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May/June 2022 year XXVI N°3

GEO MEDIA

Mobile Robotics and Autonomous Mapping

- DATA COLLECTION AND PUBLICATION WITH QGIS
- PLAYING WITH COLORS ON PANCHROMATIC AERIAL PHOTOGRAPHS
- MODELLING WATERSHED PHENOMENA WITH QGIS

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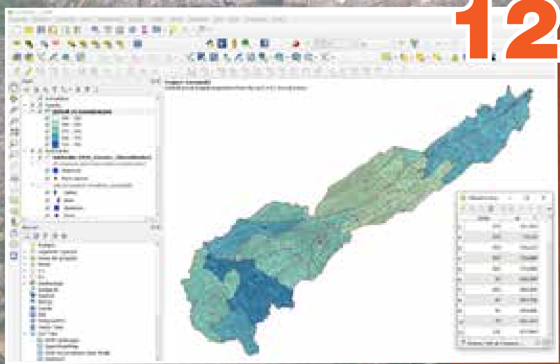
REPORT



Columns

On the cover the sensorized mobile platform developed at University of Udine, Italy.

GEO MEDIA
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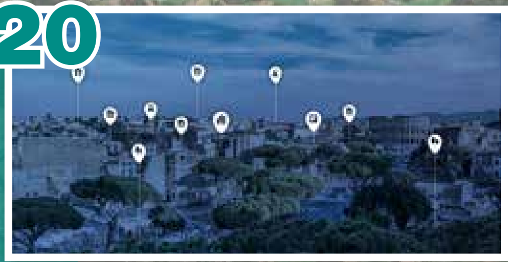

ADV

In the background image: Bonn, Germany. This Esa Image of the week, also featured on the Earth from Space video programme, was captured by the Copernicus Sentinel-2 mission, that with its high-resolution optical camera, can image up to 10 m ground resolution.

(Credits: ESA)

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L'Aerofototeca Nazionale racconta...

by Gianluca Cantoro

POTATOES, ARTIFICIAL INTELLIGENCE AND OTHER AMENITIES: PLAYING WITH COLORS ON PANCHROMATIC AERIAL PHOTOGRAPHS

Fig. 1 - Example of pan-sharpening between a satellite image and an historical panchromatic photograph (top and bottom left). In the column to the right, three different algorithms, respectively (from top to bottom) Brovey, IHS and PCA.

Towards color photography

During the first half of 19th century, photography stimulated people's imagination and wonder. Despite the impressive quality of the first trials, photographs lacked the realism provided by natural colors, at times added in post-production –as we would say today– by specialized painters (Coleman, 1897, p. 56) who felt threatened by the emergence of photography. Following Rintoul, "when the photographer has succeeded in obtaining a good likeness, it passes into the artist's hands, who, with skill and color, give to it a life-like and natural appearance" (Rintoul, 1872, p. XIII–XIV).

A French physicist, Louis Ducos du Hauron, announced a method for creating color photographs by combining colored pigments instead of light, as suggested by Maxwell's demonstration of 1861. His process required long exposure times, and this problem built on top of the absence of photographic materials sensitive to the whole range of the color spectrum. Other inventors and scientists tried to solve the challenge of color photographs, but all trials were quite expensive and needed specific equipment and complex procedures.

The first patent of color photograph, combining both screen and emulsion on the same glass support under the name Autochrome, was registered by Auguste and Louis Lumière in 1895, the same year of their invention of the Cinématographe. The manufacturing of autochrome plates was a complex process, starting with the sieving of potato starch (to isolate individual grains between 10–15 microns in diameter), whose grains were then dyed red, green and blue-violet, mixed and spread over a glass plate (around four million transparent starch grains on every square inch of it), and coated with a sticky varnish. Next, charcoal powder was spread over the plate to fill any gaps between the colored starch grains.

Autochrome plates were simple to use, they required no special apparatus and photographers were able to use their existing cameras. Exposure times, however, were long –about 30 times those of conventional plates. Nevertheless, by 1913, the Lumière factory in Lyon was

producing 6,000 autochrome plates every day. This testifies of the appeal of color photographs already in those early times.
Is it possible today to convert native black and white images (raster digital pictures, not prints or negative anymore)? And why should one take the trouble to convert panchromatic into color images after all? This paper presents some experiments to colorize historical photographs, in the effort to boost our capabilities to undisclose information from frozen moments captured by cameras and to –ideally– promote further the use of aerial images in various fields.

