DanSeed Symposium
March 10th, 2015
Kobæk Strand Konferencecenter

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Videometer A/S

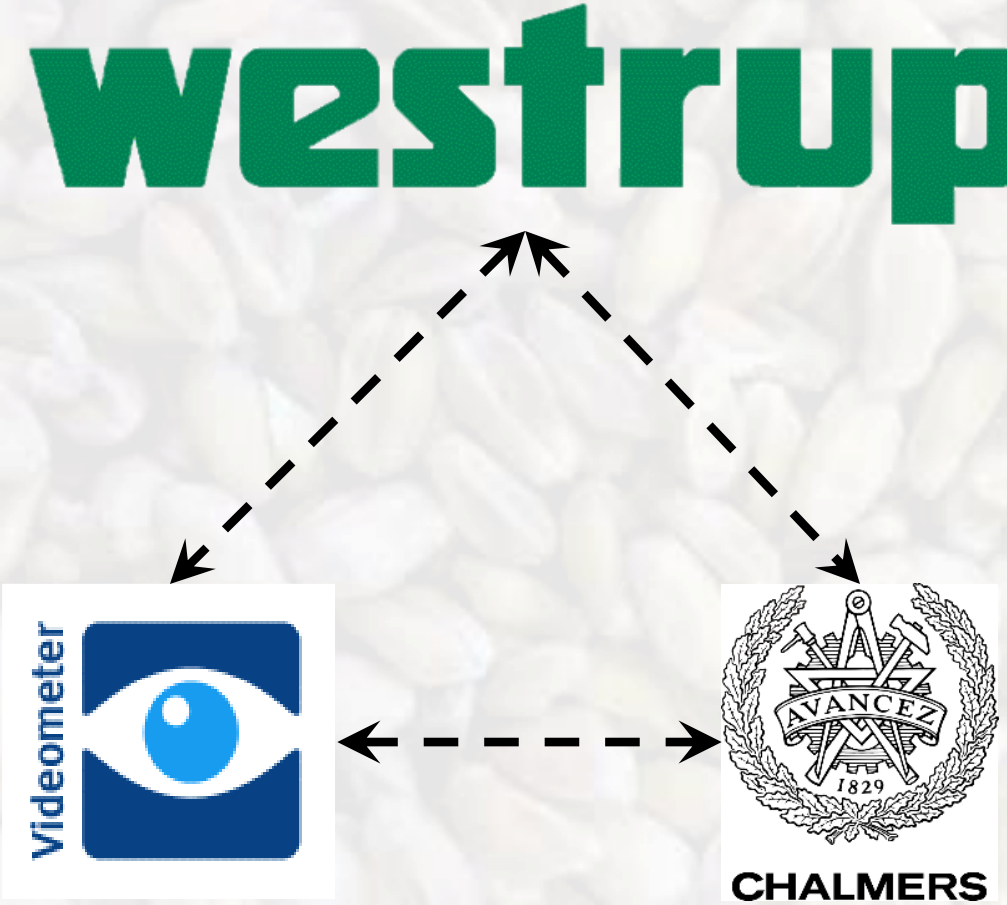
Challenges in self-adjusting gravity tables

SAGT – Self-Adjusting Gravity Table

- Efficient processing and reliable quality assessment of seeds and grains is motivated by its large commercial potential, and by the needs felt by European farmers in differentiating their products against the pressure imposed by competitors outside Europe.
  - Gravity separation (by density) is an imperative part of nearly all seed cleaning and grading processing plants.
  - Gravity separation increases seed quality by removing immature/low germination/insect damaged seeds.
  - Equipment have improved in both design and size to accommodate the need for higher throughput. (15-20 ton of crop per hour)
  - The need for experienced manual labor has become a bottleneck: Gravity tables need to be adjusted on a regular basis to ensure optimal operation. (every 15 minutes)
- SAGT aims at developing a new generation of gravity separators, which are real-time, self-adjustable, according to the type of crop.
  - Improving the quality of the cleaning process and reducing the need for experienced labor.

SAGT – Self-Adjusting Gravity Table

- EU (Marie Curie) funded project
  - Initiated by Westrup A/S in collaboration with Videometer A/S and Chalmers University.



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Seed and Grain Processing Equipment and Machinery

Spectral imaging, automated visual measurements and quality control

Computational Fluid Dynamics (virtual modelling of flow)

SAGT – Self-Adjusting Gravity Table

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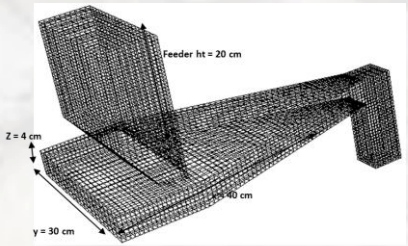


Practical experience based operation

Virtual modelling

Empirical modelling

Micro-scale modelling of grain behavior on the table using **computational fluid dynamics** (CFD).

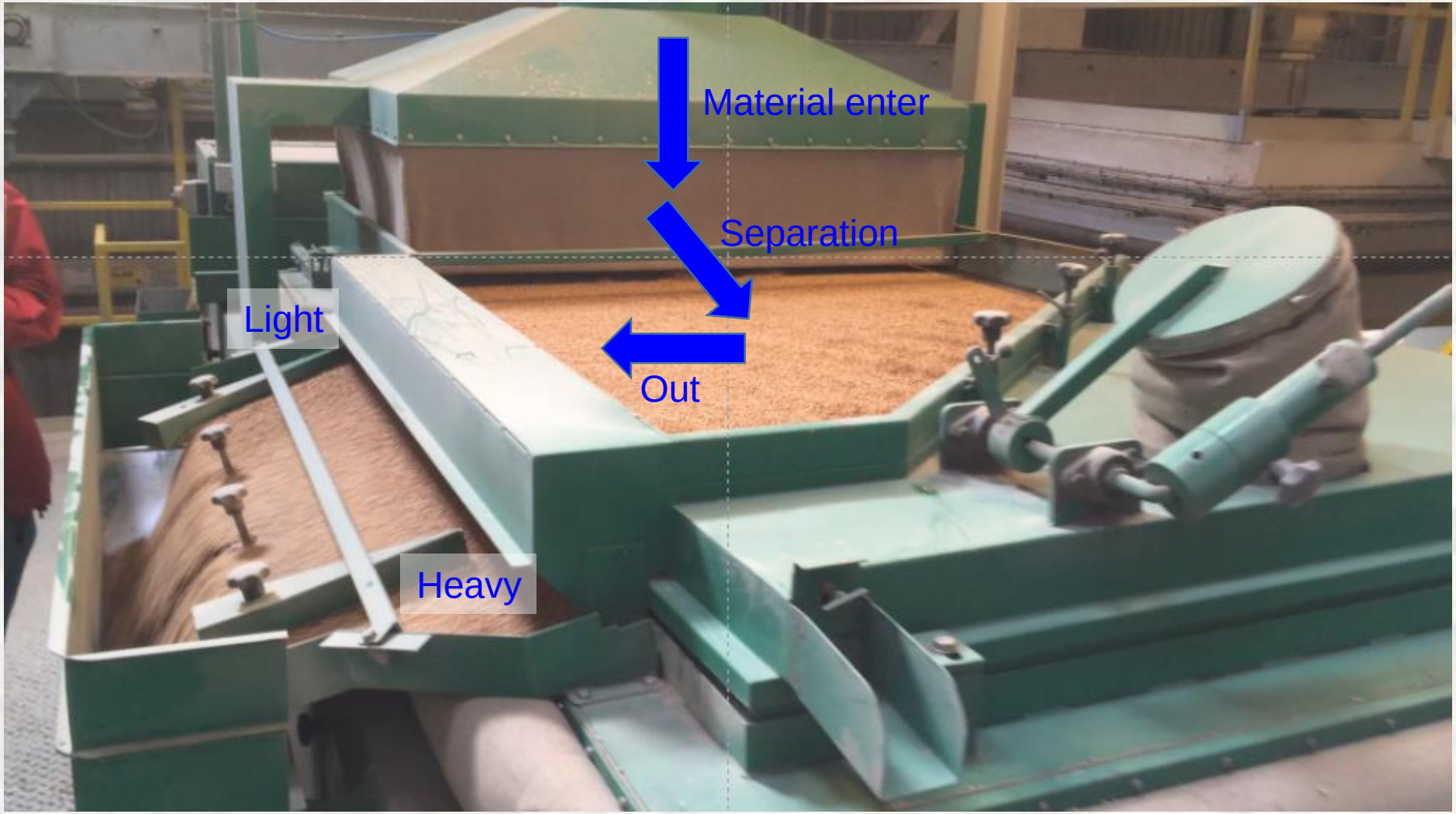
Multispectral measurement of physical properties from table output.

Outline

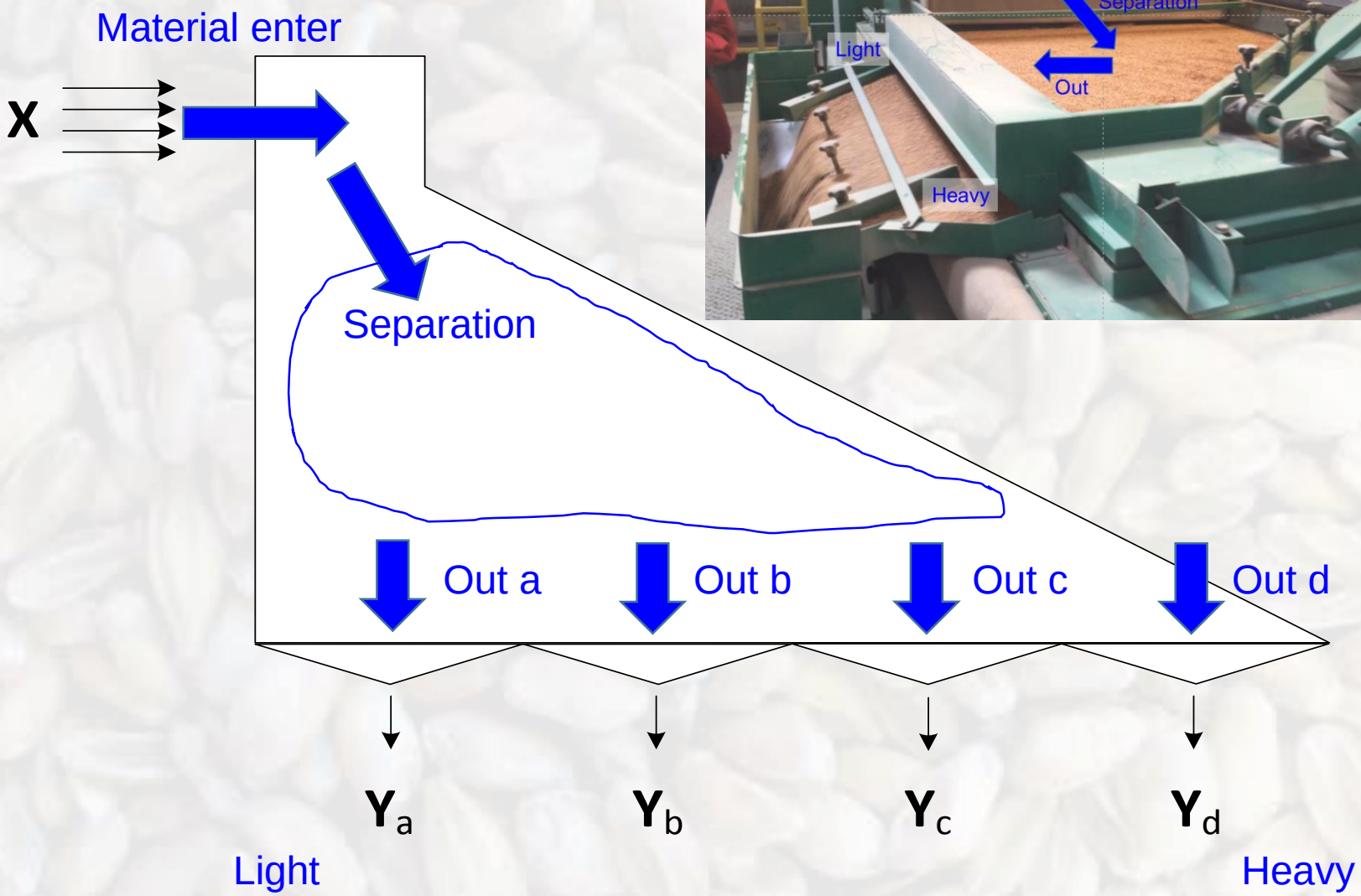
SAGT - Self Adjusting Gravity Table:

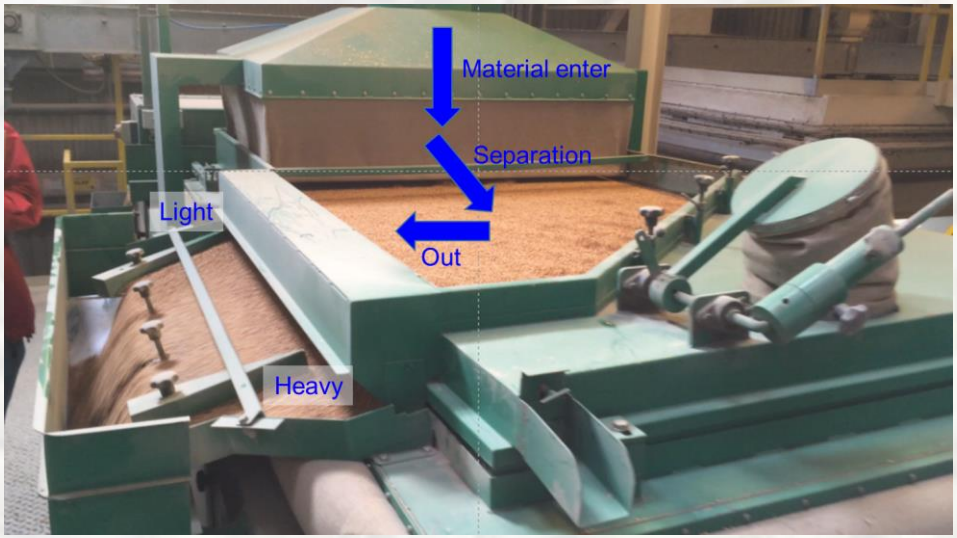
- Introduction
- Physics
- Parameters
- Modelling
- Results
- Acknowledgements

A short introduction to gravity tables



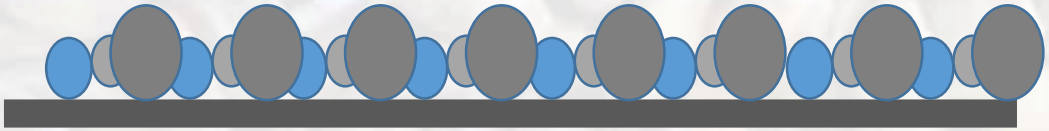
A short introduction to gravity tables





A short introduction to gravity tables

gravity table physics



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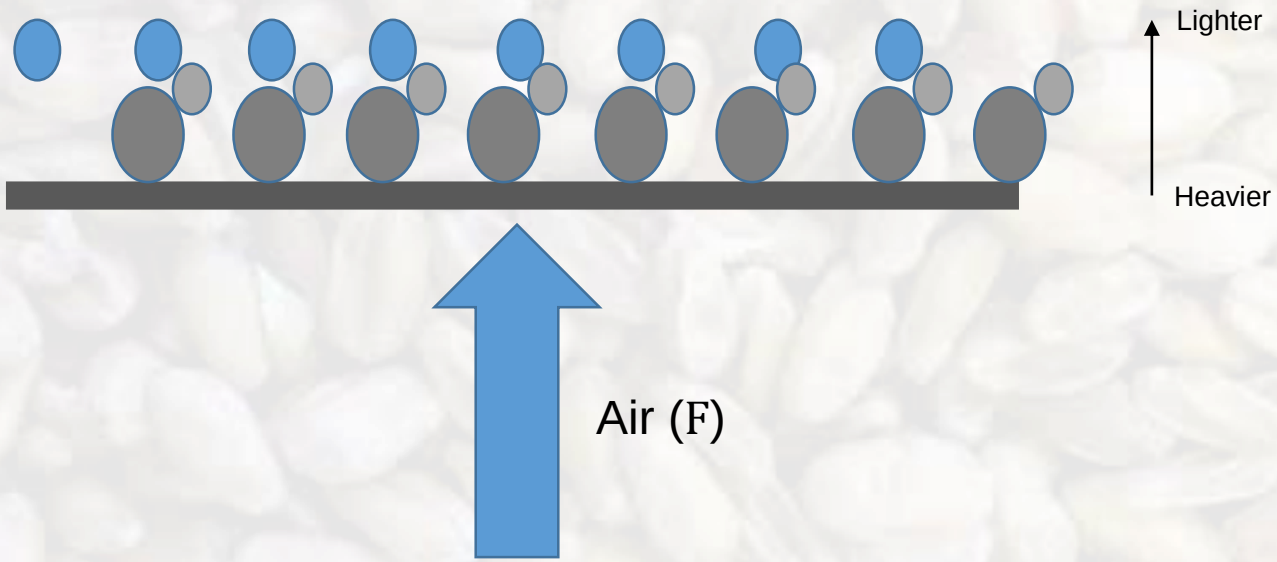

