.
95             value;
96         }
97     } else {
98         if (errno == EINVAL)
99             continue;
100        throw Exception::MicroscopeException(
101            EXCEPTION_QUERY,
102            EXCEPTION_QUERY_NR
103        );
104    }
105    getResolutions(currentCam, V4L2_PIX_FMT_YUYV);
106    getResolutions(currentCam, V4L2_PIX_FMT_MJPEG);
107    getResolutions(currentCam, V4L2_PIX_FMT_GREY);
108    close(currentCam.fd);
109    retVal.push_back(currentCam);
110 }
111 }
112
113 for (uint32_t i = 0; i < retVal.size(); i++) {
114     if (retVal[i].Resolutions.size() == 0) {
115         retVal.erase(retVal.begin() + i);
116         i--;
117     }
118 }
119
120 return retVal;
121 }
122
123 void Microscope::getResolutions(Cam_t &currentCam, int
124     FormatType) {
125     // Get image formats
126     struct v4l2_format format;
127     memset(&format, 0, sizeof(format));
128     uint32_t width[10] = {640, 800, 1280, 1280, 1920,
129                          1600, 2048, 2560, 3840, 3872};
130     uint32_t height[10] = {480, 600, 720, 960, 1080,
131                          1200, 1536, 1440, 2160, 2764};
132
133     uint32_t ResolutionID = 0;
134
135     for (uint32_t i = 0; i < 10; i++) {
136         format.type = V4L2_BUF_TYPE_VIDEO_CAPTURE;
137         format.fmt.pix.pixelformat = FormatType;
138         format.fmt.pix.width = width[i];
139         format.fmt.pix.height = height[i];
140         int ret = ioctl(currentCam.fd, VIDIOC_S_FMT, &format);
141         if (ret != -1 && format.fmt.pix.height == height[i] &&
142             format.fmt.pix.width == width[i]) {

```

```

143     Resolution_t res;
144     res.Width = format.fmt.pix.width;
145     res.Height = height[i];
146     res.ID = ResolutionID++;
147     switch (FormatType) {
148     case V4L2_PIX_FMT_YUYV:
149         res.format = PixelFormat::YUYV;
150         break;
151     case V4L2_PIX_FMT_MJPEG:
152         res.format = PixelFormat::MJPEG;
153         break;
154     case V4L2_PIX_FMT_GREY:
155         res.format = PixelFormat::GREY;
156         break;
157     default:
158         break;
159     }
160     currentCam.Resolutions.push_back(res);
161 }
162 }
163 }
164
165 bool Microscope::IsOpened() { return openedUptheCam; }
166
167 bool Microscope::openCam(Cam_t *cam) {
168     for (uint32_t i = 0; i < AvailableCams.size(); i++) {
169         if (AvailableCams[i] == *cam) {
170             closeCam(SelectedCam);
171             SelectedCam = cam;
172             for (Controls_t::iterator it = SelectedCam->Controls.
173                 begin();
174                 it != SelectedCam->Controls.end(); ++it) {
175                 SetControl(&*it);
176             }
177             SelectedCam->Pipe.currentMicroscope = this;
178             gst_init(NULL, NULL);
179
180             SelectedCam->Pipe.pipeline = gst_pipeline_new("SoilCam
181             ");
182             if (!SelectedCam->Pipe.pipeline) {
183                 throw Exception::MicroscopeException(
184                     EXCEPTION_GSTREAM_INIT_EXCEPTION,
185                     EXCEPTION_GSTREAM_INIT_EXCEPTION_NR);
186             }
187             SelectedCam->Pipe.source = gst_element_factory_make("v4l2src", "source");
188             SelectedCam->Pipe.capsfilter =
189                 gst_element_factory_make("capsfilter", "filter");
190             SelectedCam->Pipe.colorspace =
191                 gst_element_factory_make("ffmpegcolorspace", "colorspace");
192             SelectedCam->Pipe.convert =
193                 gst_element_factory_make("capsfilter", "convert");

```

```

194     SelectedCam->Pipe.sink = gst_element_factory_make("appsink", "output");
195
196     if (!SelectedCam->Pipe.source || !SelectedCam->Pipe.capsfilter ||
197         !SelectedCam->Pipe.colorspace || !SelectedCam->
198         Pipe.sink ||
199         !SelectedCam->Pipe.convert) {
200         throw Exception::MicroscopeException(
201             EXCEPTION_GSTREAM_ELEM_EXCEPTION,
202             EXCEPTION_GSTREAM_ELEM_EXCEPTION_NR);
203     }
204
205     if (SelectedCam->Name.compare("DFK 24UJ003") == 0) {
206         SelectedCam->Pipe.tisvideobuffer =
207             gst_element_factory_make(
208                 "tisvideobufferfilter", "tisvideobufferfilter");
209         SelectedCam->Pipe.tiscolorize =
210             gst_element_factory_make("tiscolorize", "tiscolorize");
211         SelectedCam->Pipe.queue = gst_element_factory_make("queue", "queue");
212         SelectedCam->Pipe.bayer =
213             gst_element_factory_make("bayer2rgb", "bayer");
214         if (!SelectedCam->Pipe.tisvideobuffer ||
215             !SelectedCam->Pipe.tiscolorize || !SelectedCam->
216             Pipe.queue ||
217             !SelectedCam->Pipe.bayer) {
218             throw Exception::MicroscopeException(
219                 EXCEPTION_GSTREAM_ELEM_EXCEPTION,
220                 EXCEPTION_GSTREAM_ELEM_EXCEPTION_NR);
221         }
222     }
223
224     g_object_set(SelectedCam->Pipe.source, "device",
225                 SelectedCam->devString.c_str());
226
227     switch (SelectedCam->SelectedResolution->format) {
228     case PixelFormat::MJPEG:
229         SelectedCam->Pipe.caps = gst_caps_new_simple(
230             "video/x-raw-rgb", "width", G_TYPE_INT,
231             SelectedCam->SelectedResolution->Width, "height"
232             , G_TYPE_INT,
233             SelectedCam->SelectedResolution->Height, NULL);
234     case PixelFormat::GREY:
235         SelectedCam->Pipe.caps = gst_caps_new_simple(
236             "video/x-raw-gray", "width", G_TYPE_INT,
237             SelectedCam->SelectedResolution->Width, "height"
238             , G_TYPE_INT,
239             SelectedCam->SelectedResolution->Height, NULL);
240         break;
241     case PixelFormat::YUYV:
242         SelectedCam->Pipe.caps = gst_caps_new_simple(
243             "video/x-raw-gray", "format", G_TYPE_STRING, "(fourcc)UYVY",
244             "UYVY");
245     }

```

```

239         "width", G_TYPE_INT, SelectedCam->
240             SelectedResolution->Width,
241         "height", G_TYPE_INT, SelectedCam->
242             SelectedResolution->Height,
243             NULL);
244     default:
245         break;
246 }
247 g_object_set(SelectedCam->Pipe.capsfilter, "caps",
248             SelectedCam->Pipe.caps,
249             NULL);
250 gst_caps_unref(SelectedCam->Pipe.caps);
251 SelectedCam->Pipe.caps = gst_caps_new_simple(
252     "video/x-raw-rgb", "width", G_TYPE_INT,
253     SelectedCam->SelectedResolution->Width, "height",
254     G_TYPE_INT,
255     SelectedCam->SelectedResolution->Height, NULL);
256 g_object_set(SelectedCam->Pipe.convert, "caps",
257             SelectedCam->Pipe.caps,
258             NULL);
259
260     SelectedCam->Pipe.bus = gst_element_get_bus(
261         SelectedCam->Pipe.pipeline);
262     g_object_set(SelectedCam->Pipe.sink, "emit-signals",
263             TRUE, NULL);
264     g_signal_connect(SelectedCam->Pipe.sink, "new-buffer",
265                     G_CALLBACK(new_buffer), &SelectedCam
266                     ->Pipe);
267
268     if (SelectedCam->Name.compare("DFK 24UJ003") == 0) {
269         gst_bin_add_many(GST_BIN(SelectedCam->Pipe.pipeline)
270             ,
271             SelectedCam->Pipe.source,
272             SelectedCam->Pipe.capsfilter,
273             SelectedCam->Pipe.tisvideobuffer,
274             SelectedCam->Pipe.tiscolorize,
275             SelectedCam->Pipe.queue,
276             SelectedCam->Pipe.bayer,
277             SelectedCam->Pipe.sink, NULL);
278         gst_element_link_many(
279             SelectedCam->Pipe.source, SelectedCam->Pipe.
280             capsfilter,
281             SelectedCam->Pipe.tisvideobuffer, SelectedCam->
282             Pipe.tiscolorize,
283             SelectedCam->Pipe.queue, SelectedCam->Pipe.bayer
284             ,
285             SelectedCam->Pipe.sink, NULL);
286     } else {
287         gst_bin_add_many(
288             GST_BIN(SelectedCam->Pipe.pipeline), SelectedCam
289             ->Pipe.source,
290             SelectedCam->Pipe.capsfilter, SelectedCam->Pipe.
291             colorspace,
292             SelectedCam->Pipe.convert, SelectedCam->Pipe.
293             sink, NULL);
294         gst_element_link_many(

```

```

277         SelectedCam->Pipe.source, SelectedCam->Pipe.
278             capsfilter,
279             SelectedCam->Pipe.colorspace, SelectedCam->Pipe.
280                 convert,
281                 SelectedCam->Pipe.sink, NULL);
282     }
283     openedUptheCam = true;
284     return true;
285 }
286 openedUptheCam = false;
287 return false;
288 }
289 bool Microscope::openCam(std::string &cam) { return openCam(
290     FindCam(cam)); }
291 bool Microscope::openCam(int &cam) { return openCam(FindCam(
292     cam)); }
293 Microscope::Cam_t *Microscope::FindCam(int cam) {
294     for (uint32_t i = 0; i < AvailableCams.size(); i++) {
295         if (cam == AvailableCams[i].ID) {
296             return &AvailableCams[i];
297         }
298     }
299     return nullptr;
300 }
301
302 Microscope::Cam_t *Microscope::FindCam(string cam) {
303     for (uint32_t i = 0; i < AvailableCams.size(); i++) {
304         if (cam.compare(AvailableCams[i].Name) == 0) {
305             return &AvailableCams[i];
306         }
307     }
308     return nullptr;
309 }
310
311 bool Microscope::closeCam(Cam_t *cam) {
312     if (openedUptheCam) {
313         gst_element_set_state(cam->Pipe.pipeline, GST_STATE_NULL
314             );
314         gst_object_unref(GST_OBJECT(cam->Pipe.pipeline));
315         openedUptheCam = false;
316     }
317 }
318
319 void Microscope::GetFrame(cv::Mat &dst) {
320     if (!IsOpened()) {
321         openCam(SelectedCam);
322     }
323     QEventLoop loop;
324     loop.connect(this, SIGNAL(imageretrieved()), SLOT(quit()))
325         ;
325     gst_element_set_state(SelectedCam->Pipe.pipeline,
326             GST_STATE_PLAYING);

```

```

326     loop.exec();
327     dst = lastFrame;
328     closeCam(SelectedCam);
329 }
330
331 void Microscope::on_imageretrieved() { return; }
332
333 void Microscope::GetHDRFrame(cv::Mat &dst, uint32_t noframes
334 ) {
335     // create the brightness steps
336     Control_t *brightness = GetControl("Brightness");
337     Control_t *contrast = GetControl("Contrast");
338
339     uint32_t brightnessStep =
340         (brightness->maximum - brightness->minimum) / noframes
341         ;
342     int8_t currentBrightness = brightness->current_value;
343     int8_t currentContrast = contrast->current_value;
344     contrast->current_value = contrast->maximum;
345
346     cv::Mat currentImg;
347     // take the shots at different brightness levels
348     for (uint32_t i = 1; i <= noframes; i++) {
349         brightness->current_value = brightness->minimum + (i *
350             brightnessStep);
351         GetFrame(currentImg);
352         HDRframes.push_back(currentImg);
353     }
354
355     // Set the brightness and back to the previous used level
356     brightness->current_value = currentBrightness;
357     contrast->current_value = currentContrast;
358
359     // Perform the exposure fusion
360     cv::Mat fusion;
361     cv::Ptr<cv::MergeMertens> merge_mertens = cv::
362         createMergeMertens();
363     merge_mertens->process(HDRframes, fusion);
364     fusion *= 255;
365     fusion.convertTo(dst, CV_8UC1);
366 }
367
368 Microscope::Control_t *Microscope::GetControl(const string
369     name) {
370     for (Controls_t::iterator it = SelectedCam->Controls.begin
371         ());
372         it != SelectedCam->Controls.end(); ++it) {
373         if (name.compare(it->name) == 0) {
374             return &*it;
375         }
376     }
377     return nullptr;
378 }
379
380 void Microscope::SetControl(Control_t *control) {

```

```

375     if ((SelectedCam->fd = open(SelectedCam->devString.c_str()
376         , O_RDWR)) == -1) {
377         throw Exception::MicroscopeException(EXCEPTION_NOCAMS ,
378                                         EXCEPTION_NOCAMS_NR);
379     }
380
381     struct v4l2_queryctrl queryctrl;
382     struct v4l2_control controlctrl;
383
384     memset(&queryctrl, 0, sizeof(queryctrl));
385     queryctrl.id = control->ID;
386     if (ioctl(SelectedCam->fd, VIDIOC_QUERYCTRL, &queryctrl)
387         == -1) {
388         if (errno != EINVAL) {
389             close(SelectedCam->fd);
390             throw Exception::MicroscopeException(EXCEPTION_QUERY ,
391                                         EXCEPTION_QUERY_NR);
392         } else {
393             close(SelectedCam->fd);
394             throw Exception::MicroscopeException(
395                 EXCEPTION_CTRL_NOT_FOUND ,
396                                         EXCEPTION_CTRL_NOT_FOUND_NR
397                                         );
398         }
399     } else if (queryctrl.flags & V4L2_CTRL_FLAG_DISABLED) {
400         close(SelectedCam->fd);
401         throw Exception::MicroscopeException(
402             EXCEPTION_CTRL_NOT_FOUND ,
403                                         EXCEPTION_CTRL_NOT_FOUND_NR
404                                         );
405     } else {
406         memset(&controlctrl, 0, sizeof(controlctrl));
407         controlctrl.id = control->ID;
408         controlctrl.value = control->current_value;
409
410         if (ioctl(SelectedCam->fd, VIDIOC_S_CTRL, &controlctrl)
411             == -1) {
412             // Fails on auto white balance
413             // throw Exception::MicroscopeException(
414             //     EXCEPTION_CTRL_VALUE ,
415             //     EXCEPTION_CTRL_VALUE_NR);
416         }
417     }
418     close(SelectedCam->fd);
419 }
420
421 void Microscope::SendImageRetrieved() { emit imageretrieved
422     (); }
423
424 void Microscope::new_buffer(GstElement *sink, CustomData *
425     data) {
426     GstBuffer *buffer;
427     g_signal_emit_by_name(sink, "pull-buffer", &buffer);
428     if (buffer) {
429         cv::Mat bufferMat(

```

```
418     data->currentMicroscope->SelectedCam->
419         SelectedResolution->Height,
420     data->currentMicroscope->SelectedCam->
421         SelectedResolution->Width,
422     CV_8UC4, (uchar *)buffer->data);
423     std::vector<cv::Mat> chans;
424     cv::split(bufferMat, chans);
425     chans.erase(chans.begin() + 4);
426     cv::merge(chans, data->currentMicroscope->lastFrame);
427     cv::namedWindow("test");
428     cv::imshow("test", data->currentMicroscope->lastFrame);
429     cv::waitKey(0);
430     data->currentMicroscope->SendImageRetrieved();
431     //      gst_element_set_state(data->currentMicroscope->
432     //      SelectedCam->Pipe.pipeline,
433     //      GST_STATE_PAUSED);
434 }
```

Beaglebone Black Class

```

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5   * Jelle Spijker)
6   * This software is proprietary and confidential
7   * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8   */
9
10  /*! \class BBB
11  The core BeagleBone Black class used for all hardware
12  related classes.
13  Consisting of universal used method, functions and variables
14  . File operations,
15  polling and threading
16  */
17
18
19  #pragma once
20
21  #define SLOTS
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45

```

```

46
47 protected:
48     bool threadRunning;           /*!< used to stop the
49     thread*/
50     pthread_t thread;           /*!< The thread*/
51     CallbackType callbackFunction; /*!< the callbackfunction*/
52
53     bool DirectoryExist(const string &path);
54     bool CapeLoaded(const string &shield);
55
56     string Read(const string &path);
57     void Write(const string &path, const string &value);
58
59     /*! Converts a number to a string
60     \param Number as typename
61     \returns the number as a string
62     */
63     template <typename T> string NumberToString(T Number) {
64         ostringstream ss;
65         ss << Number;
66         return ss.str();
67     }
68
69     /*! Converts a string to a number
70     \param Text the string that needs to be converted
71     \returns the number as typename
72     */
73     template <typename T> T StringToNumber(string Text) {
74         stringstream ss(Text);
75         T result;
76         return ss >> result ? result : 0;
77     };
78 }

```

```

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6   * This software is proprietary and confidential
7   * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8   */
9
10 #include "BBB.h"
11
12 namespace Hardware {
13 /*! Constructor*/
14 BBB::BBB() {
15     threadRunning = false;
16     callbackFunction = NULL;
17     debounceTime = 0;
18     thread = (pthread_t)NULL;
19 }
20 /*! De-constructor*/

```

```

20 BBB::~BBB() {}
21
22 /*! Reads the first line from a file
23 \param path constant string pointing towards the file
24 \returns this first line
25 */
26 string BBB::Read(const string &path) {
27     ifstream fs;
28     fs.open(path.c_str());
29     if (!fs.is_open()) {
30         throw Exception::GPIOReadException("Can't open: " +
31             path).c_str());
32     }
33     string input;
34     getline(fs, input);
35     fs.close();
36     return input;
37 }
38 /*! Writes a value to a file
39 \param path a constant string pointing towards the file
40 \param value a constant string which should be written in
41     the file
42 */
43 void BBB::Write(const string &path, const string &value) {
44     ofstream fs;
45     fs.open(path.c_str());
46     if (!fs.is_open()) {
47         throw Exception::GPIOReadException("Can't open: " +
48             path).c_str());
49     }
50     fs << value;
51     fs.close();
52 }
53 /*! Checks if a directory exist
54 \returns true if the directory exists and false if not
55 */
56 bool BBB::DirectoryExist(const string &path) {
57     struct stat st;
58     if (stat((char *)path.c_str(), &st) != 0) {
59         return false;
60     }
61     return true;
62 }
63 /*! Checks if a cape is loaded in the file /sys/devices/
64     bone_capemgr.9/slots
65 \param shield a const search string which is a (part) of the
66     shield name
67 \return true if the search string is found otherwise false
68 */
69 bool BBB::CapeLoaded(const string &shield) {
70     bool shieldFound = false;
71
72     ifstream fs;
73     string line;
74
75     fs.open(path.c_str());
76     if (!fs.is_open()) {
77         throw Exception::GPIOReadException("Can't open: " +
78             path).c_str());
79     }
80
81     while (getline(fs, line)) {
82         if (line.find(shield) != string::npos) {
83             shieldFound = true;
84             break;
85         }
86     }
87
88     fs.close();
89
90     return shieldFound;
91 }
```

```
71     fs.open(SLOTS);
72     if (!fs.is_open()) {
73         throw Exception::GPIOReadException("Can't open SLOTS");
74     }
75
76     string line;
77     while (getline(fs, line)) {
78         if (line.find(shield) != string::npos) {
79             shieldFound = true;
80             break;
81         }
82     }
83     fs.close();
84     return shieldFound;
85 }
86 }
```

GPIO Class

```

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5   * Jelle Spijker)
6   * This software is proprietary and confidential
7   * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8   * This code is based upon:
9   * Derek Molloy, "Exploring BeagleBone: Tools and Techniques
10  * for Building
11  * with Embedded Linux", Wiley, 2014, ISBN:9781118935125.
12  * See: www.exploringbeaglebone.com
13  */
14
15 #pragma once
16 #include "BBB.h"
17
18 #define EXPORT_PIN "/sys/class/gpio/export"
19 #define UNEXPORT_PIN "/sys/class/gpio/unexport"
20 #define GPIOS "/sys/class/gpio/gpio"
21 #define DIRECTION "/direction"
22 #define VALUE "/value"
23 #define EDGE "/edge"
24
25 using namespace std;
26
27 namespace Hardware {
28 class GPIO : public BBB {
29 public:
30     enum Direction { Input, Output };
31     enum Value { Low = 0, High = 1 };
32     enum Edge { None, Rising, Falling, Both };
33     int number; // Number of the pin
34     int WaitForEdge();
35     int WaitForEdge(CallbackType callback);
36     void WaitForEdgeCancel() { this->threadRunning = false; }
37     Value GetValue();
38     void SetValue(Value value);
39     Direction GetDirection();
40     void SetDirection(Direction direction);
41     Edge GetEdge();
42     void SetEdge(Edge edge);
43     GPIO(int number);
44     ~GPIO();
45
46 private:
47     string gpiopath;
48     Direction direction;

```

```

52     Edge edge;
53     friend void *threadedPollGPIO(void *value);
54
55     bool isExported(int number, Direction &dir, Edge &edge);
56     bool ExportPin(int number);
57     bool UnexportPin(int number);
58
59     Direction ReadsDirection(const string &gpiopath);
60     void WritesDirection(const string &gpiopath, Direction
61                           direction);
62
63     Edge ReadsEdge(const string &gpiopath);
64     void WritesEdge(const string &gpiopath, Edge edge);
65
66     Value ReadsValue(const string &gpiopath);
67     void WritesValue(const string &gpiopath, Value value);
68
69 void *threadedPollGPIO(void *value);
70 }

```

```

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7   * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8   */
9
10 #include "GPIO.h"
11
12 namespace Hardware {
13 GPIO::GPIO(int number) {
14
15     this->number = number;
16     gpiopath = GPIOS + NumberToString<int>(number);
17
18     if (!isExported(number, direction, edge)) {
19         ExportPin(number);
20         direction = ReadsDirection(gpiopath);
21         edge = ReadsEdge(gpiopath);
22     }
23     usleep(250000);
24 }
25
26 GPIO::~GPIO() { UnexportPin(number); }
27
28 int GPIO::WaitForEdge(CallbackType callback) {
29     threadRunning = true;
30     callbackFunction = callback;
31     if (pthread_create(&this->thread, NULL, &threadedPollGPIO,
32                       static_cast<void *>(this))) {
33         threadRunning = false;
34         throw Exception::
35             FailedToCreateGPIOPollingThreadException();
36     }
37 }

```

```

33     }
34     return 0;
35 }
36
37 int GPIO::WaitForEdge() {
38     if (direction == Output) {
39         SetDirection(Input);
40     }
41     int fd, i, epollfd, count = 0;
42     struct epoll_event ev;
43     epollfd = epoll_create(1);
44     if (epollfd == -1) {
45         throw Exception::
46             FailedToCreateGPIOPollingThreadException(
47                 "GPIO: Failed to create epollfd!");
48     }
49     if ((fd = open((gpiopath + VALUE).c_str(), O_RDONLY |
50                     O_NONBLOCK)) == -1) {
51         throw Exception::GPIOReadException();
52     }
53
54     // read operation | edge triggered | urgent data
55     ev.events = EPOLLIN | EPOLLET | EPOLLPRI;
56     ev.data.fd = fd;
57
58     if (epoll_ctl(epollfd, EPOLL_CTL_ADD, fd, &ev) == -1) {
59         throw Exception::
60             FailedToCreateGPIOPollingThreadException(
61                 "GPIO: Failed to add control interface!");
62     }
63
64     while (count <= 1) {
65         i = epoll_wait(epollfd, &ev, 1, -1);
66         if (i == -1) {
67             close(fd);
68             return -1;
69         } else {
70             count++;
71         }
72     }
73     close(fd);
74     return 0;
75 }
76
77 GPIO::Value GPIO::GetValue() { return ReadsValue(gpiopath);
78 }
79
80 void GPIO::SetValue(GPIO::Value value) { WritesValue(
81     gpiopath, value); }
82
83 GPIO::Direction GPIO::GetDirection() { return direction; }
84 void GPIO::SetDirection(Direction direction) {
85     this->direction = direction;
86     WritesDirection(gpiopath, direction);
87 }
88
89 GPIO::Edge GPIO::GetEdge() { return edge; }

```

```
84 void GPIO::SetEdge(Edge edge) {
85     this->edge = edge;
86     WritesEdge(gpiopath, edge);
87 }
88
89 bool GPIO::isExported(int number __attribute__((unused)),
90     Direction &dir,
91     Edge &edge) {
92     // Checks if directory exist and therefore is exported
93     if (!DirectoryExist(gpiopath)) {
94         return false;
95     }
96     // Reads the data associated with the pin
97     dir = ReadsDirection(gpiopath);
98     edge = ReadsEdge(gpiopath);
99     return true;
100 }
101
102 bool GPIO::ExportPin(int number) {
103     switch (number) {
104     case 7:
105         system("config-pin P9.42 gpio");
106         break;
107     case 116:
108         system("config-pin P9.91 gpio");
109         break;
110     case 112:
111         system("config-pin P9.30 gpio");
112         break;
113     case 115:
114         system("config-pin P9.27 gpio");
115         break;
116     case 14:
117         system("config-pin P9.26 gpio");
118         break;
119     case 15:
120         system("config-pin P9.24 gpio");
121         break;
122     case 49:
123         system("config-pin P9.23 gpio");
124         break;
125     case 2:
126         system("config-pin P9.22 gpio");
127         break;
128     case 3:
129         system("config-pin P9.21 gpio");
130         break;
131     case 4:
132         system("config-pin P9.18 gpio");
133         break;
134     case 5:
135         system("config-pin P9.17 gpio");
136         break;
137     case 51:
138         system("config-pin P9.16 gpio");
```

```
139     break;
140 case 48:
141     system("config-pin P9.15 gpio");
142     break;
143 case 50:
144     system("config-pin P9.14 gpio");
145     break;
146 case 31:
147     system("config-pin P9.13 gpio");
148     break;
149 case 60:
150     system("config-pin P9.12 gpio");
151     break;
152 case 30:
153     system("config-pin P9.11 gpio");
154     break;
155 case 61:
156     system("config-pin P8.26 gpio");
157     break;
158 case 22:
159     system("config-pin P8.19 gpio");
160     break;
161 case 65:
162     system("config-pin P8.18 gpio");
163     break;
164 case 27:
165     system("config-pin P8.17 gpio");
166     break;
167 case 46:
168     system("config-pin P8.16 gpio");
169     break;
170 case 47:
171     system("config-pin P8.15 gpio");
172     break;
173 case 26:
174     system("config-pin P8.14 gpio");
175     break;
176 case 23:
177     system("config-pin P8.13 gpio");
178     break;
179 case 44:
180     system("config-pin P8.12 gpio");
181     break;
182 case 45:
183     system("config-pin P8.11 gpio");
184     break;
185 case 68:
186     system("config-pin P8.10 gpio");
187     break;
188 case 69:
189     system("config-pin P8.09 gpio");
190     break;
191 case 67:
192     system("config-pin P8.08 gpio");
193     break;
194 case 66:
```

```
195     system("config-pin P8.07 gpio");
196     break;
197 }
198 usleep(250000);
199 }
200
201 bool GPIO::UnexportPin(int number) {
202     //Write(UNEXPORT_PIN, NumberToString<int>(number));
203 }
204
205 GPIO::Direction GPIO::ReadsDirection(const string &gpiopath)
206 {
207     if (Read(gpiopath + DIRECTION) == "in") {
208         return Input;
209     } else {
210         return Output;
211     }
212 }
213
214 void GPIO::WritesDirection(const string &gpiopath, Direction
215     direction) {
216     switch (direction) {
217     case Hardware::GPIO::Input:
218         Write((gpiopath + DIRECTION), "in");
219         break;
220     case Hardware::GPIO::Output:
221         Write((gpiopath + DIRECTION), "out");
222         break;
223     }
224 }
225
226 GPIO::Edge GPIO::ReadsEdge(const string &gpiopath) {
227     string reader = Read(gpiopath + EDGE);
228     if (reader == "none") {
229         return None;
230     } else if (reader == "rising") {
231         return Rising;
232     } else if (reader == "falling") {
233         return Falling;
234     } else {
235         return Both;
236     }
237 }
238
239 void GPIO::WritesEdge(const string &gpiopath, Edge edge) {
240     switch (edge) {
241     case Hardware::GPIO::None:
242         Write((gpiopath + EDGE), "none");
243         break;
244     case Hardware::GPIO::Rising:
245         Write((gpiopath + EDGE), "rising");
246         break;
247     case Hardware::GPIO::Falling:
248         Write((gpiopath + EDGE), "falling");
249         break;
250     case Hardware::GPIO::Both:
```

```
249     Write((gpiopath + EDGE), "both");
250     break;
251     default:
252     break;
253 }
254 }
255
256 GPIO::Value GPIO::ReadsValue(const string &gpiopath) {
257     string path(gpiopath + VALUE);
258     int res = StringToNumber<int>(Read(path));
259     return (Value)res;
260 }
261
262 void GPIO::WritesValue(const string &gpiopath, Value value)
263 {
264     Write(gpiopath + VALUE, NumberToString<int>(value));
265 }
266
267 void *threadedPollGPIO(void *value) {
268     GPIO *gpio = static_cast<GPIO *>(value);
269     while (gpio->threadRunning) {
270         gpio->callbackFunction(gpio->WaitForEdge());
271         usleep(gpio->debounceTime * 1000);
272     }
273 }
274 }
```

PWM Class

```
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7   * Written by Jelle Spijker <spijkert.jelle@gmail.com>, 2015
8   */
9
10 #pragma once
11 #include "BBB.h"
12 #include <dirent.h>
13
14 #define OCP_PATH "/sys/class/pwm/"
15 #define PWM_CAPE "Override Board Name,00A0,Override Manuf,
16   cape-universal"
17
18 namespace Hardware {
19 class PWM : public BBB {
20 public:
21   enum Pin // Four possible PWM pins
22   {
23     P8_13,
24     P8_19,
25     P9_14,
26     P9_16
27   };
28   enum Run // Signal generating
29   {
30     On = 1,
31     Off = 0
32   };
33   enum Polarity // Inverse duty polarity
34   {
35     Normal = 1,
36     Inverted = 0
37   };
38   Pin pin; // Current pin
39
40   uint8_t GetPixelValue() { return pixelvalue; }
41   void SetPixelValue(uint8_t value);
42
43   float GetIntensity() { return intensity; }
44   void SetIntensity(float value);
45
46   int GetPeriod() { return period; }
47   void SetPeriod(int value);
48
49   int GetDuty() { return duty; }
50   void SetDuty(int value);
51   void SetIntensity();
52
53   Run GetRun() { return run; }
54   void SetRun(Run value);
55
56   Polarity GetPolarity() { return polarity; }
57   void SetPolarity(Polarity value);
58
59   PWM(Pin pin);
```

```

52     ~PWM();
53
54     private:
55     int period;           // current period
56     int duty;            // current duty
57     float intensity;     // current intensity
58     uint8_t pixelvalue; // current pixelvalue
59     Run run;             // current run state
60     Polarity polarity; // current polaity
61
62     string basepath;    // the basepath ocp
63     string dutypath;    // base + duty path
64     string periodpath; // base + period path
65     string runpath;    // base + run path
66     string polaritypath; // base + polarity path
67
68     void calcIntensity();
69 };
70 }



---


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8   */
9
10 #include "PWM.h"
11
12 namespace Hardware {
13 /// <summary>
14 /// Constructeur
15 /// </summary>
16 /// <param name="pin">Pin</param>
17 PWM::PWM(Pin pin) {
18     this->pin = pin;
19
20     // Check if PWM cape is loaded, if not load it
21     if (!CapeLoaded(PWM_CAPE)) {
22         Write(SLOTS, PWM_CAPE);
23     }
24
25     // Init the pin
26     switch (pin) {
27         case Hardware::PWM::P8_13:
28             system("config-pin P8.13 pwm");
29             basepath = OCP_PATH;
30             basepath.append("pwmchip4/pwm1");
31             break;
32         case Hardware::PWM::P8_19:
33             system("config-pin P8.19 pwm");
34             basepath = OCP_PATH;
35             basepath.append("pwmchip4/pwm0");
36             break;

```

```
35     case Hardware::PWM::P9_14:
36         system("config-pin P9.14 pwm");
37         basepath = OCP_PATH;
38         basepath.append("pwmchip2/pwm0");
39         break;
40     case Hardware::PWM::P9_16:
41         system("config-pin P9.16 pwm");
42         basepath.append("pwmchip2/pwm1");
43         break;
44     }
45
46     // Get the working paths
47     dutypath = basepath + "/duty_cycle";
48     periodpath = basepath + "/period";
49     runpath = basepath + "/run";
50     polaritypath = basepath + "/polarity";
51
52     // Give Linux time to setup directory structure;
53     usleep(250000);
54
55     // Read current values
56     period = StringToNumber<int>(Read(periodpath));
57     duty = StringToNumber<int>(Read(dutypath));
58     run = static_cast<Run>(StringToNumber<int>(Read(runpath)))
59     ;
60     polarity = static_cast<Polarity>(StringToNumber<int>(Read(
61         polaritypath)));
62
63     // calculate the current intensity
64     calcIntensity();
65 }
66
67 PWM::~PWM() {}
68
69 /// <summary>
70 /// Calculate the current intensity
71 /// </summary>
72 void PWM::calcIntensity() {
73     if (polarity == Normal) {
74         if (duty == 0) {
75             intensity = 0.0f;
76         } else {
77             intensity = (float)period / (float)duty;
78         }
79     } else {
80         if (period == 0) {
81             intensity = 0.0f;
82         } else {
83             intensity = (float)duty / (float)period;
84         }
85     }
86 /// <summary>
87 /// Set the intensity level as percentage
88 /// </summary>
```

```
89  /// <param name="value">floating value multiplication factor
90  </param>
91  void PWM::SetIntensity(float value) {
92  if (polarity == Normal) {
93      SetDuty(static_cast<int>((value * duty) + 0.5));
94  } else {
95      SetPeriod(static_cast<int>((value * period) + 0.5));
96  }
97
98  /// <summary>
99  /// Set the output as a corresponding uint8_t value
100 /// </summary>
101 /// <param name="value">pixel value 0-255</param>
102 void PWM::SetPixelValue(uint8_t value) {
103 if (period != 255) {
104     SetPeriod(255);
105 }
106 SetDuty(255 - value);
107 pixelvalue = value;
108 }
109
110 /// <summary>
111 /// Set the period of the signal
112 /// </summary>
113 /// <param name="value">period : int</param>
114 void PWM::SetPeriod(int value) {
115     string valstr = NumberToString<int>(value);
116     Write(periodpath, valstr);
117     period = value;
118
119     calcIntensity();
120 }
121
122 /// <summary>
123 /// Set the duty of the signal
124 /// </summary>
125 /// <param name="value">duty : int</param>
126 void PWM::SetDuty(int value) {
127     string valstr = NumberToString<int>(value);
128     Write(dutypath, valstr);
129     duty = value;
130
131     calcIntensity();
132 }
133
134 /// <summary>
135 /// Run the signal
136 /// </summary>
137 /// <param name="value">On or Off</param>
138 void PWM::SetRun(Run value) {
139     int valInt = static_cast<int>(value);
140     string valstr = NumberToString<int>(valInt);
141     Write(runpath, valstr);
142     run = value;
143 }
```

```
144
145  /// <summary>
146  /// Set the polarity
147  /// </summary>
148  /// <param name="value">Normal or Inverted signal</param>
149  void PWM::SetPolarity(Polarity value) {
150      int valInt = static_cast<int>(value);
151      string valstr = NumberToString<int>(valInt);
152      Write(runpath, valstr);
153      polarity = value;
154  }
155 }
```

ADC Class

```

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8   */
9
10 /*! \class ADC
11 Interaction with the beaglebone analogue pins
12 */
13
14 #pragma once
15
16 #include "BBB.h"
17 #include "ADCReadException.h"
18
19 #define ADC0_PATH
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34

```

```

35 #define ADC6_PATH
36     \
37     "/sys/bus/iio/devices/iio:device0/in_voltage6_raw" /*!<
38     path to analogue pin \
39     \
40     "/sys/bus/iio/devices/iio:device0/in_voltage7_raw" /*!<
41     path to analogue pin \
42
43 namespace Hardware {
44 class ADC : public BBB {
45 public:
46     /*! Enumerator to indicate the analogue pin*/
47     enum ADCPin {
48         ADC0, /*!< AIN0 pin*/
49         ADC1, /*!< AIN1 pin*/
50         ADC2, /*!< AIN2 pin*/
51         ADC3, /*!< AIN3 pin*/
52         ADC4, /*!< AIN4 pin*/
53         ADC5, /*!< AIN5 pin*/
54         ADC6, /*!< AIN6 pin*/
55         ADC7 /*!< AIN7 pin*/
56     };
57     ADCPin Pin; /*!< current pin*/
58
59     ADC(APCPin pin);
60     ~ADC();
61
62     int GetCurrentValue();
63     float GetIntensity() { return Intensity; }
64     int GetMinIntensity() { return MinIntensity; }
65     int GetMaxIntensity() { return MaxIntensity; }
66
67     void SetMinIntensity();
68     void SetMaxIntensity();
69
70     int WaitForValueChange();
71     int WaitForValueChange(CallbackType callback);
72     void WaitForValueChangeCancel() { this->threadRunning =
73         false; }
74
75 private:
76     string adcpath; /*!< Path to analogue write file*/
77     float Intensity; /*!< Current intensity expressed as
78     percentage*/
79     int MinIntensity; /*!< Voltage level which represent 0
79     percentage*/
80     int MaxIntensity; /*!< Voltage level which represent 100
80     percentage*/

```

```
80     friend void *threadedPollADC(void *value); /*!< friend
81     polling function*/
82 }
83 void *threadedPollADC(void *value);
84 }



---


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8 */
9
10 #include "ADC.h"
11
12 namespace Hardware {
13 /*! Constructor
14 \param pin and ADCPin type indicating which analogue pin to
15  use
16 */
17 ADC::ADC(ADCPin pin) {
18     this->Pin = pin;
19     switch (pin) {
20     case Hardware::ADC::ADCO:
21         adcpath = ADC0_PATH;
22         break;
23     case Hardware::ADC::ADC1:
24         adcpath = ADC1_PATH;
25         break;
26     case Hardware::ADC::ADC2:
27         adcpath = ADC2_PATH;
28         break;
29     case Hardware::ADC::ADC3:
30         adcpath = ADC3_PATH;
31         break;
32     case Hardware::ADC::ADC4:
33         adcpath = ADC4_PATH;
34         break;
35     case Hardware::ADC::ADC5:
36         adcpath = ADC5_PATH;
37         break;
38     case Hardware::ADC::ADC6:
39         adcpath = ADC6_PATH;
40         break;
41     case Hardware::ADC::ADC7:
42         adcpath = ADC7_PATH;
43         break;
44     }
45 }
46
47 MinIntensity = 0;
48 MaxIntensity = 4096;
49 }
```

```

47  /*! De-constructor*/
48  ADC::~ADC() {}
49
50  /*! Reads the current voltage in the pin
51  \return an integer between 0 and 4096
52  */
53  int ADC::GetCurrentValue() {
54      int retVal = StringToNumber<int>(Read(adcpPath));
55      Intensity = (float)(retVal - MinIntensity) /
56                      (4096 - (MinIntensity + (4096 - MaxIntensity)))
57                      );
58      return retVal;
59  }
60  /*! Set the current voltage at the pin as the minimum
61  voltage*/
62  void ADC::SetMinIntensity() {
63      MinIntensity = StringToNumber<int>(Read(adcpPath));
64  }
65  void ADC::SetMaxIntensity() {
66      MaxIntensity = StringToNumber<int>(Read(adcpPath));
67  }
68
69  /*! Threading enabled polling of the analogue pin
70  \param callback the function which should be called when
71  polling indicates a
72  change CallbackType
73  \return 0
74  */
75  int ADC::WaitForValueChange(CallbackType callback) {
76      threadRunning = true;
77      callbackFunction = callback;
78      if (pthread_create(&thread, NULL, &threadedPollADC,
79                          static_cast<void *>(this))) {
80          threadRunning = false;
81          throw Exception::
82              FailedToCreateGPIOPollingThreadException();
83      }
84      return 0;
85  }
86  /*! Polling of the analogue pin
87  \return the current value
88  */
89  int ADC::WaitForValueChange() {
90      int fd, i, epollfd, count = 0;
91      struct epoll_event ev;
92      epollfd = epoll_create(1);
93      if (epollfd == -1) {
94          throw Exception::
95              FailedToCreateGPIOPollingThreadException(
96                  "GPIO: Failed to create epollfd!");
97      }
98      if ((fd = open(adcpPath.c_str(), O_RDONLY | O_NONBLOCK)) ==
99          -1) {

```

```
97     throw Exception::ADCReadException();
98 }
99 ev.events = EPOLLIN;
100 ev.data.fd = fd;
101
102 if (epoll_ctl(epollfd, EPOLL_CTL_ADD, fd, &ev) == -1) {
103     throw Exception::
104         FailedToCreateGPIOPollingThreadException(
105             "ADC: Failed to add control interface!");
106 }
107 while (count <= 1) {
108     i = epoll_wait(epollfd, &ev, 1, -1);
109     if (i == -1) {
110         close(fd);
111         return -1;
112     } else {
113         count++;
114     }
115 }
116 close(fd);
117 return StringToNumber<int>(Read(adcpPath));
118 }
119
120 /*! friendly function to start the threading*/
121 void *threadedPollADC(void *value) {
122     ADC *adc = static_cast<ADC *>(value);
123     while (adc->threadRunning) {
124         adc->callbackFunction(adc->WaitForValueChange());
125         usleep(200000);
126     }
127 }
128 }
```

EC12P Class

```
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5   * Jelle Spijker)
6   * This software is proprietary and confidential
7   * Written by Jelle Spijker <spijkert.jelle@gmail.com>, 2015
8   */
9
10 /*! \class EC12P
11 Interaction with the sparkfun RGB encoder
12 */
13
14 #pragma once
15
16 #include "eqep.h"
17 #include "GPIO.h"
18 #include "FailedToCreateThreadException.h"
19
20 #include <pthread.h>
21
22 using namespace std;
23
24 namespace Hardware {
25 class EC12P {
26 public:
27     EC12P();
28     ~EC12P();
29
30     /*! Enumerator indicating the color of the encoder shaft*/
31     enum Color {
32         Red,      /*!< Red*/
33         Pink,    /*!< Pink*/
34         Blue,    /*!< Blue*/
35         SkyBlue, /*!< SkyBlue*/
36         Green,   /*!< Green*/
37         Yellow,  /*!< Yellow*/
38         White,   /*!< White*/
39         None     /*!< Off*/
40     };
41
42     void SetPixelColor(Color value);
43     Color GetPixelColor() { return PixelColor; };
44
45     void RainbowLoop(int sleepperiod);
46     void StopRainbowLoop() { threadRunning = false; };
47
48     eQEP Rotary{eQEP2, eQEP::eQEP_Mode_Absolute}; /*!< The
49     encoder*/
50     GPIO Button{68};                                /*!< The
51     pushbutton*/
52
53     private:
54     Color PixelColor; /*!< Current shaft color*/
```

