

Interactive learning tool on the measurement of video signals quality

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Abstract - In the following, a didactic tool for the teaching on video signal quality measurements is presented. The application basically consists of simulations that permit both the subjective and objective estimation of the degradations of video signals. This tool represents an alternative to traditional lectures and regular laboratory practices and is conceived as a teaching complement.

1. INTRODUCTION

Our world is presently undergoing profound transformations at all scales, in a process often denominated globalization. Certainly one of the principal actors in these changes is the set of information technologies. Education becomes naturally affected by these transformations. It is then our duty as academics to understand and also exploit the new possibilities with which technology provides us in order to improve teaching; in a sense, to extend the classroom to the student's home.

There is a great deal of controversy about the role information technology should play in the educational process [1]. Our point of view has been sufficiently explained before [2], which can be summarized into the firm belief that the new tools should own a *complementary* character. Consequently, it is alleged that there is no point in substituting the traditionally employed teaching methods (mainly lecturing and tutoring, the realization of exercises, a good bibliography at hand). Rather, it is that something new should be offered to the student, with an approach differing from the above in the sense of an improved interaction, accomplished principally by means of simulations.

Within this frame, a web based tool devoted to the teaching on video signals quality measurements is here presented. The main idea is that, through the use of a standard browser, students can visualize and measure objective degradations video signals may suffer by the most common impairments in their manipulation, principally during their production and distribution processes. In addition, the capability to interact with the conceived simulations represents a valuable attribute in the educational environment.

The outline of this paper is then as follows: first, the didactic framework of the tool is analyzed; next, the functional description of the application is explained; subsequently, technological issues related to the final development of the platform are discussed; finally, concluding remarks are briefly presented, together with planned future improvements.

II. PEDAGOGICAL ISSUES

A. Course objectives

The use of this tool is framed in the teaching of video systems; specifically, two subjects in the bachelor curriculum of our Faculty are devoted to this end. One is theoretical, whilst the other takes place in the laboratory. Main goals of these subjects are summarized in:

- make the student comprehend the problematic associated with video capturing, recording, processing and distribution;
- establish comparison criteria between different approaches in the design of video systems;
- master the objective procedures in the quality evaluation of both analog and digital video signals.

Along with an introductory lesson, the programme is consequently split in chapters on:

1. Video signal quality
2. Video capture
3. Video distribution
4. Video processing
5. Video recording
6. Value-added services

B. Target population

In principle, the target population to which this tool is directed consists of students in the 3rd year (6th semester) of our Faculty, who pursue a bachelor degree in telecommunications engineering and receive simultaneously theoretical and practical instruction on video systems. Given the nature of nowadays students, emphasis has been put on making the tool attractive, so that they really get motivated to use it.

C. Tool content

Video systems certainly are a very wide subject [4-7]; in account of this fact, the scope of the tool has been purposely bounded in order to achieve some excellence; further enlargements are left to future endeavours. Hence, our efforts were concentrated on the measurement of video signals quality, and virtual experiments have been designed accordingly. With their help, the student should be able to:

- classify the impairments that video signals may undergo during the production and distribution processes, identifying its underlying origins.

- predict the subjective image effects that these objective signal degradations may cause upon their perception.
- establish the adequate measurement procedure to characterize, both qualitatively and quantitatively, the impairment suffered by the video signal, including the choice of the appropriate reference pattern.

III. FUNCTIONAL DESCRIPTION

The development methodology for the proposed tool is outlined in Fig.1. The process starts with the selection of the contents of the experiments by the teacher in a tailored authoring tool. Subsequently, the web based material is automatically generated on the same tool and located on a central server. The resulting interactive application (i.e. the so-called applet) will be finally used remotely by the student with the aid of a standard web browser. With its disposal, the student can visualize the behaviour of different sets that handle the video signal in a black box approach. The simulations will be finally run locally, thus relieving the main server from the huge processing load possibly caused by concurrent usage of the application (e.g. within a group session in the laboratory).

