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Original article

Digital color restoration for the preservation of reversal film heritage

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ABSTRACT

During the last four decades of the 20th century, reversal films have been very popular in many parts of the world, being used for both educational and recreative purposes, even projected in many private homes. The Romanian Animafilm studios published throughout the decades an impressive collection of such films on various subjects, mostly animated stories, but also with historical or educational topics. Today, the existing film rolls are suffering from time decay, the obvious wear and tear from being projected so many times or simply stored, but also specific reversal-film preservation issues. The goal of our research is to investigate the possibilities of reversal film image digitization, color enhancement and digital restoration for the purpose of preserving its heritage and also increasing its content availability in the digital era. In this paper, we describe the digitization, color enhancement and digital restoration results obtained on degraded reversal films containing animated stories by proposing and applying a specific set of unsupervised, pipelined image processing tasks performing color cast removal and color correction. We present our experimental results, discussion and conclusions.

1. Introduction and research aim

Reversal film (or *diafilm* as it is known in Romania and some other countries) is a type of film that produces a positive image on a transparent celluloid base. Given its low processing cost, reversal film has been very popular during the 20th century until the 1990s. In Romania an impressive collection of reversal films has been published and made commercially available in this period of time, containing animated stories, documentaries, touristic and historical exhibitions and so on [16]. Many people own even today such films in their personal archives, but even more important, they are archived in many educational and cultural institutions. They are today a part of the 20th century legacy, in the same time containing images of sights, monuments, panoramas that can no longer be seen in the real world, and their reversal film images are sometimes the only thing preserving their heritage.

However, aging is a process that brings unwanted consequences on these reversal film stocks, like the common decay caused by natural factors like temperature, humidity and light (few of these film stocks have been properly stored in controlled conditions) [8], but also specific issues like the low exposure latitude of the reversal film. This last issue is a known one regarding this type of film [15], making it more dependent on correct exposure and the choice of scene contrast [4]. Thus, preserving reversal film is a challenging task, but one that has been underlined by film theoreticians half a decade ago [25], who anticipated the growth of interest in reversal films as time went on, and emphasized the need for preserving them given its constructive low longevity span.

There are two distinct degradation phenomena that affect the reversal film: degradation of the celluloid film material and the color dye fading. The celluloid degradation is caused by four distinct processes: thermal, chemical, photochemical and physical [18]. The first three types of degradation imply chemical reactions that modify the celluloid at a molecular level and that are influenced mainly by environmental factors which are represented by the storage conditions. The last degradation type – physical degradation – can occur as a consequence of the other three deterioration processes and can also be related to the physical manipulation of the film roll [18]. Since the reversal film is a unitary celluloid strip comprising all the slides, one can assume that the film roll, as a whole, has been the subject to the same degradation processes affecting the celluloid, thus it is expected that every section of the roll (every slide) was affected similarly.

The second degradation phenomenon that affects reversal films is color dye fading, a process that occurs because of chemical reactions at the molecular level [17]. Dye fading is a natural aging phenomenon, caused mainly by heat energy and moisture in the case of dark fading (which goes on in the dark, when the film is

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(a) Original film slide (b) Histogram equalization (c) Contrast enhancement

Fig. 1. Grayscale reversal film slide – color cast removal examples.

(a) Făt Frumos din Lacrimă (b) Iarna pe Uliţă

(c) Mircea cel Batrân (d) Greierele şi Furnica

(e) Moş Ion Roată (f) Turtiţa

Fig. 2. Several scanned diafilm slides exhibiting color cast and scratches.

stored), and light exposure in the case of light fading (which happens when the film is on display) [17]. This process affects each dye individually, according to the specificity of its molecular structure, but it affects all the molecules of the same dye in the same manner [17]. Fading is a loss of density, reducing the contrast of each individual dye layer according to the dye's specific fading characteristics [4]. This density loss is noticeable at first in the highlights, where detail and texture disappear, followed by the loss of medium tones [22]. Consequently, we can consider the degradation caused by dye fading to affect all slides within the film roll in the same way.

For the case of grayscale reversal films, correcting the dye fading effect is a relatively simple task, using either a histogram equalization or contrast enhancement using a sigmoid level transformation function. Even though the black and white reversal film may suffer from color cast (e.g. a greenish cast like in Fig. 1a), the simple conversion to grayscale allows for the afore-mentioned techniques to be applied. For instance, in Fig. 1 we show the results of applying these methods for a grayscale film slide of the *Făt Frumos din Lacrimă* animated story.

In Fig. 2 we show several scanned diafilm slides, exhibiting various degradations and color cast as a function of their film origin/producer: *Făt Frumos din Lacrimă* is a grayscale diafilm on AGFA (Germany) film, relatively well preserved and showing a slight greenish color cast; *Iarna pe Uliţă* (Winter time in the village lane) and *Mircea cel Batrân* exhibit a greenish color cast and they are ORWO (Germany) films; the other three (*Greierele şi*

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