Cross-Media Colour Management via the Internet

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Abstract: In recent year, the need of high performance computer is being increased and with the development of these high performance computers and communication networks, people can send their information to others or can obtain information from others via Internet or other kinds of information networks. Among these information, image data play an important role and take great part of the information. However, due to device dependency and dissimilar environment, people can't assure whether the image they get from network has the same colour as the original one or not. The goal of this research was to develop a general methodology for colour management of pictorial images across media via the Internet. The following works had been accomplished:

- Definition of a reference colour space, CIELAB for accurate colour rendition.
- Derivation of device characterisation models for a monitor, a scanner, and a printer.
- Development of an image-dependent gamut-mapping strategy. This strategy employs image reproduction principles based on the input image data present. The strategy utilizes contrast-boosting lightness rescaling, followed by chroma-scaling procedures.

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- Application of tone- or gamut-expansion using the concepts of the tone- and gamut-compression procedures. Tone/gamut expansion was approached as the inverse problem of tone/gamut compression. The tone/gamut-expansion functions were generated by inverting the gamut-compression functions.
- Implementation of a client/server application prototype of a cross-media colour management model on the Internet using Java Servlet technology.

1. Introduction

The use of colour in imaging continues to grow at an ever-increasing pace. However, with recently maturing technologies for high performance computer-based imaging multimedia and the Internet, it exhibits a powerful synergy with the potential to provide a whole range of new applications and tools for the users of colour images. Multimedia and Internet technologies not only offer enhancements to one another, but their combination suggests entirely new communication paradigms. However, every day, most people in the industrialised parts of the world are users of colour images that come from a wide range of imaging devices; for example colour photographs, magazines, and television at home, computers with colour displays, and colour printers in the office.

In this research, we have developed novel algorithms for the colourimetric characterisation of monitors, scanners and printers providing efficient and colourimetrically accurate means of conversion between a device-independent colour space such as CIELAB, and the device-dependent colour spaces of a monitor, a scanner and a printer. Furthermore, we have developed a prototype of colour-management communication network. It allows colour-imaging researchers to directly access a powerful work environment for colour rendering experiments on various input and output devices and then make improvements of their research works on colour management system. Additionally researchers from different organisations, without frequent meeting, can have on-line collaboration to carry out the joint endeavour. While researchers have the ability to support themselves, common or even advanced users can also make use of the cooperative contributions from researchers to reproduce their coloured images optimally across a wide range of imaging devices.

2. Literature Reviews

To a significant degree, multimedia applications derive their effectiveness from the use of colour graphics, images, and video. However, the requirements for accurate or optimal colour reproduction and for the preservation of this information across a wide range imaging devices that have very different characteristics and may be geographically apart are often not clearly understand. This section describes the basic of colour science, colour management, characterisation of colour input and output devices that help in defining and meeting their requirements.

2.1 Colour Difference Formulae

Three advanced colour difference formulae, CMC(l: c) formula, CIE94 formula and BFD(l: c) are designed for uniform colour patches also. However it is important to be aware of the development of models for the calculation of colour differences between complex images with spatial characteristics, which corresponds to the spatial sensitivity of the human visual system to the given channels. S-CIELAB model is one of advanced models designed for complex images (Zhang and Wandell, 1996). Still it is needed to significantly improve its prediction performance of the results of psychophysical experiments before it can be recommended as a reliable colour difference formula used in practice.

2.2 Device Characterisation

Each mathematical model should include two forms: a forward and a reverse. The forward process predicts the colourimetric values (e.g. CIE L*a*b*/XYZ values) from a set of primaries of the medium considered. The reverse process obtains the primaries data from a set of colourimetric values.

2.2.1 Colourimetric Characterisation of Monitor Devices

Generally, the characterization of a monitor (e.g. using PLCC model) consists of two stages. The first stage is a linear or nonlinear transformation correlating normalized DAC (Digital-Analog Converter) values to luminance Y. The second stage is a multiple linear transformation to transform between the device-dependent monitor values and the device-independent CIE tristimulus values.

2.2.2 Colourimetric Characterisation of Scanners and Cameras Device

Colourimetrically, two different approaches are typically applied to characterise image acquisition devices such as scanners and CCD cameras. These are spectral and analytical models. A *spectral* characterisation technique estimates the function representing the transformation performed by the scanner, from object spectral reflectance to scanner RGB values, that is, the spectral model of the scanner. Eventually, this information can be used to obtain device-independent colour information by defining an "optimal" function (Ives, 1915).

