



PROJECT No. 508312/ CONTRACT No. COOP-CT-2003-508312

COLORMATCH

DEVELOPMENT OF AN EXPERT SYSTEM FOR THE COLORANT FORMULATION IN THE
DYEING PROCESS OF VENEER IN FURNITURE INDUSTRY.

Instrument: Co-operative Research Project

Thematic Priority: FP6-2002-SME-1

FINAL REPORTS

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1. PROJECT EXECUTION

1.1. PROJECT OBJECTIVES

The consortium aims to develop an **expert system based in computer vision which will be applied in furniture factories and automatically collect and interpret data to identify and define the adequate colorant formulation for achieving a target colour**. The proposed expert system will carry a payload of state-of-the-art in furniture industry and spectrophotometers. The proposed system will be intrinsically safe (able to operate in hazardous environments) and will be able to carry out colorant formulations in a shorter time and with less tries, reducing considerably the needed manual intervention.

The expected results are:

- Developing a computer vision system to quantify and describe the colour of non-uniformly coloured surfaces such as wood samples in furniture industry and the colour differences between them,
- Matching with visual perception,
- Together with algorithms that based on the data of a knowledge-base will propose a colorant formula for achieving a target colour when it is applied over a wood sample.
- The result of the application of the formula should be included in the knowledge-base, thus optimising the system for achieving formulae for future use.
- One user interface should also form the final software, making up together with the computer vision machine an expert system for the colorant formulation for the dies applied in the wood industry.

SCIENTIFIC/TECHNOLOGICAL OBJECTIVES: Developing a computer vision system to quantify and describe the colour of non-uniformly coloured surfaces such as wood samples in furniture industry and the colour differences between them, matching with visual perception, together with algorithms that based on the data of a knowledge-base will propose a colorant formula for achieving a target colour when it is applied over a wood sample. The result of the application of the formula should be included in the knowledge-base, thus optimising the system for achieving formulae for future use. An user interface should also form the final software, making up together with the computer vision machine an expert system for the colorant formulation for the dies applied by roller in the wood industry.

ECONOMIC AND INDUSTRIAL OBJECTIVES:

- A significant cost reduction in the furniture industry (of the order of 704 million Euros in Europe, after project end). The development of a system to automatic colorant formulation on furniture industry should minimize losses in: (1) formulation time (currently each formulation change involves at least 1 hour), (2) rebuffs of wood panels (facilitating the sustainable development). Currently these losses are due to bad formulations, so this expert system should reduce colour differences between resultant sample woods and targets according to the previous quantification method.
- Profits from sales of the system to reach 5,5 million €, 4 years after project end. The expected average price of this expert system will be between 60-120 K€.
- Increase even more EU competitiveness against USA and Japanese enterprises in the furniture industry market. 2001's furniture production in Europe was 77.950 million Euros, against 33.407 million Euros of USA and 18.986 million Euros of Japan.
- Besides to loss reduction other important improvements should be achieved: a final product quality improvement and the capacity to probe that quality quantitatively to the client in standard colour difference units, shorter formulation times which would reduce costs specially in the dyeing industry, as well as the capacity to formulate by any technician and not only by expert colourists that need years of experience to form. Preliminary works on this task gives us the result that actually colour differences are accepted up to about 2 or 3 E in CIELab, while our objective is to reduce these differences below to 1.5 E.



- The possibility of further investigations and developments will be take into account, and the generalisation of the method to other processes, as for example melamine printing or printing by spray gun. The method also will be applicable on other sectors like plastic industry or paper industry, which also deal with colorant formulation over non uniform surfaces and have the same problem with colour differences quantification.

SOCIAL OBJECTIVES:

- Elimination of labour intensive and monotonous inspection tasks
- Reduction of the exposure of the operator to work in hazardous environments
- Elimination of operator stress and error caused by the need for great attention to detail and raw material variability
- Elimination of subjective data interpretation
- Enhancement of quality improvement in different furniture finishes

ENVIRONMENTAL OBJECTIVES:

- Reduction of wastes of wood panels, facilitating the sustainable development. Currently, rebuffs in furniture industry born once the whole furniture piece is assembled. In case colours don't match, the whole furniture piece is rebuffed. Thus, a deviation in a furniture piece implies a similar cost of a whole assembled furniture piece, and is eliminated of the market chain and later burnt.
- Reduction of the amount of employed dyes, which constitutes dangerous products, and their spillages, as well as the reduction of the exposure of furniture industry technicians to these toxic products.



1.2. CONTRACTORS INVOLVED

| PROJECT COORDINATOR | |
|---------------------|--|
| A1 | INDUSTRIAS QUÍMICAS IRURENA S.A. Contact details: Carretera de Tolosa s/n, 20730, Azpeitia (Guipúzcoa) SPAIN Represented by Ignacio Javier Olea Bereciartúa |
| PARTNERS | |
| A2 | Alberto Mora Galiana, S.A. OMAR |
| A3 | METROTEC, S.A. |
| A4 | Wessendorf Oberflächentechnik GmbH |
| A5 | 3H-LACKE Lackfabrik Hammen GmbH & Co. KG |
| A6 | Camila Moveis Industria de mobiliario LDA. |
| RTD PERFORMERS | |
| B1 | CIDEMCO |
| B2 | Institute für Holztechnologie Dresden GmbH |
| B3 | University of Leeds |

1.3. WORK PERFORMED AND RESULTS ACHIEVED

The activities developed during the project are the following:

| PER | TASK | DELIVERABLE |
|--|---|--|
| 1 st year | WP1: System Specification. Analysis of the current descriptors and factors. Specification of wood sample colorants and solvents. | D1- Analysis of the current method and the knowledge-base preparation. |
| | WP2: Development of the image acquisition system construction of the prototypes and development of the acquisition software. | D2- Specifications and design of the prototype |
| | | D3- Image acquisition software. |
| | | D4- System parameter's adjustment |
| | WP3: Image analysis and colour coordinate transformation development. | D5- Image correction algorithms D6- Descriptors extraction algorithms D7- RGB to XYZ and Lab transformation |
| WP4: Knowledge-base preparation. | D8- Knowledge-base D9- Absorption and diffusion curves | |
| 2 nd year | WP5: Colour differences quantification | D10- Analysis of colour difference formula |
| | | D11- Analysis of metamerism D12- Final colour difference formula and tolerance's values |
| | WP6: Development of the rules | D13- Development of the formulation algorithm approximation theory |
| | | D14- Development of the formulation algorithm networks |
| | | D15- Development of the formulation algorithm Kubelka-Munk theory |
| | WP7: Development of the program | D16- Determination and improvement of formulation algorithm |
| | | D17- Analysis of graphical ways to show D18- Final program |
| | WP8: Final tests, validations and specifications | D19- System testing and validation |
| | | D20- Gathering of specifications D21- Analysis of the extension of the field |
| | WP9: Marketing study | D22- Marketing study |
| WP10: MANAGEMENT, EXPLOITATION, DISSEMINATION | | |



WP 1: SYSTEM SPECIFICATION. ANALYSIS OF THE CURRENT METHOD, DESCRIPTORS AND FACTORS. SPECIFICATION OF WOOD SAMPLES, VARNISHES, COLORANTS AND SOLVENTS

Nowadays, the process starts when a client wants to obtain a specific dye. With this aim, the client brings a wood sample as a reference, in order to show the colour and final visual aspect he/she wants to obtain. The application method will be used with this dye is defined at this moment too. At this point the operator has two options:

- Using manual methods:

Some basic colorants and solvents are combined. Thanks to his / her experience and the *test-error* method, the responsible of the colorant recipe obtains the formula to achieve the desired visual aspect as better as possible.

- Using semiautomatic methods:

Using a spectrophotometer is possible doing an approximate colour measurement, measuring some points on the sample's surface. Using this approximation data is possible to use the colour recipe prediction software that is prepared for uniform surfaces in order to obtain the desired formula. After some test-error cycles the aimed recipe is obtained. As it is evident, this software doesn't use all the information over the wood's surface because the spectrophotometer is not able to obtain it.

In any case, the final result is visually evaluated, because there is not any device to measure the colour on non-uniform surfaces. Again, it is possible to do an approximate measurement by a spectrophotometer.

During this process, a lot of factors can influence in a sample's final visual aspect: colorant, solvent, substrate, application method, etc.

Factors related to the visual aspect of dyed wood

In this point, all the factors could influence in the final wood's visual aspects are explained. These factors are quite usual concepts in the wood sector, but few explanations can make easier to understand the taken decisions.

1. Illuminant

During the viewing experience 3 elements interact one to each other to obtain the perception of colour: Light source's illuminant, viewed object and the observer.

In our system, the viewed object will be the wood sample, the observer will be a 10° observer (as the cie standard says) but when speaking about the light source's illuminant we have a lot of options: D65, A, TL84, etc...

Each one of these illuminants have each own properties and uses. Normally they simulate a typical light. For example, D65 simulates the daylight, A incandescent light, TL84 fluorescent light...

2. Substrates

The substrate is the wood sample we want to dye. Some of its properties can affect on the final visual aspect

- *Initial visual aspect:*

The wood sample will have a initial visual aspect. This aspect will influence in the result since the dyes are not opaque.

-Average colour: is the average colour of the sample's entire surface.

-Grain average colour: It's the average colour of the sample's grain part.

-Background average colour: It's the average colour of the sample's background.



-Homogeneity: It's the distance (from a colorimetric point of view) between the darkest and less dark part of the sample. Grain aspect: the grain could have different shapes. These shapes could be characterized with some physical magnitudes as frequency, orientation, etc.

- *Absorption:*

Depending on the substrate's absorption level, it absorbs the dye in a different way, so, the final visual aspect is different. The absorption level is related also to the affinity between the wood sample and the dye we are using. Not all the substrates absorb the same dye in the same way.

- *Size:*

The total wood's surface it's important in order to obtain the information about the color, but more important to obtain a good information about the grain color.

- *Dye:*

The dye is a coloured substance, solved in a specific solvent or carrier. Once this substance is deposited over the wood, and once the solvent is evaporated, it distributes a transparent coloration to the wood. A dye could be composed by different basic components:

- Binder: homogenize the colour and allows dyeing varnished surfaces.
- Colorants or pigments: they will give the final coloration. The colorants allow seeing absolutely the wood, not covering it, just giving colour. The pigments cover the wood partial or totally.
- Solvents: They dilute the binders, colorants and pigments. Their function is to facilitate the penetration of the dye in the wood. This effect depends on the velocity of the solvent.

It is possible to do the classification of these dyes in two ways:

About its disolution:

- Water based dyes
- Hidroalcoholic dyes
- Solvent dyes

About its nature:

- Transparent dyes
- Semipigmented or semitransparent dyes.
- Special effects

- *Water based dyes*

Typically these products are sold as powder, but it is also possible to find them solved.

Some advantages of these products are the following:

- Not inflammable
- Not toxicity
- Good absorption and penetration on the wood
- Good grain enhancement is obtained.

