The Teaching of Engineering Concepts through Arts: Filling the Interdisciplinary Gap

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***Abstract*—The introduction of arts in STEM (Science, Technology, Engineering, and Maths) teaching has gain momentum in the last years. The benefits of a joint academic programme design between both schools -arts and science- remarks the stimulation of creativity and critical thinking during the learning process towards the development of novel ideas and products by the students. In this paper, we put forward some preliminary concerns to establish connections between the teaching of engineering core concepts supported by visual arts that could help increase the pregnancy of main topics in the engineering field. In particular, we illustrate *entropy*, a complex but fundamental mathematical notion to understand communications technologies. Through perceptions, supported by a video frame exhibiting different stages in the history of painting, we provide some guidelines to teach better the fundamentals of this core concept in a multisensorial approach.**

***Index Terms*—Higher education, engineering teaching, visual arts, video coding, entropy.**

I. Introduction

Arts and technical fields are today completely disjoint schools regarding their teaching pedagogy. Generally, the teaching of technical and pure sciences follows academic programmes that focus on specific fields from Mathematics, Biology, or Physics, for instance, to describe natural phenomena and how to interact with them to produce technological tools. Arts is much more connected to perception and production of visual, auditory or other sensory elements (frames, videos, sculptures, music, dance, for instance). Apparently, due to the different outputs of these two disciplines, both have developed their own means of transmission in separate intellectual domains, apparently without the need to interact with each other.

The exclusion of art in the technical-field academic programmes has produced a segregation of feelings and knowledge as a common basis [1] when teaching applied concepts. By addressing the analyticity of technical concepts, perceptions and feelings are commonly disregarded at the expense of the natural balance between emotion and intellectual upgrowths. The creativity and critical thinking processes (more connected to perceptions and emotions in arts) are intrinsically mutilated in the teaching of technical concepts which relay more on the bare connections between concepts and their implications. The artistic creativity stimulates new insights, as well as multiple and alternative ways to get approached to a concept or object, which in turn enlarge the potentials of thoughts and actions [2]. The arts create space for thinking differently [3], and the tools from art-based programmes can be also incorporated on the teaching of technical concepts to support this direction.

To conceive art-based teaching-programmes in a technical field will implicitly account for creativity processes in the conception of novel solutions. Regarding the pedagogical standpoint, the inclusion of arts in technical academic programmes will demand to explore the connection of ideas through emotions and intuitions in a multisensorial approach. The devising of such a methodology will allow to take concepts beyond their conventional understanding [4] for a better internalization of core contents.

In this direction, a few studies have been reported to include art-based methods to teach technical concepts. Some academic programmes offer subjects provided by different departments to promote an interdisciplinary dialogue between arts and engineering [5]. This is the case in [6], where students are motivated to take part in cultural activities, such as museum visits or concerts, or even to participate in academic projects coached by professors both from social sciences and STEM departments [7]. The programme in [8] increases student's motivation in learning by integrating arts and animation in teaching computer programming. Through the use of emoticoding, the integration of algebra, geometry, music, and 3D art seems to improve student learning [9]. The proposal in [10] involves web-designers, who smartly combine technology, arts, and psychology to attract the attention of potential customers of their webpages. Besides, the work in [11] presents abstract mathematical objects and concepts turned into other forms of visual arts using mathematical animations, which can be perceived as a more tangible experience that can potentially improve and enrich their understanding.

