UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

CHIMSLAB
Chemometrics Imaging and Spectroscopy Lab

Doctorate in Agri-Food Sciences, Technologies and Bio-Technologies
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DEVELOPMENT OF MULTIVARIATE IMAGE ANALYSIS METHODS FOR FOOD COLOUR CHARACTERIZATION

Dott.ssa Giorgia Orlandi
Tutor: Prof. Alessandro Ulrici
Co-tutor: Dott.ssa Rosalba Calvini

Outline

- Introduction:
  - the importance of colour for food
  - RGB images
- Ⅰ Section:
  - image standardization
  - image data reduction
- Ⅱ Section:
  - RGB image correction GUI
  - Colourgrams GUI v2.0: calibration of the colourgram matrix
- Conclusions

The importance of colour for food

- ✓ The very first evaluation of food is often based on its visual aspect.
- ✓ Color is related to food chemical composition.

BLUE-VIOLET: anthocyanins

RED: lycopene and anthocyanins

YELLOW-ORANGE: beta-carotene (provitamin A)

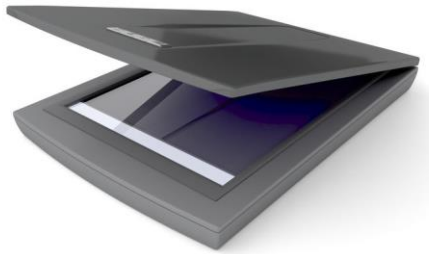
WHITE: polyphenols, flavonoids, ...

GREEN: chlorophylls, pheophytines

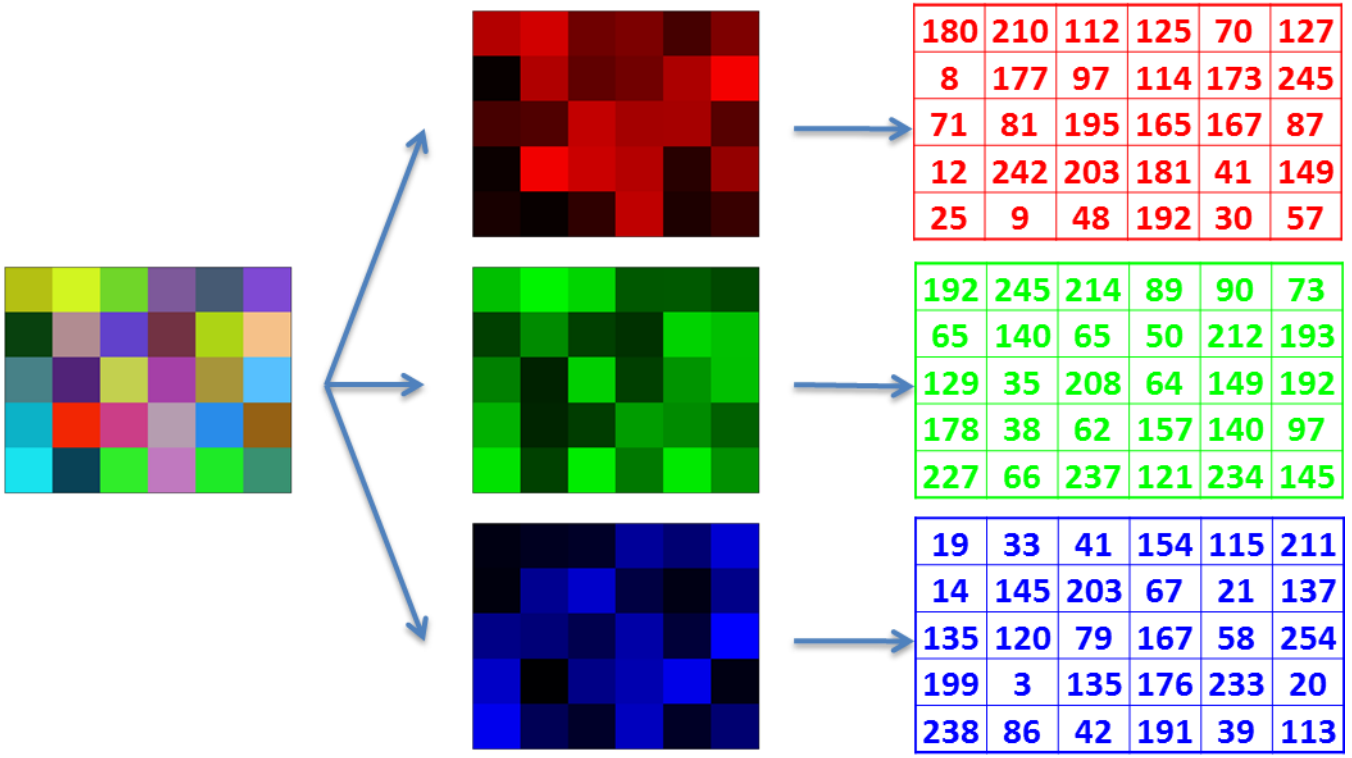
From human to electronic eye

ELECTRONIC EYE:

- ✓ Fast
- ✓ Cheap
- ✓ Objective
- ✓ Reliable
- ✓ Transferable
- ✓ Sensitive
- ✓ Quantitative



RGB images



- ✓ The three R,G,B channels correspond to three matrices (tables of numbers) containing the R, G and B values, which are used as analytical measurements.

Image standardization

The possible variations in the experimental setup, including, for instance:

- ✓ drifts in the acquisition system,
- ✓ variations of the illumination conditions,
- ✓ camera inconsistencies,
- ✓ variations of the environmental conditions.

can heavily affect the quality of the digital images and, as consequence, the further processing and the related results.

The first important preprocessing step is the standardization of the images.

From single images to image sets

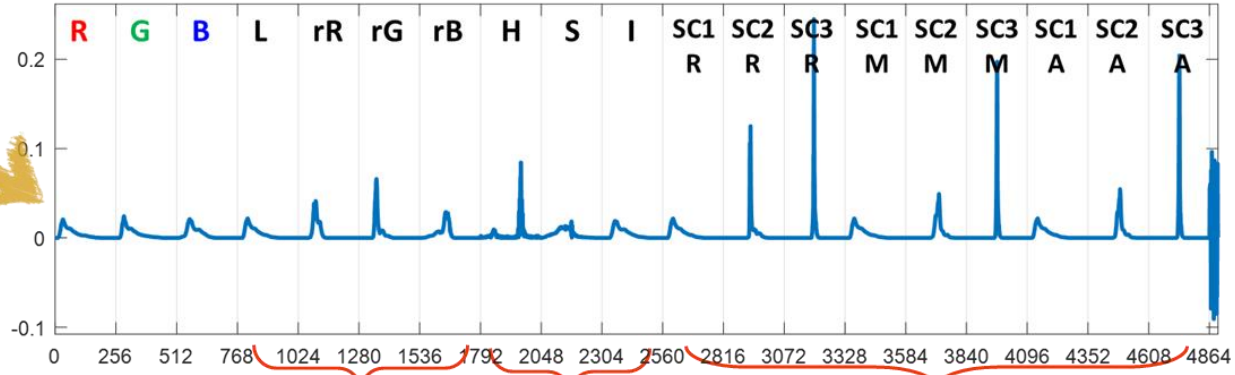
Comparing multiple images

- Average image color values
- Color variability
- Spatial variability
- Local features of interest / defects
- Outlier samples
- Instrumental faults (e.g., lighting conditions…)
- **Calibration of image-related properties**
- …