```

51
52     GPIO R{31}; /*!< Red LED*/
53     GPIO B{48}; /*!< Blue LED*/
54     GPIO G{51}; /*!< Green LED*/
55
56     pthread_t thread; /*!< the thread*/
57     bool threadRunning; /*!< Bool used to stop the thread*/
58     int sleepperiod; /*!< Sleep period*/
59     friend void *colorLoop(void *value);
60 };
61 void *colorLoop(void *value);
62 }



---


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7  * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8 */
9
10 #include "EC12P.h"
11
12 namespace Hardware {
13 /*! Constructor*/
14 EC12P::EC12P() {
15     // Init Rotary button
16     Button.SetDirection(GPIO::Input);
17     Button.SetEdge(GPIO::Rising);
18
19     // Init Encoder
20     Rotary.set_period(100000000L);
21
22     // Init Encoder color
23     R.SetDirection(GPIO::Output);
24     B.SetDirection(GPIO::Output);
25     G.SetDirection(GPIO::Output);
26     SetPixelColor(None);
27 }
28
29 /*! De-constructor*/
30 EC12P::~EC12P() {}
31
32 /*! Set the shaft color
33 \param value as Color enumerator
34 */
35 void EC12P::SetPixelColor(Color value) {
36     switch (value) {
37     case Hardware::EC12P::Red:
38         R.SetValue(GPIO::High);
39         B.SetValue(GPIO::Low);
40         G.SetValue(GPIO::Low);
41         break;

```

```
42     case Hardware::EC12P::Pink:
43         R.SetValue(GPIO::High);
44         B.SetValue(GPIO::High);
45         G.SetValue(GPIO::Low);
46         break;
47     case Hardware::EC12P::Blue:
48         R.SetValue(GPIO::Low);
49         B.SetValue(GPIO::High);
50         G.SetValue(GPIO::Low);
51         break;
52     case Hardware::EC12P::SkyBlue:
53         R.SetValue(GPIO::Low);
54         B.SetValue(GPIO::High);
55         G.SetValue(GPIO::High);
56         break;
57     case Hardware::EC12P::Green:
58         R.SetValue(GPIO::Low);
59         B.SetValue(GPIO::Low);
60         G.SetValue(GPIO::High);
61         break;
62     case Hardware::EC12P::Yellow:
63         R.SetValue(GPIO::High);
64         B.SetValue(GPIO::Low);
65         G.SetValue(GPIO::High);
66         break;
67     case Hardware::EC12P::White:
68         R.SetValue(GPIO::High);
69         B.SetValue(GPIO::High);
70         G.SetValue(GPIO::High);
71         break;
72     case Hardware::EC12P::None:
73         R.SetValue(GPIO::Low);
74         B.SetValue(GPIO::Low);
75         G.SetValue(GPIO::Low);
76         break;
77     }
78     PixelColor = value;
79 }
80
81 /*! Loops through all the colors except of as a thread */
82 void EC12P::RainbowLoop(int sleepperiod) {
83     this->sleepperiod = sleepperiod;
84     this->threadRunning = true;
85     if (pthread_create(&thread, NULL, colorLoop, this)) {
86         throw Exception::FailedToCreateThreadException();
87     }
88 }
89
90 /*! The thread function that runs trough all the colors*/
91 void *colorLoop(void *value) {
92     int i = 0;
93     EC12P *ec12p = static_cast<EC12P *>(value);
94     EC12P::Color pcolor;
95     while (ec12p->threadRunning) {
96         pcolor = static_cast<EC12P::Color>(i);
97         ec12p->SetPixelColor(pcolor);
```

```
98     usleep(ec12p->sleepperiod);
99     i++;
100    if (i == 6) {
101        i = 0;
102    }
103 }
104 return ec12p;
105 }
106 }
```

eQep Class

```
1  /*
2  *  TI eQEP driver interface API
3  *
4  *  Copyright (C) 2013 Nathaniel R. Lewis - http://
5  *          nathanielrlewis.com/
6  *
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8  *  /or modify
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10 *  published by
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14 *
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22 *
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24 *  License
25 *  along with this program; if not, write to the Free
26 *  Software
27 *  Foundation, Inc., 675 Mass Ave, Cambridge, MA 02139, USA.
28 *
29 *
30 *  This code is changed by Jelle Spijker (C) 2014.
31 *  Introducing polling with threading.
32 *
33 */
34
35 #pragma once
36
37 #include <iostream>
38 #include <stdint.h>
39 #include <string>
40 #include "BBB.h"
41
42 #define eQEPO "/sys/devices/ocp.3/48300000.epwmss/48300180.
43         eqep"
44 #define eQEP1 "/sys/devices/ocp.3/48302000.epwmss/48302180.
45         eqep"
46 #define eQEP2 "/sys/devices/ocp.3/48304000.epwmss/48304180.
47         eqep"
48
49 namespace Hardware {
50 // Class which defines an interface to my eQEP driver
51 class eQEP : public BBB {
52     // Base path for the eQEP unit
53     std::string path;
```

```

43 public:
44     // Modes of operation for the eQEP hardware
45     typedef enum {
46         // Absolute positioning mode
47         eQEP_Mode_Absolute = 0,
48
49         // Relative positioning mode
50         eQEP_Mode_Relative = 1,
51
52         // Error flag
53         eQEP_Mode_Error = 2,
54     } eQEP_Mode;
55
56     // Default constructor for the eQEP interface driver
57     eQEP(std::string _path, eQEP_Mode _mode);
58
59     // Reset the value of the encoder
60     void set_position(int32_t position);
61
62     // Get the position of the encoder, pass poll as true to
63     // poll the pin, whereas
64     // passing false reads the immediate value
65     int32_t get_position(bool _poll = true);
66
67     // Thread of the poll
68     int WaitForPositionChange(CallbackType callback);
69     void WaitForPositionChangeCancel() { this->threadRunning =
70         false; }
71
72     // Set the polling period
73     void set_period(long long unsigned int period);
74
75     // Get the polling period of the encoder
76     uint64_t get_period();
77
78     // Set the mode of the eQEP hardware
79     void set_mode(eQEP_Mode mode);
80
81     // Get the mode of the eQEP hardware
82     eQEP_Mode get_mode();
83
84     private:
85         friend void *threadedPolleqep(void *value);
86     };
87 }



---


1  /*
2  *  TI eQEP driver interface API
3  *
4  *  Copyright (C) 2013 Nathaniel R. Lewis - http://
5  *          nathanielrlewis.com/
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```

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24 * Software
25 * Foundation, Inc., 675 Mass Ave, Cambridge, MA 02139, USA.
26 *
27 * This file is modified by Jelle Spijker 2014
28 * Added polling and threading capabilties
29 *
30 */
31
32
33 // Pull in our eQEP driver definitions
34 #include "eqep.h"
35
36
37 // Language dependencies
38 #include <cstdint>
39 #include <cstdlib>
40 #include <stdio>
41
42 // POSIX dependencies
43 #include <unistd.h>
44 #include <fcntl.h>
45 #include <poll.h>
46 #include <sys/types.h>
47 #include <sys/stat.h>
48
49
50 namespace Hardware {
51 // Constructor for eQEP driver interface object
52 eQEP::eQEP(std::string _path, eQEP::eQEP_Mode _mode) : path(
53     _path) {
54     if (_path == eQEP0) {
55         if (!CapeLoaded("bone_eqep0")) {
56             Write(SLOTS, "bone_eqep0");
57         }
58     } else if (_path == eQEP1) {
59         if (!CapeLoaded("bone_eqep1")) {
60             Write(SLOTS, "bone_eqep1");
61         }
62     } else if (_path == eQEP2) {
63         if (!CapeLoaded("bone_eqep2b")) {
64             Write(SLOTS, "bone_eqep2b");
65         }
66     }
67 }
```

```
55     }
56
57     // Set the mode of the hardware
58     this->set_mode(_mode);
59
60     // Reset the position
61     this->set_position(0);
62 }
63
64 // Set the position of the eQEP hardware
65 void eQEP::set_position(int32_t position) {
66     // Open the file representing the position
67     FILE *fp = fopen((this->path + "/position").c_str(), "w");
68
69     // Check that we opened the file correctly
70     if (fp == NULL) {
71         // Error, break out
72         std::cerr << "[eQEP " << this->path << "] Unable to open
73             position for write"
74             << std::endl;
75     }
76
77     // Write the desired value to the file
78     fprintf(fp, "%d\n", position);
79
80     // Commit changes
81     fclose(fp);
82 }
83
84 // Set the period of the eQEP hardware
85 void eQEP::set_period(long long unsigned int period) {
86     // Open the file representing the position
87     FILE *fp = fopen((this->path + "/period").c_str(), "w");
88
89     // Check that we opened the file correctly
90     if (fp == NULL) {
91         // Error, break out
92         std::cerr << "[eQEP " << this->path << "] Unable to open
93             period for write"
94             << std::endl;
95     }
96
97     // Write the desired value to the file
98     fprintf(fp, "%llu\n", period);
99
100    // Commit changes
101    fclose(fp);
102 }
103
104 // Set the mode of the eQEP hardware
105 void eQEP::set_mode(eQEP::eQEP_Mode _mode) {
106     // Open the file representing the position
107     FILE *fp = fopen((this->path + "/mode").c_str(), "w");
108 }
```

```
109 // Check that we opened the file correctly
110 if (fp == NULL) {
111     // Error, break out
112     std::cerr << "[eQEP " << this->path << "] Unable to open
113         mode for write"
114         << std::endl;
115     return;
116 }
117 // Write the desired value to the file
118 fprintf(fp, "%u\n", _mode);
119
120 // Commit changes
121 fclose(fp);
122 }
123
124 int eQEP::WaitForPositionChange(CallbackType callback) {
125     threadRunning = true;
126     callbackFunction = callback;
127     if (pthread_create(&this->thread, NULL, &threadedPolleqep,
128                         static_cast<void *>(this))) {
129         threadRunning = false;
130         throw Exception::
131             FailedToCreateGPIOPollingThreadException();
132     }
133     return 0;
134 }
135
136 // Get the position of the hardware
137 int32_t eQEP::get_position(bool _poll) {
138     // Position temporary variable
139     int32_t position;
140     char dummy;
141     struct pollfd ufd;
142
143     // Do we want to poll?
144     if (_poll) {
145         // Open a connection to the attribute file.
146         if ((ufd.fd = open((this->path + "/position").c_str(),
147                           O_RDWR)) < 0) {
148             // Error, break out
149             std::cerr << "[eQEP " << this->path
150                 << "] unable to open position for polling"
151                 << std::endl;
152         }
153         // Dummy read
154         read(ufd.fd, &dummy, 1);
155
156         // Poll the port
157         ufd.events = (short)EPOLLET;
158         if (poll(&ufd, 1, -1) < 0) {
159             // Error, break out
```

```

160     std::cerr << "[eQEP " << this->path << "] Error
161         occurred whilst polling"
162         << std::endl;
163         close(ufd.fd);
164     }
165 }
166
167 // Read the position
168 FILE *fp = fopen((this->path + "/position").c_str(), "r");
169
170 // Check that we opened the file correctly
171 if (fp == NULL) {
172     // Error, break out
173     std::cerr << "[eQEP " << this->path << "] Unable to open
174         position for read"
175         << std::endl;
176         close(ufd.fd);
177     return 0;
178 }
179
180 // Write the desired value to the file
181 fscanf(fp, "%d", &position);
182
183 // Commit changes
184 fclose(fp);
185
186 // If we were polling, close the polling file
187 if (_poll) {
188     close(ufd.fd);
189 }
190
191 // Return the position
192 return position;
193
194 // Get the period of the eQEP hardware
195 uint64_t eQEP::get_period() {
196     // Open the file representing the position
197     FILE *fp = fopen((this->path + "/period").c_str(), "r");
198
199     // Check that we opened the file correctly
200     if (fp == NULL) {
201         // Error, break out
202         std::cerr << "[eQEP " << this->path << "] Unable to open
203             period for read"
204             << std::endl;
205     }
206
207     // Write the desired value to the file
208     uint64_t period = 0;
209     fscanf(fp, "%llu", &period);
210
211     // Commit changes
212     fclose(fp);

```

```
213     // Return the period
214     return period;
215 }
216 }
217
218 // Get the mode of the eQEP hardware
219 eQEP::eQEP_Mode eQEP::get_mode() {
220     // Open the file representing the position
221     FILE *fp = fopen((this->path + "/mode").c_str(), "r");
222
223     // Check that we opened the file correctly
224     if (fp == NULL) {
225         // Error, break out
226         std::cerr << "[eQEP " << this->path << "] Unable to open
227             mode for read"
228             << std::endl;
229         return eQEP::eQEP_Mode_Error;
230     }
231
232     // Write the desired value to the file
233     eQEP::eQEP_Mode mode;
234     fscanf(fp, "%u", (unsigned int *)&mode);
235
236     // Commit changes
237     fclose(fp);
238
239     // Return the mode
240     return mode;
241 }
242
243 void *threadedPolleqep(void *value) {
244     eQEP *eqep = static_cast<eQEP *>(value);
245     while (eqep->threadRunning) {
246         eqep->callbackFunction(eqep->get_position(true));
247         usleep(eqep->debounceTime * 1000);
248     }
249 }
250 }
```

SoilCape Class

```

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7   * Written by Jelle Spijker <spijkerspijker.jelle@gmail.com>, 2015
8   */
9
10 #pragma once
11
12 #include "EC12P.h"
13 #include "GPIO.h"
14 #include "PWM.h"
15 #include "ADC.h"
16
17 namespace Hardware {
18 class SoilCape {
19 public:
20     EC12P RGBEncoder;
21     PWM MicroscopeLEDs{PWM::P9_14};
22     ADC MicroscopeLDR{ADC::ADC0};
23
24     SoilCape();
25     ~SoilCape();
26 };
27 }
```

```

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8   */
9
10 #include "SoilCape.h"
11
12 namespace Hardware {
13     SoilCape::SoilCape() {}
14     SoilCape::~SoilCape() {}
15 }
```

USB Class

```

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8   */
9
10 #pragma once
11
12 #include <stdio.h>
13 #include <unistd.h>
14 #include <fcntl.h>
15 #include <errno.h>
16 #include <sys/ioctl.h>
17
18 namespace Hardware {
19 class USB {
20 public:
21     USB();
22     ~USB();
23     void ResetUSB();
24 };
25 }
```

```

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8   */
9
10 #include "USB.h"
11
12 namespace Hardware {
13 USB::USB() {}
14
15 USB::~USB() {}
16
17 void USB::ResetUSB() {
18     int fd, rc;
19
20     fd = open("/dev/bus/usb/001/002", O_WRONLY);
21     rc = ioctl(fd, USBDEVFS_RESET, 0);
22     if (rc < 0) {
23         throw - 1;
24     }
25     close(fd);
26 }
```


General project files

```
1 #-----
2 #
3 # Project created by QtCreator 2015-06-06T10:49:23
4 #
5 #-----
6 QT      += core gui concurrent
7 greaterThan(QT_MAJOR_VERSION, 4): QT += widgets
8
9 TARGET = SoilHardware
10 TEMPLATE = lib
11 VERSION = 0.9.2
12
13 DEFINES += SOILHARDWARE_LIBRARY
14 QMAKE_CXXFLAGS += -std=c++11 -pthread
15 unix:!macx: QMAKE_RPATHDIR += $$PWD/../../../../build/install/
16
17 SOURCES += \
18     USB.cpp \
19     SoilCape.cpp \
20     PWM.cpp \
21     Microscope.cpp \
22     GPIO.cpp \
23     eqep.cpp \
24     EC12P.cpp \
25     BBB.cpp \
26     ADC.cpp
27
28 HEADERS += \
29     ValueOutOfBoundsException.h \
30     USB.h \
31     SoilCape.h \
32     PWM.h \
33     MicroscopeNotFoundException.h \
34     Microscope.h \
35     Hardware.h \
36     GPIOReadException.h \
37     GPIO.h \
38     FailedToCreateThreadException.h \
39     FailedToCreateGPIOPollingThreadException.h \
40     eqep.h \
41     EC12P.h \
42     CouldNotGrabImageException.h \
43     BBB.h \
44     ADCReadException.h \
45     ADC.h
46
47 #opencv
48 LIBS += -L/usr/local/lib -lopencv_core -lopencv_highgui - \
49         -lopencv_photo -lopencv_imgcodecs -lopencv_videoio
50 INCLUDEPATH += /usr/local/include/opencv
51 INCLUDEPATH += /usr/local/include
52 #boost
53 DEFINES += BOOST_ALL_DYN_LINK
```

```

54 INCLUDEPATH += /usr/include/boost
55 LIBS += -L/usr/lib/x86_64-linux-gnu/ -lboost_filesystem -
      lboost_system
56
57 unix {
58     target.path = $PWD/../../build/install
59     INSTALLS += target
60 }
61
62 #Gstreamer
63 INCLUDEPATH += /usr/include/gstreamer-0.10
64 INCLUDEPATH += /usr/include/glib-2.0/
65 INCLUDEPATH += /usr/lib/x86_64-linux-gnu/glib-2.0/include/
66 INCLUDEPATH += /usr/include/libxml2/
67 LIBS += 'pkg-config --cflags --libs gstreamer-0.10'

```

```

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7  * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8 */
9
10 #pragma once
11
12 #include "ADC.h"
13 #include "EC12P.h"
14 #include "eqep.h"
15 #include "GPIO.h"
16 #include "PWM.h"
17 #include "SoilCape.h"
18 #include "Microscope.h"
19 #include "CouldNotGrabImageException.h"
20 #include "ADCReadException.h"
21 #include "FailedToCreateGPIOPollingThreadException.h"
22 #include "FailedToCreateThreadException.h"
23 #include "GPIOReadException.h"
24 #include "MicroscopeNotFoundException.h"
25 #include "ValueOutOfBoundsException.h"

```

```

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6  * This software is proprietary and confidential
7  * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8 */
9
10 #include <exception>
11 #include <string>
12

```

```
13 using namespace std;
14
15 namespace Hardware {
16 namespace Exception {
17 class ValueOutOfBoundsException : public std::exception {
18 public:
19     ValueOutOfBoundsException(string m = "Value out of bounds!
20     ") : msg(m){};
20     ~ValueOutOfBoundsException() _GLIBCXX_USE_NOEXCEPT{};
21     const char *what() const _GLIBCXX_USE_NOEXCEPT { return
22         msg.c_str(); };
23
24     private:
25         string msg;
26     };
27 }
28
29
30 /* Copyright (C) Jelle Spijker - All Rights Reserved
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34  * Jelle Spijker)
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37 */
38
39 #pragma once
40 #include <exception>
41 #include <string>
42
43 using namespace std;
44
45 namespace Hardware {
46 namespace Exception {
47 class ADCReadException : public std::exception {
48 public:
49     ADCReadException(string m = "Can't read ADC data!") : msg(
50         m){};
51     ~ADCReadException() _GLIBCXX_USE_NOEXCEPT{};
52     const char *what() const _GLIBCXX_USE_NOEXCEPT { return
53         msg.c_str(); };
54
55     private:
56         string msg;
57     };
58 }
59
60
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```

```

6  */
7
8 #pragma once
9
10 #include <exception>
11 #include <string>
12
13 using namespace std;
14
15 namespace Hardware {
16 namespace Exception {
17 class FailedToCreateGPIOPollingThreadException : public std
18   : exception {
19 public:
20   FailedToCreateGPIOPollingThreadException(
21     string m = "Failed to create GPIO polling thread!")
22   : msg(m){};
23   ~FailedToCreateGPIOPollingThreadException() _GLIBCXX_USE_NOEXCEPT{};
24   const char *what() const _GLIBCXX_USE_NOEXCEPT { return
25     msg.c_str(); };
26
27 private:
28   string msg;
29 }

```

```

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8 */
9
10 #pragma once
11
12 #include <exception>
13 #include <string>
14
15 namespace Hardware {
16 namespace Exception {
17 class FailedToCreateThreadException : public std::exception
18 {
19 public:
20   FailedToCreateThreadException(string m = "Couldn't create
21     the thread!")
22   : msg(m){};
23   ~FailedToCreateThreadException() _GLIBCXX_USE_NOEXCEPT{};
24   const char *what() const _GLIBCXX_USE_NOEXCEPT { return
25     msg.c_str(); };
26
27
28
29

```



```
42
43     private:
44         string msg;
45         int nr;
46     };
47 }
48 }



---


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7  * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8  */
9
10 #pragma once
11 #include <exception>
12 #include <string>
13
14 using namespace std;
15
16 namespace Hardware {
17     namespace Exception {
18         class CouldNotGrabImageException : public std::exception {
19             public:
20                 CouldNotGrabImageException(string m = "Unable to grab the
21                     next image!")
22                 : msg(m){};
23             ~CouldNotGrabImageException() _GLIBCXX_USE_NOEXCEPT{};
24             const char *what() const _GLIBCXX_USE_NOEXCEPT { return
25                 msg.c_str(); };
26         };
27     }
28 }



---


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7  * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8  */
9
10 #pragma once
11 #include <exception>
12 #include <string>
13
14 using namespace std;
```

```
15 namespace Hardware {
16 namespace Exception {
17 class GPIOReadException : public std::exception {
18 public:
19     GPIOReadException(string m = "Can't read GPIO data!") :
20         msg(m){};
21     ~GPIOReadException() __GLIBCXX_USE_NOEXCEPT{};
22     const char *what() const __GLIBCXX_USE_NOEXCEPT { return
23         msg.c_str(); };
24
25     private:
26     string msg;
27 }
28
29
30
31 /* Copyright (C) Jelle Spijker - All Rights Reserved
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38 */
39
40 #pragma once
41
42
43 #include <exception>
44 #include <string>
45
46
47 using namespace std;
48
49
50
51 namespace Hardware {
52 namespace Exception {
53 class GPIOReadException : public std::exception {
54 public:
55     GPIOReadException(string m = "Can't read GPIO data!") :
56         msg(m){};
57     ~GPIOReadException() __GLIBCXX_USE_NOEXCEPT{};
58     const char *what() const __GLIBCXX_USE_NOEXCEPT { return
59         msg.c_str(); };
60
61     private:
62     string msg;
63 };
64 }
```



J. Vision Library

Image processing Class

```
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8   */
9
10 #pragma once
11 /*! Current class version*/
12 #define IMAGEPROCESSING_VERSION 1
13
14 /*! MACRO which sets the original pointer to the original
15   * image or a clone of
16   * the earlier processed image */
17 #define CHAIN_PROCESS(chain, 0, type)
18
19 if (chain) {
20
21     \
22     TempImg = ProcessedImg.clone();
23
24     0 = (type *)TempImg.data;
25
26 } else {
27
28     \
29     0 = (type *)OriginalImg.data;
30 }
```

```
21 /*! MACRO which trows an EmtpyImageException if the matrix
22     is empty*/
23 #define EMPTY_CHECK(img)
24
25     if (img.empty()) {
26
27         \
28         throw Exception::EmtpyImageException();
29     \
30
31 }
32
33 #include <opencv2/core.hpp>
34 #include <opencv2/highgui.hpp>
35 #include <opencv2/imgproc.hpp>
36
37 #include <stdint.h>
38 #include <cmath>
39 #include <vector>
40 #include <string>
41
42 #include <boost/signals2.hpp>
43 #include <boost/bind.hpp>
44
45 #include "EmptyImageException.h"
46 #include "WrongKernelSizeException.h"
47 #include "ChannelMismatchException.h"
48 #include "PixelValueOutOfBoundException.h"
49 #include "VisionDebug.h"
50
51 using namespace cv;
52
53 namespace Vision {
54 class ImageProcessing {
55 public:
56     typedef boost::signals2::signal<void(float, std::string)>
57     Progress_t;
58     boost::signals2::connection
59     connect_Progress(const Progress_t::slot_type &subscriber);
60
61 protected:
62     uchar *GetNRow(int nData, int hKsize, int nCols, uint32_t
63     totalRows);
64     Mat TempImg;
65
66     Progress_t prog_sig;
67
68 public:
69     ImageProcessing();
70     ~ImageProcessing();
71     Mat OriginalImg;
72     Mat ProcessedImg;
73
74     static void getOriententated(Mat &BW, cv::Point_<double> &
75         centroid,
76
77         double &theta, double &
78         eccentricity);
```

```

68     static void RotateImg(Mat &src, Mat &dst, double &theta,
69         cv::Point_<double> &Centroid, Rect &ROI);
70
71     double currentProg = 0.;
72     double ProgStep = 0.;
73
74     static std::vector<Mat> extractChannel(const Mat &src);
75
76     /*! Copy a matrix to a new matrix with a LUT mask
77     \param src the source image
78     \param *LUT type T with a LUT to filter out unwanted pixel
79     values
80     \param cvType an in where you can pas CV_UC8C1 etc.
81     \return The new matrix
82     */
83     template <typename T1, typename T2>
84     static Mat CopyMat(const Mat &src, T1 *LUT, int cvType) {
85         Mat dst(src.size(), cvType);
86         uint32_t nData = src.rows * src.cols * dst.step[1];
87         if (cvType == 0 || cvType == 8 || cvType == 16 || cvType
88             == 24) {
89             for (uint32_t i = 0; i < nData; i += dst.step[1]) {
90                 dst.data[i] =
91                     static_cast<uint8_t>(LUT[*(T2 *) (src.data + (i *
92                         src.step[1]))]);
93             }
94         } else if (cvType == 1 || cvType == 9 || cvType == 17 ||

95             cvType == 25) {
96             for (uint32_t i = 0; i < nData; i += src.step[1]) {
97                 dst.data[i] =
98                     static_cast<int8_t>(LUT[*(T2 *) (src.data + (i *
99                         src.step[1]))]);
100            }
101        } else if (cvType == 2 || cvType == 10 || cvType == 18
102             || cvType == 26) {
103            for (uint32_t i = 0; i < nData; i += src.step[1]) {
104                dst.data[i] =
105                    static_cast<uint16_t>(LUT[*(T2 *) (src.data + (i *
106                         src.step[1]))]);
107            }
108        } else if (cvType == 4 || cvType == 12 || cvType == 20
109             || cvType == 28) {
110            for (uint32_t i = 0; i < nData; i += src.step[1]) {
111                dst.data[i] =
112                    static_cast<int32_t>(LUT[*(T2 *) (src.data + (i *
113                         src.step[1]))]);
114            }
115        }
116    }
117
118    return dst;

```

```

112     }
113
114     /*! Copy a matrix to a new matrix with a mask
115     \param src the source image
116     \param *LUT type T with a LUT to filter out unwanted pixel
117     values
118     \param cvType an in where you can pas CV_UC8C1 etc.
119     \return The new matrix
120 */
121 template <typename T1>
122 static Mat CopyMat(const Mat &src, const Mat &mask, int
123     cvType) {
124     if (src.size != mask.size) {
125         throw Exception::WrongKernelSizeException(
126             "Mask not the same size as src Exception!");
127     }
128     if (mask.channels() != 1) {
129         throw Exception::WrongKernelSizeException(
130             "Mask has more then 1 channel Exception!");
131     }
132     Mat dst(src.size(), cvType);
133
134     vector<Mat> exSrc = Vision::ImageProcessing::
135         extractChannel(src);
136     vector<Mat> exDst;
137
138     int cvBaseType = cvType % 8;
139     for_each(exSrc.begin(), exSrc.end(), [&](&b>const Mat &
140         sItem) {
141         Mat dItem(src.size(), cvBaseType);
142         std::transform(sItem.begin<T1>(), sItem.end<T1>(),
143             mask.begin<T1>(),
144                 dItem.begin<T1>(),
145                 [](&b>const T1 &s, const T1 &m) -> T1 {
146                     return s * m; });
147         exDst.push_back(dItem);
148     });
149     merge(exDst, dst);
150
151     return dst;
152 }
153
154
155 template <typename T1>
156 static void ShowDebugImg(cv::Mat img, T1 maxVal, std::
157     string windowName,
158                 bool scale = true) {
159     if (img.rows > 0 && img.cols > 0) {
160         cv::Mat tempImg(img.size(), img.type());

```

```

160     if (scale == true) {
161         std::vector<cv::Mat> exSrc = extractChannel(img);
162         std::vector<cv::Mat> exDst;
163         int cvBaseType = img.type() % 8;
164         T1 MatMin = std::numeric_limits<T1>::max();
165         T1 MatMax = std::numeric_limits<T1>::min();
166
167         // Find the global max and min
168         for_each(exSrc.begin(), exSrc.end(), [&](const Mat &
169             sItem) {
170             std::for_each(sItem.begin<T1>(), sItem.end<T1>(),
171                         [&](const T1 &s) {
172                 if (s > MatMax) {
173                     MatMax = s;
174                 } else if (s < MatMin) {
175                     MatMin = s;
176                 }
177             });
178             int Range = MatMax - MatMin;
179             if (Range < 1)
180                 Range = maxVal;
181
182             // Convert the values
183             for_each(exSrc.begin(), exSrc.end(), [&](const cv::
184                 Mat &sItem) {
185                 Mat dItem(img.size(), cvBaseType);
186                 std::transform(sItem.begin<T1>(), sItem.end<T1>(),
187                               dItem.begin<T1>(),
188                               [&](const T1 &s) -> T1 {
189                                 return (T1)round(((s - MatMin) *
190                                     maxVal) / Range);
191                             });
192                 exDst.push_back(dItem);
193             });
194
195             merge(exDst, tempImg);
196         } else {
197             tempImg = img;
198         }
199         cv::namedWindow(windowName, cv::WINDOW_NORMAL);
200         cv::imshow(windowName, tempImg);
201         cv::waitKey(0);
202         cv::destroyWindow(windowName);
203     };
204 };
205 };
206 };

```

```

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```

```

5  * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
6  */
7
8  /*! \class ImageProcessing
9  \brief Core class of all the image classes
10 Core class of all the image classes with a few commonly
    shared functions and
11 variables
12 */
13 #include "ImageProcessing.h"
14
15 namespace Vision {
16 /*! Constructor of the core class*/
17 ImageProcessing::ImageProcessing() {}
18
19 /*! De-constructor of the core class*/
20 ImageProcessing::~ImageProcessing() {}
21
22 /*! Create a LUT indicating which iteration variable i is
    the end of an row
23 \param nData an int indicating total pixels
24 \param hKsize int half the size of the kernel, if any. which
    acts as an offset
25 from the border pixels
26 \param nCols int number of columns in a row
27 \return array of uchar where a zero is a middle column and
    a 1 indicates an end
28 of an row minus the offset from half the kernel size
29 */
30 uchar *ImageProcessing::GetNRow(int nData, int hKsize, int
    nCols,
                               uint32_t totalRows) {
31     // Create LUT to determine when there is a new row
32     uchar *nRow = new uchar[nData + 1]{};
33     // int i = 0;
34     int shift = nCols - hKsize - 1;
35     for (uint32_t i = 0; i < totalRows; i++) {
36         nRow[(i * nCols) + shift] = 1;
37     }
38     return nRow;
39 }
40 }
41
42 std::vector<Mat> ImageProcessing::extractChannel(const Mat &
    src) {
43     vector<Mat> chans;
44     split(src, chans);
45     return chans;
46 }
47
48 void ImageProcessing::getOrientented(cv::Mat &BW, cv::Point_
    <double> &centroid,
49                                         double &theta, double &
    eccentricity) {
50     cv::Moments Mu = cv::moments(BW, true);
51     centroid.x = Mu.m10 / Mu.m00;

```

```

53     centroid.y = Mu.m01 / Mu.m00;
54
55     theta = 0;
56     double muPrime20 = (Mu.m20 / Mu.m00) - pow(centroid.x, 2);
57     double muPrime02 = (Mu.m02 / Mu.m00) - pow(centroid.y, 2);
58     double diffmuprime2 = muPrime20 - muPrime02;
59     double muPrime11 = (Mu.m11 / Mu.m00) - (centroid.x *
60                           centroid.y);
61
62     if (diffmuprime2 != 0) {
63         theta = 0.5 * atan((2 * muPrime11) / diffmuprime2);
64     }
65
66     double term1 = (muPrime20 + muPrime02) / 2;
67     double term2 = sqrt(4 * pow(muPrime11, 2) + pow(
68                           diffmuprime2, 2)) / 2;
69     eccentricity = sqrt(1-(term1 - term2)/ (term1 + term2));
70 }
71
72 void ImageProcessing::RotateImg(Mat &src, Mat &dst, double &
73                                 theta,
74                                 cv::Point_<double> &Centroid
75                                 , cv::Rect &ROI) {
76
77     cv::Mat temp;
78     temp.setTo(0);
79     double alpha = cos(theta);
80     double beta = sin(theta);
81     double cx = src.cols / 2;
82     double cy = src.rows / 2;
83     double dx = cx - Centroid.x;
84     double dy = cy - Centroid.y;
85     double rotData[2][3]{{alpha, beta, alpha * dx + beta * dy
86                           + Centroid.x},
87                           {-beta, alpha, alpha * dy + beta * dx
88                           + Centroid.y}};
89
90     cv::Mat totalrot(2, 3, CV_64FC1, rotData);
91
92     cv::warpAffine(src, temp, totalrot, cv::Size(src.rows *
93                           2.5, src.cols * 2.5),
94                           INTER_LINEAR);
95
96     // determine the actual ROI
97     cv::Point minP(0, 0);
98
99     if (src.channels() == 1) {
100         uchar *0 = temp.data;
101         uint32_t nData = temp.rows * temp.cols;
102         minP.x = temp.rows;
103         minP.y = temp.cols;
104         cv::Point maxP(0, 0);
105         int X, Y;
106         for (uint32_t i = 0; i < nData; i++) {
107             if (0[i] != 0) {
108                 Y = floor(i / temp.cols);
109                 X = (i % temp.cols);
110                 if (X < minP.x) {
111                     minP.x = X;
112                 }
113             }
114         }
115     }

```

```
102         if (Y < minP.y) {
103             minP.y = Y;
104         }
105         if (X > maxP.x) {
106             maxP.x = X;
107         }
108         if (Y > maxP.y) {
109             maxP.y = Y;
110         }
111     }
112 }
113 ROI = cv::Rect(minP, maxP);
114 }
115
116 if (src.channels() > 1) {
117     Centroid.x -= cx;
118     Centroid.y -= cy;
119
120     double xnew = Centroid.x * alpha - Centroid.y * beta;
121     double ynew = Centroid.x * beta - Centroid.y * alpha;
122
123     Centroid.x = xnew + cx + minP.x;
124     Centroid.y = ynew + cy + minP.y;
125 }
126 dst = temp(ROI).clone();
127 }
128
129 boost::signals2::connection
130 ImageProcessing::connect_Progress(const Progress_t::
131     slot_type &subscriber) {
132     return prog_sig.connect(subscriber);
133 }
```

Conversion Class

```

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7   */
8
9 #pragma once
10 #include "ImageProcessing.h"
11 #include "ConversionNotSupportedException.h"
12
13 namespace Vision {
14 class Conversion : public ImageProcessing {
15 public:
16     /*! Enumerator which indicates the colorspace used*/
17     enum ColorSpace {
18         CIE_lab,      /*!< CIE La*b* colorspace */
19         CIE_XYZ,      /*!< CIE XYZ colorspace */
20         RI,           /*!< Redness Index colorspace */
21         RGB,          /*!< RGB colorspace */
22         Intensity,    /*!< Grayscale colorspace */
23         None          /*!< none */
24     };
25     ColorSpace OriginalColorSpace; /*!< The original colorspace*/
26     ColorSpace ProcessedColorSpace; /*!< The destination colorspace*/
27
28     Conversion();
29     Conversion(const Mat &src);
30     Conversion(const Conversion &rhs);
31
32     ~Conversion();
33
34     Conversion &operator=(Conversion rhs);
35
36     void Convert(ColorSpace convertFrom, ColorSpace convertTo,
37                  bool chain = false);
38     void Convert(const Mat &src, Mat &dst, ColorSpace
39                  convertFrom,
40                  ColorSpace convertTo, bool chain = false);
41
42 private:
43     /*!< Conversion matrix used in the conversion between RGB and CIE XYZ*/
44     float XYZmat[3][3] = {{0.412453, 0.357580, 0.180423},
45                           {0.212671, 0.715160, 0.072169},
46                           {0.019334, 0.119194, 0.950227}};
47
48     float whitePoint[3] = {
49         0.9504, 1.0000, 1.0889}; /*!< Natural whitepoint in XYZ colorspace D65
50
51
52
53
54
55
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64
65
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48                                     according to Matlab */
49 // float whitePoint[3] = { 0.9642, 1.0000, 0.8251 }; /*!<
50     Natural whitepoint
51 // in XYZ colorspace D50 according to Matlab */
52
52 void Lab2RI(float *0, float *P, int nData);
53 void RGB2XYZ(uchar *0, float *P, int nData);
54 void XYZ2Lab(float *0, float *P, int nData);
55 void RGB2Intensity(uchar *0, uchar *P, int nData);
56 inline float f_xyz2lab(float t);
57 };
58 }



---


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3  * strictly prohibited
4  * and only allowed with the written consent of the author (
5  * Jelle Spijker)
6  * This software is proprietary and confidential
7  * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8  */
9
8 /*! \class Conversion
9  class which converts a cv::Mat image from one colorspace to
10 the next colorspace
10 */
11 #include "Conversion.h"
12 namespace Vision {
13 /*! Constructor of the class */
14 Conversion::Conversion() {
15     OriginalColorSpace = None;
16     ProcessedColorSpace = None;
17 }
18
19 /*! Constructor of the class
20 \param src a cv::Mat object which is the source image
21 */
22 Conversion::Conversion(const Mat &src) {
23     OriginalColorSpace = None;
24     ProcessedColorSpace = None;
25     OriginalImg = src;
26 }
27
28 /*! Copy constructor*/
29 Conversion::Conversion(const Conversion &rhs) {
30     this->OriginalColorSpace = rhs.OriginalColorSpace;
31     this->OriginalImg = rhs.OriginalImg;
32     this->ProcessedColorSpace = rhs.ProcessedColorSpace;
33     this->ProcessedImg = rhs.ProcessedImg;
34     this->TempImg = rhs.TempImg;
35 }
36
37 /*! De-constructor of the class*/
38 Conversion::~Conversion() {}
39
40 /*! Assignment operator*/

```

```

41 Conversion &Conversion::operator=(Conversion rhs) {
42     if (&rhs != this) {
43         this->OriginalColorSpace = rhs.OriginalColorSpace;
44         this->OriginalImg = rhs.OriginalImg;
45         this->ProcessedColorSpace = rhs.ProcessedColorSpace;
46         this->ProcessedImg = rhs.ProcessedImg;
47         this->TempImg = rhs.TempImg;
48     }
49     return *this;
50 }
51
52 /*! Convert the source image from one colorspace to a
53    destination colorspace
54 - RGB 2 Intensity
55 - RGB 2 XYZ
56 - RGB 2 Lab
57 - RGB 2 Redness Index
58 - XYZ 2 Lab
59 - XYZ 2 Redness Index
60 - Lab 2 Redness Index
61 \param src a cv::Mat object which is the source image
62 \param dst a cv::Mat object which is the destination image
63 \param convertFrom the starting colorspace
64 \param convertTo the destination colorspace
65 \param chain use the results from the previous operation
66     default value = false;
67 */
68 void Conversion::Convert(const Mat &src, Mat &dst,
69                         ColorSpace convertFrom,
70                         ColorSpace convertTo, bool chain) {
71     OriginalImg = src;
72     Convert(convertFrom, convertTo, chain);
73     dst = ProcessedImg;
74 }
75
76 /*! Convert the source image from one colorspace to a
77    destination colorspace
78 possibilities are:
79 - RGB 2 Intensity
80 - RGB 2 XYZ
81 - RGB 2 Lab
82 - RGB 2 Redness Index
83 - XYZ 2 Lab
84 - XYZ 2 Redness Index
85 - Lab 2 Redness Index
86 \param convertFrom the starting colorspace
87 \param convertTo the destination colorspace
88 \param chain use the results from the previous operation
89     default value = false;
90 */
91 void Conversion::Convert(ColorSpace convertFrom, ColorSpace
92                         convertTo,
93                         bool chain) {
94     OriginalColorSpace = convertFrom;
95     ProcessedColorSpace = convertTo;
96 }
```

```
91 // Exception handling
92 EMPTY_CHECK(OriginalImg);
93 currentProg = 0.;
94 prog_sig(currentProg, "Converting colorspace");
95
96 int nData = OriginalImg.rows * OriginalImg.cols;
97 // uint32_t i, j;
98
99 if (convertFrom == RGB && convertTo == Intensity) // RGB 2
100     Intensity
101 {
102     ProcessedImg.create(OriginalImg.size(), CV_8UC1);
103     uchar *P = ProcessedImg.data;
104     uchar *0;
105     CHAIN_PROCESS(chain, 0, uchar);
106
107     prog_sig(currentProg, "RGB 2 Intensity conversion");
108     RGB2Intensity(0, P, nData);
109     currentProg += ProgStep;
110     prog_sig(currentProg, "RGB 2 Intensity conversion
111         Finished");
112 } else if (convertFrom == RGB && convertTo == CIE_XYZ) // RGB 2 XYZ
113 {
114     ProcessedImg.create(OriginalImg.size(), CV_32FC3);
115     float *P = (float *)ProcessedImg.data;
116     uchar *0;
117     CHAIN_PROCESS(chain, 0, uchar);
118
119     prog_sig(currentProg, "RGB 2 CIE XYZ conversion");
120     RGB2XYZ(0, P, nData);
121     currentProg += ProgStep;
122     prog_sig(currentProg, "RGB 2 CIE XYZ conversion Finished
123         ");
124 } else if (convertFrom == RGB && convertTo == CIE_lab) // RGB 2 Lab
125 {
126     ProcessedImg.create(OriginalImg.size(), CV_32FC3);
127     float *P = (float *)ProcessedImg.data;
128     uchar *0;
129     CHAIN_PROCESS(chain, 0, uchar);
130
131     prog_sig(currentProg, "RGB 2 CIE XYZ conversion");
132     RGB2XYZ(0, P, nData);
133     currentProg += ProgStep;
134     prog_sig(currentProg, "RGB 2 CIE XYZ conversion Finished
135         ");
136     Convert(CIE_XYZ, CIE_lab, true);
137 } else if (convertFrom == RGB && convertTo == RI) // RGB 2
138     RI
139 {
140     ProcessedImg.create(OriginalImg.size(), CV_32FC3);
141     float *P = (float *)ProcessedImg.data;
142     uchar *0;
143     CHAIN_PROCESS(chain, 0, uchar);
144 }
```

