A Watermarking System for Teaching Intellectual Property Rights: Implementation and Performance

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***Abstract*—In this paper we propose a watermarking system, which we call WaterIP, that can be efficiently used in support of teaching students to respect intellectual property rights. Our system uses an efficient technique for watermarking images by exploiting certain properties of a specific 2D representation of permutations, it has a friendly graphical user interface, and shows interesting performance figures. We demonstrate the educational effectiveness of our WaterIP system by presenting ways of how it can be applied in class and show that WaterIP helps to understand what intellectual property rights really stand for. We have implemented our system and evaluated it in an simulated environment; the experimental results show that WaterIP has optimal time and space performance. Apart from that the figures show that the system provides watermarked images of high quality and everything is accessed through a user interface leading to the desired educational efficiency.**

***Index Terms*—Watermarking Techniques, Intellectual Property Rights, Teaching IP, Educational Tools.**

I. Introduction

As internet technology becomes an indispensable tool for everyday life, it is more important than ever for educational reform which favours the establishment of a culture where the notion of intellectual property is respected by people.

In a synchronous context of education, teachers need to have pedagogical and technological content knowledge of intellectual property if they are to incorporate it into their learning programmes to teach students to respect others' intellectual property and protect their own ideas. In such a context, the pedagogical tools are constantly changing as the world in which teaching is situated evolves. Hence, pedagogical tools that support not only the teaching but also ideas about intellectual property rights are developing within the technological world.

A technological tool that supports and helps both teachers and students to understand, protect and respect intellectual property is of great importance, useful, and valuable. The educational value of such a tool is mainly based on the technology used, and also on the technique or method adopted for the design and implementation of the tool.

Watermarking is a technique that is currently being studied to prevent or discourage piracy and deter unauthorized copying of digital media. It incorporates many important technological and theoretical properties which enable us to design an efficient educational tool, with pedagogic value, for teaching intellectual property rights inside the classroom.

We next briefly describe the main idea behind the watermarking technique, some issues about intellectual property rights (IP), the motivation of our work, and our contribution which is an educational watermarking tool for teaching IP.

Watermarking. Digital watermarking (or, simply, watermarking) is a technique for protecting the intellectual property of a digital object; the idea is simple: a unique identifier, which is called *watermark*, is embedded into a digital object which may be used to verify its authenticity or the identity of its owners [5], [13]. A digital object may be audio, picture, video, or software, and the watermark is embedded into object's data through the introduction of errors not detectable by human perception [7]; note that, if the object is copied then the watermark also is carried in the copy.

The watermarking problem can be described as the problem of embedding a watermark w into an object I and, thus, producing a new object I_w, such that w can be reliably located and extracted from I_w even after I_w has been subjected to transformations [5]; for example, compression in case the object is an image [4], [16]. Note that, there are two general types of watermarking, namely, *visible* and *invisible* watermarking. In visible watermarking, information (i.e., the watermark) is visible in the object, i.e., audio, image, or video, while in invisible watermarking, information is added as digital data to object, but it cannot be perceived as such (although it may be possible to detect that some amount of information is hidden in the object).

It is worth noting that although digital watermarking has made considerable progress and become a popular technique for copyright protection of software and multimedia information [4], [7], [26], research on watermarking tool designing for educational purposes has not yet received sufficient attention.

Intellectual Property. The term intellectual property (IP) refers to a creation of a mind for which a set of exclusive rights are recognized [22]. That creation may have any possible form; for example, it may be a work of art, an invention, literary or artistic work, a discovery or even a phrase. More precisely, IP can be divided into two categories: *industrial property*, which includes inventions (patents), trademarks, industrial designs, and geographic indications of source; and *copyright*, which includes literary and artistic works such as novels, poems, plays, films, video games, software applications, musical works, drawings, paintings, photographs, sculptures, and architectural designs.

The objective of recognizing intellectual property is to encourage innovation. That is because people won't have the incentive to create if they are not legally protected in order to get the social value that they deserve from their creations [18]. Of course the world's evolution and economic growth depends on creations and inventions and that makes intellectual property such an important and vital aspect [14].