From single images to image sets

Image data reduction

A possible solution: convert each image into a signal



Lightness (L) = R + G + B

Relative red (rR) = R / L

Relative green (rG) = G / L

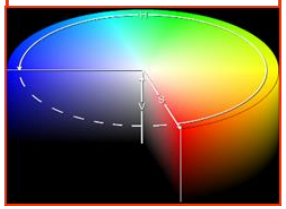
Relative blue (rB) = B / L

Hue

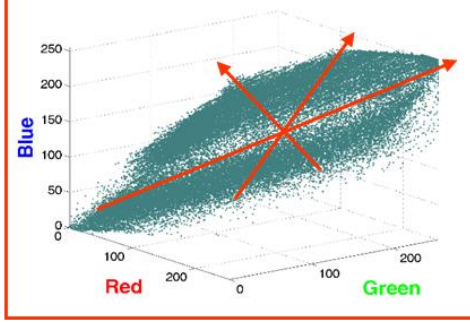
Saturation

Value

colour space



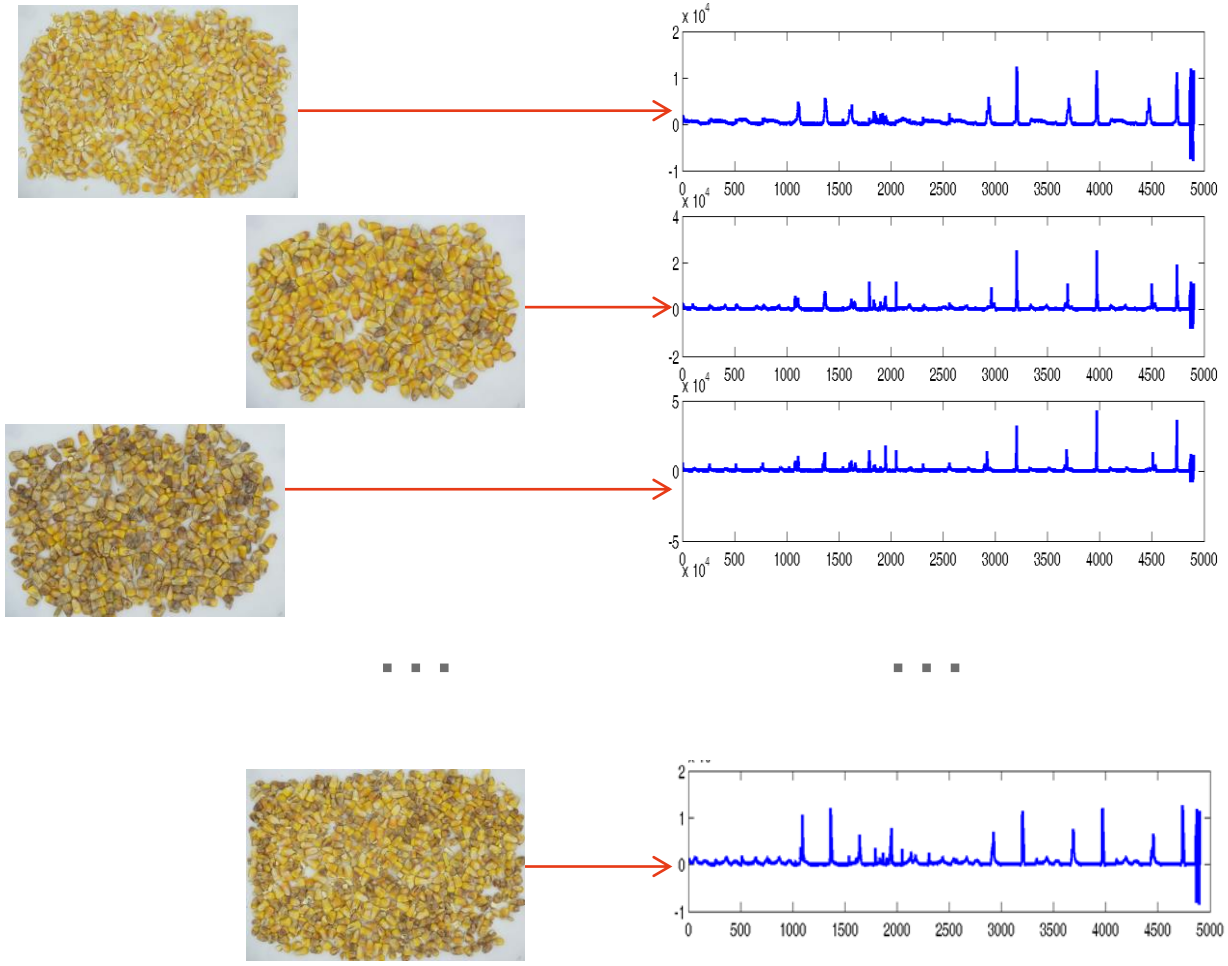
PCA of RGB matrix



- ✓ A colourgram codifies the image color-related properties
- ✓ Reduction of data size: from millions of values in an image to 4900 values in a colourgram

Colourgrams matrix

Having dimension {n × 4900}



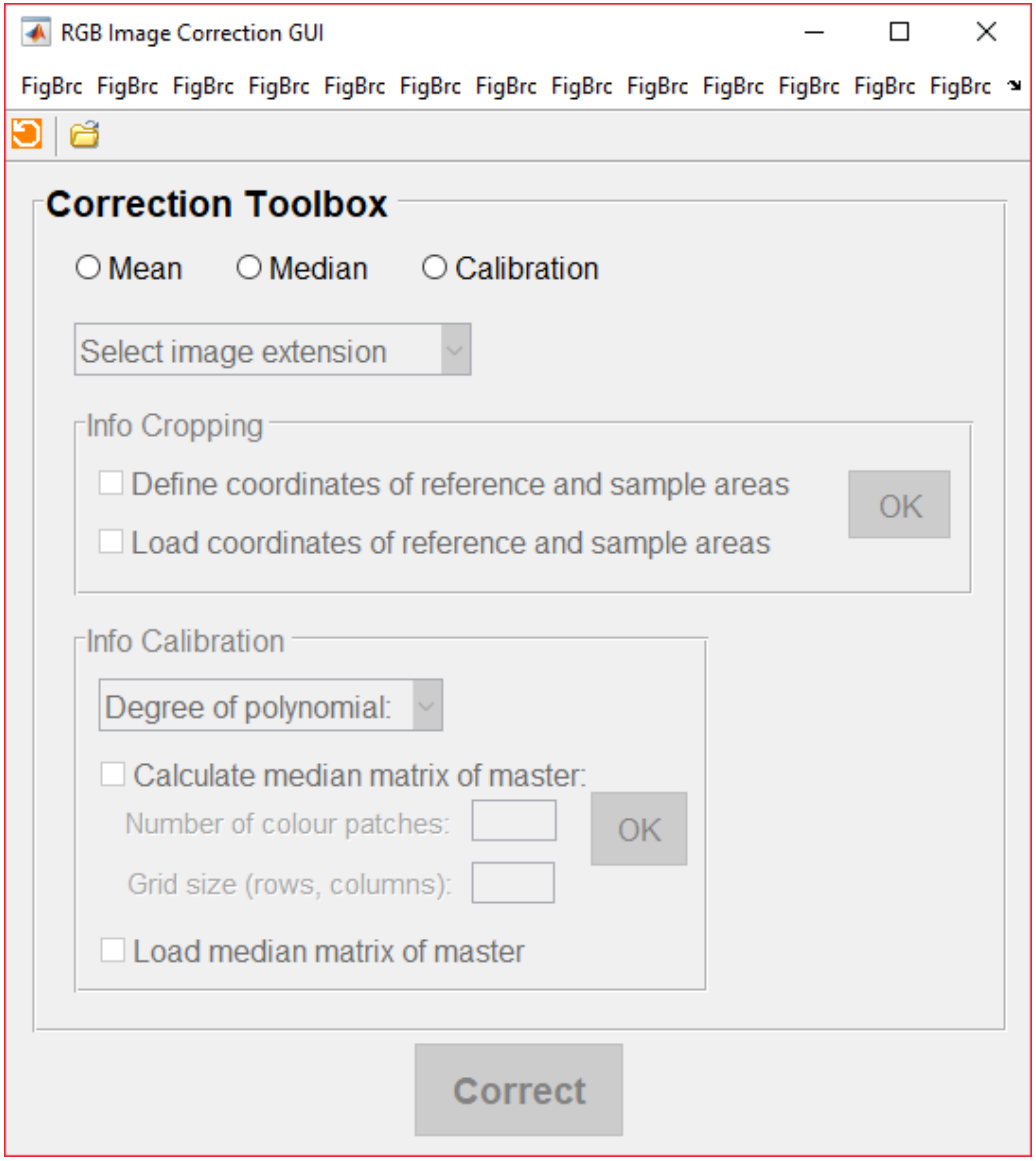
EXPLORATIVE ANALYSIS (e.g., PCA): similar images, outlier images