```

140     prog_sig(currentProg, "RGB 2 CIE XYZ conversion");
141     RGB2XYZ(0, P, nData);
142     currentProg += ProgStep;
143     prog_sig(currentProg, "RGB 2 CIE XYZ conversion Finished
144     ");
145     Convert(CIE_XYZ, CIE_lab, true);
146     Convert(CIE_lab, RI, true);
147 } else if (convertFrom == CIE_XYZ && convertTo == CIE_lab)
148     // XYZ 2 Lab
149 {
150     ProcessedImg.create(OriginalImg.size(), CV_32FC3);
151     float *P = (float *)ProcessedImg.data;
152     float *O;
153     CHAIN_PROCESS(chain, 0, float);
154
155     prog_sig(currentProg, "CIE XYZ 2 CIE La*b* conversion");
156     XYZ2Lab(0, P, nData);
157     currentProg += ProgStep;
158     prog_sig(currentProg, "CIE XYZ 2 CIE La*b* conversion
159     Finished");
160 } else if (convertFrom == CIE_XYZ && convertTo == RI) // // XYZ 2 RI
161 {
162     ProcessedImg.create(OriginalImg.size(), CV_32FC3);
163     float *P = (float *)ProcessedImg.data;
164     float *O;
165     CHAIN_PROCESS(chain, 0, float);
166
167     prog_sig(currentProg, "CIE XYZ 2 CIE La*b* conversion");
168     XYZ2Lab(0, P, nData);
169     currentProg += ProgStep;
170     prog_sig(currentProg, "CIE XYZ 2 CIE La*b* conversion
171     Finished");
172     Convert(CIE_lab, RI, true);
173 } else if (convertFrom == CIE_lab && convertTo == RI) // // Lab 2 RI
174 {
175     ProcessedImg.create(OriginalImg.size(), CV_32FC1);
176     float *P = (float *)ProcessedImg.data;
177     float *O;
178     CHAIN_PROCESS(chain, 0, float);
179
180     prog_sig(currentProg, "CIE La*b* 2 Redness Index
181     conversion");
182     Lab2RI(0, P, nData * 3);
183     currentProg += ProgStep;
184     prog_sig(currentProg, "CIE La*b* 2 Redness Index
185     conversion Finsihed");
186 } else {
187     throw Exception::ConversionNotSupportedException();
188 }
189 }
190
191 /*! Conversion from RGB to Intensity
192 \param O a uchar pointer to the source image
193 \param P a uchar pointer to the destination image

```

```

188  \param nData an int indicating the total number of pixels
189  */
190  void Conversion::RGB2Intensity(uchar *O, uchar *P, int nData
191  ) {
192      uint32_t i;
193      int j;
194      i = 0;
195      j = 0;
196      while (j < nData) {
197          P[j++] = (*(O + i + 2) * 0.2126 + *(O + i + 1) * 0.7152
198          +
199          *(O + i) * 0.0722); // Grey value
200          i += 3;
201      }
202  }
203  /*! Conversion from RGB to CIE XYZ
204  \param O a uchar pointer to the source image
205  \param P a uchar pointer to the destination image
206  \param nData an int indicating the total number of pixels
207  */
208  void Conversion::RGB2XYZ(uchar *O, float *P, int nData) {
209      uint32_t endData = nData * OriginalImg.step.buf[1];
210      float R, G, B;
211      for (uint32_t i = 0; i < endData; i += OriginalImg.step.
212          buf[1]) {
213          R = static_cast<float>(*(O + i + 2) / 255.0f);
214          B = static_cast<float>(*(O + i + 1) / 255.0f);
215          G = static_cast<float>(*(O + i) / 255.0f);
216          P[i] = (XYZmat[0][0] * R) + (XYZmat[0][1] * B) + (XYZmat
217          [0][2] * G); // X
218          P[i + 1] = (XYZmat[1][0] * R) + (XYZmat[1][1] * B) + (
219          XYZmat[1][2] * G); // Y
220          P[i + 2] = (XYZmat[2][0] * R) + (XYZmat[2][1] * B) + (
221          XYZmat[2][2] * G); // Z
222      }
223  }
224  /*! Conversion from CIE XYZ to CIE La*b*
225  \param O a uchar pointer to the source image
226  \param P a uchar pointer to the destination image
227  \param nData an int indicating the total number of pixels
228  */
229  void Conversion::XYZ2Lab(float *O, float *P, int nData) {
230      uint32_t endData = nData * 3;
231      float yy0, xx0, zz0;
232      for (size_t i = 0; i < endData; i += 3) {
233          xx0 = *(O + i) / whitePoint[0];
234          yy0 = *(O + i + 1) / whitePoint[1];
235          zz0 = *(O + i + 2) / whitePoint[2];
236
237          if (yy0 > 0.008856) {
238              P[i] = (116 * pow(yy0, 0.333f)) - 16; // L
239          } else {
240              P[i] = 903.3 * yy0; // L
241          }

```

```
238
239     P[i + 1] = 500 * (f_xyz2lab(xx0) - f_xyz2lab(yy0));
240     P[i + 2] = 200 * (f_xyz2lab(yy0) - f_xyz2lab(zz0));
241 }
242 }
243
244 inline float Conversion::f_xyz2lab(float t) {
245     if (t > 0.008856) {
246         return pow(t, 0.3333333333f);
247     }
248     return 7.787 * t + 0.137931034482759f;
249 }
250
251 /*! Conversion from CIE La*b* to Redness Index
252 \param O a uchar pointer to the source image
253 \param P a uchar pointer to the destination image
254 \param nData an int indicating the total number of pixels
255 */
256 void Conversion::Lab2RI(float *O, float *P, int nData) {
257     uint32_t j = 0;
258     float L, a, b;
259     for (int i = 0; i < nData; i += 3) {
260         L = *(O + i);
261         a = *(O + i + 1);
262         b = *(O + i + 2);
263         P[j++] =
264             (L * (pow((pow(a, 2.0f) + pow(b, 2.0f)), 0.5f) * (
265                 pow(10, 8.2f)))) /
266             (b * pow(L, 6.0f));
267     }
268 }
```

Enhance Class

```

1  /* Copyright (C) Jelle Spijker - All Rights Reserved
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4   * and only allowed with the written consent of the author (Jelle Spijker)
5   * This software is proprietary and confidential
6   * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
7   */
8
9 #pragma once
10 #define ENHANCE_VERSION 1
11
12 #include "ImageProcessing.h"
13 #include "../SoilMath/SoilMath.h"
14
15 using namespace std;
16 using namespace SoilMath;
17
18 namespace Vision {
19 class Enhance : public ImageProcessing {
20 private:
21     void CalculateSumOfNeighboringPixels(uchar *0, int i, int
22     hKsize, int nCols,
23                                     uint32_t &sum);
24     float CalculateStdOfNeighboringPixels(uchar *0, int i, int
25     hKsize, int nCols,
26                                     int noNeighboursPix,
27                                     float mean);
28
29 public:
30     /*! Enumerator indicating the requested enhancement
31      operation*/
32     enum EnhanceOperation {
33         _AdaptiveContrastStretch, /*!< custom adaptive contrast
34                                 stretch operation*/
35         _Blur,                      /*!< Blur operation*/
36         _HistogramEqualization     /*!< Histogram equalization*/
37     };
38
39     Enhance();
40     Enhance(const Mat &src);
41     Enhance(const Mat &src, Mat &dst, uint8_t kernelsize = 9,
42             float factor = 1.0,
43             EnhanceOperation operation = _Blur);
44     Enhance(const Enhance &rhs);
45
46     ~Enhance();
47
48     Enhance &operator=(Enhance rhs);
49
50     void AdaptiveContrastStretch(uint8_t kernelsize, float
51             factor,
52                                     bool chain = false);
53
54     void HistogramEqualization();
55
56     void Blur();
57
58     void AdaptiveContrastStretch();
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1656  void AdaptiveContrastStretch();
1657
1657
1658  void HistogramEqualization();
1659
1660  void Blur();
1661
1661
1662  void AdaptiveContrastStretch();
1663
1664  void HistogramEqualization();
1665
1666  void Blur();
1667
1668  void AdaptiveContrastStretch();
1669
1669
1670  void HistogramEqualization
```

```

45  void AdaptiveContrastStretch(const Mat &src, Mat &dst,
46      uint8_t kernelsize,
47      float factor);
48
49  void Blur(uint8_t kernelsize, bool chain = false);
50  void Blur(const Mat &src, Mat &dst, uint8_t kernelsize);
51
52  void HistogramEqualization(bool chain = false);
53  void HistogramEqualization(const Mat &src, Mat &dst);
54 }

```

```

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7  * Written by Jelle Spijker <spijkerv.jelle@gmail.com>, 2015
8  */
9
10 /*! \class Enhance
11 class which enhances a greyscale cv::Mat image
12 */
13 #include "Enhance.h"
14
15 namespace Vision {
16 /*! Constructor
17 Enhance::Enhance() {}
18
19 /*! Constructor
20 \param src cv::Mat source image
21 */
22 Enhance::Enhance(const Mat &src) {
23     OriginalImg = src;
24     ProcessedImg.create(OriginalImg.size(), CV_8UC1);
25 }
26
27 Enhance::Enhance(const Enhance &rhs) {
28     this->OriginalImg = rhs.OriginalImg;
29     this->ProcessedImg = rhs.OriginalImg;
30     this->TempImg = rhs.TempImg;
31 }
32
33 /*! Constructor
34 \param src cv::Mat source image
35 \param dst cv::Mat destination image
36 \param kernelsize an uchar which represent the kernelsize
37     should be an uneven
38     number higher than two
39 \param factor float which indicates the amount the effect
40     should take place
41     standard value is 1.0 only used in the adaptive contrast
42     stretch enhancement
43 \param operation enumerator EnhanceOperation which
44     enhancement should be

```

```

39 performed
40 */
41 Enhance::Enhance(const Mat &src, Mat &dst, uchar kernelsize,
42     float factor,
43     EnhanceOperation operation) {
44     OriginalImg = src;
45     ProcessedImg.create(OriginalImg.size(), CV_8UC1);
46     switch (operation) {
47     case Vision::Enhance::_AdaptiveContrastStretch:
48         AdaptiveContrastStretch(kernelsize, factor);
49         break;
50     case Vision::Enhance::_Blur:
51         Blur(kernelsize);
52         break;
53     case Vision::Enhance::_HistogramEqualization:
54         HistogramEqualization();
55         break;
56     }
57     dst = ProcessedImg;
58 }
59 /*! Dec-constructor*/
60 Enhance::~Enhance() {}

61 Enhance &Enhance::operator=(Enhance rhs) {
62     if (&rhs != this) {
63         this->OriginalImg = rhs.OriginalImg;
64         this->ProcessedImg = rhs.ProcessedImg;
65         this->TempImg = rhs.ProcessedImg;
66     }
67     return *this;
68 }
69 }

70 /*! Calculate the standard deviation of the neighboring
71     pixels
72 \param 0 uchar pointer to the current pixel of the original
73     image
74 \param i current counter
75 \param hKsize half the kernelsize
76 \param nCols total number of columns
77 \param noNeighboursPix total number of neighboring pixels
78 \param mean mean value of the neighboring pixels
79 \return standard deviation
80 */
81 float Enhance::CalculateStdOfNeighboringPixels(uchar *0,
82     int i, int hKsize,
83                                         int nCols,
84                                         int
85                                         noNeighboursPix
86                                         ,
87                                         float mean) {
88     uint32_t sum_dev = 0.0;
89     float Std = 0.0;
90     sum_dev = 0.0;
91     Std = 0.0;
92     for (int j = -hKsize; j < hKsize; j++) {

```

```

88     for (int k = -hKsize; k < hKsize; k++) {
89         // sum_dev += pow((0[i + j * nCols + k] - mean), 2);
90         sum_dev += SoilMath::quick_pow2((0[i + j * nCols + k]
91                                         - mean));
92     }
93     // Std = sqrt(sum_dev / noNeighboursPix);
94     Std = SoilMath::fastPow(static_cast<double>(sum_dev) /
95                             noNeighboursPix), 2);
96     return Std;
97 }
98 /*! Calculate the sum of the neighboring pixels
99 \param 0 uchar pointer to the current pixel of the original
100    image
101 \param i current counter
102 \param hKsize half the kernelsize
103 \param nCols total number of columns
104 \param sum Total sum of the neighboringpixels
105 */
106 void Enhance::CalculateSumOfNeighboringPixels(uchar *0, int
107                                                 i, int hKsize,
108                                                 int nCols,
109                                                 uint32_t &
110                                                 sum) {
111     for (int j = -hKsize; j < hKsize; j++) {
112         for (int k = -hKsize; k < hKsize; k++) {
113             sum += 0[i + j * nCols + k];
114         }
115     }
116     /*! Homebrew AdaptiveContrastStretch function which
117        calculate the mean and
118        standard deviation from the neighboring pixels if the
119        current pixel is higher
120        then the mean the value is incremented with an given factor
121        multiplied with the
122        standard deviation, and decreased if it's lower then the
123        mean.
124 \param src cv::Mat source image
125 \param dst cv::Mat destination image
126 \param kernelsize an uchar which represent the kernelsize
127        should be an uneven
128        number higher than two
129 \param factor float which indicates the amount the effect
130        should take place
131 \param standard value is 1.0 only used in the adaptive contrast
132        stretch enhancement
133 */
134 void Enhance::AdaptiveContrastStretch(const Mat &src, Mat &
135                                         dst,
136                                         uchar kernelsize,
137                                         float factor) {
138     OriginalImg = src;
139     ProcessedImg.create(OriginalImg.size(), CV_8UC1);

```

```

129     AdaptiveContrastStretch(kernelsize, factor);
130     dst = ProcessedImg;
131 }
132
133 /*! Homebrew AdaptiveContrastStretch function which
134 calculate the mean and
135 standard deviation from the neighboring pixels if the
136 current pixel is higher
137 then the mean the value is incremented with an given factor
138 multiplied with the
139 standard deviation, and decreased if it's lower then the
140 mean.
141 \param kernelsize an uchar which represent the kernelsize
142 should be an uneven
143 number higher than two
144 \param factor float which indicates the amount the effect
145 should take place
146 standard value is 1.0 only used in the adaptive contrast
147 stretch enhancement
148 \param chain use the results from the previous operation
149 default value = false;
150 */
151 void Enhance::AdaptiveContrastStretch(uchar kernelsize,
152                                     float factor,
153                                     bool chain) {
154
155     // Exception handling
156     EMPTY_CHECK(OriginalImg);
157     if (kernelsize < 3 || (kernelsize % 2) == 0) {
158         throw Exception::WrongKernelSizeException();
159     }
160     CV_Assert(OriginalImg.depth() != sizeof(uchar));
161
162     // Make the pointers to the Data
163     uchar *O;
164     CHAIN_PROCESS(chain, 0, uchar);
165     uchar *P = ProcessedImg.data;
166
167     int i = 0;
168     int hKsize = kernelsize / 2;
169     int nCols = OriginalImg.cols;
170     int pStart = (hKsize * nCols) + hKsize + 1;
171
172     int nData = OriginalImg.rows * OriginalImg.cols;
173     int pEnd = nData - pStart;
174     uint32_t noNeighboursPix = kernelsize * kernelsize;
175     uint32_t sum;
176     float mean = 0.0;
177
178     uchar *nRow = GetNRow(nData, hKsize, nCols, OriginalImg.
179                           rows);
180
181     i = pStart;
182     while (i++ < pEnd) {
183         // Checks if pixel isn't a border pixel and progresses
184         // to the new row
185         if (nRow[i] == 1) {

```

```

174         i += kernelsize;
175     }
176
177     // Fill the neighboring pixel array
178     sum = 0;
179     mean = 0;
180
181     // Calculate the statistics
182     CalculateSumOfNeighboringPixels(0, i, hKsize, nCols, sum
183                                     );
184     mean = (float)(sum / noNeighboursPix);
185     float Std = CalculateStdOfNeighboringPixels(0, i, hKsize
186                                     , nCols,
187                                     noNeighboursPix
188                                     , mean);
189
190     // Stretch
191
192     if (O[i] > mean) {
193         // int addValue = O[i] + (int)(round(factor * Std));
194         int addValue = O[i] + static_cast<int>(round(factor *
195                                         * Std));
196         if (addValue < 255) {
197             P[i] = addValue;
198         } else {
199             P[i] = 255;
200         }
201     } else if (O[i] < mean) {
202         // int subValue = O[i] - (int)(round(factor * Std));
203         int subValue = O[i] - static_cast<int>(round(factor *
204                                         * Std));
205         if (subValue > 0) {
206             P[i] = subValue;
207         } else {
208             P[i] = 0;
209         }
210     }
211
212     // Stretch the image with an normal histogram equalization
213     HistogramEqualization(true);
214
215
216     /*! Blurs the image with a NxN kernel
217     \param src cv::Mat source image
218     \param dst cv::Mat destination image
219     \param kernelsize an uchar which represent the kernelsize
220         should be an uneven
221         number higher than two
222     */
223     void Enhance::Blur(const Mat &src, Mat &dst, uchar
224 kernelsize) {

```

```
223     OriginalImg = src;
224     ProcessedImg.create(OriginalImg.size(), CV_8UC1);
225     Blur(kernelsize);
226     dst = ProcessedImg;
227 }
228
229 /*! Blurs the image with a NxN kernel
230 \param kernelsize an uchar which represent the kernelsize
231     should be an uneven
232 number higher than two
233 \param chain use the results from the previous operation
234     default value = false;
235 */
236 void Enhance::Blur(uchar kernelsize, bool chain) {
237     // Exception handling
238     EMPTY_CHECK(OriginalImg);
239     if (kernelsize < 3 || (kernelsize % 2) == 0) {
240         throw Exception::WrongKernelSizeException();
241     }
242     CV_Assert(OriginalImg.depth() != sizeof(uchar));
243
244     // Make the pointers to the Data
245     uchar *O;
246     CHAIN_PROCESS(chain, O, uchar);
247     uchar *P = ProcessedImg.data;
248
249     int nData = OriginalImg.rows * OriginalImg.cols;
250     int hKsize = kernelsize / 2;
251     int nCols = OriginalImg.cols;
252     int pStart = (hKsize * nCols) + hKsize + 1;
253     int pEnd = nData - pStart;
254     int noNeighboursPix = kernelsize * kernelsize;
255     uint32_t sum;
256
257     int i;
258     uchar *nRow = GetNRow(nData, hKsize, nCols, OriginalImg.
259                           rows);
260     i = pStart;
261     while (i++ < pEnd) {
262         // Checks if pixel isn't a border pixel and progresses
263         // to the new row
264         if (nRow[i] == 1) {
265             i += kernelsize;
266         }
267
268         // Calculate the sum of the kernel
269         sum = 0;
270         CalculateSumOfNeighboringPixels(0, i, hKsize, nCols, sum
271                                         );
272         P[i] = (uchar)(round(sum / noNeighboursPix));
273     }
274     delete [] nRow;
275 }
```

```
274 /*! Stretches the image using a histogram
275 \param chain use the results from the previous operation
276     default value = false;
277 */
278 void Enhance::HistogramEqualization(bool chain) {
279     // Exception handling
280     EMPTY_CHECK(OriginalImg);
281     CV_Assert(OriginalImg.depth() != sizeof(uchar));
282
283     // Make the pointers to the Data
284     uchar *O;
285     CHAIN_PROCESS(chain, 0, uchar);
286     uchar *P = ProcessedImg.data;
287
288     // Calculate the statics of the whole image
289     ucharStat_t imgStats(0, OriginalImg.rows, OriginalImg.cols
290                         );
291     float sFact;
292     if (imgStats.min != imgStats.max) {
293         sFact = 255.0f / (imgStats.max - imgStats.min);
294     } else {
295         sFact = 1.0f;
296     }
297
298     uint32_t i = 256;
299     uchar LUT_changeValue[256];
300     while (i-- > 0) {
301         LUT_changeValue[i] = (uchar)((float)(i)*sFact) + 0.5f;
302     }
303
304     O = OriginalImg.data;
305
306     i = OriginalImg.cols * OriginalImg.rows + 1;
307     while (i-- > 0) {
308         *P++ = LUT_changeValue[*O++ - imgStats.min];
309     }
310 }
```

Morphological filter Class

```

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8   */
9
10 #pragma once
11 #define MORPHOLOGICALFILTER_VERSION 1
12
13 namespace Vision {
14 class MorphologicalFilter : public ImageProcessing {
15 public:
16     enum FilterType { OPEN, CLOSE, ERODE, DILATE, NONE };
17
18     MorphologicalFilter();
19     MorphologicalFilter(FilterType filtertype);
20     MorphologicalFilter(const Mat &src, FilterType filtertype
21                         = FilterType::NONE);
22     MorphologicalFilter(const MorphologicalFilter &rhs);
23
24     ~MorphologicalFilter();
25
26     MorphologicalFilter &operator=(MorphologicalFilter &rhs);
27
28     void Dilation(const Mat &mask, bool chain = false);
29     void Erosion(const Mat &mask, bool chain = false);
30
31     void Close(const Mat &mask, bool chain = false);
32     void Open(const Mat &mask, bool chain = false);
33
34 private:
35     void Filter(const Mat &mask, bool chain, uchar startVal,
36                 uchar newVal,
37                 uchar switchVal);
38 };
39 }
```

```

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8   */
9
10 #include "MorphologicalFilter.h"
11
12 namespace Vision {
```

```
11 MorphologicalFilter::MorphologicalFilter() {}
12
13 MorphologicalFilter::MorphologicalFilter(FilterType
14     filtertype) {
15     switch (filtertype) {
16     case FilterType::OPEN:
17         Open(OriginalImg);
18         break;
19     case FilterType::CLOSE:
20         Close(OriginalImg);
21         break;
22     case FilterType::ERODE:
23         Erosion(OriginalImg);
24         break;
25     case FilterType::DILATE:
26         Dilation(OriginalImg);
27         break;
28     case FilterType::NONE:
29         break;
30     }
31
32 MorphologicalFilter::MorphologicalFilter(const Mat &src,
33                                         FilterType
34                                         filtertype) {
35     OriginalImg = src;
36     ProcessedImg.create(OriginalImg.size(), CV_8UC1);
37     switch (filtertype) {
38     case FilterType::OPEN:
39         Open(OriginalImg);
40         break;
41     case FilterType::CLOSE:
42         Close(OriginalImg);
43         break;
44     case FilterType::ERODE:
45         Erosion(OriginalImg);
46         break;
47     case FilterType::DILATE:
48         Dilation(OriginalImg);
49         break;
50     case FilterType::NONE:
51         break;
52     }
53
54 MorphologicalFilter::MorphologicalFilter(const
55     MorphologicalFilter &rhs) {
56     this->OriginalImg = rhs.OriginalImg;
57     this->ProcessedImg = rhs.ProcessedImg;
58     this->TempImg = rhs.ProcessedImg;
59 }
60 MorphologicalFilter::~MorphologicalFilter() {}
61
62 MorphologicalFilter &MorphologicalFilter::operator=(  
    MorphologicalFilter &rhs) {
```

```

63     if (&rhs != this) {
64         this->OriginalImg = rhs.OriginalImg;
65         this->ProcessedImg = rhs.ProcessedImg;
66         this->TempImg = rhs.TempImg;
67     }
68     return *this;
69 }
70
71 void MorphologicalFilter::Open(const Mat &mask, bool chain)
72 {
73     Erosion(mask, chain);
74     Dilation(mask, true);
75 }
76 void MorphologicalFilter::Close(const Mat &mask, bool chain)
77 {
78     Dilation(mask, chain);
79     Erosion(mask, true);
80 }
81 void MorphologicalFilter::Dilation(const Mat &mask, bool
82         chain) {
83     Filter(mask, chain, 0, 1, 1);
84 }
85 void MorphologicalFilter::Erosion(const Mat &mask, bool
86         chain) {
87     Filter(mask, chain, 1, 0, 0);
88 }
89 void MorphologicalFilter::Filter(const Mat &mask, bool chain
90         , uchar startVal,
91                     uchar newVal, uchar
92                     switchVal) {
93     // Exception handling
94     CV_Assert(OriginalImg.depth() != sizeof(uchar));
95     EMPTY_CHECK(OriginalImg);
96     if (mask.cols % 2 == 0 || mask.cols < 3) {
97         throw Exception::WrongKernelSizeException("Wrong
98             Kernelsize columns!");
99     }
100    if (mask.rows % 2 == 0 || mask.rows < 3) {
101        throw Exception::WrongKernelSizeException("Wrong
102             Kernelsize rows!");
103    }
104    // make Pointers
105    Mat workOrigImg(ProcessedImg.rows + mask.rows,
106                     ProcessedImg.cols + mask.cols,
107                     CV_8UC1);
108    workOrigImg.setTo(0);
109    if (chain) {
110        ProcessedImg.copyTo(workOrigImg(

```



```
152         c = mask.cols;
153         r = mask.rows;
154     }
155 }
156 }
157 }
158 delete [] nRow;
159 SHOW_DEBUG_IMG(workProcImg, uchar, 255, "workProcImg
160     Filter!", true);
160 ProcessedImg = workProcImg(Rect(hKsizeCol, hKsizeRow,
161         ProcessedImg.cols,
162             ProcessedImg.rows)).clone
162     ());
162 SHOW_DEBUG_IMG(ProcessedImg, uchar, 255, "Processed Image
163     Filter!", true);
163 }
164 }
```

Segment Class

```

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8   */
9
10 #pragma once
11
12 #include <vector>
13 #include <queue>
14 #include <string>
15 #include <stdint.h>
16 #include <iostream>
17 #include <algorithm>
18 #include <utility>
19
20 #include <boost/range/adaptor/reversed.hpp>
21
22 #include "ImageProcessing.h"
23 #include "MorphologicalFilter.h"
24 #include "../SoilMath/SoilMath.h"
25
26 namespace Vision {
27 class Segment : public ImageProcessing {
28 public:
29     /*! Coordinates for the region of interest*/
30     typedef struct Rect {
31         uint16_t leftX; /*!< Left X coordinate*/
32         uint16_t leftY; /*!< Left Y coordinate*/
33         uint16_t rightX; /*!< Right X coordinate*/
34         uint16_t rightY; /*!< Right Y coordinate*/
35         Rect(uint16_t lx, uint16_t ly, uint16_t rx, uint16_t ry)
36             : leftX(lx), leftY(ly), rightX(rx), rightY(ry){}
37     } Rect_t;
38
39     typedef std::vector<Vision::Segment::Rect_t> RectList_t;
40
41     /*! Individual blob*/
42     typedef struct Blob {
43         uint16_t Label; /*!< ID of the blob*/
44         cv::Mat Img; /*!< BW image of the blob all the pixel
45                     belonging to the blob
46                     are set to 1 others are 0*/
47         cv::Rect ROI; /*!< Coordinates for the blob in the
48                     original picture as a
49                     cv::Rect*/
50         uint32_t Area; /*!< Calculated stats of the blob*/
51         cv::Point<double> Centroid;
52         double Theta;

```

```

51     Blob(uint16_t label, uint32_t area) : Label(label), Area
52         (area){}
53     } Blob_t;
54
55     typedef std::vector<Blob_t> BlobList_t;
56     BlobList_t BlobList; /*!< vector with all the individual
57         blobs*/
58
59     /*! Enumerator to indicate what kind of object to extract
60         */
61     enum TypeOfObjects {
62         Bright, /*!< Enum value Bright object */
63         Dark    /*!< Enum value Dark object. */
64     };
65
66     /*! Enumerator to indicate how the pixel correlate between
67         each other in a
68         * blob*/
69     enum Connected {
70         Four =
71             2, /*!< Enum Four connected, relation between Center
72                 , North, East, South
73                 and West*/
74         Eight =
75             4 /*!< Enum Eight connected, relation between Center
76                 , North, NorthEast,
77                 East, SouthEast, South, SouthWest, West and
78                 NorthWest */
79     };
80
81     /*!< Enumerator which indicate which Segmentation
82         technique should be used */
83     enum SegmentationType {
84         Normal, /*!< Segmentation looking at the intensity of an
85                 individual pixel */
86         LabNeuralNet, /*!< Segmentation looking at the chromatic
87                         a* and b* of the
88                         processed pixel and it's surrounding
89                         pixels, feeding it in
90                         an Neural Net */
91         GraphMinCut /*!< Segmentation using a graph function and
92                         the minimum cut */
93     };
94
95     cv::Mat LabelledImg; /*!< Image with each individual
96         blob labeled with a
97             individual number */
98     uint16_t MaxLabel = 0; /*!< Maximum labels found in the
99         labelled image*/
100    uint16_t noOfFilteredBlobs =
101        0; /*!< Total numbers of blobs that where filtered
102            beacuse the where
103            smaller than the minBlobArea*/
104
105    ucharStat_t OriginalImgStats; /*!< Statistical data from
106        the original image*/

```

```

91     uint8_t ThresholdLevel = 0;      /*!< Current calculated
92         threshold level*/
93
94     float sigma = 2;
95     uint32_t thresholdOffset = 4;
96
97     Segment();
98     Segment(const Mat &src);
99     Segment(const Segment &rhs);
100
101    ~Segment();
102
103    Segment &operator=(Segment &rhs);
104
105    void LoadOriginalImg(const Mat &src);
106
107    void ConvertToBW(TypeOfObjects Typeobjects);
108    void ConvertToBW(const Mat &src, Mat &dst, TypeOfObjects
109        Typeobjects);
110
111    void GetEdges(bool chain = false, Connected conn = Eight);
112    void GetEdges(const Mat &src, Mat &dst, bool chain = false
113        ,
114            Connected conn = Eight);
115
116    void GetEdgesEroding(bool chain = false);
117
118    void GetBlobList(bool chain = false, Connected conn =
119        Eight);
120
121    void Threshold(uchar t, TypeOfObjects Typeobjects);
122
123    void LabelBlobs(bool chain = false, uint16_t minBlobArea =
124        25,
125            Connected conn = Eight);
126
127    private:
128        uint8_t GetThresholdLevel(TypeOfObjects TypeObject);
129        void SetBorder(uchar *P, uchar setValue);
130        void FloodFill(uchar *O, uchar *P, uint16_t x, uint16_t y,
131            uchar fillValue,
132                uchar OldValue);
133        void MakeConsecutive(uint16_t *valueArr, uint32_t noElem,
134            uint16_t &maxlabel);
135        void MakeConsecutive(uint16_t *valueArr, uint16_t *keyArr,
136            uint16_t noElem,
137                uint16_t &maxlabel);
138        void SortAdjacencyList(std::vector<std::vector<uint16_t>>
139            &adj);
140
141        void ConnectedBlobs(uchar *O, uint16_t *P,

```

```

136             std::vector<std::vector<uint16_t>> &
137                 adj, uint32_t nCols,
138                 uint32_t nRows, Connected conn);
139     void InvertAdjacencyList(std::vector<std::vector<uint16_t
140                               >> &adj,
141                               std::vector<std::vector<uint16_t
142                               >> &adjInv);
143 }
144 }



---


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7  */
8 /*! \class Segment
9 \brief Segmentation algorithms
10 With this class, various segmentation routines can be
11 applied to a greyscale or
12 black and white source image.
13 */
14
15 namespace Vision {
16 //! Constructor of the Segmentation class
17 Segment::Segment() {}
18
19 //! Constructor of the Segmentation class
20 Segment::Segment(const Mat &src) {
21     OriginalImg = src;
22     ProcessedImg.create(OriginalImg.size(), CV_8UC1);
23     LabelledImg.create(OriginalImg.size(), CV_16UC1);
24 }
25
26 Segment::Segment(const Segment &rhs) {
27     this->BlobList = rhs.BlobList;
28     this->LabelledImg = rhs.LabelledImg;
29     this->MaxLabel = rhs.MaxLabel;
30     this->noOfFilteredBlobs = rhs.noOfFilteredBlobs;
31     this->OriginalImg = rhs.OriginalImg;
32     this->OriginalImgStats = rhs.OriginalImgStats;
33     this->ProcessedImg = rhs.ProcessedImg;
34     this->TempImg = rhs.TempImg;
35     this->ThresholdLevel = rhs.ThresholdLevel;
36 }
37
38 //! De-constructor
39 Segment::~Segment() {}
40
41 Segment &Segment::operator=(Segment &rhs) {
42     if (&rhs != this) {
43         this->BlobList = rhs.BlobList;

```

```

44     this->LabelledImg = rhs.LabelledImg;
45     this->MaxLabel = rhs.MaxLabel;
46     this->noOfFilteredBlobs = rhs.noOfFilteredBlobs;
47     this->OriginalImg = rhs.OriginalImg;
48     this->OriginalImgStats = rhs.OriginalImgStats;
49     this->ProcessedImg = rhs.ProcessedImg;
50     this->TempImg = rhs.TempImg;
51     this->ThresholdLevel = rhs.ThresholdLevel;
52 }
53 return *this;
54 }
55
56 void Segment::LoadOriginalImg(const Mat &src) {
57     OriginalImg = src;
58     ProcessedImg.create(OriginalImg.size(), CV_8UC1);
59     LabelledImg.create(OriginalImg.size(), CV_16UC1);
60 }
61
62 /*! Determine the threshold level by iteration, between two
63 distribution,
64 presumably back- and foreground. It works towards the
65 average of the two
66 averages and finally sets the threshold with two time the
67 standard deviation
68 from the mean of the set object
69 \param TypeOfObject is an enumerator indicating if the bright
70 or the dark pixels
71 are the object and should be set to one
72 \return The threshold level as an uint8_t */
73 uint8_t Segment::GetThresholdLevel(TypeOfObjects TypeOfObject)
74 {
75     // Exception handling
76     EMPTY_CHECK(OriginalImg);
77     CV_Assert(OriginalImg.depth() != sizeof(uchar));
78
79     // Calculate the statistics of the whole picture
80     ucharStat_t OriginalImgStats(OriginalImg.data, OriginalImg
81         .rows,
82                                     OriginalImg.cols);
83
84     // Sets the initial threshold with the mean of the total
85     // picture
86     pair<uchar, uchar> T;
87     T.first = (uchar)(OriginalImgStats.Mean + 0.5);
88     T.second = 0;
89
90     uchar Rstd = 0;
91     uchar Lstd = 0;
92     uchar Rmean = 0;
93     uchar Lmean = 0;
94
95     // Iterate till optimum Threshold is found between back- &
96     // foreground
97     while (T.first != T.second) {
98         // Gets an array of the left part of the histogram
99         uint32_t i = T.first;
100
101         for (i = T.first; i < T.second; i++)
102             Rstd += (uchar)(OriginalImg.data[i] - Rmean) *
103                 (uchar)(OriginalImg.data[i] - Rmean);
104
105         Rstd = Rstd / (T.second - T.first);
106
107         for (i = T.first; i < T.second; i++)
108             Lstd += (uchar)(OriginalImg.data[i] - Lmean) *
109                 (uchar)(OriginalImg.data[i] - Lmean);
110
111         Lstd = Lstd / (T.second - T.first);
112
113         T.first = (uchar)(Rmean + 0.5);
114         T.second = (uchar)(Lmean + 0.5);
115
116         Rmean = (uchar)(Rstd / (T.second - T.first));
117         Lmean = (uchar)(Lstd / (T.second - T.first));
118
119     }
120
121     return T.first;
122 }

```

```
92     uint32_t *Left = new uint32_t[i]{};
93     while (i-- > 0) {
94         Left[i] = OriginalImgStats.bins[i];
95     }
96
97     // Gets an array of the right part of the histogram
98     uint32_t rightEnd = 256 - T.first;
99     uint32_t *Right = new uint32_t[rightEnd]{};
100    i = rightEnd;
101    while (i-- > 0) {
102        Right[i] = OriginalImgStats.bins[i + T.first];
103    }
104
105    // Calculate the statistics of both histograms,
106    // taking into account the current threshold
107    ucharStat_t sLeft(Left, 0, T.first);
108    ucharStat_t sRight(Right, T.first, 256);
109
110    // Calculate the new threshold the mean of the means
111    T.second = T.first;
112    T.first = (uchar)((sLeft.Mean + sRight.Mean) / 2) +
113        0.5;
114
115    Rmean = (uchar)(sRight.Mean + 0.5);
116    Lmean = (uchar)(sLeft.Mean + 0.5);
117    Rstd = (uchar)(sRight.Std + 0.5);
118    Lstd = (uchar)(sLeft.Std + 0.5);
119    delete[] Left;
120    delete[] Right;
121 }
122
123 // Assumes the pixel value of the sought object lies
124 // between 2 sigma
125 int val = 0;
126 switch (TypeObject) {
127 case Bright:
128     val = Rmean - (sigma * Rstd) - thresholdOffset;
129     if (val < 0) {
130         val = 0;
131     } else if (val > 255) {
132         val = 255;
133     }
134     T.first = (uchar)val;
135     break;
136 case Dark:
137     val = Lmean + (sigma * Lstd) + thresholdOffset;
138     if (val < 0) {
139         val = 0;
140     } else if (val > 255) {
141         val = 255;
142     }
143     T.first = (uchar)val;
144     break;
145 }
146
147 return T.first;
```

```

146 }
147
148 /*! Convert a greyscale image to a BW using an automatic
149   Threshold
150 \param src is the source image as a cv::Mat
151 \param dst destination image as a cv::Mat
152 \param TypeObject is an enumerator indicating if the bright
153   or the dark pixels
154 are the object and should be set to one */
155 void Segment::ConvertToBW(const Mat &src, Mat &dst,
156   TypeOfObjects Typeobjects) {
157   OriginalImg = src;
158   ProcessedImg.create(OriginalImg.size(), CV_8UC1);
159   LabelledImg.create(OriginalImg.size(), CV_16UC1);
160   ConvertToBW(Typeobjects);
161   dst = ProcessedImg;
162 }
163
164 /*! Convert a greyscale image to a BW using an automatic
165   Threshold
166 \param TypeObject is an enumerator indicating if the bright
167   or the dark pixels
168 are the object and should be set to one */
169 void Segment::ConvertToBW(TypeOfObjects Typeobjects) {
170   // Determine the threshold
171   uchar T = GetThresholdLevel(Typeobjects);
172   // Threshold the picture
173   Threshold(T, Typeobjects);
174 }
175
176 /*! Convert a greyscale image to a BW
177 \param t uchar set the value which is the tipping point
178 \param TypeObject is an enumerator indicating if the bright
179   or the dark pixels
180 are the object and should be set to one */
181 void Segment::Threshold(uchar t, TypeOfObjects Typeobjects)
182 {
183   // Exception handling
184   EMPTY_CHECK(OriginalImg);
185   CV_Assert(OriginalImg.depth() != sizeof(uchar) ||
186             OriginalImg.depth() != sizeof(uint16_t));
187
188   // Create LUT
189   uchar LUT(newValue[256]{0};
190   if (Typeobjects == Bright) {
191     for (uint32_t i = t; i < 256; i++) {
192       LUT(newValue[i] = 1;
193     }
194   } else {
195     for (uint32_t i = 0; i <= t; i++) {
196       LUT(newValue[i] = 1;
197     }
198   }
199
200   // Create the pointers to the data

```

```
195     uchar *P = ProcessedImg.data;
196     uchar *O = OriginalImg.data;
197
198     // Fills the ProcessedImg with either a 0 or 1
199     for (int i = 0; i < OriginalImg.cols * OriginalImg.rows; i
200        ++) {
201         P[i] = LUT_newValue[O[i]];
202     }
203
204     /*! Set all the border pixels to a set value
205     \param *P uchar pointer to the Mat.data
206     \param setValue uchar the value which is written to the
207         border pixels
208 */
209     void Segment::SetBorder(uchar *P, uchar setValue) {
210         // Exception handling
211         EMPTY_CHECK(OriginalImg);
212         CV_Assert(OriginalImg.depth() != sizeof(uchar) ||
213             OriginalImg.depth() != sizeof(uint16_t));
214
215         uint32_t nData = OriginalImg.cols * OriginalImg.rows;
216
217         // Set borderPixels to 2
218         uint32_t i = 0;
219         uint32_t pEnd = OriginalImg.cols + 1;
220
221         // Set the top row to value 2
222         while (i < pEnd) {
223             P[i++] = setValue;
224         }
225
226         // Set the bottom row to value 2
227         i = nData + 1;
228         pEnd = nData - OriginalImg.cols;
229         while (i-- > pEnd) {
230             P[i] = setValue;
231         }
232
233         // Sets the first and the last Column to 2
234         i = 1;
235         pEnd = OriginalImg.rows;
236         while (i < pEnd) {
237             P[(i * OriginalImg.cols) - 1] = setValue;
238             P[(i++ * OriginalImg.cols)] = setValue;
239         }
240
241     /*! Remove the blobs that are connected to the border
242     \param conn set the pixel connection eight or four
243     \param chain use the results from the previous operation
244         default value = false;
245 */
246     void Segment::RemoveBorderBlobs(uint32_t border, bool chain)
247     {
248         CV_Assert(OriginalImg.depth() != sizeof(uchar));
```

```

247     EMPTY_CHECK(OriginalImg);
248     // make Pointers
249     uchar *O;
250     CHAIN_PROCESS(chain, 0, uchar);
251     if (chain) {
252         ProcessedImg = TempImg.clone();
253     } else {
254         ProcessedImg = OriginalImg.clone();
255     }
256
257     SHOW_DEBUG_IMG(OriginalImg, uchar, 255, "Original Image
258                     RemoverBorderBlobs!",
259                     true);
260     SHOW_DEBUG_IMG(TempImg, uchar, 255, "Temp Image
261                     RemoverBorderBlobs!", true);
262
263     uchar *P = ProcessedImg.data;
264     uint32_t cols = ProcessedImg.cols;
265     uint32_t rows = ProcessedImg.rows;
266
267     try {
268         for (uint32_t i = 0; i < border; i++) {
269             for (uint32_t j = 0; j < cols; j++) {
270                 if (O[(i * cols) + j] == 1 && P[(i * cols) + j] !=
271                     2) {
272                     cv::floodFill(ProcessedImg, cv::Point(j, i), (
273                         uchar)2);
274                 }
275             }
276         }
277         for (uint32_t i = rows - border - 1; i < rows; i++) {
278             for (uint32_t j = 0; j < cols; j++) {
279                 if (O[(i * cols) + j] == 1 && P[(i * cols) + j] !=
280                     2) {
281                     cv::floodFill(ProcessedImg, cv::Point(j, i), (
282                         uchar)2);
283                 }
284             }
285         }
286         for (uint32_t i = border; i < rows - border; i++) {
287             for (uint32_t j = 0; j < border; j++) {
288                 if (O[(i * cols) + j] == 1 && P[(i * cols) + j] !=
289                     2) {
290                     cv::floodFill(ProcessedImg, cv::Point(j, i), (
291                         uchar)2);
292                 }
293             }
294         }
295     } catch (cv::Exception &e) {

```

```

294     }
295     SHOW_DEBUG_IMG(ProcessedImg, uchar, 255,
296                     "Processed Image RemoverBorderBlobs before
297                     LUT!", true);
298
299     // Change values 2 -> 0
300     uchar LUT(newValue[3]{0, 1, 0};
301     P = ProcessedImg.data;
302     uint32_t nData = rows * cols;
303     for (uint32_t i = 0; i < nData; i++) {
304         P[i] = LUT(newValue[P[i]]);
305     }
306
307     SHOW_DEBUG_IMG(ProcessedImg, uchar, 255,
308                     "Processed Image RemoverBorderBlobs!", true
309                     );
310
311     /*! Label all the individual blobs in a BW source image. The
312        result are written
313        to the labelledImg as an ushort
314        \param conn set the pixel connection eight or four
315        \param chain use the results from the previous operation
316        default value = false;
317        \param minBlobArea minimum area when an artifact is
318        considered a blob
319
320     */
321     void Segment::LabelBlobs(bool chain, uint16_t minBlobArea,
322                             Connected conn) {
323         // Exception handling
324         CV_Assert(OriginalImg.depth() != sizeof(uchar));
325         EMPTY_CHECK(OriginalImg);
326
327         // make the Pointers to the data
328         uchar *O;
329         if (chain) {
330             TempImg = ProcessedImg.clone();
331             ProcessedImg = cv::Mat(OriginalImg.rows, OriginalImg.
332                                   cols, CV_16UC1);
333             O = (uchar *)TempImg.data;
334         } else {
335             O = (uchar *)OriginalImg.data;
336         }
337         uint16_t *P = (uint16_t *)LabelledImg.data;
338
339         uint32_t nCols = OriginalImg.cols;
340         uint32_t nRows = OriginalImg.rows;
341         uint32_t nData = nCols * nRows;
342
343         vector<vector<uint16_t>> CLdownstream;
344
345         ConnectedBlobs(O, P, CLdownstream, nCols, nRows,
346                         conn); // First loop through the image
347         SortAdjacencyList(
348             CLdownstream); // Sort all the adjacencylists and make
349                         unique,

```