In this proposal we follow a learning through the arts

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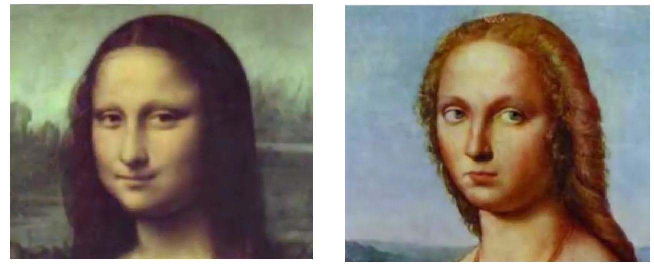
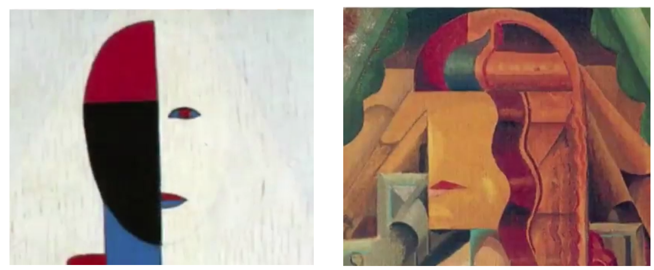
approach [12] for the teaching of the technical topic of video coding. Considering the concept of *entropy* (in the communication theory field) [13] we revisit their teaching through the perception through arts. *Entropy* represents a central topic for the analysis and development of communication systems. Typically, its understanding becomes difficult because of their abstract definition in terms of analytical formulations. In [14], we outlined a methodology to blend artistic perception into the apprehension of engineering concepts. Latter on, we introduced specific exercises based on sound and still images to illustrate a course on multimedia coding methods that belongs to a Telecommunications Engineering Programme. Here we aim to provide a better apprehension and pregnancy of such concepts by developing connections with their visual perception including motion [15]. By means of this exercise, we contribute with a preliminary attempt to provide a framework where students will experience –differently– a technical concept through the arts.

We describe this approach on the next Section II by providing the specifics on the pedagogical guidelines. Although our proposal stands in the analysis standpoint (through perceptions), we also discuss on the synthesis by producing pieces of art in their connection to the better understanding of this technical concept in Section III. Finally, the conclusions remark the main ideas and future outlook on this approach as outlined in Section IV .



(a) (b)

Fig. 1: Initial and final frames representing the Renaissance period. a) Mona Lisa. b) Lady with a Unicorn.



(a) (b)

Fig. 2: Initial and final frames representing the Cubism period. a) Woman Torso. b) American Beauty.

II. Video Art and Video Coding: The Proposal

The subject of video coding in engineering academic programmes covers several technical topics concerning the implementation of the most relevant standards. This is the case of the families of video coder standards MPEG-X or H26X, for instance. By these coders, the main goal is to implement coding techniques that reduce the size of video files affecting as low as possible the quality of the motion pictures.

In this direction, the conception of coding techniques relays on the concept of *entropy*. This concept provides a metric (given by a numerical quantity) below which the source of information can not be perfectly reproduced. The main goal of these coders is to represent the captured video by a binary sequence of 1's and 0's that best approaches the metric of *entropy*.

The *entropy* is analytically defined by a very abstract formula which is typically difficult to teach by the instructors, and difficult to learn by the students. This perceived difficulty prevents the proper understanding of this core concept, around which the video coding techniques are implemented.

To support a better understanding of this concept, we can refer to its qualitative description instead of the analytical standpoint only. Through proper video sequences, we can visually perceive the meaning of its definition and its interpretation. Higher values of *entropy* mean a very random nature of the source, lower values of *entropy* mean a more deterministic behavior. By exploiting the contrasting perception of the random nature (perceived surprise) and deterministic behavior (perceived predictability) of video sequences we aim to illustrate the perception of *entropy*.

To that end, we illustrate our proposal through the art video: "500 Years of Women in Western Art" by Philip Scott Johnson [16]. This video surveys the most representative female portraits made between the 12th to 20th centuries [17]. The clip illustrates the evolution of art painting by using a video morphing technique to gradually transform one face into another through several painting styles: Byzantine, Renaissance, à la grecque, Romantic, Impressionism, Cubism, etc. Here, we conveniently select two video transitions to illustrate a more random evolution in the Renaissance period and a more deterministic transition in the Cubism style. Renaissance portraits represent a vivid experience of real person's presence [18], which in turn demands to reflect a detailed description with colors and shapes. On the other hand, Cubism reflects the reality with elementary shapes and colors and the objects are represented by their streamlined nature [19]. Considering these two contrasting examples, the concept of *entropy* may be illustrated by the appreciation of these two sequences. In general, it is expected to observe a higher value in the case of portraits from the Renaissance period than the Cubism style.