2.2.3 *Colourimetric Characterisation of Printer Device*

The characterisation of a colour output device such as a digital colour printer defines the relationship between the device colour space and a device-independent colour space, typically based on CIE colourimetry. In practical use for colour reproduction, what we typically need is to transform images colourimetrically defined in a given colour space into the colour space specific to the printer. Therefore both these groups of printer models described above have to be inverted. The solution to this inverse problem is difficult to find. Often it is needed to use iterated optimisation algorithms to determine the device colour coordinates which reproduce a given colour defined in a device-independent colour space (Mahy and Delabastita, 1996).

2.3 Gamut Mapping Techniques

On the process of digital colour reproduction, a key feature is the use of gamut mapping techniques to adjust the dissimilar colour gamut between two devices. The colour gamut of a device such as a monitor is defined as the range of colours that can be reproduced with this device. Several researchers have addressed this gamut mapping issue (Stone *et al.*, 1988, Gentile *et al.*, 1990, Stone and Wallace, 1991; Hoshino and Berns, 1993, Luo and Morovic, 1996; Morovic and Luo, 1997; 1998).

3. Colour Reproduction System and Device Characterisation

The colour reproduction system chosen for derivation of device characterisation models comprised of a CRT monitor and a scanner, a printer, which will be described in this section.

3.1 Monitor Device Characterisation

A Barco Monitor was characterized. The measurement equipment used was a PR650 spectrocolourimeter, manufactured by Photo Research. Three white points were tested under both the average (bright room) and the dim (darkened room) surrounds in this study: D_{50}, D_{65} and D_{93}. The Barco monitor was internally set close to each colour temperature considered. The correlated colour temperatures (CCTs), luminance, and colourimetric values used in both surrounds tested are given in Table 3.1.

Various models for characterizing HDTV monitors were derived, and compared the predictions' performance using single stimuli. The results clearly show that the PLCC model gave the monitor considered satisfactory performance if applied under dim surround, but not under average surround due to a lack of gun independence and phosphor chromaticity-constancy. This implies that the effectuation in predictability of the PLCC model depends on the monitor considered having a gun independence and phosphor chromaticity-constancy. However, the characterizing precision for monitors considered, in default of gun independence and phosphor chromaticity-constancy, can be greatly improved by applying appropriate polynomial models using regression methods (e.g. 3rd_SVD). More clearly speaking, the PLCC and 3rd_SVD models can be implemented and used under the dim and the average surrounds respectively. These well-performing models, therefore, was effectively applied in the implementation of a colour management system (CMS) in a later work, an integrated Work Package applied on Internet as mentioned earlier. Particularly, the 3rd_SVD model was also used to characterising a scanner and a printer used in this integrated Work Package of colour management system.

Table 3.1 The correlated colour temperatures, luminance, and colourimetric values used in both the average and the dim surrounds.

White Point	CCT	Luminance (cd/m^2)	X	Y	X	Y	Z
Average Surround							
D_{50}	5031	67.58	0.3450	0.3601	95.81	100.00	81.93
D_{65}	6440	70.23	0.3132	0.3331	93.03	100.00	106.15
D_{93}	8737	70.92	0.2865	0.3033	94.46	100.00	135.21
Dim Surround							
D_{50}	4941	59.42	0.3487	0.3617	96.40	100.00	80.09
D_{65}	6324	59.87	0.3161	0.3349	94.40	100.00	104.19
D_{93}	9143	59.57	0.2841	0.3003	94.61	100.00	138.39

3.2 Sub-Division Approach

Besides global approach established using all data set to characterize devices concerned, an image segmentation approach was also applied in this study. This technique was used to reduce the dimensionality of the problem by subdividing the colour gamut into smaller groupings. The image colour distribution were categorised into nine groups. These included four lightness (chromatic-colours), four near-neutral-colours (one low-lightness with low-chroma, one high-lightness with low-chroma, and two low-chroma divisions), and one chromatic-colours divisions according to the corresponding lightness and chroma attributes. This scheme allows for observation of the changes of the image segmented colours during the reproduction or transformation process.

