Optimizing multi-coloured LEDs for identifying pigments based on Self Organizing Map and Principle Component Analysis

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OUTLINE

01 Self-Organizing Map (SOM)

02 Identification of pigments using technical photography/multimodal imaging/multi-spectrum imaging

03 Building pigment database using narrow band LEDs and show flowchart of pigments

04 Applying flowchart method /Self organizing map

05 Results of PCA

01

Self-Organizing Map (SOM) and their applications

Self-Organizing Map (SOM)

Neural Comput & Applic (2019) 31:619–635
DOI 10.1007/s00521-017-3095-4

ORIGINAL ARTICLE

Supervised learning based on the self-organizing maps for forward kinematic modeling of Stewart platform

Saithip Limtrakul[1] · Banchar Arnonkijpanich[1,2]

VQTAM based on SOM was used for solving a forward kinetic problem of parallel manipulator. It is improved by autoregressive model (AR) and locally linear embedding (LLE).

Computers and Electronics in Agriculture 115 (2015) 26–33

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

An approach based on digital image analysis to estimate the live weights of pigs in farm environments

Apirachai Wongsriworaphon[a], Banchar Arnonkijpanich[b,c], Supachai Pathumnakul[a,*]

[a] Supply Chain and Logistics Research Unit, Department of Industrial Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen 40002, Thailand
[b] Department of Mathematics, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand
[c] The Centre of Excellence in Mathematics, CHE, Si Ayutthaya Rd., Bangkok 10400, Thailand

VQTAM was used for estimating system. It is improved by autoregressive model (AR) and locally linear embedding (LLE).

Standard SOM is categorized as an unsupervised learning algorithm that is designed to find the topological structure embedded within a multidimensional data space.

SOM consists of two major modules: the input space and the lateral lattice space.

It can do data visualization and clustering.

VQTAM scheme is constructed on the SOM architecture.

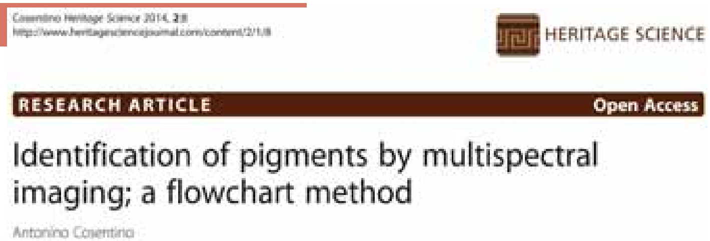
It is supervised learning algorithm.

It can perform classification and clustering simultaneously.

02

Identification of pigments using technical photography/multimodal imaging/multi-spectrum imaging

Technical Photography

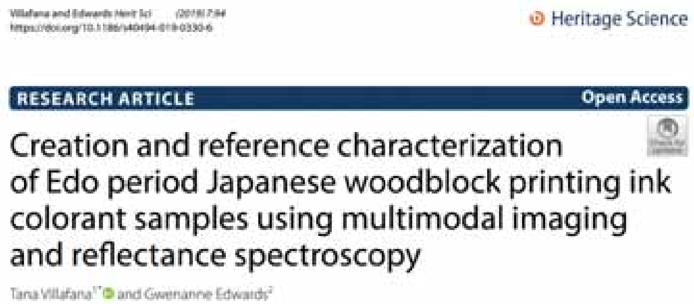

Cosentino Heritage Science 2014, 2:8
http://www.heritagesciencejournal.com/content/2/1/8

HERITAGE SCIENCE

RESEARCH ARTICLE Open Access

Identification of pigments by multispectral imaging; a flowchart method

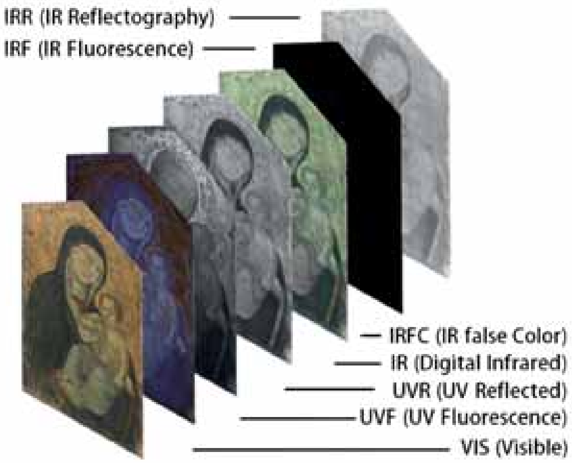
Antonino Cosentino

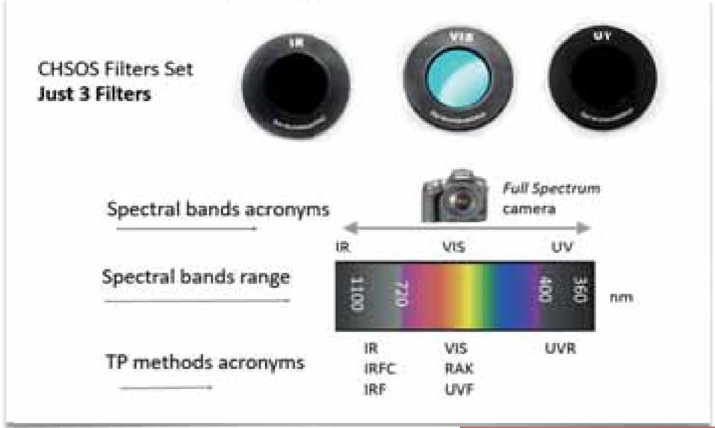

Heritage Science

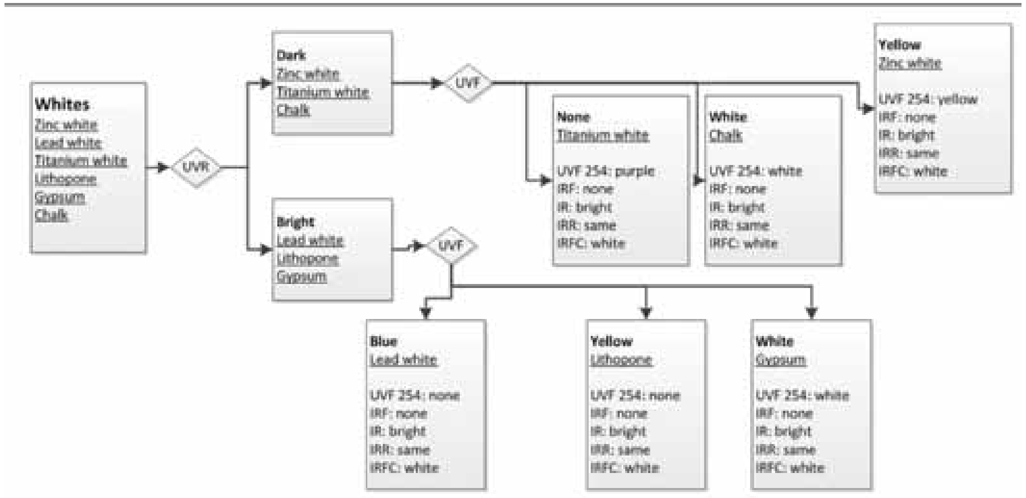
RESEARCH ARTICLE Open Access

Creation and reference characterization of Edo period Japanese woodblock printing ink colorant samples using multimodal imaging and reflectance spectroscopy

Tana Villafana and Gwenanne Edwards







	Activated colored material by	filter
VIS (visible reflected)	visible light	visible to sensor
IR (IR reflected)	visible to IR	IR to sensor
IRF (visible-induced infrared luminescence)	visible light	IR to sensor
UVF (UVA induced visible luminescence)	UV	visible to sensor
UVR (UVA reflected)	UV	UV to sensor
IRFC (IR reflected false color	IR to R, R to G, G to B	
UVFC (UV reflected false color	UV to B, B to G, G to R	

VIS

UV Reflected (UVR)

IR

UVF

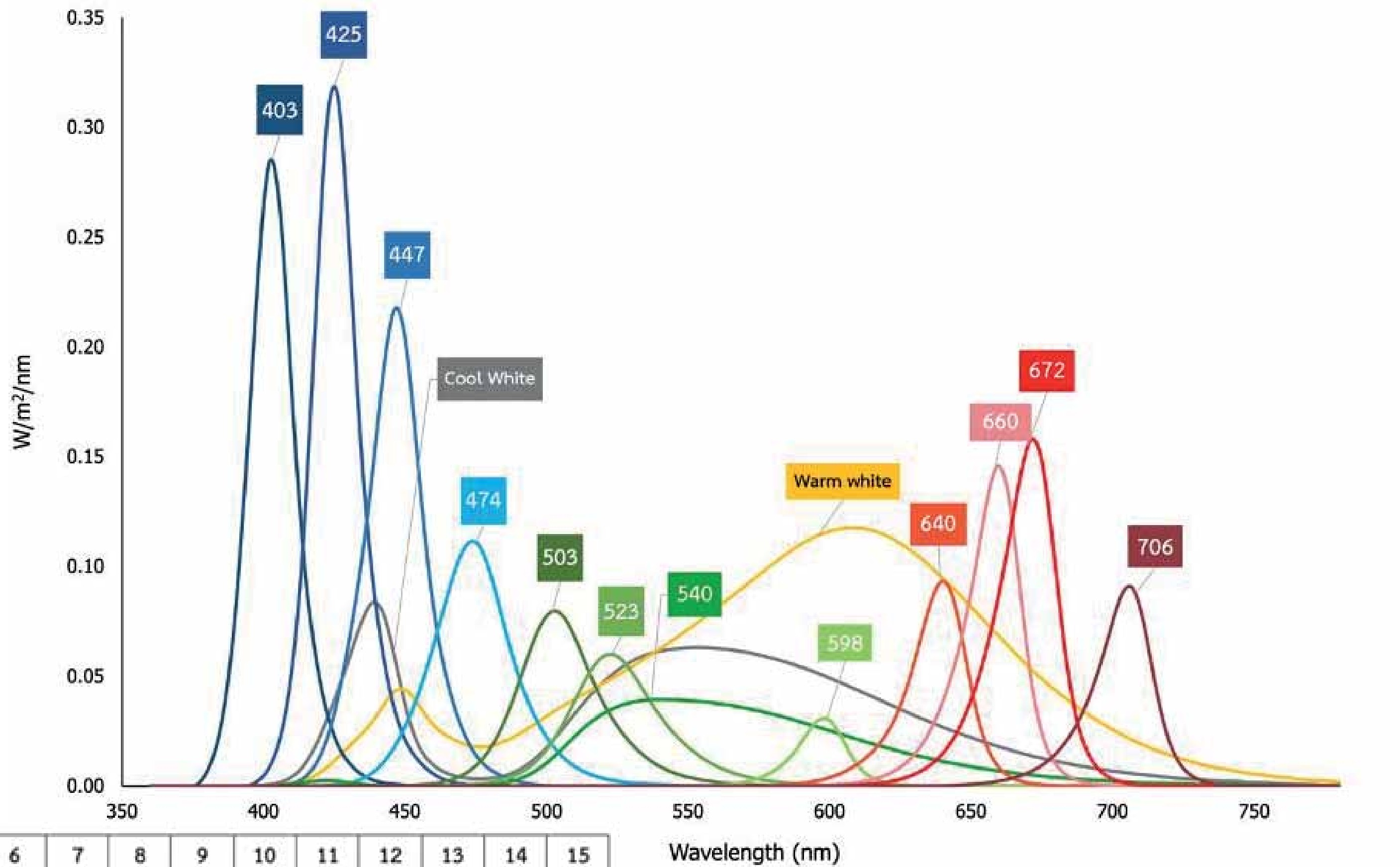
UVFC

IRFC

Image of the rooftop of Bld.1 of MEA. Around 130 yrs ago.

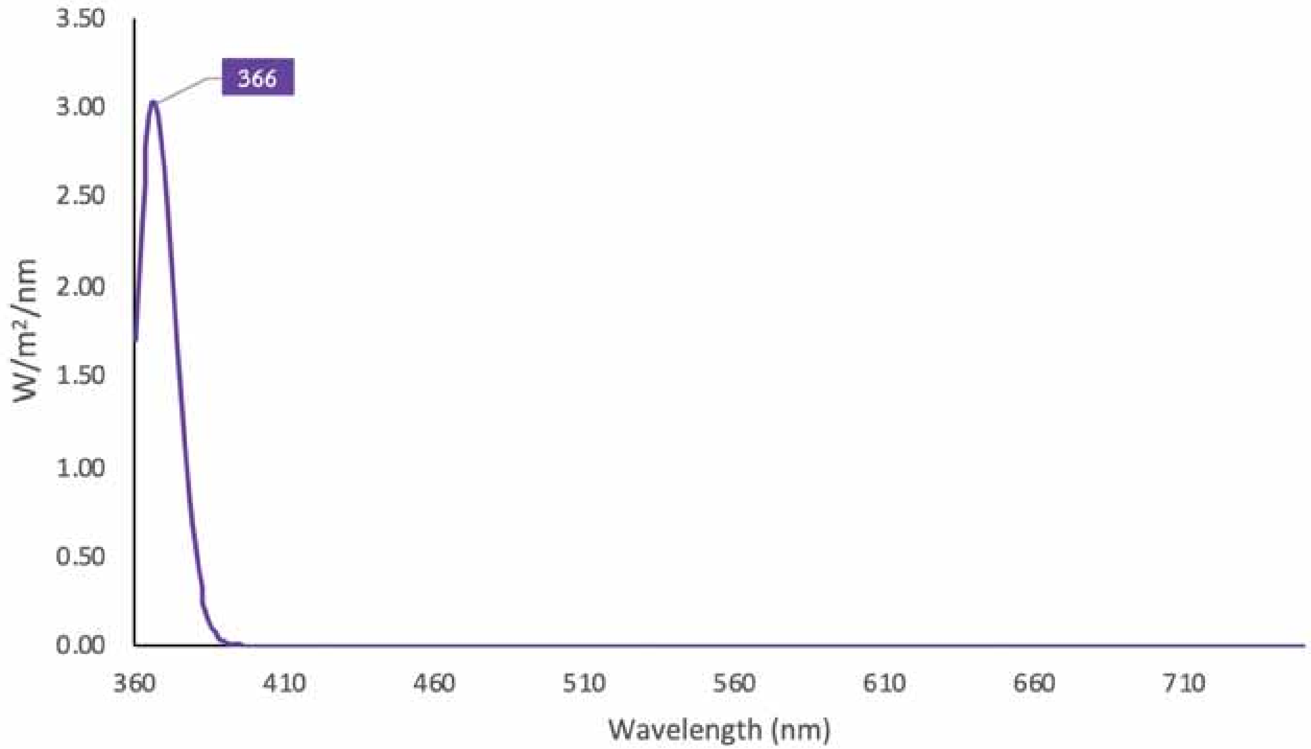
- White area: Zinc white
- Yellow area: Cobalt yellow, Orpiment, Lead tin yellow 1, Lead tine yellow 2, Gamboge, Yellow ochre
- Blue area: Maya blue, Indigo, Phthalo blue
- Green area : Green earth
- Red in the middle area: Carmine red, Alizarine, Burnt sienna
- Red at the frame: Red ochre
- Brown line: can't identify

Images taken under multi-coloured LEDs



Channels	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Peak wavelength (nm)	Cool White	Warm White	403	425	447	474	503	523	540	598	640	660	672	706	366