```

342
343 // identify all the lowest values in the adjacent list
344 uint16_t *valueArr = new uint16_t[CLdownstream.size()];
345 for (int i = CLdownstream.size() - 1; i >= 0; --i) {
346     std::vector<uint16_t *> route;
347     uint16_t minVal = i;
348
349     for (uint32_t j = 0; j < CLdownstream[i].size(); j++) {
350
351         // add the first node to the queue;
352         route.push_back(&CLdownstream[i][j]);
353
354         // iterate till the last node
355         bool lastNodeReached = false;
356         while (!lastNodeReached) {
357             uint32_t nodesVisited = route.size() - 1;
358             if (*route[nodesVisited] < minVal) {
359                 minVal = *route[nodesVisited];
360             }
361             route.push_back(&CLdownstream[*route[nodesVisited
362                 ]][0]);
363             if (route[nodesVisited] == route[nodesVisited + 1])
364             {
365                 route.pop_back();
366                 lastNodeReached = true;
367             }
368             // Set all values to the lowest value
369             for (uint32_t k = 0; k < route.size(); k++) {
370                 *route[k] = minVal;
371             }
372             valueArr[i] = minVal;
373         }
374
375         // Make numbers consecutive
376         MakeConsecutive(valueArr, CLdownstream.size(), MaxLabel);
377
378         // Second loop through the pixels to give the values a
379         // final value
380         for_each(P, P + nData, [&](uint16_t &V) { V = valueArr[V];
381             });
382         delete[] valueArr;
383     }
384
385     /*! Create a BW image with only edges from a BW image
386     \param src source image as a const cv::Mat
387     \param dst destination image as a cv::Mat
388     \param conn set the pixel connection eight or four
389     \param chain use the results from the previous operation
390     default value = false;
391 */
392     void Segment::GetEdges(const Mat &src, Mat &dst, bool chain,
393     Connected conn) {
394     OriginalImg = src;
395     GetEdges(chain, conn);

```

```
392     dst = ProcessedImg;
393 }
394
395 /*! Create a BW image with only edges from a BW image
396 \param conn set the pixel connection eight or four
397 \param chain use the results from the previous operation
398     default value = false;
399 */
400 void Segment::GetEdges(bool chain, Connected conn) {
401     // Exception handling
402     CV_Assert(OriginalImg.depth() != sizeof(uchar));
403     EMPTY_CHECK(OriginalImg);
404
405     // make Pointers
406     uchar *O;
407     CHAIN_PROCESS(chain, 0, uchar);
408     uchar *P = ProcessedImg.data;
409
410     uint32_t nCols = OriginalImg.cols;
411     uint32_t nRows = OriginalImg.rows;
412     uint32_t nData = nCols * nRows;
413     uint32_t pEnd = nData + 1;
414     uint32_t i = 0;
415
416     // Loop through the image and set each pixel which has a
417     // zero neighbor set it
418     // to two.
419     if (conn == Four) {
420         // Loop through the picture
421         while (i < pEnd) {
422             // If current value = zero processed value = zero
423             if (O[i] == 0) {
424                 P[i] = 0;
425             }
426             // If current value = 1 check North West, South and
427             // East and act
428             // accordingly
429             else if (O[i] == 1) {
430                 uchar *nPixels = new uchar[4];
431                 nPixels[0] = O[i - 1];
432                 nPixels[1] = O[i - nCols];
433                 nPixels[2] = O[i + 1];
434                 nPixels[3] = O[i + nCols];
435
436                 // Sort the neighbors for easier checking
437                 SoilMath::Sort::QuickSort<uchar>(nPixels, 4);
438                 if (nPixels[0] == 0) {
439                     P[i] = 1;
440                 } else {
441                     P[i] = 0;
442                 }
443                 delete[] nPixels;
444             } else {
445                 throw Exception::PixelValueOutOfBoundsException();
446             }
447             i++;
448         }
449     }
450 }
```

```

445      }
446  } else {
447      // Loop through the picture
448      while (i < pEnd) {
449          // If current value = zero processed value = zero
450          if (O[i] == 0) {
451              P[i] = 0;
452          }
453          // If current value = 1 check North West , South and
454          // East and act
455          // accordingly
456          else if (O[i] == 1) {
457              uchar *nPixels = new uchar[8];
458              nPixels[0] = O[i - 1];
459              nPixels[1] = O[i - nCols];
460              nPixels[2] = O[i - nCols - 1];
461              nPixels[3] = O[i - nCols + 1];
462              nPixels[4] = O[i + 1];
463              nPixels[5] = O[i + nCols + 1];
464              nPixels[6] = O[i + nCols];
465              nPixels[7] = O[i + nCols - 1];
466
467              // Sort the neighbors for easier checking
468              SoilMath::Sort::QuickSort<uchar>(nPixels, 8);
469
470              if (nPixels[0] == 0) {
471                  P[i] = 1;
472              } else {
473                  P[i] = 0;
474              }
475              delete[] nPixels;
476          } else {
477              throw Exception::PixelValueOutOfBoundException();
478          }
479          i++;
480      }
481  }
482
483 void Segment::GetEdgesEroding(bool chain) {
484     // Exception handling
485     CV_Assert(OriginalImg.depth() != sizeof(uchar));
486     EMPTY_CHECK(OriginalImg);
487
488     // make Pointers
489     uchar *O;
490     CHAIN_PROCESS(chain, O, uchar);
491     uchar *P = ProcessedImg.data;
492
493     uint32_t nCols = OriginalImg.cols;
494     uint32_t nRows = OriginalImg.rows;
495     uint32_t nData = nCols * nRows;
496
497     // Setup the erosion
498     MorphologicalFilter eroder;
499     if (chain) {

```

```

500     eroder.OriginalImg = TempImg;
501 } else {
502     eroder.OriginalImg = OriginalImg;
503 }
504 // Setup the processed image of the eroder
505 eroder.ProcessedImg.create(OriginalImg.size(), CV_8UC1);
506 eroder.ProcessedImg.setTo(0);
507 // Setup the mask
508 Mat mask(3, 3, CV_8UC1, 1);
509 // Erode the image
510 eroder.Erosion(mask, false);
511
512 // Loop through the image and set the not eroded pixels to
513 // zero
514 for (uint32_t i = 0; i < nData; i++) {
515     if (0[i] != eroder.ProcessedImg.data[i]) {
516         P[i] = 1;
517     } else {
518         P[i] = 0;
519     }
520 }
521 // ProcessedImg = OriginalImg.clone() - eroder.
522 // ProcessedImg.clone();
523 SHOW_DEBUG_IMG(eroder.ProcessedImg, uchar, 255, "Eroded
524         img Processed Image!",
525         true);
525 SHOW_DEBUG_IMG(ProcessedImg, uchar, 255, "GetEdgesEroding
526         Processed Image!",
527         true);
528 }
529 /*! Create a BlobList subtracting each individual blob out
530 of a Labelled image.
531 If the labelled image is empty build a new one with a BW
532 image.
533 \param conn set the pixel connection eight or four
534 \param chain use the results from the previous operation
535     default value = false;
536 */
537 void Segment::GetBlobList(bool chain, Connected conn) {
538     // Exception handling
539     CV_Assert(OriginalImg.depth() != sizeof(uchar));
540     EMPTY_CHECK(OriginalImg);
541
542     // If there isn't a labelledImg make one
543     if (MaxLabel < 1) {
544         LabelBlobs(chain, 5, conn);
545     }
546
547     // Make an empty BlobList
548     uint32_t nCols = OriginalImg.cols;
549     uint32_t nRows = OriginalImg.rows;
550     uint32_t nData = nCols * nRows;
551     RectList_t rectList;

```

```

549
550 // Calculate Stats the statistics
551 uint16Stat_t LabelStats((uint16_t *)LabelledImg.data,
552                         LabelledImg.cols,
553                         LabelledImg.rows, MaxLabel + 1, 0,
554                         MaxLabel);
555
556 BlobList.reserve(LabelStats.EndBin);
557 rectList.reserve(LabelStats.EndBin);
558
559 BlobList.push_back(Blob_t(0, 0));
560 rectList.push_back(Rect_t(0, 0, 0, 0));
561
562 for (uint32_t i = 1; i < LabelStats.EndBin; i++) {
563     BlobList.push_back(Blob_t(i, LabelStats.bins[i]));
564     rectList.push_back(Rect_t(nCols, nRows, 0, 0));
565 }
566
567 // make Pointers
568 uint16_t *L = (uint16_t *)LabelledImg.data;
569
570 uint32_t currentX, currentY;
571 // uint16_t leftX, leftY, rightX, rightY;
572 // Loop through the labeled image and extract the Blobs
573 for (uint32_t i = 0; i < nData; i++) {
574     if (L[i] != 0) {
575         /* Determine the current x and y value of the current
576          blob and
577          checks if it is min/max */
578         currentY = i / nCols;
579         currentX = i % nCols;
580
581         // Min value
582         if (currentX < rectList[L[i]].leftX) {
583             rectList[L[i]].leftX = currentX;
584         }
585         if (currentY < rectList[L[i]].leftY) {
586             rectList[L[i]].leftY = currentY;
587         }
588
589         // Max value
590         if (currentX > rectList[L[i]].rightX) {
591             rectList[L[i]].rightX = currentX;
592         }
593         if (currentY > rectList[L[i]].rightY) {
594             rectList[L[i]].rightY = currentY;
595         }
596     }
597
598 // Loop through the BlobList and finalize it
599 uint8_t *LUT_filter = new uint8_t[MaxLabel + 1] {};
600 for (uint32_t i = 1; i <= MaxLabel; i++) {
601     LUT_filter[i] = 1;
602     BlobList[i].ROI.y = rectList[i].leftY;
603     BlobList[i].ROI.x = rectList[i].leftX;

```

```

602     BlobList[i].ROI.height = rectList[i].rightY - rectList[i
603         ].leftY + 1;
604     BlobList[i].ROI.width = rectList[i].rightX - rectList[i
605         ].leftX + 1;
606     BlobList[i].Img = CopyMat<uint8_t, uint16_t>(
607         LabelledImg(BlobList[i].ROI).clone(), LUT_filter,
608         CV_8UC1);
609     //SHOW_DEBUG_IMG(BlobList[i].Img, uchar, 255, "Blob",
610         true);
611     LUT_filter[i] = 0;
612 }
613 delete[] LUT_filter;
614
615 // Remove background blob
616 BlobList.erase(BlobList.begin());
617 }
618
619 void Segment::FillHoles(bool chain) {
620     // Exception handling
621     CV_Assert(OriginalImg.depth() != sizeof(uchar));
622     EMPTY_CHECK(OriginalImg);
623
624     // make Pointers
625     uchar *O;
626     CHAIN_PROCESS(chain, O, uchar);
627     if (chain) {
628         ProcessedImg = TempImg.clone();
629     } else {
630         ProcessedImg = OriginalImg.clone();
631     }
632
633     uchar *P = ProcessedImg.data;
634
635     // Determine the starting point of the floodfill
636     int itt = -1;
637     while (P[++itt] != 0)
638         ;
639     uint16_t row = static_cast<uint16_t>(itt / OriginalImg.
640         rows);
641     uint16_t col = static_cast<uint16_t>(itt % OriginalImg.
642         rows);
643
644     // Fill the outside
645     try {
646         cv::floodFill(ProcessedImg, cv::Point(col, row), cv::
647             Scalar(2));
648     } catch (cv::Exception &e) {
649     }
650
651     // Set the unreached areas to 1 and the outside to 0;
652     uchar LUT newVal[3] = {1, 1, 0};
653     uint32_t nData = OriginalImg.rows * OriginalImg.cols;
654     uint32_t i = 0;
655     while (i <= nData) {
656         P[i] = LUT newVal[P[i]];
657         i++;
658     }
659 }
```

```

651     }
652 }
653
654 /*!
655  * \brief Segment::SortAdjacencyList Sort the the sub
656  * vectors
657  * \param adj std::vector<std::vector<uint16_t>> &adj
658  */
659 void Segment::SortAdjacencyList(std::vector<std::vector<
660     uint16_t>> &adj) {
661     uint32_t j = 0;
662     for_each(adj.begin(), adj.end(), [&](std::vector<uint16_t>
663         &L) {
664         std::sort(L.begin(), L.end());
665         std::vector<uint16_t>::iterator it;
666         it = std::unique(L.begin(), L.end());
667         L.resize(std::distance(L.begin(), it));
668         if (L.size() > 1) {
669             for (std::vector<uint16_t>::iterator iter = L.begin();
670                  iter != L.end();
671                  ++iter) {
672                 if (*iter == j) {
673                     L.erase(iter);
674                     break;
675                 }
676             }
677         }
678     }
679     /*!
680  * \brief Segment::ConnectedBlobs Connect all the blobs and
681  * created the
682  * adjacency list
683  * \param 0
684  * \param P
685  * \param adj
686  * \param nCols
687  * \param nRows
688  * \param conn
689  */
690 void Segment::ConnectedBlobs(uchar *0, uint16_t *P,
691                             std::vector<std::vector<
692                                 uint16_t>> &adj,
693                             uint32_t nCols, uint32_t nRows,
694                             Connected conn) {
695     // Determine the size of the array for beginning and
696     // endrow and middle of a
697     // row
698     uint32_t noConn[3] = {static_cast<uint32_t>(conn),
699                           (static_cast<uint32_t>(conn) / 2),
700                           (static_cast<uint32_t>(conn) / 2) +
701                           1};
701     uint32_t lastConn[3] = {noConn[0] - 1, noConn[1] - 1,
702                           noConn[2] - 1};

```

```
697     uint32_t nData = nCols * nRows;
698
699     uint16_t currentlbl = 0;
700     vector<uint16_t> zeroVector;
701     zeroVector.push_back(currentlbl);
702     adj.push_back(zeroVector);
703
704     // Determine which borderpixels should be handled
705     // differently
706     uchar *nRow = new uchar[nData]{};
707     for (uint32_t i = nCols; i < nData; i += nCols) {
708         nRow[i] = 1;
709         nRow[i - 1] = 2;
710     }
711
712     // Set the first pixel
713     if (O[0] == 0) {
714         P[0] = 0;
715     } else if (O[0] == 1) {
716         P[0] = 1;
717     } else {
718         throw Exception::PixelValueOutOfBoundException();
719     }
720
721     // Walk through the toprow and determine if it's a new
722     // blob or it's connected
723     // with previously determine blob
724     for (uint32_t i = 1; i < nCols; i++) {
725         if (O[i] == 0) {
726             P[i] = 0;
727         } else if (O[i] == 1) {
728             // If West is zero assume this is a new blob
729             if (P[i - 1] == 0) {
730                 P[i] = ++currentlbl;
731                 vector<uint16_t> cVector;
732                 cVector.push_back(currentlbl);
733                 adj.push_back(cVector);
734             } else { // set as previous blob
735                 P[i] = P[i - 1];
736             }
737         } else { // Value of of bounds
738             throw Exception::PixelValueOutOfBoundException();
739         }
740     }
741
742     // walk through each pixel and determine if it's a new
743     // blob or it's connected
744     // with previously determine blob
745     for (uint32_t i = OriginalImg.cols; i < nData; i++) {
746         if (O[i] == 0) { // Original pixel = 0
747             P[i] = 0;
748         } else if (O[i] == 1) {
749             // Get an array of Neighboring Pixels
750             uint16_t *nPixels = new uint16_t[noConn[nRow[i]]];
751             if (nRow[i] != 1) {
752                 nPixels[0] = P[i - 1];
```

```

750     }
751     uint32_t j = i - nCols - ((nRow[i] == 1) ? 0 : ((conn
752         == Four) ? 0 : 1));
753     for_each(nPixels + ((nRow[i] != 1) ? 1 : 0), nPixels +
754         noConn[nRow[i]],
755         [&](uint16_t &N) { N = P[j++]; });
756
757     // Sort the neighbors for easier checking
758     SoilMath::Sort::QuickSort<uint16_t>(nPixels, noConn[
759         nRow[i]]);
760
761     // If all are zero assume this is a new blob
762     if (nPixels[lastConn[nRow[i]]] == 0) {
763         P[i] = ++currentlbl;
764         vector<uint16_t> cVector;
765         cVector.push_back(currentlbl);
766         adj.push_back(cVector);
767     } else {
768         /* Sets the processed value to the smallest non-zero
769            value and update
770            * the connectedLabels */
771         for (uint32_t j = 0; j < noConn[nRow[i]]; j++) {
772             if (nPixels[j] > 0) {
773                 P[i] = nPixels[j];
774                 break;
775             }
776         }
777         /* If previous blobs belong to different connected
778            components set the
779            * current processed value to the lowest value and
780            remember that the
781            * other values should be the lowest value*/
782         if (P[i] != nPixels[lastConn[nRow[i]]]) {
783             for (int j = lastConn[nRow[i]]; j >= 0; --j) {
784                 if (nPixels[j] <= P[i]) {
785                     break;
786                 } else {
787                     adj[nPixels[j]].push_back(P[i]);
788                 }
789             }
790         }
791     }
792     delete[] nPixels;
793 }
794
795 /*!
796 * \brief Segment::InvertAdjacencyList invert the
797 * adjacencylist for upstream
798 * (unused)
799 * \param adj

```

```

799  * \param adjInv
800  */
801 void Segment::InvertAdjacencyList(std::vector<std::vector<
802     uint16_t>> &adj,
803                                     std::vector<std::vector<
804                                         uint16_t>> &adjInv) {
805     // Build the inverted vector
806     adjInv.resize(adj.size());
807     uint16_t count = 0;
808     for_each(adj.begin(), adj.end(), [&](std::vector<uint16_t>
809               &V) {
810         for_each(V.begin(), V.end(),
811                 [&](uint16_t &C) { adjInv[C].push_back(count);
812                 });
813         count++;
814     });
815 }
816
817 /*!
818  * \brief Segment::MakeConsecutive make the valueArr
819  * consequative numbers
820  * \param valueArr
821  * \param noElem
822  * \param maxLabel
823  */
824 void Segment::MakeConsecutive(uint16_t *valueArr, uint32_t
825     noElem,
826                             uint16_t &maxLabel) {
827     std::vector<std::vector<uint16_t>> conseq;
828     conseq.resize(noElem);
829     for (uint32_t i = 0; i < noElem; i++) {
830         conseq[valueArr[i]].push_back(i);
831     }
832     uint32_t count = 1;
833     for (uint32_t i = 1; i < noElem; i++) {
834         if (conseq[i].size() > 0) {
835             for (uint32_t j = 0; j < conseq[i].size(); j++) {
836                 valueArr[conseq[i][j]] = count;
837             }
838             count++;
839         }
840     }
841     maxLabel = count - 1;
842 }
843
844 /*!
845  * \brief Segment::MakeConsecutive probably a fault in this
846  * function. Don't use
847  * \param valueArr
848  * \param keyArr
849  * \param noElem
850  * \param maxlabel
851  */
852 void Segment::MakeConsecutive(uint16_t *valueArr, uint16_t *
853     keyArr,

```

```
846                               uint16_t noElem, uint16_t &
847                               maxlabel) {
848     SoilMath::Sort::QuickSort<uint16_t>(valueArr, keyArr,
849                                         noElem);
850     uint16_t count = 0;
851     for (uint32_t i = 1; i < noElem; i++) {
852         if (valueArr[i] != valueArr[i - 1]) {
853             count++;
854         }
855         valueArr[i] = count;
856     }
857     SoilMath::Sort::QuickSort<uint16_t>(keyArr, valueArr,
858                                         noElem);
859     delete[] keyArr;
860     maxlabel = count;
861 }
```

General project files

```
1 #-----
2 #
3 # Project created by QtCreator 2015-06-06T12:07:42
4 #
5 #-----
6
7 QT      += core concurrent
8 greaterThan(QT_MAJOR_VERSION, 4): QT += widgets
9 QMAKE_CXXFLAGS += -std=c++11
10
11 TARGET = SoilVision
12 TEMPLATE = lib
13 VERSION = 0.9.2
14
15 DEFINES += SOILVISION_LIBRARY
16 unix:!macx: QMAKE_RPATHDIR += $$PWD/../../../../../build/install/
17
18 SOURCES += \
19     Segment.cpp \
20     MorphologicalFilter.cpp \
21     ImageProcessing.cpp \
22     Enhance.cpp \
23     Conversion.cpp
24
25 HEADERS += \
26     WrongKernelSizeException.h \
27     VisionDebug.h \
28     Vision.h \
29     Segment.h \
30     PixelValueOutOfBoundsException.h \
31     MorphologicalFilter.h \
32     ImageProcessing.h \
33     Enhance.h \
34     EmptyImageException.h \
35     ConversionNotSupportedException.h \
36     Conversion.h \
37     ChannelMismatchException.h
38
39 unix {
40     target.path = $$PWD/../../../../../build/install
41     INSTALLS += target
42 }
43
44 #opencv
45 LIBS += -L/usr/local/lib -lopencv_core -lopencv_highgui - \
46         opencv_imgproc
46 INCLUDEPATH += /usr/local/include/opencv
47 INCLUDEPATH += /usr/local/include
48
49 #boost
50 DEFINES += BOOST_ALL_DYN_LINK
51 INCLUDEPATH += /usr/include/boost
52
53 unix:!macx: LIBS += -L$$PWD/../../../../../build/install/ -lSoilMath
```

```

54
55 INCLUDEPATH += $$PWD/../SoilMath
56 DEPENDPATH += $$PWD/../SoilMath


---


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8 */
9
10 /*! Collection header of all the basic Vision headers*/
11
12 #pragma once
13 #include "Conversion.h"
14 #include "Enhance.h"
15 #include "Segment.h"
16 #include "MorphologicalFilter.h"


---


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8 */
9
10 #pragma once
11 // Debuging helper macros
12 #ifndef DEBUG
13 // #define DEBUG
14 #endif
15
16 #ifdef DEBUG
17 #include <limits>
18 #include <opencv2/highgui/highgui.hpp>
19 #include <vector>
20 #include "ImageProcessing.h"
21 #ifndef SHOW_DEBUG_IMG
22 #define SHOW_DEBUG_IMG(img, T1, maxVal, windowName, scale)
23   \
24   Vision::ImageProcessing::ShowDebugImg<T1>(img, maxVal,
25   windowName, scale)
26 #endif // !SHOW_DEBUG_IMG
27 #else
28 #ifndef SHOW_DEBUG_IMG
29 #define SHOW_DEBUG_IMG(img, T1, maxVal, windowName, scale)
30 #endif // !SHOW_DEBUG_IMG
31 #endif


---


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7  */
8 /*! \class ChannelMismatchException
9 Exception class which is thrown when Extracted channel out
10 of bounds exception
11 */
12 #pragma once
13
14 #include <exception>
15 #include <string>
16
17 using namespace std;
18
19 namespace Vision {
20 namespace Exception {
21 class ChannelMismatchException : public std::exception {
22 public:
23     ChannelMismatchException(
24         string m = "Extracted channel out of bounds exception!
25         ")
26     : msg(m){};
27     ~ChannelMismatchException() __GLIBCXX_USE_NOEXCEPT{};
28     const char *what() const __GLIBCXX_USE_NOEXCEPT { return
29         msg.c_str(); };
30
31     private:
32     string msg;
33 };
34
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42  */
43 /*! \class ConversionNotSupportedException
44 Exception class which is thrown when an illegal conversion
45 is requested.
46 */
47 #pragma once
48
49 #include <exception>
50 #include <string>
51
52 using namespace std;
53

```

```

18 namespace Vision {
19 namespace Exception {
20 class ConversionNotSupportedException : public std::
21 exception {
21 public:
22     ConversionNotSupportedException(
23         string m = "Requested conversion is not supported!")
24         : msg(m){};
25     ~ConversionNotSupportedException() _GLIBCXX_USE_NOEXCEPT
26     {};
26     const char *what() const _GLIBCXX_USE_NOEXCEPT { return
27         msg.c_str(); };
27
28 private:
29     string msg;
30 };
31 }
32 }



---


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8 */
8 /*! \class EmtpyImageException
9 Exception class which is thrown when operations are about to
10 start on a empty
11 image.
11 */
12
13 #pragma once
14
15 #include <exception>
16 #include <string>
17
18 using namespace std;
19
20 namespace Vision {
21 namespace Exception {
22 class EmtpyImageException : public std::exception {
23 public:
24     EmtpyImageException(string m = "Empty Image!") : msg(m){};
25     ~EmtpyImageException() _GLIBCXX_USE_NOEXCEPT{};
26     const char *what() const _GLIBCXX_USE_NOEXCEPT { return
27         msg.c_str(); };
27
28 private:
29     string msg;
30 };
31 }
32 }

```

```
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8   */
9
10 /*! \class PixelValueOutOfBoundsException
11 Exception class which is thrown when an unexpected pixel
12 value has to be
13 computed
14 */
15 #pragma once
16
17 #include <exception>
18 #include <string>
19
20 using namespace std;
21
22 namespace Vision {
23 namespace Exception {
24 class PixelValueOutOfBoundsException : public std::exception
25 {
26 public:
27     PixelValueOutOfBoundsException(string m = "Current pixel
28         value out of bounds!")
29     : msg(m){};
30     ~PixelValueOutOfBoundsException() __GLIBCXX_USE_NOEXCEPT{};
31     const char *what() const __GLIBCXX_USE_NOEXCEPT { return
32         msg.c_str(); };
33
34 private:
35     string msg;
36 };
37 }
38 }
```

```
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8   */
9
10 /*! \class WrongKernelSizeException
11 Exception class which is thrown when a wrong kernelsize is
12 requested
13 */
14 #pragma once
15
16 #include <exception>
```

```
14 #include <string>
15
16 using namespace std;
17
18 namespace Vision {
19 namespace Exception {
20 class WrongKernelSizeException : public std::exception {
21 public:
22     WrongKernelSizeException(string m = "Wrong kernel
23         dimensions!") : msg(m){};
24     ~WrongKernelSizeException() _GLIBCXX_USE_NOEXCEPT{};
25     const char *what() const _GLIBCXX_USE_NOEXCEPT { return
26         msg.c_str(); };
27     private:
28     string msg;
29 }
30 }
```



K. Analyzer Library

Analyzer Class

```
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8   */
9
10 #pragma once
11 #define STARTING_ESTIMATE_PROGRESS 300
12 #ifndef DEBUG
13 //#define DEBUG
14 #endif
15
16 #include <opencv2/core.hpp>
17 #include <opencv2/imgproc.hpp>
18 #include <vector>
19 #include <cmath>
20
21 #include "sample.h"
22 #include "soilsettings.h"
23 #include "soilanalyzerexception.h"
24
25 #include "SoilMath.h"
26
27 #include <QtCore/QObject>
28 #include <QThread>
29 #include <QtConcurrent>
30
31 #include "Vision.h"
```

```

30
31 namespace SoilAnalyzer {
32 class Analyzer : public QObject {
33     Q_OBJECT
34
35 public:
36     bool PredictShape = true;
37     float CurrentSIfactor = 0.0111915;
38     bool SIfactorDet = false;
39     struct Image_t {
40         cv::Mat FrontLight;
41         cv::Mat BackLight;
42         float SIPixelFactor = 0.0111915;
43     }; /*!< */
44
45     typedef std::vector<Image_t> Images_t; /*!< */
46     Images_t *Snapshots = nullptr;           /*!< */
47     SoilSettings *Settings = nullptr;         /*!< */
48
49     Sample *Results; /*!< */
50
51     Analyzer(Images_t *snapshots, Sample *results,
52               SoilSettings *settings);
53
54     void Analyse();
55     void Analyse(Images_t *snapshots, Sample *results,
56                  SoilSettings *settings);
57     float CalibrateSI(float SI, cv::Mat &img);
58
59     uint32_t MaxProgress = STARTING_ESTIMATE_PROGRESS; /*!< */
60
61     SoilMath::NN NeuralNet; /*!< */
62
63 signals:
64     void on_progressUpdate(int value); /*!< */
65     void on_maxProgressUpdate(int value); /*!< */
66     void on_AnalysisFinished(); /*!< */
67
68 private:
69     uint32_t currentProgress = 0; /*!< */
70     uint32_t currentParticleID = 0; /*!< */
71     double BinRanges[15]{0.0, 0.038, 0.045, 0.063, 0.075,
72                         0.09, 0.125, 0.18,
73                         0.25, 0.355, 0.5, 0.71, 1.0, 1.4,
74                         2.0};
75
76     SoilMath::FFT fft; /*!< */
77
78     void CalcMaxProgress();
79     void CalcMaxProgressAnalyze();
80     void PrepImages();
81     void GetBW(std::vector<cv::Mat> &images, std::vector<cv::
82                Mat> &BWvector);
83     void GetBW(cv::Mat &img, cv::Mat &BW);
84
85     void GetEnhancedInt(Images_t *snapshots,

```

```

81             std::vector<cv::Mat> &intensityVector)
82             ;
83     void GetEnhancedInt(cv::Mat &img, cv::Mat &intensity);
84     void GetParticles(std::vector<cv::Mat> &BW, Images_t *
85                         snapshots,
86                         Particle::ParticleVector_t &
87                         partPopulation);
86     void GetParticlesFromBlobList(Vision::Segment::BlobList_t
87                         &bloblist,
88                         Image_t *snapshot,
89                         Particle::ParticleVector_t &
90                         partPopulation);
90     void CleanUpMatVector(std::vector<cv::Mat> &mv);
91     void CleanUpMatVector(Images_t *mv);
92     void GetFFD(Particle::ParticleVector_t &particalPopulation
93                  );
94     void GetPrediction(Particle::ParticleVector_t &
95                         particlePopulation);
96 };
97 }



---


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8 */
9
8 #include "analyzer.h"
9
10 namespace SoilAnalyzer {
11
12 /*!
13  *\brief Analyzer::Analyzer
14  *\param snapshots
15  *\param results
16  *\param settings
17 */
18 Analyzer::Analyzer(Images_t *snapshots, Sample *results,
19                     SoilSettings *settings = nullptr) {
20     this->Snapshots = snapshots;
21     this->Results = results;
22     if (settings == nullptr) {
23         Settings = new SoilSettings;
24     } else {
25         this->Settings = settings;
26     }
27     NeuralNet.LoadState(Settings->NNlocation);
28 }
29

```

```
30  /*!
31   * \brief Analyzer::PrepImages
32   */
33  void Analyzer::PrepImages() {
34      if (Snapshots == nullptr || Snapshots->size() == 0) {
35          throw Exception::SoilAnalyzerException(
36              EXCEPTION_NO_SNAPSHOTS,
37              EXCEPTION_NO_SNAPSHOTS_NR
38          );
39      }
40
41      std::vector<cv::Mat> intensityVector;
42      GetEnhancedInt(Snapshots, intensityVector);
43
44      std::vector<cv::Mat> BWVector;
45      GetBW(intensityVector, BWVector);
46      CleanUpMatVector(intensityVector);
47
48      GetParticles(BWVector, Snapshots, Results->
49          ParticlePopulation);
50
51      CleanUpMatVector(BWVector);
52      CleanUpMatVector(Snapshots);
53
54      Results->isPreparedForAnalysis = true;
55  }
56
57  void Analyzer::Analyse(Images_t *snapshots, Sample *results,
58                         SoilSettings *settings) {
59      Snapshots = snapshots;
60      Results = results;
61      Settings = settings;
62      Analyse();
63  }
64
65  /*!
66   * \brief Analyzer::Analyse
67   */
68  void Analyzer::Analyse() {
69      CalcMaxProgress();
70      if (!Results->isPreparedForAnalysis && !Results->
71          IsLoadedFromDisk) {
72          PrepImages();
73      }
74
75      Results->Angularity =
76          ucharStat_t(Results->GetAngularityVector()->data(),
77                      Results->GetAngularityVector()->size(), 1,
78                      7, 0, true);
79      emit on_progressUpdate(currentProgress++);
80
81      Results->Roundness =
```

```

81         ucharStat_t(Results->GetRoundnessVector()->data(),
82                         Results->GetRoundnessVector()->size(), 1,
83                         5, 0, true);
84     Results->PSD =
85         SoilMath::PSD(Results->GetPSDVector()->data(),
86                         Results->GetPSDVector()->size(),
87                         BinRanges, 15, 14);
88     emit on_progressUpdate(currentProgress++);
89     emit on_AnalysisFinished();
90 }
91
92 void Analyzer::CleanUpMatVector(std::vector<Mat> &mv) {
93     for_each(mv.begin(), mv.end(), [](cv::Mat &I) { I.release
94         (); });
95     mv.clear();
96 }
97 /**
98  * \brief Analyzer::CleanUpMatVector
99  * \param mv
100 */
101 void Analyzer::CleanUpMatVector(Images_t *mv) {
102     for_each(mv->begin(), mv->end(), [](Image_t &I) {
103         I.BackLight.release();
104         I.FrontLight.release();
105     });
106     mv->clear();
107 }
108 /**
109  * \brief Analyzer::CalcMaxProgress
110 */
111 void Analyzer::CalcMaxProgress() {
112     // Static processing steps
113     MaxProgress += Snapshots->size() * 5;
114
115     // Optional processing steps
116     if (Settings->useBlur) {
117         MaxProgress += Snapshots->size();
118     }
119     if (Settings->useAdaptiveContrast) {
120         MaxProgress += Snapshots->size();
121     }
122     if (Settings->fillHoles) {
123         MaxProgress += Snapshots->size();
124     }
125     if (Settings->ignorePartialBorderParticles) {
126         MaxProgress += Snapshots->size();
127     }
128     if (Settings->morphFilterType != Vision::
129         MorphologicalFilter::NONE) {
130         MaxProgress += Snapshots->size();
131     }
132 }
```

```
133     emit on_maxProgressUpdate(MaxProgress);
134 }
135
136 void Analyzer::CalcMaxProgressAnalyze() {
137     MaxProgress -= STARTING_ESTIMATE_PROGRESS;
138     MaxProgress += Results->ParticlePopulation.size() * 2;
139
140     emit on_maxProgressUpdate(MaxProgress);
141 }
142
143 /**
144  * \brief Analyzer::GetEnhancedInt
145  * \param snapshots
146  * \param intensityVector
147  */
148 void Analyzer::GetEnhancedInt(Images_t *snapshots,
149                               std::vector<Mat> &
150                               intensityVector) {
151     if (Settings->useBacklightProjection) {
152         for_each(snapshots->begin(), snapshots->end(), [&]{
153             Image_t &I {
154                 cv::Mat intensity;
155                 GetEnhancedInt(I.BackLight, intensity);
156                 intensityVector.push_back(intensity);
157             });
158     } else {
159         for_each(snapshots->begin(), snapshots->end(), [&]{
160             Image_t &I {
161                 cv::Mat intensity;
162                 GetEnhancedInt(I.FrontLight, intensity);
163                 intensityVector.push_back(intensity);
164             });
165     }
166 /**
167  * \brief Analyzer::GetEnhancedInt
168  * \param img
169  * \param intensity
170  */
171 void Analyzer::GetEnhancedInt(Mat &img, Mat &intensity) {
172     Vision::Conversion IntConvertor(img.clone());
173     IntConvertor.Convert(Vision::Conversion::RGB, Vision::
174         Conversion::Intensity);
175     emit on_progressUpdate(currentProgress++);
176     SHOW_DEBUG_IMG(IntConvertor.ProcessedImg, uchar, 255, "RGB
177         2 Int", false);
178
179     if (Settings->useBlur) {
180         Vision::Enhance IntBlur(IntConvertor.ProcessedImg.clone
181             ());
182         IntBlur.Blur(Settings->blurKernelSize);
183         emit on_progressUpdate(currentProgress++);
184         uint32_t HBK = Settings->blurKernelSize / 2;
185         uint32_t BK = Settings->blurKernelSize - 1;
186         if (Settings->useAdaptiveContrast) {
```

```

183     Vision::Enhance_IntAdaptContrast(
184         IntBlur.ProcessedImg(
185             cv::Rect(HBK, HBK, IntBlur.
186                 ProcessedImg.cols - BK,
187                 IntBlur.ProcessedImg.rows -
188                 BK)).clone()));
189     IntAdaptContrast.AdaptiveContrastStretch(
190         Settings->adaptContrastKernelSize,
191         Settings->adaptContrastKernelFactor);
192     emit on_progressUpdate(currentProgress++);
193     uint32_t HAK = Settings->adaptContrastKernelSize / 2;
194     uint32_t AK = Settings->adaptContrastKernelSize - 1;
195     intensity = IntAdaptContrast.ProcessedImg(
196         cv::Rect(HAK, HAK, IntAdaptContrast.ProcessedImg.
197             cols - AK,
198             IntAdaptContrast.ProcessedImg.rows - AK));
199     ;
200 } else {
201     intensity = IntBlur.ProcessedImg(
202         cv::Rect(HBK, HBK, IntBlur.ProcessedImg.cols - BK,
203             IntBlur.ProcessedImg.rows - BK));
204 }
205 } else if (Settings->useAdaptiveContrast) {
206     Vision::Enhance_IntAdaptContrast(IntConvertor.
207         ProcessedImg.clone());
208     IntAdaptContrast.AdaptiveContrastStretch(
209         Settings->adaptContrastKernelSize, Settings->
210             adaptContrastKernelFactor);
211     emit on_progressUpdate(currentProgress++);
212     uint32_t HAK = Settings->adaptContrastKernelSize / 2;
213     uint32_t AK = Settings->adaptContrastKernelSize - 1;
214     intensity = IntAdaptContrast.ProcessedImg(
215         cv::Rect(HAK, HAK, IntAdaptContrast.ProcessedImg.
216             cols - AK,
217             IntAdaptContrast.ProcessedImg.rows - AK));
218 } else {
219     intensity = IntConvertor.ProcessedImg;
220 }
221 SHOW_DEBUG_IMG(intensity, uchar, 255, "Enhanced Int",
222     false);
223 }
224 */
225 * \brief Analyzer::GetBW
226 * \param images
227 * \param BWvector
228 */
229 void Analyzer::GetBW(std::vector<cv::Mat> &images,
230                     std::vector<cv::Mat> &BWvector) {
231     for_each(images.begin(), images.end(), [&](cv::Mat &I) {
232         cv::Mat BW;
233         GetBW(I, BW);
234         BWvector.push_back(BW);
235     });
236 }

```

```
231 /*!
232  * \brief Analyzer::GetBW
233  * \param img
234  * \param BW
235 */
236 void Analyzer::GetBW(cv::Mat &img, cv::Mat &BW) {
237     Vision::Segment SegBL(img.clone());
238     SegBL.sigma = Settings->sigmaFactor;
239     SegBL.thresholdOffset = Settings->thresholdOffsetValue;
240     SegBL.ConvertToBW(Settings->typeOfObjectsSegmented);
241     emit on_progressUpdate(currentProgress++);
242     SHOW_DEBUG_IMG(SegBL.ProcessedImg, uchar, 255, "Segment",
243                     true);
244
245     cv::Mat BWholes;
246     if (Settings->fillHoles) {
247         Vision::Segment Fillholes(SegBL.ProcessedImg);
248         Fillholes.FillHoles();
249         BWholes = Fillholes.ProcessedImg;
250         emit on_progressUpdate(currentProgress++);
251         SHOW_DEBUG_IMG(BWholes, uchar, 255, "Fillholes", true);
252     } else {
253         BWholes = SegBL.ProcessedImg;
254     }
255
256     cv::Mat BWborder;
257     if (Settings->ignorePartialBorderParticles) {
258         Vision::Segment RemoveBB(BWholes.clone());
259         RemoveBB.RemoveBorderBlobs();
260         BWborder = RemoveBB.ProcessedImg;
261         emit on_progressUpdate(currentProgress++);
262         SHOW_DEBUG_IMG(BWborder, uchar, 255, "RemoveBorderBlobs",
263                         true);
263     } else {
264         BWborder = BWholes;
265     }
266
267     if (Settings->morphFilterType != Vision::
268         MorphologicalFilter::NONE) {
269         Vision::MorphologicalFilter Morph(BWborder.clone());
270         cv::Mat kernel = cv::Mat::zeros(Settings->filterMaskSize
271                                         ,
272                                         Settings->filterMaskSize
273                                         ,
274                                         CV_8UC1);
275         uint32_t hMaskSize = Settings->filterMaskSize / 2;
276         cv::circle(kernel, cv::Point(hMaskSize, hMaskSize),
277                    hMaskSize + 1, 1, -1);
278         switch (Settings->morphFilterType) {
279             case Vision::MorphologicalFilter::CLOSE:
280                 Morph.Close(kernel);
281                 break;
282             case Vision::MorphologicalFilter::OPEN:
283                 Morph.Open(kernel);
284                 break;
285             case Vision::MorphologicalFilter::DILATE:
286                 Morph.Dilation(kernel);
```

```

281     break;
282     case Vision::MorphologicalFilter::ERODE:
283         Morph.Erosion(kernel);
284         break;
285     case Vision::MorphologicalFilter::NONE:
286         Morph.ProcessedImg = Morph.OriginalImg;
287         break;
288     }
289     BW = Morph.ProcessedImg;
290     emit on_progressUpdate(currentProgress++);
291     SHOW_DEBUG_IMG(BW, uchar, 255, "Morphological operation"
292         , true);
293 } else {
294     BW = BWholes;
295 }
296 }
297 */
298 * \brief Analyzer::GetParticles
299 * \param BW
300 * \param snapshots
301 * \param partPopulation
302 */
303 void Analyzer::GetParticles(std::vector<Mat> &BW, Images_t *
304     snapshots,
305     Particle::ParticleVector_t &
306     partPopulation) {
307     for (uint32_t i = 0; i < snapshots->size(); i++) {
308         Vision::Segment prepBW(BW[i]);
309         prepBW.GetBlobList();
310         emit on_progressUpdate(currentProgress++);
311         GetParticlesFromBlobList(prepBW.BlobList, &(snapshots->
312             at(i)),
313             partPopulation);
314         emit on_progressUpdate(currentProgress++);
315     }
316 }
317 */
318 * \brief Analyzer::GetParticlesFromBlobList
319 * \param bloblist
320 * \param snapshot
321 * \param edge
322 * \param partPopulation
323 */
324 void Analyzer::GetParticlesFromBlobList(
325     Vision::Segment::BlobList_t &bloblist, Image_t *snapshot
326     ,
327     Particle::ParticleVector_t &partPopulation) {
328     for_each(bloblist.begin(), bloblist.end(), [&](Vision::
329         Segment::Blob_t &B) {
330         Particle part;
331         part.ID = currentParticleID++;
332         part.PixelArea = B.Area;
333         Vision::Segment::getOriententated(B.Img, B.Centroid, B.
334             Theta,

```