A series of subsets (lightness/near-neutrals divisions) from the superset of colour target were individually characterised and a mathematical transformation were established for each subset of lightness/chroma-leaf division to correlate between device primaries (i.e. the device-dependent coordinates, e.g. RGB) and the colourimetric description (i.e. device independent coordinates, e.g. CIE L*a*b*).

Table 3.2 The segmented lightness/chroma divisions by using the lightness/chroma-leaf division method (CIELAB colour space)

Lightness/Chroma division	Lightness/Chroma Range (Used in Model Derivation)	Lightness/Chroma Range (Used in Model Application)
L1	0~50	0~25
L2	0~75	25~50
L3	25~100	50~75
L4	50~100	75~100
C<=50	0~100/0~50	0~100/0~25
C<=30&L<=50	0~50/0~50	0~50/0~25
C<=30&L>=50	50~100/0~50	50~100/0~25

3.3 Scanner Device Characterisation

The scanner characterisation in this study was based on a polynomial regression technique, which was also used in the characterisation of monitor device as mentioned earlier. An IT8.7/2 colour chart containing a set of colour samples and a grayscale of achromatic patches with known CIELAB values was scanned. A picture processing routine segmented each colour sample and then the mean values of its RGB scanner components were calculated. For each colour sample on the test chart, it had both the relevant RGB values (obtained from the scanner tested) and the corresponding known (theoretical) values in CIELAB space. The L*a*b* values had been calculated from the reflectance spectra of the patches measured by the GretagMacbeth Spectrolino (spectrophotometer), also used in later printer characterization. (Also Nominal values provided by the colour chart manufacturer could also be used, if we were confident in the quality of the colour chart used and in the data provided by the manufacturer.)

3.4 Printer Device Characterisation

In the printer characterization, prints were produced on Acer Foto Prisa300P Professional PhotoPrint employing Acer Foto Prisa300P printer. This test target consists of 9×9×9 matrix colour patches which represent all combinations of RGB primaries varying in 9 values equally spaced over the range of 0 to 255. Based on perceptually equal step-to-step differences, the cube data set was rendered using 9×9×9 matrix. The measurement equipment/conditions are the same as one used in the characterisation of scanner.

3.5 Results of Device Characterisation

The described colourimetric characterisation algorithms (global and sub-division approaches using 3rd_SVD) have successfully been applied to three different imaging devices, a monitor, a scanners and a printer. Some of these results for the forward process (RGB to Lab) are reported in Table 3.5. To be able to evaluate and compare the different approaches, four colourimetric measures, ΔE CIE94 were used to represent the results. These measures were calculated between the measured and predicted XYZ values (transformed from L*a*b*). The followed measures are provided:

$\overline{\Delta E}$ which is the mean ΔE CIE94 colour difference between the calculated and theoretical XYZ (transformed from CIELAB-values) in each grouped data set concerned.

ΔE _max1, ΔE _max2, ΔE _max3, which represent the three maximum ΔE CIE94 colour differences between the calculated and theoretical XYZ (transformed from CIELAB-values) in each grouped data set concerned.
ΔE >6, which are the number of samples those ΔE CIE94, calculated between the predicted and theoretical XYZ (transformed from CIELAB-values) in each grouped data set concerned, are larger than 6.0.
All (average), which is mean ΔE CIE94 colour difference between the calculated and theoretical XYZ (transformed from CIELAB-values) combined from all divisions for the complete colour chart tested.

Table 3.3 Results of characterization methods for devices of (a) monitor, (b) scanner, and (c) printer.

(a) Monitor

Monitor D50	Division	CIE94				
		$\overline{\Delta E}$	ΔE>6	ΔE_{Max1}	ΔE_{Max2}	ΔE_{Max3}
RGB2Lab	Global (No Division)	0.620	0	3.535	2.268	2.233
	C<=25	1.303	0	3.664	3.150	3.092
	C<=50	0.492	0	2.211	2.125	1.880
	C<=30&L<=50	0.570	0	1.843	1.766	1.616
	C<=30&L>=50	0.464	0	1.078	1.011	0.966
	L1 (00-050)	0.719	0	3.681	3.567	3.278
	L2 (00-075)	0.821	0	4.036	3.960	3.947
	L3 (25-100)	0.595	0	3.494	2.210	2.160
	L4 (50-100)	0.647	0	3.681	2.310	2.095
	All (average)	0.655				

Apparently, the 3rd_SVD model, combined with sub-division approach, performed effectively in the characterization of three imaging devices concerned. Those CIE94 $\overline{\Delta E}$ values are all less than 2.0 (except $\overline{\Delta E}$ = 2.750 in the division of C<=25 for printer characterisation). Also the maximum values for three devices are also practically in the acceptable range.