Fig. 2 - Example of visual trick for image colorization inspired by the Color-Assimilation-Grid-Illusion. Top-Left: historical vertical image of Ostia of 1985 precisely georeferenced over the bottom satellite image. Bottom-left: Landsat/Copernicus satellite image of the same area of 2019. Top-Right: historical panchromatic with over-saturated color grid extracted from the available satellite image. Bottom-Right: Detail of the image above to show a close-up look at the colored grid and the black and white background.

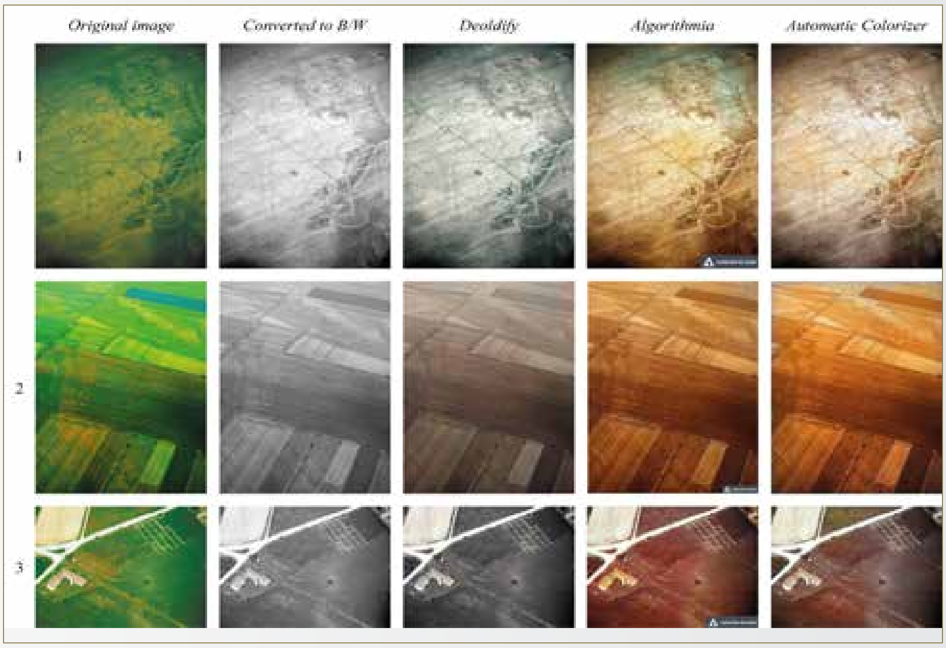

Fig. 3 - Application of automatic colorization algorithms (Deoldify, Algorithmia and Automatic Colorizer) to three oblique photographs (Original Image). Photographs by Otto Braasch (Musson et al., 2005, fig. 10.8, 10.9, 10.7) edited for the proposed approach.

Colors in Remote Sensing

Some procedures in remote sensing are known and frequently applied to satellite images, to improve the resolution of a color image with the details of its panchromatic twin. This fusion procedure, known with the term pan-sharpening, can be applied to satellite imagery through numerous algorithms, and it produces a sensible increase in the accuracy of photo-analysis and derived feature extraction, modeling and classification (Yang et al., 2012). The most commonly used algorithms include IHS (Intensity, Hue and Saturation) (Schetselaar, 1998), PCA (Principal Component Analysis) (Chavez et al., 1990), the Gram-Schmidt Spectral Sharpening (Laben Craig and Brower Bernard, 2000) and the Weighted Brovey transform (Chavez et al., 1990).
The various pan-sharpening techniques have two main factors in common: 1) they are normally applied to satellite images, namely multispectral and panchromatic bands; 2) the two datasets to be fused should have been captured (almost) simultaneously. For these reasons it is apparently not possible to fuse an historical aerial image with a satellite image, which is what we are going to try here. Proposed methods are not conventional and may therefore attract comprehensible skepticism, but they should be intended as a proof-of-concept or experiments