```

330                     part.Eccentricity);
331     cv::Mat RGB = Vision::Segment::CopyMat<uchar>(snapshot->
332                     FrontLight(B.ROI),
333                     B.Img,
334                     CV_8UC3
335                     ).clone
336                     ());
337     cv::Rect ROI;
338     Vision::Segment::RotateImg(B.Img, part.BW, B.Theta, B.
339                     Centroid, ROI);
340     Vision::Segment::RotateImg(RGB, part.RGB, B.Theta, B.
341                     Centroid, ROI);
342     Vision::Segment edgeSeg(part.BW);
343     edgeSeg.GetEdgesEroding();
344     part.Edge = edgeSeg.ProcessedImg.clone();
345     part.SIPixelFactor = snapshot->SIPixelFactor;
346     part.isPreparedForAnalysis = false;
347     part.SetRoundness();
348     partPopulation.push_back(part);
349   });
350 }
351
352 /*!
353  * \brief Analyzer::GetFFD
354  * \param particlePopulation
355  */
356 void Analyzer::GetFFD(Particle::ParticleVector_t &
357   particlePopulation) {
358   //for_each(particlePopulation.begin(), particlePopulation.
359   //           end(), [&](Particle &P) {
360   QtConcurrent::blockingMap<Particle::ParticleVector_t>(
361     particlePopulation, [&](Particle &P) {
362       if (!P.isPreparedForAnalysis) {
363         try {
364           SoilMath::FFT fft;
365           P.FFDescriptors = fft.GetDescriptors(P.Edge);
366           P.isPreparedForAnalysis = true;
367         } catch (SoilMath::Exception::MathException &e) {
368           if (*e.id() == EXCEPTION_NO_CONTOUR_FOUND_NR) {
369             P.isSmall = true;
370           }
371         }
372         emit on_progressUpdate(currentProgress++);
373       }
374     });
375   });
376 }
377
378 /*!
379  * \brief Analyzer::GetPrediction
380  * \param particlePopulation
381  */
382 void Analyzer::GetPrediction(Particle::ParticleVector_t &
383   particlePopulation) {
384   for_each(particlePopulation.begin(), particlePopulation.
385             end(),
386             [&](Particle &P) {

```

```

376     if (P.isPreparedForAnalysis) {
377         if (!P.isSmall) {
378             ComplexVect_t usedFFDescr(P.FFDescriptors.
379                                         begin(),
380                                         P.FFDescriptors.
381                                         begin() +
382                                         NeuralNet.
383                                         GetInputNeurons
384                                         ());
385             P.Classification = NeuralNet.Predict(
386                                         usedFFDescr);
387             P.isAnalysed = true;
388         }
389     }
390 }
391
392 float Analyzer::CalibrateSI(float SI, Mat &img) {
393     Vision::Conversion greyConv(img);
394     greyConv.Convert(Vision::Conversion::RGB, Vision::
395                     Conversion::Intensity);
396     Vision::Segment segment(greyConv.ProcessedImg);
397     segment.ConvertToBW(Vision::Segment::Dark);
398     segment.GetBlobList(true);
399     uint32_t maxCircle = 0;
400     for_each(segment.BlobList.begin(), segment.BlobList.end(),
401               [&](Vision::Segment::Blob_t &B) {
402                   if (B.ROI.height > maxCircle) {
403                       maxCircle = B.ROI.height;
404                   }
405                   if (B.ROI.width > maxCircle) {
406                       maxCircle = B.ROI.width;
407                   }
408               });
409   qDebug() << "Maximum circle in pixels: " << maxCircle;
410   CurrentSIfactor = SI / maxCircle;
411   qDebug() << "Current SI factor : " << CurrentSIfactor;
412   return CurrentSIfactor;
413 }
414 }
```

Sample Class

```
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3   * strictly prohibited
4   * and only allowed with the written consent of the author (
5   * Jelle Spijker)
6   * This software is proprietary and confidential
7   * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8   */
9
10 #pragma once
11
12 #include "stdint.h"
13 #include <vector>
14 #include <string>
15 #include "Stats.h"
16 #include "psd.h"
17 #include "particle.h"
18 #include <fstream>
19 #include <boost/archive/binary_iarchive.hpp>
20 #include <boost/archive/binary_oarchive.hpp>
21 #include <boost/serialization/string.hpp>
22 #include <boost/serialization/version.hpp>
23 #include <boost/serialization/vector.hpp>
24 #include <boost/iostreams/filter/zlib.hpp>
25 #include <boost/iostreams/filtering_streambuf.hpp>
26 #include "zlib.h"
27 #include "soilanalyzertypes.h"
28
29 namespace SoilAnalyzer {
30 class Sample {
31 public:
32     Sample();
33     uint32_t ID;           /*!< The sample ID*/
34     std::string Location; /*!< The Location where the sample
35     was taken*/
36     double Longitude = 4.629618299999947;
37     double Latitude = 51.8849149;
38     double Depth = 0;
39     std::string Date = "01-09-2015";
40     std::string Name; /*!< The sample name identifier*/
41     Particle::ParticleVector_t
42         ParticlePopulation; /*!< the individual particles of
43         the sample*/
44     SoilMath::PSD PSD; /*!< The Particle Size Distribution*/
45     ucharStat_t Roundness;
46     ucharStat_t Angularity;
47     floatStat_t RI; /*!< The statistical Redness Index data*/
48     void Save(const std::string &filename);
49     void Load(const std::string &filename);
50 }
```

```

51     Particle::PSDVector_t *GetPSDVector();
52     Particle::ClassVector_t *GetRoundnessVector();
53     Particle::ClassVector_t *GetAngularityVector();
54     Particle::doubleVector_t *GetCIELab_aVector();
55     Particle::doubleVector_t *GetCIELab_bVector();
56
57     bool isPreparedForAnalysis =
58         false; /*!< is the sample ready for analysis, are all
59             the particles
60                 extracted*/
61     bool isAnalysed = false; /*!< is the sample analyzed*/
62
63     bool ChangesSinceLastSave = false;
64     bool ParticleChangedStatePSD = false;
65     bool ParticleChangedStateClass = false;
66     bool ParticleChangedStateRoundness = false;
67     bool ParticleChangedStateAngularity = false;
68     bool ColorChange = false;
69
70     bool IsLoadedFromDisk = false;
71
72 private:
73     Particle::PSDVector_t Diameter; /*!< The PSD raw data*/
74     bool PSDGathered = false; /*!< is the raw data
75             gathered*/
76     Particle::ClassVector_t RoundnessVec;
77     bool RoundnessGathered = false;
78     Particle::ClassVector_t AngularityVec;
79     bool AngularityGathered = false;
80     Particle::doubleVector_t CIELab_aVec;
81     bool CIELab_aGathered = false;
82     Particle::doubleVector_t CIELab_bVec;
83     bool CIELab_bGathered = false;
84
85     friend class boost::serialization::access;
86     template <class Archive>
87     void serialize(Archive &ar, const unsigned int version) {
88         ar &ID;
89         ar &Location;
90         ar &Name;
91         ar &ParticlePopulation;
92         ar &Diameter;
93         ar &RoundnessVec;
94         ar &AngularityVec;
95         ar &PSD;
96         ar &Roundness;
97         ar &Angularity;
98         ar &RI;
99         ar &isPreparedForAnalysis;
100        ar &isAnalysed;
101        ar &ChangesSinceLastSave;
102        ar &ParticleChangedStatePSD;
103        ar &ParticleChangedStateClass;
104        ar &ParticleChangedStateAngularity;
105        ar &ParticleChangedStateRoundness;
106        ar &PSDGathered;

```

```

105     ar &RoundnessGathered;
106     ar &AngularityGathered;
107     ar &IsLoadedFromDisk;
108     if (version > 0) {
109         ar &Longitude;
110         ar &Latitude;
111         ar &Date;
112         ar &Depth;
113         ar &AngularityVec;
114         ar &AngularityGathered;
115         ar &CIELab_aVec;
116         ar &CIELab_aGathered;
117         ar &CIELab_bVec;
118         ar &CIELab_bGathered;
119         ar &ColorChange;
120     } else {
121         Latitude = 51.8849149;
122         Longitude = 4.629618299999947;
123         Date = "01-10-2015";
124         Depth = 0;
125         CIELab_aVec = Particle::doubleVector_t();
126         CIELab_aGathered = false;
127         CIELab_bVec = Particle::doubleVector_t();
128         CIELab_bGathered = false;
129         ColorChange = false;
130     }
131 }
132 };
133 }
134 BOOST_CLASS_VERSION(SoilAnalyzer::Sample, 1)

```

```

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6   * This software is proprietary and confidential
7   * Written by Jelle Spijker <spijker.jelle@gmail.com>, 2015
8   */
9
10
11  namespace SoilAnalyzer {
12  namespace io = boost::iostreams;
13
14  /**
15   * \brief Sample::Sample
16   */
17  Sample::Sample() {}
18
19  /**
20   * \brief Sample::Save
21   * \param filename
22   */
23  void Sample::Save(const std::string &filename) {

```

```

24     std::ofstream ofs(filename.c_str(), std::ios::out | std::
25         ios::binary);
26     {
27         io::filtering_streambuf<io::output> out;
28         out.push(io::zlib_compressor(io::zlib::best_compression)
29             );
30         out.push(ofs);
31         {
32             boost::archive::binary_oarchive oa(out);
33             oa << boost::serialization::make_nvp("Sample", *this);
34         }
35         ofs.close();
36     }
37
38 /*!
39 * \brief Sample::Load
40 * \param filename
41 */
42 void Sample::Load(const std::string &filename) {
43     std::ifstream ifs(filename.c_str(), std::ios::in | std::
44         ios::binary);
45     {
46         io::filtering_streambuf<io::input> in;
47         in.push(io::zlib_decompressor());
48         in.push(ifs);
49         {
50             boost::archive::binary_iarchive ia(in);
51             ia >> boost::serialization::make_nvp("Sample", *this);
52         }
53     }
54     ifs.close();
55 }
56
57 /*!
58 * \brief Sample::GetPSDVector
59 * \return
60 */
61 Particle::PSDVector_t *Sample::GetPSDVector() {
62     if (!PSDGathered || ParticleChangedStatePSD) {
63         Diameter.clear();
64         for_each(ParticlePopulation.begin(), ParticlePopulation.
65             end(),
66             [&](Particle &P) { Diameter.push_back(P.
67                 GetSiDiameter()); });
68     }
69     PSDGathered = true;
70     ParticleChangedStatePSD = false;
71 }
72 Particle::ClassVector_t *Sample::GetAngularityVector() {
73     if (!AngularityGathered || ParticleChangedStateAngularity)
74     {

```

```

74     AngularityVec.clear();
75     for_each(ParticlePopulation.begin(), ParticlePopulation.
76             end(),
77             [&](Particle &P) { AngularityVec.push_back(P.
78                 GetAngularity()); });
79     AngularityGathered = true;
80     ParticleChangedStateAngularity = false;
81 }
82
83 Particle::ClassVector_t *Sample::GetRoundnessVector() {
84     if (!RoundnessGathered || ParticleChangedStateRoundness) {
85         RoundnessVec.clear();
86         for_each(ParticlePopulation.begin(), ParticlePopulation.
87             end(),
88             [&](Particle &P) { RoundnessVec.push_back(P.
89                 GetRoundness()); });
90     RoundnessGathered = true;
91     ParticleChangedStateRoundness = false;
92 }
93
94 Particle::doubleVector_t *Sample::GetCIELab_aVector() {
95     if (!CIELab_aGathered || ColorChange) {
96         CIELab_aVec.clear();
97         for_each(ParticlePopulation.begin(), ParticlePopulation.
98             end(),
99             [&](Particle &P) { CIELab_aVec.push_back(P.
100                 getMeanLab().a); });
101     CIELab_aGathered = true;
102 }
103
104 Particle::doubleVector_t *Sample::GetCIELab_bVector() {
105     if (!CIELab_bGathered || ColorChange) {
106         CIELab_bVec.clear();
107         for_each(ParticlePopulation.begin(), ParticlePopulation.
108             end(),
109             [&](Particle &P) { CIELab_bVec.push_back(P.
110                 getMeanLab().b); });
111     CIELab_bGathered = true;
112 }
113 }

```

Particle Class

```

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6   * This software is proprietary and confidential
7   * Written by Jelle Spijker <spijkert.jelle@gmail.com>, 2015
8   */
9  #pragma once
10
11 #include <opencv2/core.hpp>
12 #include <stdint.h>
13 #include <vector>
14 #include "SoilMath.h"
15 #include <fstream>
16 #include <boost/archive/binary_iarchive.hpp>
17 #include <boost/archive/binary_oarchive.hpp>
18 #include <boost/serialization/string.hpp>
19 #include <boost/serialization/version.hpp>
20 #include <boost/serialization/vector.hpp>
21 #include <boost/iostreams/filter/zlib.hpp>
22 #include <boost/iostreams/filtering_streambuf.hpp>
23 #include "zlib.h"
24 #include "soilanalyzerexception.h"
25 #include "lab_t_archive.h"
26 #include "soilanalyzertypes.h"
27 #include "Vision.h"
28
29 namespace SoilAnalyzer {
30 class Particle {
31 public:
32     typedef std::vector<Particle>
33     ParticleVector_t; /*!< a vector consisting of
34     individual particles*/
35     typedef std::vector<double> PSDVector_t; /*!< a vector
36     used in the PSD*/
37     typedef std::vector<uint8_t>
38     ClassVector_t; /*!< a vector used in the
39     classification histogram*/
40     typedef std::vector<float> floatVector_t;
41     typedef std::vector<double> doubleVector_t;
42
43     Particle();
44
45     uint32_t ID; /*!< The particle ID*/
46
47     cv::Mat BW; /*!< The binary image of the particle*/
48     cv::Mat Edge; /*!< The binary edge image of the particle*/
49     cv::Mat RGB; /*!< The RGB image of the particle*/
50
51     Point_t Centroid = {0, 0};
52     std::vector<Complex_t> FFDescriptors; /*!< The Fast
53     Fourier Descriptors

```

```
48                                     describing the
49                                     contour in the
50                                     Frequency domain
51                                     */
50     Predict_t Classification;           /*!< The
51     classification prediction*/
51     double SIPixelFactor = 0.0111915; /*!< The conversion
52     factor from pixel to SI*/
52     uint32_t PixelArea = 0;           /*!< The total area of
53     the binary image*/
53     double Eccentricity = 1;
54
55     float GetSIVolume();
56     float GetSiDiameter();
57     uint8_t GetRoundness();
58     uint8_t GetAngularity();
59     float GetMeanRI();
60     Lab_t getMeanLab();
61
62     void SetRoundness();
63
64     void Save(const std::string &filename);
65     void Load(const std::string &filename);
66
67     bool isPreparedForAnalysis = false; /*!< is the particle
68     ready for analysis*/
68     bool isAnalysed = false;           /*!< is the particle
69     analyzed*/
69     bool isSmall = false;
70
71 private:
72     float SIVolume = 0.; /*!< The correspondening SI volume*/
73     float SIDiameter = 0.;
74
75     float meanRI = 0;
76     Lab_t meanLab{0,0,0};
77     cv::Mat LAB;
78
79     void getLabImg();
80
81     friend class boost::serialization::access;
82     template <class Archive>
83     void serialize(Archive &ar, const unsigned int version) {
84
85         ar &ID;
86         ar &BW;
87         ar &Edge;
88         ar &RGB;
89         ar &FFDescriptors;
90         ar &Classification;
91         ar &SIPixelFactor;
92         ar &PixelArea;
93         ar &SIVolume;
94         ar &isPreparedForAnalysis;
95         ar &isAnalysed;
96         if (version > 0) {
```

```

97     ar &isSmall;
98     ar &SIDiameter;
99     ar &Centroid.x;
100    ar &Centroid.y;
101    ar &Eccentricity;
102 } else {
103     isSmall = false;
104     SIDiameter = GetSiDiameter();
105     Centroid.x = 0;
106     Centroid.y = 0;
107     Eccentricity = 1;
108 }
109 if (version > 1) {
110     ar &meanLab;
111     ar &meanRI;
112 }
113 else {
114     meanLab.L = 0;
115     meanLab.a = 0;
116     meanLab.b = 0;
117 }
118 }
119 };
120 }
121 BOOST_CLASS_VERSION(SoilAnalyzer::Particle, 2)

```

```

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7  * Written by Jelle Spijker <spijkerv.jelle@gmail.com>, 2015
8  */
9
8 #include "particle.h"
9
10 namespace SoilAnalyzer {
11 namespace io = boost::iostreams;
12
13 Particle::Particle() {}
14
15 /*!
16  * \brief Particle::Save
17  * \param filename
18  */
19 void Particle::Save(const std::string &filename) {
20     std::ofstream ofs(filename.c_str(), std::ios::out | std::ios::binary);
21     {
22         io::filtering_streambuf<io::output> out;
23
24         out.push(io::zlib_compressor(io::zlib::best_compression)
25                 );
26         out.push(ofs);
27     }

```

```
27         boost::archive::binary_oarchive oa(out);
28         oa << boost::serialization::make_nvp("Particle", *this
29             );
30     }
31     ofs.close();
32 }
33
34 /*
35  * \brief Particle::Load
36  * \param filename
37  */
38 void Particle::Load(const std::string &filename) {
39     std::ifstream ifs(filename.c_str(), std::ios::in | std::
40         ios::binary);
41     {
42         io::filtering_streambuf<io::input> in;
43         in.push(io::zlib_decompressor());
44         in.push(ifs);
45         {
46             boost::archive::binary_iarchive ia(in);
47             ia >> boost::serialization::make_nvp("Particle", *this
48                 );
49         }
50         ifs.close();
51     }
52
53 /*
54  * \brief Particle::GetSIVolume
55  * \return
56  */
57 float Particle::GetSIVolume() {
58     if (SIVolume == 0.) {
59         if (PixelArea == 0) {
60             throw Exception::SoilAnalyzerException(
61                 EXCEPTION_PARTICLE_NOT_ANALYZED,
62                 EXCEPTION_PARTICLE_NOT_ANALYZED_NR);
63         }
64         SIVolume = SoilMath::calcVolume(PixelArea) *
65             SIPixelFactor * (Eccentricity/2 + 0.5);
66     }
67     return SIVolume;
68 }
69
70 float Particle::GetSiDiameter() {
71     if (SIDiameter == 0.) {
72         if (PixelArea == 0) {
73             throw Exception::SoilAnalyzerException(
74                 EXCEPTION_PARTICLE_NOT_ANALYZED,
75                 EXCEPTION_PARTICLE_NOT_ANALYZED_NR);
76         }
77         SIDiameter = SoilMath::calcDiameter(PixelArea) *
78             SIPixelFactor * (Eccentricity/2 + 0.5);
79     }
80 }
```

```

76     return SIDiameter;
77 }
78
79 uint8_t Particle::GetAngularity() {
80     uint8_t angularity = ((Classification.Category - 1) % 6) +
81     1;
82     return angularity;
83 }
84
85 uint8_t Particle::GetRoundness() {
86     uint8_t roundness = ((Classification.Category - 1) / 6) +
87     1;
88     return roundness;
89 }
90
91 void Particle::SetRoundness() {
92     uint8_t ang = GetAngularity() - 1;
93     Classification.Category +=
94         ang + (static_cast<uint8_t>(floor(Eccentricity / 0.33)) *
95         6);
96     Classification.ManualSet = true;
97 }
98
99 Lab_t Particle::getMeanLab() {
100    if (BW.empty() || RGB.empty()) {
101        throw SoilAnalyzer::Exception::SoilAnalyzerException(
102            EXCEPTION_NO_IMAGES_PRESENT,
103            EXCEPTION_NO_IMAGES_PRESENT_NR);
104    }
105    if (meanLab.L == 0 && meanLab.a == 0 && meanLab.b == 0) {
106        // convert to Lab
107        if (LAB.empty()) {
108            getLabImg();
109        }
110        std::vector<cv::Mat> LABvect = Vision::Conversion::
111            extractChannel(LAB);
112        std::vector<float> labvect;
113        for_each(LABvect.begin(), LABvect.end(), [&](cv::Mat &I)
114        {
115            floatStat_t labStat((float *)I.data, I.rows, I.cols, (
116                uchar *)BW.data, 1,
117                0, true);
118            labvect.push_back(labStat.Mean);
119        });
120        meanLab.L = labvect[0];
121        meanLab.a = labvect[1];
122        meanLab.b = labvect[2];
123    }
124    return meanLab;
125 }
126
127 float Particle::GetMeanRI() {
128    if (BW.empty() || RGB.empty()) {
129        throw SoilAnalyzer::Exception::SoilAnalyzerException(
130            EXCEPTION_NO_IMAGES_PRESENT,
131            EXCEPTION_NO_IMAGES_PRESENT_NR);

```

```
124     }
125     if (meanRI == 0) {
126         if (LAB.empty()) {
127             getLabImg();
128         }
129         Vision::Conversion convertor(LAB);
130         convertor.Convert(Vision::Conversion::CIE_lab, Vision::
131             Conversion::RI);
131         floatStat_t RIstat((float *)convertor.ProcessedImg.data,
132             LAB.rows, LAB.cols,
133             (uchar *)BW.data, 1, 0, true);
133         meanRI = RIstat.Mean;
134     }
135     return meanRI;
136 }
137
138 void Particle::getLabImg() {
139     Vision::Conversion convertor(RGB);
140     convertor.Convert(Vision::Conversion::RGB, Vision::
141         Conversion::CIE_lab);
141     LAB = convertor.ProcessedImg.clone();
142 }
143 }
```

```

46                                     contrast
47                                     stretch*/
48     bool useBlur = false; /*< Should the mediaan blur be used
49     during analysis*/
50     uint32_t blurKernelSize = 5; /*< the median blurkernel*/
51
52     Vision::Segment::TypeOfObjects typeOfObjectsSegmented =
53         Vision::Segment::Dark; /*< Which type of object
54         should be segmented*/
55     bool ignorePartialBorderParticles =
56         true; /*< Indication of partial border particles
57         should be used*/
58     bool fillHoles = true; /*< should the holes be filled*/
59     float sigmaFactor = 2; /*< The sigma factor or the
60         bandwidth indicating which
61             pixel intensity values count
62                 belong to an object*/
63
64     int thresholdOffsetValue = 0; /*< an tweaking offset
65         value*/
66
67     Vision::MorphologicalFilter::FilterType morphFilterType =
68         Vision::MorphologicalFilter::OPEN; /*< Indicating
69             which type of
70                 morphological
71                     filter should
72                         be
73                             used*/
74
75     uint32_t filterMaskSize = 5; /*< the filter
76         mask*/
77
78     uint32_t HDRframes =
79         5; /*< The number of frames which should be used for
80             the HDR image*/
81     float lightLevel = 0.5; /*< The light level of the
82         environmental case*/
83     bool encInv = false; /*< invert the values gained form
84         the encoder*/
85     bool enableRainbow =
86         true; /*< run a rainbow loop on the RGB encoder
87             during analysis*/
88     bool useBacklightProjection = true; /*< use
89         Projection*/
90     bool useHDR = false; /*< use HDR
91         */
92     std::string defaultWebcam = "USB Microscope"; /*< The
93         defaultWebcam string*/
94     int Brightness_front = 0; /*< cam brightness setting
95         front light*/
96     int Brightness_proj = -10; /*< cam brightness setting
97         projected light*/
98     int Contrast_front = 36; /*< cam contrast setting front
99         light*/
100    int Contrast_proj = 36; /*< cam contrast setting
101        projected light*/

```

```

79     int Saturation_front = 64; /*!< cam saturation setting
80     front light*/
81     int Saturation_proj = 0;    /*!< cam saturation setting
82     projected light*/
83     int Hue_front = 0;          /*!< cam hue setting front
84     light*/
85     int Hue_proj = -40;         /*!< cam hue setting projected
86     light*/
87     int Gamma_front = 100;      /*!< cam gamma setting front
88     light*/
89     int Gamma_proj = 200;        /*!< cam gamma setting
90     projected light*/
91     int PowerLineFrequency_front =
92     1; /*!< cam powerline freq setting front light*/
93     int PowerLineFrequency_proj =
94     1; /*!< cam powerline freq setting
95     projected light*/
96     int Sharpness_front = 12;    /*!< cam sharpness setting front
97     light*/
98     int Sharpness_proj = 25;      /*!< cam sharpness setting
99     projected light*/
100    int BackLightCompensation_front =
101    1; /*!< cam backlight compensation setting front light
102    */
103    int BackLightCompensation_proj =
104    1; /*!< cam backlight compensation setting projected
105    light*/
106    std::string NNlocation = "NeuralNet/Default.NN";
107    bool useCUDA = false; /*!< CUDA enabled*/
108    int selectedResolution = 0;
109    std::string SampleFolder = "~/Samples";
110    std::string SettingsFolder = "Settings";
111    std::string NNFolder = "NeuralNet";
112    std::string StandardSentTo = "j.spijker@ihcmerwede.com";
113    std::string StandardPrinter = "PDF printer";
114    uint32_t StandardNumberOfShots = 10;
115    bool PredictTheShape = true;
116    bool Revolution = true;
117    private:
118    friend class boost::serialization::access;
119    template <class Archive>
120    void serialize(Archive &ar, const unsigned int version) {
121        if (version >= 0) {
122            ar &BOOST_SERIALIZATION_NVP(useAdaptiveContrast);
123            ar &BOOST_SERIALIZATION_NVP(adaptContrastKernelFactor)
124            ;
125            ar &BOOST_SERIALIZATION_NVP(adaptContrastKernelSize);
126            ar &BOOST_SERIALIZATION_NVP(useBlur);
127            ar &BOOST_SERIALIZATION_NVP(blurKernelSize);
128            ar &BOOST_SERIALIZATION_NVP(typeOfObjectsSegmented);
129            ar &BOOST_SERIALIZATION_NVP(
130                ignorePartialBorderParticles);
131            ar &BOOST_SERIALIZATION_NVP(fillHoles);
132            ar &BOOST_SERIALIZATION_NVP(sigmaFactor);
133            ar &BOOST_SERIALIZATION_NVP(morphFilterType);
134            ar &BOOST_SERIALIZATION_NVP(filterMaskSize);

```

```

122     ar &BOOST_SERIALIZATION_NVP(thresholdOffsetValue);
123     ar &BOOST_SERIALIZATION_NVP(HDRframes);
124     ar &BOOST_SERIALIZATION_NVP(lightLevel);
125     ar &BOOST_SERIALIZATION_NVP(encInv);
126     ar &BOOST_SERIALIZATION_NVP(enableRainbow);
127     ar &BOOST_SERIALIZATION_NVP(useBacklightProjection);
128     ar &BOOST_SERIALIZATION_NVP(useHDR);
129     ar &BOOST_SERIALIZATION_NVP(defaultWebcam);
130     ar &BOOST_SERIALIZATION_NVP(Brightness_front);
131     ar &BOOST_SERIALIZATION_NVP(Brightness_proj);
132     ar &BOOST_SERIALIZATION_NVP(Contrast_front);
133     ar &BOOST_SERIALIZATION_NVP(Contrast_proj);
134     ar &BOOST_SERIALIZATION_NVP(Saturation_front);
135     ar &BOOST_SERIALIZATION_NVP(Saturation_proj);
136     ar &BOOST_SERIALIZATION_NVP(Hue_front);
137     ar &BOOST_SERIALIZATION_NVP(Hue_proj);
138     ar &BOOST_SERIALIZATION_NVP(Gamma_front);
139     ar &BOOST_SERIALIZATION_NVP(Gamma_proj);
140     ar &BOOST_SERIALIZATION_NVP(PowerLineFrequency_front);
141     ar &BOOST_SERIALIZATION_NVP(PowerLineFrequency_proj);
142     ar &BOOST_SERIALIZATION_NVP(Sharpness_front);
143     ar &BOOST_SERIALIZATION_NVP(Sharpness_proj);
144     ar &BOOST_SERIALIZATION_NVP(
145         BackLightCompensation_front);
146     ar &BOOST_SERIALIZATION_NVP(BackLightCompensation_proj
147         );
148     ar &BOOST_SERIALIZATION_NVP(NNlocation);
149     ar &BOOST_SERIALIZATION_NVP(useCUDA);
150     ar &BOOST_SERIALIZATION_NVP(selectedResolution);
151     ar &BOOST_SERIALIZATION_NVP(SampleFolder);
152     ar &BOOST_SERIALIZATION_NVP(SettingsFolder);
153     ar &BOOST_SERIALIZATION_NVP(NNFolder);
154     ar &BOOST_SERIALIZATION_NVP(StandardSentTo);
155     ar &BOOST_SERIALIZATION_NVP(StandardPrinter);
156     ar &BOOST_SERIALIZATION_NVP(StandardNumberOfShots);
157 }
158 }
159 };
160 }
161 BOOST_CLASS_VERSION(SoilAnalyzer::SoilSettings, 0)

```

```

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8   */
9
10 #include "soilsettings.h"
11
12 namespace SoilAnalyzer {
13     SoilSettings::SoilSettings() {}
14 }

```

```
12
13 void SoilSettings::LoadSettings(string filename) {
14     std::ifstream ifs(filename.c_str());
15     boost::archive::xml_iarchive ia(ifs);
16     ia >> boost::serialization::make_nvp("SoilSettings", *this
17         );
18 }
19 void SoilSettings::SaveSettings(string filename) {
20     std::ofstream ofs(filename.c_str());
21     boost::archive::xml_oarchive oa(ofs);
22     oa << boost::serialization::make_nvp("SoilSettings", *this
23         );
24 }
```

General project files

```
1 #-----
2 #
3 # Project created by QtCreator 2015-08-08T18:57:27
4 #
5 #-----
6
7 QT      += core gui concurrent
8 QMAKE_CXXFLAGS += -std=c++11
9
10 greaterThan(QT_MAJOR_VERSION, 4): QT += widgets
11 @@
12 CONFIG(release, debug|release):DEFINES += QT_NO_DEBUG_OUTPUT
13 @@
14
15 TARGET = SoilAnalyzer
16 TEMPLATE = lib
17 VERSION = 0.9.96
18
19 DEFINES += SOILANALYZER_LIBRARY
20
21 SOURCES += \
22     soilsettings.cpp \
23     sample.cpp \
24     particle.cpp \
25     analyzer.cpp
26
27 HEADERS += \
28     soilsettings.h \
29     sample.h \
30     particle.h \
31     analyzer.h \
32     soilanalyzerexception.h \
33     soilanalyzer.h \
34     lab_t_archive.h \
35     soilanalyzertypes.h
36
37 #opencv
38 LIBS += -L/usr/local/lib -lopencv_core -lopencv_highgui
39 INCLUDEPATH += /usr/local/include/opencv
40 INCLUDEPATH += /usr/local/include
41
42 #boost
43 DEFINES += BOOST_ALL_DYN_LINK
44 INCLUDEPATH += /usr/include/boost
45 LIBS += -L/usr/lib/x86_64-linux-gnu/ -lboost_serialization -lboost_iostreams
46
47 #Zlib
48 LIBS += -L/usr/local/lib -lz
49 INCLUDEPATH += /usr/local/include
50
51 unix:!macx: LIBS += -L$$PWD/../../build/install/ -lSoilMath
52 INCLUDEPATH += $$PWD/../SoilMath
53 DEPENDPATH += $$PWD/../SoilMath
```

```

54
55 unix:!macx: LIBS += -L$$PWD/../../build/install/ -
56   lSoilVision
56 INCLUDEPATH += $$PWD/./SoilVision
57 DEPENDPATH += $$PWD/./SoilVision
58
59 #MainLib
60
61 target.path = $$PWD/../../build/install
62 INSTALLS += target

```

```

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8 */
9
10 #pragma once
11
12 #include <boost/archive/binary_iarchive.hpp>
13 #include <boost/archive/binary_oarchive.hpp>
14 #include <boost/serialization/access.hpp>
15 #include "soilanalyzertypes.h"
16
17 namespace boost {
18 namespace serialization {
19 /*!
20  * \brief serialize Serialize the openCV mat to disk
21  */
22 template <class Archive>
23 inline void serialize(Archive &ar, SoilAnalyzer::Lab_t &P,
24   const unsigned int version __attribute__((unused))) {
25   ar &P.L;
26   ar &P.a;
27   ar &P.b;
28 }
29 }
30

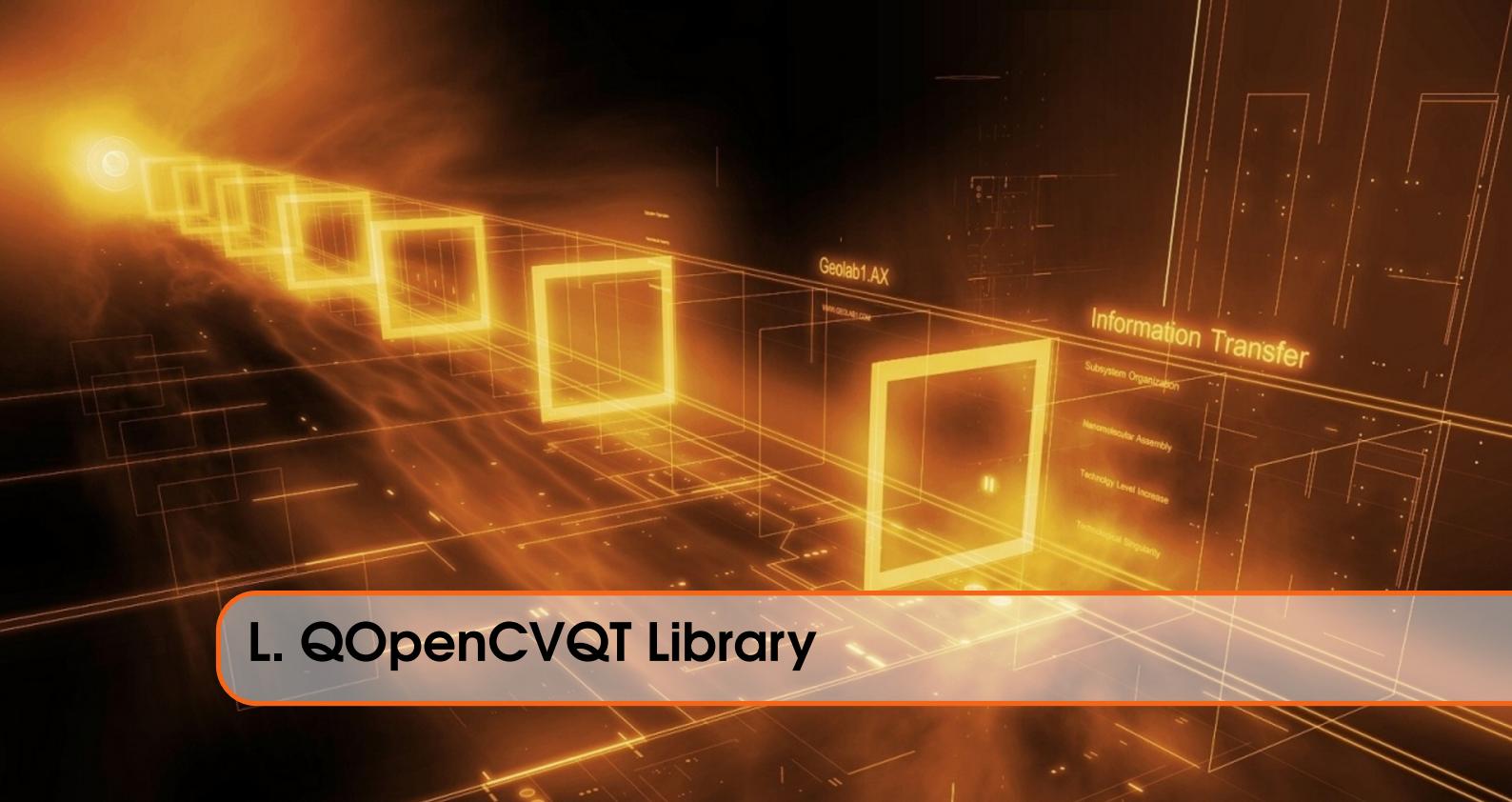
```

```

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8 */
9
10 #define EXCEPTION_PARTICLE_NOT_ANALYZED "Particle not
11   analyzed Exception!"
12 #define EXCEPTION_PARTICLE_NOT_ANALYZED_N 0
13 #define EXCEPTION_NO_SNAPSHOTS "No snapshots Exception!"
14 #define EXCEPTION_NO_SNAPSHOTS_N 1

```

```
11 #define EXCEPTION_NO_IMAGES_PRESENT "No images to analyse
12 #define EXCEPTION_NO_IMAGES_PRESENT_NR 2
13
14 #pragma once
15 #include <exception>
16 #include <string>
17
18 namespace SoilAnalyzer {
19     namespace Exception {
20         class SoilAnalyzerException : public std::exception {
21     public:
22         SoilAnalyzerException(std::string m =
23             EXCEPTION_PARTICLE_NOT_ANALYZED,
24             int n =
25                 EXCEPTION_PARTICLE_NOT_ANALYZED_NR
26             ) : msg(m), nr(n) { }
27         ~SoilAnalyzerException() _GLIBCXX_USE_NOEXCEPT {}
28         const char *what() const _GLIBCXX_USE_NOEXCEPT {
29             return msg.c_str(); }
30         const int *id() const _GLIBCXX_USE_NOEXCEPT { return &
31             nr; }
32     private:
33         std::string msg;
34         int nr;
35     };
36 }
37
38 #ifndef SOILANALYZERTYPES
39 #define SOILANALYZERTYPES
40
41 namespace SoilAnalyzer {
42     struct Point_t {
43         double x;
44         double y;
45     };
46
47     struct Lab_t {
48         float L;
49         float a;
50         float b;
51     };
52 }
53 #endif // SOILANALYZERTYPES
```



L. QOpenCVQT Library

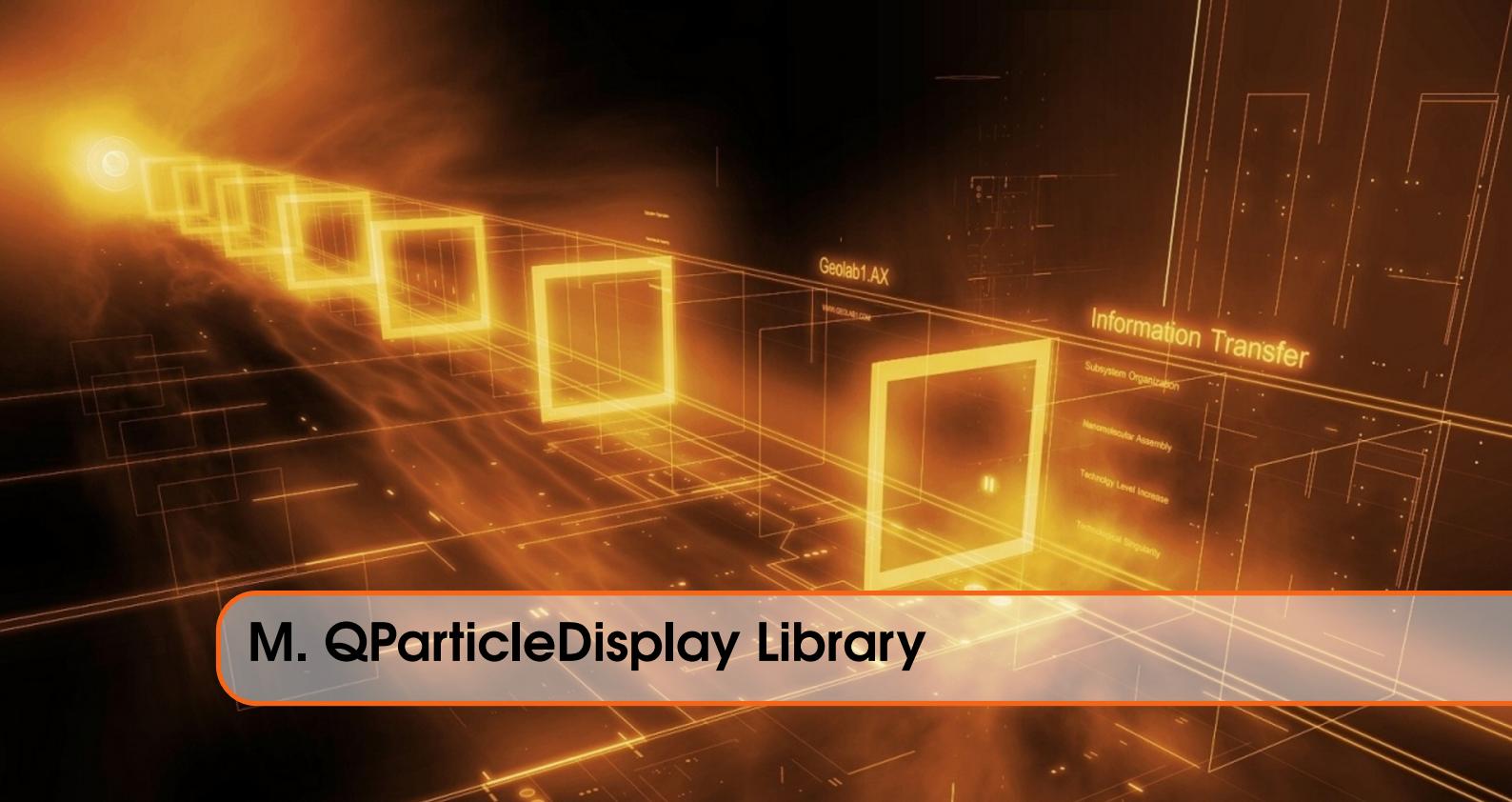
```
1 #-----
2 #
3 # Project created by QtCreator 2015-08-08T08:11:34
4 #
5 #-----
6
7 TARGET = QOpenCVQT
8 TEMPLATE = lib
9
10 QT += gui
11
12 DEFINES += QOPENCVQT_LIBRARY
13 VERSION = 1.1.0
14 CONFIG += shared
15
16 SOURCES += qopencvqt.cpp
17
18 HEADERS += qopencvqt.h
19
20 #opencv
21 LIBS += -L/usr/local/lib -lopencv_core
22 INCLUDEPATH += /usr/local/include/opencv
23 INCLUDEPATH += /usr/local/include
24
25 #MainLib
26 unix {
27     target.path = $PWD/../../../../build/install
28     INSTALLS += target
29 }
```

```
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8  */
9
10
11 #ifndef QOPENCVQT_H
12 #define QOPENCVQT_H
13
14
15
16 class QOpenCVQT
17 {
18 public:
19     QOpenCVQT();
20     static cv::Mat WhiteBackground(const cv::Mat &src) {
21         cv::Mat dst;
22         cv::floodFill(src, dst, cv::Point(1,1), cv::Scalar_<
23             uchar>(255,255,255));
24         return dst;
25     }
26
27     static QImage Mat2QImage(const cv::Mat &src) {
28         QImage dest;
29         if (src.channels() == 1) {
30             cv::Mat destRGB;
31             std::vector<cv::Mat> grayRGB(3, src);
32             cv::merge(grayRGB, destRGB);
33             dest = QImage((uchar *)destRGB.data, destRGB.cols,
34                           destRGB.rows,
35                           destRGB.step, QImage::Format_RGB888);
36         } else {
37             dest = QImage((uchar *)src.data, src.cols, src.rows,
38                           src.step,
39                           QImage::Format_RGB888);
40             dest = dest.rgbSwapped();
41         }
42     }
43 #endif // QOPENCVQT_H
```