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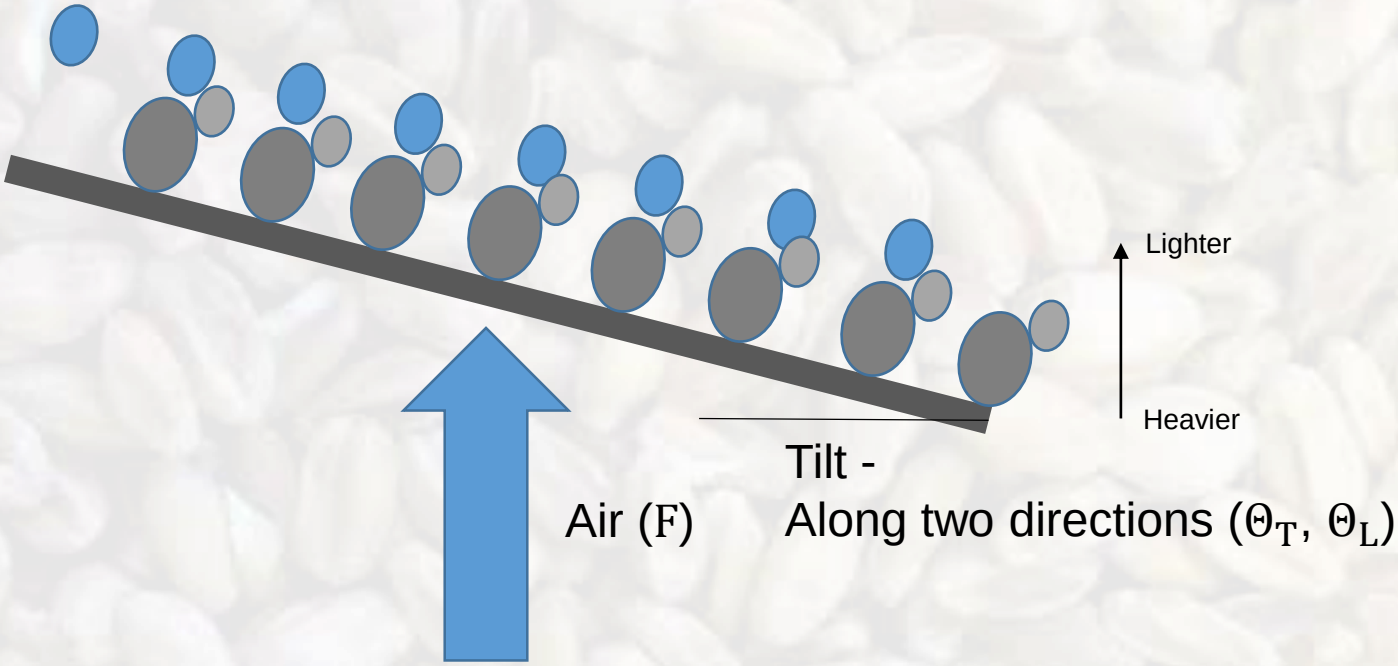
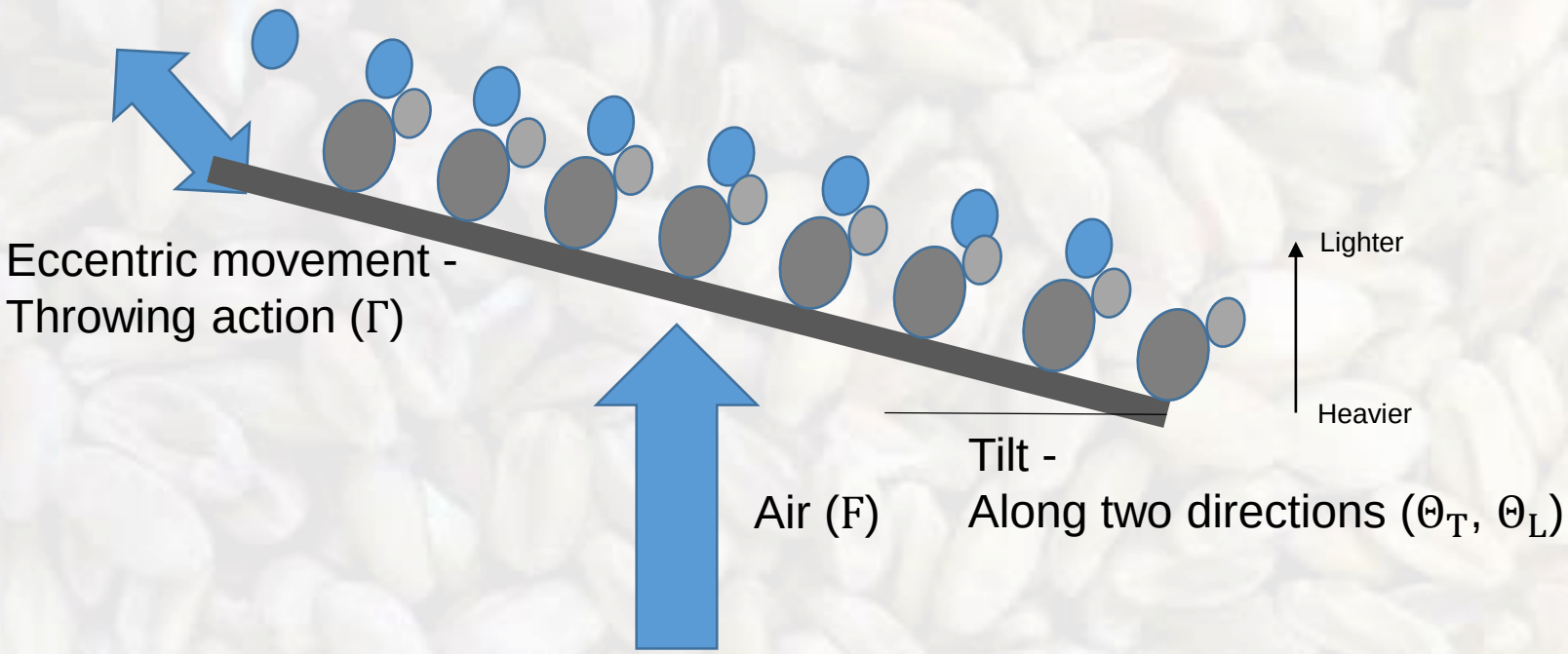


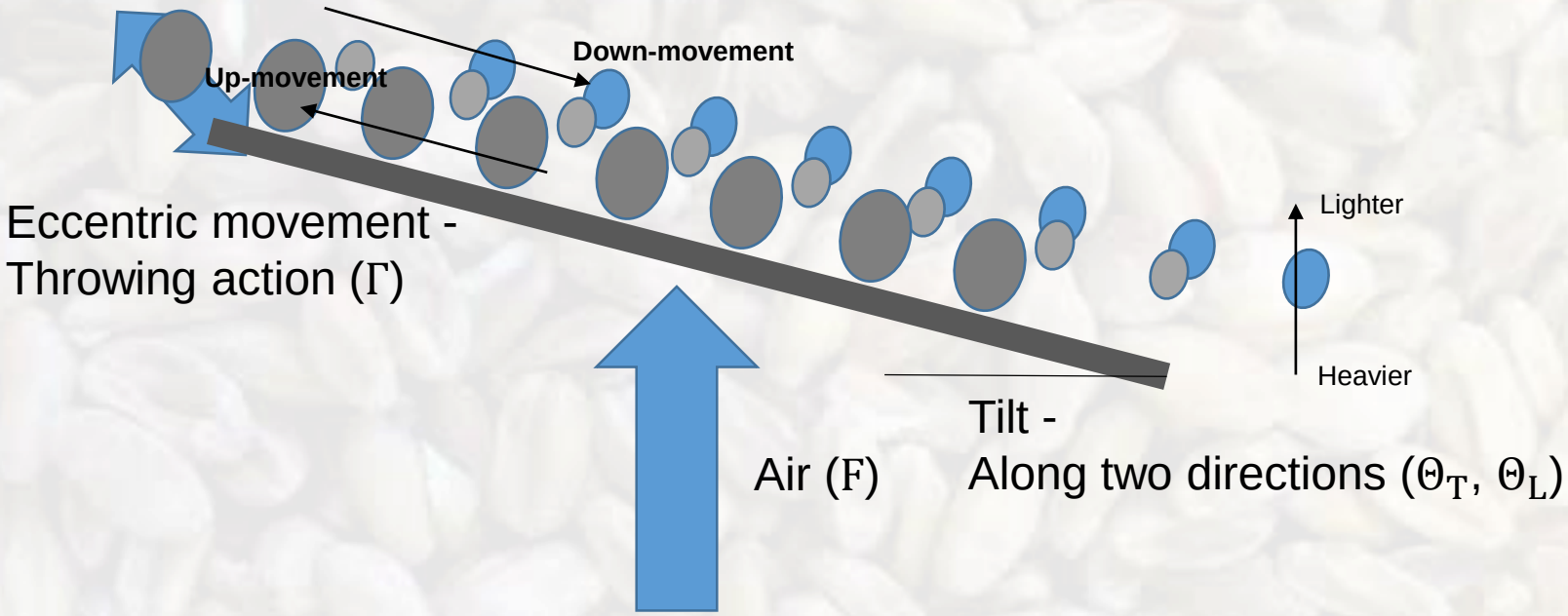
A short introduction to gravity tables

gravity table physics



A short introduction to gravity tables

gravity table physics

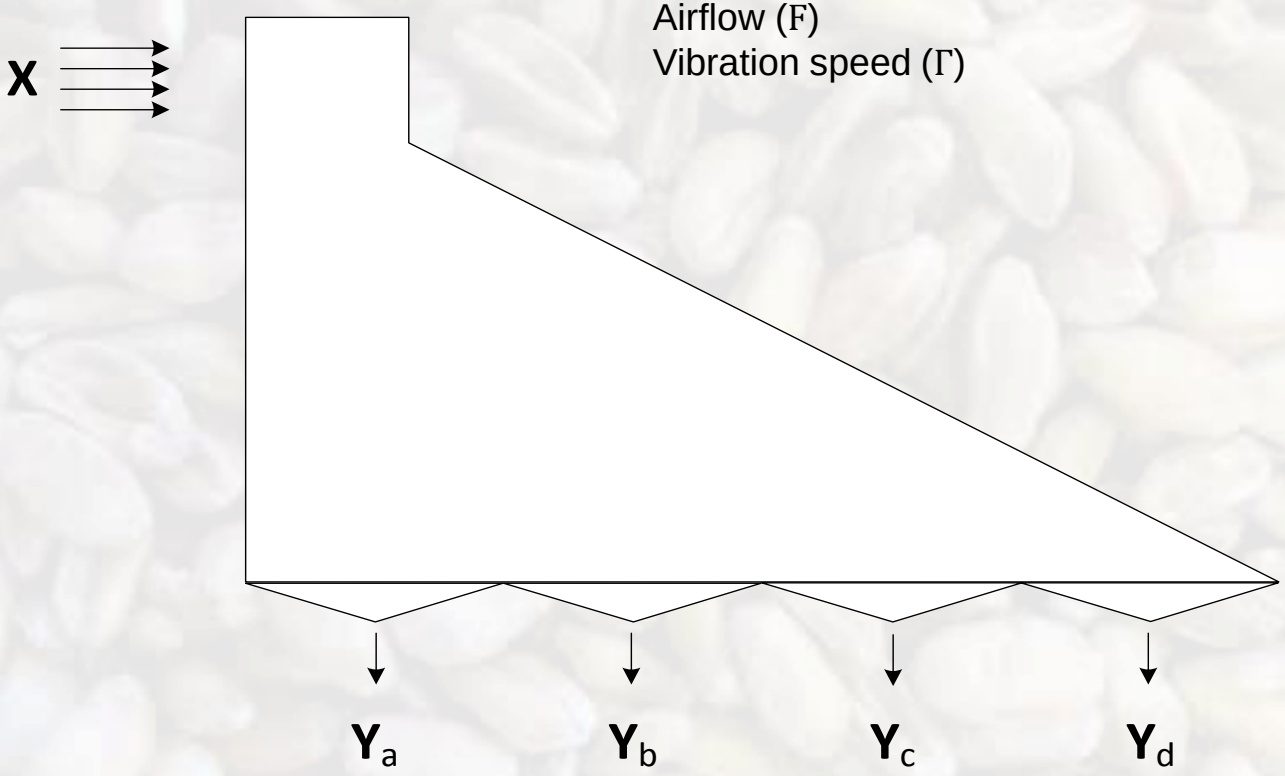


A short introduction to gravity tables

gravity table parameters

Parameters

Load (V)
Angles (Θ_T and Θ_L)
Airflow (F)
Vibration speed (Γ)

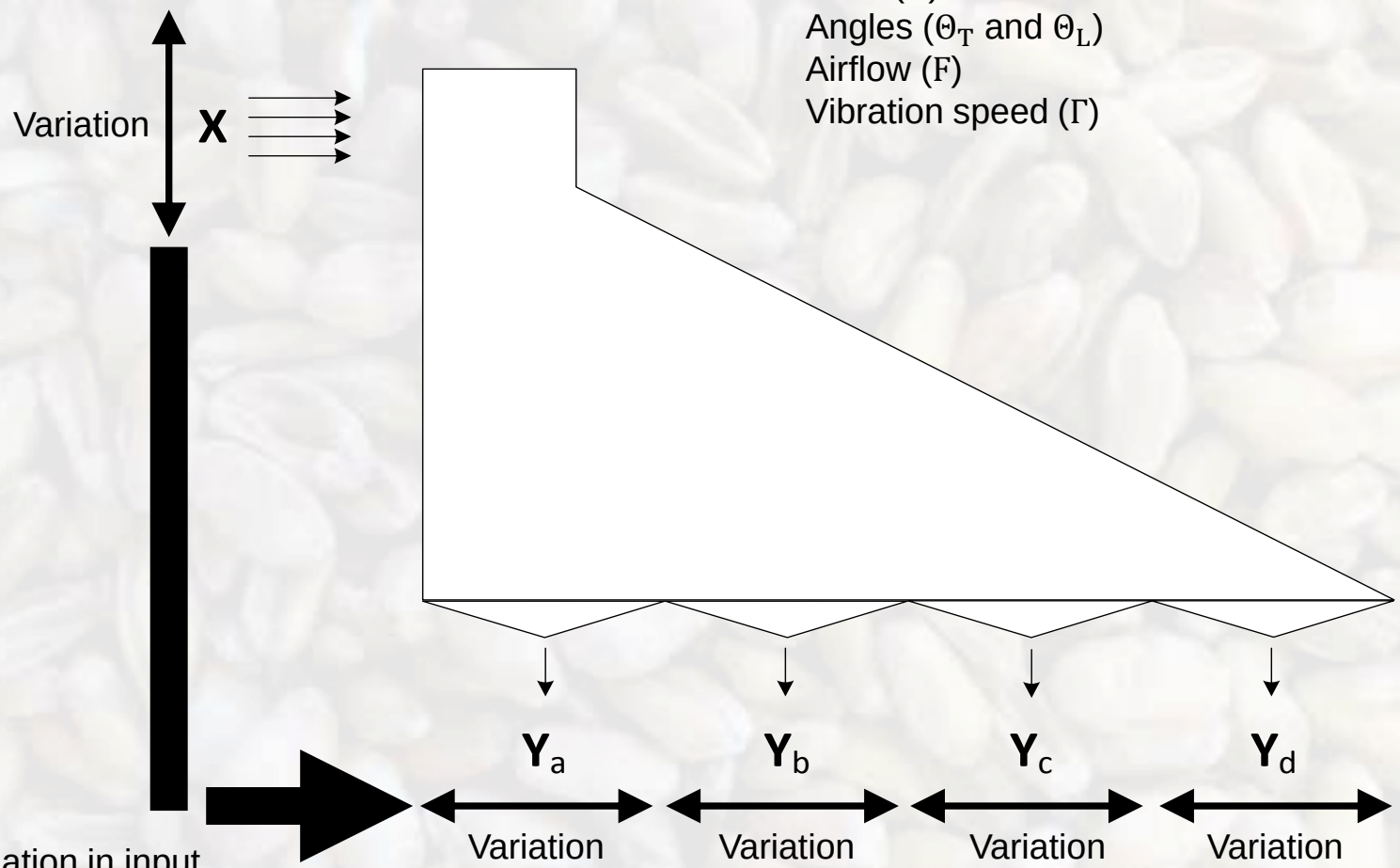


A short introduction to gravity tables

empirical modelling

Parameters

Load (V)
Angles (Θ_T and Θ_L)
Airflow (F)
Vibration speed (Γ)



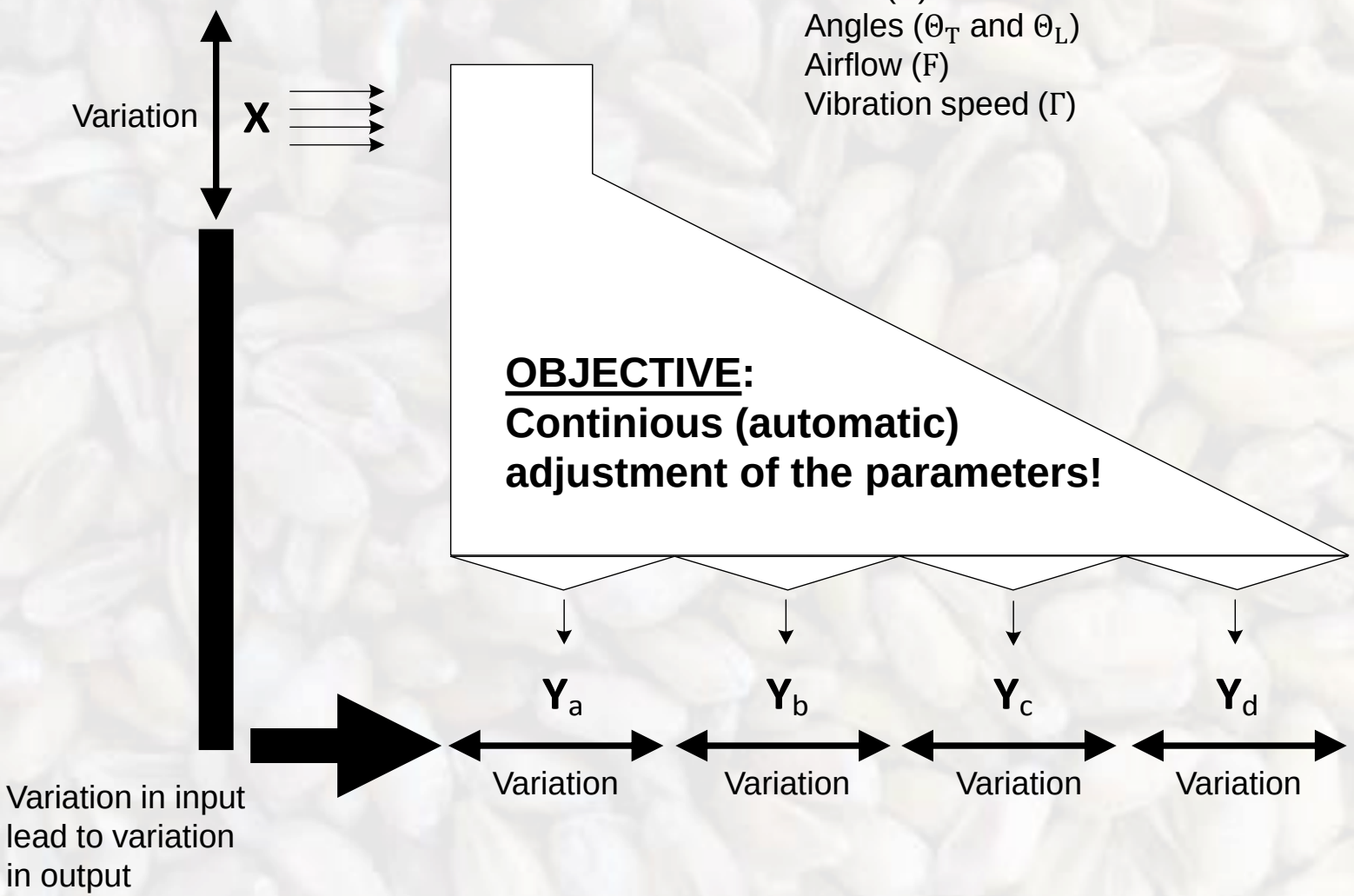
Variation in input lead to variation in output

A short introduction to gravity tables

empirical modelling

Parameters

Load (V)
Angles (Θ_T and Θ_L)
Airflow (F)
Vibration speed (Γ)



A short introduction to gravity tables

empirical modelling

Parameters

Load (V)
Angles (Θ_T and Θ_L)
Airflow (F)
Vibration speed (Γ)

X

<u>OBJECTIVE</u>:
Continious (automatic) adjustment of the parameters!