Over the last years the internet has been expanding very rapidly and, thus, information is now spread freely, easily and cost-efficiently and that gives a greater importance to intellectual property. Because of the internet, the distribution of intellectual material went out of control. Just the fact that nearly every intellectual material that is produced today is published in digital form or can be transformed into digital form means that it can be easily transmitted free via the internet, without any permission from the creator.

All that urged the adoption of new laws and the development of systems for the protection of intellectual property [8], [22]. But still the cyberspace is chaotic nowadays and that makes it extremely difficult to have any kind of control over it. The figures talk by themselves; according to IFPI (International Federation of the Phonographic Industry) 95% of music downloads are pirated. What is more, a survey from Digital Life America showed us that things aren't any better for the movies. If we also take into account the fact that the internet population is consisted of nearly seven billion we may realize that its power is greater than the law and the systems for protection. And that's where education comes to place.

Motivation. We believe that the best way to gain people's respect towards intellectual property rights is to start from the roots. Respecting intellectual property should be within a person's morals, and something like that can be acquired by a person during his early education. We also believe that students should not only be taught theoretically what intellectual property is, but they should also have an experience in order to be better motivated to learn about this aspect; that is what our work suggests: motivating students through the act of claiming a property using a watermarking technique provided by a friendly and easy to understand manner through our watermarking system. After such an experience a student will realize that intellectual property is a matter that concerns him as well. Thus, he will pay more attention at his teacher talking about it and actually make the respect towards intellectual property part of his character.

Contribution. Based on the above motivation, we propose a watermarking system supporting the teaching process for educating students to respect intellectual property rights. In particular, we propose an educational tool, which we named *WaterIP*, that can be efficiently used by students to enable them to consider how to protect their own ideas. Moreover, WaterIP can be incorporated into school learning programmes to teach students to respect others' intellectual property rights.

Our WaterIP system uses an efficient technique for watermarking images and provides students with two main working levels corresponding to two main components:

(I) The first component allows a student to create a secret key (i.e., the watermark) and select a picture I in which he wants to embed the watermark; in our system the watermark w consists of 6 distinct numbers from 1 to 6, and is embedded into the original picture I resulting the watermarked picture I_w.

(II) The second component is responsible for making the marks of a watermarked image I_w visible to the student so that he will be able to easily extract the watermark w automatically or by hand; in particular, the system returns the marked picture I_m to the student and he extracts the watermark from I_m either using the system or using only, for pedagogical reasons, a ruler and a pencil.

We would like to point out that we consider important, for pedagogical reasons, that the student must participate interactively in the process of proving ownership and thus we chose to include in our WaterIP system a feature which allows the student to complete the extracting task manually if he wants to.

Usability and Performance. The usability of the WaterIP system is based on a watermarking technique used through a friendly graphical user interface. Using it the student can easily produce his watermark w using his mouse without making any mistakes. He can also choose an image I from his computer and he can either embed a watermark into I resulting the watermarked image I_w or make the marks of I_w visible so that he will be able to prove to his teacher that the picture belongs to him.

The method behind the WaterIP system can be applied to all educational levels, as part of different lesson plans, beginning from early childhood; teachers of elementary schools can demonstrate the system to young learners by uploading an image or photo and set them ethical dilemmas concerning the proper use of that image or photo, while teachers of higher education can go on more complex meanings and explain learners the concepts of watermarking, embedding, extracting, permutation, image analysis, etc.

We show that our system has optimal time and space performance. Indeed, let $N \times M$ be the size of the input image, that is, the number of pixels of both the original image I and the watermarked image I_w. The total asymptotic time performance of our system, neglecting the image's conversion from the initial format to raw raster format and vice versa, is of order $N + M$ for embedding the watermark w into I, and of order $N \times M$ for marking the image I_w and producing the image I_m, where $n = N \times M$. Moreover, the extra space needed by the system is constant since it uses only some extra auxiliary variables.

In order to demonstrate the educational effectiveness of our WaterIP system, we used the system in a real scenario with computer science students of our faculty in order to show the level that our system accomplishes its target, which is to teach them the notion of Intellectual Property and the technical means that exist to protect their digital property. We also, describe a course design that we applied inside the classroom.

II. Theoretical Tools

In this section we present representations of the two main objects of our watermarking system: the permutations and the digital color images. In particular, we propose a 2D representation of permutations and describe a 3D representation of color images.