```
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8  */
```

```
7
8 #include "qopencvqt.h"
9
10
11 QOpenCVQT::QOpenCVQT()
12 {
13 }
```



M. QParticleDisplay Library

```
1 #-----  
2 #  
3 # Project created by QtCreator 2015-08-07T22:02:49  
4 #  
5 #-----  
6  
7 QT      += core gui concurrent  
8 QMAKE_CXXFLAGS += -std=c++11  
9  
10 greaterThan(QT_MAJOR_VERSION, 4): QT += widgets  
11  
12 TARGET = QParticleDisplay  
13 TEMPLATE = lib  
14 CONFIG += shared  
15 VERSION = 1.3.25  
16  
17 SOURCES += qparticledisplay.cpp  
18  
19 HEADERS  += qparticledisplay.h  
20  
21 FORMS    += qparticledisplay.ui  
22  
23 unix:!macx: LIBS += -L$$PWD/../../build/install/ -  
    lpictureflow-qt  
24  
25 INCLUDEPATH += $$PWD/../pictureflow-qt  
26 DEPENDPATH += $$PWD/../pictureflow-qt  
27  
28 #MainLib  
29 unix {  
30     target.path = $$PWD/../../../../build/install  
31     INSTALLS += target
```

```

32 }
33
34 unix:!macx: LIBS += -L$$PWD/../../build/install/ -lSoilAnalyzer
35
36 INCLUDEPATH += $$PWD/./SoilAnalyzer
37 DEPENDPATH += $$PWD/./SoilAnalyzer
38
39 unix:!macx: LIBS += -L$$PWD/../../build/install/ -lSoilMath
40
41 INCLUDEPATH += $$PWD/./SoilMath
42 DEPENDPATH += $$PWD/./SoilMath
43
44 unix:!macx: LIBS += -L$$PWD/../../build/install/ -lQOpenCVQT
45
46 INCLUDEPATH += $$PWD/./QOpenCVQT
47 DEPENDPATH += $$PWD/./QOpenCVQT
48
49 unix:!macx: LIBS += -L$$PWD/../../build/install/ -lSoilVision
50 INCLUDEPATH += $$PWD/./SoilVision
51 DEPENDPATH += $$PWD/./SoilVision

```

```

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8 */
9
10 #pragma once
11 #include <QWidget>
12 #include <QImage>
13 #include <qopencvqt.h>
14 #include <QColor>
15 #include <QWheelEvent>
16
17 namespace Ui {
18     class QParticleDisplay;
19 }
20
21 class QParticleDisplay : public QWidget
22 {
23     Q_OBJECT
24
25 public:
26     explicit QParticleDisplay(QWidget *parent = 0);
27     ~QParticleDisplay();
28     void SetSample(SoilAnalyzer::Sample *sample);
29     SoilAnalyzer::Particle *SelectedParticle;
30     void wheelEvent( QWheelEvent * event );
31     void next();

```

```

32
33 signals:
34     void particleChanged(int newValue);
35     void shapeClassificationChanged(int newValue);
36     void particleDeleted();
37
38 public slots:
39     void setSelectedParticle(int newValue);
40
41 private slots:
42     void on_selectedParticleChangedWidget(int value);
43     void on_selectedParticleChangedSlider(int value);
44     void on_pushButton_delete_clicked();
45
46 private:
47     Ui::QParticleDisplay *ui;
48     SoilAnalyzer::Sample *Sample;
49     QVector<QImage> images;
50     QImage ConvertParticleToQImage(SoilAnalyzer::Particle *
51                                     particle);
51     bool dontDoIt = false;
52 };


---


1  /* Copyright (C) Jelle Spijker - All Rights Reserved
2  * Unauthorized copying of this file, via any medium is
3  * strictly prohibited
4  * and only allowed with the written consent of the author (
5  * Jelle Spijker)
6  * This software is proprietary and confidential
7  * Written by Jelle Spijker <spijkert.jelle@gmail.com>, 2015
8  */
9
10
11 #include "qparticledisplay.h"
12 #include "ui_qparticledisplay.h"
13
14 QParticleDisplay::QParticleDisplay(QWidget *parent)
15     : QWidget(parent), ui(new Ui::QParticleDisplay) {
16     ui->setupUi(this);
17     ui->widget->setBackgroundColor(QColor("white"));
18     ui->widget->setSlideSize(QSize(230, 230));
19     connect(ui->widget, SIGNAL(centerIndexChanged(int)), this,
20             SLOT(on_selectedParticleChangedWidget(int)));
21     connect(ui->horizontalSlider, SIGNAL(valueChanged(int)),
22             this,
23             SLOT(on_selectedParticleChangedSlider(int)));
24 }
25
26 QParticleDisplay::~QParticleDisplay() {
27     for (uint32_t i = 0; i < ui->widget->slideCount(); i++) {
28         ui->widget->removeSlide(0);
29     }
30     delete ui->widget;
31     delete ui;
32 }
33
34 void QParticleDisplay::setSelectedParticle(int newValue) {

```

```

31     ui->widget->setCenterIndex(newValue);
32     ui->horizontalSlider->setValue(newValue);
33 }
34
35 void QParticleDisplay::SetSample(SoilAnalyzer::Sample *
36     sample) {
37     this->Sample = sample;
38     images.clear();
39     ui->widget->clear();
40     ui->horizontalSlider->setMaximum(this->Sample->
41         ParticlePopulation.size() - 1);
42     for (uint32_t i = 0; i < this->Sample->ParticlePopulation.
43         size(); i++) {
44         images.push_back(
45             ConvertParticleToQImage(&Sample->ParticlePopulation.
46                 at(i)));
47     }
48     ui->widget->addSlide(images[images.size() - 1]);
49 }
50 SelectedParticle = &Sample->ParticlePopulation[ui->widget
51     ->centerIndex()];
52 on_selectedParticleChangedSlider(0);
53 }
54
55 QImage
56 QParticleDisplay::ConvertParticleToQImage(SoilAnalyzer::
57     Particle *particle) {
58     QImage dst(particle->BW.cols + 10, particle->BW.rows + 10,
59     QImage::Format_RGB32);
60     uint32_t nData = particle->BW.cols * particle->BW.rows;
61     uint32_t sData = ((dst.width() - 1) * 5) + 5;
62     uchar *QDst = dst.bits();
63     uchar *CVBW = particle->BW.data;
64     uchar *CVRGB = particle->RGB.data;
65     for (uint32_t i = 0; i < sData; i++) {
66         *(QDst++) = 255;
67         *(QDst++) = 255;
68         *(QDst++) = 255;
69         *(QDst++) = 0;
70     }
71     for (uint32_t i = 0; i < nData; i++) {
72         if ((i % particle->BW.cols) == 0) {
73             for (uint32_t j = 0; j < 10; j++) {
74                 *(QDst++) = 255;
75                 *(QDst++) = 255;
76                 *(QDst++) = 255;
77                 *(QDst++) = 0;
78             }
79         }
80         if (CVBW[i]) {
81             *(QDst++) = *(CVRGB);
82             *(QDst++) = *(CVRGB + 1);
83             *(QDst++) = *(CVRGB + 2);
84             *(QDst++) = 0;
85             CVRGB += 3;
86         } else {
87             *(QDst++) = 255;
88         }
89     }
90 }

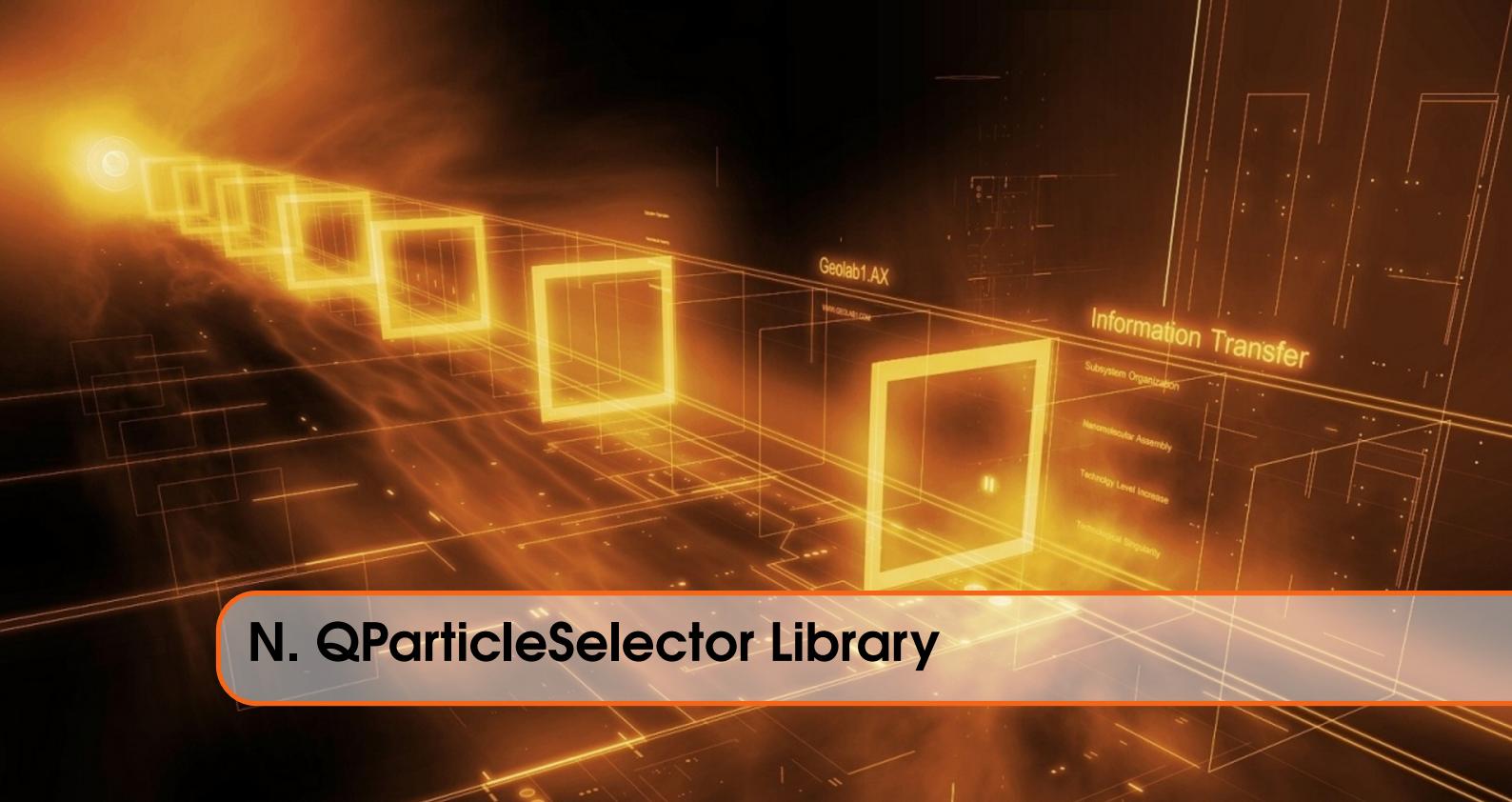
```

```

81         *(QDst++) = 255;
82         *(QDst++) = 255;
83         *(QDst++) = 0;
84         CVRGB += 3;
85     }
86 }
87 for (uint32_t i = 0; i < sData; i++) {
88     *(QDst++) = 255;
89     *(QDst++) = 255;
90     *(QDst++) = 255;
91     *(QDst++) = 0;
92 }
93 return dst;
94 }
95
96 void QParticleDisplay::on_pushButton_delete_clicked() {
97     Sample->ParticlePopulation.erase(Sample->
98         ParticlePopulation.begin() +
99             ui->widget->centerIndex());
100    ui->widget->removeSlide(ui->widget->centerIndex());
101    ui->horizontalSlider->setMaximum(this->Sample->
102        ParticlePopulation.size() - 1);
103    Sample->ParticleChangedStatePSD = true;
104    Sample->ParticleChangedStateAngularity = true;
105    Sample->ParticleChangedStateRoundness = true;
106    Sample->ChangesSinceLastSave = true;
107    Sample->ColorChange = true;
108    SelectedParticle = &Sample->ParticlePopulation[ui->widget
109        ->centerIndex()];
110    emit particleDeleted();
111 }
112
113 void QParticleDisplay::on_selectedParticleChangedWidget(int
114     value) {
115     if (!dontDoIt) {
116         dontDoIt = true;
117         ui->horizontalSlider->setValue(value);
118         SelectedParticle = &Sample->ParticlePopulation[ui->
119             widget->centerIndex()];
120         QString volume;
121         volume.sprintf("%+06.2f", SelectedParticle->
122             GetSiDiameter());
123         ui->label_Volume->setText(volume);
124         emit particleChanged(value);
125         emit shapeClassificationChanged(SelectedParticle->
126             Classification.Category);
127         dontDoIt = false;
128     }
129 }
130
131 void QParticleDisplay::on_selectedParticleChangedSlider(int
132     value) {
133     if (!dontDoIt) {
134         dontDoIt = true;
135         ui->widget->setCenterIndex(value);
136     }
137 }

```

```
128     SelectedParticle = &Sample->ParticlePopulation[ui->
129         widget->centerIndex()];
130     QString volume;
131     volume.sprintf("%+06.2f", SelectedParticle->
132         GetSiDiameter());
133     ui->label_Volume->setText(volume);
134     emit particleChanged(value);
135     emit shapeClassificationChanged(SelectedParticle->
136         Classification.Category);
137     dontDoIt = false;
138 }
139 }
140 }
141 }
142 }
143 }
144 }
145 }
146 }
147 }
148 }
149 }
150 void QParticleDisplay::wheelEvent(QWheelEvent *event) {
151     int i = ui->widget->centerIndex();
152     i -= event->delta() / 120;
153     if (i < 0) {
154         i = ui->widget->slideCount() - abs(i) - 1;
155     } else if (i >= ui->widget->slideCount()) {
156         i = 0;
157     }
158     ui->widget->setCenterIndex(i);
159     on_selectedParticleChangedWidget(i);
160 }
```



N. QParticleSelector Library

```
1 #-----  
2 #  
3 # Project created by QtCreator 2015-08-07T18:56:27  
4 #  
5 #-----  
6  
7 QT      += core gui  
8 QMAKE_CXXFLAGS += -std=c++11  
9  
10 greaterThan(QT_MAJOR_VERSION, 4): QT += widgets  
11  
12 TARGET = QParticleSelector  
13 TEMPLATE = lib  
14 CONFIG += shared  
15 VERSION = 0.1.11  
16  
17 SOURCES += qparticleselector.cpp  
18  
19 HEADERS  += qparticleselector.h  
20  
21 FORMS    += qparticleselector.ui  
22  
23 RESOURCES += \  
24     qparticleselector.qrc  
25  
26 #MainLib  
27 unix {  
28     target.path = $PWD/../../../../build/install  
29     INSTALLS += target  
30 }  
31  
32 unix:!macx: LIBS += -L$$PWD/../../../../build/install/ -lSoilMath
```

```
33
34 INCLUDEPATH += $$PWD/../SoilMath
35 DEPENDPATH += $$PWD/../SoilMath


---


1 #ifndef QPARTICLESELECTOR_H
2 #define QPARTICLESELECTOR_H
3
4 #include <QWidget>
5 #include <QPushButton>
6
7 namespace Ui {
8     class QParticleSelector;
9 }
10
11 class QParticleSelector : public QWidget
12 {
13     Q_OBJECT
14
15 public:
16     explicit QParticleSelector(QWidget *parent = 0);
17     ~QParticleSelector();
18
19     void setDisabled(bool value, int currentClass = 1);
20
21 signals:
22     void valueChanged(int newValue);
23
24 public slots:
25     void setValue(int newValue);
26
27 private slots:
28     void on_pb_1_clicked(bool checked);
29
30     void on_pb_2_clicked(bool checked);
31
32     void on_pb_3_clicked(bool checked);
33
34     void on_pb_4_clicked(bool checked);
35
36     void on_pb_5_clicked(bool checked);
37
38     void on_pb_6_clicked(bool checked);
39
40     void on_pb_7_clicked(bool checked);
41
42     void on_pb_8_clicked(bool checked);
43
44     void on_pb_9_clicked(bool checked);
45
46     void on_pb_10_clicked(bool checked);
47
48     void on_pb_11_clicked(bool checked);
49
50     void on_pb_12_clicked(bool checked);
51
52     void on_pb_13_clicked(bool checked);
```

```
53     void on_pb_14_clicked(bool checked);
54
55     void on_pb_15_clicked(bool checked);
56
57     void on_pb_16_clicked(bool checked);
58
59     void on_pb_17_clicked(bool checked);
60
61     void on_pb_18_clicked(bool checked);
62
63
64 private:
65     QVector<QPushButton *> btns;
66     Ui::QParticleSelector *ui;
67 };
68
69 #endif // QPARTICLESELECTOR_H


---


1 #include "qparticleselector.h"
2 #include "ui_qparticleselector.h"
3
4 QParticleSelector::QParticleSelector(QWidget *parent)
5     : QWidget(parent), ui(new Ui::QParticleSelector) {
6     ui->setupUi(this);
7     btns.push_back(ui->pb_1);
8     btns.push_back(ui->pb_2);
9     btns.push_back(ui->pb_3);
10    btns.push_back(ui->pb_4);
11    btns.push_back(ui->pb_5);
12    btns.push_back(ui->pb_6);
13    btns.push_back(ui->pb_7);
14    btns.push_back(ui->pb_8);
15    btns.push_back(ui->pb_9);
16    btns.push_back(ui->pb_10);
17    btns.push_back(ui->pb_11);
18    btns.push_back(ui->pb_12);
19    btns.push_back(ui->pb_13);
20    btns.push_back(ui->pb_14);
21    btns.push_back(ui->pb_15);
22    btns.push_back(ui->pb_16);
23    btns.push_back(ui->pb_17);
24    btns.push_back(ui->pb_18);
25 }
26
27 QParticleSelector::~QParticleSelector() {
28     for (auto b : btns) {
29         delete b;
30     }
31     btns.clear();
32     delete ui;
33 }
34
35 void QParticleSelector::setValue(int newValue) {
36     btns[newValue - 1]->setChecked(true);
37 }
```

```
39 void QParticleSelector::setDisabled(bool value, int
40     currentClass) {
41     for (auto b : btns) {
42         b->setDisabled(value);
43     }
44     if (currentClass > 18 || currentClass < 1) {
45         bns[0]->setChecked(true);
46     } else {
47         bns[currentClass - 1]->setChecked(true);
48     }
49 }
50 void QParticleSelector::on_pb_1_clicked(bool checked) {
51     if (checked) {
52         emit valueChanged(1);
53     }
54 }
55
56 void QParticleSelector::on_pb_2_clicked(bool checked) {
57     if (checked) {
58         emit valueChanged(2);
59     }
60 }
61
62 void QParticleSelector::on_pb_3_clicked(bool checked) {
63     if (checked) {
64         emit valueChanged(3);
65     }
66 }
67
68 void QParticleSelector::on_pb_4_clicked(bool checked) {
69     if (checked) {
70         emit valueChanged(4);
71     }
72 }
73
74 void QParticleSelector::on_pb_5_clicked(bool checked) {
75     if (checked) {
76         emit valueChanged(5);
77     }
78 }
79
80 void QParticleSelector::on_pb_6_clicked(bool checked) {
81     if (checked) {
82         emit valueChanged(6);
83     }
84 }
85
86 void QParticleSelector::on_pb_7_clicked(bool checked) {
87     if (checked) {
88         emit valueChanged(7);
89     }
90 }
91
92 void QParticleSelector::on_pb_8_clicked(bool checked) {
93     if (checked) {
```

```
94     emit valueChanged(8);
95 }
96 }
97
98 void QParticleSelector::on_pb_9_clicked(bool checked) {
99     if (checked) {
100         emit valueChanged(9);
101     }
102 }
103
104 void QParticleSelector::on_pb_10_clicked(bool checked) {
105     if (checked) {
106         emit valueChanged(10);
107     }
108 }
109
110 void QParticleSelector::on_pb_11_clicked(bool checked) {
111     if (checked) {
112         emit valueChanged(11);
113     }
114 }
115
116 void QParticleSelector::on_pb_12_clicked(bool checked) {
117     if (checked) {
118         emit valueChanged(12);
119     }
120 }
121
122 void QParticleSelector::on_pb_13_clicked(bool checked) {
123     if (checked) {
124         emit valueChanged(13);
125     }
126 }
127
128 void QParticleSelector::on_pb_14_clicked(bool checked) {
129     if (checked) {
130         emit valueChanged(14);
131     }
132 }
133
134 void QParticleSelector::on_pb_15_clicked(bool checked) {
135     if (checked) {
136         emit valueChanged(15);
137     }
138 }
139
140 void QParticleSelector::on_pb_16_clicked(bool checked) {
141     if (checked) {
142         emit valueChanged(16);
143     }
144 }
145
146 void QParticleSelector::on_pb_17_clicked(bool checked) {
147     if (checked) {
148         emit valueChanged(17);
149     }

```

```
150  }
151
152 void QParticleSelector::on_pb_18_clicked(bool checked) {
153     if (checked) {
154         emit valueChanged(18);
155     }
156 }
```

O. QReportGenerator Library

```
1  #-----  
2  #  
3  # Project created by QtCreator 2015-08-20T08:46:42  
4  #  
5  #-----  
6  
7  QT      += core gui concurrent network  
8  QMAKE_CXXFLAGS += -std=c++11  
9  
10 greaterThan(QT_MAJOR_VERSION, 4): QT += widgets printsupport  
     multimedia multimediawidgets  
11  
12 @  
13 CONFIG(release, debug|release):DEFINES += QT_NO_DEBUG_OUTPUT  
14 @  
15  
16 unix:!macx: QMAKE_RPATHDIR += $$PWD/../../../../../build/install/  
17  
18 TARGET = QReportGenerator  
19 TEMPLATE = lib  
20 CONFIG += shared  
21 VERSION = 0.1.00  
22  
23 SOURCES += \  
24     qreportgenerator.cpp \  
25     ../../qcustomplot/examples/text-document-integration/  
         qcpdocumentobject.cpp  
26  
27 HEADERS += \  
28     qreportgenerator.h \  
29     ../../qcustomplot/examples/text-document-integration/  
         qcpdocumentobject.h
```

```

30
31 FORMS     += \
32     qreportgenerator.ui
33
34 #MainLib
35 unix {
36     target.path = $PWD/../../build/install
37     INSTALLS += target
38 }
39
40 unix:!macx: LIBS += -L$$PWD/../../build/install/ -lSoilMath
41 INCLUDEPATH += $$PWD/../SoilMath
42 DEPENDPATH += $$PWD/../SoilMath
43
44 DEFINES += QCUSTOMPLOT_USE_LIBRARY
45 unix:!macx: LIBS += -L$$PWD/../../build/install/ -
    lqcustomplot
46
47 INCLUDEPATH += $$PWD/../qcustomplot
48 DEPENDPATH += $$PWD/../qcustomplot
49
50 unix:!macx: LIBS += -L$$PWD/../../build/install/ -
    lSoilAnalyzer
51 INCLUDEPATH += $$PWD/../SoilAnalyzer
52 DEPENDPATH += $$PWD/../SoilAnalyzer
53
54 unix:!macx: LIBS += -L$$PWD/../../build/install/ -
    lSoilVision
55 INCLUDEPATH += $$PWD/../SoilVision
56 DEPENDPATH += $$PWD/../SoilVision
57
58 RESOURCES += \
59     qreportresources.qrc \
60     ../VSA/vsa_resources.qrc
61
62 #maps
63 Mapstarget.path += $$OUT_PWD/Maps
64 Mapstarget.files += $$PWD/Maps/*
65 INSTALLS += Mapstarget
66 bMapstarget.path += $$PWD/../../build/install/Maps
67 bMapstarget.files += $$PWD/Maps/*
68 INSTALLS += bMapstarget

```

```

1 #ifndef QREPORTGENERATOR_H
2 #define QREPORTGENERATOR_H
3
4 #include <QMainWindow>
5 #include <QTextDocument>
6 #include <QDebug>
7 #include <QTextBlockFormat>
8 #include <QTextCharFormat>
9 #include <QTextBlock>
10 #include <QNetworkAccessManager>
11 #include <QNetworkReply>
12 #include <QTextDocumentWriter>
13 #include <QPrinter>

```

```
14
15 #include "soilanalyzer.h"
16 #include "SoilMath.h"
17
18 #include <qcustomplot.h>
19 #include "../qcustomplot/examples/text-document-integration/
20     qcpdocumentobject.h"
21
22 namespace Ui {
23     class QReportGenerator;
24 }
25
26 class QReportGenerator : public QMainWindow
27 {
28     Q_OBJECT
29
30     public:
31         QTextDocument *Report = nullptr;
32         SoilAnalyzer::Sample *Sample = nullptr;
33         SoilAnalyzer::SoilSettings *Settings = nullptr;
34         QCustomePlot *PSD = nullptr;
35         QCustomePlot *Roundness = nullptr;
36         QCustomePlot *Angularity = nullptr;
37
38     explicit QReportGenerator(QWidget *parent = 0,
39         SoilAnalyzer::Sample *sample = nullptr, SoilAnalyzer::
40         SoilSettings *settings = nullptr, QCustomePlot *psd =
41         nullptr, QCustomePlot *roundness = nullptr, QCustomePlot
42         *angularity = nullptr);
43     ~QReportGenerator();
44
45     private slots:
46         void on_locationImageDownloaded(QNetworkReply *reply);
47
48         void on_actionSave_triggered();
49
50         void on_actionExport_to_PDF_triggered();
51
52     private:
53         Ui::QReportGenerator *ui;
54         QCustomePlot *CIELabPlot = nullptr;
55
56         QImage *mapLocation = nullptr;
57
58         QTextCursor rCurs;
59
60         // Layout formats
61         QTextBlockFormat TitleFormat;
62         QTextBlockFormat HeaderFormat;
63         QTextBlockFormat GeneralFormat;
64         QTextBlockFormat ImageGraphFormat;
65
66         QTextCharFormat TitleTextFormat;
```

```
65     QTextCharFormat HeaderTextFormat;
66     QTextCharFormat GtxtFormat;
67     QTextCharFormat GFieldtxtFormat;
68
69     QTextListFormat GeneralSampleList;
70     QTextTableFormat GeneralTextTableFormat;
71
72
73     QFont TitleFont;
74     QFont HeaderFont;
75     QFont GeneralFont;
76     QFont FieldFont;
77 }
78
79 #endif // QREPORTGENERATOR_H
```

```
1 #include "qreportgenerator.h"
2 #include "ui_qreportgenerator.h"
3
4 QReportGenerator::QReportGenerator(QWidget *parent,
5                                     SoilAnalyzer::Sample *
6                                     sample,
7                                     SoilAnalyzer::
8                                     SoilSettings *settings
9                                     ,
10                                     QCustomPlot *psd,
11                                     QCustomPlot *roundness
12                                     ,
13                                     QCustomPlot *angularity)
14     : QMainWindow(parent), ui(new Ui::QReportGenerator) {
15     ui->setupUi(this);
16     if (settings == nullptr) {
17         settings = new SoilAnalyzer::SoilSettings;
18     }
19     this->Settings = settings;
20     if (sample == nullptr) {
21         sample = new SoilAnalyzer::Sample;
22     }
23     this->Sample = sample;
24
25     if (psd == nullptr) {
26         psd = new QCustomPlot;
27     }
28     this->PSD = psd;
29
30     if (roundness == nullptr) {
31         roundness = new QCustomPlot;
32     }
33     this->Roundness = roundness;
34
35     if (angularity == nullptr) {
36         angularity = new QCustomPlot;
37     }
38     this->Angularity = angularity;
39
40     Report = new QTextDocument(ui->textEdit);
```

```
36     ui->textEdit->setDocument(Report);
37     rCurs = QTextCursor(Report);
38
39     // Setup the layout
40     TitleFormat.setAlignment(Qt::AlignCenter);
41     TitleFont.setBold(true);
42     TitleFont.setPointSize(36);
43     TitleTextFormat.setFont(TitleFont);
44
45     HeaderFormat.setAlignment(Qt::AlignCenter);
46     HeaderFormat.setPageBreakPolicy(QTextFormat::
47         PageBreak_AlwaysBefore);
47     HeaderFormat.setTopMargin(40);
48     HeaderFormat.setBottomMargin(10);
49     HeaderFont.setBold(true);
50     HeaderFont.setPointSize(18);
51     HeaderTextFormat.setFont(HeaderFont);
52
53     ImageGraphFormat.setAlignment(Qt::AlignCenter);
54     ImageGraphFormat.setTopMargin(10);
55     ImageGraphFormat.setBottomMargin(10);
56
57     GeneralFormat.setAlignment(Qt::AlignLeft);
58
59     GeneralFont.setPointSize(12);
60     GeneralFont.setBold(false);
61     GtxtFormat.setFont(GeneralFont);
62
63     FieldFont.setBold(true);
64     GFieldtxtFormat.setFont(FieldFont);
65
66     GeneralSampleList.setStyle(QTextListFormat::ListDisc);
67
68     GeneralTextTableFormat.setHeaderRowCount(1);
69     GeneralTextTableFormat.setBorderStyle(QTextFrameFormat::
70         BorderStyle_None);
70     GeneralTextTableFormat.setWidth(
71         QTextLength(QTextLength::PercentageLength, 90));
72     GeneralTextTableFormat.setAlignment(Qt::AlignCenter);
73
74     // Setup the Title
75     rCurs.setBlockFormat(TitleFormat);
76     rCurs.insertText("Soil Report", TitleTextFormat);
77     rCurs.insertBlock();
78
79     // Setup the general Text
80     rCurs.insertBlock(ImageGraphFormat);
81     QTextTable *mainTable = rCurs.insertTable(5, 2,
82         GeneralTextTableFormat);
82     rCurs = mainTable->cellAt(0, 0).firstCursorPosition();
83     rCurs.insertText("Sample name:", GFieldtxtFormat);
84     rCurs.movePosition(QTextCursor::NextCell);
85     rCurs.insertText(QString::fromStdString(Sample->Name),
86         GtxtFormat);
86     rCurs.movePosition(QTextCursor::NextCell);
87
```

```

88 rCurs.insertText("Sample ID:", GFieldtxtFormat);
89 rCurs.movePosition(QTextCursor::NextCell);
90 rCurs.insertText(QString::number(Sample->ID), GtxtFormat);
91 rCurs.movePosition(QTextCursor::NextCell);
92
93 rCurs.insertText("Date:", GFieldtxtFormat);
94 rCurs.movePosition(QTextCursor::NextCell);
95 rCurs.insertText(QString::fromStdString(Sample->Date),
96                 GtxtFormat);
97 rCurs.movePosition(QTextCursor::NextCell);
98
99 rCurs.insertText("Location:", GFieldtxtFormat);
100 rCurs.movePosition(QTextCursor::NextCell);
101 rCurs.insertText(QString::number(Sample->Latitude),
102                  GtxtFormat);
103 rCurs.movePosition(QTextCursor::NextCell);
104
105 rCurs.insertText("Sample depth:", GFieldtxtFormat);
106 rCurs.movePosition(QTextCursor::NextCell);
107 rCurs.insertText(QString::number(Sample->Depth),
108                  GtxtFormat);
109 rCurs.insertText(" [m]", GtxtFormat);
110 rCurs.movePosition(QTextCursor::NextBlock);
111 rCurs.insertBlock();
112
113 // Insert the Google map
114 getLocationMap(Sample->Latitude, Sample->Longitude);
115
116 // Setup the QCustomplot handler
117 QCPDocumentObject *plotObjectHandler = new
118     QCPDocumentObject(this);
119 ui->textEdit->document()->documentLayout()->
120     registerHandler(
121         QCPDocumentObject::PlotTextFormat, plotObjectHandler);
122
123 // Setup the Textdata for the PSD
124 rCurs.insertBlock(HeaderFormat, HeaderTextFormat);
125 rCurs.insertText("Particle Size Distribution");
126
127 rCurs.insertBlock(ImageGraphFormat);
128 QTextTable *PSDdescr = rCurs.insertTable(6, 2,
129                                         GeneralTextTableFormat);
130 rCurs = PSDdescr->cellAt(0, 0).firstCursorPosition();
131 rCurs.insertText("No of particles:", GFieldtxtFormat);
132 rCurs.movePosition(QTextCursor::NextCell);
133 rCurs.insertText(QString::number(Sample->PSD.n),
134                 GtxtFormat);
135 rCurs.movePosition(QTextCursor::NextCell);
136
137 rCurs.insertText("Mean: ", GFieldtxtFormat);
138 rCurs.movePosition(QTextCursor::NextCell);
139 rCurs.insertText(QString::number(Sample->PSD.Mean),
140                 GtxtFormat);

```

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135     rCurs.movePosition(QTextCursor::NextCell);
136
137     rCurs.insertText("Minimum: ", GFieldtxtFormat);
138     rCurs.movePosition(QTextCursor::NextCell);
139     rCurs.insertText(QString::number(Sample->PSD.min),
140                     GtxtFormat);
140     rCurs.movePosition(QTextCursor::NextCell);
141
142     rCurs.insertText("Maximum: ", GFieldtxtFormat);
143     rCurs.movePosition(QTextCursor::NextCell);
144     rCurs.insertText(QString::number(Sample->PSD.max),
145                     GtxtFormat);
145     rCurs.movePosition(QTextCursor::NextCell);
146
147     rCurs.insertText("Range: ", GFieldtxtFormat);
148     rCurs.movePosition(QTextCursor::NextCell);
149     rCurs.insertText(QString::number(Sample->PSD.Range),
150                     GtxtFormat);
150     rCurs.movePosition(QTextCursor::NextCell);
151
152     rCurs.insertText("Standard deviation: ", GFieldtxtFormat);
153     rCurs.movePosition(QTextCursor::NextCell);
154     rCurs.insertText(QString::number(Sample->PSD.Std),
155                     GtxtFormat);
155     rCurs.movePosition(QTextCursor::NextBlock);
156
157 // Setup the PSD
158 rCurs.insertBlock(ImageGraphFormat);
159 rCurs.insertText(QString(QChar::ObjectReplacementCharacter
160                     ),
161                     QCPDocumentObject::generatePlotFormat(PSD
162                     , 600, 350));
163
164 rCurs.insertBlock(ImageGraphFormat);
165 QTextTable *PSDdata = rCurs.insertTable(16, 3,
166                                         GeneralTextTableFormat);
167 rCurs.insertText("Mesh Size [mm]", GFieldtxtFormat);
168 rCurs.movePosition(QTextCursor::NextCell);
169 rCurs.insertText("Cummulative [%]", GFieldtxtFormat);
170 rCurs.movePosition(QTextCursor::NextCell);
171 rCurs.insertText("Retained [-]", GFieldtxtFormat);
172 rCurs.movePosition(QTextCursor::NextCell);
173 rCurs.insertText("2", GFieldtxtFormat);
174 rCurs.movePosition(QTextCursor::NextCell);
175 rCurs.insertText(QString::number(Sample->PSD.CFD[14]),
176                     GtxtFormat);
177 rCurs.movePosition(QTextCursor::NextCell);
178 rCurs.insertText("1.4", GFieldtxtFormat);
179 rCurs.movePosition(QTextCursor::NextCell);

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180 rCurs.insertText(QString::number(Sample->PSD.bins[13]),  
181     GtxtFormat);  
182 rCurs.movePosition(QTextCursor::NextCell);  
183 rCurs.insertText("1", GFieldtxtFormat);  
184 rCurs.movePosition(QTextCursor::NextCell);  
185 rCurs.insertText(QString::number(Sample->PSD.CFD[12]),  
186     GtxtFormat);  
187 rCurs.movePosition(QTextCursor::NextCell);  
188 rCurs.insertText("0.71", GFieldtxtFormat);  
189 rCurs.movePosition(QTextCursor::NextCell);  
190 rCurs.insertText(QString::number(Sample->PSD.CFD[11]),  
191     GtxtFormat);  
192 rCurs.movePosition(QTextCursor::NextCell);  
193 rCurs.insertText(QString::number(Sample->PSD.bins[11]),  
194     GtxtFormat);  
195 rCurs.movePosition(QTextCursor::NextCell);  
196 rCurs.insertText(QString::number(Sample->PSD.CFD[10]),  
197     GtxtFormat);  
198 rCurs.movePosition(QTextCursor::NextCell);  
199 rCurs.insertText(QString::number(Sample->PSD.bins[10]),  
200     GtxtFormat);  
201 rCurs.movePosition(QTextCursor::NextCell);  
202 rCurs.insertText(QString::number(Sample->PSD.CFD[9]),  
203     GtxtFormat);  
204 rCurs.movePosition(QTextCursor::NextCell);  
205 rCurs.insertText(QString::number(Sample->PSD.bins[9]),  
206     GtxtFormat);  
207 rCurs.movePosition(QTextCursor::NextCell);  
208 rCurs.insertText(QString::number(Sample->PSD.CFD[8]),  
209     GtxtFormat);  
210 rCurs.movePosition(QTextCursor::NextCell);  
211 rCurs.insertText(QString::number(Sample->PSD.bins[8]),  
212     GtxtFormat);  
213 rCurs.movePosition(QTextCursor::NextCell);  
214 rCurs.insertText(QString::number(Sample->PSD.CFD[7]),  
215     GtxtFormat);  
216 rCurs.movePosition(QTextCursor::NextCell);  
217 rCurs.insertText(QString::number(Sample->PSD.bins[7]),  
218     GtxtFormat);  
219 rCurs.movePosition(QTextCursor::NextCell);  
220 rCurs.insertText(QString::number(Sample->PSD.CFD[6]),  
221     GtxtFormat);  
222 rCurs.movePosition(QTextCursor::NextCell);
```

```

222 rCurs.insertText(QString::number(Sample->PSD.bins[6]),
223     GtxtFormat);
224 rCurs.movePosition(QTextCursor::NextCell);
225 rCurs.insertText("0.09", GFieldtxtFormat);
226 rCurs.movePosition(QTextCursor::NextCell);
227 rCurs.insertText(QString::number(Sample->PSD.CFD[5]),
228     GtxtFormat);
229 rCurs.movePosition(QTextCursor::NextCell);
230 rCurs.insertText("0.075", GFieldtxtFormat);
231 rCurs.movePosition(QTextCursor::NextCell);
232 rCurs.insertText(QString::number(Sample->PSD.CFD[4]),
233     GtxtFormat);
234 rCurs.movePosition(QTextCursor::NextCell);
235 rCurs.insertText(QString::number(Sample->PSD.bins[4]),
236     GtxtFormat);
237 rCurs.movePosition(QTextCursor::NextCell);
238 rCurs.insertText(QString::number(Sample->PSD.CFD[3]),
239     GtxtFormat);
240 rCurs.movePosition(QTextCursor::NextCell);
241 rCurs.insertText(QString::number(Sample->PSD.bins[3]),
242     GtxtFormat);
243 rCurs.movePosition(QTextCursor::NextCell);
244 rCurs.insertText(QString::number(Sample->PSD.CFD[2]),
245     GtxtFormat);
246 rCurs.movePosition(QTextCursor::NextCell);
247 rCurs.insertText(QString::number(Sample->PSD.bins[2]),
248     GtxtFormat);
249 rCurs.movePosition(QTextCursor::NextCell);
250 rCurs.insertText(QString::number(Sample->PSD.CFD[1]),
251     GtxtFormat);
252 rCurs.movePosition(QTextCursor::NextCell);
253 rCurs.insertText(QString::number(Sample->PSD.bins[1]),
254     GtxtFormat);
255 rCurs.movePosition(QTextCursor::NextCell);
256 rCurs.insertText(QString::number(Sample->PSD.CFD[0]),
257     GtxtFormat);
258 rCurs.movePosition(QTextCursor::NextCell);
259 rCurs.insertText(QString::number(Sample->PSD.bins[0]),
260     GtxtFormat);
261 // Setup the Textdata for the Roundness
262 rCurs.insertBlock(HeaderFormat, HeaderTextFormat);
263 rCurs.insertText("Sphericity Classification");
264

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```
265 rCurs.insertBlock(ImageGraphFormat);
266 QTextTable *Rounddescr = rCurs.insertTable(6, 2,
267     GeneralTextTableFormat);
268 rCurs = Rounddescr->cellAt(0, 0).firstCursorPosition();
269 rCurs.insertText("No of particles:", GFieldtxtFormat);
270 rCurs.movePosition(QTextCursor::NextCell);
271 rCurs.insertText(QString::number(Sample->Roundness.n),
272     GtxtFormat);
273 rCurs.movePosition(QTextCursor::NextCell);
274
275 rCurs.insertText("Mean: ", GFieldtxtFormat);
276 rCurs.movePosition(QTextCursor::NextCell);
277 rCurs.insertText(QString::number(Sample->Roundness.Mean),
278     GtxtFormat);
279 rCurs.movePosition(QTextCursor::NextCell);
280
281 rCurs.insertText("Minimum: ", GFieldtxtFormat);
282 rCurs.movePosition(QTextCursor::NextCell);
283 rCurs.insertText(QString::number(Sample->Roundness.min),
284     GtxtFormat);
285 rCurs.movePosition(QTextCursor::NextCell);
286
287 rCurs.insertText("Maximum: ", GFieldtxtFormat);
288 rCurs.movePosition(QTextCursor::NextCell);
289 rCurs.insertText(QString::number(Sample->Roundness.max),
290     GtxtFormat);
291 rCurs.movePosition(QTextCursor::NextCell);
292
293 rCurs.insertText("Range: ", GFieldtxtFormat);
294 rCurs.movePosition(QTextCursor::NextCell);
295 rCurs.insertText(QString::number(Sample->Roundness.Range),
296     GtxtFormat);
297 rCurs.movePosition(QTextCursor::NextCell);
298
299 // Setup the Roundness Graph
300 rCurs.insertBlock(ImageGraphFormat);
301 rCurs.insertText(QString(QChar::ObjectReplacementCharacter
302     ),
303     QCPDocumentObject::generatePlotFormat(
304         Roundness, 600, 400));
305
306 // Setup the Textdata for the Roundness
307 rCurs.insertBlock(HeaderFormat, HeaderTextFormat);
308 rCurs.insertText("Angularity Classification");
309
310 rCurs.insertBlock(ImageGraphFormat);
311 QTextTable *Angularitydescr = rCurs.insertTable(6, 2,
312     GeneralTextTableFormat);
313 rCurs = Angularitydescr->cellAt(0, 0).firstCursorPosition()
314     (;
```