Table 3.3 Results of characterization methods for devices of (a) monitor, (b) scanner, and (c) printer. (continue)

(b) Scanner

Scanner D50	Division	CIE94				
		$\overline{\Delta E}$	$\Delta E > 6$	ΔE_{Max1}	ΔE_{Max2}	ΔE_{Max3}
RGB2Lab	Global (No Division)	1.585	0	5.371	5.251	5.214
	C<=25	1.597	0	5.995	5.176	4.805
	C<=50	1.598	0	5.375	5.259	5.234
	C<=30&L<=50	0.916	0	5.047	3.610	3.550
	C<=30&L>=50	0.985	0	5.707	2.848	2.816
	L1 (00-050)	0.882	1	6.810	4.427	4.352
	L2 (00-075)	0.881	1	8.736	4.666	4.605
	L3 (25-100)	1.337	0	4.186	4.144	3.462
	L4 (50-100)	0.943	0	5.683	3.081	2.982
	All (average)	1.123				

(c) Printer

Printer D50	Division	CIE94				
		$\overline{\Delta E}$	$\Delta E > 6$	ΔE_{Max1}	ΔE_{Max2}	ΔE_{Max3}
RGB2Lab	Global (No Division)	1.813	0	5.947	5.364	5.072
	C<=25	2.750	1	6.375	5.834	5.623
	C<=50	1.943	0	5.790	5.391	5.047
	C<=30&L<=50	1.888	0	6.324	4.467	4.352
	C<=30&L>=50	1.172	0	4.942	3.536	2.709
	L1 (00-050)	1.658	0	5.257	5.002	4.814
	L2 (00-075)	1.804	0	5.895	5.083	5.069
	L3 (25-100)	1.726	0	5.769	5.031	5.024
	L4 (50-100)	1.822	0	5.535	4.656	4.452
	All (average)	1.791				

3.6 Cross-Media Colour Reproduction and Tone/Gamut Compression/Expansion

Colour gamut mapping algorithms were also used in this study to map the colours recorded with a source device optimally into the gamut of the destination device. Both constant-luminance clipping and chord clipping were derived, and could be applied by selection from the menu designed on the Internet.

Also as shown in Figure 3.1, in each device of image rendering process, a sigmoidal-compression function (tone compression) was applied for the calculation of images presumably that came from a lightness range of [0, 100]. The inverse-sigmoidal function, obtained by inversing the sigmoidal-contrast model, would sequentially used for remapping the perceived lightness contrast in images. Also, the full source dynamic lightness range of [0, 100] was used to rescale the image lightness by using a sigmoidal-lightness expansion function (tone/expansion) before images were transformed into destination gamut.

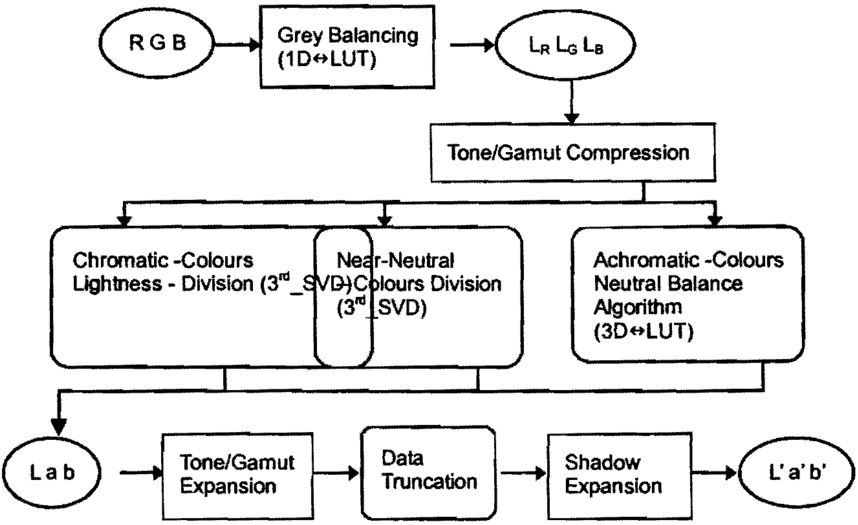

Figure 3.1 Flow chart used for the device characterisation combined with gamut compression/expansion approaches implemented in a prototype of colour-management communication network.