A. Permutations

Informally, a permutation of a set of objects S is an arrangement of those objects into a particular order, while in a formal (mathematical) way a permutation of a set of objects S is defined as a bijection from S to itself (i.e., a map $S \rightarrow S$ for which every element of S occurs exactly once as image value).

Permutations may be represented in many ways. The most straightforward is simply a rearrangement of the elements of the set S, as in the example of Figure 1, where S is the set $N_6 = \{1, 2, \ldots, 6\}$; in this way we think of the permutation $\pi = (2, 5, 3, 1, 6, 4)$ as a rearrangement of the elements of the set N_6 such that "1 goes to 2", "2 goes to 5", "3 goes to 3", "4 goes to 1", and so on [11].

index	1	2	3	4	5	6
permutation	2	5	3	1	6	4

Fig. 1. The permutation $\pi = (2, 5, 3, 1, 6, 4)$ and the indices of its elements.

Based on the above representation, we can also think of a permutation $\pi = (\pi_1, \pi_2, \ldots, \pi_n)$ over the set $N_n = \{1, 2, \ldots, n\}$ as a sequence $(\pi_1, \pi_2, \ldots, \pi_n)$ of the elements of the set N_n; so, for example, the permutation of Figure 1 has $\pi_1 = 2$, $\pi_2 = 5$, ..., $\pi_6 = 4$, and $\pi_1^{-1} = 4$, $\pi_2^{-1} = 1$, ..., $\pi_6^{-1} = 5$ [11].

2D Representation of Permutations. Given a permutation π over the set $N_n = \{1, 2, \ldots, n\}$, we first define a two-dimensional representation (2D-representation) of the permutation π that is useful for studying properties which help us to define, later, a more suitable representation of π for efficient use in our watermarking system.

In this representation, the elements of the permutation $\pi = (\pi_1, \pi_2, \ldots, \pi_n)$ are mapped in specific cells of an $n \times n$ matrix A as follows:

- integer $i \quad \longrightarrow \quad$ entry $A(\pi_i^{-1}, i)$

or, equivalently, the cell at row i and column π_i is labeled by the number π_i, for each $i = 1, 2, \ldots, n$.

Figure 2 shows the 2D representation of the permutation $\pi = (2, 5, 3, 1, 6, 4)$. Note that, there is one label in each row and in each column of the matrix A, so each cell in A corresponds to a unique pair of labels: the one in its row and

	1	2	3	4	5	6
1		**2**				
2					**5**	
3			**3**			
4	**1**					
5						**6**
6				**4**		

Fig. 2. A 2D representation of $\pi = (2, 5, 3, 1, 6, 4)$.

the one in its column; see, [23] for a long bibliography on permutation representations and also in [11].

2DM Representation of Permutations. Based on the previous 2D representation of a permutation π, we next propose a slightly deferent two-dimensional representation of π, which we call 2D marked representation (or, 2MD for short), providing us with a combinatorial tool efficient for our watermarking technique used in our image watermarking system.

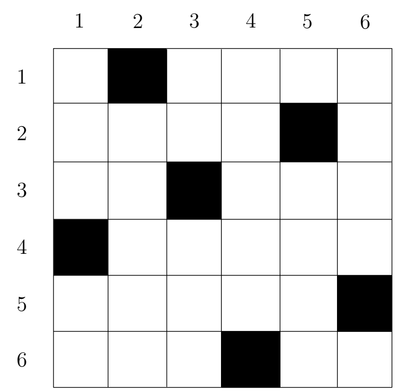


Fig. 3. A 2DM representation of $\pi = (2, 5, 3, 1, 6, 4)$.

Formally, in our 2DM representation a permutation π over the set $N_n = \{1, 2, \ldots, n\}$ is represented by an $n \times n$ matrix A as follows:

- the cell at row i and column π_i is marked by a specific symbol, for each $i = 1, 2, \ldots, n$.

Figure 3 shows the 2D marked representation of the permutation π. Note that, as in the 2D representation, there is also one symbol in each row and in each column of the matrix A.

B. Color Images

A digital image is a numeric representation of a 2-dimensional image; it has a finite set of values, called *picture elements* or *pixels*, that represent the brightness of a given color at any specific point in the image [12].