UV LEDs



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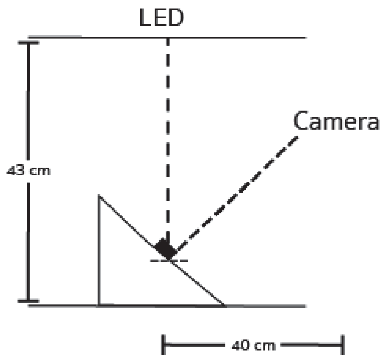
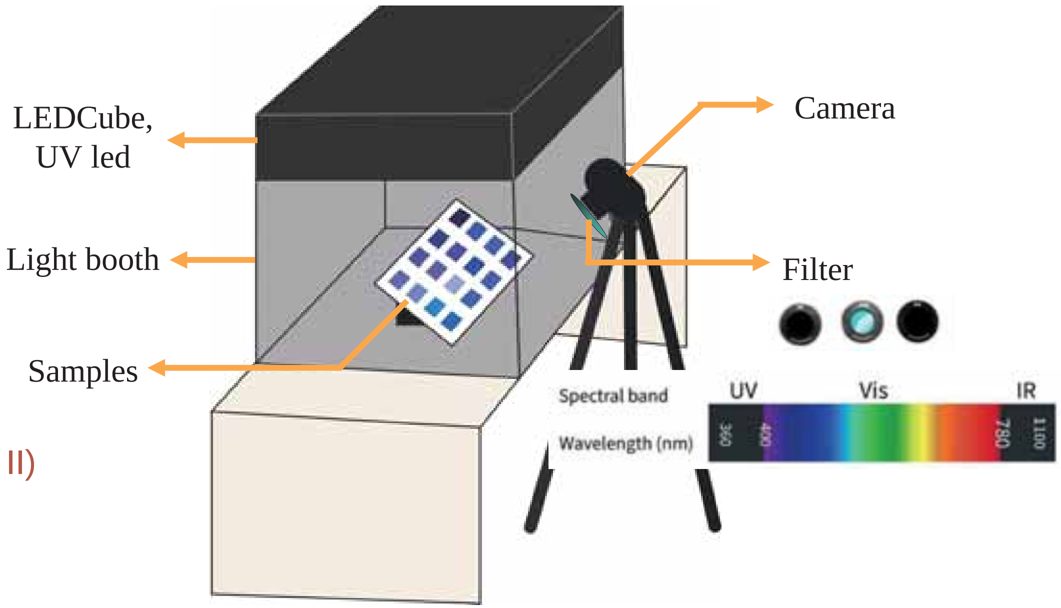




- Camera (Canon EOS 5D Mark II) taken off the IR and UV blocks
- Multi-colored LEDs
- 356 Kremer's Pigments
- 3 filters (UV, VIS, IR)

4 of blind single pigments for test sample

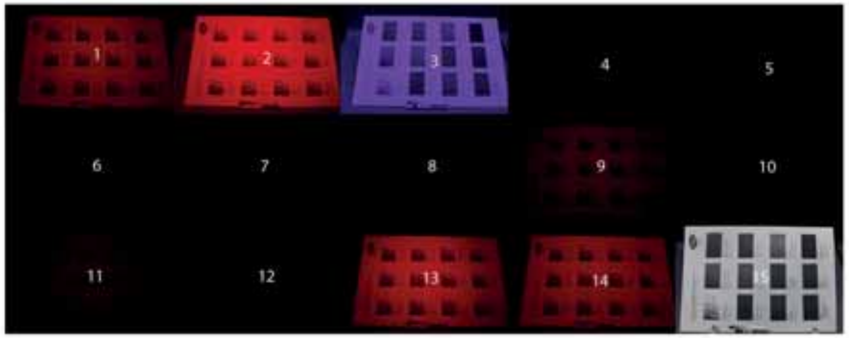
1. Green (Chrome Oxide Green)
2. Yellow (Yellow ochre)
3. Red (Cinnabar)
4. Brown (Red ochre)

356 Selected pigments

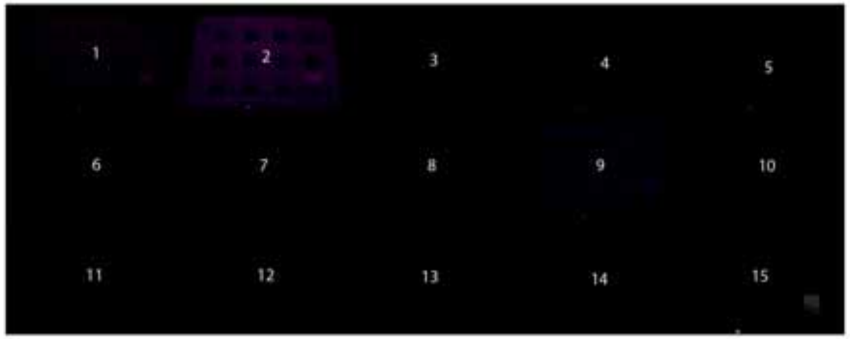
- Red colors
- Green colors
- Blue colors
- Yellow colors
- Organic pigments
- Earth colors
- Cadmium pigments
- Iron oxide and translucent pigments
- Pigments of our product

Captured images

Vis (1)



UV (2)



IR (3)

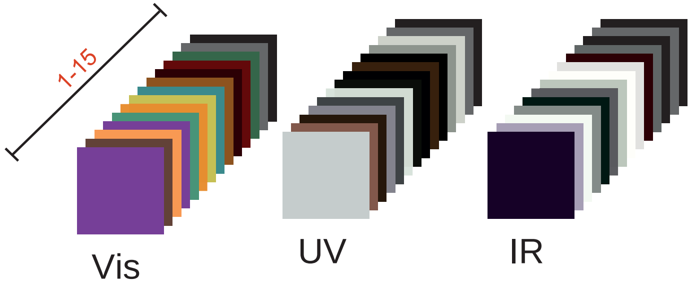
Image of Kremer's pigment under 15 LEDs through Vis (1), UV (2), IR (3) filters

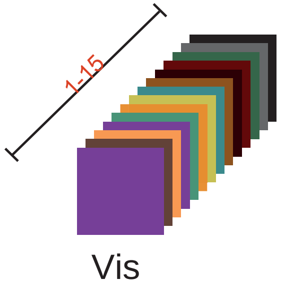
White balance & exposure

LED channels	filter	exposure
1-14	Vis	0
	UV	(+3)
	IR	(+3)
15	Vis, UV, IR	0

Before adjusting white balance (Vis)

After adjusting white balance (Vis)





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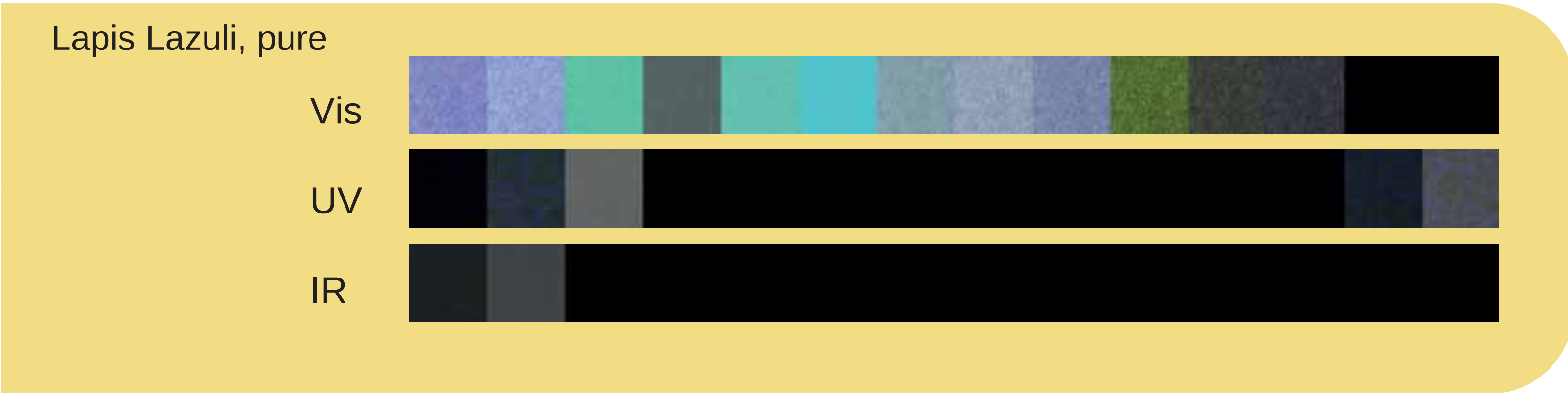


03

FLOWCHART of PIGMENT

Flowchart of pigments

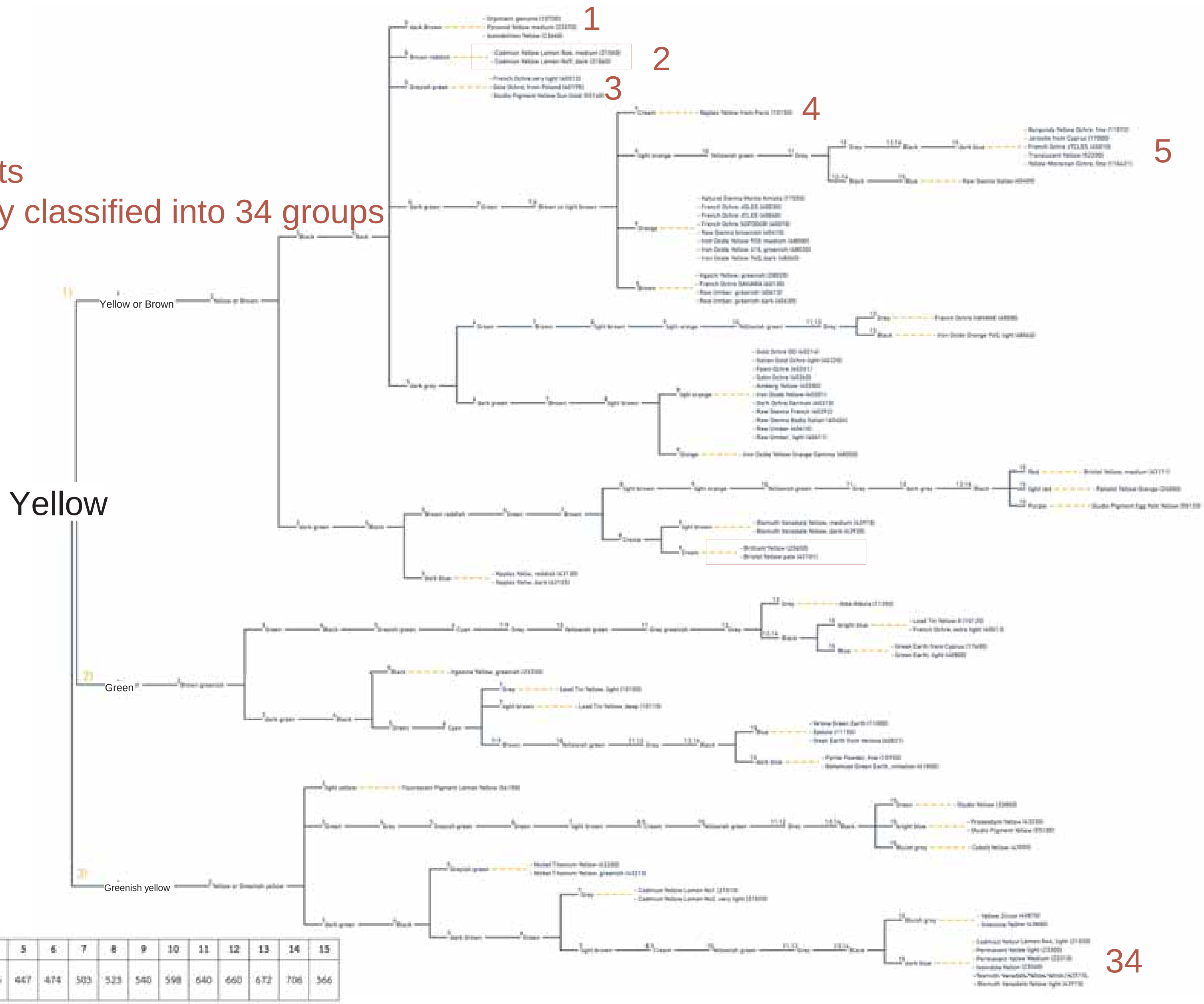
1. **Purple : 17 colors**
2. **Blue : 38 colors**
3. **Green : 38 colours**
4. **Yellow : 80 colours**
5. **Orange : 37 colors**
6. **Red : 52 colors**
7. **White, Grey, Black and Brown : 94 colours**

= 356 colors

Yellow

80 yellow pigments

They were visually classified into 34 groups



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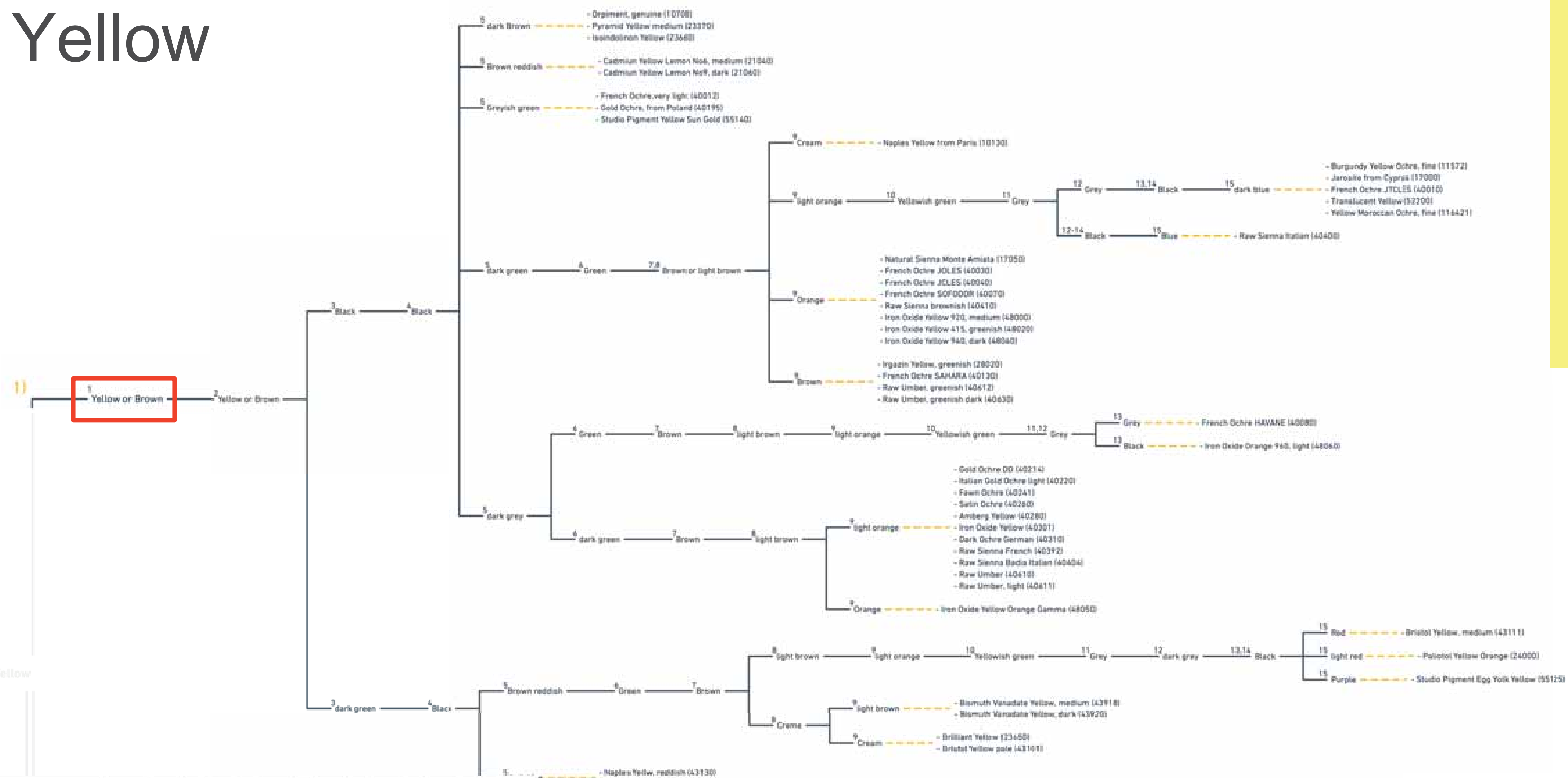
Peak wavelength (nm)	Cool White	Warm White	403	425	447	474	503	523	540	598	640	660	672	706	366