4. Software Implementation

This section discusses the software implementation of the colour management model on the Internet. With the popularity of the Internet, it is of increasing interest to place colour-processing services publicly on the Internet so that more people can share the profiles of their experiments. The first section in this chapter describes the solution to the available problems through the traditional communication means, and also the technologies the solution employs.

4.1 Overview

The colour management group has built up a web-site to publish the related documentations such as ICC profile specifications. While this kind of web-sites greatly help the academia and industry alike with enough information about the latest development of the technology, many researchers and developers are still doing their work independently. As an largely empirical field, colour science has great amount of materials to be shared. This section introduces a solution that facilitates resource sharing and ultimately builds up an efficient and economical environment.

With such an environment, remote users around the world can convert their coloured image files through a browser programme like IE or Netscape. Researchers can download or upload their device characterization data, and produce device profiles for colour space transformation. Device profiles as well as primitive measurement data are stored centrally on the server to be shared by the users and employed by the rendering service module.

The system is designed following an object-oriented approach. Object-oriented design is a method that sees everything in the real world as an object. And an object is depicted by an identity, a list of attributes and behaviours. The identity is usually a name of the object, the attributes describe the state and various properties of the object, and the behaviours refer to the operations that will happen to the object. Objects that share a common set of attributes and operations are said to belong to the same class. Classes are used to model a set of concepts or entities with common characterizations [UML in Nutshell, p.140].

4.2 Analysis

This section covers the requirement analysis of the whole system. The first part of it is the user analysis in which potential users are categorized into different groups that require different services. The second part lists the possible scenarios of application of the system. And finally objects are derived in compliance with the object-oriented design methodology.

4.2.1 User analysis

There are basically three groups of users who will be likely to enjoy the services. The groups are described in the following table.

Table 4.1 User analysis

1. Casual Users	This group includes Internet users who casually visits the web site for information and others who occasionally require to transform a coloured image to be reproduced on a certain output device. The image rendering functionality for this group of users is quite limited, and the transformation is carried out only based on profiles existed for the designated device.
2. Advanced Users	Advanced users require more complex manipulation of the image rendering process. In other words, the user is allowed to fine-tune the settings, or parameters that affect the style and quality of the transformation. The user will decide to use grayscale check for a particular image and possibly set a chroma value as a threshold to identify a colour boundary.
3. Researchers	The biggest advantage of the system may be the ability to collect device profiles from various manufacturers. And it is the researchers responsibility to make the measurements and characterization for the device. This is the so-called Study Model on the web page. Through this interface, the research people can view, download, edit and upload the primitive and calculated data including lookup table and coefficients. A training programme is also available for the researchers to test their data, and the result is immediately available on the same web page.

4.2.2 Scenarios

Scenarios are occasions the users will try to operate with the system. Each group of the users requires a different interface, and there are at least three scenarios as presented in the table below.

Table 4.2 Scenarios

Simple image rendering	The user first selects one of the available profiles for the source device that produced the image, and one of the profiles for the destination device to which the image is to be reproduced, and then gives a JPEG image file, which will be automatically uploaded onto the server for processing. After transformation, the picture will be transferred back to the user in another window.

Complex image rendering	With complex rendering, the operation process is similar to the above. The difference is that the user is allowed to set a group of parameters. Before delivering the image file, the user can specify whether gray detection is to be used, and what chroma value to be used as a threshold for gamut clipping. Concerning the gamut clipping, two algorithms can be selected for different rendering effect. Multiple divisions can also be specified as well as their weight to contribute to the whole manipulation.
Study model access	Study model is designed for research purposes. This scenario can be divided into several sub-scenarios or use cases (discussed later) for different aspects of operation including download and upload of training data, execution of training program, display of coefficient values and delta-E values as well.

The use cases based on the above scenarios are presented in the following use case diagram.