There are several models used for representing color. In our system, we use the RGB model; it is an additive color model in which *red*, *green*, and *blue* light is added together in various ways to reproduce a broad array of colors. The name of the model comes from the initials of the three additive primary colors, Red, Green, and Blue [12].

III. Our Watermarking System

In this section we describe the implementation process and the main operations of the proposed watermarking system, as well as the operational characteristics of it. Our system, which we named WaterIP, provides to a student two main working levels:

(I) **Embed level**: Through a friendly graphical user interface, the student creates a secret key (i.e., the watermark w) and selects a picture I in which he wants to embed the watermark; in our system the watermark w is a permutation π over the set N_6 and it is embedded into the original picture I, using the 2DM representation, resulting the watermarked picture I_w.

(II) **Mark level**: The student, in order to prove that he is the owner of the picture I_w, inputs the watermarked picture I_w into the system which makes the marks visible to the student so that he will be able to easily extract the watermark w (i.e., his secret key) just by looking at the marks; in particular, the system returns the marked picture I_m to the student.

The development process of WaterIP included the requirement analysis of end-users (in our implementation, teachers and students), the learning objectives, the technological infrastructure of schools and universities, and the knowledge of end-users on information and communication technologies (ICT). Having determined the specifications and the purposes of the system, we designed our WaterIP system, implemented, and evaluated it's performance, based on software engineering principles (see, [10], [25], [27] for a long bibliography on software design).

Our WaterIP system was designed to be accessible from users of different educational levels and in some cases with little experience on ICT, and to be operational on different computer platforms. Our system's design incorporates the learning objectives concerning the understanding of IP rights and watermarking techniques from the end-users, as well as the embedding and extracting processes which correspont to the two main working levels described above. The system guides the user to easily form a watermark w by giving a permutation π to embed it into the uploaded image I using the 2DM representation of π (see, Section II).

A. Implementation

We developed the WaterIP under an integrated development environment which was Netbeans 7.0.1 and Java was selected as the programming language, meaning that it is an object oriented program with very little restrictions concerning the required software and hardware, and also it is extensible. The

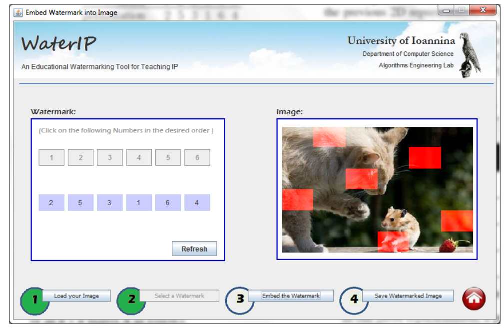


Fig. 4. Forming the watermark to be embedded.

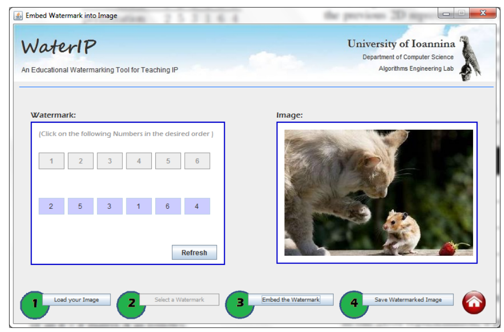


Fig. 5. Saving the watermarked image.

system has also a graphical user interface (or, GUI for short) thanks to the Java Swing toolkit.

We should mention that our WaterIP system uses a permutation π over the set N_6 for the watermark w. The set N_6 was selected in purpose; we preferred to use a fixed size rather than giving the size as a choice to the user. That choice was made in order to make the system simple as it is designed to serve educational needs. Also 6 is not a great number so it is relatively easy to memorize by a student, nor it is a very small number and that makes the permutation more presentable.

The WaterIP system consists of two main subsystems each of which contains algorithmic techniques responsible for particular operations, and also two auxiliary subsystems which are in fact the "welcome screen" and the "ending screen" of the system. Each subsystem is independent from each other as it is a different Java Class. We next briefly discuss the four subsystems:

S.a First, there is the welcome screen which is actually the first window to appear when running WaterIP giving choices to the user to either run the embedding process or the extracting process and last the choice to proceed in exiting the WaterIP system.