CALIBRATION: quantitative prediction of image properties

CLASSIFICATION: attribution of images to given categories

RGB image correction GUI

A graphical user-friendly interface to standardize the RGB images

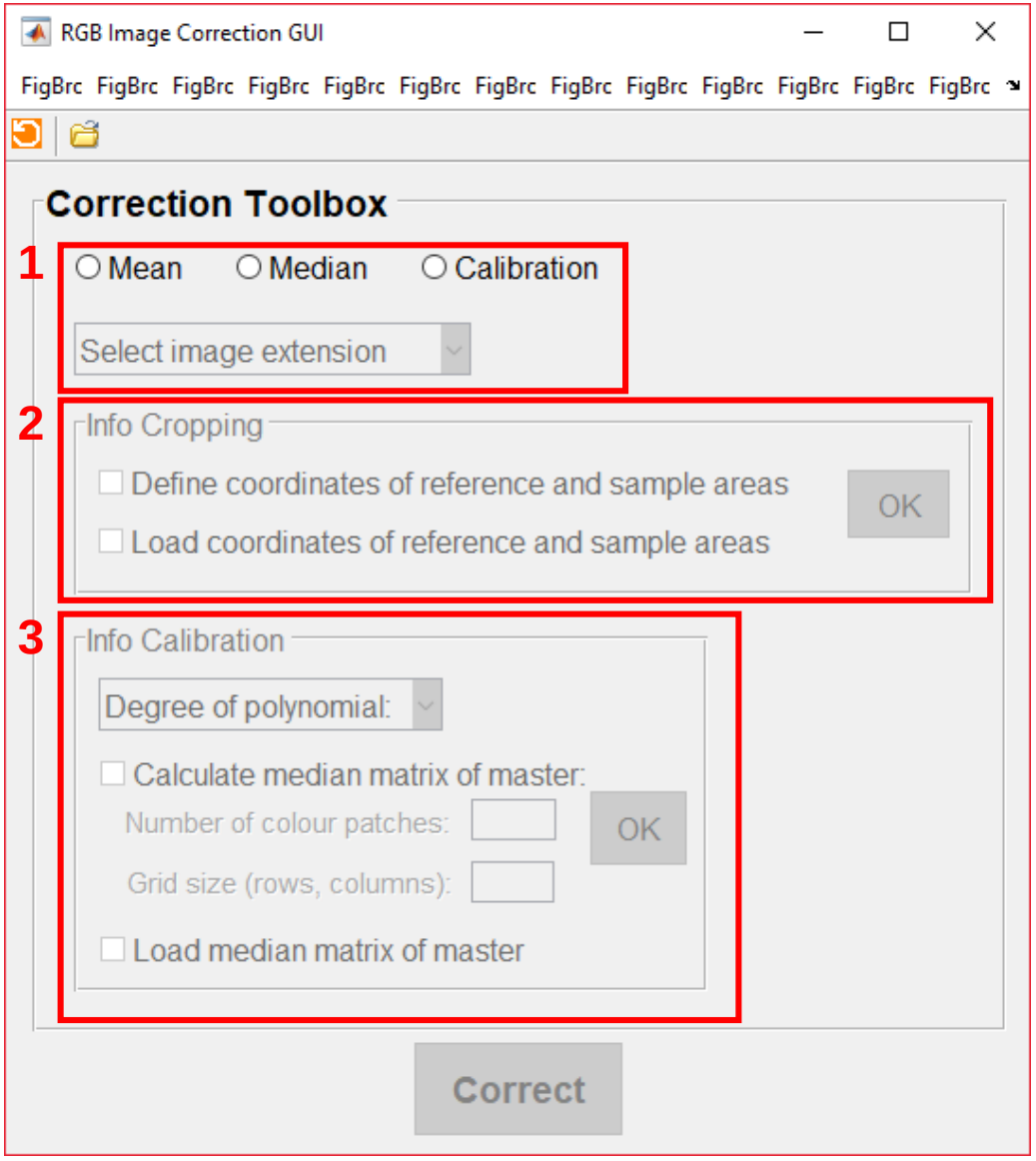


The GUI has three modes for the correction of images:

- ***Mean*** and ***Median*** are basic correction methods useful to quickly reduce slight differences between the images.
- ***Calibration*** is an advanced standardiztaion method suitable to correct the images by computing the appropriate regression model, verified case-by-case.

RGB image correction GUI – Main Window

A graphical user-friendly interface to standardize the RGB images



The **main window** of the GUI has been subdivided in **three** subsequent **sections** reflecting the operating procedure required for computing each one of the correction method:

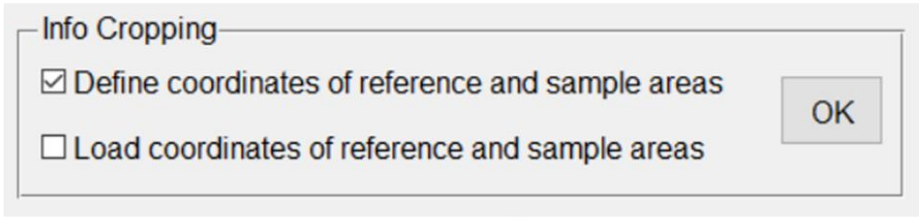
1. **choose** the **correction method** and the image **file format**;
2. **crop** the images according to the **reference and sample areas**;
3. **define the information** needed for calculating the **regression model** (section enabled only for calibration correction method).