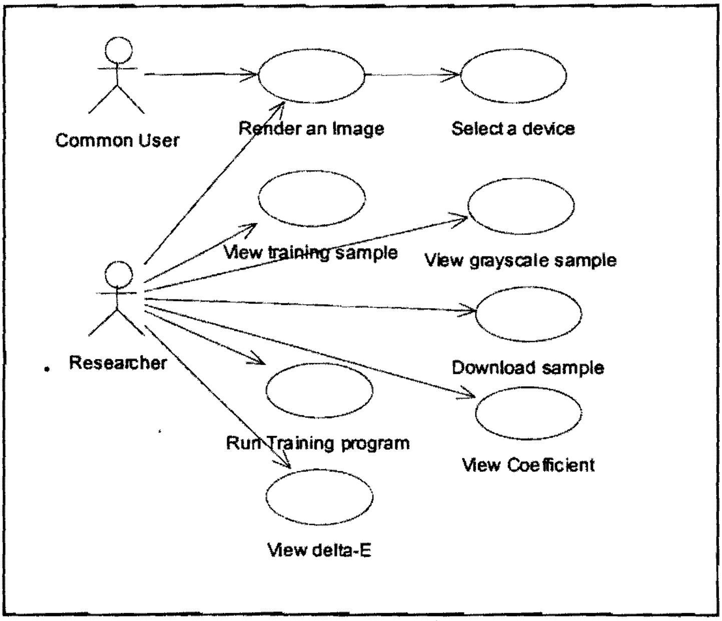

Figure 4.1. Use case diagram.

As shown in the use case diagram, common users and researchers experience different use cases. As a researcher is allowed to access all related data for the devices, several use cases are required as "Run Training program", "View Coefficient", etc.

4.2.3 Object classification

Classes are abstracted based on the analysis of the system. While use cases specify the operations of the users on the system, objects depict the entities that contain such operations. Apparently the operations concerning device characterization belong to one class, yet image transformation belongs to another. The following class diagram shows the fundamental classes and their relationships.

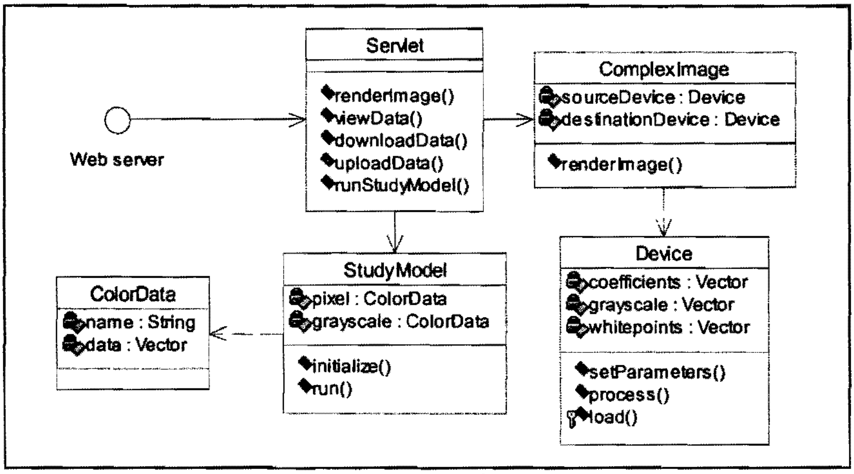

Figure 4.2. Class diagram.

All service requests come from the web server which serves as an interface to the outside world. The user connects to the web server using his/her own web browser and sends over one of the commands supported by the Servlet object, such as *renderImage*, *viewData*, and so on. The servlet recognizes the command and invokes local operations like *viewData*, or calls the *renderImage* operation offered by the *ComplexImage* class, or the run operation in *StudyModel* class.

4.3 Design

In this section, system design is discussed with a focus on web site building, servlet programming and data formatting.

4.3.1 Web site construction

The web site is set up to be platform independent by design, and implemented on Microsoft IIS web server. A virtual directory is created to encapsulate all static web pages, web page templates and Java servlet programs. Apart from

Java programs including two servlet programs, there are several static web pages as initial home pages and later pages are delivered through the Java servlet modules.

4.3.2 Static web pages

Static web pages contain only HTML tagged text without dynamic modifications before delivery to the client browser. There are initially four static web pages, namely, Default.htm, plain0.htm, advanced0.htm, and study0.htm. Their relationship is shown in the diagram.