Y_a **Y_b** **Y_c** **Y_d**



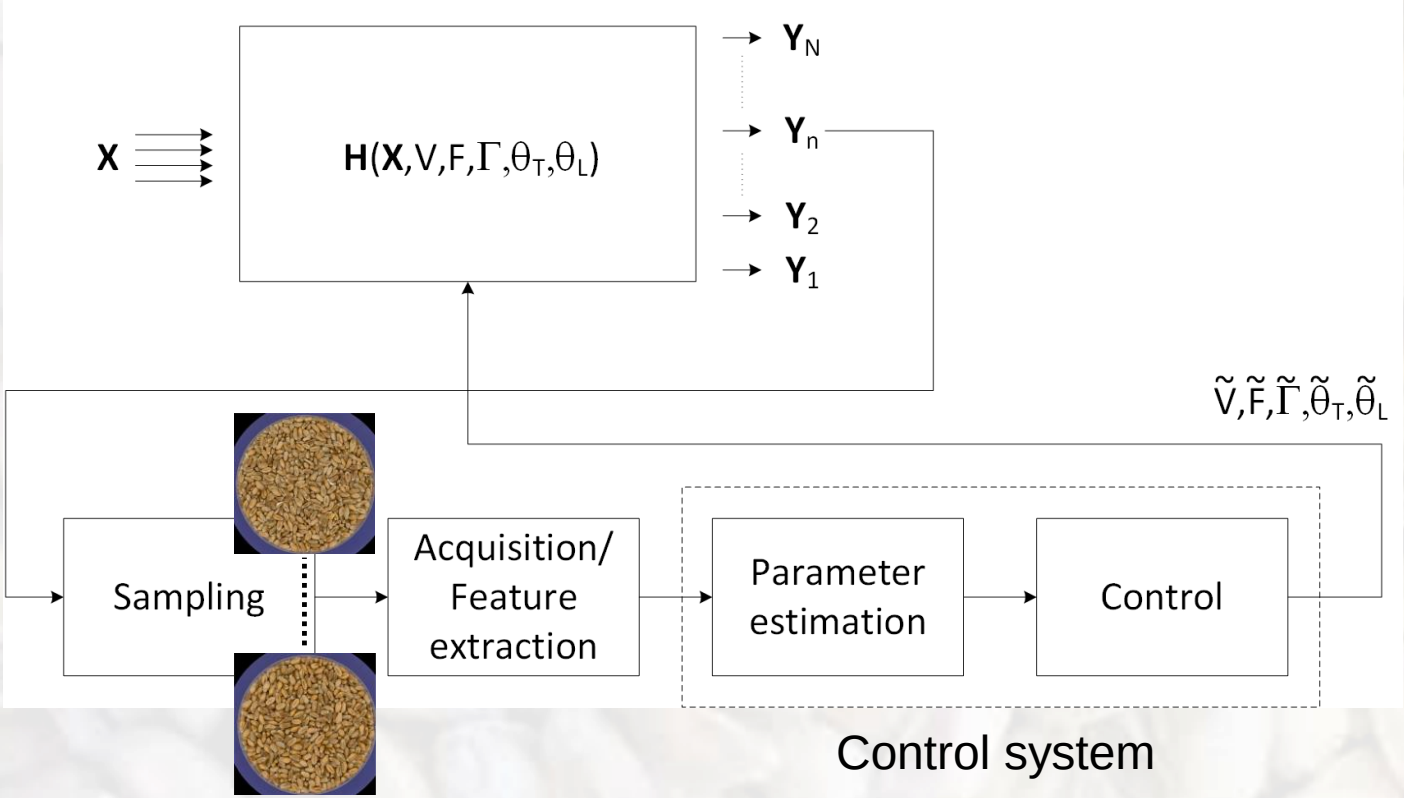



A short introduction to gravity tables

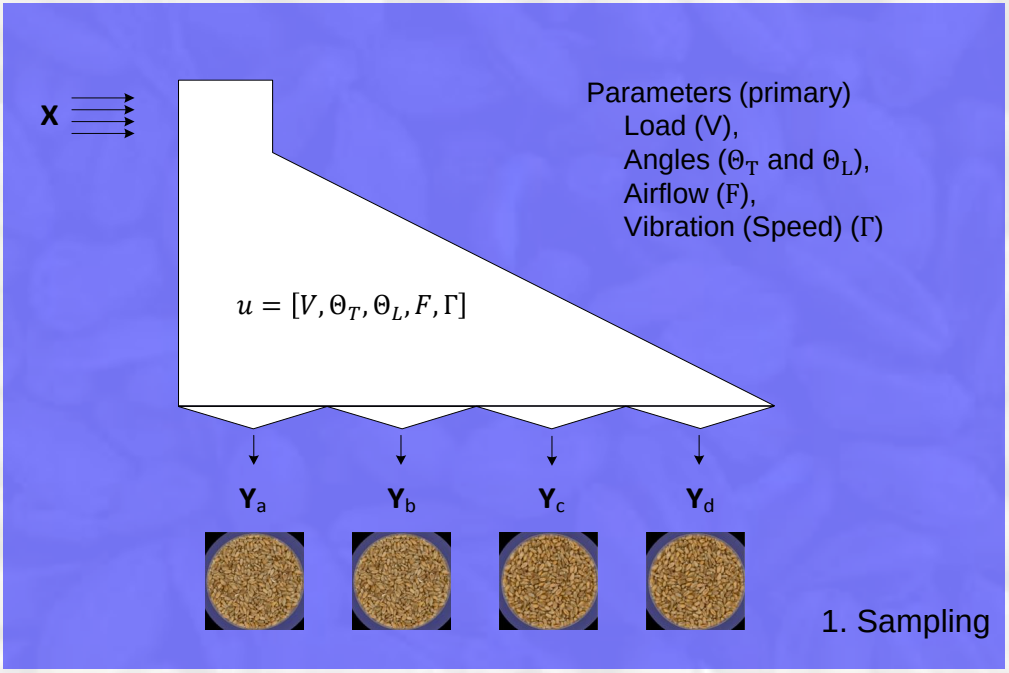
empirical modelling

Parameters

Load (V)
Angles (Θ_T and Θ_L)
Airflow (F)
Vibration speed (Γ)



Empirical modelling – SAGT gravity table



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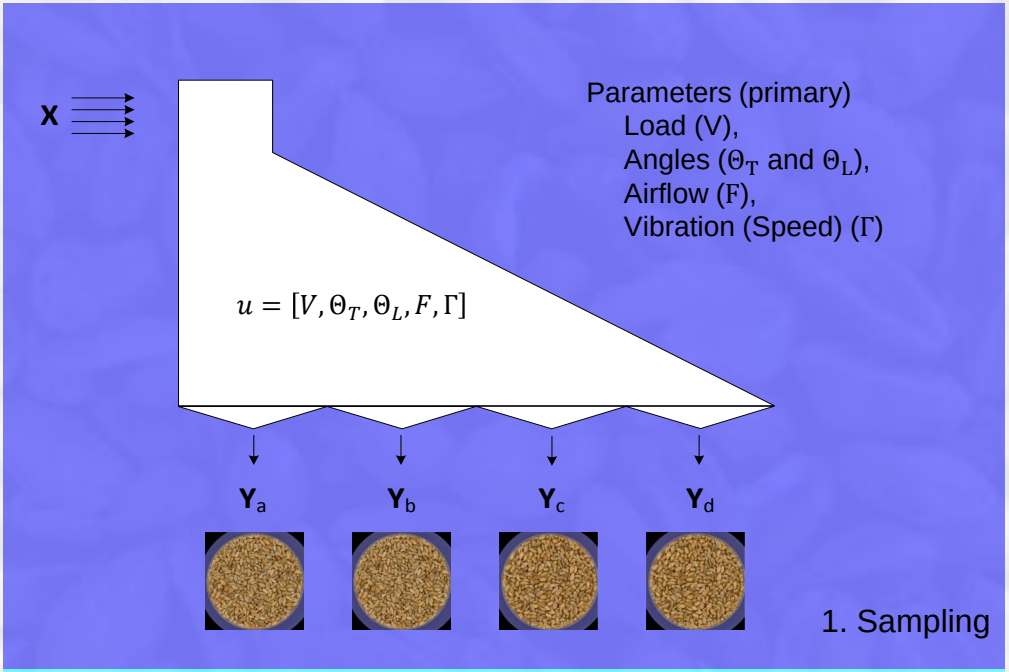

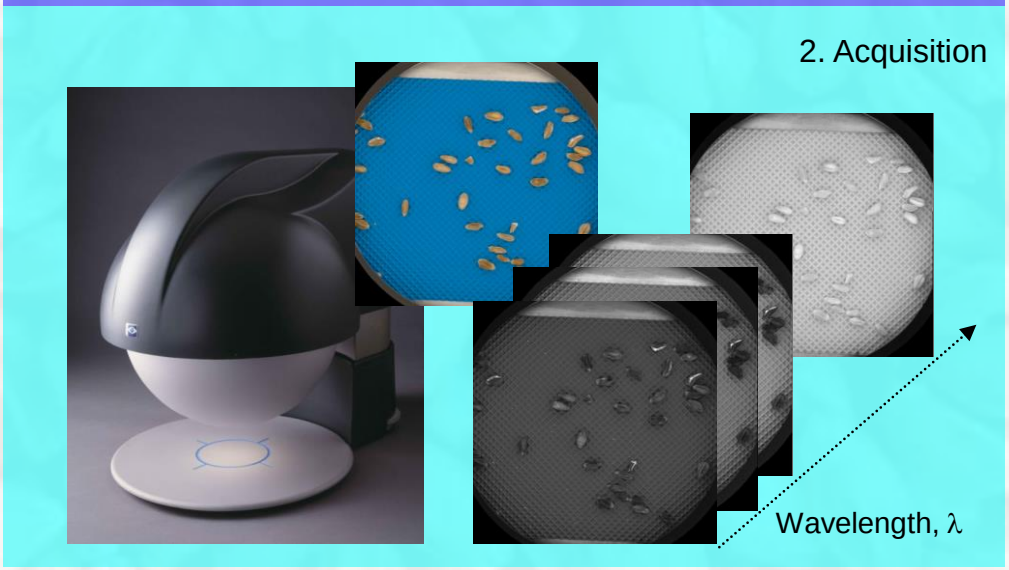

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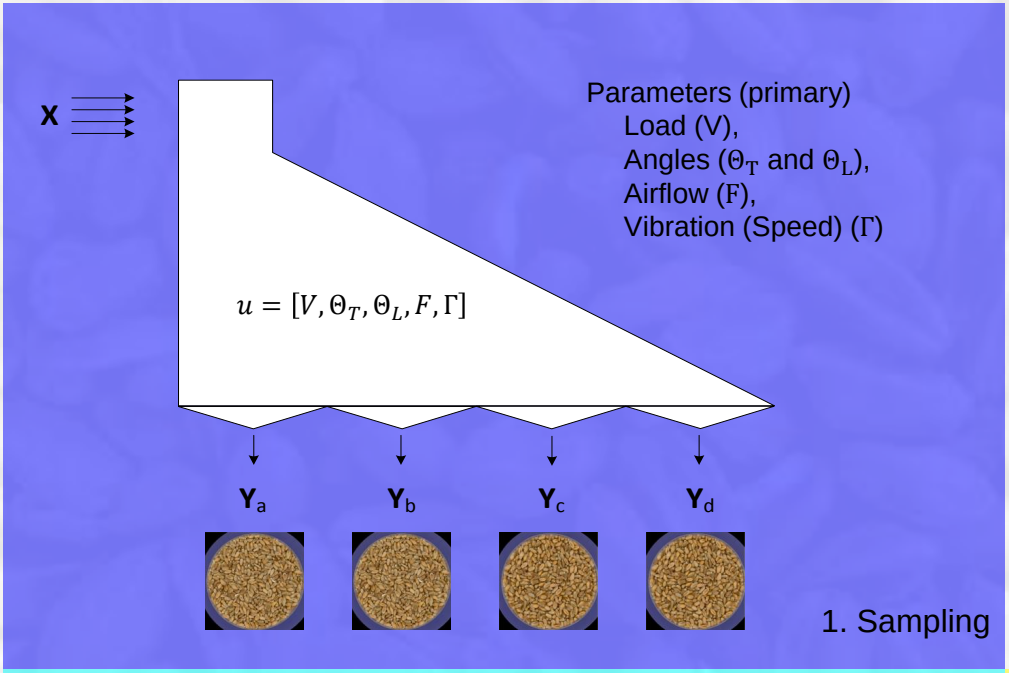
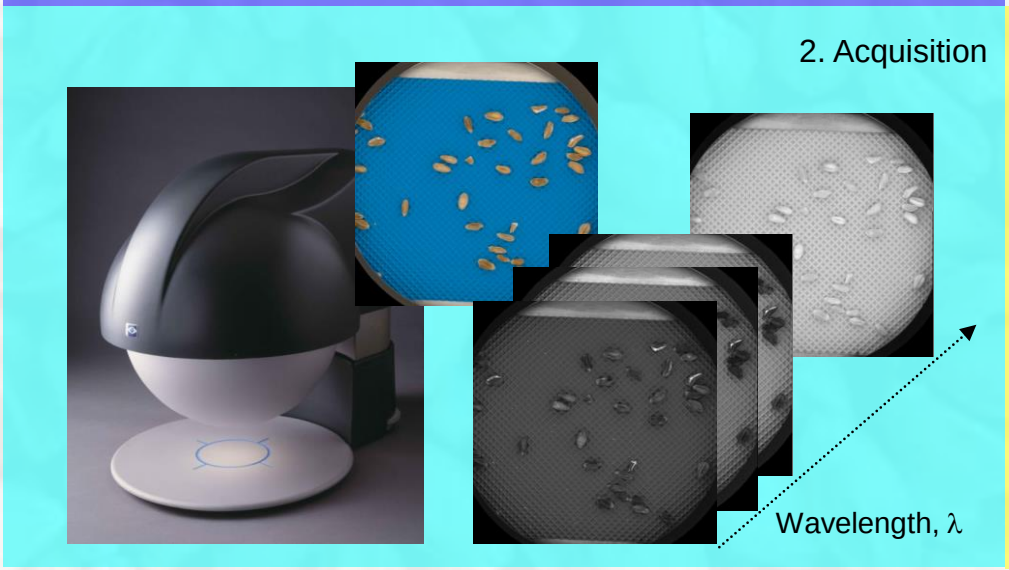
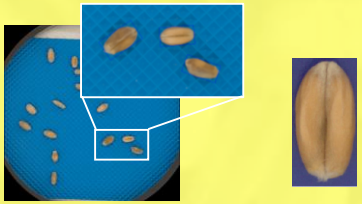




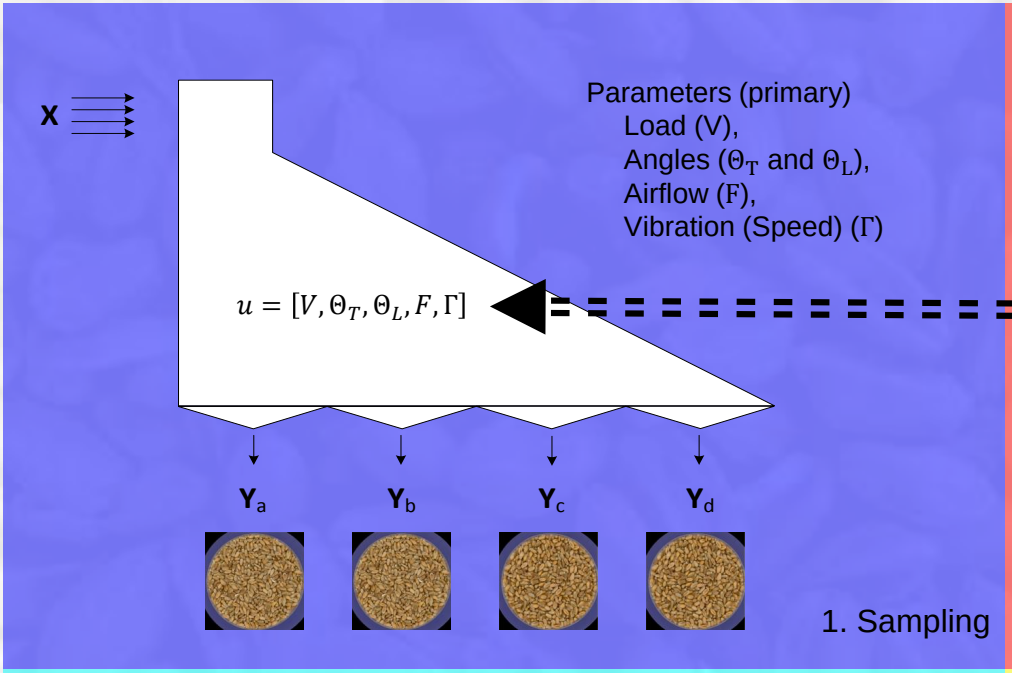
3. Image processing and gravity table state estimation