Yellow



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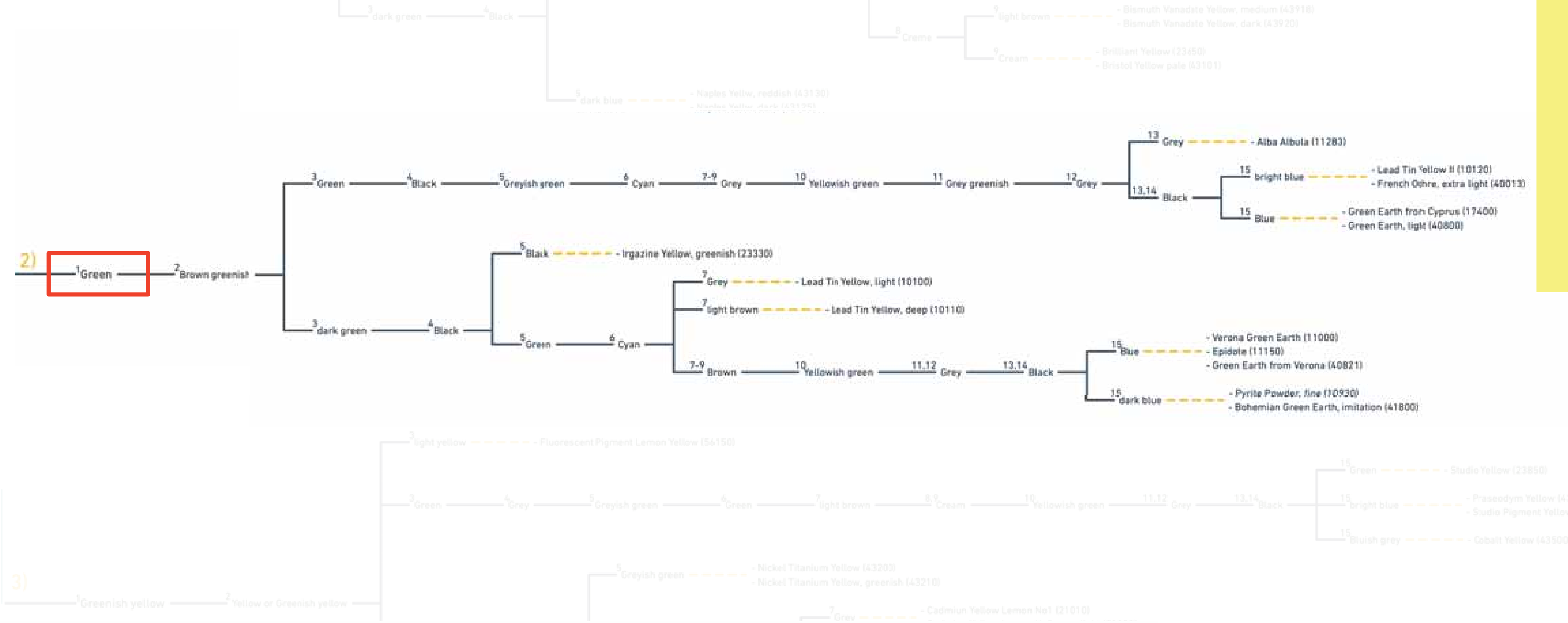
Peak wavelength (nm)	Cool White	Warm White	403	425	447	474	503	523	540	598	640	660	672	706	366

Yellow



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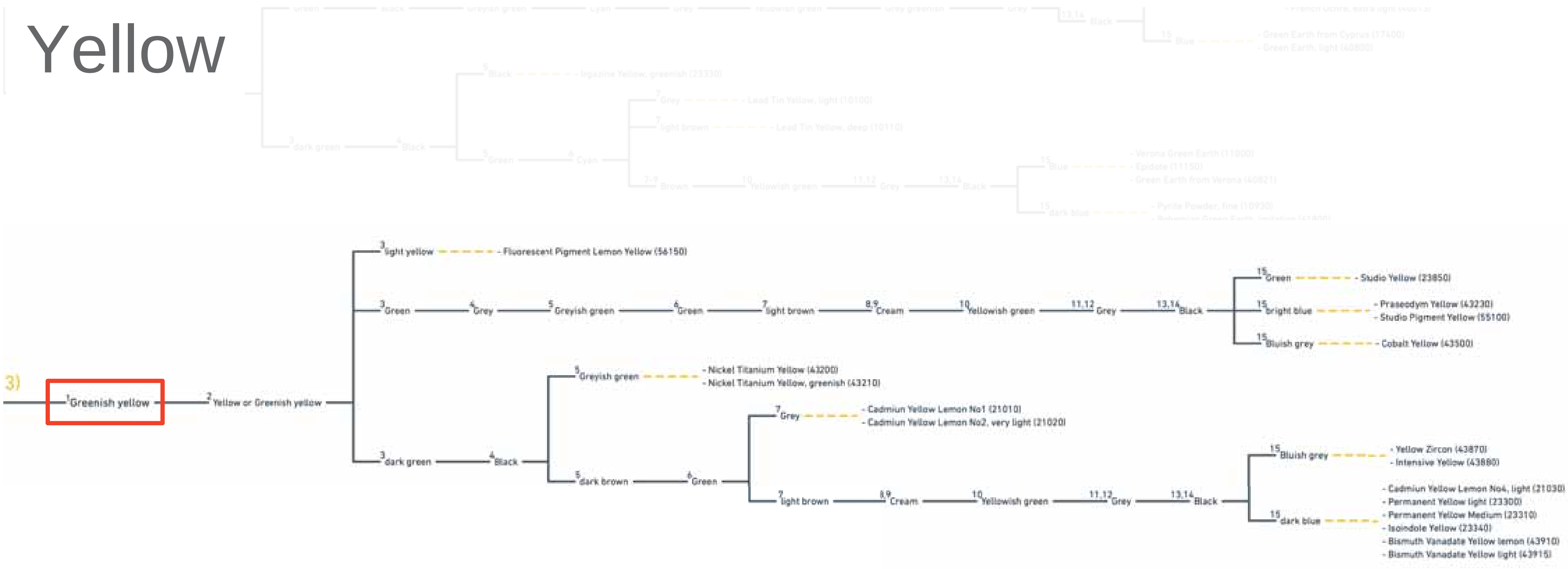
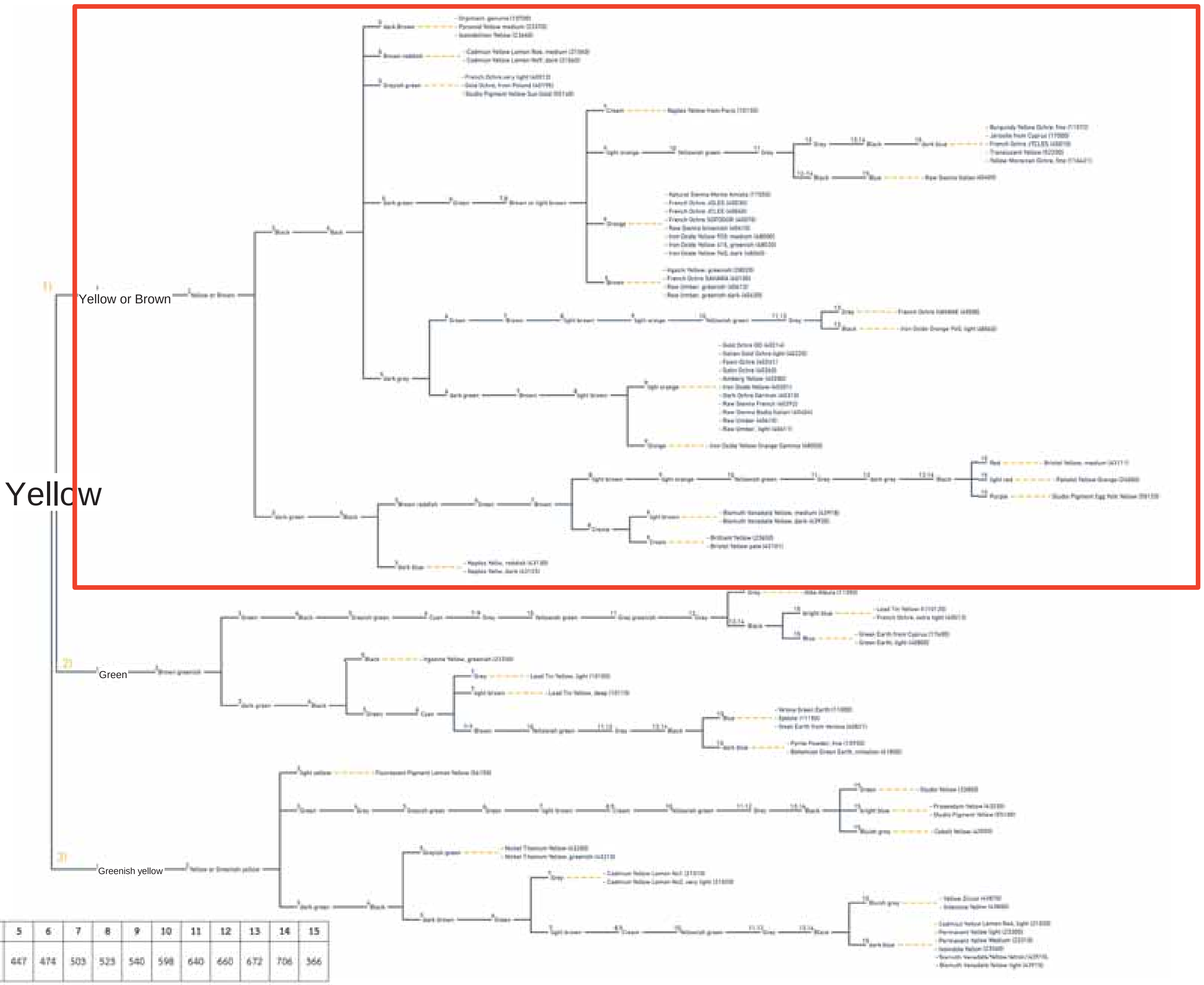
Peak wavelength (nm)	Cool White	Warm White	403	425	447	474	503	523	540	598	640	660	672	706	366

Yellow



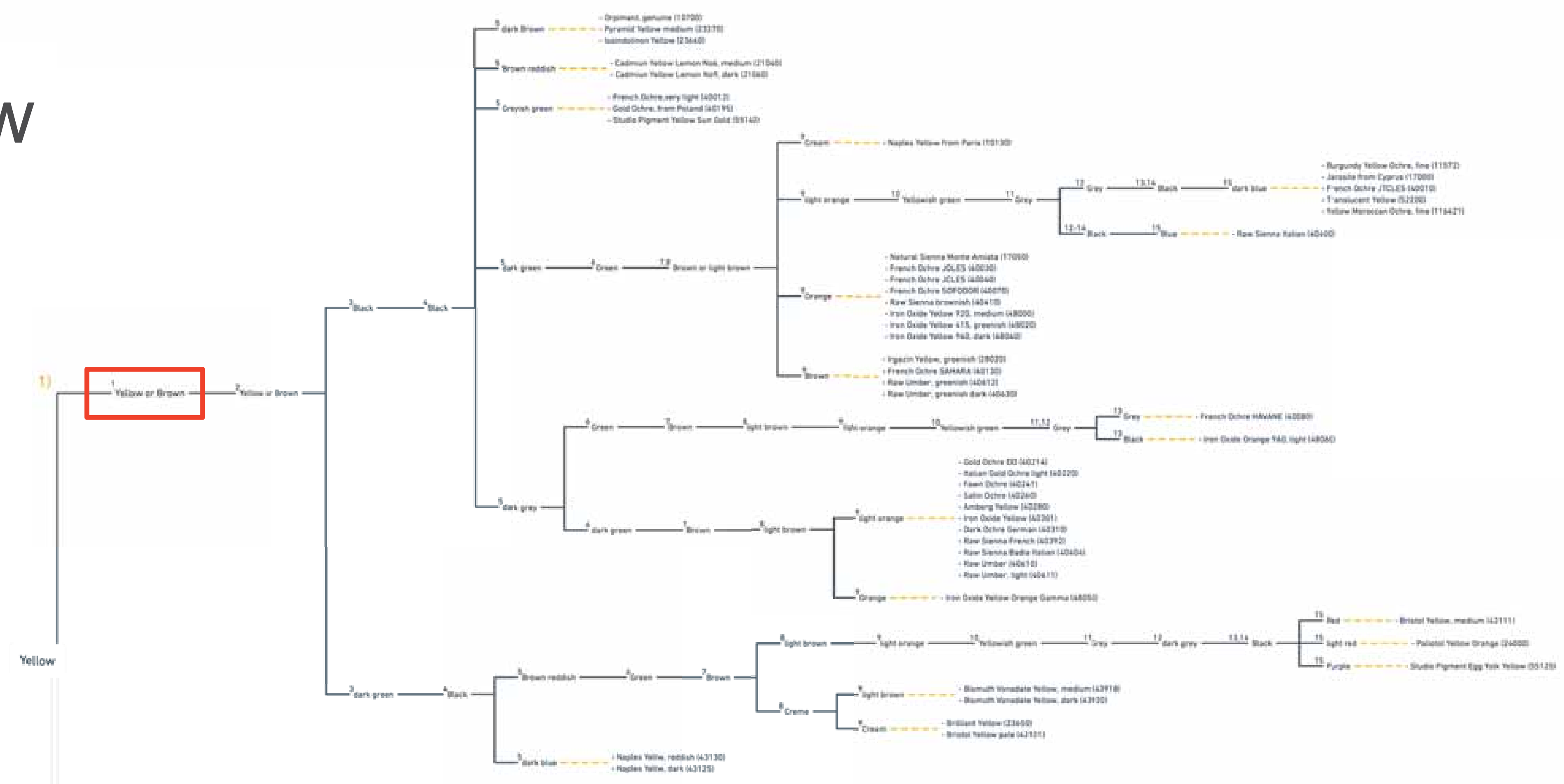
Channels	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Peak wavelength (nm)	Cool White	Warm White	403	425	447	474	503	523	540	598	640	660	672	706	366

Yellow



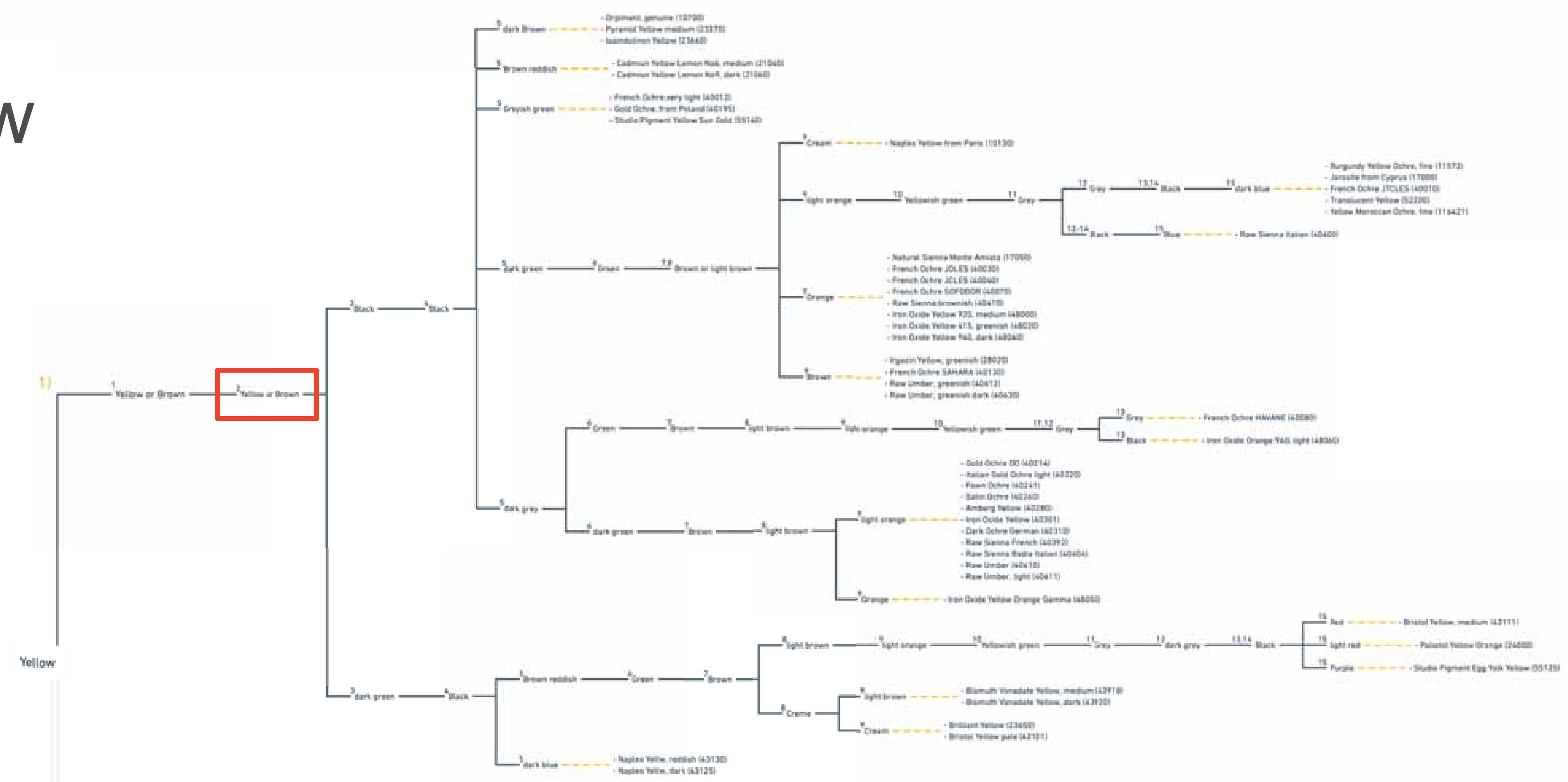
Channels	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Peak wavelength (nm)	Cool White	Warm White	403	425	447	474	503	523	540	598	640	660	672	706	366

