

AUTOMATIC DESIGN & CORRECTION OF CERAMIC COLOURS





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Sensitivity: Internal



Project Tasks:

Develop ceramic glaze recipes which:

- > match a desired ceramic colour
- correct/fine tune a ceramic colour

Outcome: Taguchi's method, Regression & GUI

Work supported by: URSS & Erasmus



Erasmus+

Research hosted by:

Universitea 1st Decembrie 1918, Alba Iulia, Romania & IPEC











IPEC Alba Iulia

- Leading ceramics producer (1%)
- Key supplier for IKEA
- > Top company for Innovation
- CMMRC project: 103.000 Euros



Challenge:

The company is highly automatized. Colour design is largely based on trial and error.













|Current Industrial Process

Key steps in making coloured ceramics:

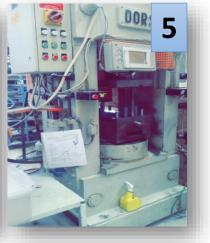
Largely based on skilled human operators:

- Costly
- Time-intensive



Machine producing the glaze Weighing machine to weigh glaze and pigments concentration

Mixtures poured into glasses with different pigment concentrations

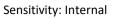


Machine to make biscuits (tiles)





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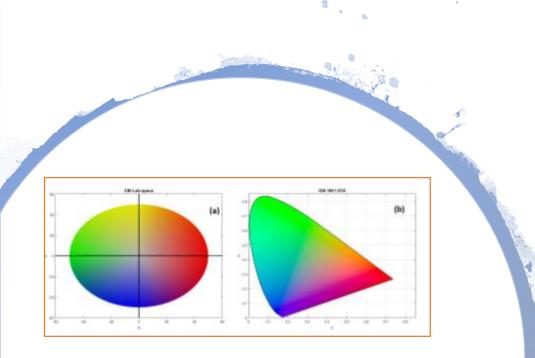


Biscuits dipped into glaze mixtures (matte or glossy, containing various concentrations of pigments)

Biscuits (Tiles) fired in the oven for 6 hours



Colorimeter used to measure the L, a, b of each tile



Used Commission Internationale de IEclairage L, a, b Coordinates (threedimensional Lab colour space) to identify colour differences where L* indicating lightness, a* is the red/green coordinate, and b* is the yellow/blue coordinate.

Objectives

- Collect experimental data in a standard format
- Improve the accuracy of the colour prediction and correction processes by implementing mathematical models
- Mathematical Models
 - 1. Taguchi method
 - Orthogonal arrays
 - Signal to noise ration (S/N)
 - Analysis of variance (ANOVA)

2. Regression and cross-validation techniques

- predict sample colour measurement
- Based on statistical package R
- Implementation
- MATLAB, Excel, R
- Graphical user interface (GUI)
- Colorimeter: colour differences between the sample and standard (L, a, b)
- Export Taguchi methods' results to Excel



Project 1. Taguchi's Method

- Robust design technique (Japanese statistician Genichi Taguchi) applied to Engineering, biotechnology, marketing and advertising etc.
- > Allows:
 - To study the effect of individual factors on the performance
 - To determine which factors most influence the product quality
 - To adjust the design parameters to their optimal levels
 - To define how well the process is functioning
- > Key technical features:
 - Orthogonal arrays
 - Signal to noise ration (S/N)
 - Analysis of variance (ANOVA)
 - Implemented for this project in MATLAB
- Creating superior production processes with a minimum amount of experimentation, thus saving time, cost, resources





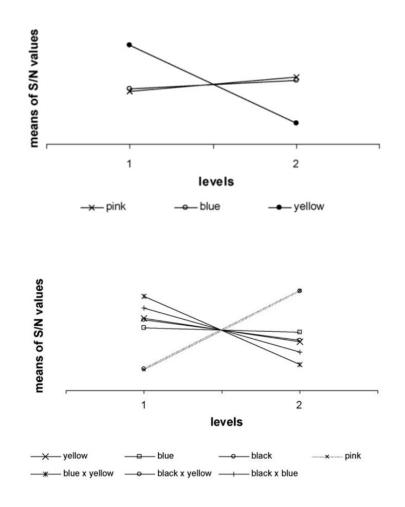
Orthogonal arrays

- Special standard experimental design requiring small number of experimental trials to find the main factors effects on output
- Organise the factors (affecting the process and the levels at which they should be varied)
- Choice depends on the number of controllable factors and levels
- Allows evaluating the interaction between factors, particularly important in case of formulation of colours
- Taguchi arrays: L4(2^3) (3 factors and 2 levels), L8(2^4) (4 factors and 2 levels)



Signal-to-Noise Ratio (S/N)

- Quantifies the variation between the target value and the obtained result.
- Three categories of the performance characteristics in the analysis of the S/N ratio:
 - 1. the lower-the-better
 - 2. the higher-the-better
 - 3. the nominal-the-better
- Depends on the quality characteristics of the product/process to be optimised
- Uses mean and the variability of the experimental result
- The optimal level of each factor is the level with the highest S/N ratio mean.





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ANOVA TESTS

- > Help choosing pigments with significant influence on the desired colour.
- N-way ANOVA

'Source'	'Sum Sq.'	'd	.f.'	'Mean Sq.'	'F'	'Prob>F'	'R'
'D'	[0.8603]	[1]	[0.8603]	[3.1400]	[2.1658]	[3.1778]
'B'	[0.2740]	[1]	[0.2740]	[]	[]	[]
'A'	[25.9392]	[1]	[25.9392]	[94.6685]	[94.7981]	[95.8101]
'Error + B'	[0.2740]	[1]	[0.2740]	[]	[3.0362]	[1.0121]
'Total'	[27.0735]	[3]	[]	[]	[100]	[100]

- Variance of B is the lowest, thus pooled in the error
- Contribution of pigment A is 95%



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- Only this factor's F-value higher than the tabulated one for a 95% confidence level (161.44).
- Thus, the quantities of the other pigments on the final combination can be the lower ones, hence reducing costs
- Therefore, the best combination for this glaze is D1B1A1.