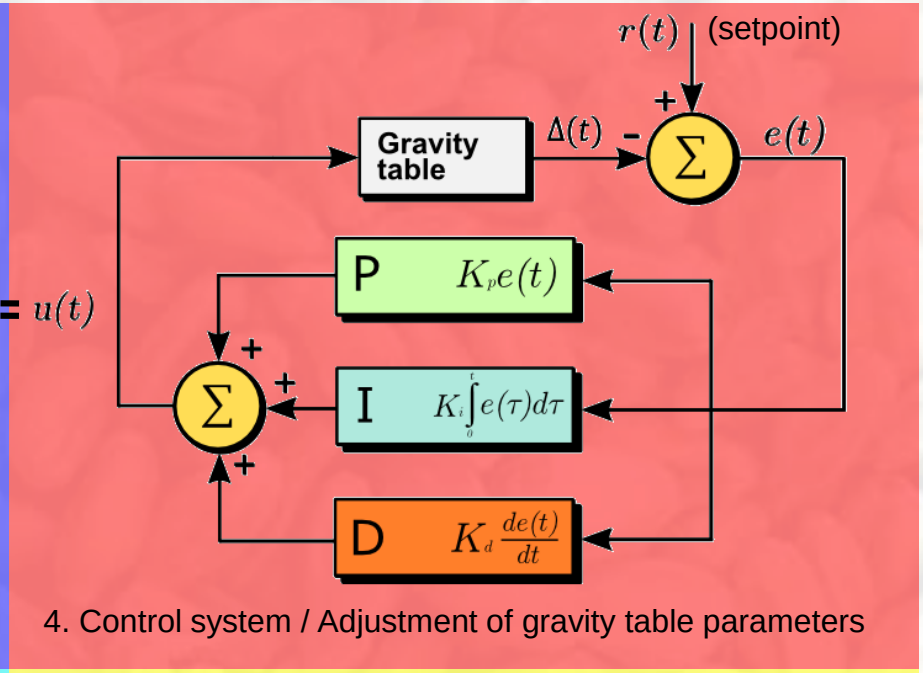
$$\boldsymbol{x}_n = \{x_1, \dots, x_M\}$$

$$\overbrace{\underbrace{\underbrace{\begin{bmatrix} x_{11} & \cdots & x_{1M} \\ \vdots & \cdots & \vdots \\ x_{n1} & \cdots & x_{nM} \\ \vdots & \cdots & \vdots \\ x_{N1} & \cdots & x_{NM} \end{bmatrix}}_{\tilde{\mathbf{Y}}_{\blacksquare} = f(\boldsymbol{X}, \widehat{\boldsymbol{\beta}}_{\mathrm{crop}})}}_{[\tilde{\mathbf{Y}}_a, \tilde{\mathbf{Y}}_b, \tilde{\mathbf{Y}}_c, \tilde{\mathbf{Y}}_d]}}_{\Delta = \tilde{\mathbf{Y}}_a - \tilde{\mathbf{Y}}_d} = \boldsymbol{X}$$

Empirical modelling – SAGT gravity table

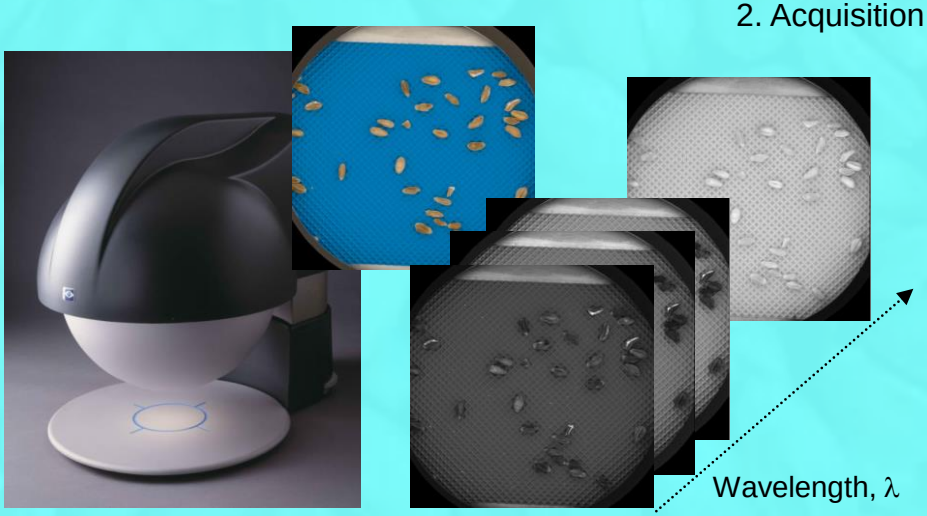


1. Sampling



4. Control system / Adjustment of gravity table parameters

2. Acquisition



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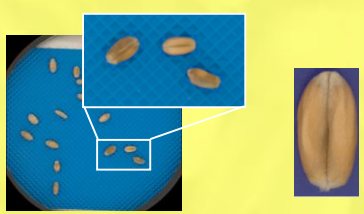


$$\Delta = \tilde{\mathbf{Y}}_a - \tilde{\mathbf{Y}}_d$$

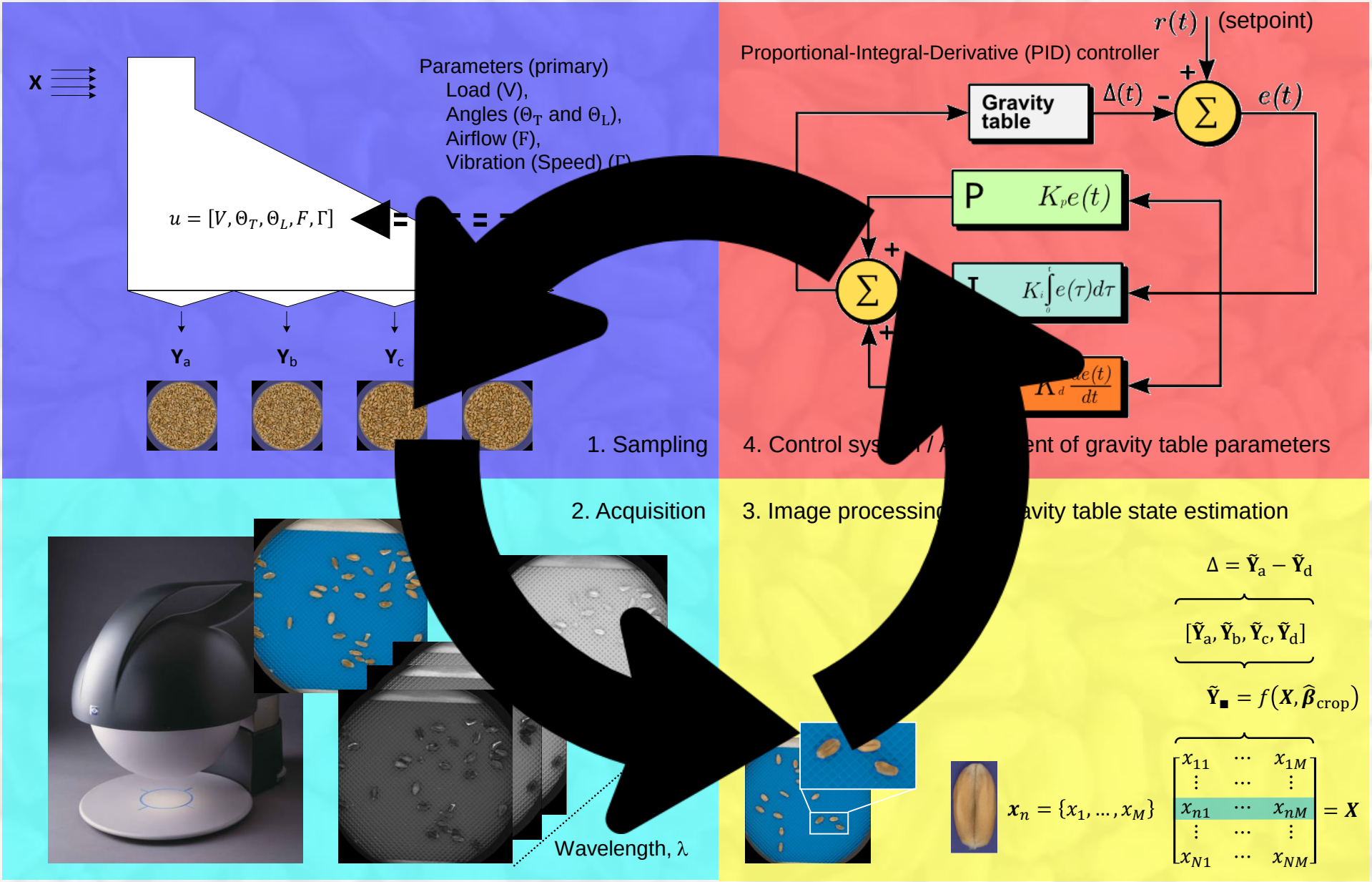
$$[\tilde{\mathbf{Y}}_a, \tilde{\mathbf{Y}}_b, \tilde{\mathbf{Y}}_c, \tilde{\mathbf{Y}}_d]$$

$$\tilde{\mathbf{Y}}_{\blacksquare} = f(\boldsymbol{X}, \widehat{\boldsymbol{\beta}}_{\text{crop}})$$

$$\boldsymbol{x}_n = \{x_1, \dots, x_M\}$$

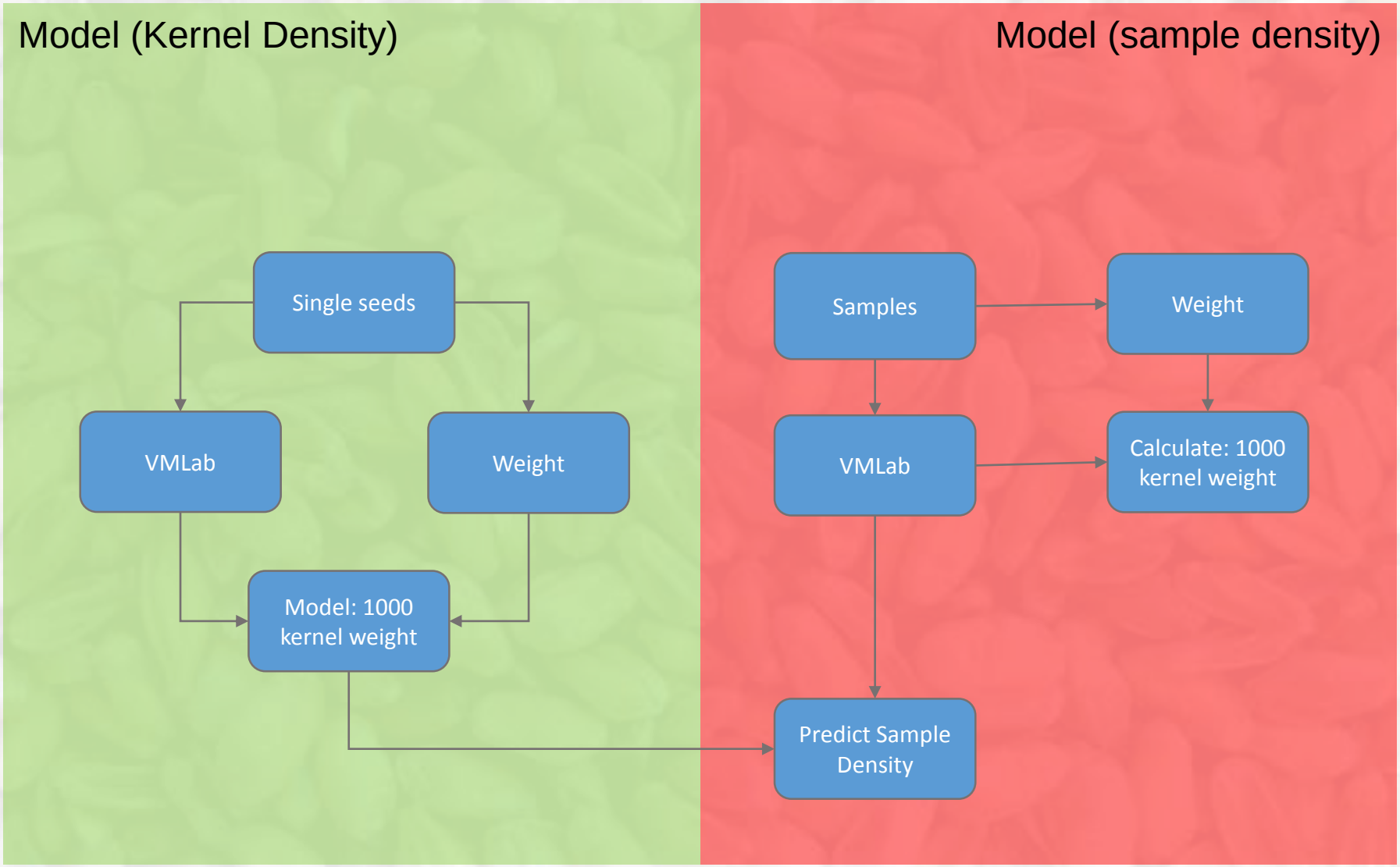
$$\begin{bmatrix} x_{11} & \cdots & x_{1M} \\ \vdots & \cdots & \vdots \\ x_{n1} & \cdots & x_{nM} \\ \vdots & \cdots & \vdots \\ x_{N1} & \cdots & x_{NM} \end{bmatrix} = \boldsymbol{X}$$

Empirical modelling – SAGT gravity table



Empirical modelling – SAGT gravity table

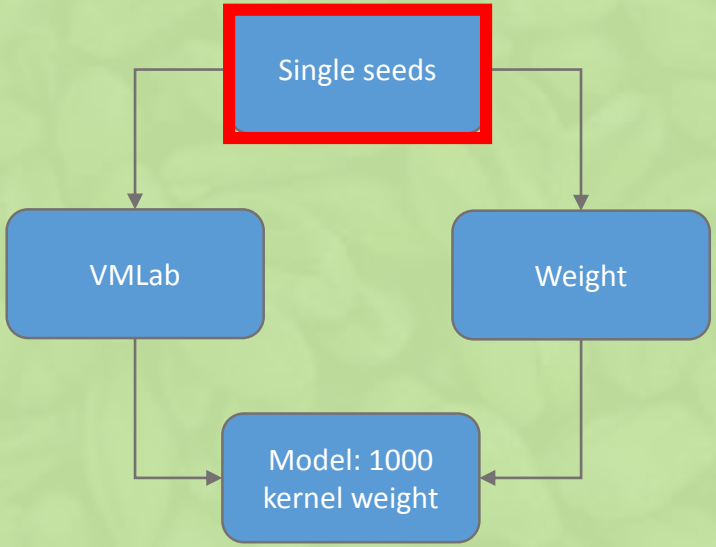
(Modelling the kernel weight)

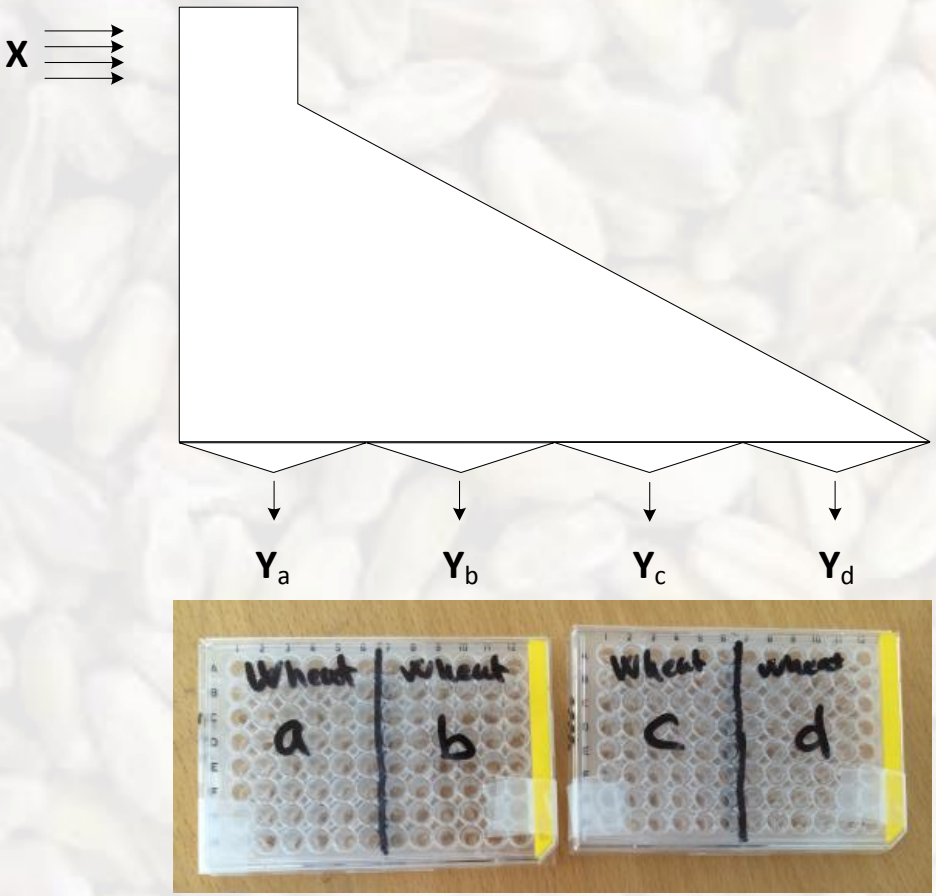


Empirical modelling – SAGT gravity table

(Modelling the kernel weight)

Model (Kernel Density)

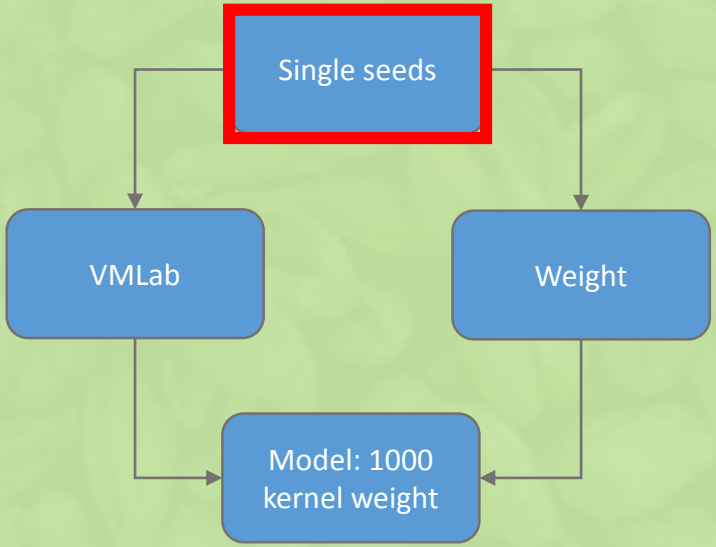


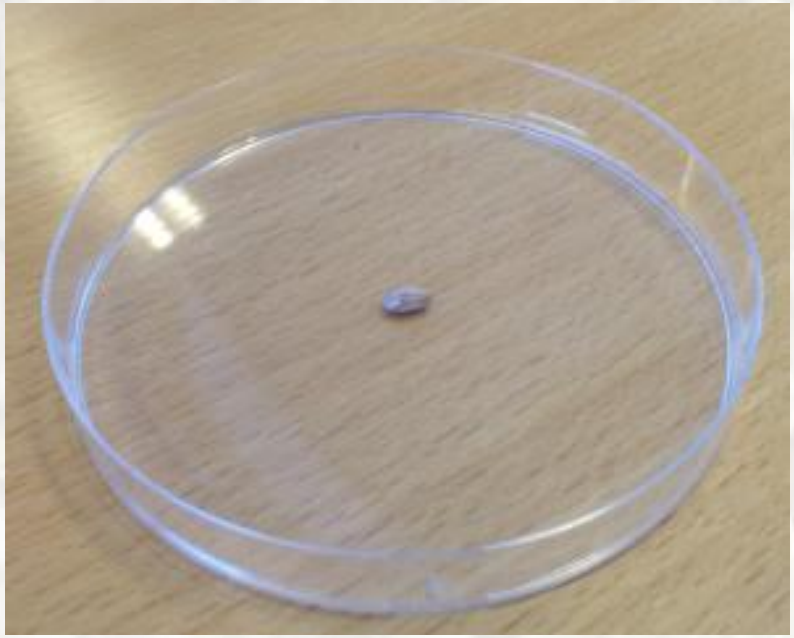


Empirical modelling – SAGT gravity table

(Modelling the kernel weight)