The authoring tool considered for content outline has been actually developed for a broader range of application. With its aid, the instructor must first select the elements involved in the experiment, together with their connections. For that purpose, a set of basic building blocks is provided. At the same time, the actions that the student will be able to test can be restricted if necessary through disclosure (or concealment) of the parameters that control the behaviour of the selected blocks. Likewise, initial settings can be configured for both concealed and non-concealed parameters. Once block interconnection have been undertaken, link of their underlying code is automatically performed to generate a web application that properly emulates the behaviour of real image and video systems.

On the following, the basic blocks developed in the final interactive application are briefly described.

A. Pattern generator

Patterns are needed to put into evidence the limitations of video systems, thus bringing their working point into the

limits to characterize their performance. Due to the diversity of video and image formats deployed in real systems, a wide set of reference patterns must be provided. Equally important is the provision of a flexible tool to extend the initial pattern set offered without the requirement of a video capture device, making profit of the large image database already on the Internet. In the first version of the tool, .RAW, .GIF and .JPG image file formats are potential image input formats.

Despite the fact that no particular restriction of the image size is normally established in the image processing field, several conditions must be guaranteed if a proper video signal is to be generated. For that reason, manual resizing of image files (equivalent to resampling) is initially performed whenever a unique number of pixels and lines must be assured, as it is the case in video systems. The well-known 4:4:4 component RGB image format, with 4:3 aspect ratio, has been considered as the original source video format.

Regarding the colorimetric standard selection, even though RGB PAL primaries have been chosen as the primary source of information, a colour matrixing block have been developed to easily deal with the translation to other colour standars (e.g. RGB NTSC primaries, $Y'CbCr$, $Y'UV$, YIQ). Likewise, a full PAL colour coder is available to perform the matrixing and resampling required to obtain the 4fsc PAL composite video format, thus overcoming the initial restriction to component video signal formats in the platform.

Finally, information in the blanking interval is included, which, though not visible, maybe instrumental in the analysis of video distribution or recording processes. Both synchronizing pulses and reference colour burst (only for composite video) completes the construction of the video signal.

B. Image and video processing

Provided that almost any video processing system can be modelled as a chain of linear and non-linear individual processes, several simple processing blocks have been developed to deal with colour images.

Within the class of linear processes, white balance for adaptation to different light sources in the scene is easily accomplished through independent control of the gain of the three component paths. Also, filtering in the spatial

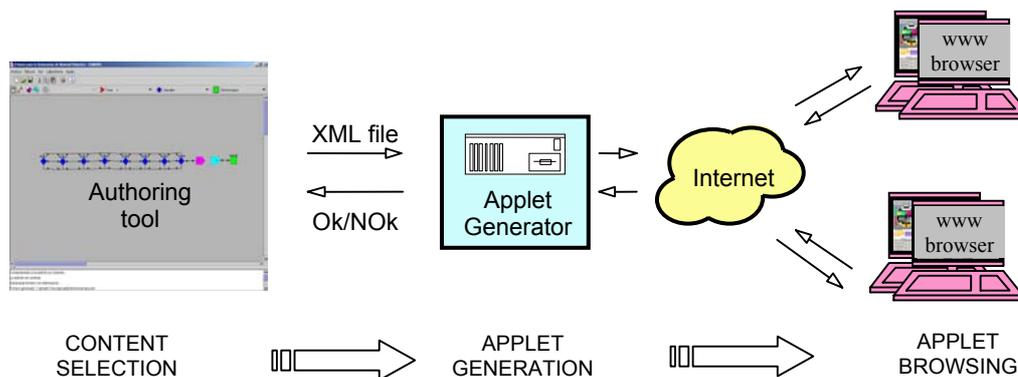


Fig. 1 Information flow among the different modules in the interactive learning platform .

domain, common in image processing systems, is attained through masking. For that purpose, several common 3*3 (i.e. 8-neighbourhood) masks selectable by the user are given in text files, which makes extension rather straightforward. Likewise, filtering in the temporal domain, characteristic of analog video systems, is achieved through construction of its equivalent digital counterpart. For ease of configuration, automatic reckoning of the filter coefficients is carried out on the fly from specifications of the desired type of filter given by the student. Thus, the student is able to experiment with different filtering approaches over the video content.

Within the non-linear processes, gamma non-linearity is provided to emulate the pre-correction present in video cameras for the non-linear behaviour of CRT electron gun. Likewise, a more flexible approach to contrast handling is achieved by means of knee contrast compression and white clip, commonplace in video systems.