Some of the disadvantages are the following:

- Very slow drying time.
- Necessary to apply hot for drying.
- The surface of the wood is raised, and this means more effort when sanding the wood piece.
- If the wood is a veneer-wood and has glue stains, this defect is enhanced.

- *Hidroalcoholic dyes*

They are very similar to the water based dyes, but they have a little alcohol percentage, in this way the drying process is faster and still the grain is enhanced.



- *Solvent dyes*

Nowadays, universal solvent dyes are used. These dyes could be used within slow evaporation solvents or fast evaporation solvents; basically, depending on the application method that is going to be used. If fast evaporation solvent is used, the dye is quickly dried and the colorants doesn't enter deeply in the wood so grain enhancement is not obtained. If we use slow or intermediate evaporation solvents the opposite effect is obtained.

- **Solvents**

The solvent is the substance where the colorant is diluted to obtain a dye. It doesn't change the colour of the dye. It's just the carrier for the colorant. Basically 3 solvent types exist: water, hidroalcoholic and organic.

The main characteristic of a solvent, at least related to the final visual aspect, is the evaporation speed. As we mentioned above, if the evaporation speed is slow, the dye penetrate more deeply in the substrate getting a better enhancement between background and grain.

However, if the solvent is fast, the dye doesn't have enough time to penetrate deeply in the substrate, so the resultant final surface's appearance is more homogeneous, with fewer enhancements between background and grain.

- **Dye application systems**

The existing dye application systems could be classified in this way:

- Wiping or brushing
- Spray gun. (Aerographic gun)
- Mechanized spray gun
- Electrostatic spray gun
- Roller
- Immersion

- *Wiping or brushing*

Is not very used, generally is used with water based dyes, or very slow hidroalcohols. The dye is applied abundantly using wiping or brushing, trying to distribute it following the grain's direction. Then, the remaining dye is eliminated using a clean and dye rag, before the dye is absolutely dried.

Using this method is quite secure about equality and uniformity, because it allows the extending of the dye in an easy way and the operator can work easily.

- *Spray gun*

By a bomb or by gravity, the material is impelled and the dye is pulverized. Generally fast or intermediate solvent as well as hidroalcoholic are used, but is possible using it with water too..

By controlling the air pressure, the spray gun's overture as well as the number of layers is possible to obtain a good colour uniformity, keeping in mind the basic idea of dyeing that is applying always the same dye quantity in order to obtain always the same result, as long as the substrate is homogeneous and analogous.

This way is so important to determinate all the parameters for the applications methods. This parameters are: material pressure, number of dye layers per each wood sample, application speed per each dye layer, pulverization pressure, spray gun overture...



Controlling these parameters is very possible to obtain a colour homogeneity and equality.

- *Mechanized spray guns*

The same case as the normal spray gun but removing the human factor. Basically is used on varnishing robots. Using this method is much more easy because is possible to fix all the parameters mentioned above.

- *Electrostatic spray gun*

The main idea behind this technique is that the electromagnetic fields are enveloping.

An electromagnetic field is generated in front of the piece to be coloured and the dyed envelops practically all the piece uniformly. This method is very used in chair sector.

Organic solvent dyes are used, since the big resistance in the work area (because of the wood) doesn't allow using water because of its big conductivity.

- *Roller*

It's used basically in flat furniture. The machine is composed by a Roller system placed in parallel. These Rollers has direct contact with the sample to be coloured, so they deposit a determinate dye quantity over the sample. Dyes with a very slow evaporation speed are used, being solvent or water based solvents, because otherwise, the fast solvents could evaporate too quickly and the dye could get too concentrate.

In this case, the parameters to be controlled, in order to obtain good colour uniformity and equality, are:

- Application speed, being less the quantity when bigger is the pass velocity.
- Roller hardness, being bigger the quantity when the Rollers are softer.
- Colour concentration.

- *Immersion*

The idea behind this technique is to fill a deposit with the dye to be used and introduce the pieces inside during the necessary time to obtain the desired penetration of the colour.

It's used basically for small pieces. This method is used very little because for big pieces, a big quantity of dye and big recipients are necessary.

If the dye is based on organic solvent big evaporations are produced with the logical colour concentration. If the dye is water based are stability problems, because in a short time a putrefaction process starts.

System specification

As we mentioned above, there are a lot of variables that could affect directly on the final visual aspect of a dyed wood. But of course, not all of them have the same importance and the same presence in the wood sector.

Keeping in mind the project has a limited time period and the goal is to build a practical and functional solution, was decided to limit the number of variables are going to have in consideration when specifying the system.



The goal of this limitation is to optimize the investigation time and concentrate on the most common and practice cases, leaving it for the future, the most special and difficult cases that could slow the project's progress.

The specification is divided in three parts:

- a) The first part is about the dyeing process. Since the solution will be based on an expert system we need to realize real dying cases. So, in this document how this process is going to be done is described. It includes all the things related to the dying process: colorants, substrates, solvents....
- b) The second part is about the hardware to be used. Since the formulation system will work with the data obtained from an image, is really important to obtain good images from the wood samples.
- c) The third part is about the software. Briefly the main aspects about the software are explained.

a) Dyeing process

This are the things related to the dyeing process:

- *Substrate*

The substrate is the wood piece is going to be dyed. These properties are going to be taken in consideration:

Visual aspect:

Within all the properties on the substrate's visual aspect, we decide to used the followings:

- Average colour
- Average grain colour
- Average background colour
- Homogeneity.

Absorption

Due to the complexity to know the exact absorption of each wood sample individually, just the wood type is being used, assuming the real absorption will be reasonable similar in each wood type..

Size

In order to analyze correctly the average colour, grain colour, background colour and the problems related to the metamerism, the size per each wood sample have to be at least 20x20cm.

Wood Types

Because of their extended use in the sector of wood and furniture, we decide using 3 types of wood:

- European oak (veneer)
- Not vaporized beech (veneer)

- Polish pine (massive)

Sample preparation

Each sample will be sanded with this particle size sands:

- Oak → 150 / 180
- Beech → 120 / 150
- Pine → 180 / 220



- *Solvents*

Even nowadays organic solvents and water are used to dilute the colorant to compound the dyes, due to ecological and legal reasons, during the next years we will see a big increase on the use of water and a big decrease in the use of solvent in the dyeing industry. Since we hope that the result of the project will be used during the future and not just during the next few years, the water will be the first solvent we will use to prepare the dyes in order to populate the database.

In case the project is going properly and we have enough time before the project will be finished, a second database will be prepared this time using colorants based on organic solvents. In this way we will be able to cover both water and organic solvent based colorants.

- *Colorants*

As mentioned above, colorants based on water will be used. They will be 5 basic colorants from Basf Basantol family:

- Basantol Yellow 215
- Basantol Brown 269
- Basantol Red 311
- Basantol Black X82
- Basantool Orange 273

The possible values per each colorant will be the following:

Red, Orange and Yellow:

- Percentages: 0, 0.25, 0.50, 1.00, 2.50, 5.00

Black and Brown:

- Percentages: 0, 0.25, 0.50, 1.00

The colorant combination proportion will be never more than 5% of the dye. The rest of the dye will be water and a 1% of blinder.

All the basic colorant combinations are going to be done following the same criteria as the sector follows, avoiding non-sense combinations in order to optimise the future expert system.

If a second database is prepared for colorants based on organic solvent as mentioned above, 5 colorants from Ciba Irgasperse are going to be used, since Basf Basantol are just for water-based solvents.

- *Application method.*

Because of its extended use in the market, flexibility and not so long cleaning time, a spray gun will be used to dye all the wood samples.

The spray gun will apply 60 gr/m² of dye per each sample. The spray overture, pressure and the rest of parameters will be adjusted in order to obtain this dye quantity per m².

- *Process*

The dyeing process will be the following:

- Select the wood sample to be dyed. It has to be 20x20 and it has to be sanded as mentioned above.
- The sample's image will be captured by the system in order to store its descriptors in the data base, before it is dyed.
- The sample will be dyed using the spray gun applying 60 gr/m². The information of the recipe will be introduced in the database.
- After the sample is dry, a varnish will be applied. The varnish has to be a semi mate varnish with a gloss of 60°.



- After the varnish is dry, the sample's image will be captured again by the system in order to store it's descriptors in the data base, after all the process is finished.

These steps will be done per each wood sample.

Each time the dye is going to be changed, the spray gun will be cleaned in order to obtain a clean original colour, without any corruption in the colour.

Every day the gun will be checked in order to secure it is applying the same dye quantity and to ensure any of it's parameters (air pressure, overture etc) is properly fixed.

b) System's hardware and software initial specification

These points will be deeply explained in the WP3 and WP7 according to the deliverables of the project plan, but here we will do the initial introduction.

- *Hardware*

The system will be composed by 3 hardware components: Camera, Lighting system, Computer.

- *Camera*

Since there is not possible using an spectrophotometer to measure wood piece's colour, because the piece to be analyzed is a non-uniform surface, we will use a camera to measure the colour, having in consideration all the piece's surface, not just some little areas as the spectrophotometer does. So, the camera has to take a good enough image to analyze the colour. Good enough means:

- c) Good resolution to have as many detail as possible
- d) Enough bits per colour channel to capture the colour in detail. A 10 bits per channel camera will be used, in this way we will be able to obtain 1024 values per each colour channel, more than 100 million colours in total.
 - 3 CCD. When capturing the colour, a 3 CCD system works better than 1 CCD system, because each CCD is specialized on taking its own colour, obtaining more accurate detail than having just one general CCD per all three colours.

A more detailed study and specification will be done on work package 2.

- *Illumination system*

The illumination system have to give a constant and as uniform as possible light over all the sampled to be analyzed. Is possible to obtain a quite good illumination using lighting cabinets, but is impossible to obtain a perfect image. This is way the software will have to solve some illumination problems correcting the taken image (Flat field correction).

About the metamerism, is necessary to use at least two different illuminants. We decided using D65 and TL84. We have chosen D65 because is one of the most used and standard illuminants. It is so used because this illuminant represents the daylight. The other one, TL84, is representing a fluorescence light, very common in the indoor spaces.

Using these two illuminants is possible to study and measure the metamerism.

A more detailed specification will be done on work package 2.



- *Computer*

We will know the specific needs for the computer when the software will be developed, but anyway, it has to be an standard computer, running a Windows operative system able to connect the camera and the rest of the devices.

c) Software

The software will do all the “hard” work. It will take the image obtained by the camera, correct it to obtain a good enough image and analyze it. After this the user will be able to compare different pieces between them, and to formulate dye recipes to obtain the desired color.

1. Goals

The software will have a triple goal.

- Quantify visual aspects on non-uniform surfaces such as wood surfaces. This information will be used in the comparisons.
- To do comparisons between two wood samples, in order to prepare the information for the formulation
- Automatic colorant formulation method for furniture industry. Matching with visual perception, together with algorithms that based on the data of a knowledge-base will propose a colorant formula for achieving a target colour when it is applied over a wood sample.

2. General points

User interface

The user interface has to be user friendly and as simple as possible. It will represent graphically the required data. But of course, this data will be accessible in text mode too.