S.I The first main subsystem (i.e., embedding subsystem) implements the embedding algorithm taking as input an image I and the desired watermark w and saving the watermarked image I_w. Note that, the algorithms behind the embedding process use the 2DM representation of a permutation π and a technique which modifies specific pixels of the input image I so that the marks in the resulting watermarked image I_w are invisible. Moreover, there is a window from which the user may select, upload and view an image and then form the watermark w to be embedded. This can be done by choosing with the mouse the numbers from 1 to 6 without being able to use a number two times (recall that, w is a permutation). Simultaneously the user watches a visualization of the watermark to be embedded as specific cells of the image highlighted red (see, Figure 4). Last there is a button giving the choice to the user to save the watermarked image at a directory of his computer (see, Figure 5).

S.II The second main subsystem (i.e., extracting subsystem) implements the extracting process. In that case the input is a watermarked image I_w and the output the watermark w that is being extracted. There is also a window supporting the extracting subsystem from which the user may choose, upload and view a watermarked image. Then, there are two more choices. The user may run the extracting algorithm and view on the uploaded image red films over the marked cells (see, Figure 6). Secondly the user may select and view each value of the six digits that form the watermark (see, Figure 7).

S.b Last, there is the ending screen; it appears when the users selects `Quit` from the welcome screen. In this case a message appears to the user and the user selects whether he wants to proceed in exiting the WaterIP system.

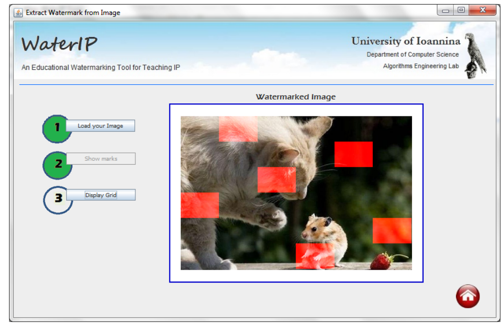


Fig. 6. Showing the watermarked image's marks.

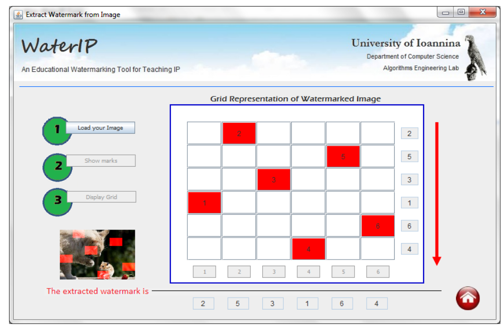


Fig. 7. Viewing the watermark's values.

We next discuss some issues concerning the performance of the WaterIP system; in particular, we mainly focus on the quality of the watermarked image I_w produced by the system and also on the time and space complexity of the two main system's algorithms, i.e., the embedding algorithm and the extracting (or, marking) algorithm.

B. Performance

We have evaluated our embedding algorithm by testing it on more that 100 images selected from various websites and we are in a position to claim that the watermarking technique used by the algorithm can be considered efficient because the watermark w is hidden very well in the images I_w; in other words, after an image has been watermarked we can not figure out by looking at it where exactly it has been marked.

We believe that the watermark w is well hidden in image I_w because we mark the image by changing the difference between the average brightness of the 5 central pixels (forming a cross) of each cell of a 6×6 imaginary grid, which covers the whole image, and the average brightness of 12 specific neighboring pixels. Among the 36 grid-cells of the image we consider as marked for each one of the 6 grid-rows the cell that has the maximum brightness difference between the center (i.e., the cross pixels) and its neighborhood (i.e., the 12 specific pixels). Note that, when we change this difference to mark a cell if the i-th grid-row $(1 \leq i \leq 6)$, we make it equal to the maximum difference of all the 6 differences belonging to the i-th grid-row plus a constant value c. We add this value because in case of compressing the image with a lossy method, we want to avoid a distortion of the watermark; in other words, we want the difference of the marked cell be greater than any other cell in the same grid-row. We also believe that this technique despite being simple is efficient as well because the brightness of each of the 6 marked cross pixels does not have a great difference anyway from the brightness of the corresponding 12 neighborhood pixels, and thus the modified cross pixels does not change something significantly in the image.