C. Channel simulator

The analysis of the effects produced by the analog distribution of video signals requires the provision of a channel emulator. Apart from lineal and non-linear distortion blocks mentioned above, an AWG (i.e. additive white gaussian) random noise source has been developed to fulfil the requirements.

D. Visualization tools

Representation of the effects from different processing techniques has a paramount impact on the usefulness of any interactive learning tool. Consequently, emulation of the diverse measurement equipment currently offered by the manufacturers is crucial, so the addition of visualization tools in the final web application is a must. The corresponding development effort was large, since representation of video signals may be simultaneously desired in the time domain (as in a waveform monitor or oscilloscope), in the frequency domain (as in a spectrum analyser), in the spatial domain (as in an image monitor) and in the colour domain (as in a vectorscope).

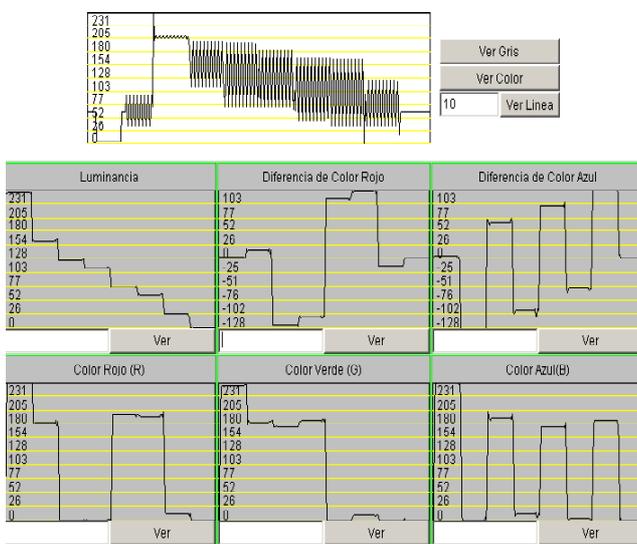


Fig. 2 Visualization tools in the time domain.

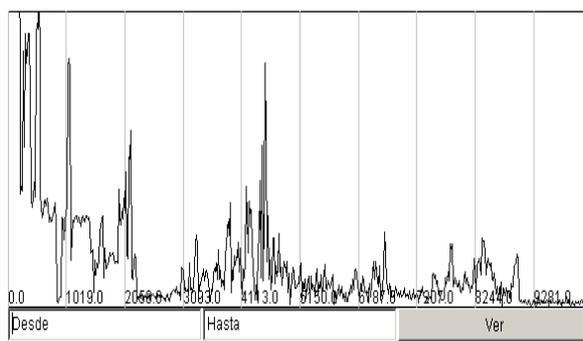


Fig. 3 Visualization tools in the frequency domain.

Fig.2-4 represent the main visualization tools developed for this application, where the colour bar video signal has been selected as the displayed pattern. Fig. 2 depicts the measurements in the temporal domain where amplitude measurements are normally performed. Over this window, transcoding among the diverse video formats is also reckoned and represented. Fig. 3 depicts the measurements in the frequency domain, where a FFT radix 1024 has been used. In the example, the energy concentrated around the colour subcarrier frequency indicates the presence of a composite video signal. Finally, fig. 2c shows the different representations of the 3-D colour space (i.e. UV, YUV, RGB), where colour gamut is normally checked. Shared by all the visualizers is the capability to select the line(s) of the image frame over which analysis takes place.

Selective activation of the probe points visible by the student in the simulated system must be carried out by the instructor before-hand during the content configuration process. It is worth noting the influence that this issue has over the memory requirements, because of the storage of intermediate results in the reckoning process.

E. Measurement tools

Unlike former measurement procedures, which were carried out manually, it is becoming more and more usual the employment of tools that yield measurements that are operator independent. Therefore, this module quantifies the impairment upon the video signal automatically. Within this category, a peak signal-to-noise (PSNR) measurement module is available, which quantifies the random noise influence, provided the correct image pattern is selected.