A. The Guidelines

In this proposal we consider two segments from the video in [16] regarding the Renaissance (00:05 s to 00:07 s) and the

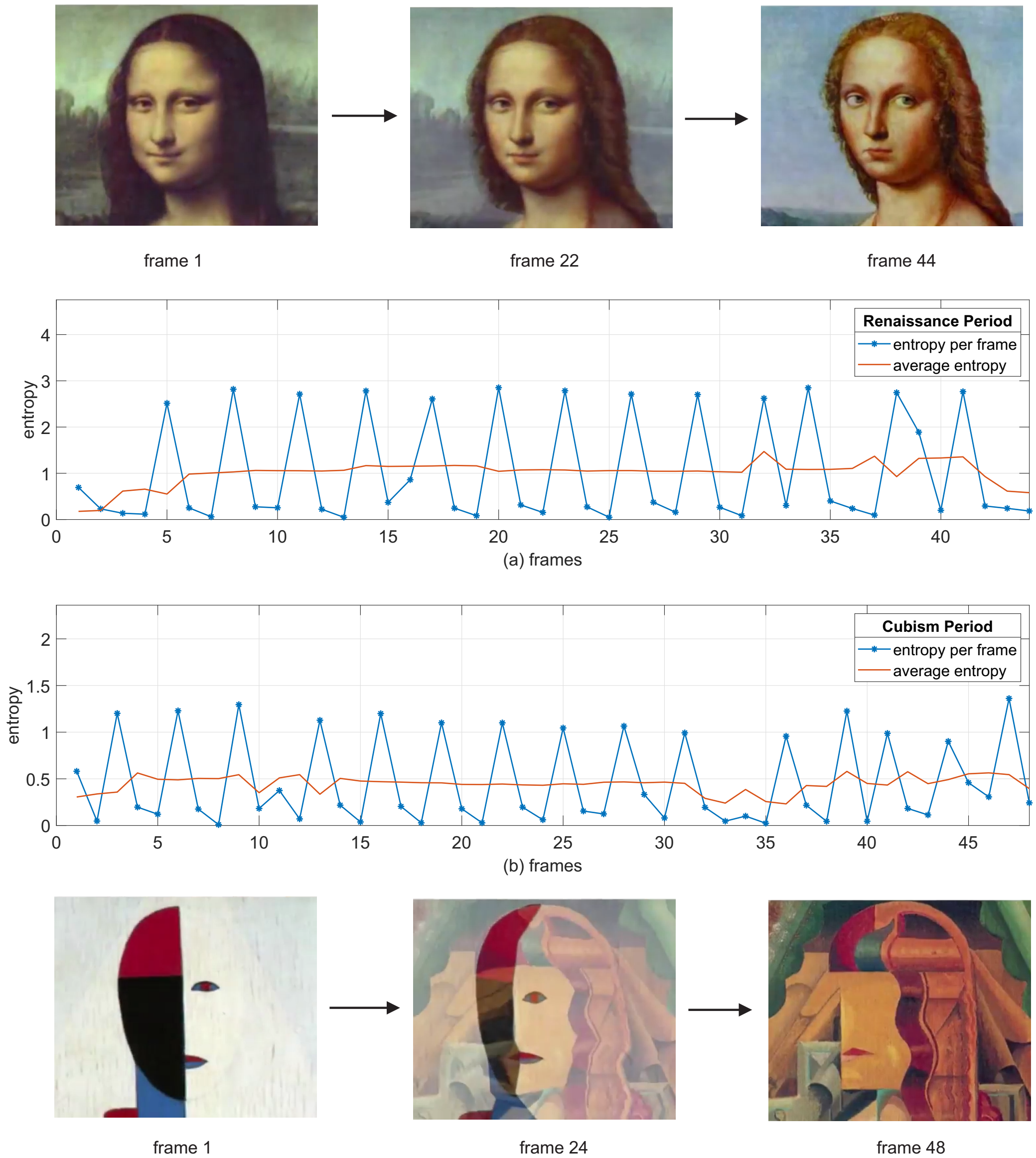


Fig. 3: The *entropy* of frames difference for the two videos.

Cubism styles (02:35 s to 02:37 s). In the case of Renaissance, it exhibits the shape transformation between the Mona Lisa (La Gioconda) portrait by Leonardo da Vinci and Lady with a Unicorn portrait by Raphael as shown in Fig. 1. In the case of Cubism, the video illustrates the shape transformation between Woman Torso portrait by Kazimir Malevich and American Beauty (The Movie Star) portrait by Knud Merrild as depicted in Fig. 2. On these two sequences, we measure the change in entropy from frame to frame usually employed in what is referred to as INTER (frame) coding.