RGB image correction GUI – Algorithms

A graphical user-friendly interface to standardize the RGB images

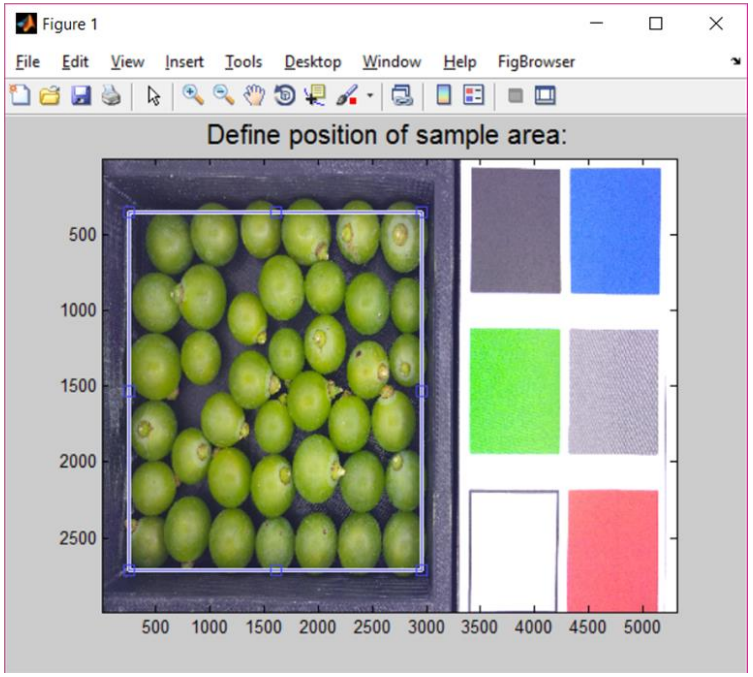
All three methods are based on the following procedure: **an image is chosen as "master" image** (the default is the first image in the folder), then **each other "slave" image is corrected by elaborating the RGB values of standard colours references** included in the image scene.

a.



b1.

b2.



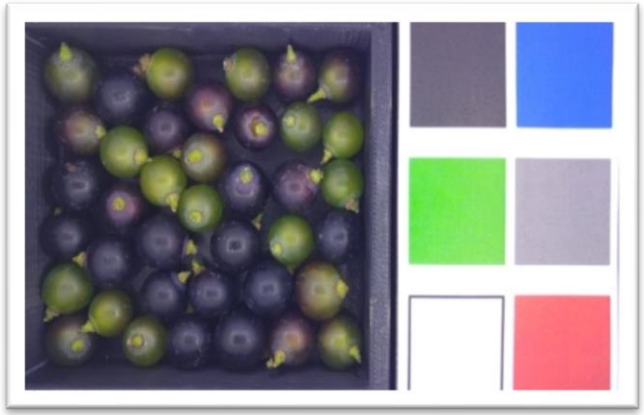
RGB image correction GUI – Application

Automated on-field estimation of anthocyanins/color index of grapes by smartphone

AIM OF THE WORK:

develop a smartphone-based device for the evaluation of grape phenolic maturity directly in the vineyard.

- ✓ Two grape varieties considered: **Ancellotta** and **Salamino**.
- ✓ **270** digital images of grape berries were collected at **different harvest times** from veraison to maturity.



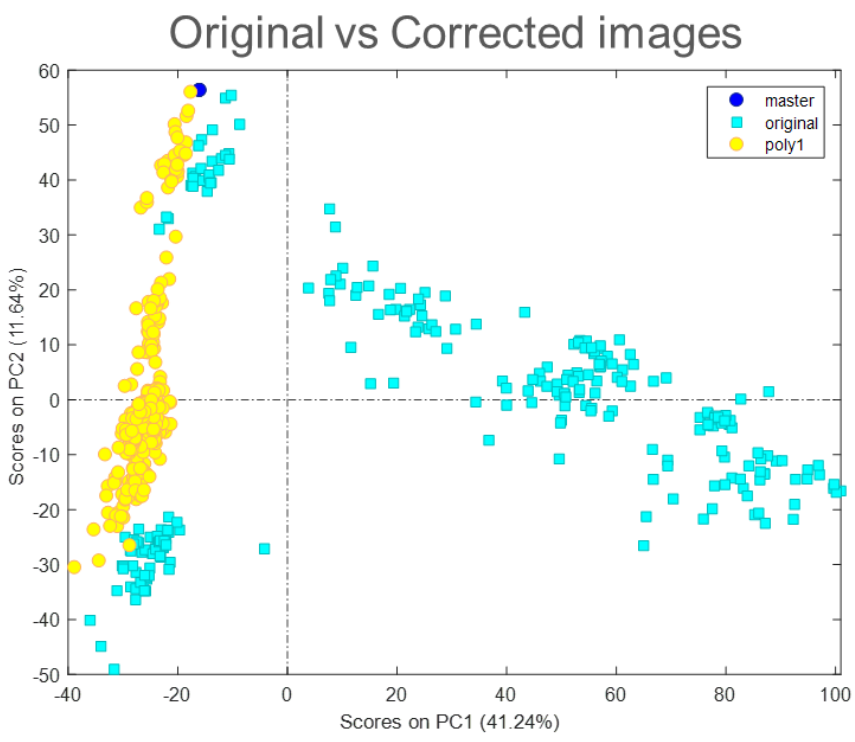
RGB image correction GUI – Application

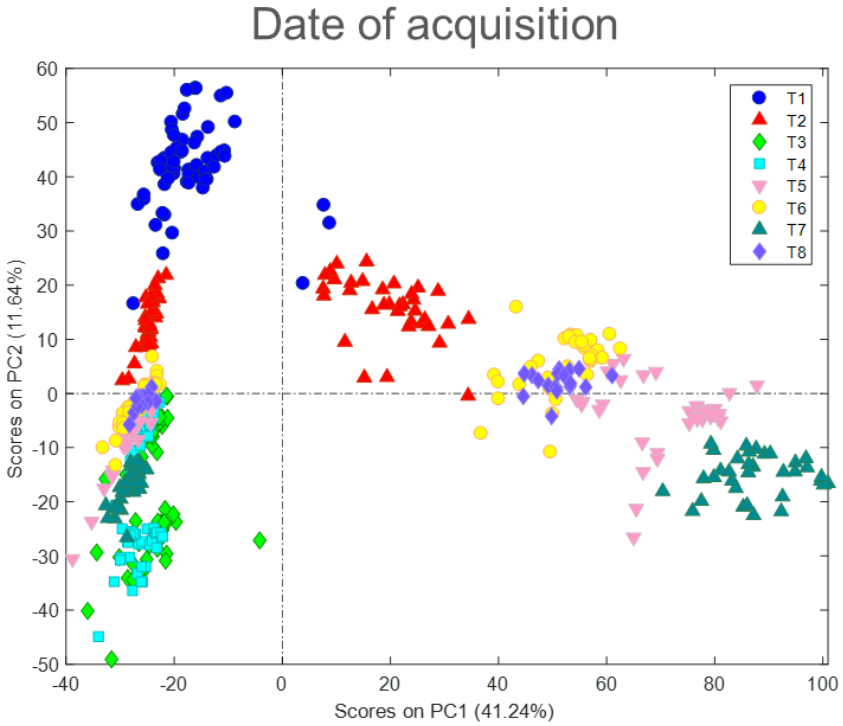
Verify the stability of the imaging acquisition system