Information showing way

The application will show the information by text, in a numerical way but it has to show this information in a graphical way too, in order to do it more intuitive and easy to understand.

Language

Since it's a project thinking in European, the application will be able to show all the information and interfaces on different languages as English, Germany, Spanish, etc.

3. Task by task

At this point the input and output data is going to be used will be briefly defined per each software's task:

Quantification

Input data:

- wood sample's image

Output data:

- a numerical value per each image descriptor

Comparison

Input data:

- Pattern's descriptors obtained during the quantification.
- Sample's descriptors obtained during the quantification.

Output data:

- The differences per each descriptor

Formulation

Input data: Input data:

- Pattern's descriptors obtained during the quantification.



- Sample's descriptors obtained during the quantification.
- Output data:
- A collection of possible colour recipes with the possibility to order them by the best option to obtain the less difference on each descriptor. For example if the recipes are ordered by average colour, applying the first recipe the best average colour should be obtained.
 - Per each recipe, the proportion per each component in the dye (each colorant and solvent)
 - Per each recipe, the distance in all the descriptor should be obtained if the recipe were applied in the sample.

WP 2: DEVELOPMENT OF THE IMAGE ACQUISITION SYSTEM. DESIGN AND CONSTRUCTION OF THE PROTOTYPES AND DEVELOPMENT OF THE IMAGE ACQUISITION SOFTWARE

Two prototypes will be designed and constructed on this workpackage. It will be divided in the next tasks:

1. Specification of requirements. Analysis of different possible designs of camera-illumination-structure systems and their advantages and weaknesses. Three possible systems could be:
 - ❖ Linear colour camera, high intensity fluorescent lamps or linear optical fiber lamp, conveyor belt
 - ❖ Area scan colour camera, fluorescent diffuse backlight lamps
 - ❖ High colour quality scanner
2. Search of components for each system's subsystems. Gathering of specifications, prices and documentation.

SPECIFICATIONS AND DESIGN OF THE PROTOTYPES

❖ HARDWARE

In this section the basic properties are discussed for the critical hardware components of the imaging system. The critical hardware components are considered to be the camera (including lens arrangement) and viewing cabinet (including the illumination).

Camera: A digital camera will be used to capture colour images of the wood samples. The three most important aspects of the digital camera system are (i) the bit-depth of the channels, (ii) the spatial resolution of the sensor array, and (iii) the channel spectral sensitivities.

Bit-Depth: Many cameras generate 24-bit RGB signals. That is, the values in each colour channel are represented by 8-bit numbers which give 256 value levels (0-255). However, for accurate colour representation this is generally not considered to be adequate. For applications that require accurate colour representation at least 10 bits per channel are required. This gives 1024 value levels per channel. It is recommended that a camera with 10 bits per channel bit-depth be used.



Spatial Resolution: The spatial resolution of the camera is defined by the number of pixels on the sensor array. Approximately 4 million pixels are required to give an image quality that is comparable to traditional photographic processes (35mm). However, for this project it is not clear that such a high resolution is necessary. However, at least mega-pixel resolution is likely to be required and therefore a camera resolution of 1000 x1000 pixels is required.

Channel Sensitivities: One of the most important aspects of the camera system is whether the channel spectral sensitivities are a linear transform of the CIE colour-matching functions. Cameras that satisfy this condition are said to satisfy the Luther condition. Such a camera is often said to be colorimetric and the implication of this is that it is possible to convert the linearized RGB values from the camera into CIE XYZ values using a linear transform that is specific to the camera and the camera settings¹. The reason that this is so important is that it implies a one-to-one correspondence between RGB and XYZ. However, most commercially available cameras suffer from device metamerism because they do not satisfy the Luther condition. Device metamerism would affect the accuracy of RGB→ XYZ transformations. Device metamerism implies that the camera would give the same RGB values for two surfaces with different XYZ values or that the camera would give different RGB values for two surfaces with the same XYZ values. This is clearly undesirable. It is our understanding that the spectral sensitivities of a 3CDD camera are more likely to be a linear transform of the colour-matching functions than those of an interlaced (e.g. Bayer-Mosaic) camera². It is therefore recommended that a 3CCD camera be specified. Indeed, such cameras are widely used in colour-critical medical applications but are quite expensive.

Miscellaneous: A camera with relatively buttons and switches would be advisable so that all settings can be controlled by the software. Of particular importance is the setting for white-point balancing. White-point balancing is a process whereby the camera RGB values are all set to be equal (e.g. R=G=B = 255 for an 8-bit per channel system) for a white or neutral sample. The camera needs to be able to allow white-point balancing to be performed once and then fixed thereafter; this ensures that the gains for the RGB channels remain fixed for imaging purposes. If white-point balancing occurs frequently, especially in an arbitrary fashion, it will make camera characterization difficult².

At the Project Kick-Off meeting it was agreed that samples of about 20cm by 20cm should be imaged. At imaging distances, determined by the viewing cabinet (see later), of about 50cm this requires a lens with a focal length of 8-16mm. Ideally the lens should be optimized to minimise chromatic aberration (to achieve this a lens matched for a 3CCD camera is recommended).

Viewing Cabinet: Perhaps the most critical component of the whole system is the ability to be able to provide illumination that is stable both spatially and temporally. For this reason (but also for reasons of cost), a conveyer belt system is not considered. Rather, the specification is for a viewing box into which the samples to be imaged can be placed and to which the camera will be fixed. The majority of viewing boxes allow a sample to be placed on the floor of the box with the illumination above. However, in our experience this arrangement makes it very difficult to achieve a spatially uniform distribution of light even if diffusing plates are employed. A more unusual configuration is to have the illumination at the bottom of the viewing box so that it reflects off the top of the box to provide illumination for the sample. Such a configuration has been developed by our research group and is being developed by a company called DigiEye³. Given the relatively short time available for this project and the ambitious targets we have decided to integrate the DigiEye viewing box into our system design.

Cabinet Design: The viewing box design can be seen in Figure 1. In this Figure the side-view of the cabinet is shown with two fluorescent tubes at the bottom. These tubes provide illumination via reflections off the sides and inside top of the cabinet. The top surface of the inside of the cabinet is curved and is engineered to provide spatially uniform illumination intensity to the sample area in the centre of the bottom surface of the cabinet. The front on the cabinet should be a hinged or sliding door which can be opened to allow the sample to be placed on the sample area but then closed to ensure that all four sides of the cabinet are identical. The inside surfaces of the cabinet should be painted a neutral grey colour so that the colour temperature of the illumination is not compromised. The top surface of the cabinet contains a hold in the centre through which the camera is placed.

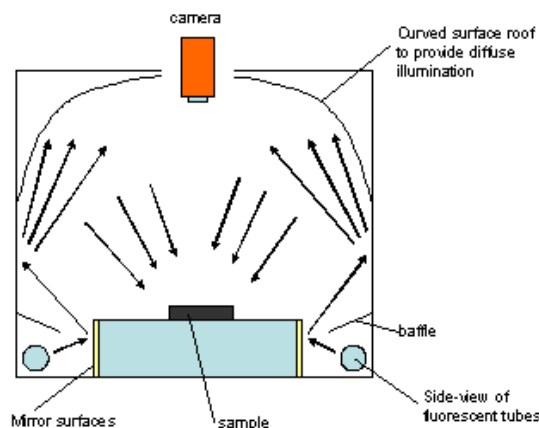


Figure 1: Schematic design for the viewing cabinet

- *Illumination*

The cabinet should have the facility for two different colours of illumination. Ideally, these should correspond closely to CIE illuminants D65 and A. It is likely that D65 will be the primary illuminant but the provision of a secondary illuminant (A) would enable greater flexibility.

❖ **SOFTWARE**

The image acquisition software must capture images but must also check illumination conditions and correct for any deviations where necessary.

Illumination Check: Although the viewing cabinet will be designed to provide stable and consistent illumination, one of the first steps in the initialization of the software must be to measure the intensity and chromaticity of the illumination. A good way to achieve this is capture an image of the cabinet floor (which is neutral grey) and to compute the average RGB values. A check is required to make sure that the mean RGB values are within the expected range for the system. Initially, it is proposed that this is a simple check; that is, no corrective action is taken. In principle, it would be possible to change the gains or the white-point of the camera to correct for any deviation in the illumination. However, if the system illumination is stable enough, no corrections will be required. (Note that changing the camera settings on an *ad hoc* basis should be avoided if at all possible.)

Spatial Uniformity Check/Correction: It is expected that the viewing cabinet will provide excellent spatial uniformity for the illumination. However, it would be prudent to make a correction for any deviation from homogeneity. Spatial correction can be performed according to a method previously used by Hardeberg⁴ and later by Sun and Fairchild⁵. This method requires that images be captured for a dark response (this can be achieved by grabbing an image with lens cap in place) and for a white surface that fills the imaging field. The average channel response for the white and black images can be denoted by R_W and R_B respectively and the channel response at each pixel i for the white and black images by R_{Wi} and R_{Bi} . To apply the correction to an image with channel response R_i at each pixel the following equation is applied,

$$R_{Ci} = (R_W - R_B)(R_i - R_{Bi}) / (R_{Wi} - R_{Bi}),$$

to obtain the corrected channel response R_{Ci} . However, when R_{Bi} is zero for all i , this equation reduces to

$$R_{Ci} = R_W R_i / R_{Wi},$$

which implies a simple ratio correction. This assumption is probably justified based on the fact that spatial corrections will be small given the quality of the viewing cabinet. This simplified correction can be carried out using the nominally spatially uniform grey background of the cabinet floor. However, prior to the correction the spatial variation should be checked that it is within some pre-set tolerances. If the system fails on either illumination level or spatial uniformity then no correction is made and the system is halted for adjustment.

Camera Characterization: Following checks on the level and uniformity of the illumination and the correction for minor spatial inhomogeneity, the next step is to convert the RGB values into CIE XYZ values. This is typically accomplished using data-driven linear or non-linear transforms^{1,4}. The Macbeth ColorChecker DC chart contains about 200 coloured samples that are appropriate for building the characterization transform. The Macbeth ColorChecker chart contains a much smaller number (24) of samples (see Figures 2).

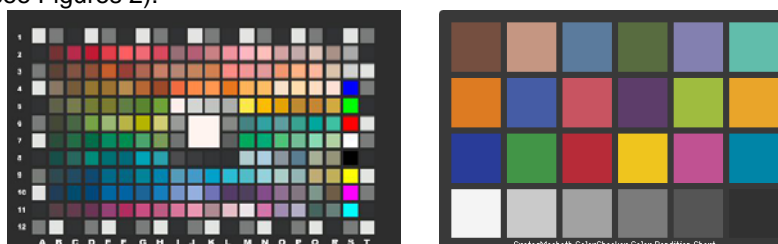


Figure 2: Macbeth ColorChecker DC (left) and ColorChecker (right) charts

It is proposed that the greater number of samples in the Macbeth ColorChecker DC would enable a more accurate transform to be built. This transform will be a one-off operation; that is, once the transform is developed it will be fixed. However, the ColorChecker chart can be used on a daily basis to ensure that consistent RGB values are obtained. Therefore, the RGB values will be obtained for the ColorChecker samples and stored by the software. On a daily basis – or more frequently if required – the RGB values for the ColorChecker samples will be imaged and compared with those that are stored. Given the quality of the light box and the checks and corrections for the illumination the captured RGB values should be very close to those that are stored. The system could report on the accuracy of these values or could perform a correction that would be applied to all subsequent images.