Model (Kernel Density)

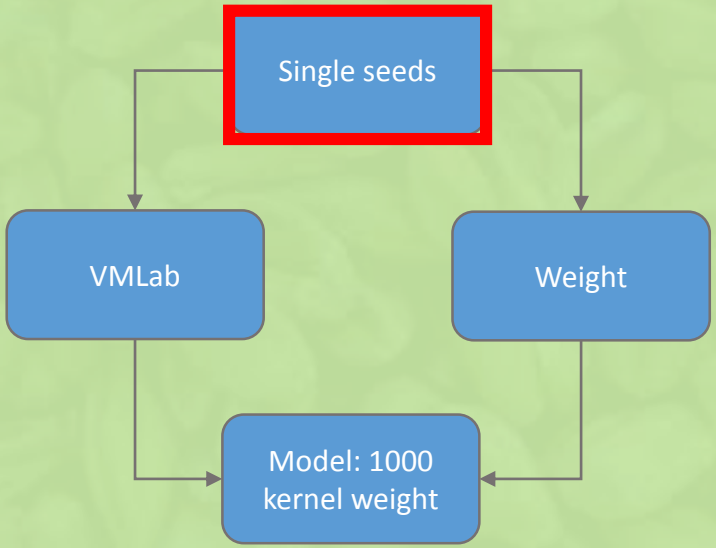


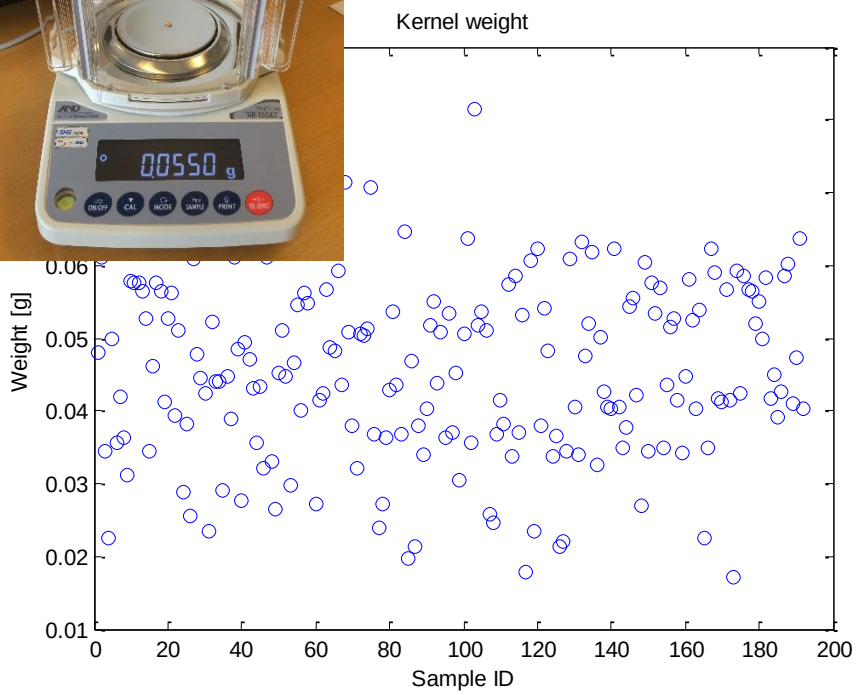


Empirical modelling – SAGT gravity table

(Modelling the kernel weight)

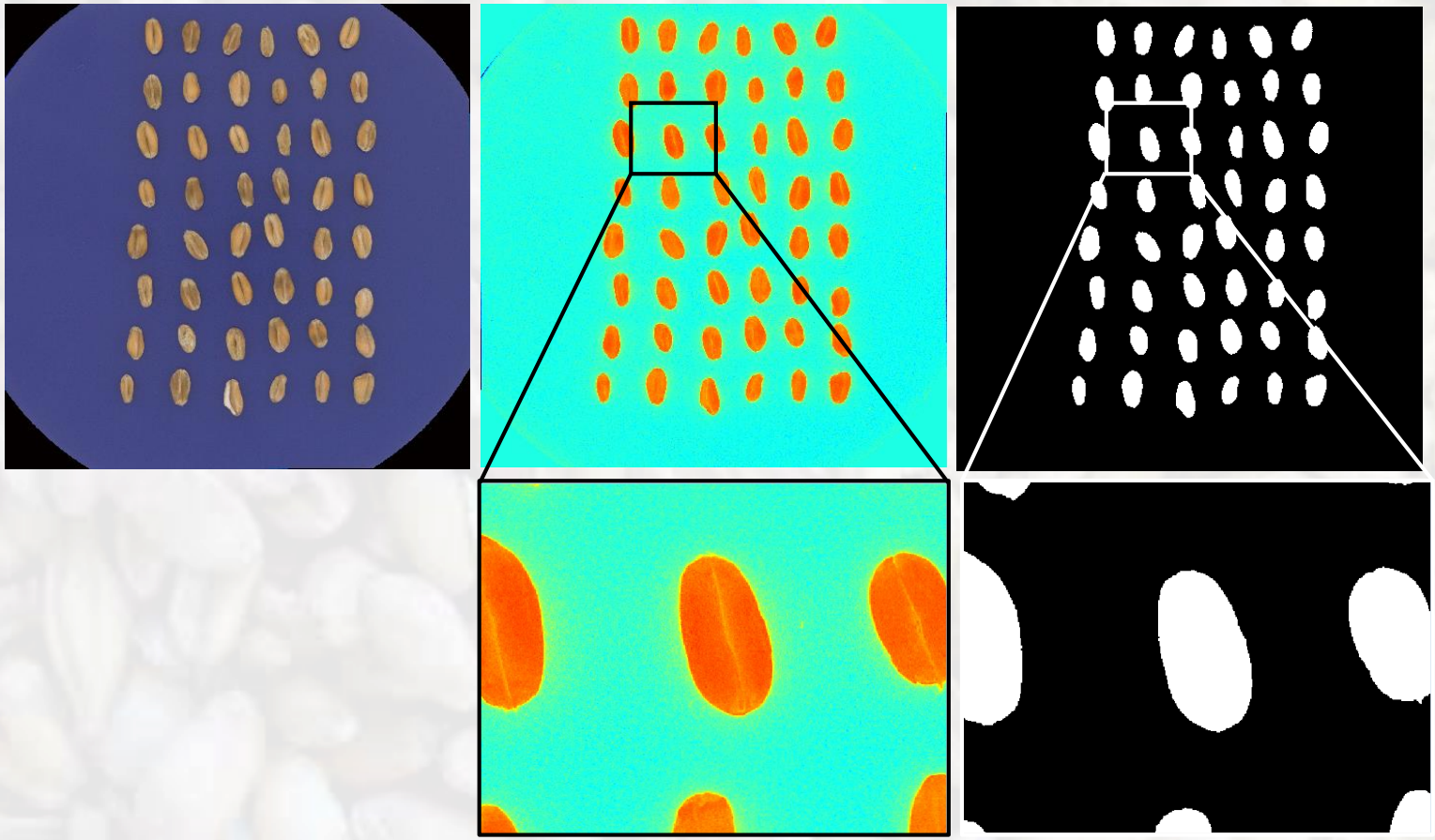
Model (Kernel Density)





Empirical modelling – SAGT gravity table

(Modelling the kernel weight)



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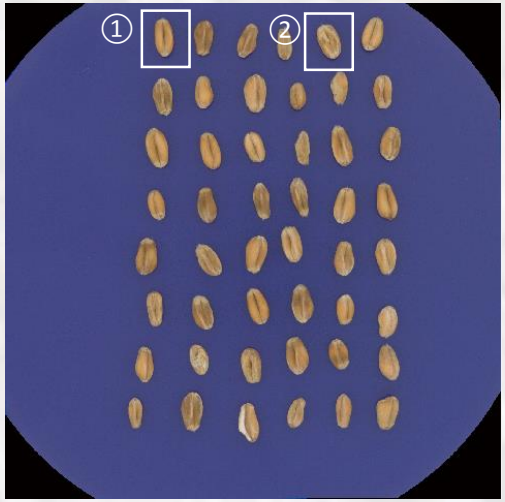
(Modelling the kernel weight)



Empirical modelling – SAGT gravity table

(Modelling the kernel weight)

We extract:

$$\boldsymbol{X} = \begin{bmatrix} x_{11} & \cdots & x_{1M} \\ \vdots & \cdots & \vdots \\ x_{n1} & \cdots & x_{nM} \\ \vdots & \cdots & \vdots \\ x_{N1} & \cdots & x_{NM} \end{bmatrix}$$

$$\boldsymbol{x}_n = \underbrace{\{x_1, \ldots, x_M\}}$$

Shape features (binary)
Reflectance features (multispectral)
Texture features (multispectral)

We model:

$\hat{\boldsymbol{y}}_{\text{weight}} = f(\boldsymbol{X}, \hat{\boldsymbol{\beta}})$ (*f* can be a linear/nonlinear model)

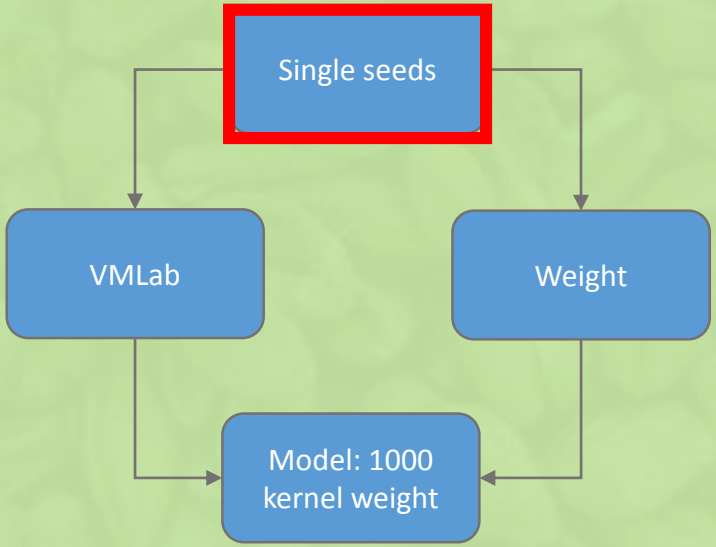
$\boldsymbol{X} =$

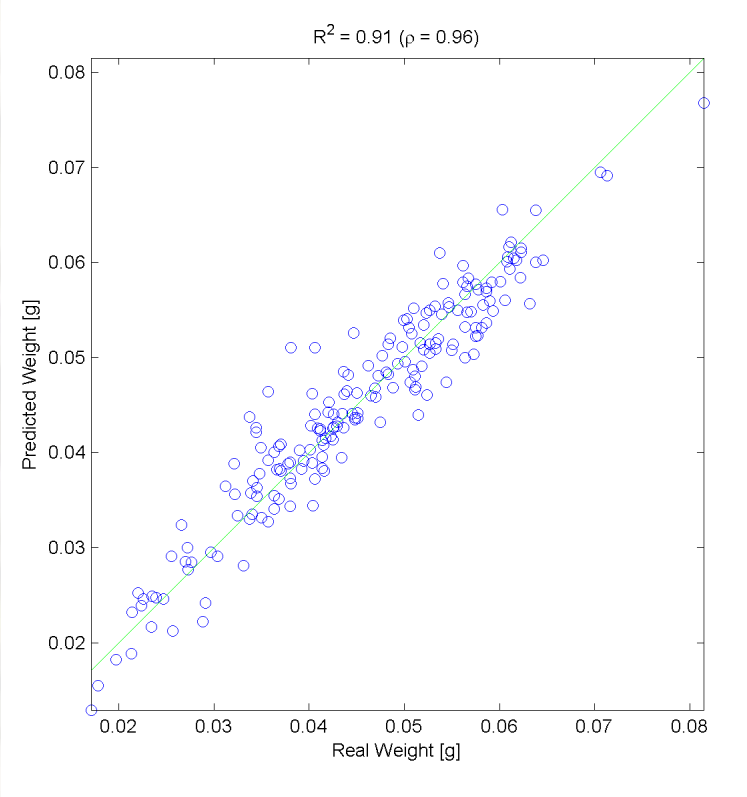
Using feature selection and cross validation, features are selected by yielding the best model for predicting

Empirical modelling – SAGT gravity table

(Modelling the kernel weight)

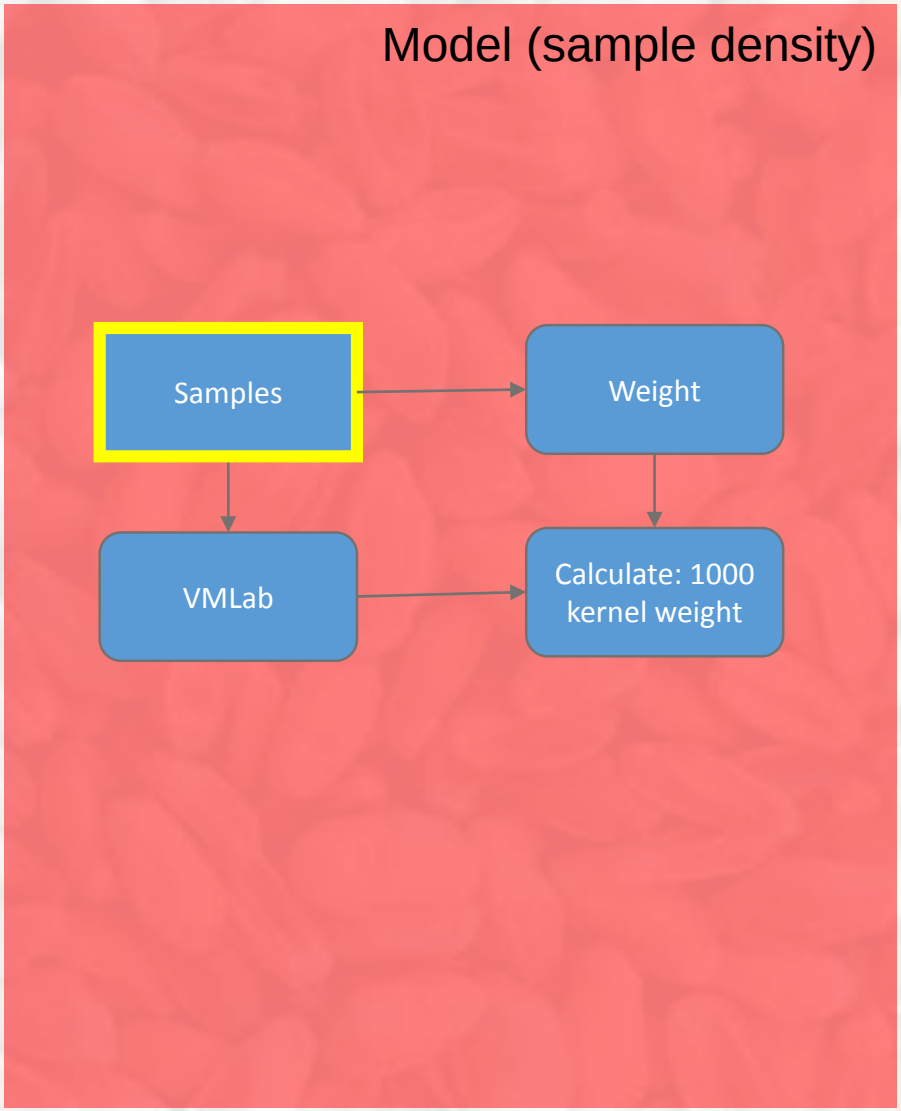
Model (Kernel Density)





Empirical modelling – SAGT gravity table

(Modelling the sample density)



Empirical modelling – SAGT gravity table

(Modelling the sample density)

- Primary parameters:
  - Load (V) – FIXED (80-85%)
  - Stroke Length – FIXED (7 mm)
  - Angles (Θ_T and Θ_L)
  - Airflow (F)
  - Vibration speed (Γ)

- Optimal settings (Jan Straby - Westrup A/S):
  - (Θ_T , Θ_L , F , Γ) = (15, 8, 40, 85)

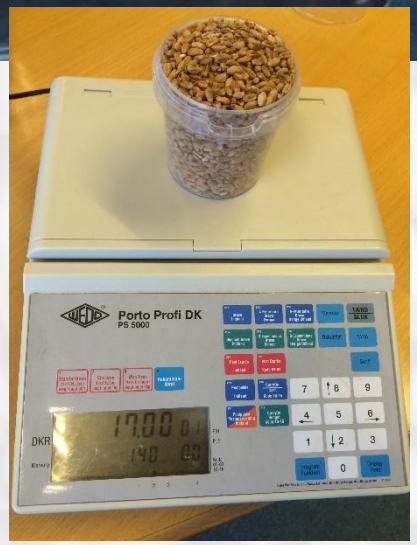
- Experiment (parameter variation):
  - 1: (Θ_T , Θ_L , F , Γ) = (**15**, 8, 46, 85) ± (5%, 0, 0, 0)
  - 2: (Θ_T , Θ_L , F , Γ) = (15, **8**, 46, 85) ± (0, 5%, 0, 0)
  - 3: (Θ_T , Θ_L , F , Γ) = (15, 8, **40**, 85) ± (0, 0, 5%, 0)
  - 4: (Θ_T , Θ_L , F , Γ) = (15, 8, 46, **85**) ± (0, 0, 0, 5%)