The colourgrams of references are **grouped** according to the **date of acquisition.**

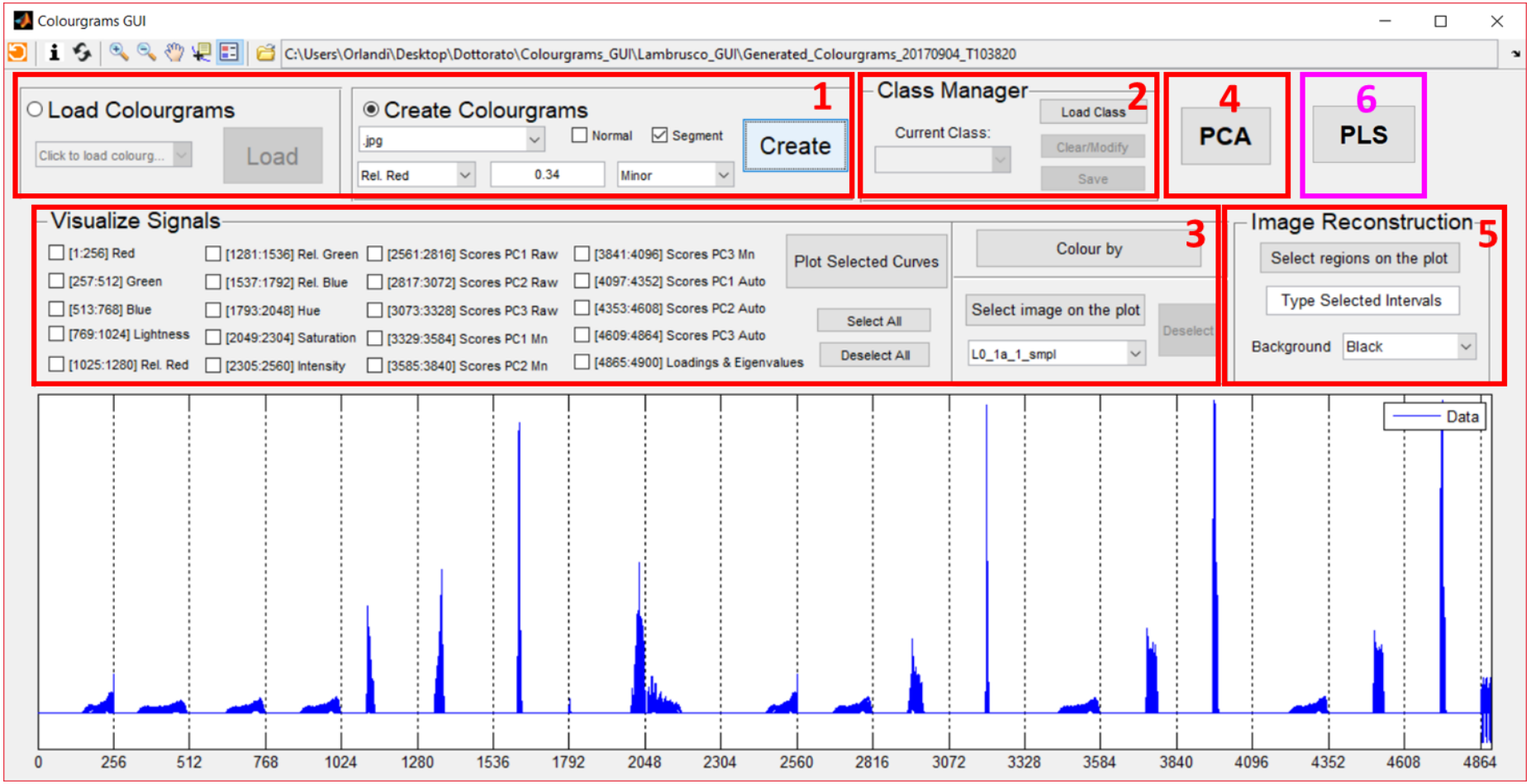
Three types of correction (mean, median and calibration) have been tested in order to identify the most appropriate method.

Linear calibration allow to remove the dispersion of the references along PC1 and to further significantly reduce the separation along PC2 of the references acquired at time T3 and time T4.





Colourgrams GUI v2.0



1. Load or create colourgrams dataset.
2. Add supplementary information.
3. Visualize signals.
4. Perform PCA.
5. Reconstruct images using features of interest.
6. **Perform PLS.**

Colourgrams GUI v2.0 – Application

Identification of defective maize kernels

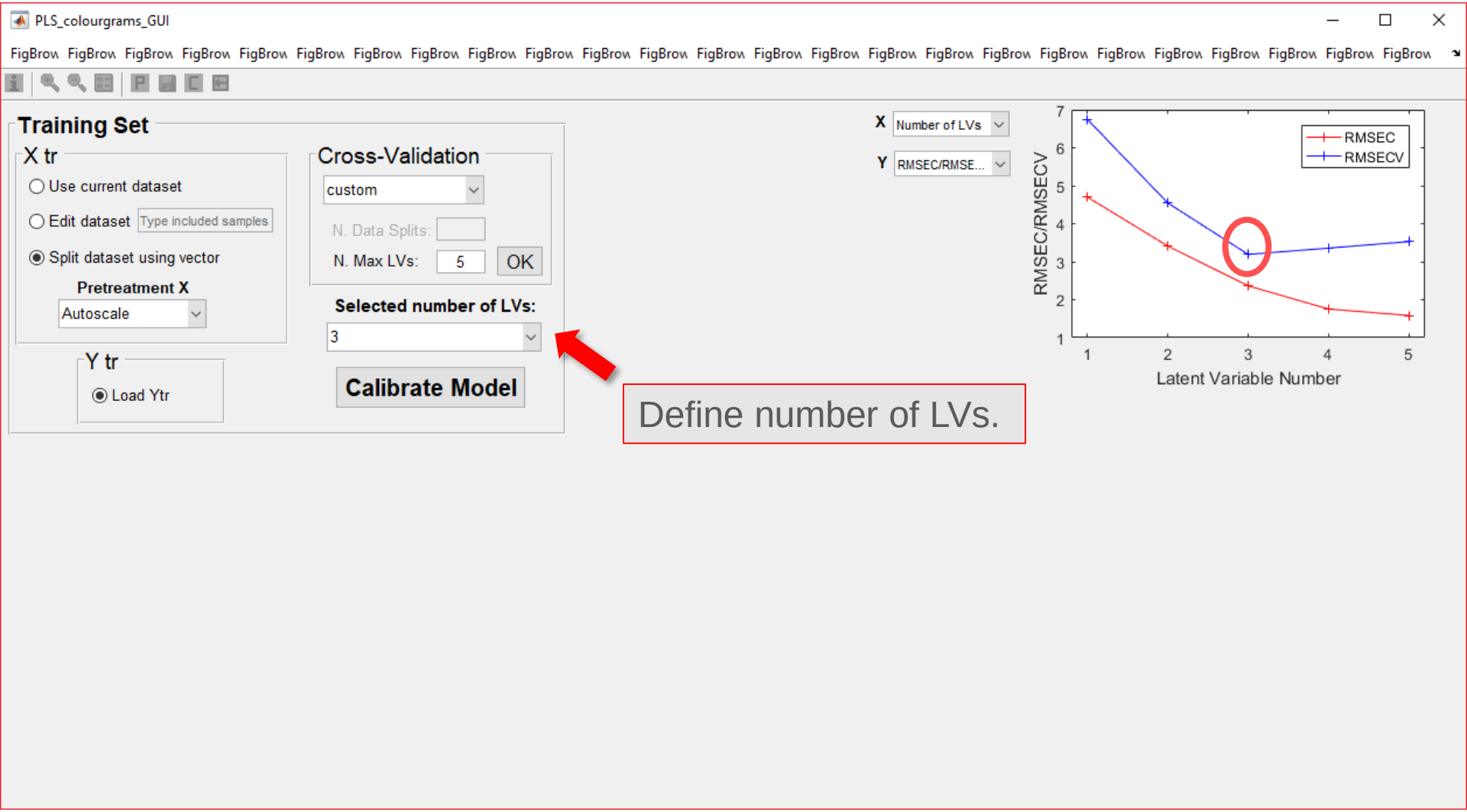
AIM OF THE WORK:

- Quantify the percentage of defective maize kernels in the sample → defective kernels are generally contaminated by the DON micotoxin.

- ✓ Two maize types considered: **wet** and **dry** maize.
- ✓ **332** digital images of mixtures with **different percentages** of defective maize kernels.

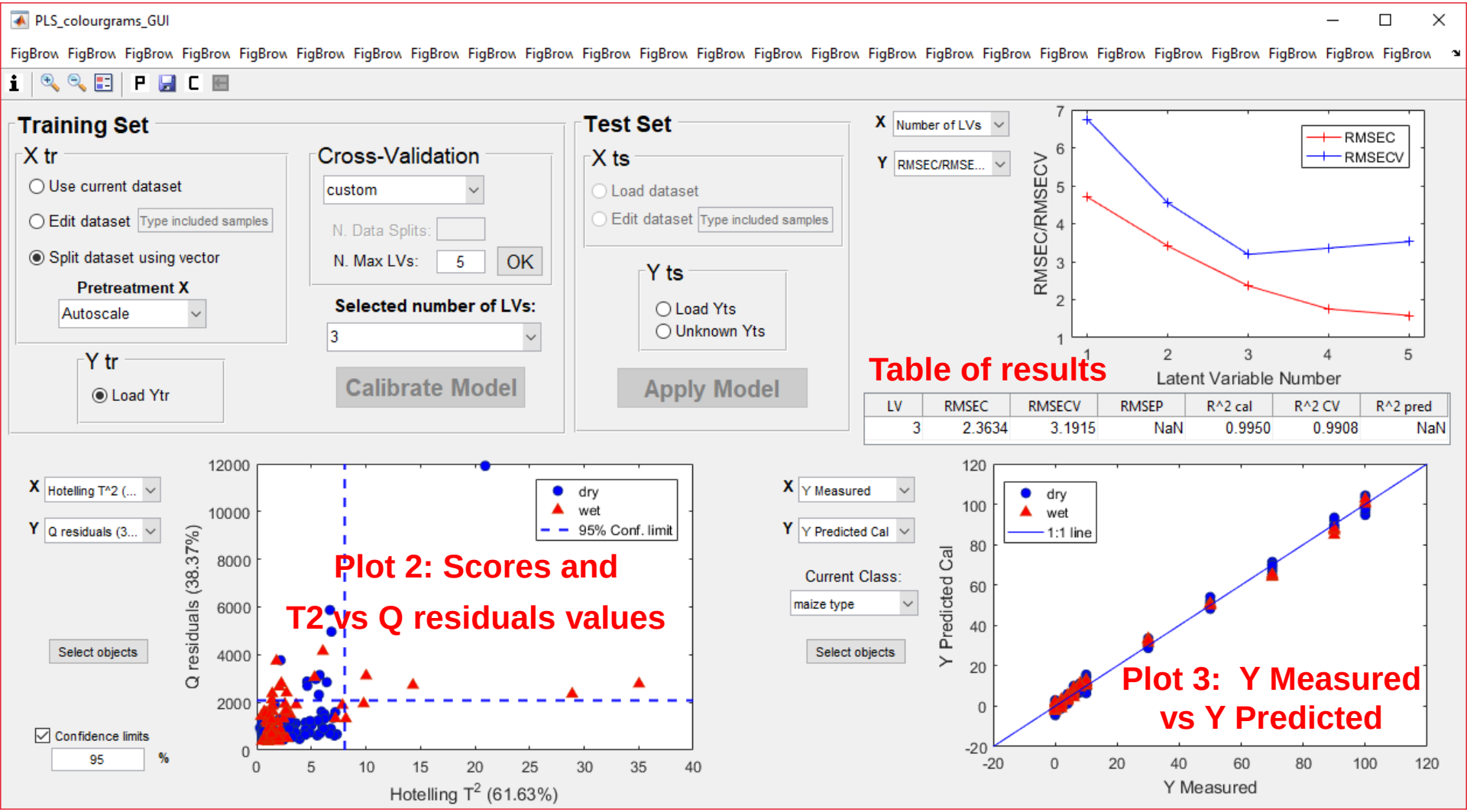
Colourgrams GUI v2.0 – Training Set

Calibration of the colourgram matrix



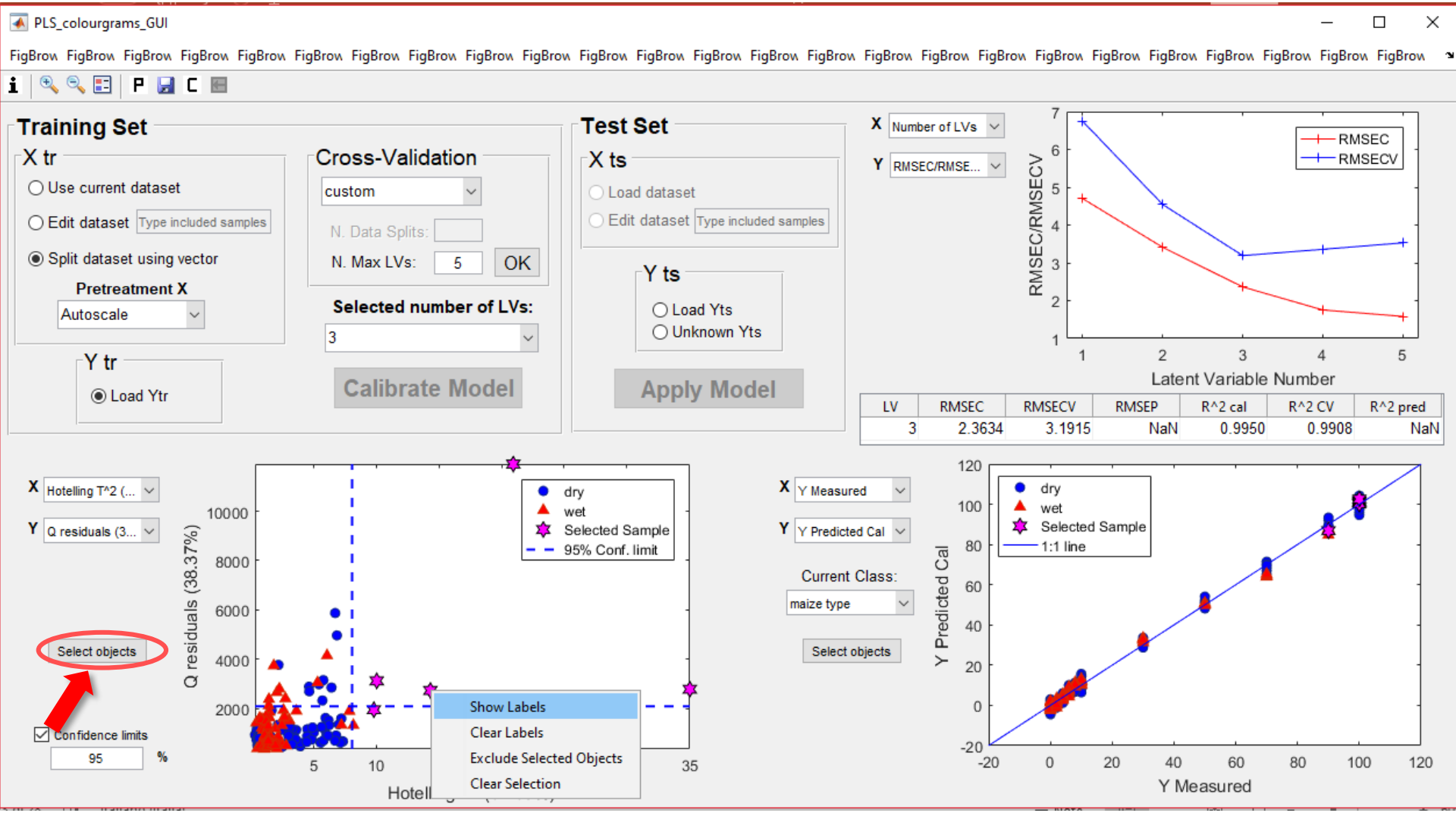
Colourgrams GUI v2.0 – Calibrate Model

Calibration of the colourgram matrix



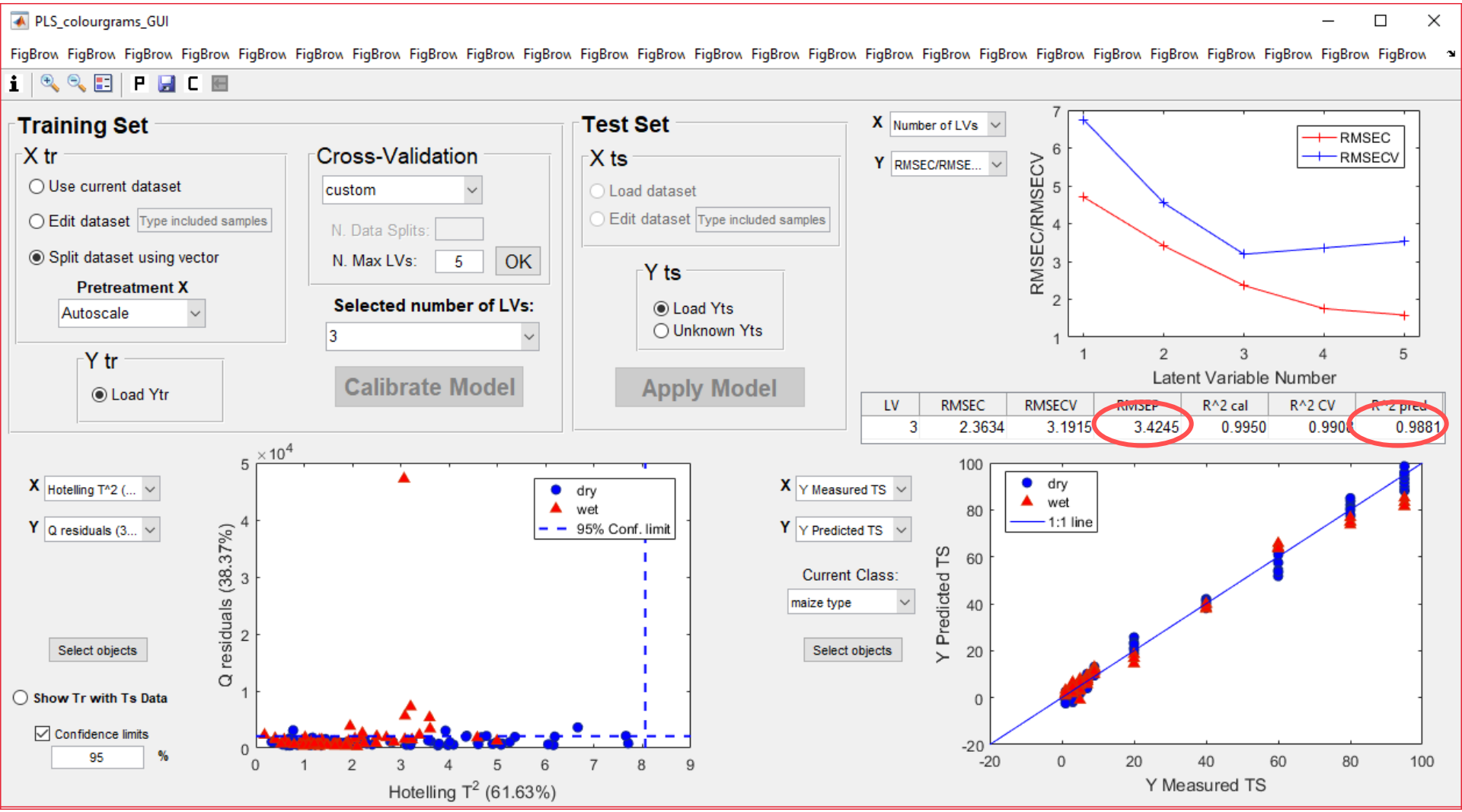