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310 rCurs.insertText("No of particles:", GFieldtxtFormat);
311 rCurs.movePosition(QTextCursor::NextCell);
312 rCurs.insertText(QString::number(Sample->Angularity.n),
313     GtxtFormat);
314 rCurs.movePosition(QTextCursor::NextCell);
315 rCurs.insertText("Mean: ", GFieldtxtFormat);
316 rCurs.movePosition(QTextCursor::NextCell);
317 rCurs.insertText(QString::number(Sample->Angularity.Mean),
318     GtxtFormat);
319 rCurs.movePosition(QTextCursor::NextCell);
320 rCurs.insertText("Minimum: ", GFieldtxtFormat);
321 rCurs.movePosition(QTextCursor::NextCell);
322 rCurs.insertText(QString::number(Sample->Angularity.min),
323     GtxtFormat);
324 rCurs.movePosition(QTextCursor::NextCell);
325 rCurs.insertText("Maximum: ", GFieldtxtFormat);
326 rCurs.movePosition(QTextCursor::NextCell);
327 rCurs.insertText(QString::number(Sample->Angularity.max),
328     GtxtFormat);
329 rCurs.movePosition(QTextCursor::NextCell);
330 rCurs.insertText("Range: ", GFieldtxtFormat);
331 rCurs.movePosition(QTextCursor::NextCell);
332 rCurs.insertText(QString::number(Sample->Angularity.Range),
333     GtxtFormat);
334 rCurs.movePosition(QTextCursor::NextCell);
335 rCurs.insertText("Standard deviation: ", GFieldtxtFormat);
336 rCurs.movePosition(QTextCursor::NextCell);
337 rCurs.insertText(QString::number(Sample->Angularity.Std),
338     GtxtFormat);
339 rCurs.movePosition(QTextCursor::NextBlock);
340 // Setup the Roundness Graph
341 rCurs.insertBlock(ImageGraphFormat);
342 rCurs.insertText(QString(QChar::ObjectReplacementCharacter),
343     ),
344             QCPDocumentObject::generatePlotFormat(
345                 Angularity, 600, 400));
346
347 // Setup the CIE La*b* graph
348 // Setup the Textdata for the Roundness
349 rCurs.insertBlock(HeaderFormat, HeaderTextFormat);
350 rCurs.insertText("CIE La*b*");
351
352 SetupCIELabPPlot();
353 rCurs.insertBlock(ImageGraphFormat);
354 rCurs.insertText(QString(QChar::ObjectReplacementCharacter),
355     ),
356             QCPDocumentObject::generatePlotFormat(
357                 CIELabPlot, 600, 400));
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```

```
356
357 void QReportGenerator::getLocationMap(double &latitude,
358     double &longitude) {
359     QNetworkAccessManager *manager = new QNetworkAccessManager
360     ;
361     connect(manager, SIGNAL(finished(QNetworkReply *)), this,
362             SLOT(on_locationImageDownloaded(QNetworkReply *)))
363     ;
364     QString locationURL("http://maps.googleapis.com/maps/api/
365         staticmap?center=");
366     locationURL.append(QString::number(latitude));
367     locationURL.append(",");
368     locationURL.append(QString::number(longitude));
369     locationURL.append("&zoom=17&size=600x750&maptype=hybrid&&
370         format=png&visual_"
371         "refresh=true&markers=size:mid%7Ccolor
372             :0xff0000%7Clabel:S%
373             "7C");
374     locationURL.append(QString::number(latitude));
375     locationURL.append(",");
376     locationURL.append(QString::number(longitude));
377     qDebug() << locationURL;
378     QUrl googleStaticMapUrl(locationURL);
379     manager->get(QNetworkRequest(googleStaticMapUrl));
380 }
381
382 void QReportGenerator::on_locationImageDownloaded(
383     QNetworkReply *reply) {
384     if (mapLocation == nullptr) {
385         mapLocation = new QImage;
386     }
387     mapLocation->loadFromData(reply->readAll());
388
389     if (mapLocation->isNull()) {
390         mapLocation->load("Maps/SampleLocation.png");
391     }
392
393     QTextBlock location = Report->findBlockByNumber(15);
394     QTextCursor insertMap(location);
395     insertMap.setBlockFormat(ImageGraphFormat);
396     insertMap.insertImage(*mapLocation);
397     insertMap.insertBlock();
398     insertMap.insertHtml("<br>");
399 }
400
401 void QReportGenerator::~QReportGenerator()
402 {
403     delete CIELabPlot;
404     delete mapLocation;
405     delete ui;
406 }
407
408 void QReportGenerator::on_actionSave_triggered() {
409     QString fn = QFileDialog::getSaveFileName(
410         this, tr("Save Report"), QString::fromStdString(
411             Settings->SampleFolder),
```

```

404     tr("Report (*.odf")));
405     if (!fn.isEmpty()) {
406         if (!fn.contains(tr(".odf"))) {
407             fn.append(tr(".odf"));
408         }
409         QTextDocumentWriter m_write;
410         m_write.setFileName(fn);
411         m_write.setFormat("odf");
412         m_write.write(Report);
413     }
414 }
415
416 void QReportGenerator::on_actionExport_to_PDF_triggered() {
417     QString fn = QFileDialog::getSaveFileName(
418         this, tr("Save Report"), QString::fromStdString(
419             Settings->SampleFolder),
420         tr("Report (*.pdf)"));
421     if (!fn.isEmpty()) {
422         if (!fn.contains(tr(".pdf"))) {
423             fn.append(tr(".pdf"));
424         }
425         QPrinter printer;
426         printer.setOutputFormat(QPrinter::PdfFormat);
427         printer.setOutputFileName(fn);
428         Report->print(&printer);
429     }
430 }
431 void QReportGenerator::SetupCIELabPPlot() {
432     if (CIELabPlot == nullptr) {
433         CIELabPlot = new QCustomPlot();
434     }
435
436     QPen binPen;
437     binPen.setColor((QColor("blue")));
438     binPen.setStyle(Qt::SolidLine);
439     binPen.setWidthF(1);
440
441     // Setup the CIELabplot plot
442     QCPPlotTitle *CIEtitle = new QCPPlotTitle(CIELabPlot);
443     CIEtitle->setText("mean CIE Lab - a* vs. b*");
444     CIEtitle->setFont(QFont("sans", 8, QFont::Bold));
445     CIELabPlot->plotLayout()->insertRow(0);
446     CIELabPlot->plotLayout()->addElement(0, 0, CIEtitle);
447
448     CIELabPlot->addGraph(CIELabPlot->xAxis, CIELabPlot->yAxis)
449         ;
450     CIELabPlot->graph(0)
451         ->setScatterStyle(QCPScatterStyle(QCPScatterStyle::
452             ssCircle, 8));
453     CIELabPlot->graph(0)->setPen(binPen);
454     CIELabPlot->graph(0)->setName("a* vs. b*");
455     CIELabPlot->graph(0)->setData(*Sample->GetCIELab_bVector()
456         , *Sample->GetCIELab_aVector());
457     CIELabPlot->graph(0)->setScatterStyle(QCPScatterStyle::
458             ssCross);

```

```
455     CIElabPlot->graph(0)->setLineStyle(QCPGraph::lsNone);  
456  
457     CIElabPlot->xAxis->setLabel("mean chromatic b*");  
458     CIElabPlot->xAxis->setTickLabelFont(QFont("sans", 8, QFont  
        ::Normal));  
459     CIElabPlot->xAxis->setScaleType(QCPAxis::stLinear);  
460     CIElabPlot->xAxis->setRange(-128,128);  
461  
462     CIElabPlot->yAxis->setLabel("mean chromatic a*");  
463     CIElabPlot->yAxis->setTickLabelFont(QFont("sans", 8, QFont  
        ::Normal));  
464     CIElabPlot->yAxis->setScaleType(QCPAxis::stLinear);  
465     CIElabPlot->yAxis->setRange(-128,128);  
466     CIElabPlot->replot();  
467  
468 }
```



P. Vision Soil Analyzer Program

General project files

```
1  #
2  #
3  # Project created by QtCreator 2015-08-07T16:50:24
4  #
5  #
6  #
7
8  QT      += core gui concurrent
9  QMAKE_CXXFLAGS += -std=c++11
10
11 greaterThan(QT_MAJOR_VERSION, 4): QT += widgets printsupport
12     multimedia multimediawidgets
13
14 TARGET = VSA
15 TEMPLATE = app
16 VERSION = 0.9.7
17
18 unix:!macx: QMAKE_RPATHDIR += $$PWD/../../../../../build/install/
19
20 CONFIG(release, debug|release):DEFINES += QT_NO_DEBUG_OUTPUT
21
22
23 SOURCES += main.cpp \
24             vsemainwindow.cpp \
25             dialogsettings.cpp \
26             dialognn.cpp
27
28 HEADERS  += vsemainwindow.h \
29             dialogsettings.h \
30             dialognn.h
```

```
31
32 FORMS    += vsemainwindow.ui \
33     dialogsettings.ui \
34     dialognn.ui
35
36 #opencv
37 LIBS    += -L/usr/local/lib -lopencv_core -lopencv_highgui - \
38             opencv_imgcodecs
39 INCLUDEPATH += /usr/local/include/opencv
40 INCLUDEPATH += /usr/local/include
41
42 #boost
43 DEFINES += BOOST_ALL_DYN_LINK
44 INCLUDEPATH += /usr/include/boost
45 LIBS    += -L/usr/lib/x86_64-linux-gnu/ -lboost_filesystem - \
46             lboost_serialization -lboost_system -lboost_iostreams
47
48 #Gstreamer
49 INCLUDEPATH += /usr/include/gstreamer-0.10
50 INCLUDEPATH += /usr/include/glib-2.0/
51 INCLUDEPATH += /usr/lib/x86_64-linux-gnu/glib-2.0/include/
52 INCLUDEPATH += /usr/include/libxml2/
53 LIBS    += `pkg-config --cflags --libs gstreamer-0.10`
54
55 #SoilMath lib
56 unix:!macx: LIBS += -L$$PWD/../../build/install/ -lSoilMath
57 INCLUDEPATH += $$PWD/../SoilMath
58 DEPENDPATH += $$PWD/../SoilMath
59
60 #SoilHardware lib
61 unix:!macx: LIBS += -L$$PWD/../../build/install/ - \
62             lSoilHardware
63 INCLUDEPATH += $$PWD/../SoilHardware
64 DEPENDPATH += $$PWD/../SoilHardware
65
66 #SoilVision lib
67 unix:!macx: LIBS += -L$$PWD/../../build/install/ - \
68             lSoilVision
69 INCLUDEPATH += $$PWD/../SoilVision
70 DEPENDPATH += $$PWD/../SoilVision
71
72 #QCustomplot lib
73 DEFINES += QCUSTOMPLOT_USE_LIBRARY
74 unix:!macx: LIBS += -L$$PWD/../../build/install/ - \
75             lqcustomplot
76 INCLUDEPATH += $$PWD/../qcustomplot
77 DEPENDPATH += $$PWD/../qcustomplot
78
79 #QParticleSelector
80 unix:!macx: LIBS += -L$$PWD/../../build/install/ - \
81             lQParticleSelector
82 INCLUDEPATH += $$PWD/../QParticleSelector
83 DEPENDPATH += $$PWD/../QParticleSelector
84
85 #QParticleDisplay
```

```

80 unix:!macx: LIBS += -L$$PWD/../../build/install/ -lQParticleDisplay
81 INCLUDEPATH += $$PWD/../../QParticleDisplay
82 DEPENDPATH += $$PWD/../../QParticleDisplay
83
84 #QOpenCVQT
85 unix:!macx: LIBS += -L$$PWD/../../build/install/ -lQOpenCVQT
86 INCLUDEPATH += $$PWD/../../QOpenCVQT
87 DEPENDPATH += $$PWD/../../QOpenCVQT
88
89 #QSoilAnalyzer
90 unix:!macx: LIBS += -L$$PWD/../../build/install/ -lSoilAnalyzer
91 INCLUDEPATH += $$PWD/../../SoilAnalyzer
92 DEPENDPATH += $$PWD/../../SoilAnalyzer
93
94 #QReportGenerator
95 unix:!macx: LIBS += -L$$PWD/../../build/install/ -lQReportGenerator
96 INCLUDEPATH += $$PWD/../../QReportGenerator
97 DEPENDPATH += $$PWD/../../QReportGenerator
98
99 #NeuralNetFiles
100 NNtarget.path += $$OUT_PWD/NeuralNet
101 NNtarget.files += $$PWD/NeuralNet/*.NN
102 INSTALLS += NNtarget
103 bNNtarget.path += $$PWD/../../build/install/NeuralNet
104 bNNtarget.files += $$PWD/NeuralNet/*.NN
105 INSTALLS += bNNtarget
106
107 #SettingFiles
108 INITtarget.path += $$OUT_PWD/Settings
109 INITtarget.files += $$PWD/Settings/*.ini
110 INSTALLS += INITtarget
111 bINITtarget.path += $$PWD/../../build/install/Settings
112 bINITtarget.files += $$PWD/Settings/*.ini
113 INSTALLS += bINITtarget
114
115 #SoilSamples
116 IMGTtarget.path += $$OUT_PWD/SoilSamples
117 IMGTtarget.files += $$PWD/SoilSamples/*.VSA
118 INSTALLS += IMGTtarget
119 bIMGTtarget.path += $$PWD/../../build/install/SoilSamples
120 bIMGTtarget.files += $$PWD/SoilSamples/*.VSA
121 INSTALLS += bIMGTtarget
122
123 #Images
124 Imgtarget.path += $$OUT_PWD/Images
125 Imgtarget.files += $$PWD/Images/*
126 INSTALLS += Imgtarget
127 bImgtarget.path += $$PWD/../../build/install/Images
128 bImgtarget.files += $$PWD/Images/*
129 INSTALLS += bImgtarget
130
131 #TestedSample
132 TestedSamplesTarget.path += $$OUT_PWD/TestedSamples

```

```
133 TestedSamplesTarget.files += $$PWD/TestedSamples/*
134 INSTALLS += Imgtarget
135 bTestedSamplesTarget.path += $$PWD/../../build/install/
    TestedSamples
136 bTestedSamplesTarget.files += $$PWD/TestedSamples/*
137 INSTALLS += bImgtarget
138
139 RESOURCES += \
    vsa_resources.qrc
140
141
142 #MainProg
143 unix {
144     target.path = $PWD/../../build/install
145     INSTALLS += target
146 }
147
148 DISTFILES += \
    Settings/Default.ini \
    NeuralNet/Default.NN \
    Settings/User.ini \
    SoilSamples/Eurogrit_B3_01__Cat.VSA \
    SoilSamples/Gran_K1_0.5_2.5__01_Cat.VSA \
    TestedSamples/Filterzand_0.2_1.6.csv \
    TestedSamples/Magro_dol.csv \
    TestedSamples/Gran_K1.csv \
    TestedSamples/GL70.csv \
    TestedSamples/Gannet_20_40.csv \
    TestedSamples/Eurogrit.csv \
    TestedSamples/0.8_1.25.csv
```

```
1 #include "vsamainwindow.h"
2 #include <QApplication>
3
4 int main(int argc, char *argv[])
5 {
6     QApplication a(argc, argv);
7     VSAMainWindow w;
8     w.show();
9
10    return a.exec();
11 }
```

Main window Class

```
1 #ifndef VSAMAINWINDOW_H
2 #define VSAMAINWINDOW_H
3
4 #include <QDebug>
5 #include <QMainWindow>
6 #include <QErrorMessage>
7 #include <QMessageBox>
8 #include <QProgressBar>
9 #include <QBrush>
10
11 #include <stdint.h>
12
13 #include <qcustomplot.h>
14
15 #include "soilanalyzer.h"
16 #include "Hardware.h"
17
18 #include "dialognn.h"
19 #include "dialogsettings.h"
20 #include "qparticleselector.h"
21 #include "qreportgenerator.h"
22
23 namespace Ui {
24 class VSAMainWindow;
25 }
26
27 class VSAMainWindow : public QMainWindow {
28     Q_OBJECT
29
30 public:
31     explicit VSAMainWindow(QWidget *parent = 0);
32     ~VSAMainWindow();
33
34 private slots:
35     void on_actionSettings_triggered();
36
37     void on_analyzer_finished();
38
39     void on_actionNeuralNet_triggered();
40
41     void on_actionNewSample_triggered();
42
43     void on_actionSaveSample_triggered();
44
45     void on_actionLoadSample_triggered();
46
47     void on_actionUseLearning_toggled(bool arg1);
48
49     void on_actionCalibrate_triggered();
50
51     void on_Classification_changed(int newValue);
52
53     void on_particle_deleted();
```

```

105 #endif // VSAMAINWINDOW_H

1 #include "vsamainwindow.h"
2 #include "ui_vsamainwindow.h"
3
4 VSAMainWindow::VSAMainWindow(QWidget *parent)
5     : QMainWindow(parent), ui(new Ui::VSAMainWindow) {
6     ui->setupUi(this);
7
8     // Load the usersettings
9     Settings = new SoilAnalyzer::SoilSettings;
10    Settings->LoadSettings("Settings/Default.ini");
11
12    // Set the message windows
13    CamError = new QErrorMessage(this);
14    SaveMeMessage = new QMessageBox(this);
15    SaveMeMessage->setText(tr("Sample is not saved, Save
16        sample?"));
17    SaveMeMessage-> addButton(QMessageBox::Abort);
18    SaveMeMessage-> addButton(QMessageBox::Close);
19
20    BacklightMessage = new QMessageBox(this);
21    BacklightMessage->setText("Turn off Frontlight! Turn on
22        Backlight!");
23    ShakeItBabyMessage = new QMessageBox(this);
24
25    // Load the Microscope
26    Microscope = new Hardware::Microscope;
27    try {
28        Microscope->FindCam(Settings->defaultWebcam)->
29            SelectedResolution =
30                &Microscope->FindCam(Settings->defaultWebcam)
31                    ->Resolutions[Settings->selectedResolution];
32    } catch (exception &e) {
33        Microscope->FindCam(0)->SelectedResolution =
34            &Microscope->FindCam(0)->Resolutions[Settings->
35                selectedResolution];
36    }
37    try {
38        if (!Microscope->openCam(Settings->defaultWebcam)) {
39            int defaultCam = 0;
40            Microscope->openCam(defaultCam);
41            Settings->defaultWebcam = Microscope->SelectedCam->
42                Name;
43        }
44    } catch (Hardware::Exception::MicroscopeException &e) {
45        if (*e.id() == EXCEPTION_OPENCAM_NR) {
46            try {
47                int defaultCam = 0;
48                Microscope->openCam(defaultCam);
49                Settings->defaultWebcam = Microscope->SelectedCam->
50                    Name;
51            } catch (Hardware::Exception::MicroscopeException &e)
52            {
53                if (*e.id() == EXCEPTION_NOCAMS_NR) {
54                    CamError->showMessage(
55

```

```
48         tr("No cams found! Connect the cam and set the  
49             default"));  
50     settingsWindow = new DialogSettings(this, Settings  
51             , Microscope);  
52     }  
53 }  
54  
55 // Setup the sample  
56 Sample = new SoilAnalyzer::Sample;  
57 Images = new SoilAnalyzer::Analyzer::Images_t;  
58 Analyzer = new SoilAnalyzer::Analyzer(Images, Sample,  
59             Settings);  
60  
61 // Setup the setting Window  
62 if (settingsWindow == nullptr) {  
63     settingsWindow =  
64         new DialogSettings(this, Settings, Microscope, &  
65             Analyzer->NeuralNet);  
66 }  
67  
68 // Setup the NN window  
69 if (nnWindow == nullptr) {  
70     nnWindow =  
71         new DialogNN(this, &Analyzer->NeuralNet, Settings,  
72             settingsWindow);  
73 }  
74  
75 // Setup the progressbar and connect it to the Analyzer  
76 Progress = new QProgressBar(ui->statusBar);  
77 Progress->setMaximum(Analyzer->MaxProgress);  
78 Progress->setValue(0);  
79 Progress->setAlignment(Qt::AlignLeft);  
80 Progress->setMinimumSize(750, 19);  
81 ui->statusBar->addWidget(Progress);  
82 connect(Analyzer, SIGNAL(on_progressUpdate(int)), Progress  
83             ,  
84                 SLOT(setValue(int)));  
85 connect(Analyzer, SIGNAL(on_progressUpdate(int)), Progress  
86             ,  
87                 SLOT(setMaximum(int)));  
88 connect(Analyzer, SIGNAL(on_AnalysisFinished()), this,  
89                 SLOT(on_analyzer_finished()));  
90  
91 // Setup the plot linestyles;  
92 QPen pdfPen;  
93 pdfPen.setColor(QColor("gray"));  
94 pdfPen.setStyle(Qt::DashDotDotLine);  
95 pdfPen.setWidthF(1);  
96  
97 QPen meanPen;  
98 meanPen.setColor(QColor("darkBlue"));  
99 meanPen.setStyle(Qt::DashLine);  
100 meanPen.setWidthF(1);  
101  
102 QPen binPen;
```

```

97     binPen.setColor((QColor("blue")));
98     binPen.setStyle(Qt::SolidLine);
99     binPen.setWidthF(2);
100
101 // Setup the PSD plot
102 QCPPPlotTitle *PSDtitle = new QCPPPlotTitle(ui->Qplot_PSD);
103 PSDtitle->setText("Particle Size Distribution");
104 PSDtitle->setFont(QFont("sans", 8, QFont::Bold));
105 ui->Qplot_PSD->plotLayout()->insertRow(0);
106 ui->Qplot_PSD->plotLayout()->addElement(0, 0, PSDtitle);
107
108 ui->Qplot_PSD->addGraph(ui->Qplot_PSD->xAxis, ui->
109     Qplot_PSD->yAxis);
110 ui->Qplot_PSD->graph(0)
111     ->setScatterStyle(QCPSscatterStyle(QCPSscatterStyle:::
112         ssCircle, 8));
113 ui->Qplot_PSD->graph(0)->setPen(binPen);
114 ui->Qplot_PSD->graph(0)->setName("Particle Size
115     Distribution");
116 ui->Qplot_PSD->graph(0)->addToLegend();
117
118 ui->Qplot_PSD->xAxis->setLabel("Particle size [mm]");
119 ui->Qplot_PSD->xAxis->setRange(0.01, 10);
120 ui->Qplot_PSD->xAxis->setAutoTicks(false);
121 ui->Qplot_PSD->xAxis->setTickVector(QVector<double>:::
122     fromStdVector(PSDTicks));
123 ui->Qplot_PSD->xAxis->setTickLabelRotation(30);
124 ui->Qplot_PSD->xAxis->setTickLabelFont(QFont("sans", 8,
125     QFont::Normal));
126 ui->Qplot_PSD->xAxis->setScaleType(QCPAxis::stLogarithmic)
127     ;
128
129 QFont legendfont;
130 legendfont.setPointSize(10);
131 ui->Qplot_PSD->legend->setFont(legendfont);
132 ui->Qplot_PSD->legend->setSelectedFont(legendfont);
133 ui->Qplot_PSD->legend->setVisible(true);
134 ui->Qplot_PSD->axisRect()->insetLayout()->
135     setInsetAlignment(
136         0, Qt::AlignTop | Qt::AlignLeft);
137
138 ui->Qplot_PSD->yAxis->setLabel("Percentage [%]");
139 ui->Qplot_PSD->yAxis->setRange(0, 100);
140 ui->Qplot_PSD->setInteractions(QCP::iRangeDrag | QCP:::
141         iRangeZoom);
142 ui->Qplot_PSD->yAxis->grid()->setSubGridVisible(true);
143
144 connect(ui->Qplot_PSD, SIGNAL(mouseDoubleClick(QMouseEvent
145         *)), this,
146             SLOT(on_reset_graph(QMouseEvent *)));
147 ui->Qplot_PSD->setContextMenuPolicy(Qt::CustomContextMenu)
148     ;
149 connect(ui->Qplot_PSD, SIGNAL(customContextMenuRequested(
150         QPoint)), this,
151             SLOT(on_PSD_contextMenuRequest(QPoint)));

```

```

142 // Setup the Roundness plot
143 QCPPlotTitle *Roundnesstitle = new QCPPlotTitle(ui->
144     QPlot_Roudness);
145 Roundnesstitle->setText("Sphericity Histogram");
146 Roundnesstitle->setFont(QFont("sans", 8, QFont::Bold));
147 ui->QPlot_Roudness->plotLayout()->insertRow(0);
148 ui->QPlot_Roudness->plotLayout()->addElement(0, 0,
149     Roundnesstitle);
150
151 ui->QPlot_Roudness->addGraph(ui->QPlot_Roudness->xAxis,
152                                     ui->QPlot_Roudness->yAxis2);
153 ui->QPlot_Roudness->addGraph(ui->QPlot_Roudness->xAxis,
154                                     ui->QPlot_Roudness->yAxis2);
155 ui->QPlot_Roudness->graph(0)->setPen(pdfPen);
156 ui->QPlot_Roudness->graph(1)->setPen(meanPen);
157
158 RoundnessBars =
159     new QCPBars(ui->QPlot_Roudness->xAxis, ui->
160                 QPlot_Roudness->yAxis);
161 ui->QPlot_Roudness->addPlottable(RoundnessBars);
162 RoundnessBars->setPen(binPen);
163
164 ui->QPlot_Roudness->xAxis->setAutoTicks(false);
165 ui->QPlot_Roudness->xAxis->setAutoTickLabels(false);
166 ui->QPlot_Roudness->xAxis->setTickVector(
167     QVector<double>::fromStdVector(RoundnessTicks));
168 ui->QPlot_Roudness->xAxis->setTickVectorLabels(
169     RoundnessCat);
170 ui->QPlot_Roudness->xAxis->setTickLabelRotation(30);
171 ui->QPlot_Roudness->xAxis->setSubTickCount(0);
172 ui->QPlot_Roudness->xAxis->setTickLength(0, 4);
173 ui->QPlot_Roudness->xAxis->grid()->setVisible(true);
174 ui->QPlot_Roudness->xAxis->setRange(0, 4);
175 ui->QPlot_Roudness->xAxis->setLabel("Count [-]");
176 ui->QPlot_Roudness->xAxis->setLabelFont(QFont("sans", 8,
177     QFont::Bold));
178 ui->QPlot_Roudness->xAxis->setTickLabelFont(QFont("sans",
179     8, QFont::Normal));
180 ui->QPlot_Roudness->xAxis->setPadding(25);
181 ui->QPlot_Roudness->yAxis->setLabel("Sphericity [-]");
182 ui->QPlot_Roudness->yAxis->setLabelFont(QFont("sans", 8,
183     QFont::Bold));
184
185 // Setup the angularity plot
186 QCPPlotTitle *Angularitytitle = new QCPPlotTitle(ui->
187     QPlot_Angularity);
188 Angularitytitle->setText("Angularity Histogram");
189 Angularitytitle->setFont(QFont("sans", 8, QFont::Bold));
190 ui->QPlot_Angularity->plotLayout()->insertRow(0);
191 ui->QPlot_Angularity->plotLayout()->addElement(0, 0,
192     Angularitytitle);
193
194 ui->QPlot_Angularity->addGraph(ui->QPlot_Angularity->xAxis,
195                                     ui->QPlot_Angularity->
196                                     yAxis2);

```

```

187     ui->QPlot_Angularity->addGraph(ui->QPlot_Angularity->xAxis
188             ,
189             ui->QPlot_Angularity->
190             yAxis2);
191     AngularityBars =
192         new QCPlotBars(ui->QPlot_Angularity->xAxis, ui->
193             QPlot_Angularity->yAxis);
194     ui->QPlot_Angularity->addPlottable(AngularityBars);
195     AngularityBars->setPen(binPen);
196
197     ui->QPlot_Angularity->xAxis->setAutoTicks(false);
198     ui->QPlot_Angularity->xAxis->setAutoTickLabels(false);
199     ui->QPlot_Angularity->xAxis->setTickVector(
200         QVector<double>::fromStdVector(AngularityTicks));
201     ui->QPlot_Angularity->xAxis->setTickVectorLabels(
202         AngularityCat);
203     ui->QPlot_Angularity->xAxis->setTickLabelRotation(30);
204     ui->QPlot_Angularity->xAxis->setSubTickCount(0);
205     ui->QPlot_Angularity->xAxis->setTickLength(0, 4);
206     ui->QPlot_Angularity->xAxis->grid()->setVisible(true);
207     ui->QPlot_Angularity->xAxis->setRange(0, 7);
208     ui->QPlot_Angularity->xAxis->setLabel("Count [-]");
209     ui->QPlot_Angularity->xAxis->setLabelFont(QFont("sans", 8,
210         QFont::Bold));
211     ui->QPlot_Angularity->xAxis->setTickLabelFont(
212         QFont("sans", 8, QFont::Normal));
213     ui->QPlot_Angularity->yAxis->setLabel("Sphericity [-]");
214     ui->QPlot_Angularity->yAxis->setLabelFont(QFont("sans", 8,
215         QFont::Bold));
216     ui->QPlot_Angularity->graph(0)->setPen(pdfPen);
217     ui->QPlot_Angularity->graph(1)->setPen(meanPen);
218
219     // Setup the Amplitude diagram
220     QCPlotTitle *Amptitle = new QCPlotTitle(ui->QPlot_Amp);
221     Amptitle->setText("Fast Fourier Amplitude for the current
222         particle");
223     Amptitle->setFont(QFont("sans", 8, QFont::Bold));
224     ui->QPlot_Amp->plotLayout()->insertRow(0);
225     ui->QPlot_Amp->plotLayout()->addElement(0, 0, Amptitle);
226
227     ui->QPlot_Amp->addGraph(ui->QPlot_Amp->xAxis, ui->
228         QPlot_Amp->yAxis);
229
230     ui->QPlot_Amp->xAxis->setTickLabelRotation(30);
231     ui->QPlot_Amp->xAxis->setSubTickCount(0);
232     ui->QPlot_Amp->xAxis->setTickLength(0, 4);
233     ui->QPlot_Amp->xAxis->grid()->setVisible(true);
234     ui->QPlot_Amp->xAxis->setRange(0, 512);
235     ui->QPlot_Amp->xAxis->setLabel("Frequency [-]");
236     ui->QPlot_Amp->xAxis->setLabelFont(QFont("sans", 8, QFont
237         ::Bold));
238     ui->QPlot_Amp->xAxis->setTickLabelFont(QFont("sans", 8,
239         QFont::Normal));
240     ui->QPlot_Amp->yAxis->setLabel("Amplitude [-]");
241     ui->QPlot_Amp->yAxis->setLabelFont(QFont("sans", 8, QFont
242         ::Bold));

```

```
232     ui->QPlot_Amp->yAxis->setScaleType(QCPAxis::stLogarithmic)
233     ;
234     ui->QPlot_Amp->graph()->setPen(binPen);
235     ui->QPlot_Amp->graph()->setLineStyle(QCPGraph::lsLine);
236     ui->QPlot_Amp->graph()->setBrush(QBrush(QColor
237         (50,50,200,40)));
238
239     // Connect the Particle display and Selector
240     connect(ui->widget_ParticleSelector, SIGNAL(valueChanged(
241         int)), this,
242             SLOT(on_Classification_changed(int)));
243     connect(ui->widget_ParticleDisplay, SIGNAL(
244         shapeClassificationChanged(int)),
245             ui->widget_ParticleSelector, SLOT(setValue(int)));
246     connect(ui->widget_ParticleDisplay, SIGNAL(particleDeleted
247         ()), this,
248             SLOT(on_particle_deleted()));
249     connect(ui->widget_ParticleDisplay, SIGNAL(particleChanged
250         (int)), this,
251             SLOT(on_particleChanged(int)));
252 }
253
254 VSAMainWindow::~VSAMainWindow() {
255     delete Settings;
256     delete Microscope;
257     delete Analyzer;
258     delete Sample;
259     delete Images;
260
261     delete settingsWindow;
262     delete nnWindow;
263     delete CamError;
264     delete SaveMeMessage;
265     delete BacklightMessage;
266     delete ShakeItBabyMessage;
267     delete ui;
268 }
269
270 void VSAMainWindow::on_actionSettings_triggered() {
271     settingsWindow->openTab(0);
272     settingsWindow->show();
273 }
274
275 void VSAMainWindow::on_analyzer_finished() {
276     if (!ParticleDisplayerFilled && Sample->ParticlePopulation
277         .size() > 0) {
278         ui->widget_ParticleDisplay->SetSample(Sample);
279     }
280     SetPSDgraph();
```

```

280     setRoundnessHistogram();
281     setAngularityHistogram();
282     ParticleDisplayerFilled = true;
283 }
284
285 void VSAMainWindow::SetPSDgraph() {
286     std::vector<double> stdPSDvalue(Sample->PSD.CFD, Sample->
287         PSD.CFD + 15);
288     ui->Qplot_PSD->graph(0)->setData(PSDTicks, stdPSDvalue);
289     ui->Qplot_PSD->replot();
290 }
291
292 void VSAMainWindow::setRoundnessHistogram() {
293     // Setup the Histogram bins
294     std::vector<double> stdValues(Sample->Roundness.bins + 1,
295                                     Sample->Roundness.bins + 4);
296
297     ui->QPlot_Roudness->yAxis->setRange(
298         0, static_cast<double>(Sample->Roundness.
299             HighestFrequency())));
300     RoundnessBars->setData(RoundnessTicks, stdValues);
301
302     // Setup the Prediction Density Function
303     std::vector<double> stdPDFkey, stdPDFvalues;
304     Sample->Roundness.GetPDFfunction(stdPDFkey, stdPDFvalues,
305         0.2, 0, 4);
306     ui->QPlot_Roudness->graph(0)->setData(stdPDFkey,
307         stdPDFvalues);
308     ui->QPlot_Roudness->yAxis2->setRange(0, Sample->Roundness.
309         HighestPDF);
310
311     // Setup the mean Vector
312     QVector<double> meanKey(2, static_cast<double>(Sample->
313         Roundness.Mean));
314     QVector<double> meanValue(2);
315     meanValue[0] = 0;
316     meanValue[1] = Sample->Roundness.HighestPDF;
317     ui->QPlot_Roudness->graph(1)->setData(meanKey, meanValue);
318     ui->QPlot_Roudness->replot();
319 }
320
321 void VSAMainWindow::setAngularityHistogram() {
322     // Setup the Histogram bins
323     std::vector<double> stdValues(Sample->Angularity.bins + 1,
324                                     Sample->Angularity.bins + 7)
325                                     ;
326
327     ui->QPlot_Angularity->yAxis->setRange(
328         0, static_cast<double>(Sample->Angularity.
329             HighestFrequency()));
330     AngularityBars->setData(AngularityTicks, stdValues);
331
332     // Setup the Prediction Density Function
333     std::vector<double> stdPDFkey, stdPDFvalues;
334     Sample->Angularity.GetPDFfunction(stdPDFkey, stdPDFvalues,
335         0.2, 0, 7);

```

```
327     ui->QPlot_Angularity->graph(0)->setData(stdPDFkey,
328         stdPDFvalues);
329     ui->QPlot_Angularity->yAxis2->setRange(0, Sample->
330         Angularity.HighestPDF);
329
330     // Setup the mean Vector
331     QVector<double> meanKey(2, static_cast<double>(Sample->
332         Angularity.Mean));
332     QVector<double> meanValue(2);
333     meanValue[0] = 0;
334     meanValue[1] = Sample->Angularity.HighestPDF;
335     ui->QPlot_Angularity->graph(1)->setData(meanKey, meanValue
336         );
336     ui->QPlot_Angularity->replot();
337 }
338
339 void VSAMainWindow::setAmpgraph() {
340     ui->QPlot_Amp->graph(0)->clearData();
341     ComplexVect_t *comp =
342         &ui->widget_ParticleDisplay->SelectedParticle->
343             FFDescriptors;
343     uint32_t count = (comp->size() > 64) ? 64 : comp->size();
344     for (uint32_t i = 0; i < count; i++) {
345         ui->QPlot_Amp->graph(0)->addData(i, abs(comp->at(i)));
346     }
347     ui->QPlot_Amp->rescaleAxes();
348     ui->QPlot_Amp->replot();
349 }
350
351 void VSAMainWindow::on_particleChanged(int newPart) {
352     setAmpgraph(); }
353
354 void VSAMainWindow::on_actionNeuralNet_triggered() {
355     if (nnWindow != nullptr) {
356         nnWindow =
357             new DialogNN(this, &Analyzer->NeuralNet, Settings,
358                         settingsWindow);
358     }
359     nnWindow->show();
360 }
361
362 void VSAMainWindow::on_actionNewSample_triggered() {
363     if (Sample->ChangesSinceLastSave) {
364         if (SaveMeMessage->exec() == QMessageBox::Abort) {
365             return;
366         }
367         delete Sample;
368         Sample = nullptr;
369         delete Images;
370         Images = nullptr;
371         Sample = new SoilAnalyzer::Sample;
372         Images = new SoilAnalyzer::Analyzer::Images_t;
373         TakeSnapShots();
374         try {
375             Analyzer->Analyse(Images, Sample, Settings);
```

```

376     } catch (SoilAnalyzer::Exception::SoilAnalyzerException &e
377         ) {
378     if (*e.id() == EXCEPTION_NO_SNAPSHOTS_NR) {
379         CamError->showMessage(
380             "No images acquired! Check your microscope settings
381             ");
382     }
383     Sample->ChangesSinceLastSave = true;
384     if (Sample->ParticlePopulation.size() > 0) {
385         ui->widget_ParticleSelector->setDisabled(
386             false,
387             ui->widget_ParticleDisplay->SelectedParticle->
388                 Classification.Category);
389     }
390 }
391 void VSAMainWindow::TakeSnapShots() {
392     Analyzer->SIfactorDet = true; // remember to remove
393     if (!Analyzer->SIfactorDet) {
394         QMessageBox *DetSIFactor = new QMessageBox(this);
395         DetSIFactor->setText("Put calibration Disc under the
396             microscope");
397         DetSIFactor->exec();
398         on_actionCalibrate_triggered();
399         DetSIFactor->setText("Place sample under the microscope"
400             );
401         DetSIFactor->exec();
402     }
403     if (Settings->useBacklightProjection && !Settings->useHDR)
404     {
405         for (uint32_t i = 0; i < Settings->StandardNumberOfShots
406             ; i++) {
407             SoilAnalyzer::Analyzer::Image_t newShot;
408             newShot.SIPixelFactor = Analyzer->CurrentSIfactor;
409             Microscope->GetFrame(newShot.FrontLight);
410             BacklightMessage->exec();
411             Microscope->GetFrame(newShot.BackLight);
412             Images->push_back(newShot);
413             QString ShakeMsg = "Shake it baby! ";
414             int number = Settings->StandardNumberOfShots - i;
415             ShakeMsg.append(QString::number(number));
416             ShakeMsg.append(" to go!");
417             ShakeItBabyMessage->setText(ShakeMsg);
418             ShakeItBabyMessage->exec();
419     }
420     } else if (Settings->useBacklightProjection && Settings->
421         useHDR) {
422         for (uint32_t i = 0; i < Settings->StandardNumberOfShots
423             ; i++) {
424             SoilAnalyzer::Analyzer::Image_t newShot;
425             newShot.SIPixelFactor = Analyzer->CurrentSIfactor;
426             Microscope->GetHDRFrame(newShot.FrontLight, Settings->
427                 HDRframes);
428             BacklightMessage->exec();
429     }
430 }

```

```

422     Microscope->GetFrame(newShot.BackLight);
423     Images->push_back(newShot);
424     QString ShakeMsg = "Shake it baby! ";
425     int number = Settings->StandardNumberOfShots - i - 1;
426     ShakeMsg.append(QString::number(number));
427     ShakeMsg.append(" to go!");
428     ShakeItBabyMessage->setText(ShakeMsg);
429     ShakeItBabyMessage->exec();
430 }
431 } else if (!Settings->useBacklightProjection && Settings->
432     useHDR) {
433     for (uint32_t i = 0; i < Settings->StandardNumberOfShots
434         ; i++) {
435         SoilAnalyzer::Analyzer::Image_t newShot;
436         newShot.SIPixelFactor = Analyzer->CurrentSIfactor;
437         Microscope->GetHDRFrame(newShot.FrontLight, Settings->
438             HDRframes);
439         Images->push_back(newShot);
440         QString ShakeMsg = "Shake it baby! ";
441         int number = Settings->StandardNumberOfShots - i - 1;
442         ShakeMsg.append(QString::number(number));
443         ShakeMsg.append(" to go!");
444         ShakeItBabyMessage->setText(ShakeMsg);
445         ShakeItBabyMessage->exec();
446     }
447 } else if (!Settings->useBacklightProjection && !Settings
448     ->useHDR) {
449     for (uint32_t i = 0; i < Settings->StandardNumberOfShots
450         ; i++) {
451         SoilAnalyzer::Analyzer::Image_t newShot;
452         newShot.SIPixelFactor = Analyzer->CurrentSIfactor;
453         Microscope->GetFrame(newShot.FrontLight);
454         Images->push_back(newShot);
455         QString ShakeMsg = "Shake it baby! ";
456         int number = Settings->StandardNumberOfShots - i - 1;
457         ShakeMsg.append(QString::number(number));
458         ShakeMsg.append(" to go!");
459         ShakeItBabyMessage->setText(ShakeMsg);
460         ShakeItBabyMessage->exec();
461     }
462 }
463 void VSAMainWindow::on_actionSaveSample_triggered() {
464     QString fn = QFileDialog::getSaveFileName(
465         this, tr("Save Sample"), QString::fromStdString(
466             Settings->SampleFolder),
467             tr("Sample (*.VSA)"));
468     if (!fn.isEmpty()) {
469         if (!fn.contains(tr(".VSA"))) {
470             fn.append(tr(".VSA"));
471         }
472         Sample->IsLoadedFromDisk = true;
473         Sample->ChangesSinceLastSave = false;
474         Sample->Save(fn.toStdString());
475         qDebug() << "Saving finished";

```

```

472     }
473 }
474
475 void VSAMainWindow::on_actionLoadSample_triggered() {
476     if (Sample->ChangesSinceLastSave) {
477         if (SaveMeMessage->exec() == QMessageBox::Abort) {
478             return;
479         }
480     }
481
482     QString fn = QFileDialog::getOpenFileName(
483         this, tr("Open Sample"), QString::fromStdString(
484             Settings->SampleFolder),
485         tr("Sample (*.VSA)"));
486     if (!fn.isEmpty()) {
487         if (!fn.contains(tr(".VSA")))
488             fn.append(tr(".VSA"));
489
490         delete Sample;
491         Sample = nullptr;
492         delete Images;
493         Images = nullptr;
494         Sample = new SoilAnalyzer::Sample;
495         Images = new SoilAnalyzer::Analyzer::Images_t;
496         try {
497             Sample->Load(fn.toStdString());
498         } catch (boost::archive::archive_exception &e) {
499             // qDebug() << *e.what();
500         }
501         ParticleDisplayerFilled = false;
502         Sample->Angularity.Data = Sample->GetAngularityVector()
503             ->data();
504         Sample->Roundness.Data = Sample->GetRoundnessVector()->
505             data();
506         Sample->PSD.Data = Sample->GetPSDVector()->data();
507         Analyzer->Results = Sample;
508         on_analyzer_finished();
509         ui->widget_ParticleSelector->setDisabled(
510             false,
511             ui->widget_ParticleDisplay->SelectedParticle->
512                 Classification.Category);
513     }
514 }
515
516 void VSAMainWindow::on_actionUseLearning_toggled(bool arg1)
517 {
518     Analyzer->PredictShape = !arg1;
519 }
520
521 void VSAMainWindow::on_actionCalibrate_triggered() {
522     cv::Mat calib;
523     Microscope->GetFrame(calib);
524     Analyzer->CalibrateSI(16.25, calib);
525 }
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```