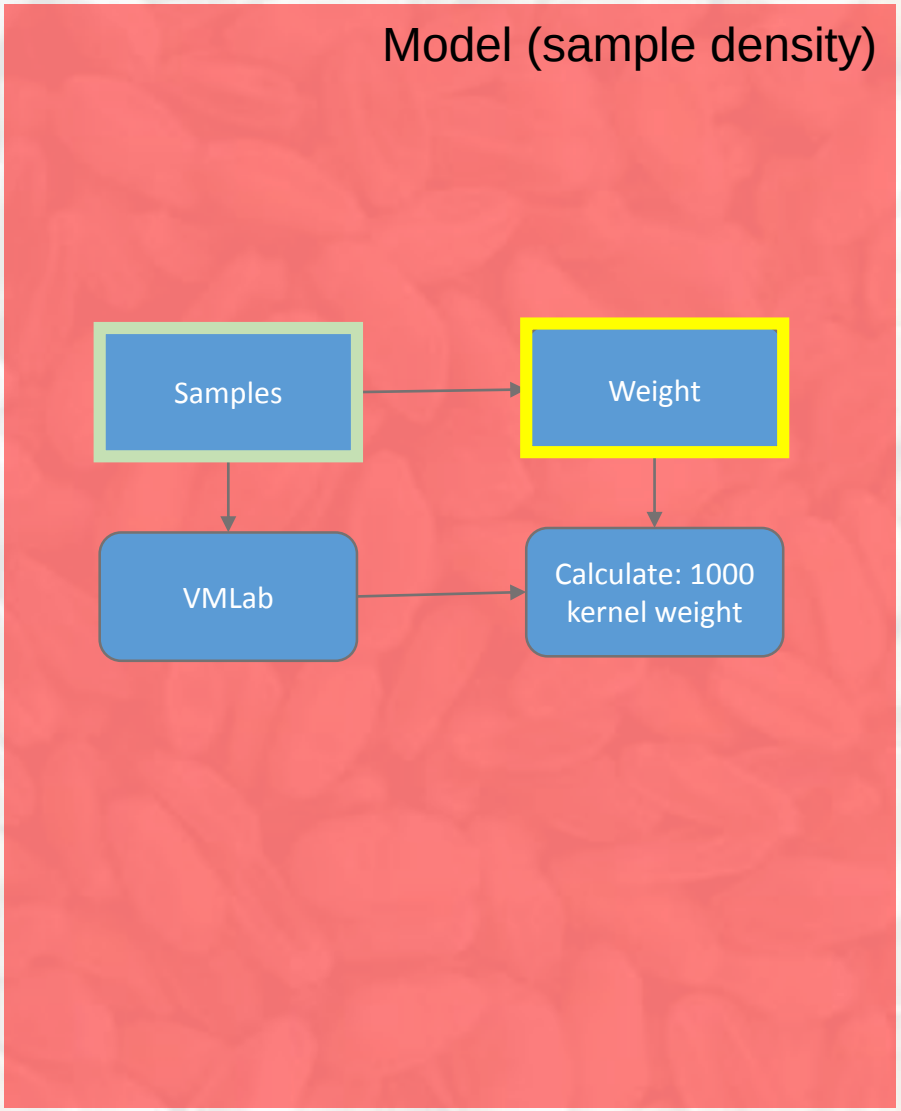
- Experiment (parameter values):
  - 1: (Θ_T , Θ_L , F , Γ) = ([13 14 **15** 16 17], 8, 40, 85) = ID:1,2,3,4,5
  - 2: (Θ_T , Θ_L , F , Γ) = (15, [6 7 **8** 9 10], 40, 85) = ID:6,7,8,9,10
  - 3: (Θ_T , Θ_L , F , Γ) = (15, 8, [36 38 **40** 42 44], 85) = ID:11,12,13,14,15
  - 4: (Θ_T , Θ_L , F , Γ) = (15, 8, 40, [81 83 **85** 87 89]) = ID:16,17,18,19,20

Exp.	Outlet	Cont. ID	Load	Tvær	Længde	Airflow	Speed
1	a	1	85	13	8	40	85
	b	2	85	13	8	40	85
	c	3	85	13	8	40	85
	d	4	85	13	8	40	85
2	a	5	85	14	8	40	85
	b	6	85	14	8	40	85
	c	7	85	14	8	40	85
	d	8	85	14	8	40	85
3	a	9	85	15	8	40	85
	b	10	85	15	8	40	85
	c	11	85	15	8	40	85
	d	12	85	15	8	40	85
4	a	13	85	16	8	40	85
	b	14	85	16	8	40	85
	c	15	85	16	8	40	85
	d	16	85	16	8	40	85
5	a	17	85	17	8	40	85
	b	18	85	17	8	40	85
	c	19	85	17	8	40	85
	d	20	85	17	8	40	85
6	a	21	85	15	6	40	85
	b	22	85	15	6	40	85
	c	23	85	15	6	40	85
	d	24	85	15	6	40	85
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
19	a	73	85	15	8	40	87
	b	74	85	15	8	40	87
	c	75	85	15	8	40	87
	d	76	85	15	8	40	87
20	a	77	85	15	8	40	89
	b	78	85	15	8	40	89
	c	79	85	15	8	40	89
	d	80	85	15	8	40	89

Empirical modelling – SAGT gravity table

(Modelling the sample density)



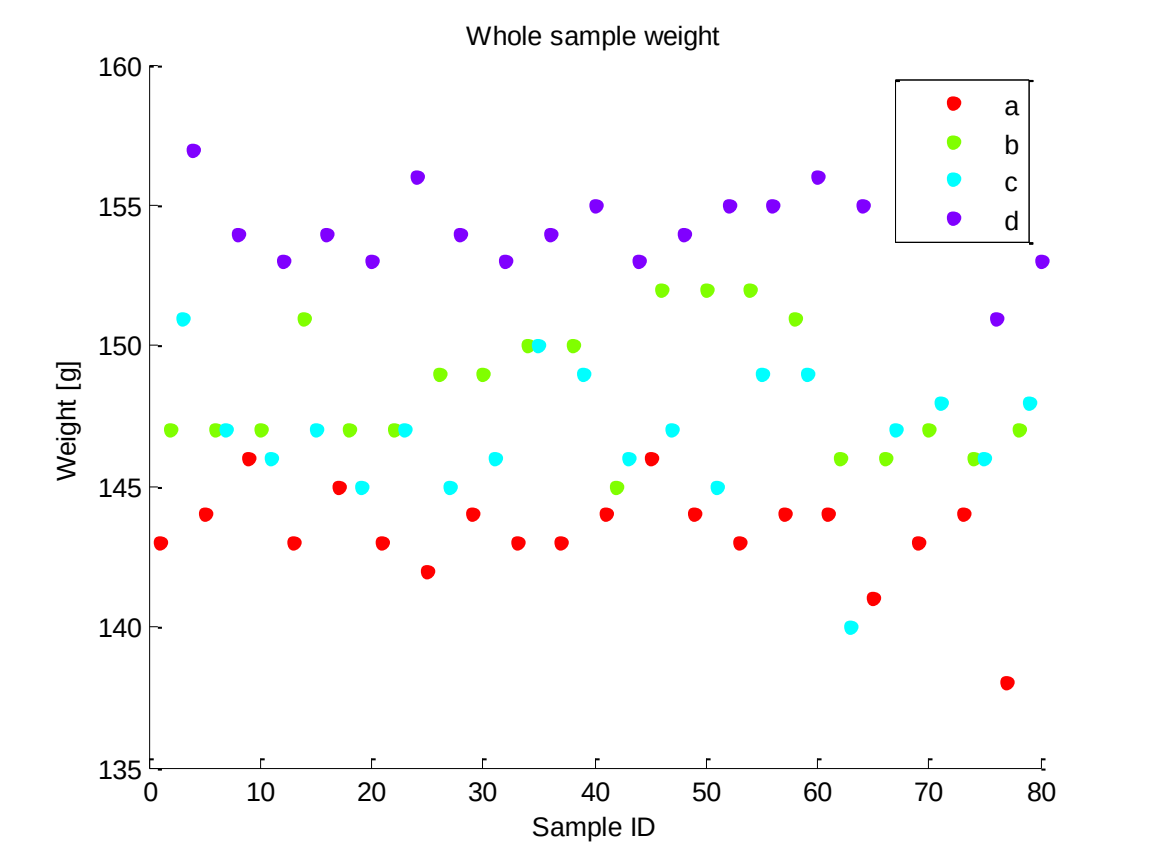


Empirical modelling – SAGT gravity table

(Modelling the sample density)

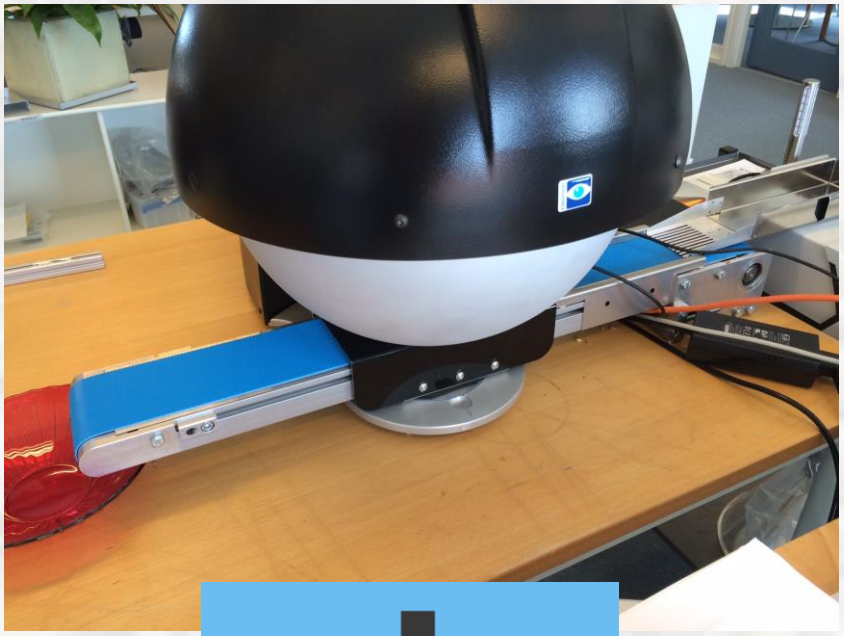
- Sample weight - All experiments

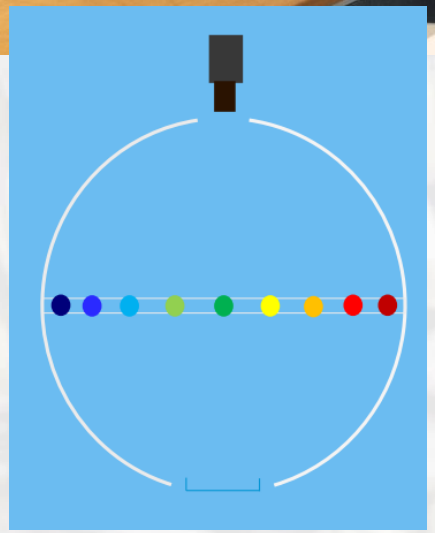
Δ ≈ 7%

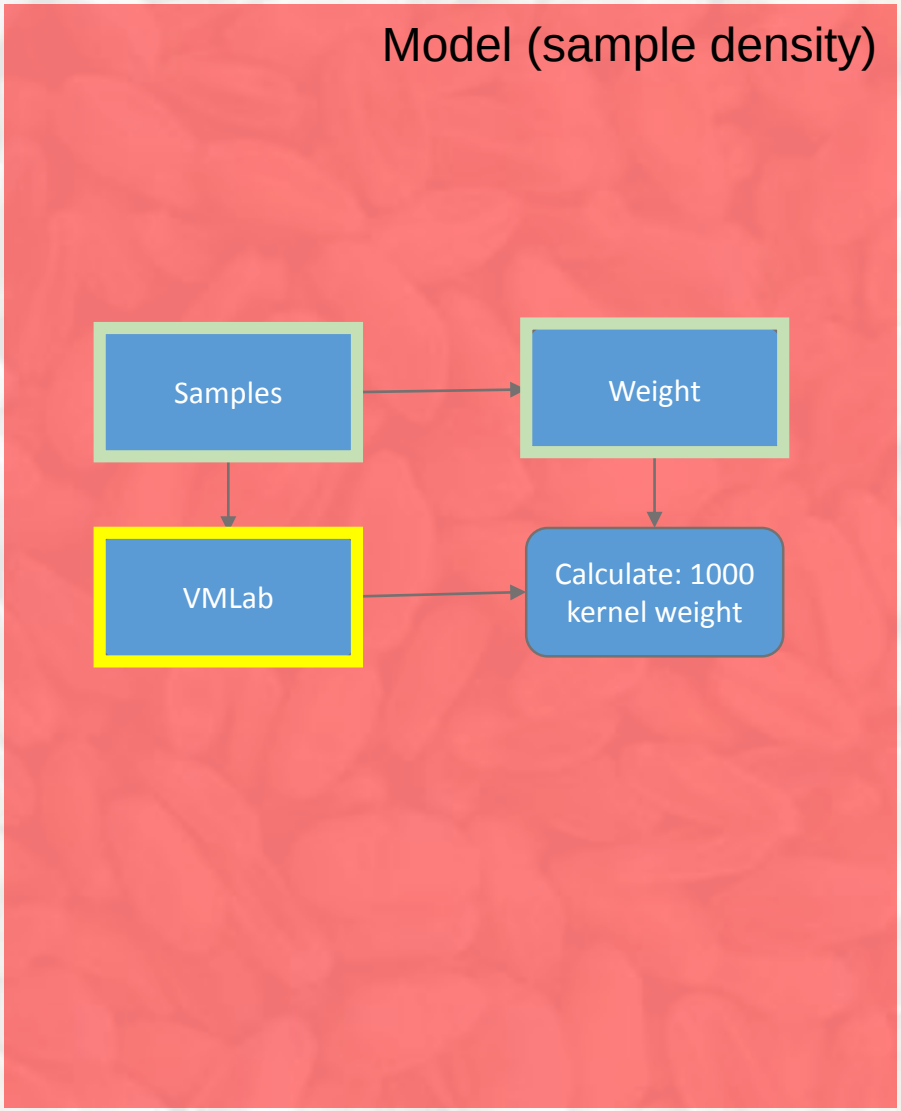


Empirical modelling – SAGT gravity table

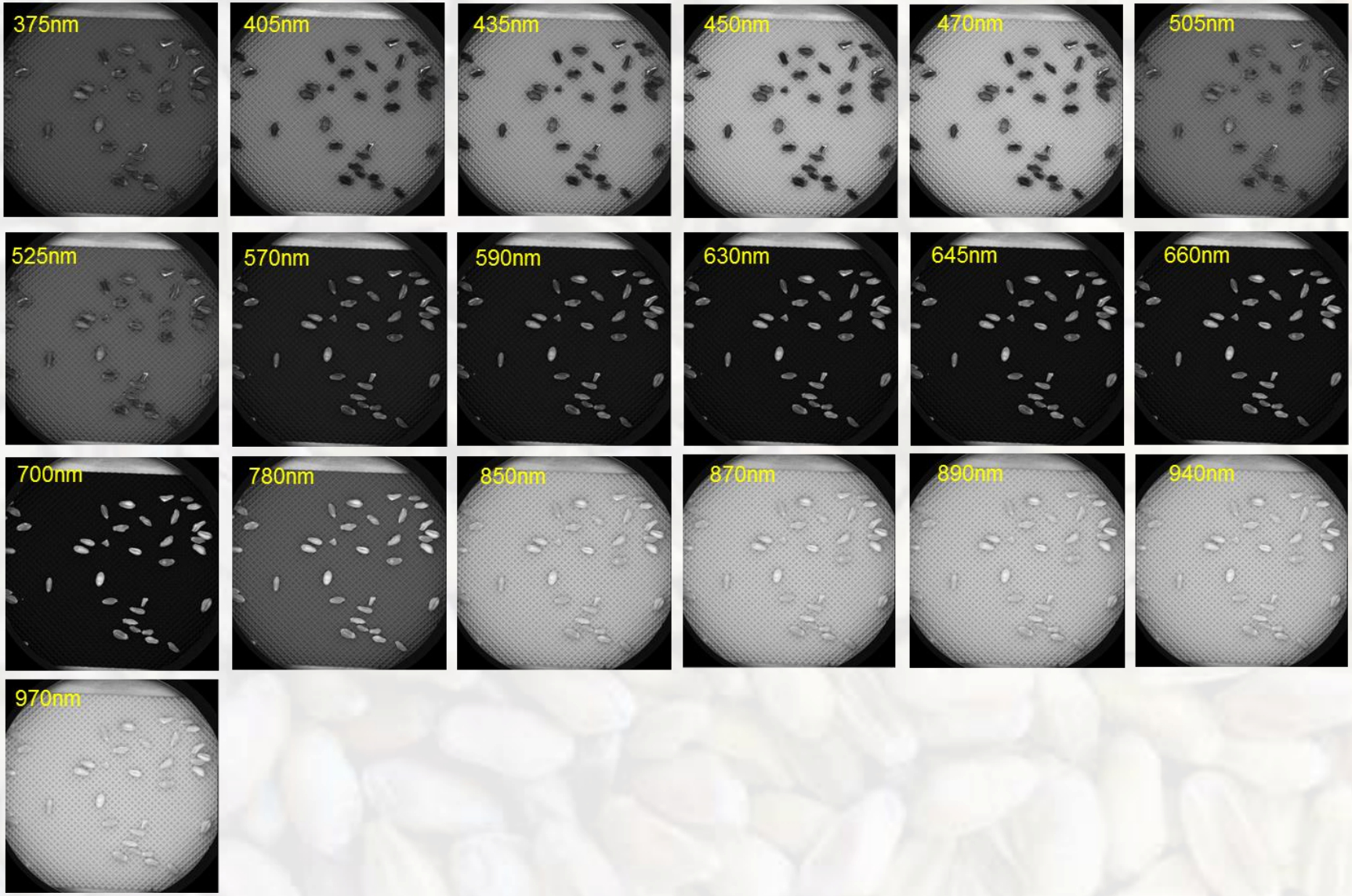
(Modelling the sample density)