Yellow



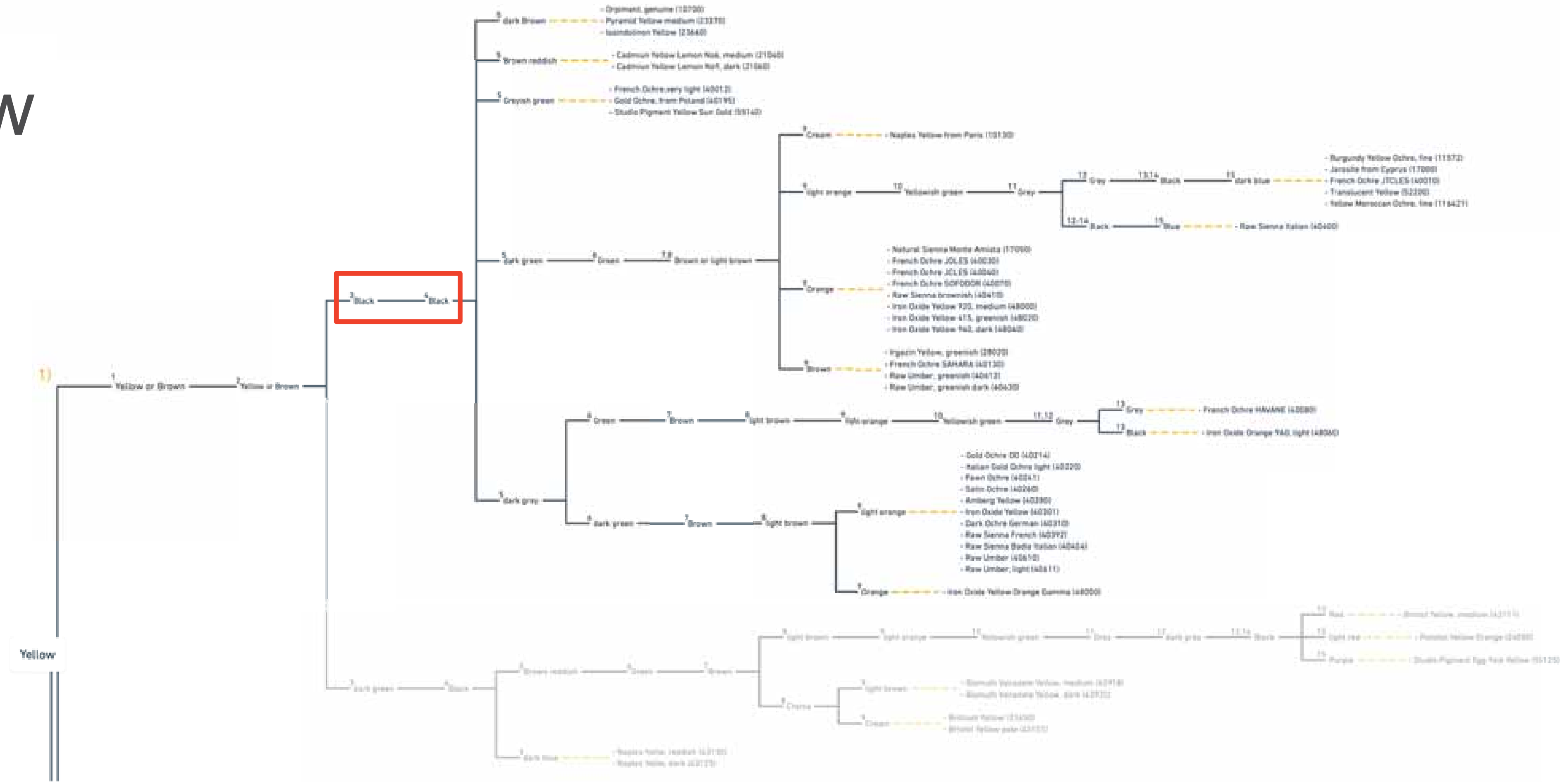
Ch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
color	Yellow or Brown	Yellow	Black	Black	dark green	Green	Brown	light Brown	Orange	Yellowish green	Grey	Grey	Black	Black	Blue
Test Sample															

Yellow



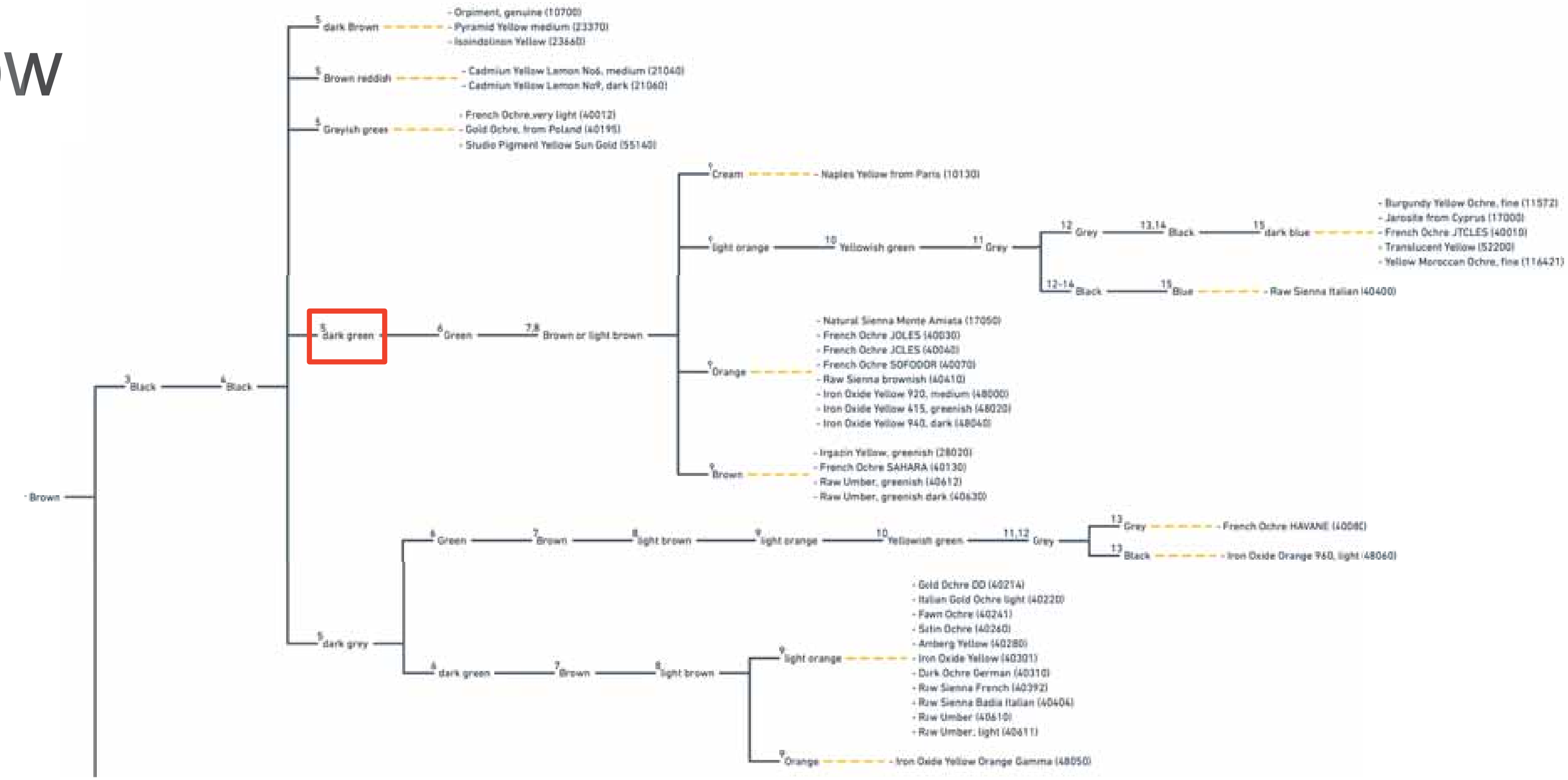
Ch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
color	Yellow or Brown	Yellow	Black	Black	dark green	Green	Brown	light Brown	Orange	Yellowish green	Grey	Grey	Black	Black	Blue
Test Sample															

Yellow



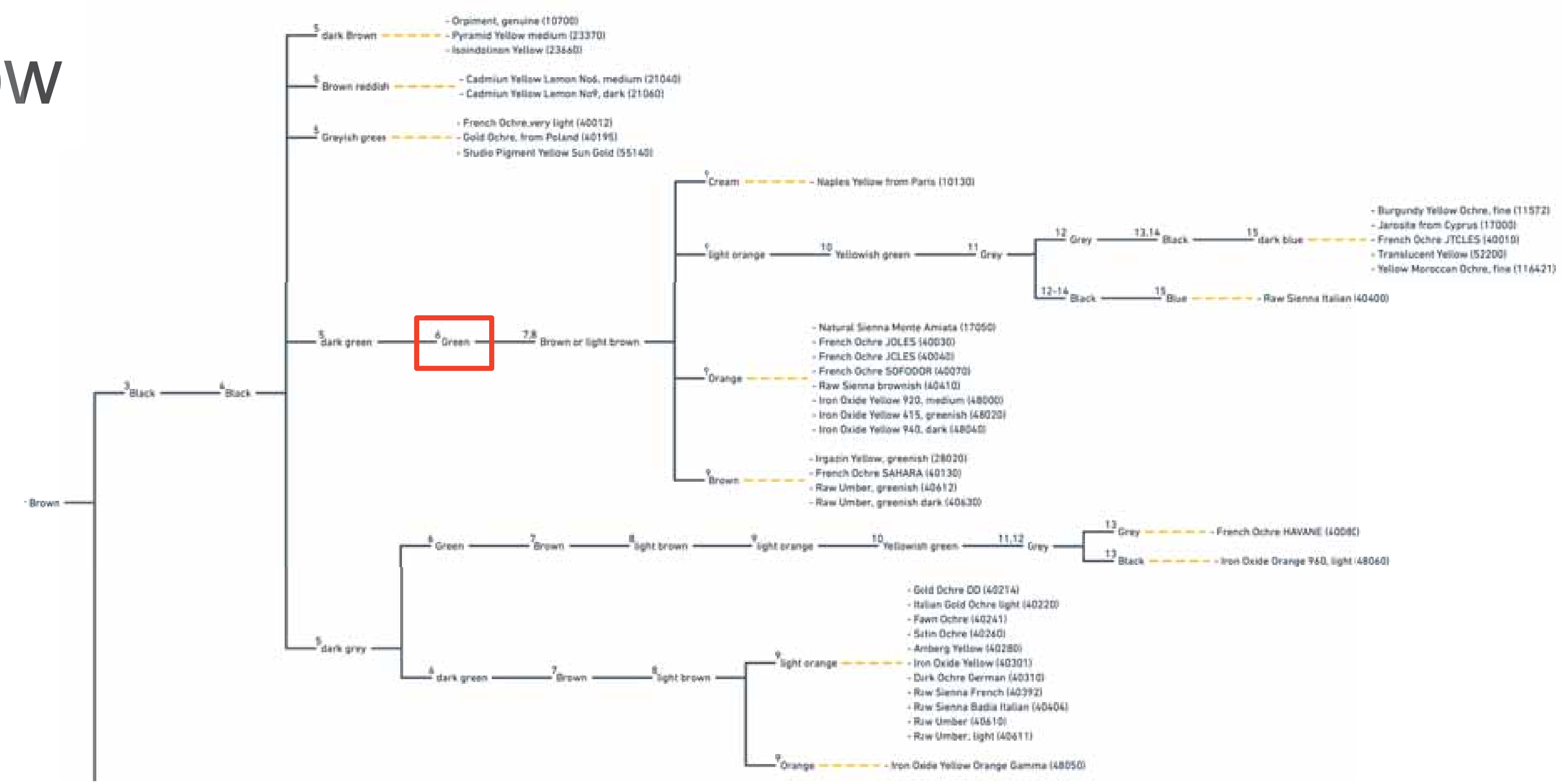
Ch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
color	Yellow or Brown	Yellow	Black	Black	dark green	Green	Brown	light Brown	Orange	Yellowish green	Grey	Grey	Black	Black	Blue
Test Sample															

Yellow



	Ch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	color	Yellow or Brown	Yellow	Black	Black	dark green	Green	Brown	light Brown	Orange	Yellowish green	Grey	Grey	Black	Black	Blue
Test Sample																