Programming Language/Environment: The MATLAB programming environment has been adopted for the development of the image acquisition prototype software. A decision can be made later as to whether it is necessary to convert the MATLAB code into something more portable. However, for the development of the prototype MATLAB provides maximum flexibility and speed which will allow a better exploration of ideas during the formative stages of the project.

❖ **Equipment Purchased**

○ **Camera System**

Jai CV-M9 CL 3CCD Progressive Scan RGB Colour Camera incorporating:

3 × 1/3" CCD arrays
1034 (h) × 779 (v) pixels for each CCD
30 frames per second with full resolution
24-bit RGB output via camera link base and 30-bit RGB output via medium configuration

Coreco Imaging X64 I Pro Frame Grabber incorporating:

dual independent base or single medium camera link interface
85 MHz input with 32MB local memory
64-bit OC164/PCIX bus
image transfer rates of 340MB/sec

COIM Sopera LT software:

suite of hardware-independent C and C++ software libraries for image acquisition
compatible with Microsoft Visual Studio C/C++, .Net, VB 6.0 and Borland C++ Builder
support for Windows XP, 2000 and NT platforms

○ **Viewing Cabinet**

DigiEye viewing cabinet as following:

dimensions – 70 cm (width) × 67 cm (depth) × 67 cm (height)
Illumination D65 (subsequent filters to be provided to add a source close to illuminant A)
size of area for sample – 26 cm × 46 cm
distance from lens to sample 40cm (approximately)
mechanical switch to allow diffuse or angular illumination



Figure 3: DigiEye viewing cabinet



IMAGE ACQUISITION SOFTWARE

❖ PROGRAMMING LANGUAGE/ENVIRONMENT

The MATLAB programming environment has been adopted for the development of the image acquisition prototype software. A decision can be made later as to whether it is necessary to convert the MATLAB code into something more portable. However, for the development of the prototype MATLAB provides maximum flexibility and speed which will allow a better exploration of ideas during the formative stages of the project.

Code has been written using the following version of MATLAB and related platform:

MATLAB Version 7.0.4.365 (R14) Service Pack 2

Operating System: Microsoft Windows XP Version 5.1 (Build 2600: Service Pack 1)

Java VM Version: Java 1.5.0 with Sun Microsystems Inc. Java HotSpot (TM) Client VM

The following toolboxes are installed:

| | | |
|---------------------------|---------------|----------|
| MATLAB | Version 7.0.4 | (R14SP2) |
| Curve Fitting Toolbox | Version 1.1.3 | (R14SP2) |
| Image Acquisition Toolbox | Version 1.8 | (R14SP2) |
| Image Processing Toolbox | Version 5.0.2 | (R14SP2) |
| Neural Network Toolbox | Version 4.0.5 | (R14SP2) |
| Optimization Toolbox | Version 3.0.2 | (R14SP2) |
| Signal Processing Toolbox | Version 6.3 | (R14SP2) |
| Statistics Toolbox | Version 5.0.2 | (R14SP2) |

In addition, a proprietary toolbox (companion software for Computational Colour Science using MATLAB available from <http://www.colourware.co.uk/compute/>) for colour is used¹.

❖ MODULES

This section details the most critical components of the software.

○ Image Capture and Representation

The camera and frame grabber selected (see report D2: Specifications and Design of the Prototype) allow image capture at a colour depth of 10 bits per channel. Images are captured and represented internally by the software at 30-bit colour resolution. However, for display purposes only, images will be down-sampled to 24-bit colour.

○ Calibration/Characterization Workflow

Figure 1 describes the calibration workflow for the software which consists of 7 stages:

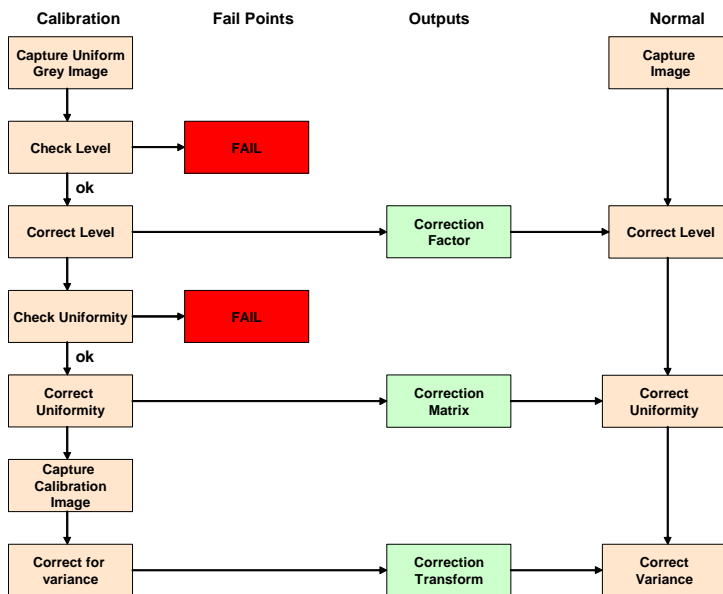


Figure 1: Schematic design of calibration workflow

- *Capture Uniform Grey Image*

The first stage in the calibration workflow is to capture a uniform grey image. The floor of the viewing cabinet is used for this purpose.

- *Check Level*

The average RGB values are computed for the grey image. If this average differs from the expected values by more than 5% a *system fail* message is sent and no further progress is allowed until the reason for the discrepancy is discovered and rectified.

- *Correct Level*

Assuming that the average intensity of the illumination is within 5% of the target intensity a correction factor is computed for each channel:

$$F_R = T_R/A_R$$

$$F_G = T_G/A_G$$

$$F_B = T_B/A_B$$

where F_i are the correction factors, T_i are the target intensities and A_i are the actual intensities ($i \in \{RGB\}$). Each pixel in the image (and in each image subsequently captured) is multiplied by these correction factors.

- *Check Uniformity*

After the image has been corrected for the intensity level the variation in spatial intensity is checked. The image is divided into four quarter sub-images and the mean RGB values of each quarter are compared to the mean values for the whole image. If any quarter deviates by more than 10% a system fail message is sent and no further progress is allowed until the reason for the discrepancy is discovered and rectified.

- *Correct Uniformity*

Assuming that the uniformity check is passed, a correction matrix is computed according to M/A_i , where M_i is the mean response for each channel i ($i \in \{RGB\}$) and A_i is the response for each pixel. This generates a uniformity correction matrix. Subsequently captured images are multiplied by the correction matrix.

- *Capture Calibration Image*

Following the computation of the correction factors and the uniformity correction matrix, the user is prompted for the Macbeth ColorChecker Image (Figure 2).



Figure 2: Macbeth ColorChecker chart

The software should provide visual confirmation that the chart is correctly positioned and then the average RGB values are computed for each of the 24 squares. A linear transform is computed to allow a correction transformation between the measured RGB values and the expected RGB values thus,

$$R' = aR + bG + cB + d$$

$$G' = eR + fG + gB + h$$

$$B' = jR + kG + mB + n.$$

- *Correct for Variance*

The correction transformation (section 3.2.6) is applied to all subsequent images.

- **Image Processing Workflow**

The processing of each image in normal operation requires five steps: capture, correct for intensity, correct for spatial variance, correct for variance from expected values, and characterization. The first four of these steps are illustrated on the right-hand side of Figure 1. The final step is to characterize the image. This requires that the RGB values be converted into XYZ values.

Given the nature of the camera (3CCD) a linear or nearly linear transformation $RGB \rightarrow XYZ$ will be used. The coefficients of this transformation are determined prior to use of the system based on measurements of the colour samples from the Macbeth ColorChecker DC chart (Figure 3).

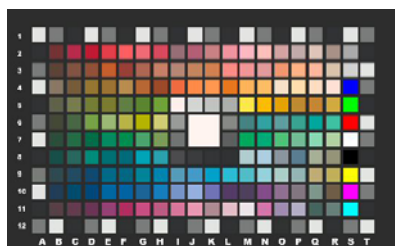


Figure 3: Macbeth ColorChecker DC chart

3. SYSTEM PARAMETER'S ADJUSTMENT

❖ HARDWARE

○ Camera

The 10-bit per channel camera system (Jai CV-M9 CL 3CCD Progressive Scan RGB camera) has proved adequate. The 3CCD camera that was incorporated has been found to have advantages and disadvantages. One of the disadvantages is the relatively small choice of lenses that can be used with the camera system (this is caused by the small distance between the optical arrangement of the camera and the lens attachment port). Another disadvantage is a lack of spatial uniformity, especially towards the corners of the imaging field where coloured shadows can sometimes be evident. However, the advantage of the 3CCD is a more appropriate set of filters so that an RGB→XYZ transform can be obtained with minimal device metamerism. The camera did, however, satisfy our condition of having few buttons that are accessible to the user. Indeed, the only physical button on the camera is one that allows white-point balancing.

At the Project Kick-Off meeting it was agreed that samples of about 20cm by 20cm should be imaged. At imaging distances, determined by the viewing cabinet (see later), of about 50cm this requires a lens with a focal length of 8-16mm. However, the 16mm lens that was initially used with the system was found to provide an insufficiently large imaging area and did not meet the 20cm by 20cm specification. Therefore, an 8mm lens has been sourced that is compatible with the camera and we are currently waiting for its delivery from the supplier.

○ Viewing Cabinet

It was mentioned in D2 that the most critical component of the whole system is the ability to be able to provide illumination that is stable both spatially and temporally. We were therefore fortunate to obtain a professionally designed and constructed cabinet from the company DigiEye. In principle, the design of this viewing cabinet could be replicated by a third-party constructor. However, the intention at the time was that DigiEye could become involved with the project and play an active role in the marketing and distribution of the final product. This would be desirable given that there is some overlap in the product that DigiEye product and that which will be output from this project. DigiEye have many years experience and an extensive customer base and it was our opinion tht they would be valuable business partners in the future.

The initial viewing cabinet was provided to us at a reduced cost because DigiEye were enthusiastic about the potential collaboration. Since the Leeds meeting, at which DigiEye were introduced to the consortium, the response of the consortium has been somewhat negative with regards the involvement of DigiEye. In the long term this is not a problem because if the prototype proves successful then a manufacturing process could be established to make similar viewing cabinets for Colormatch. However, in the short-term it might make the development of a 2nd prototype difficult because it will be difficult to



mimic the DigiEye box design in the laboratory. Work is underway, however, regarding the construction of the 2nd prototype.