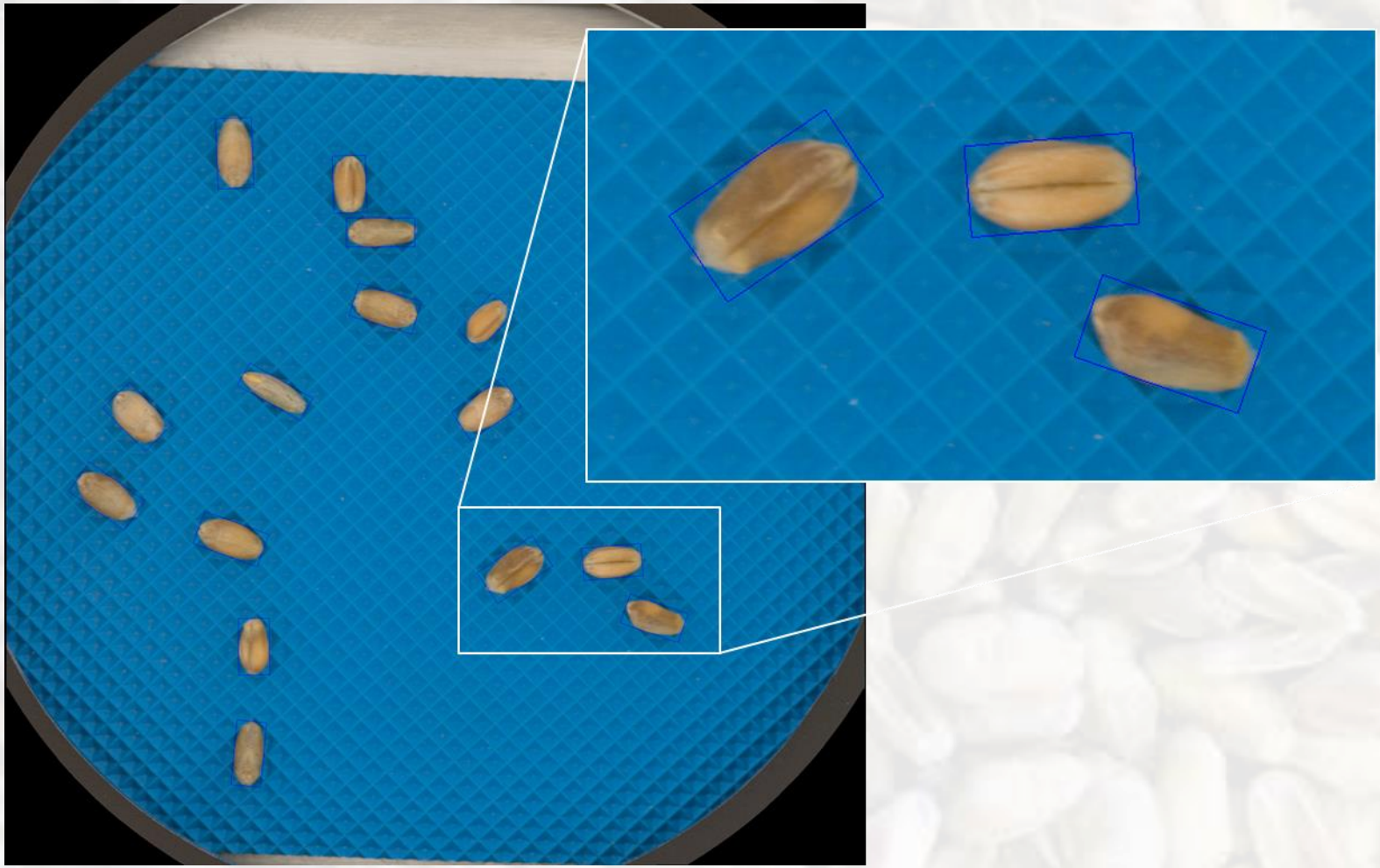




VMLab: Acquisition, Processing and Feature Extraction



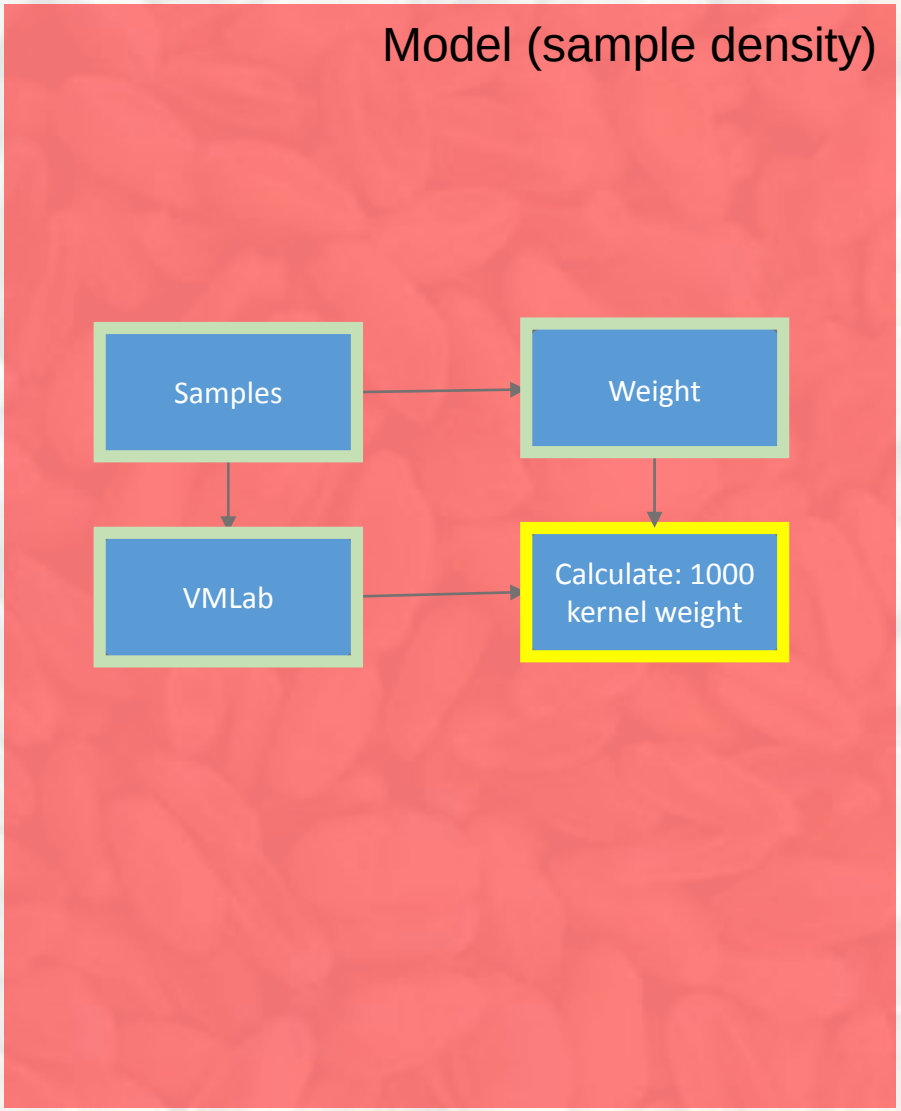
VMLab: Acquisition, Processing and Feature Extraction



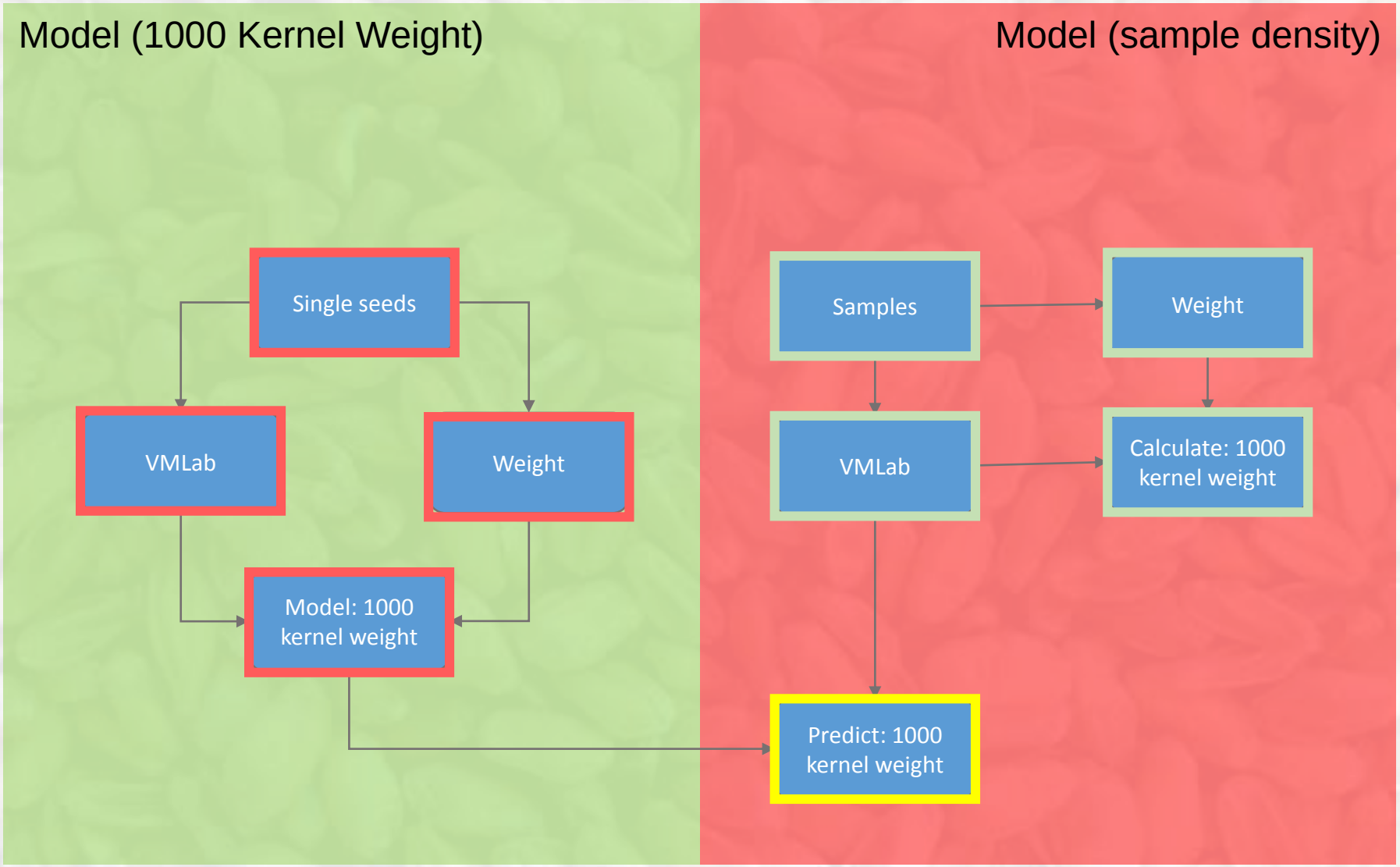
Empirical modelling – SAGT gravity table

(Modelling the sample density)

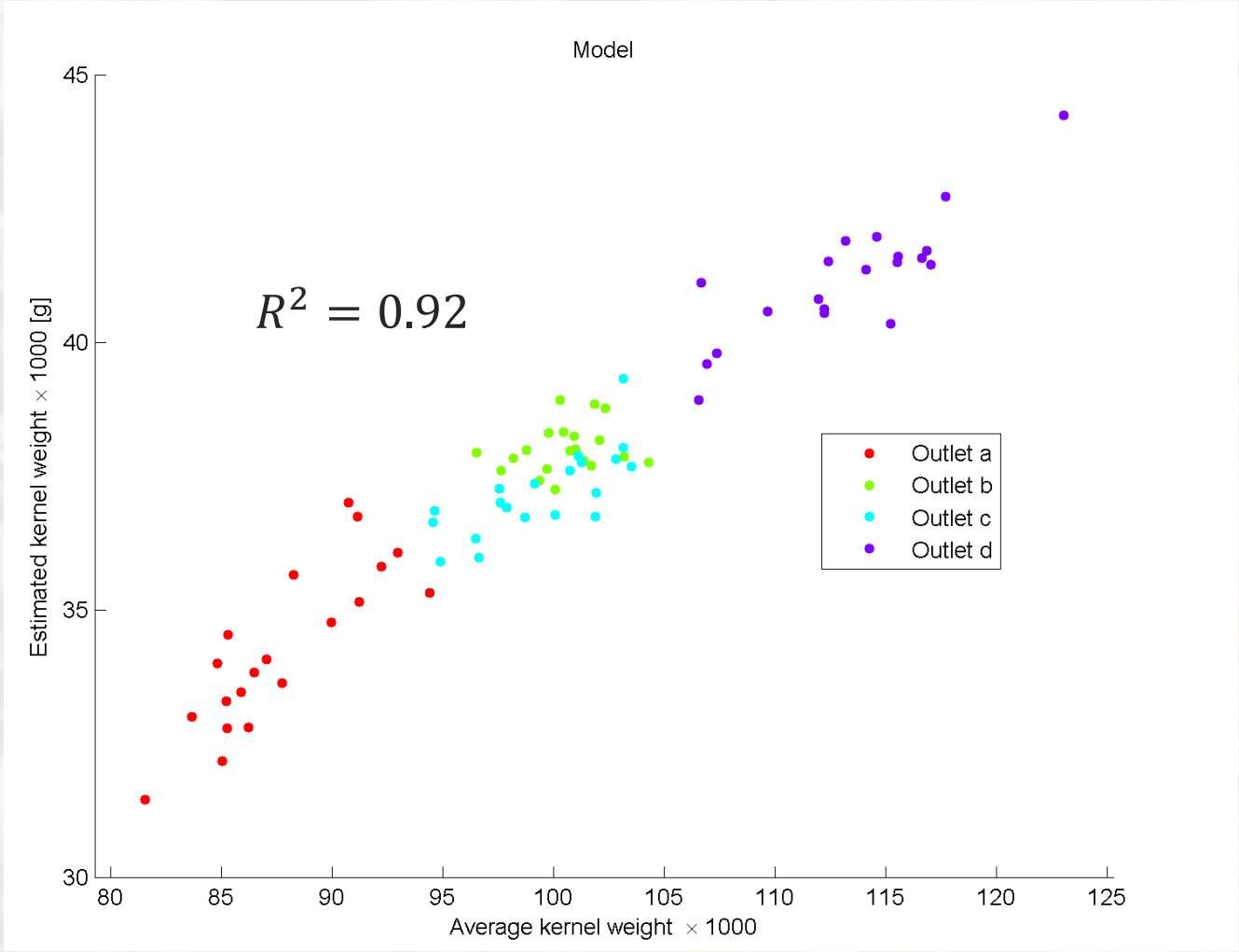
$$\text{1000 kernel weight} = \frac{X \text{ gram}}{N \text{ seeds}} \cdot 1000$$



Empirical modelling – SAGT gravity table



Empirical modelling – SAGT gravity table



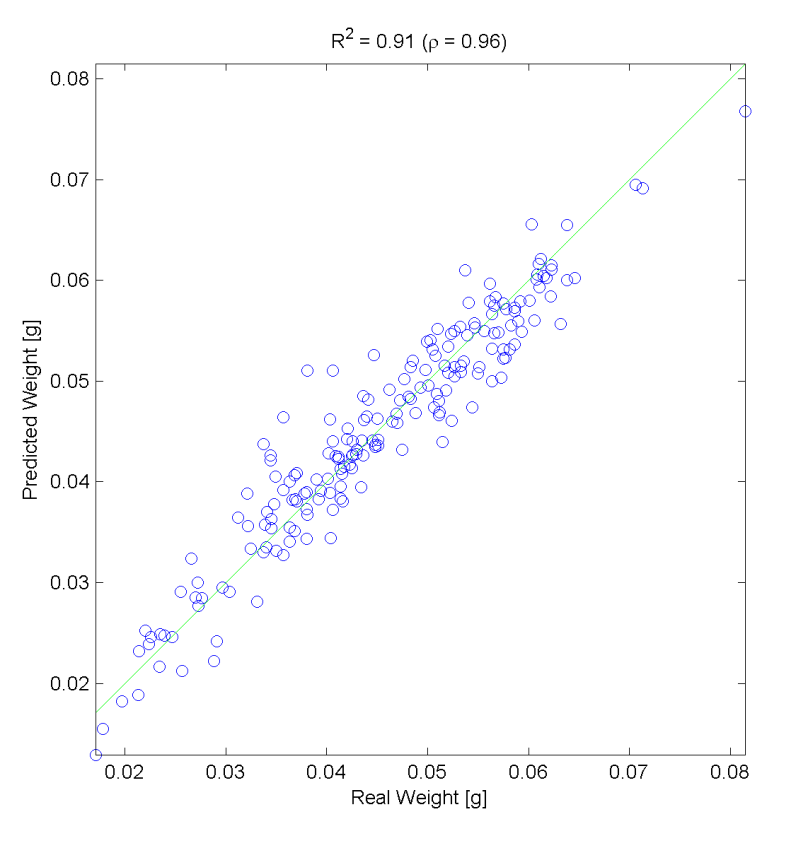
Δ ≈ 20%

Δ ≈ 28%

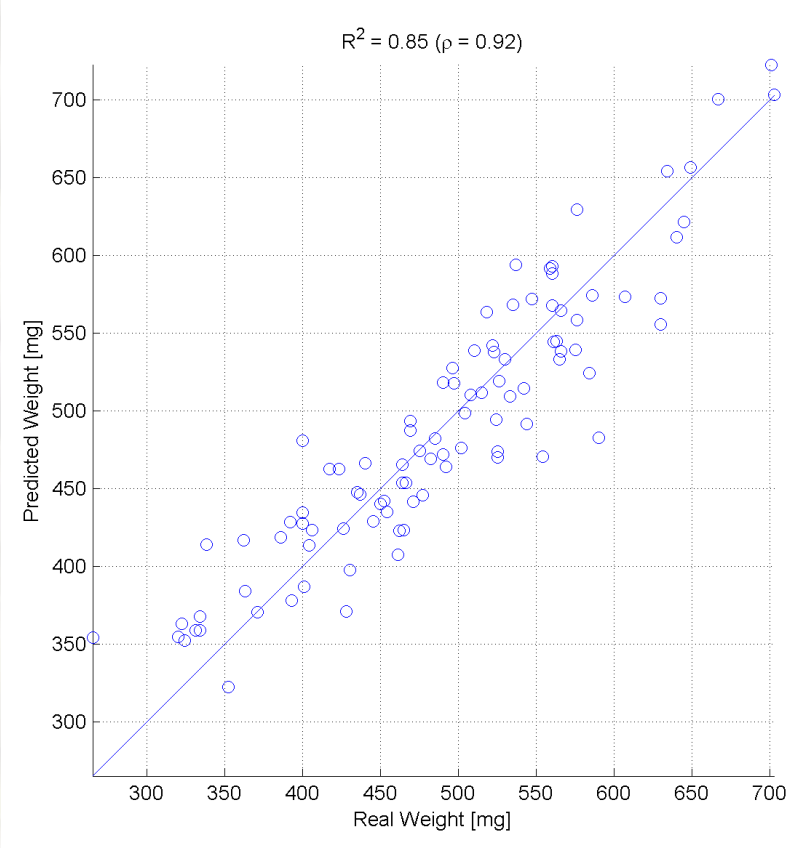
Empirical modelling – SAGT gravity table