F. Interactive Applet

Finally, these modules are to be located within a framework that should be flexible enough to deal with the diverse simulation experiments without any tailoring effort. Fig. 5 depicts the graphical user interface of the final interactive application displayed on a standard web browser. On the upper part, images on several end or intermediate probe points in the system are provided. On the middle part, the structure of the emulated system is displayed. In this example, the emulated equipment is a professional video camera including colour balance, aperture correction, gamma correction, contrast handling and composite coding. On the lower part, two control panels enable the user to launch the different visualization tools and regulate the selected parameters of the

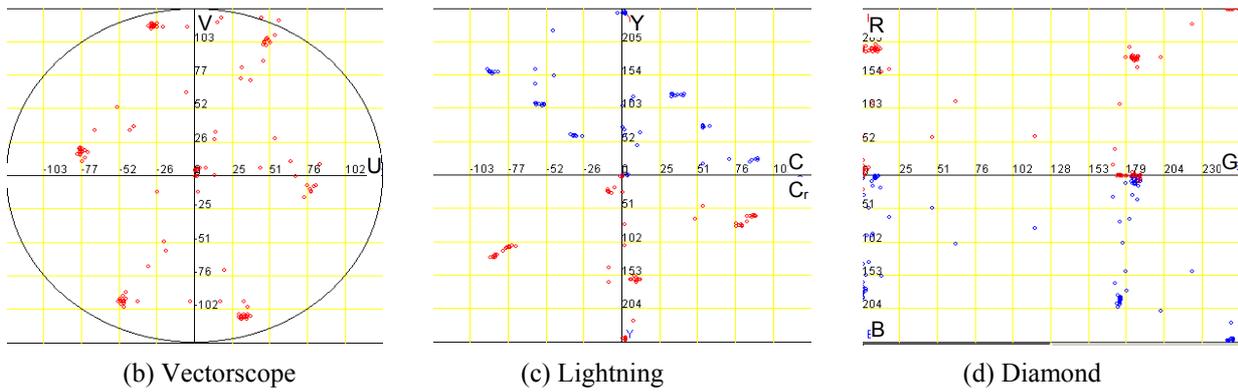


Fig. 4 Visualization tools in the colour domain.

interconnected subsystems. Likewise, control for selective launching of visualizers is also provided.

IV. TECHNICAL DESCRIPTION

A. Technological choices

Java has been selected for the implementation of the interactive tool. The benefits of the Java programming language compared to other object oriented languages have already been highlighted in numerous references (e.g. [3]). On the following, the discussion will be focused on its application on the development of learning material.

From the developer point of view, the applet program is naturally integrated with hypertext documents which are believed to be important for providing context to the learning materials. At the same time, its modularity extends the possibility to share or reuse of parts of the code by different modules in the application, minimizing the developing effort. Likewise, capabilities such multi-threading, automatic memory management and standardized error detection make the programming task more efficient, whilst its simplicity favours the reliability of the final applications. In addition, the availability of

extensive development resources for free (Java Development Kit, JDK; more at [8]) facilitates the programming of graphical applications, which is essential in interactive applications.

From the user side, its universality is instrumental in ensuring platform independency for the applications, which is a key requirement if availability of the course materials to students from home PC and campus workstations is targeted. Likewise, the use of standard web browsers avoids the need for maintaining complex user interfaces. In addition, the Java architecture was designed with security in mind (and not as an afterthought), providing a consistent means of protecting the computing environment, and consequently discouraging potential saboteurs in the academic community. Finally, applets run on the client side, thus relieving the server from heavy computing and reducing the traffic on the net, crucial in massive sessions where concurrent access to a centralized point may be not desirable (both for speed and reliability issues).