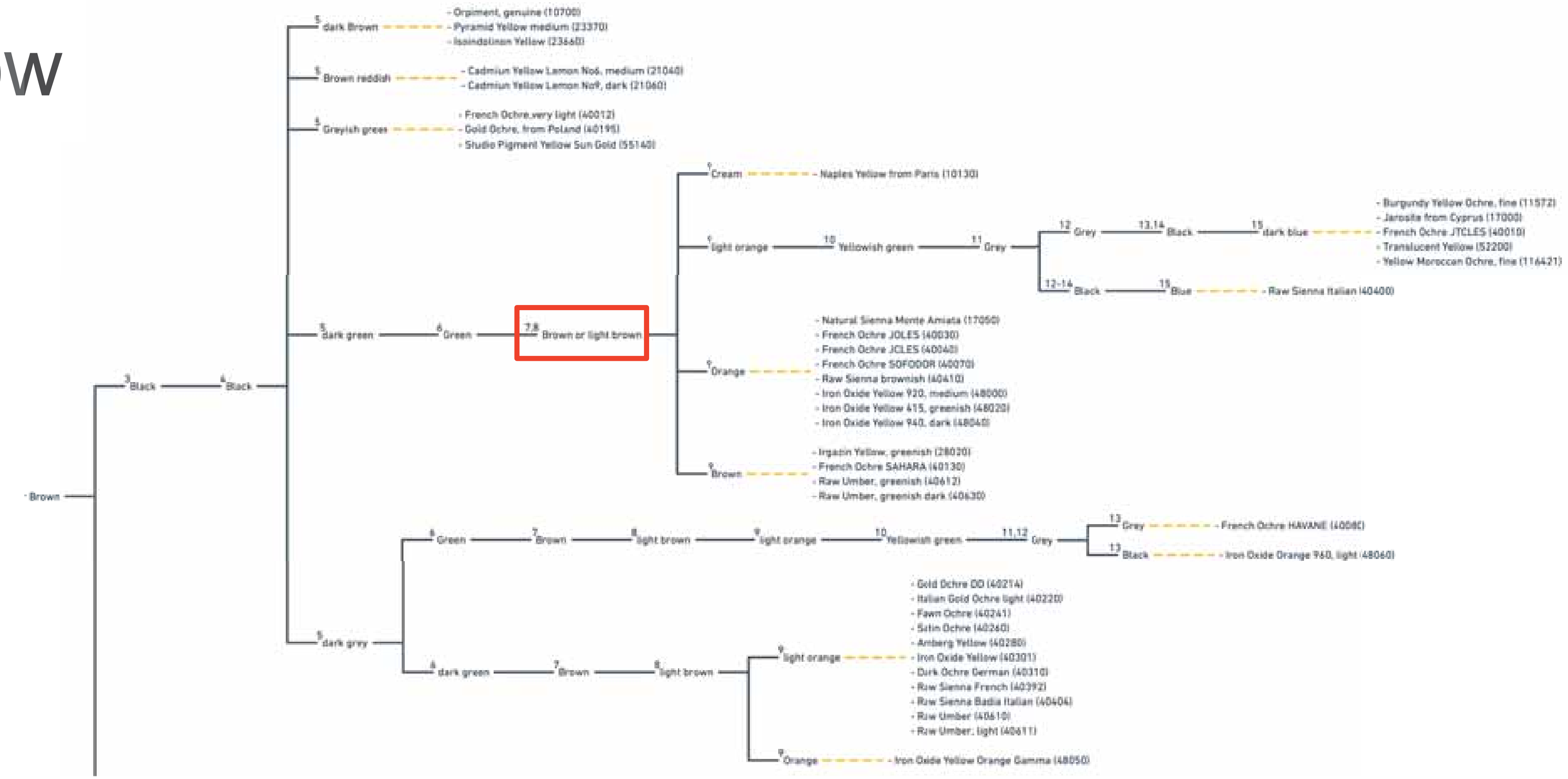
Yellow



Ch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
color	Yellow or Brown	Yellow	Black	Black	dark green	Green	Brown	light Brown	Orange	Yellowish green	Grey	Grey	Black	Black	Blue

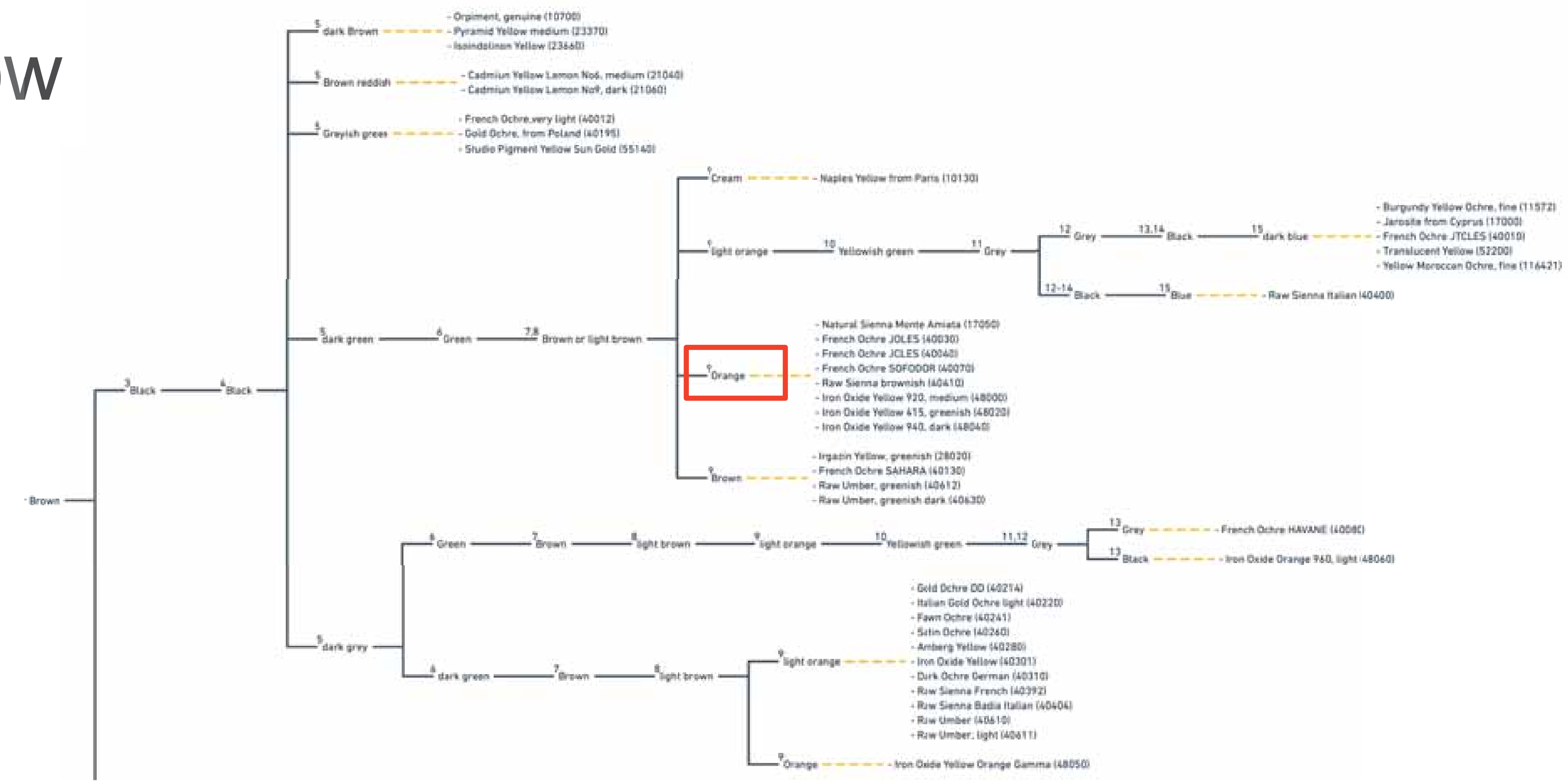
Test Sample

Yellow



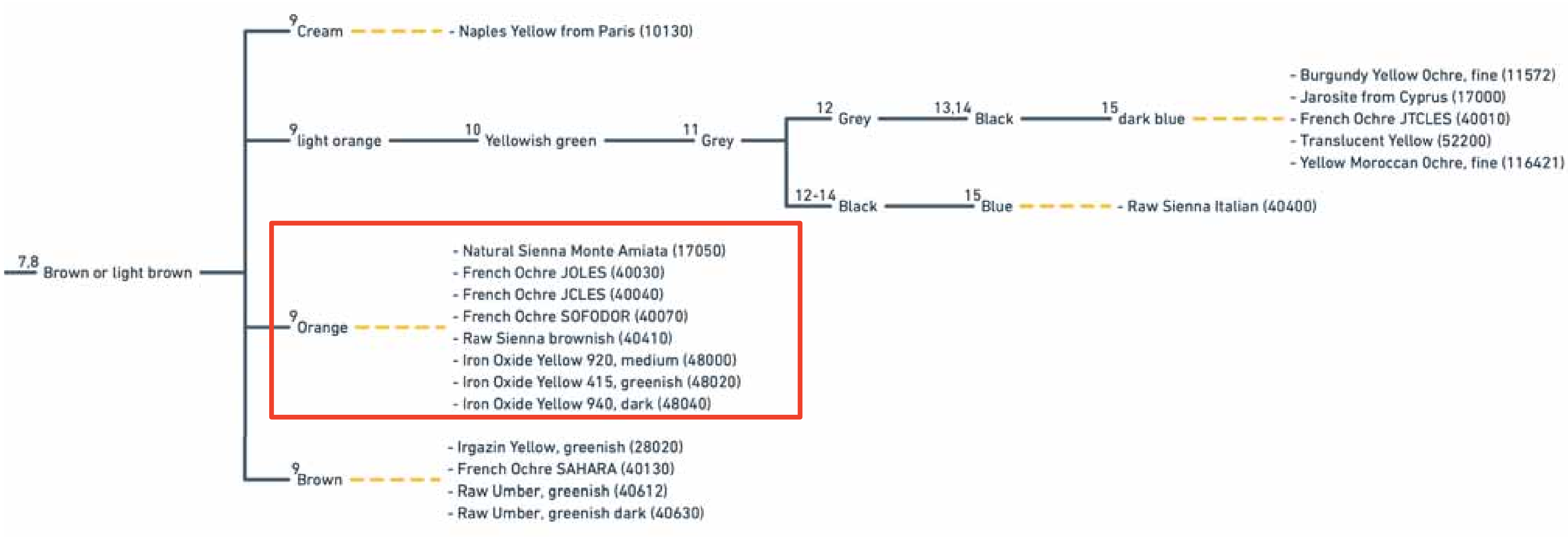
Ch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
color	Yellow or Brown	Yellow	Black	Black	dark green	Green	Brown	light Brown	Orange	Yellowish green	Grey	Grey	Black	Black	Blue
Test Sample															

Yellow



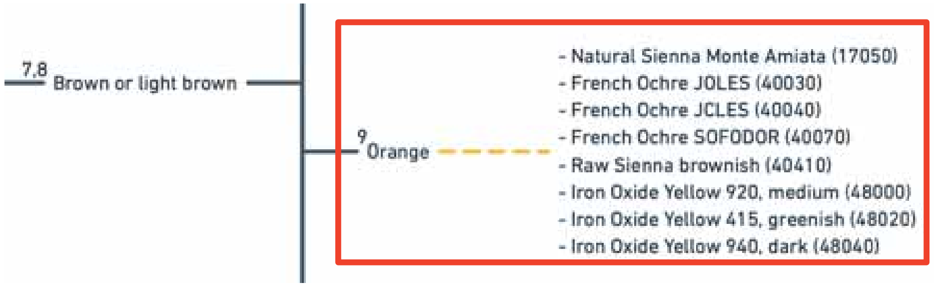
Ch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
color	Yellow or Brown	Yellow	Black	Black	dark green	Green	Brown	light Brown	Orange	Yellowish green	Grey	Grey	Black	Black	Blue
Test Sample															

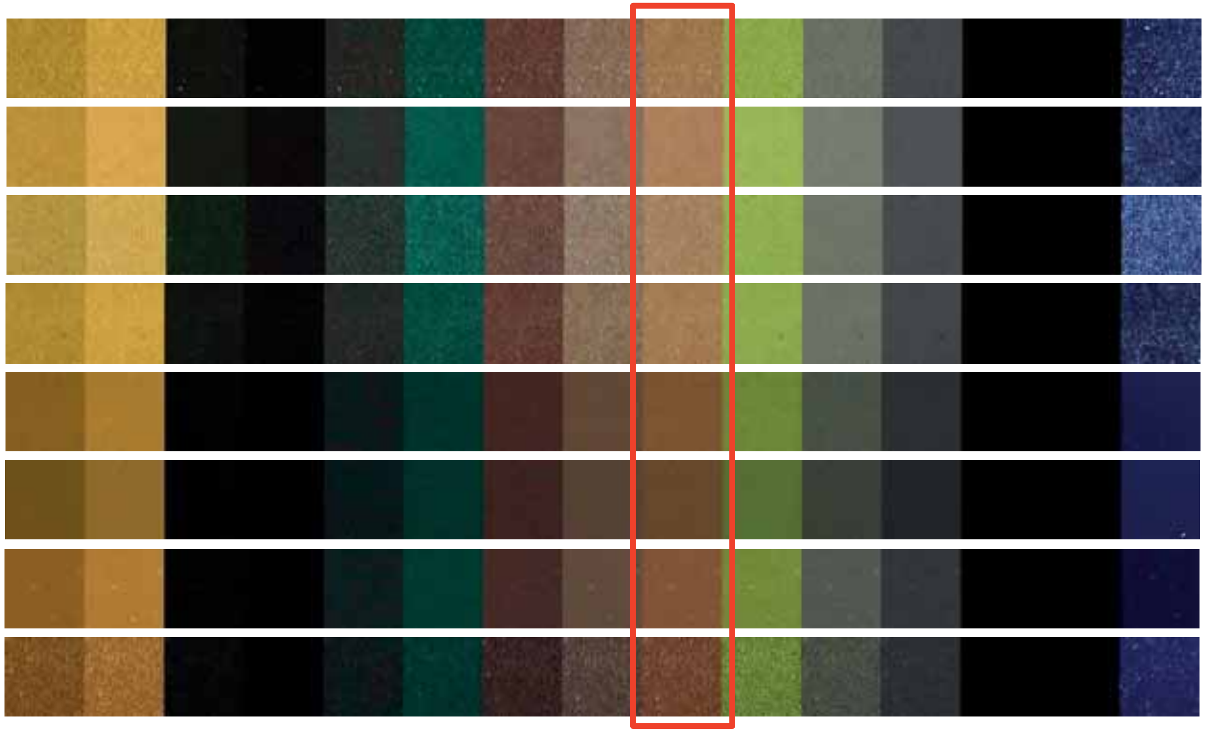
Yellow



	Ch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	color	Yellow or Brown	Yellow	Black	Black	dark green	Green	Brown	light Brown	Orange	Yellowish green	Grey	Grey	Black	Black	Blue
Test Sample																

Yellow





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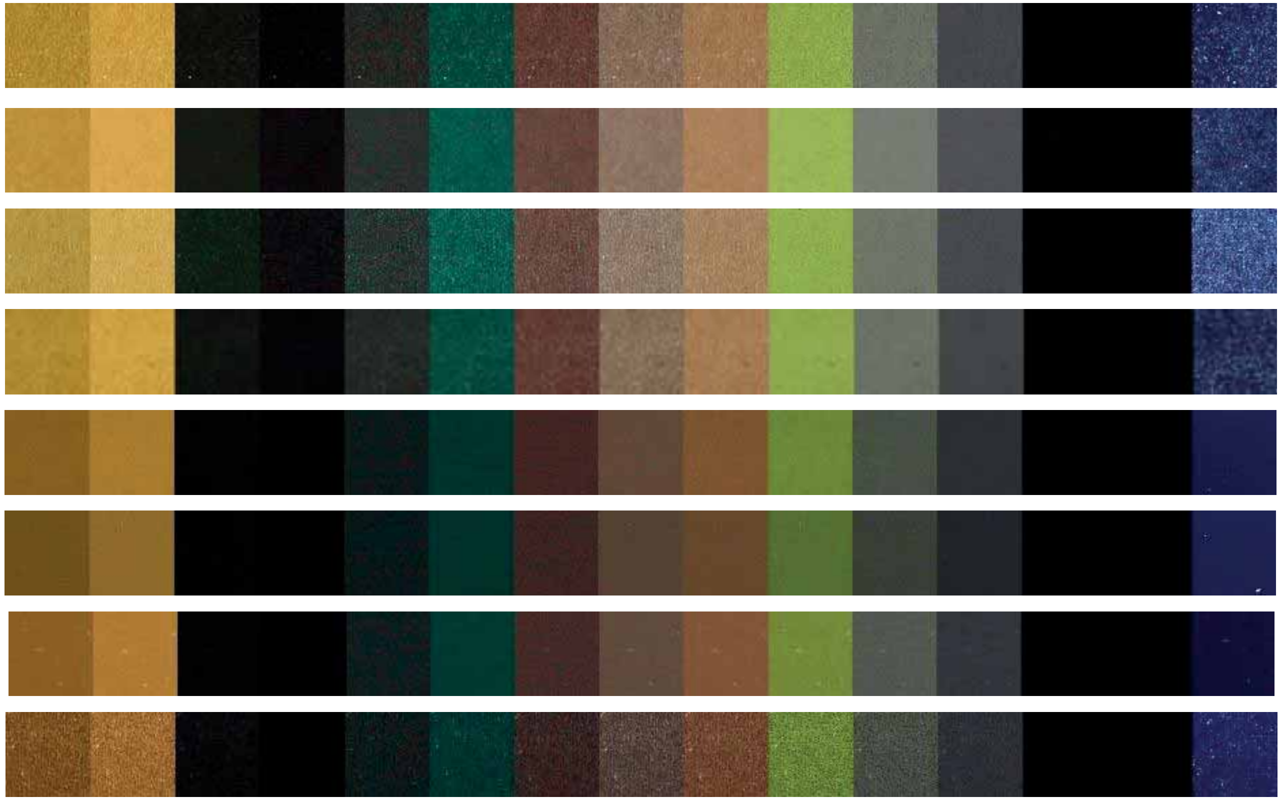
color	Yellow or Brown	Yellow	Black	Black	dark green	Green	Brown	light Brown	Orange	Yellowish green	Grey	Grey	Black	Black	Blue
Test Sample															