As far as the time and space complexity of our system is concerned, we should mention that it is asymptotically linear in the size (i.e., number of pixels) of the input images.

More precisely, the embedding algorithm is very fast; it has almost constant time complexity since it operates only on the 36 grid-cells of the image I. Note that, in our implementation the length of the watermark is 6 and thus we always have 36 grid-cells. Expressing the algorithm's complexity by the size of the input image I, we can say that it is of order $N + M$, where N and M are the two dimensions of I.

The marking algorithm is also very fast since it also operates mainly on the 36 grid-cells of the input image I_w. The most time consuming step of the algorithm is that of placing a red film over the whole area of each of the 6 marked grid-cell. This step takes $O(n)$ time, where n is the number of the pixels of I_w (in fact, it requires $(N \times M)/6$ operations); recall that, $n = N \times M$.

Finally, it is fair for the time performance of our system to take into consideration the time needed for converting the input image I that the system takes as input from the initial format to raw raster format; note that, the system usually uses compressed images as input. It is obvious that the time needed for converting the image I into a *raw raster format* depends on the type of the image selected. The most common types of images would be the JPEG as digital cameras store images of this type and also nearly every image on the WWW (world wide web) is in JPEG format. The compression to a JPEG requires the usage of the DCT (discrete cosine transform); the DCT is similar to a Fourier transform and it is of order n^2, but it is also possible to do the same thing by doing something similar to the FFT (fast fourier transform) which is of order $n \log n$. Note that the same techniques applies for the JIF images which are also popular on the WWW [1], [6].

Summarizing, the total asymptotic time performance of our WaterIP system, neglecting the conversion of the input image I into raw raster format, is $O(N + M)$ for embedding the watermark w into I, and $O(n)$ for marking the image I_w and producing the image I_m, where n is the number of pixels of the input image I and $n = N \times M$. Moreover, the extra space needed by the system is constant, i.e., it uses only some extra auxiliary variables.

IV. Evaluation Inside the Classroom

Our work proposes a supporting educational tool for teaching, inside the classroom, the value of intellectual property. As mentioned before we believe that the best way to gain people's respect towards intellectual property rights is to start from the roots, and that is the early education. Students should be taught, as part of the ethical education, to respect intellectual property at schools [28].

We also believe that a student can easier understand what is the notion behind intellectual property if himself experiences an example of his own intellectual property being theft and then having to find a way to claim it. Teaching IP only in theory may not lead into the desired learning outcomes and that's because IP covers widely and diverse issues that students with an average knowledge level may have difficulties to absorb, whereas an interactive method, which combines theory and real experience will be without any doubt much more effective [17]. That can be illustrated by using our WaterIP educational watermarking tool.

We consider that our WaterIP system can be used in all educational levels as part of various lesson plans; uploading an image or photo a teacher of an elementary school can demonstrate the system to learners and set them ethical dilemmas concerning the proper use of intellectual material, such as images or photos, while teachers of higher education can go on more complex meanings and explain learners the concepts of watermarking, embedding, extracting, permutation, image analysis, etc.

Recently, in our paper [3], we proposed an imaginary scenario where two classmates claim the ownership of the same image, Alex who is really the owner of the image and Bob who claims that he is the owner, and showed how our WaterIP system helps both to understand what intellectual property rights really stand for. The main idea of the scenario is, that Alex first paints a picture at a computer or just takes a photo and uploads it to the computer. Afterwards he runs our system and places the numbers between 1 and 6 in a random order that he memorizes and keeps secret. That order actually forms the permutation which also is the watermark that Alex wants to embed in his digital image. He selects from a menu which image he wants to use and then runs the algorithm and places the watermark into it. Then he gets the watermarked image. That watermark will later be his proof that the picture was really made by him and that he deserves to be rewarded for it and not someone else; of course we shall not forget that in order to do that he should have memorized the permutation in order to claim the property of the image. Afterwards Alex uploads the watermarked image in his personal student webpage or in the lesson's webpage, making it public.