One of the limitations of the DigiEye design, however, is that it is primarily a single-illuminant cabinet. Additional lighting tubes have been obtained at CIDEMCO to allow the use of a second illuminant. The arrangement is appropriate for laboratory use but is cumbersome and would be unsatisfactory for the commercial version.

❖ SOFTWARE

A major problem was encountered in the software development when it was discovered that the camera interface was incompatible with MATLAB. Originally it has been the intension to use MATALB for the whole development project. It allows rapid development and is particularly suited to the mathematical transformations that are required for the camera characterization and image analysis.

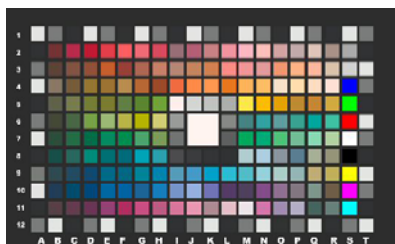


Figure 1: Macbeth ColorChecker

However, about six months into the project it became necessary to base the image capture and GUI on Visual Basic (v6.0). However, it has still been possible to use MATLAB for the numerical analysis and this has been possible through the use of the MATLAB product builder which is capable of providing functions in COM objects that can be called from Visual Basic. A small amount of time was lost because the GUI work that has been completed in MATLAB had to be translated to Visual Basic. However, in the long run the use of Visual Basic for the GUI will allow a more seamless progression from prototype to commercial product.

Some adjustment of the automatic image capture was carried out at CIDEMCO to allow the capture of the central patches of the ColorChecker (Figure 1).

Deviations: Major deviations on this work package were the use of Visual Basic instead of Matlab to program the User interface as a result of the camera specifications.



WP 3: Image analysis and colour coordinate transformation development. To develop the algorithms for image correction, the extraction of necessary descriptors and the transformation from camera's RGB coordinates to XYZ and Lab coordinates

This workpackage aims to develop all algorithms necessary to correct acquired images and extract from them the descriptors needed to describe their visual colour appearance, in units of the desired colour spaces. It will be divided in the next tasks:

1. Development of a base program to acquire images. It will be developed in a powerful language like Visual C++, and will be fully object oriented, constituting its base an image class in which all functions for image processing will be added, so that it will be easy to develop, modify and implement in every new program. This base program will be completed in successive tasks in order to allow the user to acquire an image, correct it, select a region, extract descriptors and save all them in a record of a database, which also will allow to use it in further tasks like knowledge-base completion or formulation algorithms development.
2. Measurement of the errors in the image capture, the lack of uniformity in time and space. Determination of the causes.
3. Design and construction of sample pieces for camera calibration and execution of possible modifications in order to reduce the errors.
4. Development of camera calibration and image correction software. The image must be corrected to remove the influence of the variability of the illumination in time, its lack of uniformity in space, and the different response of each camera channel, in a way that the descriptors that will be extracted from it will be the most accurate possible.
5. Measurement of the new errors with camera calibration and image correction.
6. Development of the algorithms necessary to extract all relevant descriptors considered in the first work package, like average colour, histograms or contrast descriptors.
7. Development of the colour coordinates transformations for transforming descriptors given in the camera's RGB coordinates to these other more interesting for the task, like XYZ and Lab.
8. Determination of the final errors in Lab E units.

IMAGE CORRECTION ALGORITHMS

❖ CONCEPTS

The digital camera that has been purchased for the project incorporates an in-built shading correction that attempts to ensure that the camera response at each pixel location is the same given that a spatially uniform surface is imaged. However, although this automatic shading correction is used, experience indicates that - for the purposes of accurate colour measurement - additional correction is normally required in order to ensure good performance.

The spatial uniformity of the illumination is extremely important and it is for this reason that a commercially constructed viewing booth – the DigiEye viewing box – was obtained. This viewing booth has been carefully designed so that the imaging area is uniformly illuminated. Despite the use of the camera's shading correction and the good quality of the viewing booth that housed the camera system, further spatial correction is still required.

As noted in D2, spatial correction can be performed according to a method previously used by Hardeberg¹ and later by Sun and Fairchild². This method requires that images be captured for a dark response (this can be achieved by grabbing an image with lens cap in place) and for a white surface that fills the imaging field. The average channel response for the white and black images can be denoted by R_W and R_B respectively and the channel response at each pixel i for the white and black images by R_{Wi} and R_{Bi} . To apply the correction to an image with channel response R_i at each pixel the following equation is applied,

$$R_{Ci} = (R_W - R_B)(R_i - R_{Bi}) / (R_{Wi} - R_{Bi}),$$

to obtain the corrected channel response R_{Ci} .

It was decided to relax the constraint of having to measure the dark response because it was felt that when the user attaches and removes the lens cap the focus of the lens could inadvertently be altered. Note that if we assume that R_{Bi} is zero for all i , this equation reduces to

$$R_{Ci} = R_W R_i / R_{Wi},$$

which implies a simple ratio correction. It was noted in D2 that this assumption is probably justified based on the fact that spatial corrections are expected to be small given the quality of the viewing cabinet. This simplified correction can be carried out using the nominally spatially uniform grey background of the cabinet floor.

The second important correction that needs to be implemented is that of linearity. It has been shown that for accurate $RGB \rightarrow XYZ$ transforms the camera RGB responses must be assumed to vary linearly with the light intensity³.

The raw channel responses for each surface-illuminant combination are assumed to be subject to a gamma-like input-output non-linearity that can be approximated by a power law. Thus, the camera output values R' , G' and B' are related to the raw camera outputs by a power law with exponent $1/\gamma$ thus,

$$R' = R^{1/\gamma}$$

$$G' = G^{1/\gamma}$$

$$B' = B^{1/\gamma}$$

Different techniques to estimate the non-linearity of the channels have been investigated^{4,5}. These techniques include methods based upon the luminance factor and mean reflectance of a set of achromatic samples and methods based upon a knowledge (or estimation) of the spectral sensitivities of the channels. For the case where the luminance factor or mean reflectance of the samples was used, the value of γ is estimated using linear algebra to perform a least-squares fit. These methods are referred to as Luminance and Reflectance methods respectively. It is also possible to use the CIE X , Y and Z values of the achromatic samples to fit the R , G and B values respectively and this approach has been adopted in this project.

It is important to note that linearization is carried out before spatial correction. The linearization can be conveniently performed using the central grey patches of the Macbeth ColorChecker DC (Figure 1). Ideally, since linearization is performed before spatial correction each of the grey squares should be imaged separately so that it is in the centre of the imaging space. However, this is not practical. It was decided that it is sufficient to ensure that the grey squares are imaged somewhere close to the centre. This can be accomplished in a single imaging shot because of the design of the ColorChecker DC (see Figure 1).

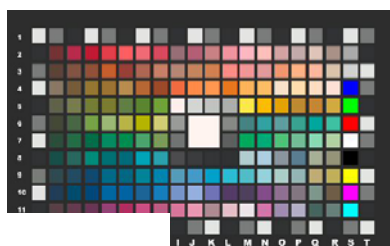


Figure 1: Macbeth ColorChecker DC



❖ **ALGORITHMS**

The RGB data is obtained from the camera system in 12-bit-per-channel representation and will be referred to as raw image data. The first stage in the calibration procedure is to grab a raw image of the cabinet base (which is assumed to be a spatially uniform grey). The raw image data of the grey base is used to determine a set of correction factors that can be applied to any future image. The second stage of the calibration procedure is to capture an image of the ColorChecker DC chart. Of course, the raw data from this image must be linearized before they can be analysed. However, the spatial correction factors will be computed from the linearized image of the grey samples from the ColorChecker DC chart.

Once the linearization and spatial correction procedures have been completed it is possible to use the system for real image capture. The right-hand process in Figure 2 illustrates that the raw data from every captured image will be linearized and spatially corrected (in this order) before any further processing or display.

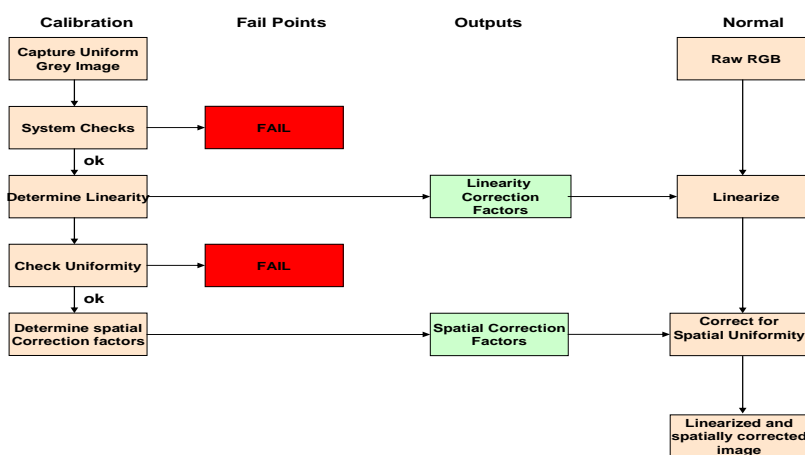


Figure 2: Image Correction Algorithm

DESCRIPTORS EXTRACTION ALGORITHMS

❖ **INTRODUCTION**

As mentioned in the system specification report, four descriptors will be used to characterize the wood samples:

- Average colour
- Average background colour
- Average grain colour
- Uniformity



❖ **ALGORITHMS**

In the following algorithms, the input always will be an image. Normally an image is formed by a matrix of pixels. Each pixel has three components: red, green and blue. This is the colour space known as RGB. Since RGB is device dependant is not very used in the colorimetric area. This is why, all the images are going to be used with this algorithm will have the L*a*b* format. "RGB to XYZ and Lab transformation algorithms" document (D7) explains how it is done.

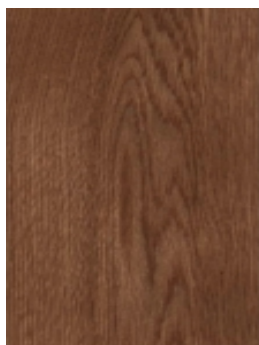
○ **Average colour**

In order to measure the average colour we just calculate the average value of each component in the image.

Input: An image (pixel matrix) in L*a*b* colour space. Output: the average colour represented by a L*a*b* value.

Steps:

- Add up the L* value of each pixel in the image and divide the result by the number of pixels to obtain the average L*.
- Add up the a* value of each pixel in the image and divide the result by the number of pixels to obtain the average a*.
- Add up the b* value of each pixel in the image and divide the result by the number of pixels to obtain the average b*.



L*:10

a*:-5

b*:45

Input

Output (example)

○ **Average background colour**

In order to obtain the average background colour, we first have to know what is background and what is grain. So, we have to find a threshold, and then use it to segment the image's pixels in two regions: background and grain. Once this is done, we can calculate the average value per each region.