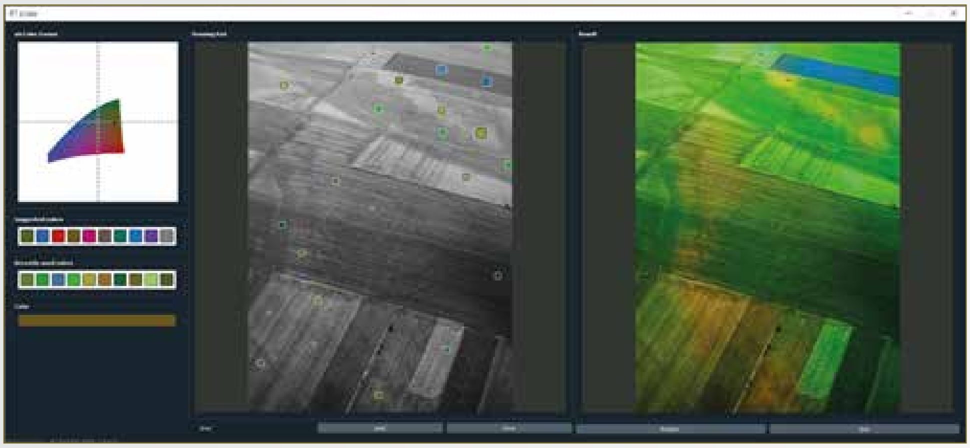

Fig. 4 - Interactive Deep Colorization User Interface. After clicking on a specific point on the black and white image (see colored spots on left image in the interface), the user can assign a color from the "ab Color Gamut", the "Suggested colors" or the "Recently used colors". Results are presented in real time to the right of the UI and can be saved at any time.

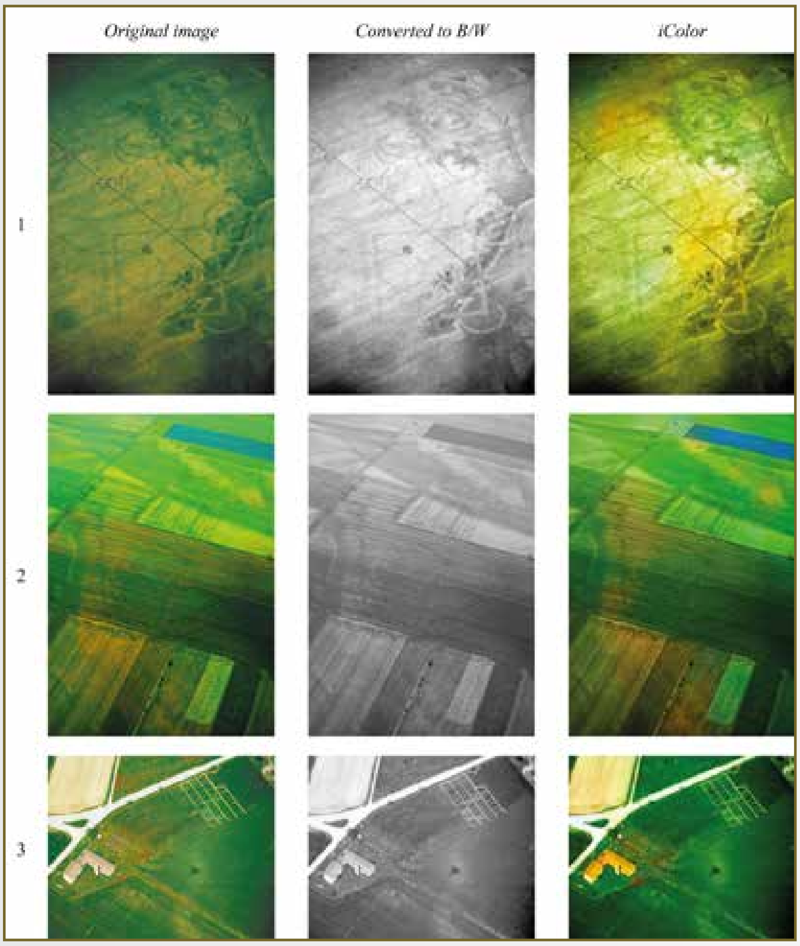

Fig. 5 - Comparison of processing of the same pictures as for Fig. 3 with Interactive Deep Colorization (or iColor).