Colourgrams GUI v2.0 – Select object

Calibration of the colourgram matrix



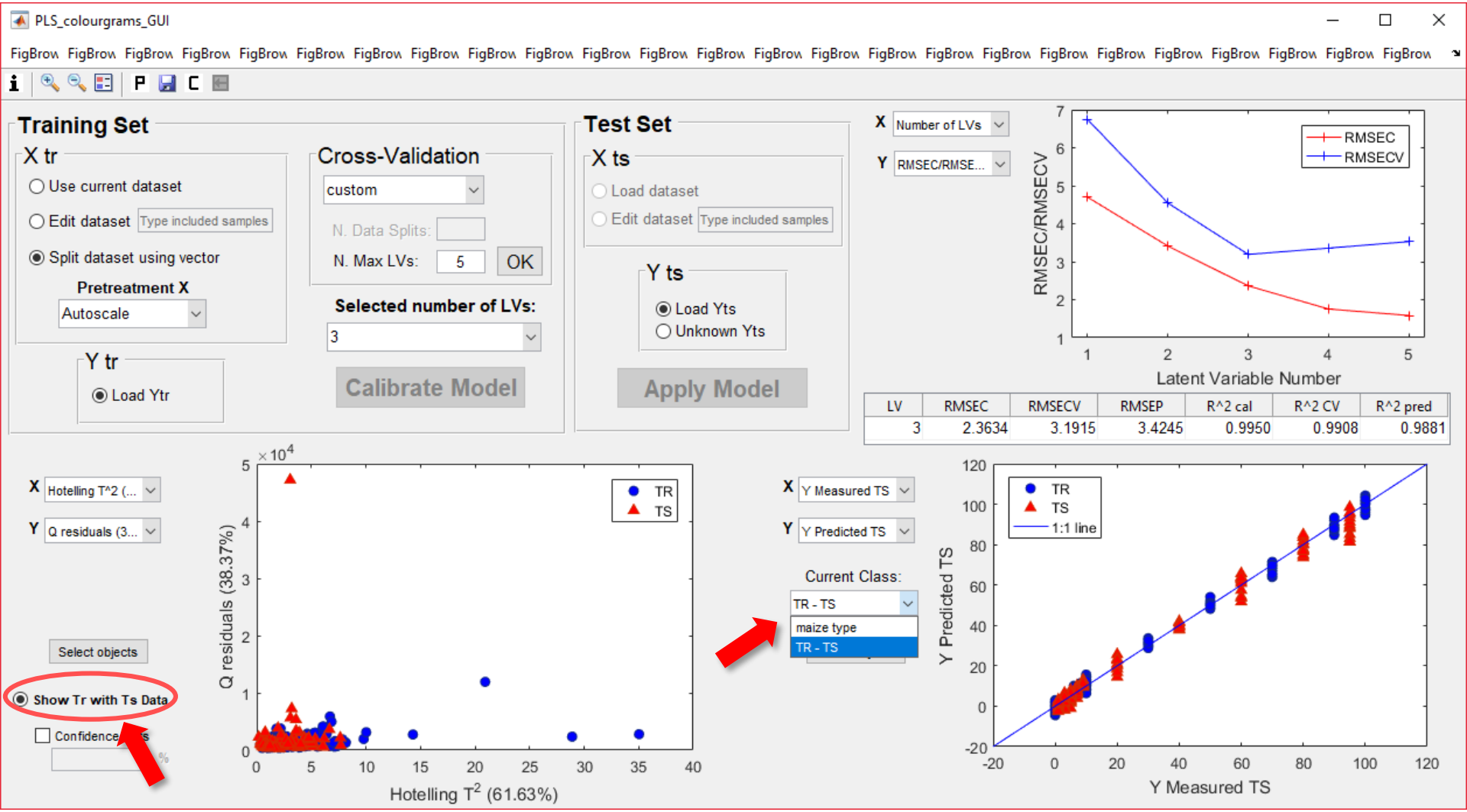
Colourgrams GUI v2.0 – Apply model

Calibration of the colourgram matrix



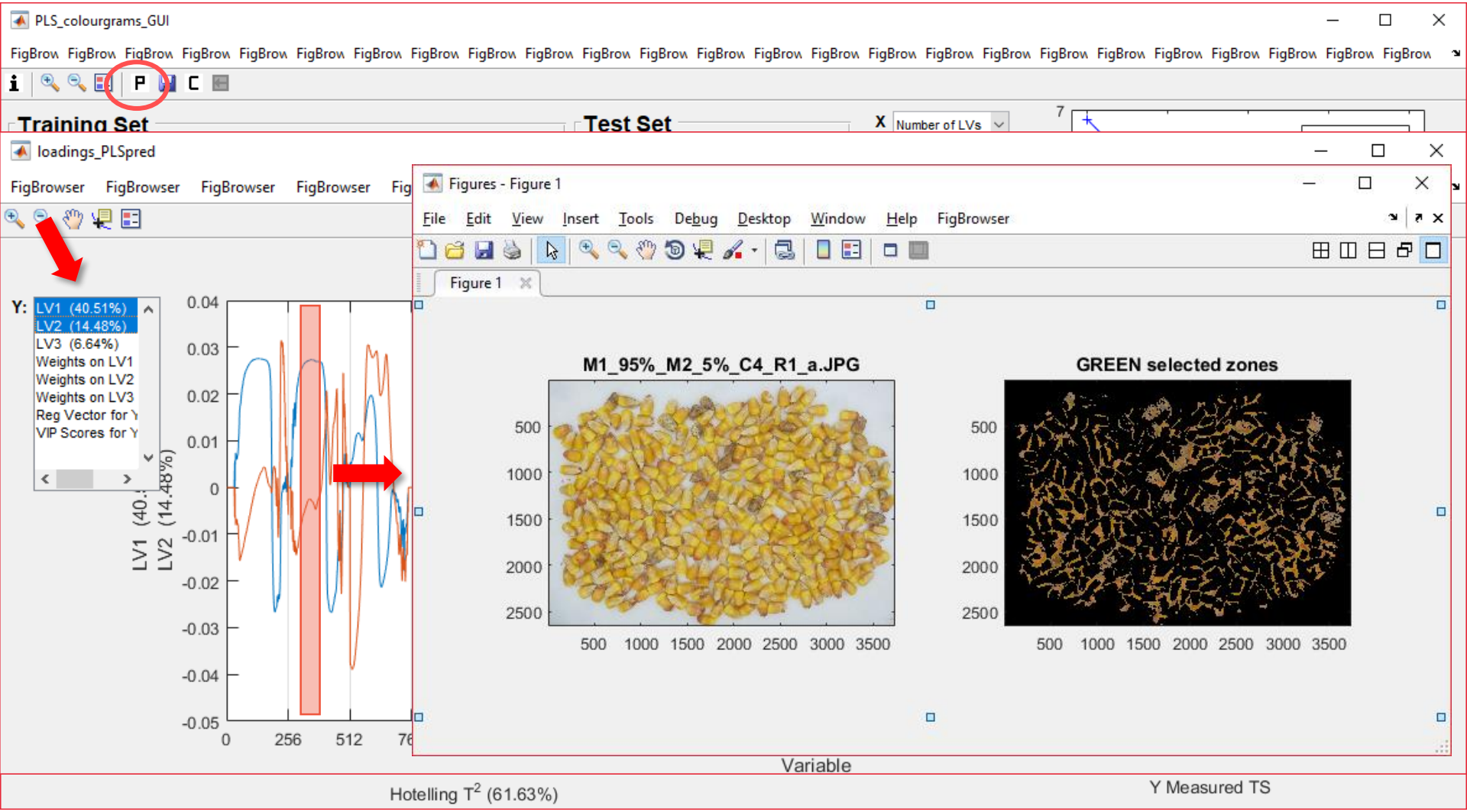
Colourgrams GUI v2.0 – Training with Test Data

Calibration of the colourgram matrix



Colourgrams GUI v2.0 – Loading vectors

Calibration of the colourgram matrix



Conclusions

- **RGB imaging systems** allow to perform **fast, non-invasive** and **low-cost** analysis on products and processes, minimizing the human intervention and obtaining an objective and reproducible sample evaluation.
- The application of appropriate **correction algorithms** can significantly **improve data reproducibility** over time.
- **Colourgrams** allows to simultaneously analyze in a completely automated way a **lot of images altogether** by means of common chemometric methods, like PCA and PLS.
- **RGB Image Correction GUI** and **Colourgrams GUI** can represent **helpful tools** to simplify the image elaboration steps.

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THANKS FOR YOUR ATTENTION!