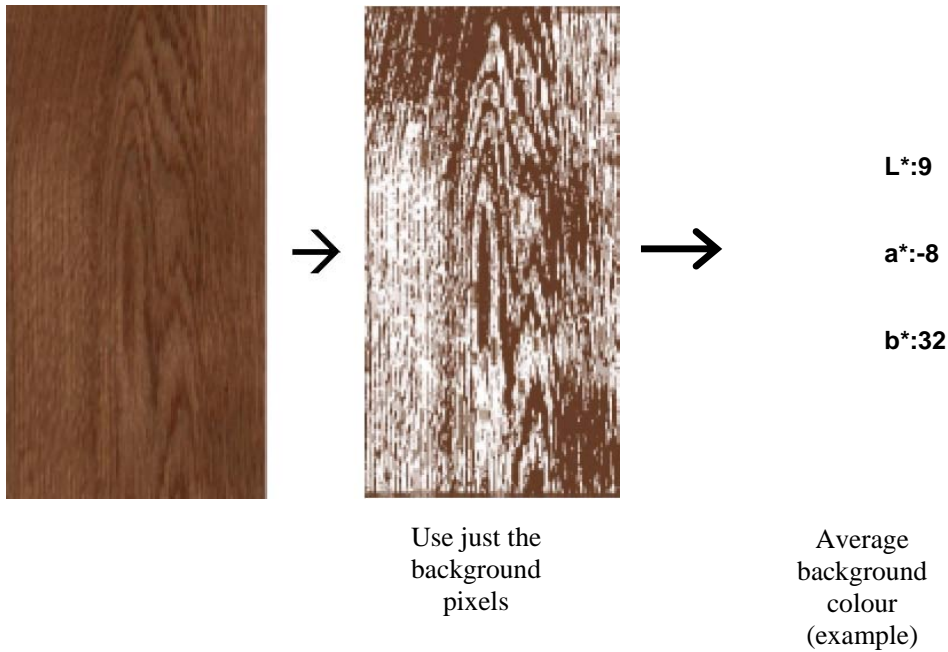
Input: An image (pixel matrix) in L*a*b* colour space.

Output: average background colour represented by a L*a*b* coordinate.

Steps:

- Use the average colour algorithm to obtain the average colour value.
- Take the average colour's L* value as a threshold
- Per each pixel, check its L* value

- If the L^* value is smaller than the threshold, this pixel is background.
- Obtain again the average colour but this time using just the pixels classified as background.

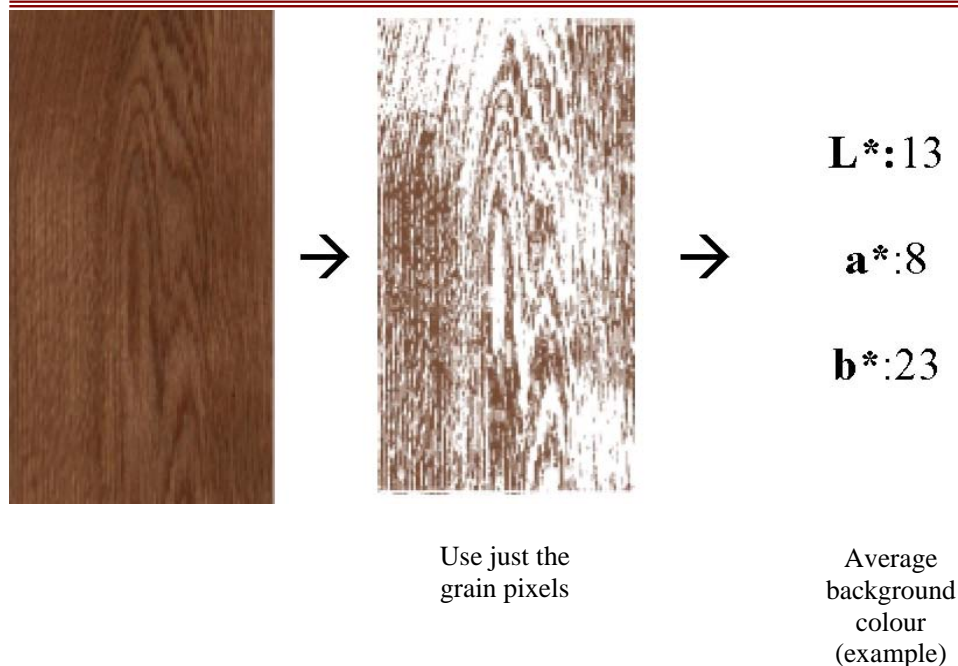


o **Average grain colour**

In a similar way, we calculate the average colour for the grain.

Steps:

- Use the average colour algorithm to obtain the average colour value.
- Take the average colour's L^* value as a threshold
- Per each pixel, check its L^* value
- If the L^* value is bigger than the threshold, this pixel is grain.
- Obtain the again average colour but this time using just the pixels classified as grain.



o **Uniformity**

In order to measure the uniformity, a statistical formula will be applied to each component, L*, a*, b*. This statistical formula is the standard deviation:

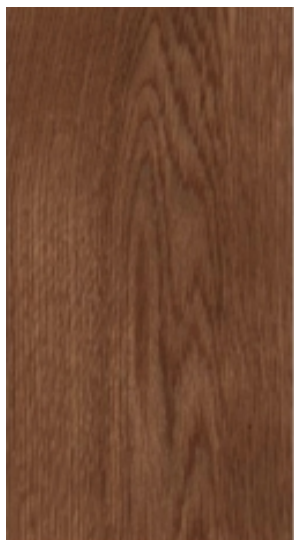
$$s = \left(\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2 \right)^{\frac{1}{2}}$$

Steps:

- Measure the average value of the component (x) considering all the image.
- Take the values per each pixel (xi) and obtain the difference between it and the average value (xi - x)
- Power it in order to obtain just positive values (xi - x)²
- Normalize the values (1/n)
- Apply a square root to all done before to obtain the value we are looking for, s.

Input: An image (pixel matrix) in L*a*b* colour space.

Output: a numerical value per each component representing the standard deviation, in our case, the uniformity. Since we are working with colour, and even the most important value here will be the luminosity (L*), we will obtain the value for the a* and b* too.



sL*: 5

sa*: 3

sb*: 8

Output
(example)

RGB TO XYZ AND LAB TRANSFORMATION ALGORITHMS

The image correction algorithms are discussed at three levels: concepts, algorithms, and implementation.

❖ **RGB→XYZ**

If a linear relationship exists between the camera's channel outputs and the tristimulus values then it is possible to determine the transform to XYZ from as few as three known samples. Thus, if we represent the *n* known XYZ values by the 3 × *n* matrix T and the *n* recorded RGB values by the 3 × *n* matrix C, then

$$T = AC$$

where A is the 3 × 3 system matrix. If three suitable samples are available then the linear system is exactly determined¹. Further samples could be used, to over-determine the system, but are only strictly necessary if a linear transform does not exist between the two colour spaces. In this situation, it is usually preferable to use a non-linear transform. Various non-linear transforms can be used such as

$$\begin{aligned} X &= a_{11}R + a_{12}G + a_{13}B + a_{14}R^2 + a_{15}G^2 + a_{16}B^2 + a_{17}RGB + a_{18} \\ Y &= a_{21}R + a_{22}G + a_{23}B + a_{24}R^2 + a_{25}G^2 + a_{26}B^2 + a_{27}RGB + a_{28} \\ Z &= a_{31}R + a_{32}G + a_{33}B + a_{34}R^2 + a_{35}G^2 + a_{36}B^2 + a_{37}RGB + a_{38} \end{aligned}$$

where, in this case, a total of 24 coefficients need to be determined. In matrix notation we can write

$$T = AD$$

where the system matrix A is now a 3 × 8 matrix of the coefficients *a*₁₁ – *a*₃₈. The matrix D is the 8 × *n* column matrix of augmented device responses (in this case given by the terms *R*, *G*, *B*, *R*², *G*², *B*², *RGB*, and 1).



The system matrix is determined by computing the pseudoinverse of the augmented matrix thus

$$A = D^+T$$

As an alternative to linear or non-linear transforms of this type it is also possible to use a neural network to perform a mapping from C to T. However, it has been shown that neural networks offer no advantage over polynomial transforms for camera characterization² and yet can be difficult and time-consuming to train.

Experience has shown that a second-order transform is sufficient and it was decided that this could be characterized using 44 samples from the central area of the ColorChecker DC chart. The function *colourchar()* was written in MATLAB to perform the characterization. The 44 by 3 array is constructed from the mean RGB values from 44 samples from a linearized and spatially corrected image of the chart. The chart should be positioned so that sample N9 is in the upper-most left part of the central field. In order to populate the 44 by 3 array, move from left to right and then from top to bottom. There are only 44 patches because the middle four patches (consisting of one large white patch) are not used.

❖ XYZ→LAB

The formulae for computing CIELAB coordinates are standardised and provided in many textbooks¹. The formulae are reproduced below:

$$\begin{aligned} L^* &= 116(Y/Y_n)^{1/3} - 16 && \text{if } Y/Y_n > 0.008856 \\ L^* &= 903.3(Y/Y_n) && \text{if } Y/Y_n \leq 0.008856 \\ a^* &= 500[f(X/X_n) - f(Y/Y_n)] \\ b^* &= 200[f(Y/Y_n) - f(Z/Z_n)] \end{aligned}$$

where

$$\begin{aligned} f(l) &= (l)^{1/3} && \text{if } l > 0.008856 \\ f(l) &= 7.787(l) + 16/116 && \text{if } l \leq 0.008856 \end{aligned}$$

and where X_n , Y_n and Z_n are the tristimulus values of a specified white object colour. For surface colours the values of X_n , Y_n and Z_n are usually computed for the perfect reflecting diffuser and are therefore equivalent to the illuminant itself. Since white surfaces tend to look chromatically neutral under an illumination to which the visual system is adapted the values of X_n , Y_n and Z_n are sometimes referred to as the neutral point. The axes L^* , a^* and b^* form a rectangular or Cartesian coordinate space where L^* represents Lightness, a^* represents redness-greenness, and b^* represents yellowness-blueness. Sometimes it is useful to represent colour stimuli in a cylindrical space and for these purposes it is possible to compute the polar coordinates C^*_{ab} and h_{ab} as shown below,

$$\begin{aligned} C^*_{ab} &= (a^{*2} + b^{*2})^{1/2} \\ h_{ab} &= \tan^{-1}(b^*/a^*)(180/\pi), \end{aligned}$$

where the term $180/\pi$ is necessary to convert the output of the inverse tan function from radians to degrees. The polar coordinates are useful since the differences in the chroma term C^*_{ab} can be correlated with differences in perceived colourfulness and differences in the hue term h_{ab} can be correlated with differences in perceived hue.



WP 4: KNOWLEDGE-BASE PREPARATION

The aim of this workpackage, is to complete the knowledge-base and determine the absorption and diffusion curves of the colorants

This work-package covers the next tasks:

1. Firstly, feed the system with a sufficiently wide variety of samples with different colorant mixtures to make a database with the data, external factors and descriptors of the initial and final samples, together with the data of the applied colorant mixture.
2. The absorption and diffusion curves depending of the concentration of each colorant will be determined for each camera channel, in order to analyse the possibility of formulation by classical Kubelka-Munk theory.