Yellow

Ch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
color	Yellow or Brown	Yellow	Black	Black	dark green	Green	Brown	light Brown	Orange	Yellowish green	Grey	Grey	Black	Black	Blue

Test sample
Yellow ochre



Natural Sienna Monte Amiata (17050)

French Ochre JOLES (40030)

French Ochre JCLES (40040)

French Ochre SOFODOR (40070)

Iron Oxide Yellow 920, medium (40410)

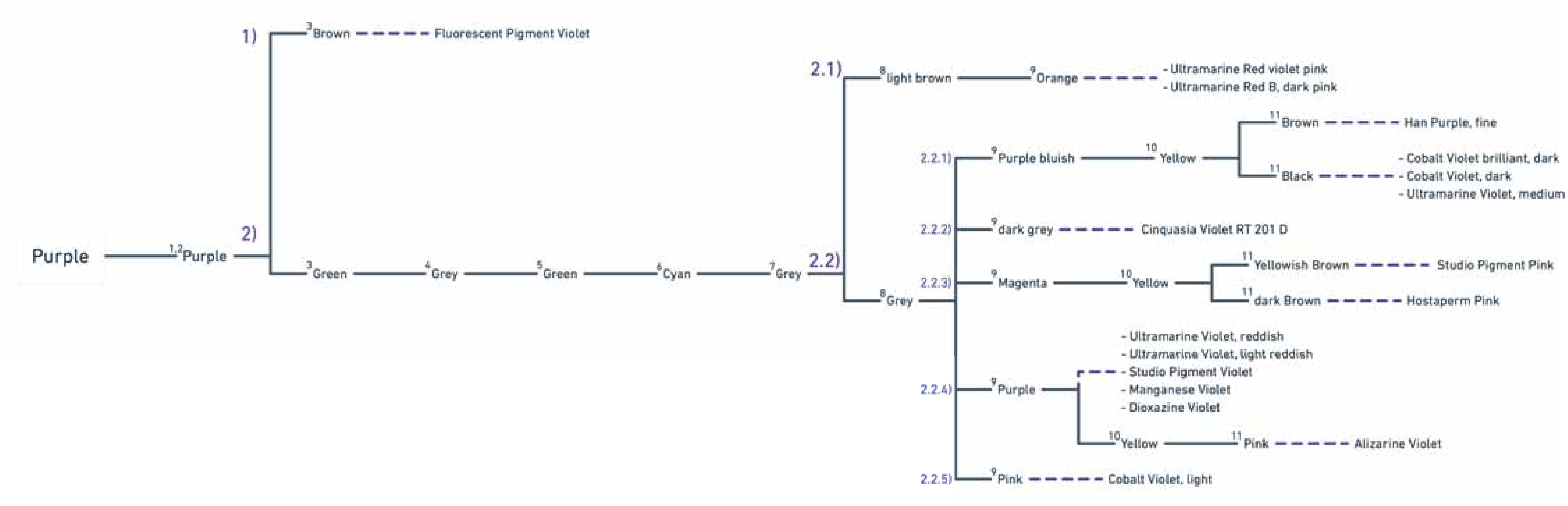
Iron Oxide Yellow 415, greenish (48000)

Iron Oxide Yellow 940, dark (48020)

Raw Sienna brownish (48040)

Purple

17 purple pigments
They were visually classified into 10 groups

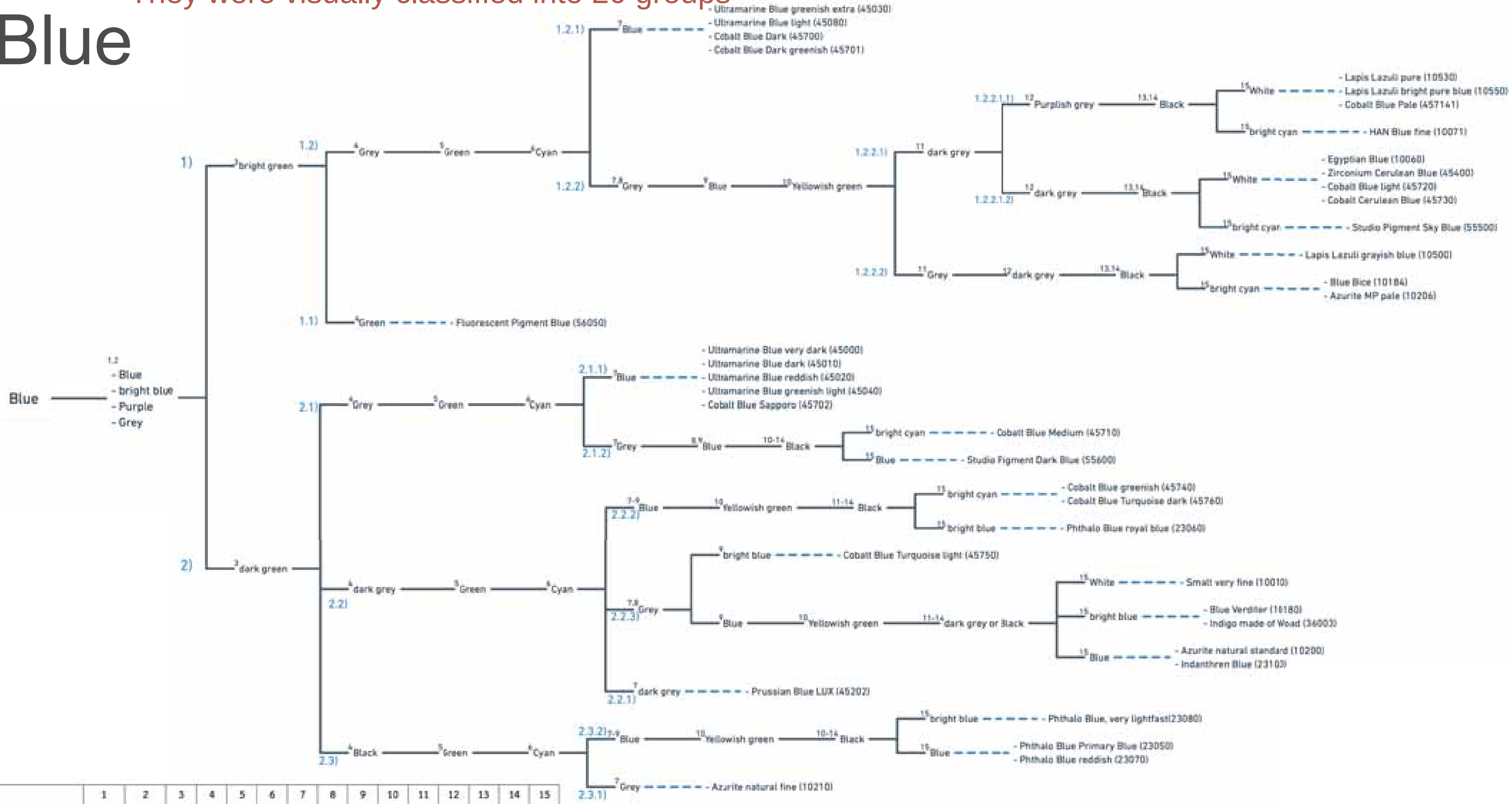


Channels	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Peak wavelength (nm)	Cool White	Warm White	403	425	447	474	503	523	540	598	640	660	672	706	366

Blue

38 blue pigments

They were visually classified into 20 groups



Channels	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Peak wavelength (nm)	Cool White	Warm White	403	425	447	474	503	523	540	598	640	660	672	706	366

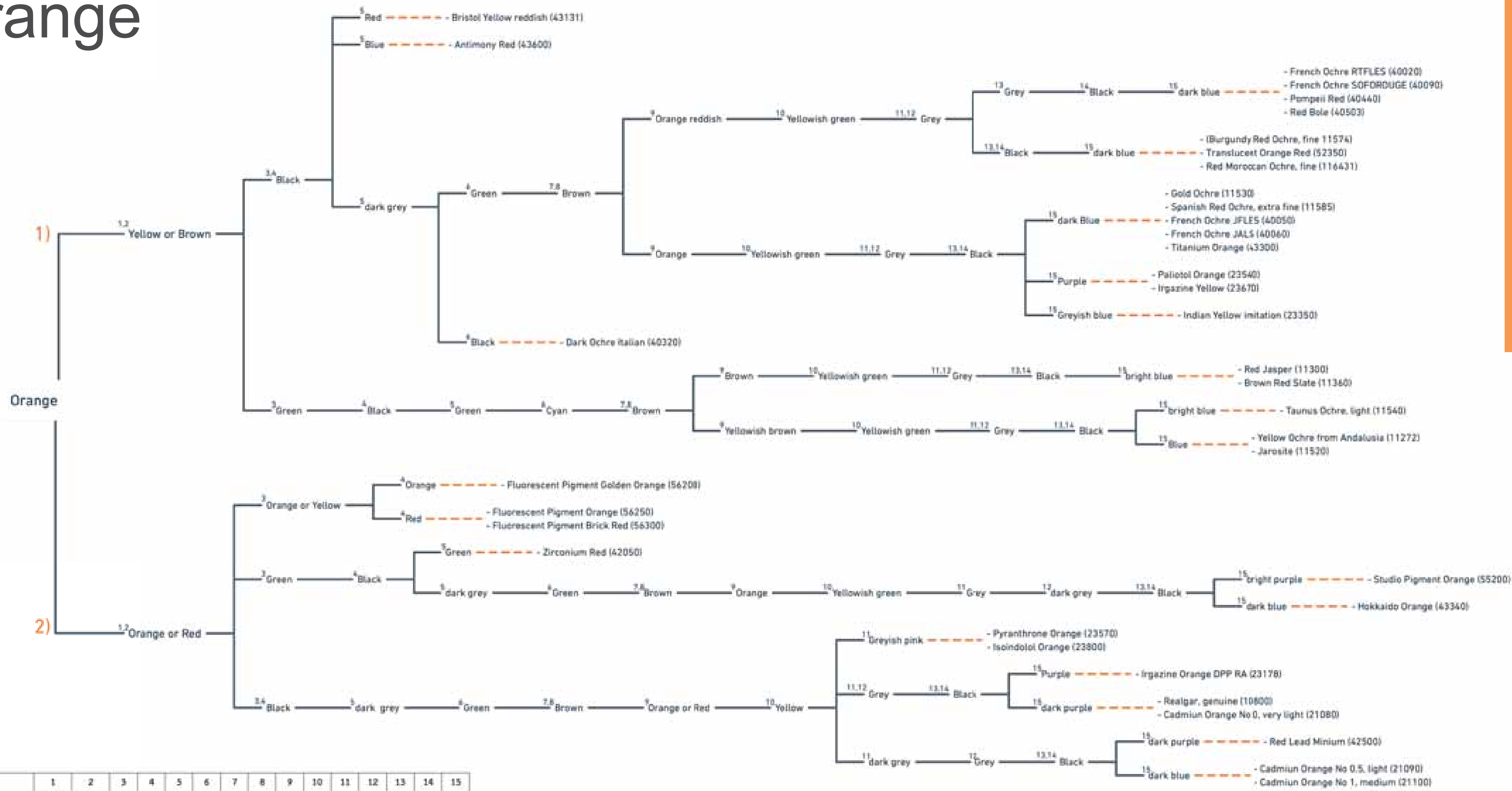
Green

38 green pigments
They were visually classified into 16 groups.

Channels	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Peak wavelength (nm)	Cool White	Warm White	403	425	447	474	503	523	540	598	640	660	672	706	366

Orange

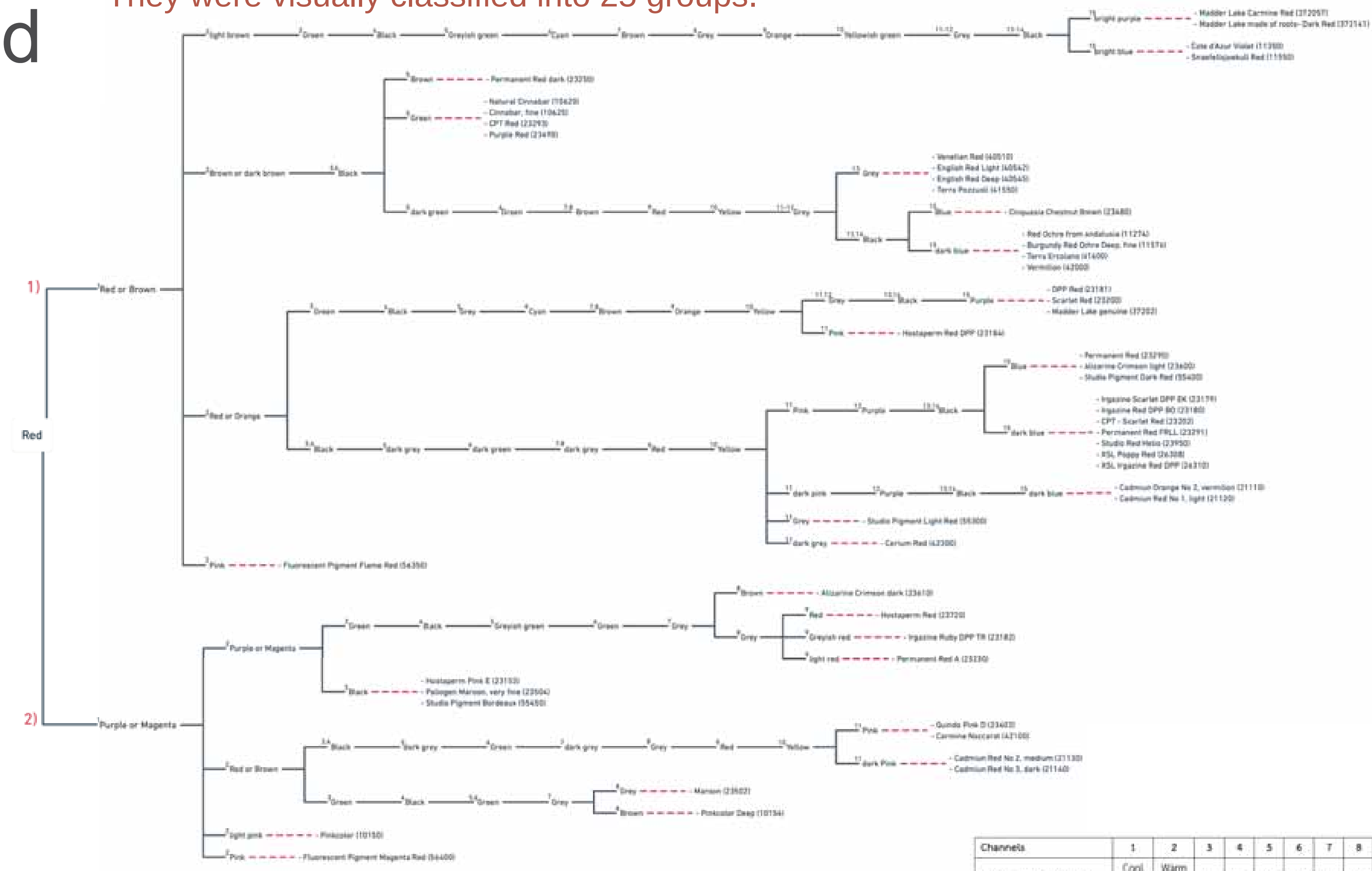
37 orange pigments
They were visually classified into 21 groups.



Channels	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Peak wavelength (nm)	Cool White	Warm White	403	425	447	474	503	525	540	598	640	660	672	706	366

Red

52 red pigments
They were visually classified into 25 groups.