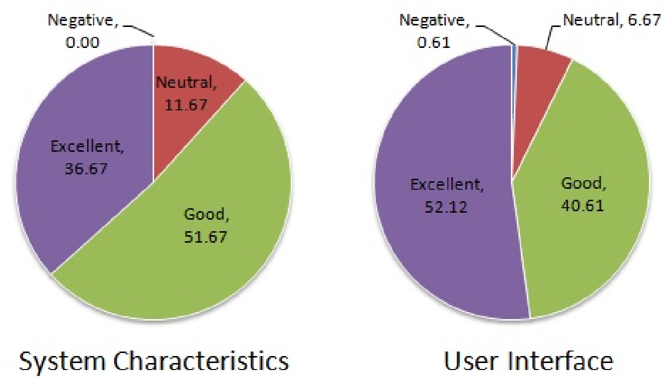


Fig. 8. The results of evaluating the technical characteristics and the user interface of the WaterIP system in the classroom.

In this paper, we describe a lesson plan of how our WaterIP system was efficiently applied, in a class of undergraduate students, in supporting a course on IP.

A. Course Design

We next describe in detail the lesson plan we applied to computer science students in order to teach them the notion of IP and the technical means that exist to protect their digital property. We also presented them in detail a watermarking technique for image authentication. The learning objectives of the course, according to Bloom's taxonomy of learning domains [2], [20], [24], are the following: (a) students to be able to recognize what kind of creations of their mind are protected and what kind of technological means exist to protect them (knowledge), (b) to be able to use a software to protect their property (skills), and (c) finally, to adopt this software in their everyday work with information and communication technologies (attitudes).

The course took place in a computer lab of our CS department where, in a class of 32 undergraduate students, we presented the aim of the course and the learning objectives of it. The course was divided into three learning-parts:

(A) In the first part we introduced the theoretical background of intellectual property rights and watermarking and we provoked discussion with the students in order to be informed about what they already know concerning these issues and which are their views before using the system.

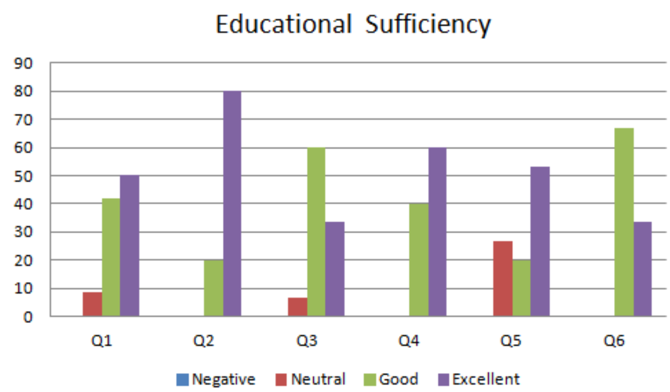
(B) In the second part we demonstrated the main characteristics and the user interface of our WaterIP system giving them the chance to familiarize themselves with it before using it.

(C) In the third part students had an hour of supervised lab to practise with the WaterIP system and complete a questionnaire; in particular, in this part each student could spend time at his computer and try the system uploading his own images and watermarking them. The images could have been whatever the student wanted, i.e., downloaded from the Internet, uploaded from a mobile phone or camera, or even from a provided database.

The goal of our course was to actively engage students in learning [21], and thus we selected for each part of the course different instructional methods [9], [15]. We next describe in detail how we applied each instructional method to each part of the course; hereafter we shall refer to a part of the course as course-action.

Course-action A: The teaching method we chose on this part was lecture with discussion. In order to figure out students' prior knowledge on IP, we used a widely known method, based on discussion, called Socratic method [29]. Each answer was written on board. The majority of the students considered that IP concerns only the right to financially benefit of a creation, ignoring the moral right on that. We also observed that they did not know many techniques to prove authorship of their digital creations; they were, although, familiar with visible watermarks on images. During lecture we used transparencies to provide visual presentation of information (definitions, flow charts, images, graphics) concerning IP and watermarking. We encouraged students to discuss on intellectual property violation in digital world and to share their experience if anyone ever violated their creations of mind and express their feelings. In each case, we explained to the students which IP right was violated. Finally, in order to prepare them for the next course-action, we defined the term of watermarking and explained a case of digital image watermarking.