* In theory, deliverable 9 should be done in this workpackage, but why the Kubelka-Mink method is not appropriate method for this project will be explained here.

Kubelka-Munk theory:

Light incident upon a surface can be reflected, transmitted, or absorbed by a film of material covering a surface. The modification of light depends drastically on the properties of the film. On the other hand, it can be a way for characterization of the materials included in the film. Different materials absorb or scatter the light differently. It can be assumed that each coloured material has a characteristic behaviour in scattering or absorption of the light. Of course, the properties of the binder affect these parameters. But in seeking simplicity, it is assumed that the absorption or scattering are due only to the colored materials.

There are some theories for calculating the optical properties of the material; absorption and scattering coefficients. The simplest and practical method was defined by Kubelka and Munk (1931). Kubelka and Munk assumed that the light diffusely strikes a surface and is considered to be scattered in only two directions, down and up. Therefore, the reflected light from the surface of the material depend on the thickness of the film, scattering and absorption coefficients of the colored materials, and the reflectance of the background upon which the film lies.

This method is the core of basically all recipe prediction applications because it could solve the opposite problem: that is, to find the recipe to obtain the desired spectral reflectance, and so the desired colour.

In summary, the Kubelka-Munk is used to predict the recipe of colorants in order to obtain the desired color using the absorption and scattering properties of the colorants.

There are two main problems that are impossible or quite difficult for the application of this method for our project.

In our case, we can't apply the stains over white and black backgrounds. So we have a problem of how to get two independent measurements. One solution could be to apply each stain at two concentration levels and then to make the two reflectance measurements. We can then solve for K and S, in principle.

But the serious problem, however, is that we don't have access to reflectance data at all since we are using an RGB-camera based system

← - - - - Con formato: Numeración y viñetas



WP 5 : COLOUR DIFFERENCES QUANTIFICATION

This task aims to develop the core of the project: the formulation algorithm. Three main ways will be analysed in order to find the best method

1. As the knowledge-base is being completed, that data will be used to quantify colour differences and acceptable tolerances. Different formulae will be analysed in order to find the best way to establish differences and tolerances, like Lab, LCh, CMC, BFD or CIE 94.
2. The importance, effects and magnitude of metamerism will be also analysed to get a final formula of colour differences and the value of acceptable tolerances.

For the assessment of the precision of the results of the colour formulation it is necessary to know which colour difference a normal human eye can see and which differences are acceptable. With this knowledge it is possible to assess which effect the colour difference between the measured original colour of a dyed surface (reference) and the expected colour as result of a colour formulation and reached colour on the finished surface can have. Colour differences can be expected in every case but it is important to know if they will be normally accepted. Former investigations are only known for uniform surfaces but not for non-uniform dyed wood surfaces. Three aspects were to be taken into consideration in the investigations in the framework of a proband test:

- The effect of metamerism (different perceptible colour at different light sources such as diffuse light in end user facilities and markets for furniture).

The effect that well experienced evaluators see a colour difference much better than the "normal" end user.

- There are different mathematical models for the colour distance and it is not clear which of it is the best for dyed wood surfaces.

Materials for the investigations

For the investigations 12 pairs of dyed samples were used. The samples with the dimension 300 mm x 200 mm per colour were dyed and lacquered with a water-based 1K- System at 3H. The following colours were used on three different wood species (beech):

6 different brown colour tones (Code B1 – B6)

6 different light brown colour tones (Code HB 1 – HB6)

6 different grey colour tones (Code G1 – G6)

6 red colour tones (Code R1 – R 6)

Methods

1. Proband test

At the IHD, 39 probands (6 of them well experienced, the rest are end users) took part in the proband test. Every proband has had to make a visual assessment of every pair of samples with two different light sources (D65 and TL 84 light) with a viewing distance of approximately 50 cm.

Every pair of samples had to be assessed with every light source by the probands with a grade according to EN ISO 3668. According to this standard for the visual assessment of colours the followings should be used:

- no perceptible difference
- small, just perceptible difference
- small, but clearly perceptible difference
- moderate difference
- considerable difference
 - very big difference



Furthermore, the question “is this colour difference acceptable for you (yes/no)? had to answered. Every proband has had to fill in his own formulary. The results of the 39 probands were analysed statistically as well as in respect of the experience with colour assessment. For both parameters (grade of colour difference and acceptance value [%]) mean value were calculated.

2. Colour measurements

Three types of colour measurements were used at IHD, 3H and Cidemco.

IHD: The colour measurements at the dyed samples were carried out with a spectral photometer from Minolta with the following parameters:

Spot diameter: 30 mm
Geometry: 10°
Gloss: included
Light sources: D65 and TL84
Number of measurements: 10 per sample
Used colour system: CIELab
Calculation: Mean value per sample, DL, Da, Db and DE between mean values

3H Measurement parameters:

Spot diameter: 16 mm
Geometry: 0/45°
Gloss: included
Light: D65
Instrument: X-Rite XR 964
No of measurements: 10 per sample
Calculation: Mean value per sample,
DL, Da, Db and DE between mean values

CIDEMCO Measurement parameters:

Test device: Prototype of developed chamber/camera system
Light: D65
Calculation: DL, Da, Db and DE, DE 2000 CMC 2:1, CMC 1.1 between mean values



WP 6: DEVELOPMENT OF THE RULES

This task aims to develop the core of the project: the **formulation algorithm**. Three main ways will be analysed in order to find the best method:

- Approximation theory: multivariate scattered data interpolation and fitting
- Neural networks: multilayer backpropagation
- Classical Kubelka-Munk theory and global minimisation

In this workpackage the development of a method for dye recipe prediction using the polynomial fitting technique will be presented.

The main objective of this part of the project is to develop a series of polynomials that describe the colour variation effect that takes place when a dye solution is applied to a piece of wood. Once available, these polynomials will provide the dye solution percentages for a given pair of natural and dyed woods.

So, the method is used in two steps:

1. Obtain the approximation polynomial. This polynomial will represent the colour relations between the dyes and the wood. This process will be done once.
2. Use the polynomial to predict the recipe. This will be done each time a recipe has to be predicted.

In order to obtain the polynomial, it is necessary to obtain information about the colour relations from real cases. With that purpose, the database developed in the previous task was used.

For colour-matching a mathematical model is required that can relate recipe (or dye concentrations) to colour (e.g. spectral reflectance, XYZ, L*a*b* etc). It is normal practice for the model to predict colour from recipe. The reason for this is that the recipe colour mapping is an often a one many mapping and this makes it difficult to model. The recipe colour mapping is a many one mapping and can therefore be modelled by traditional formulae. Traditionally, the Kubelka-Munk (K-M) model has been used for this mapping. The K-M model is able to predict spectral reflectance from a recipe vector. In order to make such predictions it is necessary to estimate various K-M parameters for each colorant and this is done using measurements of spectral reflectance for a number of samples of known recipe.

However, in the Colormatch project we do not have access to reflectance data. The camera system measures RGB values which are converted to CIE XYZ and CIELAB values but at an early stage in the project it was decided that spectral estimation (recovery) – although theoretically possible – would not be pursued. Since the measurements from the camera do not include spectral data the K-M model has not been investigated. Because of this reason, the deliverable 15 has been annulated.

An alternative to the K-M model is the use of neural networks for the recipe colour mapping. There is some evidence that Artificial Neural Networks (ANNs) can be effective in this field. ANNs have been extensively explored in this study for application to colour prediction. The first part of this report provides a very brief description of ANNs and the key issues regarding their application in this project. The second part of the report describes the experimental work that has been carried out and it demonstrates the performance attained. The third part of the work deals with the so-called inverse problem. In practice, we require a recipe to be predicted given a target colour and yet our ANN performs the recipe colour mapping. It is therefore necessary to solve the inverse mapping. The inverse problem has been extensively studied for many decades.

Finally, which of the two developed methods (polynomial fitting and artificial neural networks) is going to be used to formulate the colour recipes will be determinate. Also, the included improvements to the selected method will be included.



After both methods have been implemented and tested, there is not a clear advantage using one or other method: in some cases one method works better than the other one and vice versa.

As mentioned above, both methods are implemented so it was decided to introduce both in the final application in order to give to the user the opportunity to use one or other method. Depending on the particular cases of each user and his / her needs, one or other method could work better.

WP 7: DEVELOPMENT OF THE PROGRAM

This work-package covers the next tasks:

1. A final program will be developed basing in the algorithms developed in previous tasks. The user interface will be developed in a way that will be intuitive and easy to use and understand, providing graphical information of all significant data.
2. Different graphical ways of showing data will be analysed in order to find the best way to show these data like Lab coordinates, solvent and colorants concentrations, colour differences and tolerances limits, which constitutes important clues when formulating.
3. The program will work over Windows, developed in a powerful programming language like Visual C++, and its velocity will be optimised in order to minimise the formulation time.

The software applications have two main objectives:

- To be able to measure the colour (and so, colour differences) in non-uniform surfaces
- To give the proper dye recipe to obtain the desired colour

So, the information will be divided in the same way into groups: colour information and the dye recipe information



WP 8: FINAL TESTS, VALIDATIONS AND SPECIFICATIONS

The main objectives of this workpackage are the following: System testing, validations, gathering of specifications and analysis of the extension of the field.

This work-package covers the next tasks:

1. Final system will be tested with new measurements, as it would be industrially, and all aspects that should be covered by the program will be evaluated, analysing time, benefits and accuracy of the new formulation system. If any change of improvement is need it will be carried out.
2. Once the whole system is validated, all specifications needed to construct it industrially will be documented.
3. Finally, the possibility of extension of the field to other colorants and solvents, other printing process like spray gun, or other industrial processes will be analysed.

Progress: Next, it is described the completed work corresponding to this work-package.

Once the system was developed, several tests were designed in order to check the system work. On one hand the system's colour measurement has been tested under both D65 and TL84 light sources. In these tests, both the stability of the measurements have been studied. On the other hand, the dye formulation has also been tested. In these tests, the accuracy of the predicted recipes has been studied, as well as the real colour differences obtained when applying these estimated dye recipes.

The process followed for testing the system is describes here, as well as the results obtained. First, the colour measurement module's performance is presented, and after that the performance of the dye prediction module is analysed. the In each case, a description of the tests that have been done is presented, and, after that, the results obtained for those tests are shown.

1. Colour measurement stability test:

The stability of a colour measurement is the extent to which two measurements of the same sample will produce the same colour value. It is a very important factor, as it gives an idea of how reliable the system colour measurements are. It also limits the smallest colour difference that will be measurable by the system. For example, if the measurements have an uncertainty of 0.4 in DE2000, when the system measures a colour difference of the same or less value, it cannot be said if they are different samples or the same that has been measured twice.

The process of measuring the mean colour of a sample consists on the following steps:

- Taking an image of that sample.
- Delimiting the area of the image that will be analysed.
- Measuring the mean RGB values of the chosen area.
- Transforming the obtained RGB value into the corresponding CIE Lab colour value.