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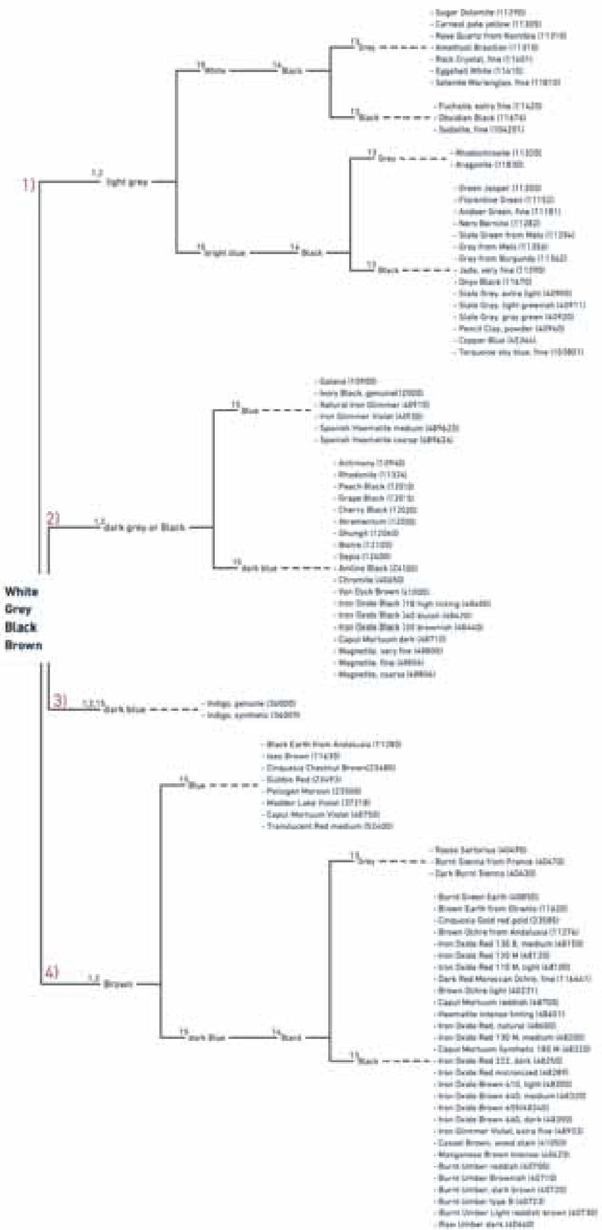
Peak wavelength (nm)	Cool White	Warm White	403	425	447	474	503	525	540	598	640	660	672	706	366

White, Grey, Black and Brown

94 pigments
They were visually classified into 10 groups.



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Peak wavelength (nm)	Cool White	Warm White	403	425	447	474	503	523	540	598	640	660	672	706	366

Database of Kremer’s

Capturing images under
15 LEDs channels

Flowchart of pigments

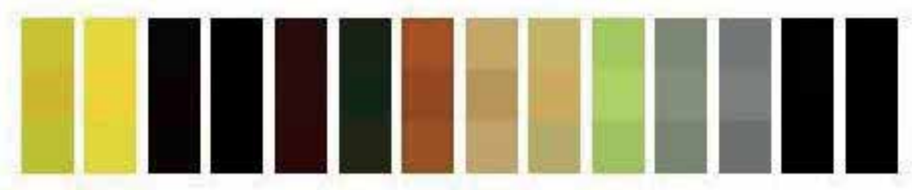
Flowchart of 7 colors group

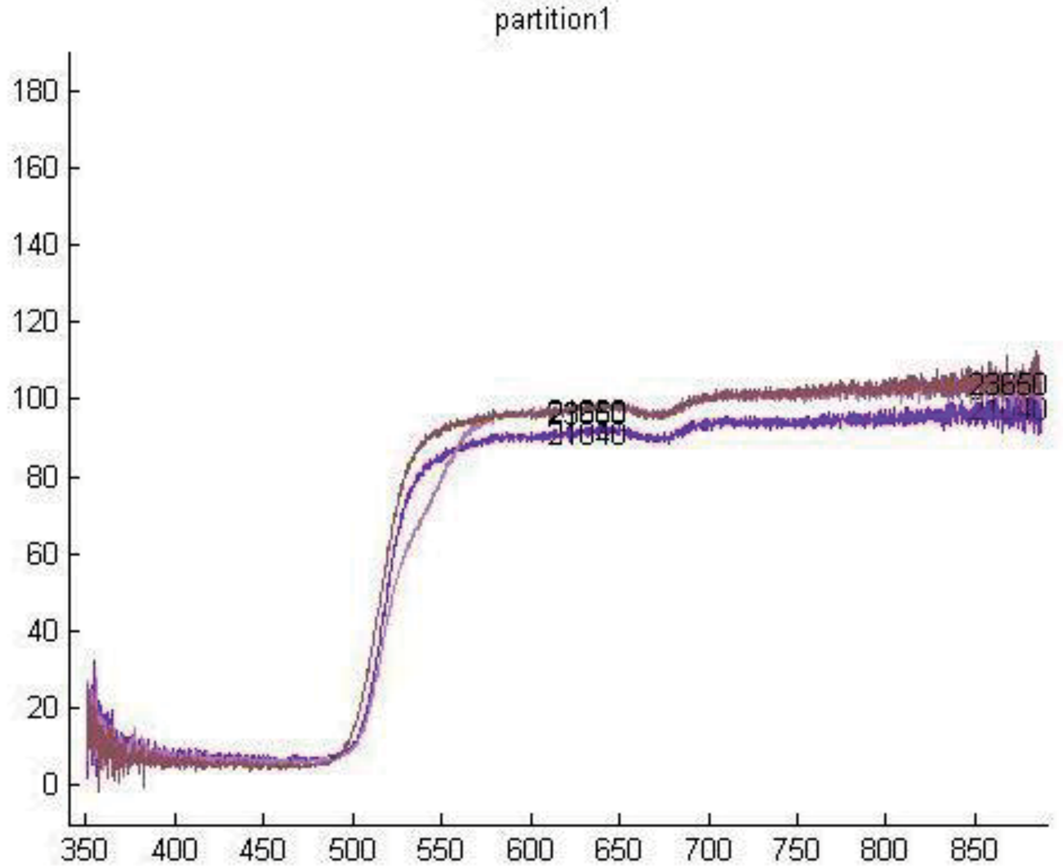
Apply SOM to
pigments database

Results_SOM

partition 1
ans = code: [21040 21060 23650]
partition 2
ans = code: [23300 23310 23340 23370]
partition 3
ans = code: [21020 21030 23660 43500 43870 43880 43910 43915]
partition 4
ans = code: [43230 55100 55140]
partition 5
ans = code: 56150
partition 6
ans = code: [24000 43111 55125]
partition 7
ans = code: [43101 43918 43920]
partition 8
ans = code: [10130 10700 43125]
partition 9
ans = code: [10110 21010 23850 43200 43210]
partition 10
ans = code: [10100 10120 11283 40013]
partition 11
ans = code: []
partition 12
ans = code: [11572 116421 17050 40030 40070]
partition 13
ans = code: [17000 40010 40040 43130]
partition 14
ans = code: [11150 40800]
partition 15
ans = code: [17400 40012 40195]
partition 16
ans = code: [40214 40220 40260 40301 40400]
partition 17
ans = code: []
partition 18
ans = code: [23330 52200]
partition 19
ans = code: [10930 41800]
partition 20
ans = code: [11000 40821]
partition 21
ans = code: 40080
partition 22
ans = code: [40410 48000 48020 48040 48050 48060]
partition 23
ans = code: [40241 40280 40310 40392 40404]
partition 24
ans = code: [28020 40130 40611]
partition 25
ans = code: [40610 40612 40630]

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cool White	Warm White	403	425	447	474	503	523	540	598	640	660	672	706

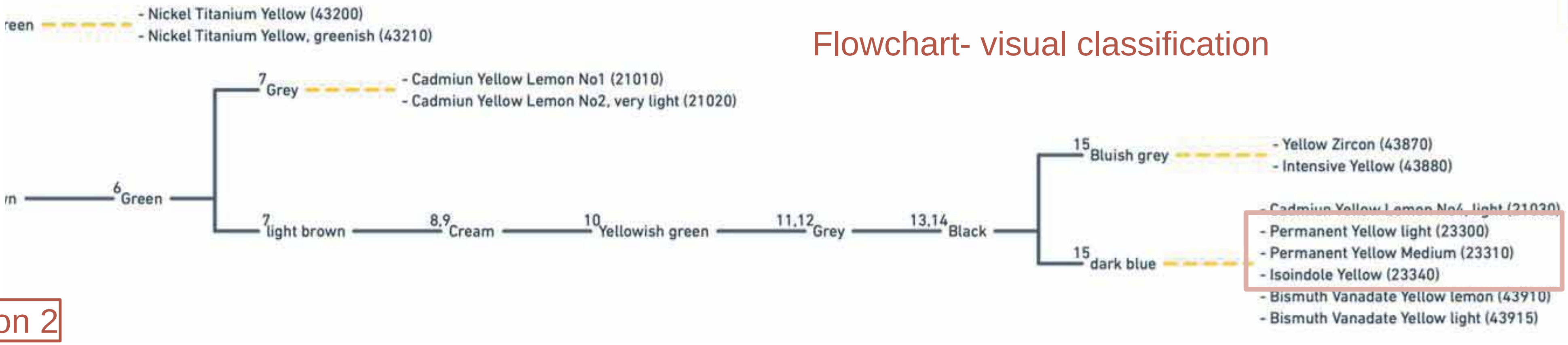


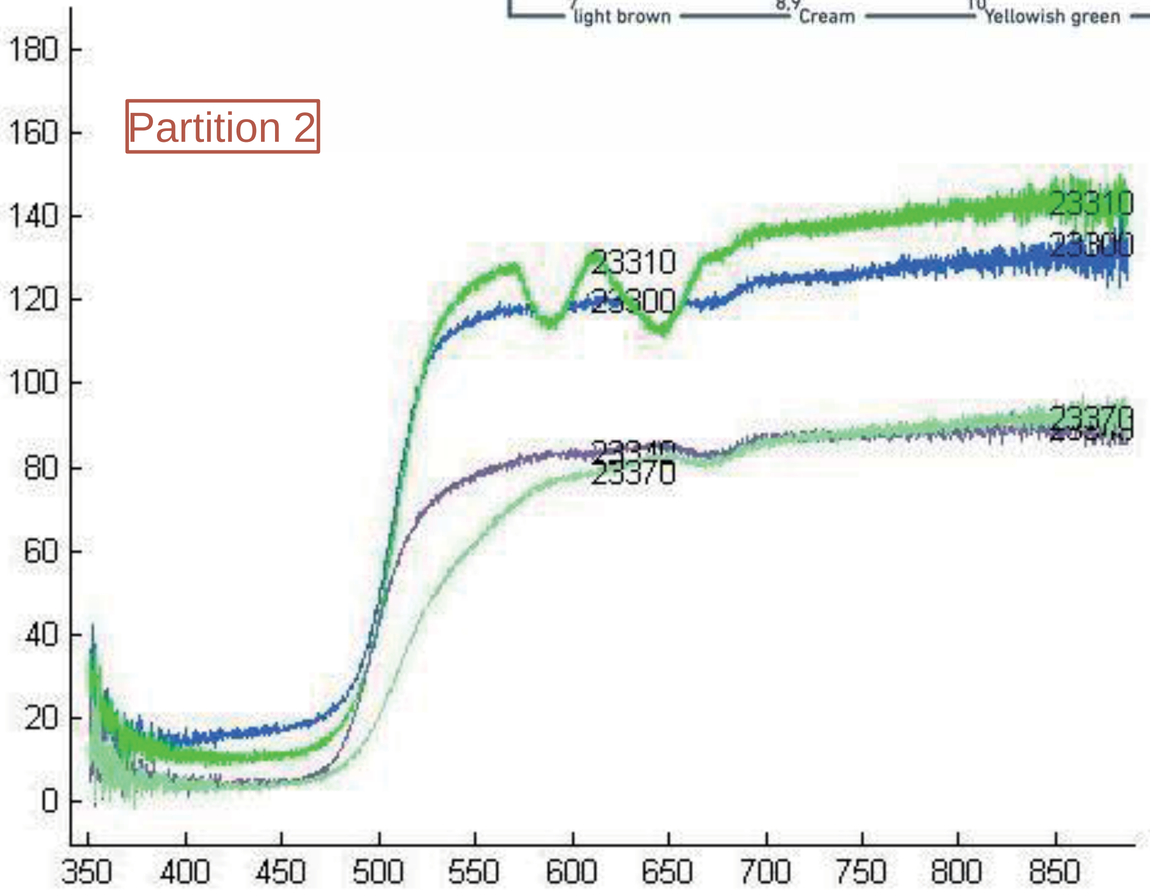


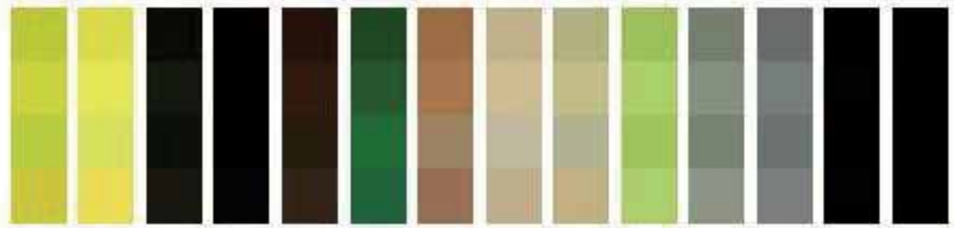
21040 Cadmiun Yellow Lemon No6- medium
21060 Cadmiun Yellow Lemon No9- dark
23650 Brilliant Yellow

code: [**21040 21060** 23650]

Flowchart- visual classification



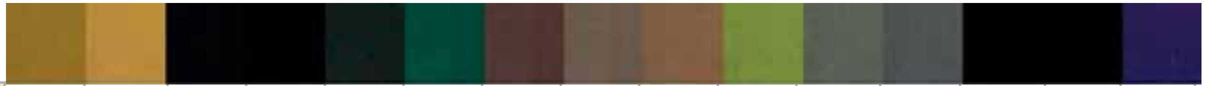




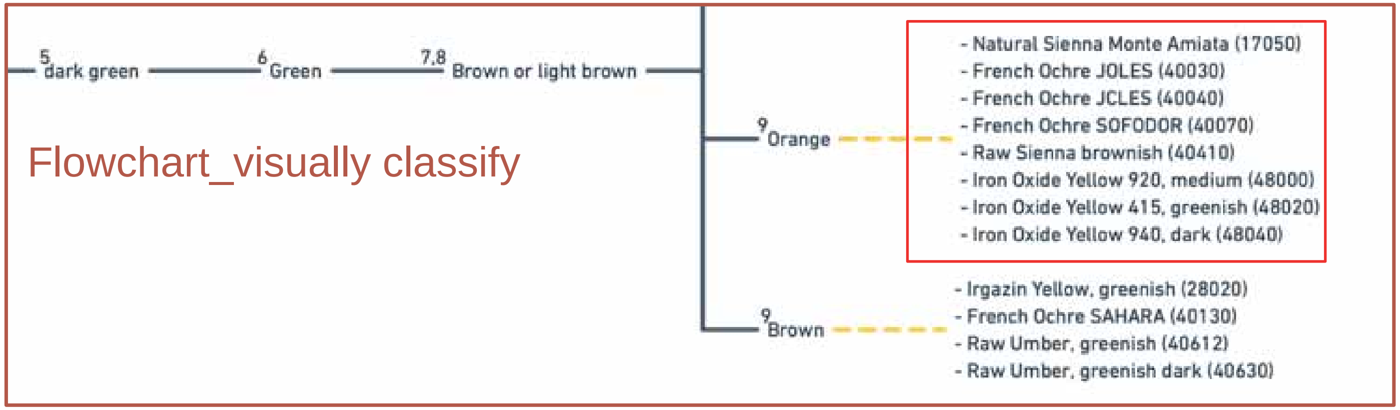
23300 Permanent Yellow light
23310 Permanent Yellow Medium
23340 Isoindole Yellow
23370 Pyramid-Yellow medium
code: [23300 23310 23340 23370]