Course-action B: In this part we demonstrated the operational characteristics of our watermarking tool. We explained step-by-step how to embed (resp. extract) a watermark into (resp. from) images selected from our image database or, alternatively, from the internet; note that, the watermark is selected by the user. We show that WaterIP is a tool which embeds and extracts invisible watermarks into images enabling a user to prove authorship.



Questionnaire:

Q1 The WaterIP system helps to understand the meaning of Intellectual Property.

Q2 The WaterIP system helps to understand the meaning of Watermarking.

Q3 The coherence and the structure of WaterIP system are capable of supporting the educational process concerning Intellectual Property.

Q4 The WaterIP software can be used in every day activities having to do with Information and Communication Technologies, i.e., watermarking images for public online usage (email, mms, facebook, websites, etc).

Q5 The waterIP motivates the students to learn more about Intellectual Property.

Q6 Being aware of the existence of WaterIP system would prevent you in using others' Intellectual Property.

Fig. 9. The results of evaluating the educational sufficiency of the WaterIP system in the classroom and the questionnaire used.

Course-action C: In the last part students downloaded the WaterIP system, from a given website, to watermark their own images. This allowed students to apply in practice the principles and theories previously presented. We observed that students went beyond the operations we demonstrated; for example, we mention that they altered the size and color depth of their images before watermarking them. Moreover, some of them watermarked images that they use in their websites, social accounts, etc. Before students answer the questionnaire, we summarized the main points of the course, we corrected misunderstandings, and asked students' opinion on the overall course. Finally, we asked if they would participate in a future learning experience concerning intellectual property rights.

B. Evaluation

In order to evaluate the course effectiveness, we asked students to complete a questionnaire based on a 4-point Likert scale (1 = Negative, 2 = Neutral, 3 = Good, 4 = Excellent) [19].

Through this questionnaire we aimed to obtain students' attitude on the following thematic issues:

(a) the technical characteristics of the WaterIP system,
(b) the interface of the system, and
(c) the course's learning objectives.

Figure 8 depicts the evaluation results on the technical characteristics and the interface of the system. Students with major in computer science practised with the system extensively, and expressed their opinion both by participating in an open discussion inside the classroom and answering the questionnaire. The majority of them considered that the interface was friendly and easy to learn. Also, they agreed that the system's operations obviously incorporate the operation presented in the lecture. According to the answers taken by the students, we concluded that the learning objectives were fulfilled, since 90% of students agreed that the educational sufficiency of WaterIP is good up to excellent. In fact, 80% of the students answered that WaterIP helped them to understand the meaning of watermarking (see, Question 2). Students were also asked to answer whether the WaterIP can be used in their every day activities such as e-mails, social networks, websites, etc; indeed, 60% of them agreed that it is useful on such activities. It is worth noting that, some part time students expressed their willing to use it professionally since they work as logo and website designers. We should also point out that, the majority of them were interested to learn more about IP and about other existing techniques or tools protecting IP (see, Question 5).

Another interesting fact is that the percentage of students who believe that WaterIP helps to better understand the meaning of IP rights (see, Question 1) is less than that who believe that WaterIP helps to better understand the image watermarking (see, Question 2). An explanation of this result is basically based on the fact that WaterIp simulates the image watermarking problem, and thus computer science students paid more attention on the technical part of the notion of watermarking and they did not focus on the idea behind it, which was the IP issue. In fact almost all students wanted to learn the exact embedding and extracting algorithms and how these algorithms have been implemented into the WaterIP system. All students found that the course was an opportunity to learn or deepen their knowledge about different concepts related to the field of IP rights and watermarking.

In closing, we point out that 51.56% of students suggested improvements on the technical part of the system; they believe that the system should warn the user with more messages for a non allowed operation.

V. Concluding Remarks

In this paper, we proposed a new pedagogical tool that provides a step-by-step demonstration of embedding and extracting watermarks into images defined by the user in the form of permutations. Our system, named WaterIP, incorporates concepts from graph theory (2D representations of permutations) and image processing (editing values of space domain), it has a friendly graphical user interface, and it is designed to be used to support the teaching and learning process on intellectual property rights. We also demonstrated its educational effectiveness by presenting ways of how it can be applied in class.

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