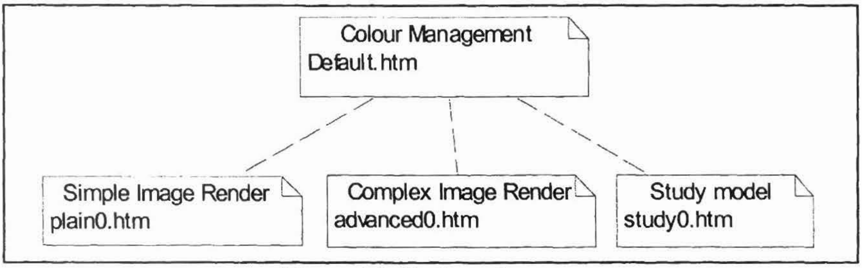

Figure 4.3. Static web pages.

HTML anchor link is used to link the other three static web pages. However the three linked pages use HTML forms to post user input to the web server which passes it on to the Java servlet.

Figure 4.4. Default.htm page.

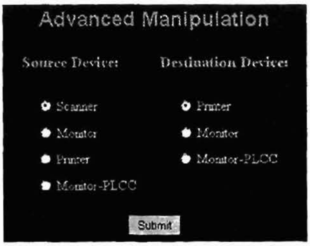

Figure 4.5. Device selection page.(advanced0.htm)

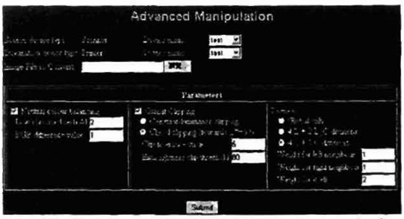

Figure 4.6. Complex image rendering page. (advanced.htm)

4.3.1.2 Web page templates

When Java servlet receives a form post request, it checks what information the user demands. Basically, the request is invoked from within one of the three secondary static web pages. For example, when a request comes form plain0.htm, a IDT (input device type) and ODT (output device type) tags are transferred as parameters, and a module parameter is included as a hidden field telling the Java servlet that the wanted dynamic page is "Plain.htm". This file is a template file in that the content is not fixed, but marked by a special tag. The template page cannot be delivered to the client directly, the Java servlet loads the content and replaces the special tag with real data, e.g., a list of scanner device names for input device, and then passes the modified content to the web server which, in turn, sends it to the client browser. There are three web page templates: plain.htm, advanced.htm and study.htm.

Figure 4.7. The rendered output in a new window.

4.3.2 Application layer

Java servlets work as a bridge between the web server and other Java classes that are in charge of image transformation or device profiling. It is important to integrate the static web pages, the templates and the Java servlets so that smooth connection is possible. The diagram in Figure 4.8 shows the relationship between the static pages, templates and the two Java servlet programs.

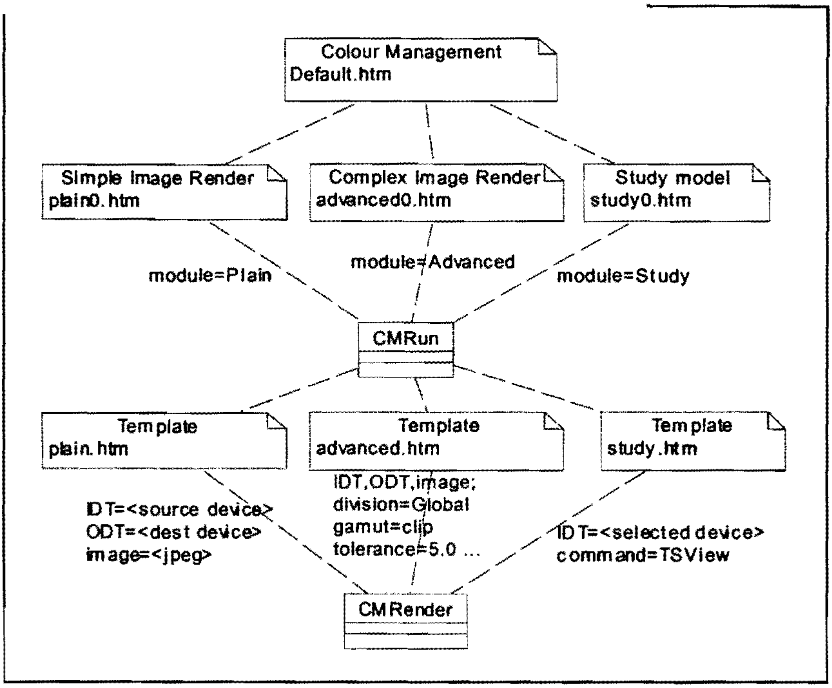

Figure 4.8. Web pages, templates, and Java servlets.