```

522 void VSAMainWindow::on_Classification_changed(int newValue)
523 {
524     uint8_t *Cat =
525         &ui->widget_ParticleDisplay->SelectedParticle->
526             Classification.Category;
527     if ((*Cat - 1) % 6 != (newValue - 1) % 6) {
528         Sample->ParticleChangedStateAngularity = true;
529     }
530     if ((*Cat - 1) / 6 != (newValue - 1) / 6) {
531         Sample->ParticleChangedStateRoundness = true;
532     }
533     ui->widget_ParticleDisplay->SelectedParticle->
534         Classification.Category =
535             newValue;
536     ui->widget_ParticleDisplay->SelectedParticle->
537         Classification.ManualSet = true;
538     Sample->ChangesSinceLastSave = true;
539     Analyzer->Analyse();
540     ui->widget_ParticleDisplay->next();
541 }
542
543 void VSAMainWindow::on_particle_deleted() { Analyzer->
544     Analyse(); }
545
546 void VSAMainWindow::on_actionAutomatic_Shape_Pediction_triggered(bool checked)
547 {
548     Settings->PredictTheShape = checked;
549 }
550
551 void VSAMainWindow::on_reset_graph(QMouseEvent *e) {
552     ui->Qplot_PSD->xAxis->setRange(0, 10);
553     ui->Qplot_PSD->yAxis->setRange(0, 100);
554     ui->Qplot_PSD->setInteractions(QCP::iRangeDrag | QCP::iRangeZoom);
555     ui->Qplot_PSD->replot();
556 }
557
558 void VSAMainWindow::on_actionReport_Generator_triggered() {
559     if (ReportGenWindow == nullptr) {
560         ReportGenWindow =
561             new QReportGenerator(this, Sample, Settings, ui->
562                 Qplot_PSD,
563                 ui->QPlot_Roudness, ui->
564                 QPlot_Angularity);
565     }
566     ReportGenWindow->show();
567 }
568
569 void VSAMainWindow::on_PSD_contextMenuRequest(QPoint point)
570 {
571     QMenu *menu = new QMenu(this);
572     menu->setAttribute(Qt::WA_DeleteOnClose);
573
574     menu->addAction("Compare against...", this, SLOT(
575         on_compare_against()));

```

```

566     menu->addAction("Restore", this, SLOT(on_restore_PSD()));
567     menu->popup(ui->Qplot_PSD->mapToGlobal(point));
568 }
569
570 void VSAMainWindow::on_compare_against() {
571     QString fn = QFileDialog::getOpenFileName(
572         this, tr("Open CSV"), QString::fromStdString(Settings
573             ->SampleFolder),
574         tr("Comma Separated Value (*.csv)"));
575     if (!fn.isEmpty()) {
576         if (!fn.contains(tr(".csv")))
577             fn.append(tr(".csv"));
578     }
579     if (ui->Qplot_PSD->graphCount() > 1) {
580         ui->Qplot_PSD->legend->removeItem(1);
581         ui->Qplot_PSD->removeGraph(1);
582     }
583
584     QStringList rows;
585     QStringList cellValues;
586
587     QFile f(fn);
588     if (f.open(QIODevice::ReadOnly)) {
589         QString data;
590         data = f.readAll();
591         rows = data.split('\n');
592         f.close();
593         for (uint32_t i = 0; i < rows.size(); i++) {
594             QStringList cols = rows[i].split(',');
595             for (uint32_t j = 0; j < cols.size(); j++) {
596                 cellValues.append(cols[j]);
597             }
598         }
599         cellValues.removeLast();
600
601         std::vector<double> compValues(15);
602         for (uint32_t i = 0; i < cellValues.size(); i += 4) {
603             bool conversionSucces = false;
604             double binValue = cellValues[i].toDouble(&
605                 conversionSucces);
606             qDebug() << cellValues[i + 3];
607             if (conversionSucces) {
608                 for (uint32_t j = 0; j < 15; j++) {
609                     if (binValue == PSDTicks[j]) {
610                         compValues[j] = cellValues[i + 3].toDouble();
611                     }
612                 }
613             }
614             ui->Qplot_PSD->addGraph(ui->Qplot_PSD->xAxis, ui->
615                 Qplot_PSD->yAxis);
616             ui->Qplot_PSD->graph(1)->setData(PSDTicks, compValues)
617             ;
618             QPen compPen;
619             compPen.setColor(QColor("darkBlue"));

```

```
618     compPen.setStyle(Qt::DashLine);
619     compPen.setWidthF(1);
620     ui->Qplot_PSD->graph(1)->setPen(compPen);
621     ui->Qplot_PSD->graph(1)->setName("Compared Particle
622         Size Distribution");
623     ui->Qplot_PSD->graph(1)->addToLegend();
624     ui->Qplot_PSD->replot();
625 }
626 }
627
628 void VSAMainWindow::on_restore_PSD() {
629     if (ui->Qplot_PSD->graphCount() > 1) {
630         ui->Qplot_PSD->legend->removeItem(1);
631         ui->Qplot_PSD->removeGraph(1);
632     }
633     on_reset_graph(nullptr);
634 }
```

Dialog window Class

```
1 #ifndef DIALOGSETTINGS_H
2 #define DIALOGSETTINGS_H
3
4 #include <QDialog>
5 #include <soilsettings.h>
6 #include <QFileDialog>
7 #include <QString>
8 #include <QDir>
9 #include <QSlider>
10 #include "Hardware.h"
11
12 namespace Ui {
13 class DialogSettings;
14 }
15
16 class DialogSettings : public QDialog {
17     Q_OBJECT
18
19 public:
20     SoilAnalyzer::SoilSettings *Settings = nullptr;
21     explicit DialogSettings(QWidget *parent = 0,
22                             SoilAnalyzer::SoilSettings *
23                             settings = nullptr,
24                             Hardware::Microscope *microscope =
25                             nullptr,
26                             SoilMath::NN *nn = nullptr, bool
27                             openNN = false);
28     ~DialogSettings();
29
30     void openTab(int newValue);
31
32     void on_pushButton_RestoreDefault_clicked();
33
34     void on_pushButton_Open_clicked();
35
36     void on_pushButton_Save_clicked();
37
38     void on_checkBox_Backlight_clicked(bool checked);
39
40     void on_comboBox_Microscopes_currentIndexChanged(const
41             QString &arg1);
42
43     void on_comboBox_Resolution_currentIndexChanged(int index)
44             ;
45
46     void on_checkBox_useHDR_clicked(bool checked);
47
48     void on_spinBox_NoFrames_editingFinished();
49
50     void on_doubleSpinBox_LightLevel_editingFinished();
51
52     void on_checkBox_useRainbow_clicked(bool checked);
```

```
50 void on_checkBox_InvertEncoder_clicked(bool checked);
51 void on_checkBox_useCUDA_clicked(bool checked);
52 void on_horizontalSlider_BrightFront_valueChanged(int
53     value);
54 void on_horizontalSlider_ContrastFront_valueChanged(int
55     value);
56 void on_horizontalSlider_SaturationFront_valueChanged(int
57     value);
58 void on_horizontalSlider_HueFront_valueChanged(int value);
59 void on_horizontalSlider_SharpnessFront_valueChanged(int
60     value);
61 void on_horizontalSlider_BrightProj_valueChanged(int value
62     );
63 void on_horizontalSlider_ContrastProj_valueChanged(int
64     value);
65 void on_horizontalSlider_SaturationProj_valueChanged(int
66     value);
67 void on_horizontalSlider_HueProj_valueChanged(int value);
68 void on_horizontalSlider_SharpnessProj_valueChanged(int
69     value);
70 void on_cb_use_adaptContrast_3_clicked(bool checked);
71 void on_cb_useBlur_3_clicked(bool checked);
72 void on_rb_useDark_3_toggled(bool checked);
73 void on_cb_ignoreBorder_3_clicked(bool checked);
74 void on_cb_fillHoles_3_clicked(bool checked);
75 void on_sb_sigmaFactor_3_editingFinished();
76 void on_rb_useOpen_3_clicked(bool checked);
77 void on_rb_useClose_3_clicked(bool checked);
78 void on_rb_useErode_3_clicked(bool checked);
79 void on_rb_useDilate_3_clicked(bool checked);
80 void on_sb_morphMask_3_editingFinished();
81 void on_spinBox_MaxGen_editingFinished();
82
```

```

98     void on_spinBox_PopSize_editingFinished();
99
100    void on_doubleSpinBox_MutationRate_editingFinished();
101
102    void on_spinBox_Elitisme_editingFinished();
103
104    void on_doubleSpinBox_endError_editingFinished();
105
106    void on_doubleSpinBox_maxWeight_editingFinished();
107
108    void on_doubleSpinBox_MinWeight_editingFinished();
109
110    void on_doubleSpinBox_Beta_editingFinished();
111
112    void on_spinBox_InputNeurons_editingFinished();
113
114    void on_spinBox_HiddenNeurons_editingFinished();
115
116    void on_spinBox_OutputNeurons_editingFinished();
117
118    void on_pushButton_selectSampleFolder_clicked();
119
120    void on_pushButton_SelectSettingFolder_clicked();
121
122    void on_pushButton_SelectNNFolder_clicked();
123
124    void on_pushButton_SelectNN_clicked();
125
126    void on_spinBox_NoShots_editingFinished();
127
128    void on_checkBox_PredictShape_clicked(bool checked);
129
130    void on_checkBox_revolt_clicked(bool checked);
131
132 private:
133     Ui::DialogSettings *ui;
134     Hardware::Microscope *Microscope;
135     SoilMath::NN *NN;
136     bool initfase = true;
137     void SetCamControl(Hardware::Microscope::Cam_t *
138                         selectedCam,
139                         QSlider *Brightness, QSlider *Contrast,
140                         QSlider *Saturation, QSlider *Hue,
141                         QSlider *Sharpness);
142
143 #endif // DIALOGSETTINGS_H

```

```

1 #include "dialogsettings.h"
2 #include "ui_dialogsettings.h"
3 #include <opencv2/core.hpp>
4
5 DialogSettings::DialogSettings(QWidget *parent,
6                                 SoilAnalyzer::SoilSettings *
7                                 settings,

```

```
7             Hardware::Microscope *
8             microscope,
9             SoilMath::NN *nn, bool openNN
10            )
11
12     : QDialog(parent), ui(new Ui::DialogSettings) {
13     ui->setupUi(this);
14
15     if (settings == nullptr) {
16         settings = new SoilAnalyzer::SoilSettings;
17     }
18
19     Settings = settings;
20
21     if (microscope == nullptr) {
22         microscope = new Hardware::Microscope;
23     }
24
25     if (nn == nullptr) {
26         nn = new SoilMath::NN;
27     }
28
29     // Setup the Hardware tab
30
31     Microscope = microscope;
32
33     QStringList Cams;
34     for (uint32_t i = 0; i < Microscope->AvailableCams.size();
35           i++) {
36         Cams << Microscope->AvailableCams[i].Name.c_str();
37     }
38
39     ui->comboBox_Microscopes->addItems(Cams);
40
41     ui->comboBox_Microscopes->setcurrentIndex(Microscope->
42
43         SelectedCam->ID);
44
45     QStringList Resolutions;
46     for (uint32_t i = 0; i < Microscope->SelectedCam->
47
48         Resolutions.size(); i++) {
49         Resolutions << Microscope->SelectedCam->Resolutions[i].
50             to_string().c_str();
51     }
52
53     ui->comboBox_Resolution->addItems(Resolutions);
54
55     ui->comboBox_Resolution->setcurrentIndex(
56         Microscope->SelectedCam->SelectedResolution->ID);
57
58     ui->spinBox_NoShots->setValue(Settings->
59
60         StandardNumberOfShots);
61
62     ui->spinBox_NoFrames->setValue(Settings->HDRframes);
63
64     ui->spinBox_NoFrames->setDisabled(true);
65
66     ui->label_nf->setDisabled(true);
67
68     ui->checkBox_Backlight->setChecked(Settings->
69
70         useBacklightProjection);
71
72     ui->tabWidget_Hardware->setTabEnabled(2, Settings->
73
74         useBacklightProjection);
75
76     ui->checkBox_InvertEncoder->setChecked(Settings->encInv);
77
78     ui->checkBox_useCUDA->setChecked(Settings->useCUDA);
79
80     Settings->useCUDA = false;
81
82     ui->checkBox_useCUDA->setDisabled(true);
83
84 }
```

```
54     ui->checkBox_useHDR->setChecked(Settings->useHDR);
55     ui->checkBox_useRainbow->setChecked(Settings->
56         enableRainbow);
57     // Get system info
58     struct utsname unameData;
59     uname(&unameData);
60
61     ui->label_machinename->setText(tr(unameData.machine));
62     ui->label_nodename->setText(tr(unameData.nodename));
63     ui->label_releasename->setText(tr(unameData.release));
64     ui->label_systemname->setText(tr(unameData.sysname));
65     ui->label_versionname->setText(tr(unameData.version));
66     if (Microscope->RunEnv == Hardware::Microscope::X64) {
67         ui->checkBox_useRainbow->setDisabled(true);
68         ui->checkBox_InvertEncoder->setDisabled(true);
69         ui->doubleSpinBox_LightLevel->setDisabled(true);
70         ui->label_ll->setDisabled(true);
71     }
72
73     SetCamControl(
74         Microscope->SelectedCam, ui->
75             horizontalSlider_BrightFront,
76             ui->horizontalSlider_ContrastFront, ui->
77                 horizontalSlider_SaturationFront,
78                 ui->horizontalSlider_HueFront, ui->
79                     horizontalSlider_SharpnessFront);
80     ui->horizontalSlider_BrightFront->setValue(Settings->
81         Brightness_front);
82     ui->horizontalSlider_ContrastFront->setValue(Settings->
83         Contrast_front);
84     ui->horizontalSlider_HueFront->setValue(Settings->
85         Hue_front);
86     ui->horizontalSlider_SaturationFront->setValue(Settings->
87         Saturation_front);
88     ui->horizontalSlider_SharpnessFront->setValue(Settings->
89         Sharpness_front);
90
91     SetCamControl(
92         Microscope->SelectedCam, ui->
93             horizontalSlider_BrightProj,
94             ui->horizontalSlider_ContrastProj, ui->
95                 horizontalSlider_SaturationProj,
96                 ui->horizontalSlider_HueProj, ui->
97                     horizontalSlider_SharpnessProj);
98     ui->horizontalSlider_BrightProj->setValue(Settings->
99         Brightness_proj);
100    ui->horizontalSlider_ContrastProj->setValue(Settings->
101        Contrast_proj);
102    ui->horizontalSlider_HueProj->setValue(Settings->Hue_proj)
103        ;
104    ui->horizontalSlider_SaturationProj->setValue(Settings->
105        Saturation_proj);
106    ui->horizontalSlider_SharpnessProj->setValue(Settings->
107        Sharpness_proj);
```

```
93 // Setup the Vision tab
94 ui->cb_fillHoles_3->setChecked(Settings->fillHoles);
95 ui->cb_ignoreBorder_3->setChecked(Settings->
96     ignorePartialBorderParticles);
97 ui->cb_useBlur_3->setChecked(Settings->useBlur);
98 if (!Settings->useBlur) {
99     ui->sb_blurMask_3->setEnabled(false);
100 }
101 ui->cb_use_adaptContrast_3->setChecked(Settings->
102     useAdaptiveContrast);
103 if (!Settings->useAdaptiveContrast) {
104     ui->sb_adaptContrastFactor_3->setEnabled(false);
105     ui->sb_adaptContrKernel_3->setEnabled(false);
106 }
107 switch (Settings->typeOfObjectsSegmented) {
108     case Vision::Segment::Bright:
109         ui->rb_useDark_3->setChecked(false);
110         ui->rb_useLight_3->setChecked(true);
111         break;
112     case Vision::Segment::Dark:
113         ui->rb_useDark_3->setChecked(true);
114         ui->rb_useLight_3->setChecked(false);
115         break;
116     switch (Settings->morphFilterType) {
117         case Vision::MorphologicalFilter::CLOSE:
118             ui->rb_useClose_3->setChecked(true);
119             ui->rb_useDilate_3->setChecked(false);
120             ui->rb_useErode_3->setChecked(false);
121             ui->rb_useOpen_3->setChecked(false);
122             break;
123         case Vision::MorphologicalFilter::OPEN:
124             ui->rb_useClose_3->setChecked(false);
125             ui->rb_useDilate_3->setChecked(false);
126             ui->rb_useErode_3->setChecked(false);
127             ui->rb_useOpen_3->setChecked(true);
128             break;
129         case Vision::MorphologicalFilter::ERODE:
130             ui->rb_useClose_3->setChecked(false);
131             ui->rb_useDilate_3->setChecked(false);
132             ui->rb_useErode_3->setChecked(true);
133             ui->rb_useOpen_3->setChecked(false);
134             break;
135         case Vision::MorphologicalFilter::DILATE:
136             ui->rb_useClose_3->setChecked(false);
137             ui->rb_useDilate_3->setChecked(true);
138             ui->rb_useErode_3->setChecked(false);
139             ui->rb_useOpen_3->setChecked(false);
140             break;
141     }
142     ui->sb_adaptContrastFactor_3->setValue(Settings->
143         adaptContrastKernelFactor);
144     ui->sb_adaptContrKernel_3->setValue(Settings->
145         adaptContrastKernelSize);
146     ui->sb_blurMask_3->setValue(Settings->blurKernelSize);
```

```

145     ui->sb_morphMask_3->setValue(Settings->filterMaskSize);
146     ui->sb_sigmaFactor_3->setValue(Settings->sigmaFactor);
147
148     // Setup the neural Network tab
149     NN = nn;
150     QPixmap NNpix("Images/feedforwardnetwork2.png");
151     ui->label_NNimage->setPixmap(NNpix);
152     ui->label_NNimage->setScaledContents(true);
153
154     ui->spinBox_InputNeurons->setValue(NN->GetInputNeurons());
155     ui->spinBox_HiddenNeurons->setValue(NN->GetHiddenNeurons()
156         );
156     ui->spinBox_OutputNeurons->setValue(NN->GetOutputNeurons()
157         );
157     ui->spinBox_Elitisme->setValue(NN->ElitismeUsedByGA);
158     ui->spinBox_MaxGen->setValue(NN->MaxGenUsedByGA);
159     ui->spinBox_PopSize->setValue(NN->PopulationSizeUsedByGA);
160     ui->doubleSpinBox_endError->setValue(NN->EndErrorUsedByGA)
161         ;
161     ui->doubleSpinBox_MutationRate->setValue(NN->
162         MutationrateUsedByGA);
162     ui->doubleSpinBox_Beta->setValue(NN->GetBeta());
163     ui->doubleSpinBox_maxWeight->setValue(NN->
164         MaxWeightUsedByGA);
164     ui->doubleSpinBox_MinWeight->setValue(NN->
165         MinWeightUsedByGA);
165     ui->checkBox_PredictShape->setChecked(Settings->
166         PredictTheShape);
166     ui->checkBox_revolt->setChecked(Settings->Revolution);
167
168     // Setup the preference tab
169     ui->lineEdit_NeuralNetFolder->setText(
170         QString::fromStdString(Settings->NNFolder));
171     ui->lineEdit_Printer->setText(
172         QString::fromStdString(Settings->StandardPrinter));
173     ui->lineEdit_Samplefolder->setText(
174         QString::fromStdString(Settings->SampleFolder));
175     ui->lineEdit_SendTo->setText(
176         (QString::fromStdString(Settings->StandardSentTo)));
177     ui->lineEdit_SettingFolder->setText(
178         QString::fromStdString(Settings->SettingsFolder));
179     ui->lineEdit__NeuralNet->setText(
180         QString::fromStdString(Settings->NNlocation));
181
182     if (openNN) {
183         ui->tabWidget->setcurrentIndex(3);
184     }
185     initfase = false;
186 }
187
188 DialogSettings::~DialogSettings() { delete ui; }
189
190 void DialogSettings::openTab(int newValue) {
191     if (newValue > ui->tabWidget->count()) {
192         ui->tabWidget->setcurrentIndex(newValue);
193     }

```

```
194 }
195
196 void DialogSettings::on_pushButton_RestoreDefault_clicked()
197 {
198     Settings->LoadSettings("Settings/Default.ini");
199 }
200
201 void DialogSettings::on_pushButton_Open_clicked() {
202     QString fn = QFileDialog::getOpenFileName(
203         this, tr("Open Settings"), QDir::homePath(), tr(
204             "Settings (*.ini)"));
205     if (!fn.isEmpty()) {
206         if (!fn.contains(tr(".ini")))
207             fn.append(tr(".ini"));
208     }
209     Settings->LoadSettings(fn.toStdString());
210 }
211
212 void DialogSettings::on_pushButton_Save_clicked() {
213     QString fn = QFileDialog::getSaveFileName(
214         this, tr("Save Settings"), QDir::homePath(), tr(
215             "Settings (*.ini)"));
216     if (!fn.isEmpty()) {
217         if (!fn.contains(tr(".ini")))
218             fn.append(tr(".ini"));
219     }
220 }
221
222 void DialogSettings::on_checkBox_Backlight_clicked(bool
223     checked) {
224     ui->tabWidget_Hardware->setTabEnabled(2, checked);
225     Settings->useBacklightProjection = checked;
226 }
227
228 void DialogSettings::
229     on_comboBox_Microscopes_currentIndexChanged(
230         const QString &arg1) {
231
232     if (!initfase) {
233         std::string selectedCam = arg1.toStdString();
234         Microscope->openCam(selectedCam);
235         Settings->defaultWebcam = selectedCam;
236
237         ui->comboBox_Resolution->clear();
238         QStringList Resolutions;
239         for (uint32_t i = 0; i < Microscope->SelectedCam->
240             Resolutions.size(); i++) {
241             Resolutions
242                 << Microscope->SelectedCam->Resolutions[i].
243                     to_string().c_str();
244         }
245         ui->comboBox_Resolution->addItem(Resolutions);
246         ui->comboBox_Resolution->setCurrentIndex(
```

```

243         Microscope->SelectedCam->SelectedResolution->ID);
244     }
245 }
246
247 void DialogSettings::
248     on_comboBox_Resolution_currentIndexChanged(int index) {
249     if (!initfase) {
250         Microscope->SelectedCam->SelectedResolution =
251             &Microscope->SelectedCam->Resolutions[index];
252         Microscope->openCam(Microscope->SelectedCam);
253         Settings->selectedResolution = index;
254     }
255 }
256 void DialogSettings::on_checkBox_useHDR_clicked(bool checked)
257 {
258     ui->spinBox_NoFrames->setDisabled(!checked);
259     ui->label_nf->setDisabled(!checked);
260     Settings->useHDR = checked;
261 }
262 void DialogSettings::SetCamControl(Hardware::Microscope::
263     Cam_t *selectedCam,
264                                         QSlider *Brightness,
265                                         QSlider *Contrast,
266                                         QSlider *Saturation,
267                                         QSlider *Hue,
268                                         QSlider *Sharpness) {
269     for (uint32_t i = 0; i < selectedCam->Controls.size(); i
270        ++)
271     {
272         if (selectedCam->Controls[i].name.compare("Brightness")
273             == 0) {
274             Brightness->setMinimum(selectedCam->Controls[i].
275                 minimum);
276             Brightness->setMaximum(selectedCam->Controls[i].
277                 maximum);
278         } else if (selectedCam->Controls[i].name.compare(""
279             "Contrast") == 0) {
280             Contrast->setMinimum(selectedCam->Controls[i].minimum)
281                 ;
282             Contrast->setMaximum(selectedCam->Controls[i].maximum)
283                 ;
284         } else if (selectedCam->Controls[i].name.compare(""
285             "Saturation") == 0) {
286             Saturation->setMinimum(selectedCam->Controls[i].
287                 minimum);
288             Saturation->setMaximum(selectedCam->Controls[i].
289                 maximum);
290         } else if (selectedCam->Controls[i].name.compare("Hue")
291             == 0) {
292             Hue->setMinimum(selectedCam->Controls[i].minimum);
293             Hue->setMaximum(selectedCam->Controls[i].maximum);
294         } else if (selectedCam->Controls[i].name.compare(""
295             "Sharpness") == 0) {
296             Sharpness->setMinimum(selectedCam->Controls[i].minimum
297                 );
298         }
299     }
300 }

```

```
281     Sharpness->setMaximum(selectedCam->Controls[i].maximum
282     );
283 }
284 }
285
286 void DialogSettings::on_spinBox_NoFrames_editingFinished() {
287     Settings->HDRframes = ui->spinBox_NoFrames->value();
288 }
289
290 void DialogSettings::
291     on_doubleSpinBox_LightLevel_editingFinished() {
292     Settings->lightLevel =
293         static_cast<float>(ui->doubleSpinBox_LightLevel->value
294         ());
295 }
296
297 void DialogSettings::on_checkBox_useRainbow_clicked(bool
298     checked) {
299     Settings->enableRainbow = checked;
300 }
301
302 void DialogSettings::on_checkBox_InvertEncoder_clicked(bool
303     checked) {
304     Settings->encInv = checked;
305 }
306
307 void DialogSettings::
308     on_horizontalSlider_BrightFront_valueChanged(int value) {
309     if (!initfase) {
310         Settings->Brightness_front = value;
311     }
312 }
313
314 void DialogSettings::
315     on_horizontalSlider_ContrastFront_valueChanged(int value)
316     {
317     if (!initfase) {
318         Settings->Contrast_front = value;
319     }
320 }
321
322 void DialogSettings::
323     on_horizontalSlider_SaturationFront_valueChanged(
324     int value) {
325     if (!initfase) {
326         Settings->Saturation_front = value;
327     }
328 }
```

```
326 void DialogSettings::  
327     on_horizontalSlider_HueFront_valueChanged(int value) {  
328     if (!initfase) {  
329         Settings->Hue_front = value;  
330     }  
331 }  
332 void DialogSettings::  
333     on_horizontalSlider_SharpnessFront_valueChanged(  
334         int value) {  
335     if (!initfase) {  
336         Settings->Sharpness_front = value;  
337     }  
338 }  
339 void DialogSettings::  
340     on_horizontalSlider_BrightProj_valueChanged(int value) {  
341     if (!initfase) {  
342         Settings->Brightness_proj = value;  
343     }  
344 }  
345 void DialogSettings::  
346     on_horizontalSlider_ContrastProj_valueChanged(int value)  
347 {  
348     if (!initfase) {  
349         Settings->Contrast_proj = value;  
350     }  
351 }  
352 void DialogSettings::  
353     on_horizontalSlider_SaturationProj_valueChanged(  
354         int value) {  
355     if (!initfase) {  
356         Settings->Saturation_proj = value;  
357     }  
358 }  
359 void DialogSettings::  
360     on_horizontalSlider_HueProj_valueChanged(int value) {  
361     if (!initfase) {  
362         Settings->Hue_proj = value;  
363     }  
364 }  
365 void DialogSettings::  
366     on_horizontalSlider_SharpnessProj_valueChanged(int value)  
367 {  
368     if (!initfase) {  
369         Settings->Sharpness_proj = value;  
370     }  
371 }  
372 void DialogSettings::on_cb_use_adaptContrast_3_clicked(bool  
373 checked) {  
374     Settings->useAdaptiveContrast = checked;
```

```
372     ui->sb_adaptContrastFactor_3->setDisabled(!checked);
373     ui->sb_adaptContrKernel_3->setDisabled(!checked);
374 }
375
376 void DialogSettings::on_cb_useBlur_3_clicked(bool checked) {
377     Settings->useBlur = checked;
378     ui->sb_blurMask_3->setDisabled(!checked);
379 }
380
381 void DialogSettings::on_rb_useDark_3_toggled(bool checked) {
382     if (checked) {
383         Settings->typeOfObjectsSegmented = Vision::Segment::Dark
384             ;
385     } else {
386         Settings->typeOfObjectsSegmented = Vision::Segment::
387             Bright;
388     }
389 }
390
391 void DialogSettings::on_cb_ignoreBorder_3_clicked(bool
392     checked) {
393     Settings->ignorePartialBorderParticles = checked;
394 }
395
396
397 void DialogSettings::on_sb_sigmaFactor_3_editingFinished() {
398     Settings->sigmaFactor = ui->sb_sigmaFactor_3->value();
399 }
400
401 void DialogSettings::on_rb_useOpen_3_clicked(bool checked) {
402     Settings->morphFilterType = Vision::MorphologicalFilter::
403         OPEN;
404 }
405
406 void DialogSettings::on_rb_useClose_3_clicked(bool checked)
407 {
408     Settings->morphFilterType = Vision::MorphologicalFilter::
409         CLOSE;
410 }
411
412
413 void DialogSettings::on_rb_useErode_3_clicked(bool checked)
414 {
415     Settings->morphFilterType = Vision::MorphologicalFilter::
416         ERODE;
417 }
418
419 void DialogSettings::on_rb_useDilate_3_clicked(bool checked)
420 {
421     Settings->morphFilterType = Vision::MorphologicalFilter::
422         DILATE;
423 }
424
```

```
417 void DialogSettings::on_sb_morphMask_3_editingFinished() {
418     Settings->filterMaskSize = ui->sb_morphMask_3->value();
419 }
420
421 void DialogSettings::on_spinBox_MaxGen_editingFinished() {
422     NN->MaxGenUsedByGA = ui->spinBox_MaxGen->value();
423 }
424
425 void DialogSettings::on_spinBox_PopSize_editingFinished() {
426     NN->PopulationSizeUsedByGA = ui->spinBox_PopSize->value();
427 }
428
429 void DialogSettings::
430     on_doubleSpinBox_MutationRate_editingFinished() {
431     NN->MutationrateUsedByGA = ui->doubleSpinBox_MutationRate
432         ->value();
433 }
434
435 void DialogSettings::on_spinBox_Elitisme_editingFinished() {
436     NN->ElitismeUsedByGA = ui->spinBox_Elitisme->value();
437 }
438
439 void DialogSettings::
440     on_doubleSpinBox_endError_editingFinished() {
441     NN->EndErrorUsedByGA = ui->doubleSpinBox_endError->value()
442         ;
443 }
444
445 void DialogSettings::
446     on_doubleSpinBox_maxWeight_editingFinished() {
447     NN->MaxWeightUsedByGA = ui->doubleSpinBox_maxWeight->value()
448         ;
449 }
450
451 void DialogSettings::
452     on_doubleSpinBox_MinWeight_editingFinished() {
453     NN->MinWeightUsedByGA = ui->doubleSpinBox_MinWeight->value()
454         ;
455 }
456
457 void DialogSettings::
458     on_spinBox_InputNeurons_editingFinished() {
459     NN->SetInputNeurons(ui->spinBox_InputNeurons->value());
460 }
```

```
461 void DialogSettings::  
462     on_spinBox_OutputNeurons_editingFinished() {  
463     NN->SetOutputNeurons(ui->spinBox_OutputNeurons->value());  
464 }  
465 void DialogSettings::  
466     on_pushButton_selectSampleFolder_clicked() {  
467     QString fn = QFileDialog::getExistingDirectory(  
468         this, tr("Select the Sample Directory"),  
469         QString::fromStdString(Settings->SampleFolder),  
470         QFileDialog::ShowDirsOnly | QFileDialog::  
471             DontResolveSymlinks);  
472     if (!fn.isEmpty()) {  
473         ui->lineEdit_Samplefolder->setText(fn);  
474         Settings->SampleFolder = fn.toStdString();  
475     }  
476 }  
477 void DialogSettings::  
478     on_pushButton_SelectSettingFolder_clicked() {  
479     QString fn = QFileDialog::getExistingDirectory(  
480         this, tr("Select the Setting Directory"),  
481         QString::fromStdString(Settings->SettingsFolder),  
482         QFileDialog::ShowDirsOnly | QFileDialog::  
483             DontResolveSymlinks);  
484     if (!fn.isEmpty()) {  
485         ui->lineEdit_SettingFolder->setText(fn);  
486         Settings->SettingsFolder = fn.toStdString();  
487     }  
488 }  
489 void DialogSettings::on_pushButton_SelectNNFolder_clicked()  
490 {  
491     QString fn = QFileDialog::getExistingDirectory(  
492         this, tr("Select the NeuralNet Directory"),  
493         QString::fromStdString(Settings->NNFolder),  
494         QFileDialog::ShowDirsOnly | QFileDialog::  
495             DontResolveSymlinks);  
496     if (!fn.isEmpty()) {  
497         ui->lineEdit_NeuralNetFolder->setText(fn);  
498         Settings->NNFolder = fn.toStdString();  
499     }  
500 }  
501 void DialogSettings::on_pushButton_SelectNN_clicked() {  
502     QString fn =  
503         QFileDialog::getOpenFileName(this, tr("Select the  
504             standard Neural Net"),  
505                                         QDir::homePath(), tr("NeuralNet (*.NN)"));  
506     if (!fn.isEmpty()) {  
507         if (!fn.contains(tr(".NN"))) {  
508             fn.append(tr(".NN"));  
509         }  
510         Settings->NNlocation = fn.toStdString();  
511         ui->lineEdit__NeuralNet->setText(fn);  
512     }  
513 }
```

```
508     }
509 }
510
511 void DialogSettings::on_spinBox_NoShots_editingFinished() {
512     Settings->StandardNumberOfShots = ui->spinBox_NoShots->
513         value();
514
515 void DialogSettings::on_checkBox_PredictShape_clicked(bool
516     checked) {
517     Settings->PredictTheShape = checked;
518 }
519 void DialogSettings::on_checkBox_revolt_clicked(bool checked
520 )
521 {
522     Settings->Revolution = checked;
523 }
```

Dialog Neural Network Class

```
1 #ifndef DIALOGNN_H
2 #define DIALOGNN_H
3
4 #include <QDialog>
5 #include "SoilMath.h"
6 #include "soilanalyzer.h"
7 #include "dialogsettings.h"
8 #include <qcustomplot.h>
9 #include <QDebug>
10
11 namespace Ui {
12     class DialogNN;
13 }
14
15 class DialogNN : public QDialog
16 {
17     Q_OBJECT
18
19 public:
20     explicit DialogNN(QWidget *parent = 0, SoilMath::NN *
21         neuralnet = nullptr, SoilAnalyzer::SoilSettings *
22         settings = nullptr, DialogSettings *settingWindow =
23         nullptr);
24     ~DialogNN();
25
26     private slots:
27     void on_pushButton_Settings_clicked();
28     void on_learnErrorUpdate(double newError);
29     void on_pushButton_SelectSamples_clicked();
30     void on_pushButton_Learn_clicked();
31     void on_pushButton_SaveNN_clicked();
32     void on_pushButton_OpenNN_clicked();
33     void on_actionAbort_triggered();
34
35     void setupErrorGraph();
36     void makeLearnVectors(InputLearnVector_t &input,
37         OutputLearnVector_t &output);
38
39     private:
40     Ui::DialogNN *ui;
41     DialogSettings *SettingsWindow = nullptr;
42     SoilMath::NN *NeuralNet = nullptr;
43     SoilAnalyzer::SoilSettings *Settings = nullptr;
44
45     QVector<double> currentError;
46     QVector<double> errorTicks;
47     double currentGeneration = 0;
```

```

51     QStringList fn;
52 };
53
54 #endif // DIALOGNN_H


---


1 #include "dialognn.h"
2 #include "ui_dialognn.h"
3
4 DialogNN::DialogNN(QWidget *parent, SoilMath::NN *neuralnet,
5                     SoilAnalyzer::SoilSettings *settings,
6                     DialogSettings *settingsWindow)
7     : QDialog(parent), ui(new Ui::DialogNN) {
8     ui->setupUi(this);
9
10    if (neuralnet == nullptr) {
11        neuralnet = new SoilMath::NN;
12    }
13    NeuralNet = neuralnet;
14    if (settings == nullptr) {
15        settings = new SoilAnalyzer::SoilSettings;
16    }
17    Settings = settings;
18    if (settingsWindow == nullptr) {
19        settingsWindow = new DialogSettings;
20    }
21    SettingsWindow = settingsWindow;
22
23    // Setup the Qplots
24    ui->widget_NNError->addGraph();
25    ui->widget_NNError->addGraph();
26
27    ui->widget_NNError->xAxis->setLabel("Generation [-]");
28    ui->widget_NNError->yAxis->setLabel("Error [%]");
29    QCPPlotTitle *widget_NNErrorTitle = new QCPPlotTitle(ui->
30        widget_NNError);
31    widget_NNErrorTitle->setText("Learning error");
32    widget_NNErrorTitle->setFont(QFont("sans", 10, QFont::Bold));
33    ui->widget_NNError->plotLayout()->insertRow(0);
34    ui->widget_NNError->plotLayout()->addElement(0, 0,
35        widget_NNErrorTitle);
36
37    // Connect the NN learn error
38    connect(NeuralNet, SIGNAL(learnErrorUpdate(double)), this,
39             SLOT(on_learnErrorUpdate(double)));
40 }
41
42 DialogNN::~DialogNN() { delete ui; }
43
44 void DialogNN::on_pushButton_Settings_clicked() {
45     SettingsWindow->openTab(2);
46     SettingsWindow->show();
47     setupErrorGraph();
48 }

```

```

49
50 void DialogNN::on_learnErrorUpdate(double newError) {
51     ui->widget_NNError->graph(0)->addData(currentGeneration,
52         newError);
53     currentGeneration += 1;
54     ui->widget_NNError->yAxis->rescale();
55     //ui->widget_NNError->yAxis->setRange(0, 20);
56     ui->widget_NNError->replot();
57 }
58
59 void DialogNN::setupErrorGraph() {
60     errorTicks.clear();
61     for (uint32_t i = 0; i < NeuralNet->MaxGenUsedByGA; i++) {
62         errorTicks.push_back(i);
63     }
64     ui->widget_NNError->xAxis->setRange(0, NeuralNet->
65         MaxGenUsedByGA);
66     QVector<double> endErrorValue(2, NeuralNet->
67         EndErrorUsedByGA);
68     QVector<double> endErrorKey(2, 0);
69     endErrorKey[1] = NeuralNet->MaxGenUsedByGA;
70     ui->widget_NNError->graph(1)->setData(endErrorKey,
71         endErrorValue);
72     ui->widget_NNError->xAxis->setAutoTicks(false);
73     ui->widget_NNError->xAxis->setTickVector(errorTicks);
74     ui->widget_NNError->xAxis->setTickLabels(false);
75     //ui->widget_NNError->yAxis->setScaleType(QCPAxis::
76         stLogarithmic);
77     ui->widget_NNError->replot();
78 }
79
80 void DialogNN::on_pushButton_SelectSamples_clicked() {
81     fn = QFileDialog::getOpenFileNames(
82         this, tr("Open Samples"), QString::fromStdString(
83             Settings->SampleFolder),
84         tr("Samples (*.VSA)"));
85     for_each(fn.begin(), fn.end(), [](QString &f) {
86         if (!f.contains(tr(".VSA"))) {
87             f.append(tr(".VSA"));
88         }
89     });
90 }
91
92 void DialogNN::on_pushButton_Learn_clicked() {
93     if (fn.size() < 1) {
94         return;
95     }
96     InputLearnVector_t InputVec;
97     OutputLearnVector_t OutputVec;
98     makeLearnVectors(InputVec, OutputVec);
99     NeuralNet->Learn(InputVec, OutputVec, NeuralNet->
100         GetInputNeurons());
101     setupErrorGraph();
102 }
103
104 void DialogNN::makeLearnVectors(InputLearnVector_t &input,
105     OutputLearnVector_t &output) {
106     for (int i = 0; i < fn.size(); i++) {
107         QString file = fn[i];
108         InputVec = readInputVector(file);
109         OutputVec = readOutputVector(file);
110         InputVec->append(1.0);
111         OutputVec->append(1.0);
112     }
113 }
114
115 void DialogNN::on_pushButton_Load_clicked() {
116     if (fn.size() < 1) {
117         return;
118     }
119     InputLearnVector_t InputVec;
120     OutputLearnVector_t OutputVec;
121     makeLearnVectors(InputVec, OutputVec);
122     NeuralNet->Load(InputVec, OutputVec, NeuralNet->
123         GetInputNeurons());
124 }
125
126 void DialogNN::on_pushButton_Save_clicked() {
127     if (fn.size() < 1) {
128         return;
129     }
130     QString file = QFileDialog::getSaveFileName(
131         this, tr("Save Model"), QString::fromStdString(
132             Settings->ModelFolder),
133         tr("Model (*.VSA)"));
134     if (!file.isEmpty()) {
135         NeuralNet->Save(file);
136     }
137 }
138
139 void DialogNN::on_pushButton_Exit_clicked() {
140     QApplication::quit();
141 }

```

```

98                         OutputLearnVector_t &output)
99                         {
100                         for (uint32_t i = 0; i < fn.size(); i++) {
101                             SoilAnalyzer::Sample sample;
102                             sample.Load(fn[i].toStdString());
103                             for_each(sample.ParticlePopulation.begin(), sample.
104                                 ParticlePopulation.end(),
105                                 [&](SoilAnalyzer::Particle &P) {
106                                     if (P.FFDescriptors.size() >= NeuralNet->
107                                         GetInputNeurons()) {
108                                         ComplexVect_t ffdesc;
109                                         for (uint32_t j = 0; j < NeuralNet->
110                                             GetInputNeurons(); j++) {
111                                             ffdesc.push_back(P.FFDescriptors[j]);
112                                         }
113                                         input.push_back(ffdsc);
114                                         Predict_t predict = P.Classification;
115                                         predict.OutputNeurons = SoilMath::
116                                             makeOutput(P.GetAngularity(), NeuralNet
117                                             ->GetOutputNeurons());
118                                         output.push_back(predict);
119                                     }
120                                 });
121                         }
122                     );
123                 }
124             );
125         }
126     }
127 }
128 }
129
130 void DialogNN::on_pushButton_SaveNN_clicked() {
131     QString fn = QFileDialog::getSaveFileName(
132         this, tr("Save NeuralNet"), QString::fromStdString(
133             Settings->NNFolder),
134             tr("NeuralNet (*.NN)"));
135     if (!fn.isEmpty()) {
136         if (!fn.contains(tr(".NN"))) {
137             fn.append(tr(".NN"));
138         }
139         NeuralNet->SaveState(fn.toStdString());
140     }
141 }
142
143 void DialogNN::on_pushButton_OpenNN_clicked() {
144     QString fn = QFileDialog::getOpenFileName(
145         this, tr("Open NeuralNet"),
146         QString::fromStdString(Settings->SampleFolder), tr(""
147             "NeuralNet (*.NN)"));
148     if (!fn.isEmpty()) {
149         if (!fn.contains(tr(".NN"))) {
150             fn.append(tr(".NN"));
151         }
152         if (NeuralNet != nullptr) {
153             delete NeuralNet;
154         }
155         NeuralNet->LoadState(fn.toStdString());
156         connect(NeuralNet, SIGNAL(learnErrorUpdate(double)),
157             this,
158             SLOT(on_learnErrorUpdate(double)));
159     }
160 }
```

```
145  }
146
147 void DialogNN::on_actionAbort_triggered()
148 {
149     NeuralNet->EndErrorUsedByGA = ui->widget_NNError->graph
150     (0)->data()->lastKey();
151 }
```