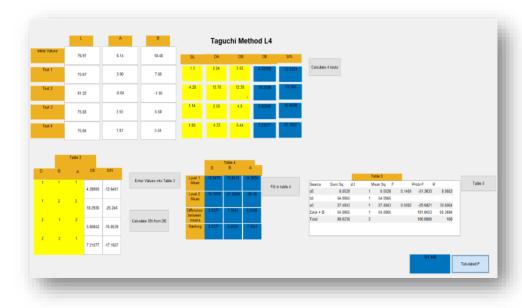


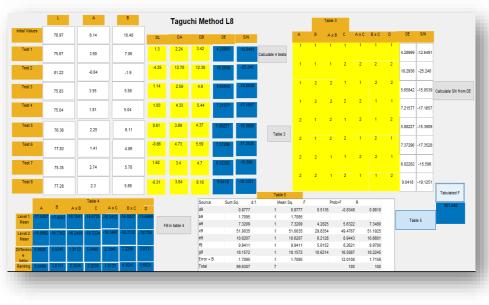
Graphical user interface (GUI)

- Built using MATLAB software
- User-friendly
- Provide immediate, visual results for each action.
- Allows multiple programs to be displayed simultaneously.
- Users do not need to know any programming languages.
- Exporting to Excel files











Project 2: Regression & Cross-Validation

- Data cleansing & merging
- Prediction of sample colour measurement using pigments data
- Different Regression (linear, random regression forest, ridge, lasso etc.) & CV techniques (Hold-out, Leave-one-out, K-fold etc.) have been used to measure the accuracy of the models
- Implemented in R

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r=0.00059 p+0.99	r=-0.042 p=0.34	r=-0.0088 p=0.84	r=-0.037 0=0.39	r=-0.026 p=0.55	r=-0.022 p=0.61	r=0.071 o=0.10	r=-0.026 0=0.55	r=0.13 p=0.0021	r=-0.015 p=0.74	r=-0.0079 p=0.86	r=-0.009 0=0.84	r=0.0079 p=0.86	r=0.0 p=0.3
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ci r=-0.14 p=0.00098	r=-0.03 p=0.49	r=-0.0086 p=0.84	r=-0.028 p=0.55	r=-0.018 p=0.68	r=0.016 p=0.71	r=-0.028 p=0.52	r=-0.018 p=0.68	r=-0.078 p=0.069	r=-0.01 p=0.81	r=-0.0055 p=0.90	r=0.04 p=0.35	r=-0.0048 p=0.91	r=-0.0 p=0.1
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30 60 9	0	0 40 100		0 40 100		0 2 4		0 4 8		0 40 100		0 40 100	

Residuals: Min 1Q Median 3Q -51.85 -14.73 0.12 10.42					
Coefficients:					
	Estimate	Std. Error	t value	Pr(> t)	
(Intercept)	46.8372	1.0505	44.59	< 2e-16	***
TTF.3533.turquoise	0.1951	0.1444	1.35	0.1772	
PGD.128.turquoise	0.0389	0.1556	0.25	0.8028	
TTF.492.galben	0.9318	0.1451	6.42	3.0e-10	***
PGD.241.coral	-0.2034	0.1536	-1.32	0.1859	
PGD.17albastru.cobalt	-0.4624	0.1555	-2.97	0.0031	**
X1cx13122.galben	3.2033	1.1532	2.78	0.0057	**
Sn02	4.0240	1.3857	2.90	0.0038	
ZrSio4	2.6669	0.3180	8.39	4.7e-16	***
PGD.122negru	-0.4148	0.1551	-2.68	0.0077	**
PGD.240.coral	-0.1108	0.1567	-0.71	0.4798	
PGD.120negru	-0.2239	0.1564	-1.43	0.1529	
PGD.066albastru.verzui	0.0093	0.1567	0.06	0.9527	
PG55001	-2.9749	1.0557	-2.82	0.0050	**
PGE.5617	-3.0688			0.2863	
PGD.146	113.3875	25.7146	4.41	1.3e-05	***
PGD.118	-6.3365	2.3964	-2.64	0.0084	¥ ¥

-4.3084

Signif codes: 0 (**** 0 001 (*** 0 01 (** 0 05 (' 0 1 ('

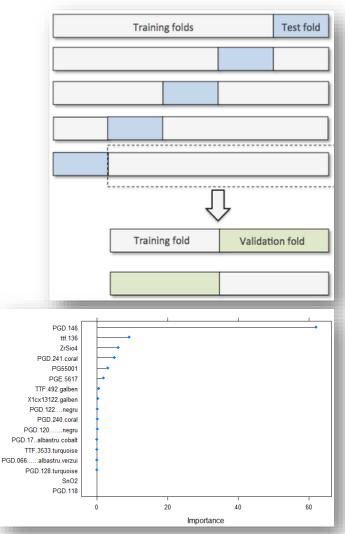
7.0994

-0.61

0.5442

lm(formula = L ~ ., data = selectedData)

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Future Work

- Orthogonal Array L9 (3*3) using (3 pigments, 3 levels)
- Orthogonal array L9 (3⁴) using 4 pigments and 3 levels
- Further use of data mining and machine learning techniques to solve the problem of automatic design and correction of ceramic colours.
- Deep learning techniques.





Thank you!

Any Questions?