Unfortunately, some price must be paid for all this flexibility. The Java programs are compiled into a pseudocode (i.e. java byte-codes) that is finally interpreted in the client side by the Java interpreter (i.e. the Java

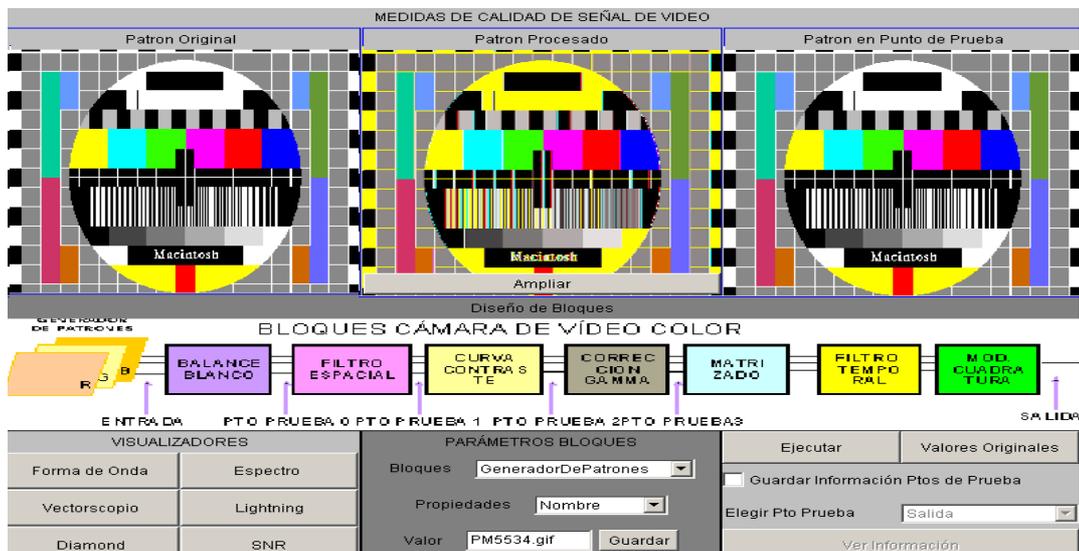


Fig. 5 Graphical user interface of the interactive applet displayed on a standard browser.

Virtual Machine), which is specifically designed for a computer architecture. Consequently, even though producing architecturally neutral code is desirable for portability, the method used to create this code is inefficient in its usage of resources.

Regarding the processing speed, Java is slower than other programming languages (e.g. 10 to 30 times slower than C++). This sluggish execution speed makes Java score poorly in this field of engineering that is digital signal processing. This situation may be even worsened in those environments with older computers (unfortunately rather usual in massive laboratories), which may risk the interactive nature of the developed application.

In addition, the need for a java virtual machine reduces the space in the RAM memory, which in this case is needed for the storage of image and video patterns along the different probe points of the simulated system (e.g. an image of 640*480 pixel with 24bits/pixel = 1MB RAM memory). Apart from the associated processing delay, correct settings of the underlying system are required if runtime errors are to be avoided. Consequently, the need for a proper configuration to execute a program complicates the installation procedure, which may at the end discourage the average Windows user.

Finally, the lack of libraries for the development of mathematical routines (compared to other programming languages such as C++) extends the initial effort required during the development stage.

B. Technical analysis

As depicted in Fig. 1, the interface of the authoring tool with the rest of the modules is performed by means of a XML (Extended Markup Language) file. In particular, this file contains all the information about the blocks (called nodes on the following) that the teacher has devised in the design of the simulation. Within its structure, each node entity entails attributes such as a designation name (unique identifier), type (functional behavior), input-output connections (connection relationship with other nodes) or properties (parameter default values).

From this piece of information, the applet generator module takes charge of the link and compile of the pieces of code that emulate the behaviour of the individual nodes. The result is the applet that represent the overall system, which will be finally run on the client machine. It is worth noting that the pre-established default values for the properties of each block can be modified during execution time, while the simulated system structure remains fixed.

V. CONCLUSIONS

A web based application on the measurement of video signals quality has been constructed. Thus, a complementary approach to video systems is accomplished. As a result, a new helpful learning tool is supplied to the students.

A number of improvements is still left for future versions of the tool. Among them, next efforts will be focused on four main directions. First, the provision of new tools that extend the capability to handle complete video sequences (instead of the single frames currently

supported) will be evaluated. Second, the addition of cursor facilities to give support to manual measurements in execution time will complement the current action set. Third, the construction of a comprehensive parameter database will ease the configuration work performed by the pupil. Finally, short HTML tutorials with a brief theoretical background are under consideration, although it is alleged that the power of this type of interactive is fully utilized in non-linear courses of explanation.

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