- Model single kernel density

Wheat



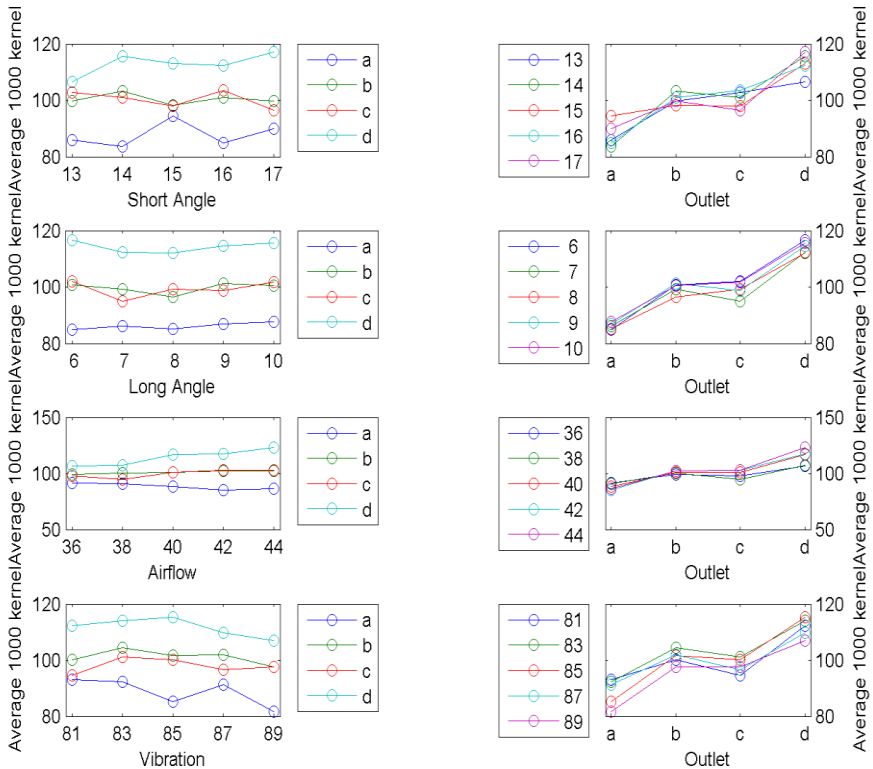
Barley



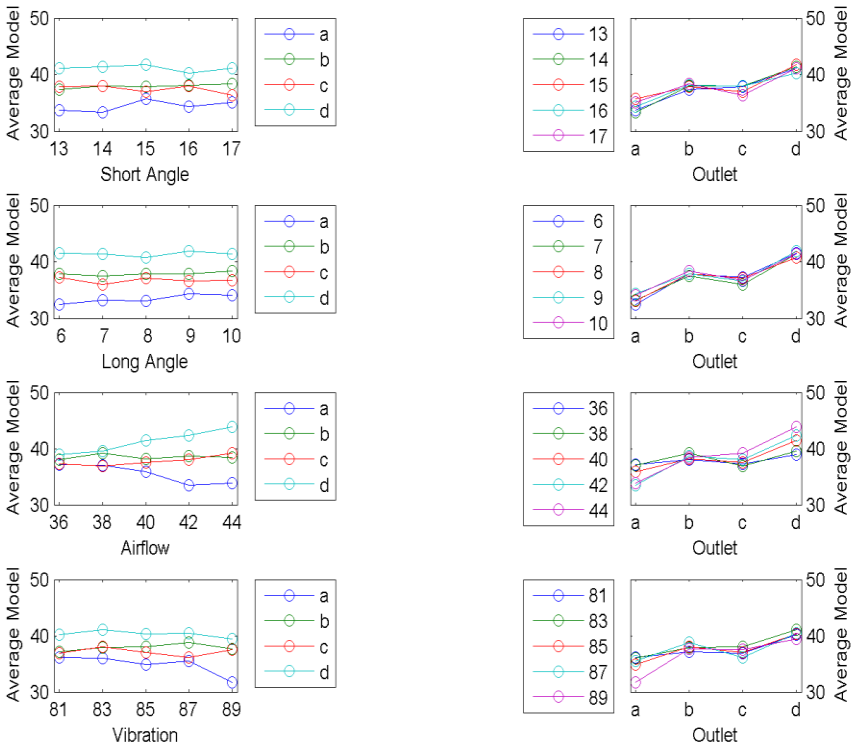
Empirical modelling – SAGT gravity table

- Model whole sample density

Kernel density



Model

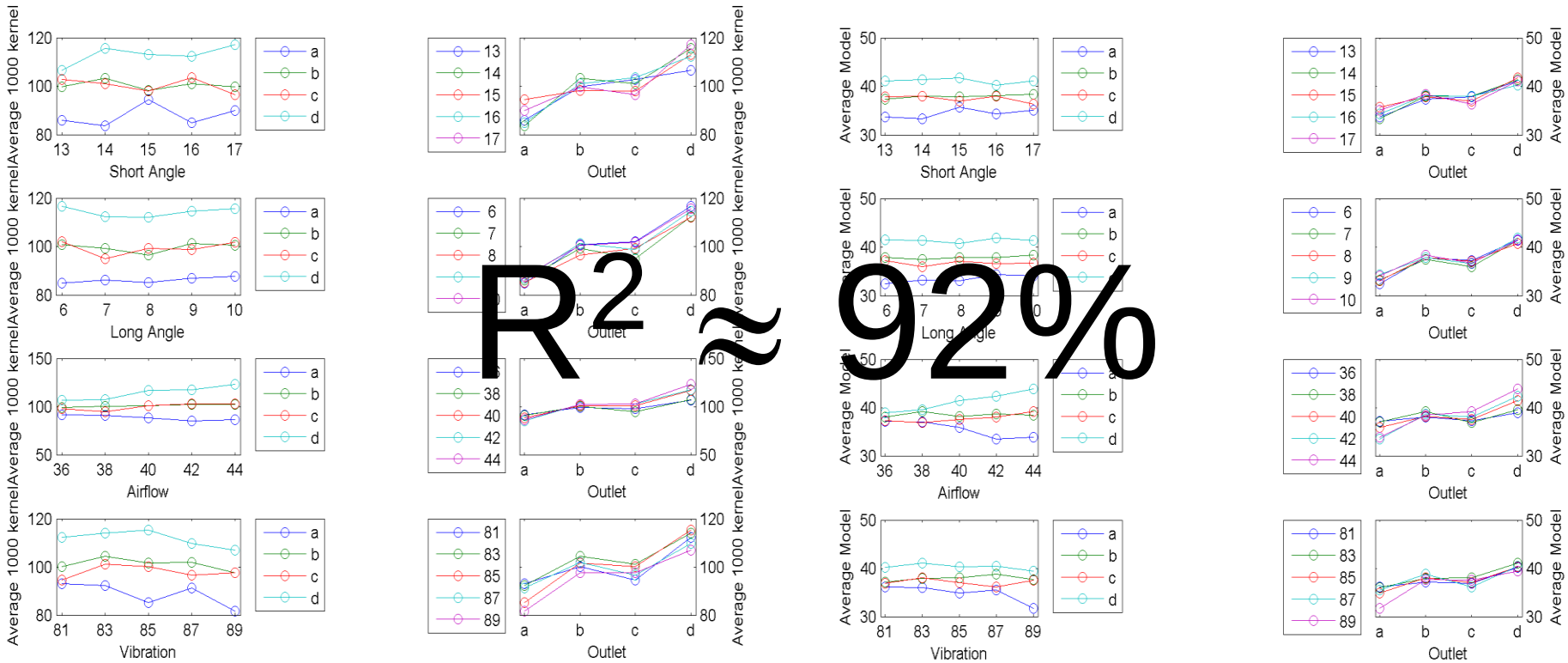


Empirical modelling – SAGT gravity table

- Model whole sample density

Kernel density

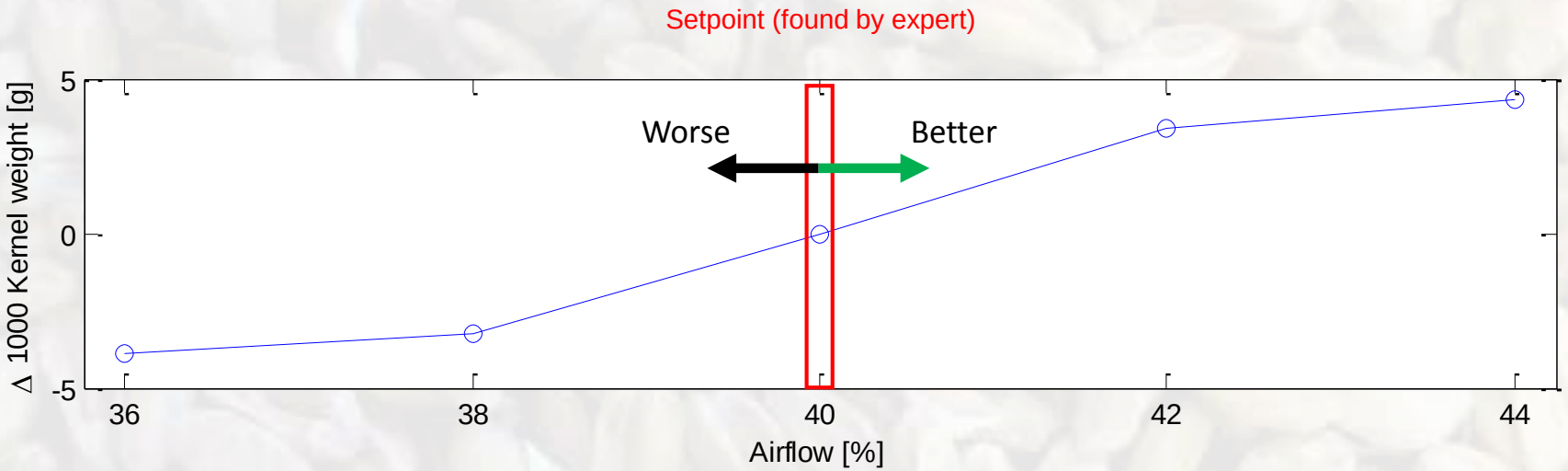
Model



$R^2 \approx 92\%$

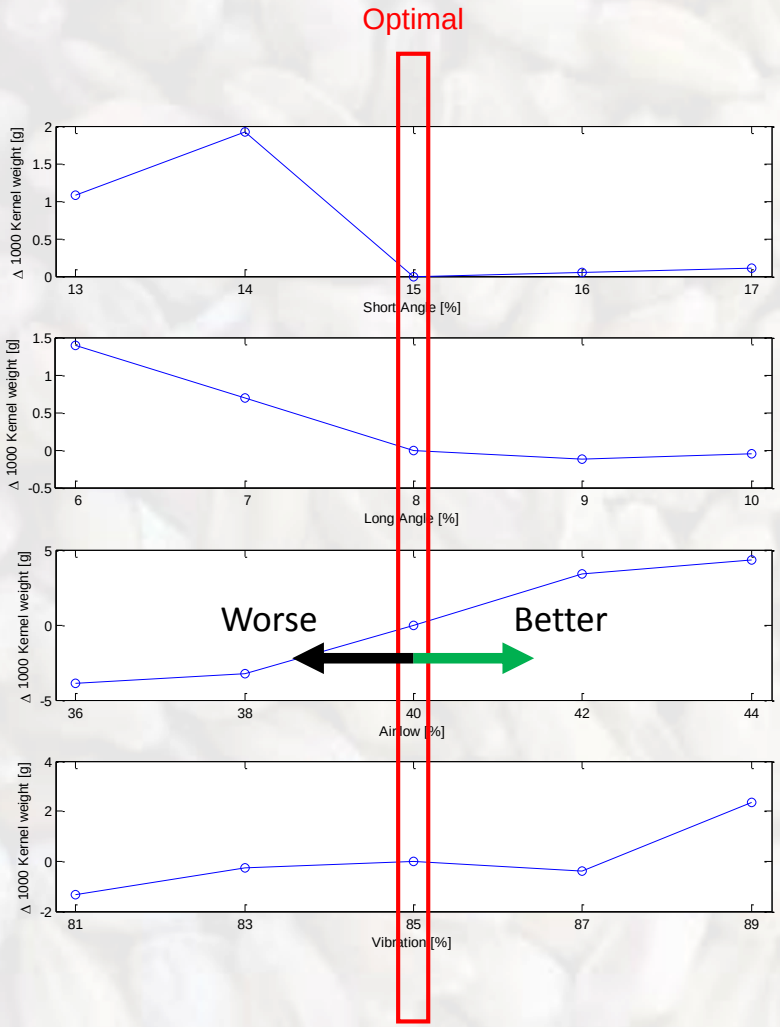
Empirical modelling – SAGT gravity table

- Example:
  - Modelling (and improving) one parameter

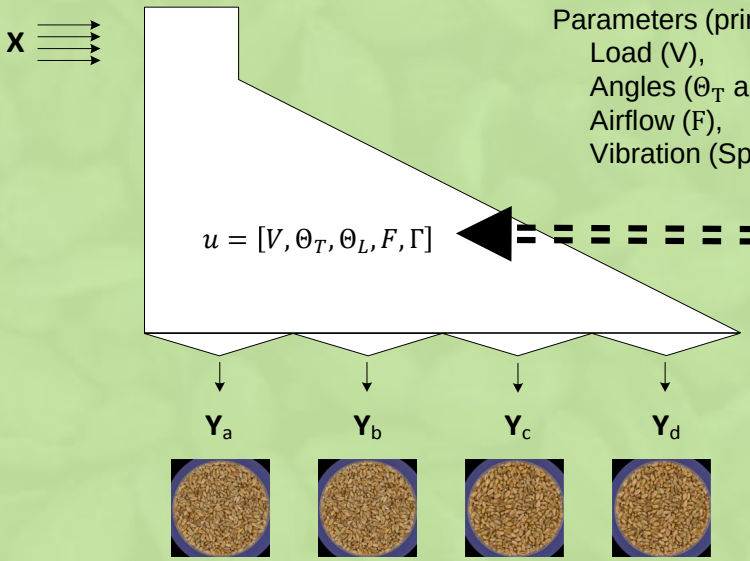


Empirical modelling – SAGT gravity table

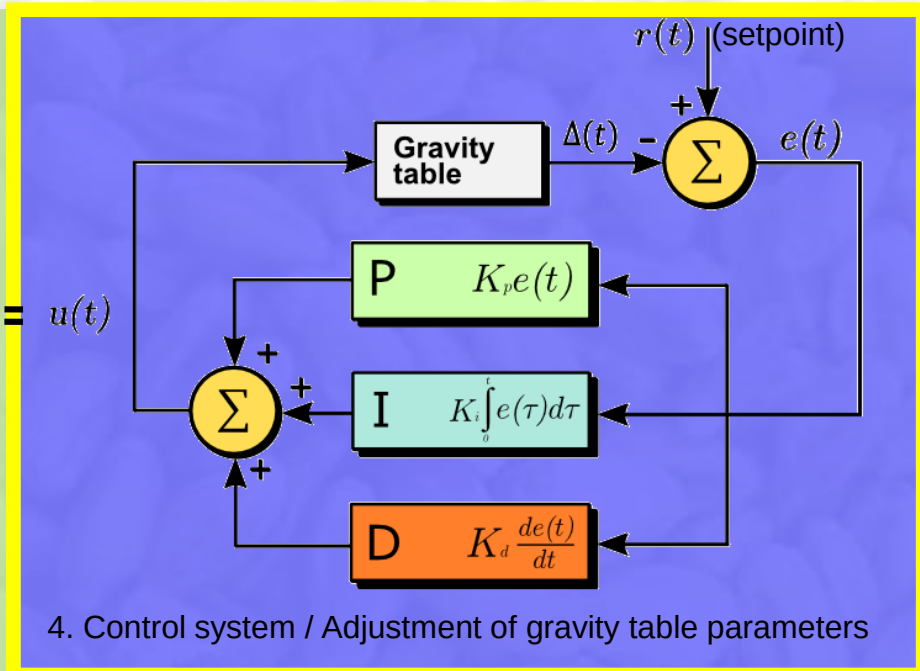
- Example:
  - Modelling (and improving) one parameter



Empirical modelling – SAGT gravity table

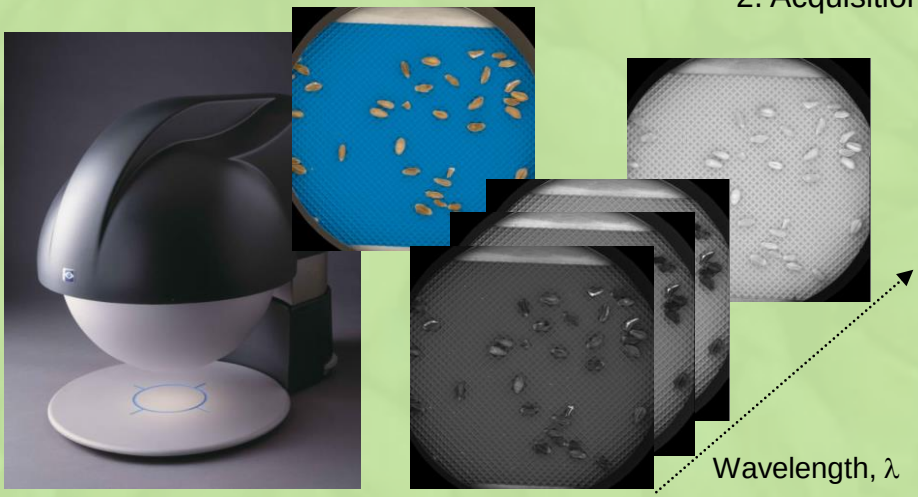


1. Sampling



4. Control system / Adjustment of gravity table parameters

2. Acquisition

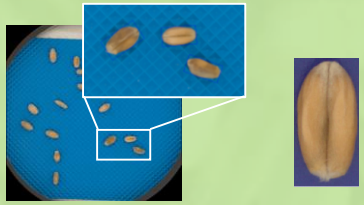


3. Image processing and gravity table state estimation

$$\Delta = \tilde{\mathbf{Y}}_a - \tilde{\mathbf{Y}}_d$$

$$[\tilde{\mathbf{Y}}_a, \tilde{\mathbf{Y}}_b, \tilde{\mathbf{Y}}_c, \tilde{\mathbf{Y}}_d]$$

$$\tilde{\mathbf{Y}}_{\blacksquare} = f(\boldsymbol{X}, \widehat{\boldsymbol{\beta}}_{\text{crop}})$$



$$\boldsymbol{x}_n = \{x_1, \dots, x_M\}$$

$$\begin{bmatrix} x_{11} & \cdots & x_{1M} \\ \vdots & \cdots & \vdots \\ x_{n1} & \cdots & x_{nM} \\ \vdots & \cdots & \vdots \\ x_{N1} & \cdots & x_{NM} \end{bmatrix} = \boldsymbol{X}$$

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  - Srdjan Sasic

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