There are some inherent errors in the process. First, when the image is taken, both the camera and the light source add some noise to the image. This noise affects the colour values of each pixel in the image, adding a degree of uncertainty to the measurements Its importance will depend on the quality of the system components, although it is impossible to remove it completely. Apart from the system noise, other factors affect the colour measurements, such as the ambient temperature, the light source warming-up, and so on. Thus, when the same sample is measured twice, the RGB values of each pixel will be different.



Once the image is taken, if the area of the image to be analysed is chosen manually, it is fairly impossible to choose the same area twice. Therefore, even taking two measurements of the same image will produce slightly different results.

The rest of the process (measurement of the RGB values, and the transformation into Lab colour space) also introduces some error due to rounding factors, but this will always be the same and will not affect on the stability of the measurements.

2. Dye prediction test:

The objective of this test is to check the functioning of the dye formulation module. For this purpose, the next steps are given:

- Defining the set of recipes that will be tried.
- Applying the recipes: target colour values.
- With these values, obtaining the dye recipes predicted by the system.
- Applying the predicted recipes: predicted colour values.
- Measuring the differences between the target and the predicted colour values.

The dye recipes used for the test have been carefully chosen to test the system in different range of data (low / medium / high values). Recipes corresponding to single, double and triple colorant dyes have been chosen, in order to try all the possibilities. The selected set is presented in the next table.

The two prototypes developed during this project, are very useful devices. They cover all the needs of the project and have been key components for the development of the algorithms. But in order to become it a commercial system, some improvements and changes should be done. There are some technical changes but the main changes are basically for making the system more user-friendly. In the next sections, the proposed changes are covered.

The possible extensions of field for the prototype and the different algorithms develop during the last two years will be explained in this workpackage. Even if the device was designed having in mind just wood, the system could be used in some other fields too.

The system has two well differenced blocks and the will be seen separately:

1. - Colour measurement in non-uniform surfaces
2. - Colour recipe prediction



WP 9: MARKETING STUDY

This task aims to analyse the market of the product, and all aspects that should be considered for marketing. A final marketing planning also will be done.

This report constitutes deliverable D22- Marketing study.

As was mentioned in other documents, the colour, and specially the colour matching between different samples is a very important issue in many sectors, including the wood sector. The process to achieve the desired colour takes a lot of time and effort to the companies. And, in a more exigent market, quality parameters like colour are more and more important.

The goal of the project was to facilitate the obtaining of this desired colours in a fast and easy way. This goal has been achieved, but only partially.

As it is possible to see in the document "D19 – System test and validation", the results show that the methods used in this project seem promising. But they are still not good enough. Summarising, in the best of the cases (using in all cases Artificial Neural Networks) the obtained median value of the colour differences (in Delta E 2000) is 3,07.

As mentioned in the deliverable D12 "Final colour difference formula an acceptable tolerance's value", the acceptance tolerance is around 1'5 Delta E. Taking into consideration that usually companies are more strict than end users, a value at least as good as 1,5 should be obtained after applying the recipe predicted by the system. In some cases this result and even better are obtained, but as mentioned above, the median value is around 3 so, by the moment the system is not accurate enough.

Taking all these aspects into consideration, it has been decided that the system is not mature enough to be marketed yet, and therefore it is not prepared for a marketing plan.

WP 10: MANAGEMENT, EXPLOITATION AND DISSEMINATION

The main objectives of this workpackage are the following ones:

- To establish a co-operation agreement amongst the partners
- Preparation of technical and committee meetings
- To establish a plan for the exploitation of the project results
- To disseminate the publishable results

Within the scope of this task all activities to control and supervise the project are planned and executed in co-operation with the project partners. A project management plan, which shows all project tasks in detail and helps to realise a continuing project and results securing with the help of milestones, will serve as the base for the activities.

The management of this project will fall back on, the prime proposer, who will design the following entities:



- Steering committee: It is in charge of taking all the strategic decisions of the project. The chairman of the steering committee will be from the leader organisation and will be composed by a member of each partner in the consortium.
- The Project Manager. will be in charge of the overall and day-to-day co-ordination of the project. His tasks include planning of activities, progress reports, meetings, reporting, cost statements overviews, etc. He will be the main interface between the Commission and the consortium.
- The Project Co-ordinator: is the responsible of all operational and technical decisions to be made for the correct development of the whole project. He belongs to the leader organisation.
- The Exploitation coordinator: is the responsible of all the operational and technical decisions to be made for the correct development of the project. He belongs to the leader organisation
- Workpackage responsible: He will be responsible for the detailed technical management of each Workpackage.

Periodical meetings (five, including kick-off meeting) called by the project co-ordinator have been developed, following the workplan schedule, where the follow up of the project has been presented. Dissemination will be performed by all partners and mainly co-ordinated and organised by both RTDs. The co-ordinator and the rest of the consortium companies have been prepared all the necessary meetings and reports. The co-ordinator has been in charge of assuring that the development of the project is as scheduled.

It is anticipated that patents will be required to protect new knowledge on the "Colormatch" system.

2.1.4. PROJECT REFERENCES

The work carried out in the project COLORMATCH has been gathered in a website created for this project, in which we can find all the information and the reports derivate from it.

www.cidemco.es/colormatch/index.htm

3. FINAL PLAN FOR USING AND DISSEMINATION THE KNOWLEDGE

2.1. EXPLOITABLE KNOWLEDGE AND ITS USE

In this section, the exploitable results from the project will be explained, that is to say, the knowledge having a potential for industrial or commercial application in research activities of for developing, creating or marketing a product or process or for creating or providing a service.

The exploitable results have been obtained from the inputs of each partner of the present project, as the table below shows:



| Exploitable knowledge | Exploitable product (s) or me | Sector(s) of appl | Timetable for comm | Owner&Other partner(s) |
|---|---------------------------------------|-------------------|--------------------|------------------------|
| Final program of the colorant formulation for f non-uniform surfaces | Colormatch complete system | Furniture sector | 2007 | METROTEC |
| Algorithm of the colorant formulation for furnit non-uniform surfaces | Colorant formulation system | | 2007 | METROTEC |
| Final colour difference formula and acceptabl values | Colour difference quantification | | 2006 | METROTEC |
| Development of the formulation algorithm for surfaces by polynomial | Colorant formulation system by theory | | 2007 | METROTEC |
| Development of the formulation algorithm for surfaces by neural networks | Colorant formulation system by theory | | 2007 | METROTEC |
| Development of the formulation algorithm for surfaces by approximation theory | Colorant formulation system by theory | | 2007 | METROTEC |
| Final program of the colorant formulation for f non-uniform surfaces | Colormatch complete system | | 2007 | METROTEC |
| Algorithm of the colorant formulation for furnit uniform surfaces | Colorant formulation system | | 2007 | METROTEC |

2.2. DISSEMINATION OF KNOWLEDGE

In this point, the plan for using and disseminating the knowledge acquired in this project is explained. It will provide a complete picture of all activities undertaken and most importantly will provide information about the future route to full use:

| Planned/actual dates | Types | Type of audience | Countries addressed | Size of audience | Partner responsible/ involved |
|-------------------------------|----------------|----------------------------|-------------------------|------------------|-------------------------------|
| European Coating Fair (Nur) | Fair | Coating and paint industry | Europe | | CIDEMCO |
| Congress of furniture (Herfo) | Congress | Furniture industry | Germany | | |
| Maderalia (Valencia, Spain, | Fair | Wood industry | Spain, Portugal, France | | CIDEMCO |
| Barnizado+encolado | Article | Coating industry | Spain | 2000 | CIDEMCO |
| Barnizado+encolado | Advertisemen | Wood and furniture industr | Spain | 2000 | CIDEMCO |
| ZOW (February 07) | Fair | Wood and furniture industr | Spain | | CIDEMCO |
| InfoCidemco | Article | Wood and construction ind | Spain | 1400 | CIDEMCO |
| October 07 | Web site links | Anybody | All world | | CIDEMCO |



Next, a short description about some of the activities explained before is shown:

- **EUROPEAN COATING FAIR (Nuremberg, 8-10 May 2007)**

The European Coatings Show gives you the essentials: new perspectives and views— seeing and recognizing chances and opportunities. Hardly any place is more suitable for this than the world's leading exhibition for the coatings and paint industry.

From 8–10 May 2007, over 700 exhibitors from around 40 countries present the complete survey of new and innovative products and services for the production of high-quality and competitive coatings, paints, sealants, construction chemicals and adhesives. The EUROPEAN COATINGS SHOW with its combination of exhibition and congress is a dynamic driving force, reliable trendsetter and top get-together for dialogue and information exchange at a high level. Use this extensive range of international contacts for your company's success.

- **FIMMA-MADERALIA 07:**

FIMMA&MADERALIA are more than just trade fairs: they offer solutions to the professionals of the wood and furniture industries. Preparations for their 33rd edition are already underway and will take place in Valencia from 7 to 10 November, 2007.

Year after year, thousands of companies, and professionals place their trust in FIMMA (The International Fair of Woodworking Machinery) and MADERALIA (The International Supplier Fair for the Furniture and Wood Industries).

More than 90% of those who visit this fair have confirmed that they will return in 2007.

The representativeness of what this fair offers exceeds 85% of that which exists throughout the sector: those who truly import and the companies that set the standard are there. Likewise, more than 93 % of the professionals from the sector have visited FIMMA-MADERALIA during its last two events in 2003 and 2005. The visitor profile at this fair comprises the whole professional scale within the segments of carpentry and joinery, furniture manufacturing and the building trade.

- **ZOW (Madrid, June 2006)**

The organisers of ZOW Spain 2006 will present the third edition of the Innovation Observatory with a panel of renowned professionals from the world of design, interior design, architecture and the furniture industry, who will be asked to evaluate the most state of the art proposals for 2006, based on creativity, utility and product quality criteria: The ten proposals with the highest score will be exhibited in exhibition modules located in the trade fair boulevards. These will bear the corresponding company logo, a description of the product and an indication of the stand it belongs to.

The aim of the Innovation Observatory is to facilitate the work of professional visitors and people from the media who wish to see the latest innovations that have come onto the market.



4. FINAL MANAGEMENT REPORT

The partners OMAR, WESSENDORF, 3H and CAMILA MOVILES have not send the Form C (Model of Financial Statement per Activity) corresponding to the second period of the project for this report submission date, so this information will be send as soon as it is available by e-mail to the project officer.

5. FINAL SCIENCE AND SOCIETY RESPORING QUESTIONNAIRE

One questionnaire has been completed on order to monitor how Science and Society has been embedded in the COLORMACTH project.

It has been complimented on-line by the project co-ordinator (INDUSTRIAS QUIMICAS IRURENA). It comprises some questions about the following items:

- Ethics
- Gender
- Science education, training and career development
- Engaging with actors beyond the research community
- Use and dissemination
- Total communication spend

6. FINAL SOCIO-ECONOMIC REPORTING QUESTIONNAIRE

This questionnaire has been completed by each contractor on-line in order to get data on the integration if the socio-economic (and foresight) aspects of the research in the project.