Test sample • Yellow ochre

pigment : gum arabic
1 : 4



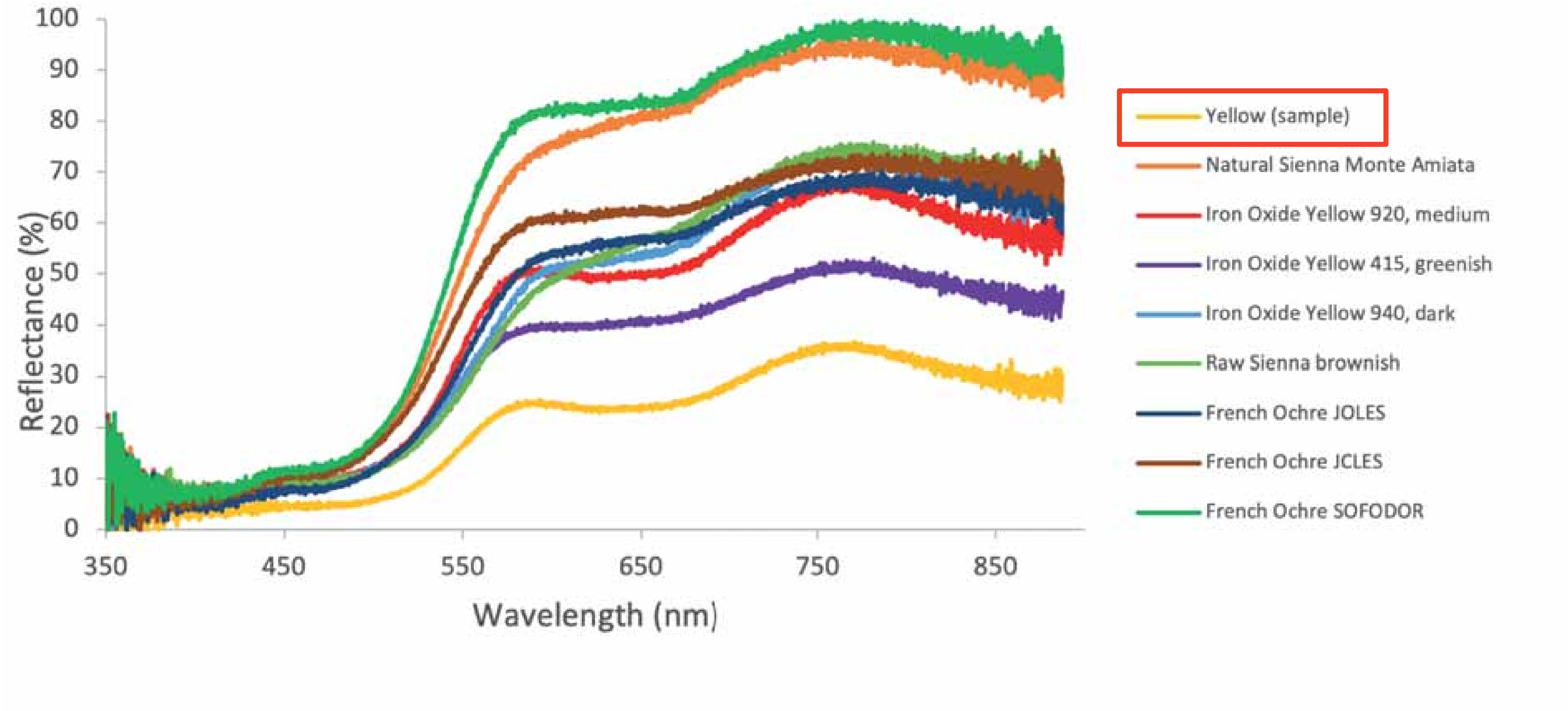
Ch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
color	Yellow or Brown	Yellow	Black	Black	dark green	Green	Brown	light Brown	Orange	Yellowish green	Grey	Grey	Black	Black	Blue

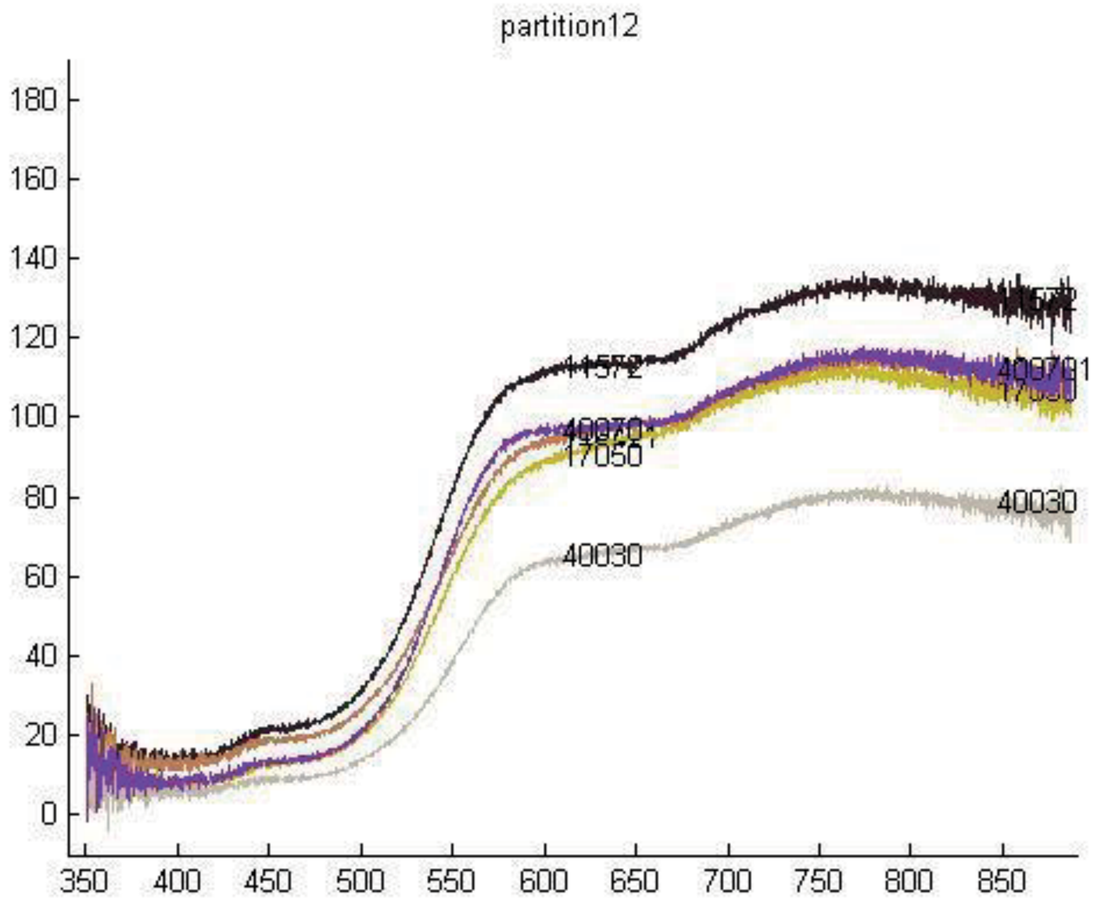


Flowchart_visually classify

SOM_result
partition 12
11572 Burgundy Yellow Ochre- fine
116421 Yellow Moroccan Ochre- fine
17050 Natural Sienna- Monte Amiata
40030 French Ochre JOLES
40070 French Ochre SOFODOR

Spectral Reflectance of a group of yellow classified visually.





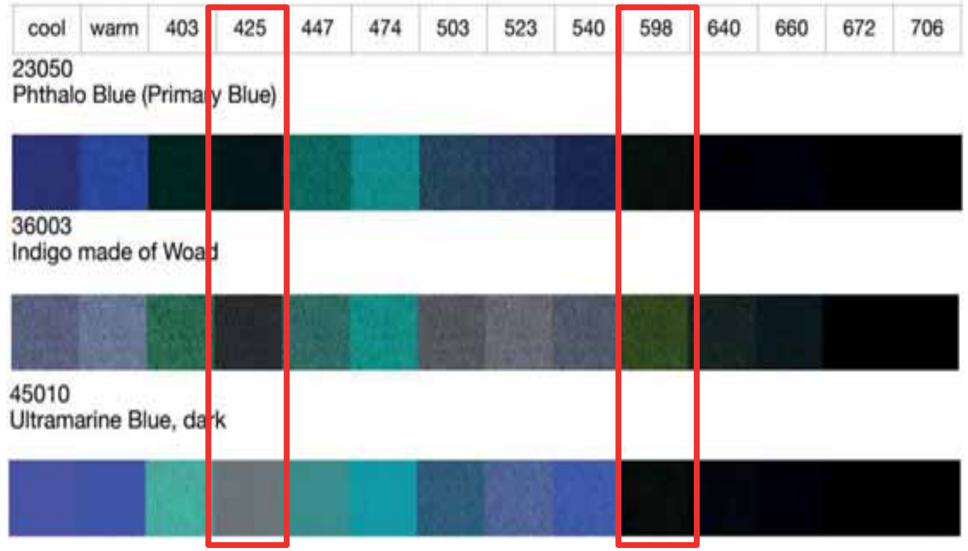
SOM_result
partition 12
11572 Burgundy Yellow Ochre- fine
116421 Yellow Moroccan Ochre- fine
17050 Natural Sienna- Monte Amiata
40030 French Ochre JOLES
40070 French Ochre SOFODOR

Results of PCA

Sureeporn Khampaeng, Pichayada Katemake, Chawan Koopipat, "Optimizing multicoloured LEDs for identifying pigments," Proc. SPIE 11784, Optics for Arts, Architecture, and Archaeology VIII, 117841B (13 July 2021); doi: 10.1117/12.2593274

SPIE.

Event: SPIE Optical Metrology, 2021, Online Only

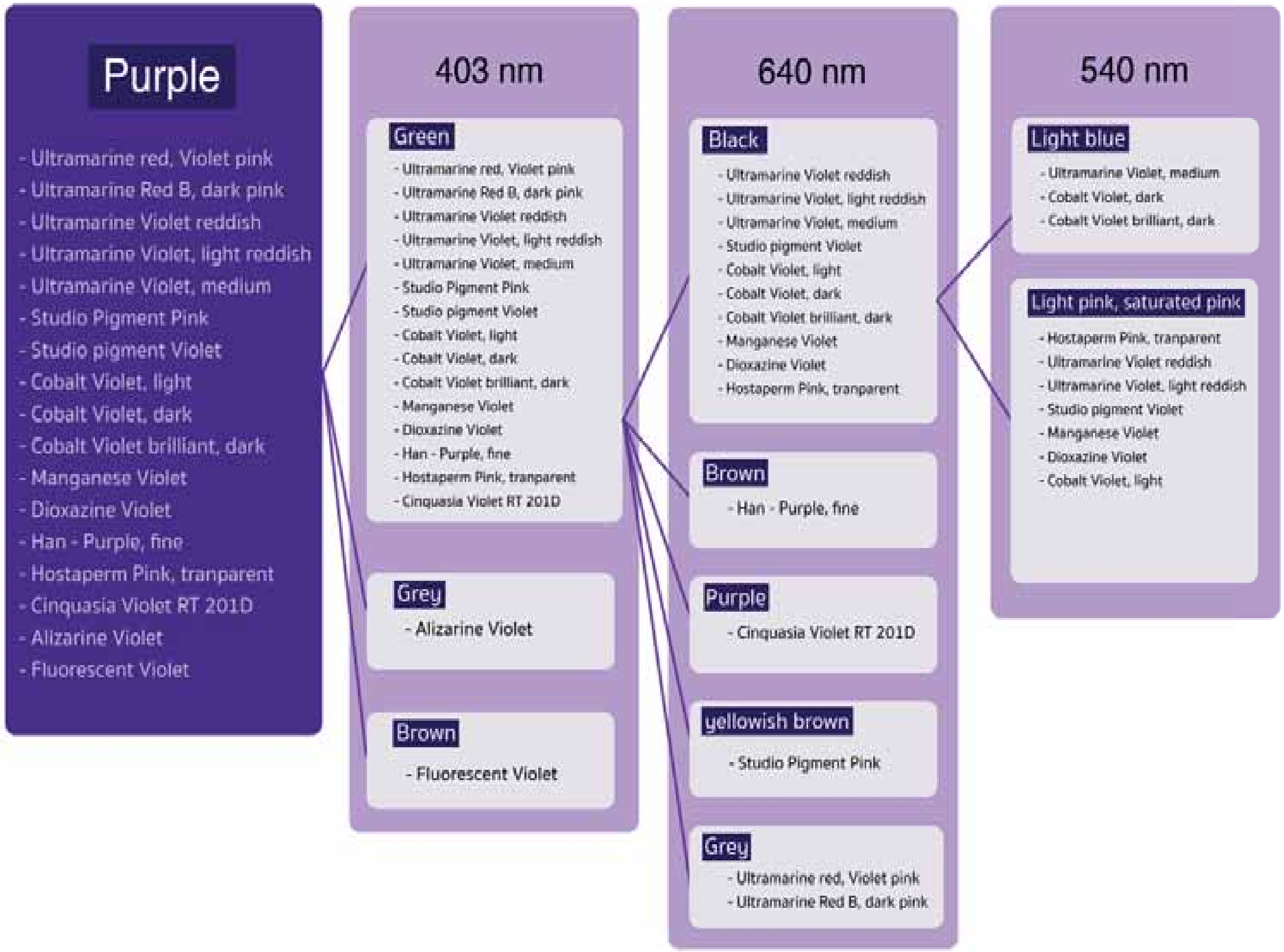


Example of Kremer blue pigments categorized by 598 nm and 425 nm.

Sureeporn Khampaeng, Pichayada Katemake, Chawan Koopipat, "Optimizing multicoloured LEDs for identifying pigments," Proc. SPIE 11784, Optics for Arts, Architecture, and Archaeology VIII, 117841B (13 July 2021); doi: 10.1117/12.2593274

SPIE.

Event: SPIE Optical Metrology, 2021, Online Only



Sureeporn Khampaeng, Pichayada Katemake, Chawan Koopipat, "Optimizing multicoloured LEDs for identifying pigments," Proc. SPIE 11784, Optics for Arts, Architecture, and Archaeology VIII, 117841B (13 July 2021); doi: 10.1117/12.2593274

SPIE.

Event: SPIE Optical Metrology, 2021, Online Only

Red	Orange	Yellow	Green	White, grey, black and brown
403nm_L*-PC1 [-0.93]	403nm_C*-PC1 [-0.84]	503nm_L*-PC1 [-0.90] 503nm_h-PC1 [-0.80] 503nm_C*-PC2 [-0.70]	503nm_C*-PC2 [-0.72]	403nm_L*-PC1 [-0.99]
540nm_L*-PC1 [-0.78] 540nm_C*-PC2 [-0.63]	447nm_L*-PC1 [-0.81]	540nm_L*-PC1 [-0.96] 540nm_C*-PC2 [-0.89]	598nm_L*-PC1 [-0.99]	503_L*-PC1 [-0.99]
660nm_L*-PC3 [0.59] **660nm**_h-PC4 [0.73]	540nm_h-PC2 [0.86] 540nm_C-PC3 [-0.83]	598nm_C*-PC1 [-0.80]	640nm_L*-PC1 [-0.98]	540nm_h-PC2 [0.81]
672nm_L*-PC4 [-0.72]	672nm_C*-PC4 [0.70]			660_L*-PC1 [-0.96]

Conclusions

- Apart from the technical photography (TP) technique used for identification pigments, we proposed a use of narrow band multi-colored LEDs for capturing images and use them for classifying and identification of pigments.

- These two methods can be used for confirmation each other.

- The self organized map is useful for clustering and visualization this type of data. We also consider using VQTAM based on SOM to improve the results.

- PCA could be used for optimizing the LEDs channels. We also consider the feature selection for optimization to improve the results.

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