4.3.3 Data storage

4.3.3.1 Directory structure

Sub-directories are arranged to group files by type and functionality.

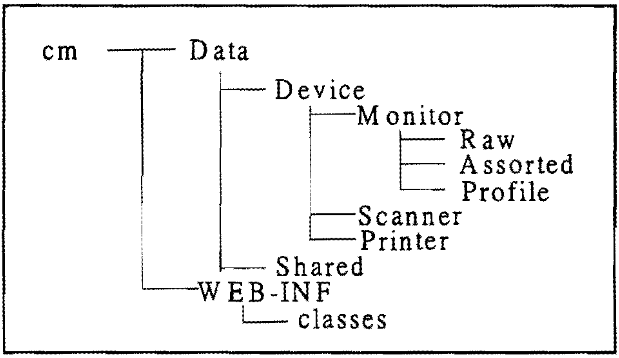

Figure 4.9. Directory structure.

In the directory shown in Figure 4.9, data folder is reserved to store device related data including primitive data in sub-folder Raw, coefficient data in Assorted, and ICC profiles in Profile. Each device shares one unique file name which is also the device name and different data files are stored in Raw, Assorted, and Profile sub-directories respectively. The Shared folder contains commonly used data files such as white point and spectrum energy distribution data. The classes folder is used to keep Java servlet programs that maintains the device related data files.

4.3.3.2 Data files

Data files are presented in XML format. The device training sample file contains the patch number, XYZ, Lab, C, H, and RGB values. An example of the content is given below.

```
<?xml version="1.0"?>
<?xml-stylesheet href="TSView.xsl" type="text/xsl"?>
<SAMPLE>
<PATCH ID="456">
<V ID="X">96.84224</V>
<V ID="Y">100.03576</V>
<V ID="Z">79.10232</V>
<V ID="L">100</V>
<V ID="a">0</V>
<V ID="b">0</V>
<V ID="C">0</V>
<V ID="H">0</V>
<V ID="R">255</V>
<V ID="G">255</V>
<V ID="B">255</V>
</PATCH>
</SAMPLE>
```

4.3.3.3 Stylesheet

Stylesheet files are for presentation purposes. Although the data are stored in XML structured data file, different views of the whole or part of the data can be transformed according to the selected style sheet formatting. To display the above sample data in a HTML table, the style sheet file is as follows:

```
<?xml version="1.0"?>
<xsl:stylesheet xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0"
xmlns:xt="http://www.jclark.com/xt"
extension-element-prefixes="xt">
<xsl:template match="/">
```

```
<html>
<head>
<link rel="stylesheet" href="/cm/styles.css" type="text/css"/>
</head>
<body background="/cm/images/arttilea.jpg">
<xsl:apply-templates/>
</body>
</html>
</xsl:template>
```

5. Conclusions

Finally, in this section we conclude this paper and discuss possible future work based on the results reported here.

5.1 Contributions

The goal of this research was to develop a general methodology for colour management of pictorial images across media via the Internet. The following works had been accomplished:

Definition of a reference colour space, CIELAB for accurate colour rendition.
Derivation of device characterisation models for a monitor, a scanner, and a printer.
Development of an image-dependent gamut-mapping strategy. This strategy employs image reproduction principles based on the input image data present. The strategy utilizes contrast-boosting lightness rescaling, followed by chroma-scaling procedures.
Application of tone- or gamut-expansion using the concepts of the tone- and gamut-compression procedures. Tone/gamut expansion was approached as the inverse problem of tone/gamut compression. The tone/gamut-expansion functions were generated by inverting the gamut-compression functions.
Implementation of a client/server application prototype of a cross-media colour management model on the Internet using Java Servlet technology.

5.2 Future Work

In the research field of Colour Management System, we found that there is not linear relationship among the colour space transformations. Basically, we needed to segment the colour image first, and then transform each part by different transform methods. The goal of our research is to investigate an automatic image segmentation method which substitutes the traditional heuristic and intuited methods. In the recent years, not many researchers deal with the research of colour image segmentation. Most of them using grey level image segmentation methods to apply on colour images; they are totally ignoring the special properties of colour. Some of them do the segmentations on the device dependent colour spaces, which don not fully support the information during cross-media colour management system. In accordance with the properties of colour, we can segment colour images in different colour spaces to fulfil the functionality of colour management system.

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