To illustrate video standard recommendations, we implement an algorithm to compute the change of entropy for both sequences as it evolves in time, and how this quantity is related to the painting technique in each period of art history. By this end, we use the software MATLAB®[1], provided the flexibility to manipulate videos and perform simulations. The aforementioned videos are composed of 30 frames per second, that is, 30 images to represent 1 second of transformation between the initial and final painting. The entropy metric quantifies the lack of predictability experienced among frame transitions. Based on that, we expect to see the higher entropy values for the Renaissance video segment in contrast to the lower entropy values for the Cubism video segment.

Fig. 3 shows the temporary evolution of the entropy change associated with each frame transition, represented by asterisks in blue lines, to transform one painting into the other by using the morphing technique in both cases. We must point out that slope changes on entropy plots are a consequence

[1]MATLAB is a registered trademark of The MathWorks, Inc.

of two scenarios during the transformation processes. The first one is that some frames only varying slightly between them resulting in lower entropy change values. The second one refers to remaining frames suffer abrupt changes in the current frame regarding the previous one represented by peaks in both entropy plots. On the other hand, we exposed the average behavior of entropy, depicted by red lines, with the aim of comparing the amount of disorder (randomness) in two paintings. As we expected, Renaissance painters explored nuanced shapes and colors to capture the real world, and that is measured as more entropy. In contrast, Cubism painters employed more streamlined patterns to create their artwork, and that implies less entropy. In these specific cases, the video segment of Renaissance has approximately twice the average temporal entropy of the Cubism video.

III. Discussion

By these proposed guidelines we aim to introduce a connection between the perceptions and the meaning of technical concepts to improve their internalization. The approach remarks the qualitative attribute of the concept, then to perceive it by arts. In this specific case, the concept of *entropy* provides a metric regarding randomness that can be experienced in connection to the time evolution of video sequences.

To that end, we have selected the hypothetical evolution between portraits chosen from the Renaissance period in contrast to those chosen from the Cubism style as captured in [16]. Somehow, from these two video sequences, the viewer can comparatively perceive the amount of new details introduced in between portraits to transform the starting into the final frames. Because the Renaissance style expresses a more realistic representation, which in turn implies a more detailed description of objects and elements, then it is expected that their time evolution will be much more random than in the case of Cubism. The frames chosen from he Cubism style introduce fewer elements of spatial *surprise*[2], their conception is to represent reality by simplified constitutive components, where objects and elements are illustrated by their most basic essential units. Note that this mathematical concept of surprise can be in stark contrast with the artistic perception of *surprise* and this could drive a discussion among the students that encourages critical thinking. We hope that approaching these concepts in this manner could make them more pregnant.

Also, we capture this qualitative experience by measuring the *entropy* regarding the difference between consecutive frames in the video sequence in [16] since this is a core idea in most video coding standards. These usually exploit the predictability of the pixels within a frame, referred as INTRA coding and that between adjacent frames, i.e. INTER coding. Here the amount of randomness introduced by the morphing procedure is quantified by measuring -on average- the new information introduced in the current frame in comparison to the previous one. This time evolution of the newly introduced information brings into the technical concept of temporal evolution of *entropy*. This link between perception and the technical concept will bring a different experience for a better understanding beyond the analytical definition of *entropy*.

[2]Spatial surprise as measured for example with the relative entropy or Kullback-Leibler divergence.

IV. Conclusions

In this paper we present a preliminary approach to employ arts to improve the teaching of multimedia coding techniques to engineering students. With this method we encourage the students to think about core concepts in communications such as *entropy* or *information* through reasoning about different stages in the history of painting.

Our proposal, described in Section II, concerns only an analysis procedure. The perceived complexity in the video sequence is linked to the technical concept of *entropy* by perception. However, further insights can be devised by also including a synthesis phase, that is, by allowing the students to elaborate a piece of art relying on this technical concept.

In this direction, we can ask them to produce a video sequence of increasing and decreasing temporal *entropy*. By using the shape transformation, similar to [16], the first and last frames can be conveniently selected to maximize or minimize the average temporal *entropy*. Besides, the transformation between the first and last frame can be conveniently designed by the student to modify the rate of the temporal *entropy*.

In this particular regard, creativity can be motivated when trying to produce their own video sequence with maximized or minimized rate of *entropy* change. Current and future technical benefits as well as their applications can be further discussed regarding the use of new or novel video encoders.

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