to test the capabilities of modern computer approach to obtain a realistic representation of past environments in natural colors for the benefits of photo-readers.
For example, since our objective is mainly to get a colorized historical image, we can adjust reciprocal resolution of our vertical and satellite images of exactly the same area. A similar approach has been explored recently (Siok and Ewiak, 2020) with aerial and satellite images of about the same period and without dramatic changes in cultivations or plot sizes. Indeed, the processing of areas that changed across time (i.e. between the date of the historical photograph and the date of the chosen satellite image in terms of time of the day, season or cultivations/urbanization processes) may produce some unpleasant artifact (see in Fig. 1 the details of the trees and bushes colors which are larger than in the historical image), but in this case a targeted editing with computer graphic software may minimize the problem, if needed.
Once such high-resolution color image is being generated, the applicability of multiple operations can be explored, such as image classification and feature extraction.
Another approach, completely different in terms of processing and output, is the use of an operation called Color-Assimilation-Grid-Illusion (Kolås, 2019). As the name suggests, this approach is a mere visual trick and it is presented here mainly for dissemination purposes (not for an improved photo-interpretation) and as a sort of mild invasive way to add colors to black and white images. It consists in overlaying grids (or lines or dots) of over-saturated colors over black and white images; our brain essentially fills in the missing colors that it would anticipate, or expect, to be there in a full color image.
The image processing is intended to be used on one single color image, that is converted to grayscale and overlaid with the original colors only through a grid. Instead, in our case, starting from the same inspiring principle, we take the historical aerial photograph that we want to colorize, and a satellite image (ideally of about the same season) of the same

Fig. 6 - Possible variants generated with iColor of the same image with deliberate selection of false colors to make specific features more visible or for other applications.

area; we generate the color grid from the satellite image, over-saturate it and overlay it over the panchromatic picture (Fig. 2). Calibration of the above experiment may be needed according to the printing or screen zoom size, nevertheless, it is an easy effect to colorize historical photographs.

The Machine Learning automatic and semi-automatic approach

Machine learning has been explored in several fields for its ability to "learn" the intended process from A to B with the help of prepared dataset. Algorithms are available to convert black and white images into color one, based exactly on a learning dataset. In this sense it could be applied to historical aerial images as well, but again, here the intent is to generate an image with colors that are plausible, not to produce an accurate representation of the actual snapshot in time.
Below (Fig. 3) are some examples of oblique photographs originally taken with digital camera in color, then converted to black and white for the sake of the experiment, and colorized back with three automatic algorithms for image processing: Deoldify (Antic, 2021) (or DeepAI), Algorithmia (Zhang et al., 2016) and Automatic Colorizer (Larsson et al., 2017).
The chosen algorithms, selected for their simplicity of use, for their advertised capabilities and for their availability as open-source code or online demo, are examples of a computer problem called image-to-image translation, whose success depends by the provision of sufficient (and compatible) training data (Tripathy et al., 2018). Since the training data is mostly made of ground photographs of natural subjects, portraits or architectures, the obtained result in our case is mostly unsatisfactory, especially when looking at the original (our "ground truth") but also if we consider the generated images on their own for photointerpretation.
Different result is instead achievable with another algorithm of the same family, which has an interactive model that allows user to manually input colors on black and white image based on chrominance gamut: it is the case of Interactive Deep Colorization (or iColor) (Zhang et al., 2017) (Fig.4).
By default, the first proposed colorized image in this algorithm is very much similar to the ones generated by similar algorithms (see Fig. 3), but once specific colors are selected, the result improves considerably reaching a good proximity to the original images of our test cases (Fig. 5).
If from one side the Interactive Deep Colorization algorithm allows one to create images with plausible colors, possibly similar to the originally depicted subject, it also provides the option to deliberately choose "wrong" colors, and somehow create a completely unreal scenario (Fig. 6), which may make sense if they are employed in our case to highlight specific features or shadows.

Conclusions

In modern photo-interpretation, crop-marks – as well as weed-marks, germination-marks and grass-marks – by definition are made of vegetational stress or differential growth in green fields. Even with soil-marks, shades of brown help us recognizing patterns in arable lands.
Seeing black-and-white images in color has the potential to brings certain details to life that would otherwise be missed or hardly be visible. This sense of immediacy is why color images feel more relatable.
Historical vertical photographs traditionally served (and still serve) immensely for the study of landscape changes and the identification of archaeological traces (among others) for the reconstruction of topic palimpsests. They often provide details that have no equals in color images so far and, training on photo-interpretation black and white images cannot be ignored or replaced in any way.
In the paper an effort is presented to push the boundaries of consolidated

practice in remote sensing and artificial intelligence, together with the attempt of presenting a visual trick for dissemination purposes. The proposed methods change the current paradigm with respect to employed algorithms and dataset to which the algorithms are applied, aiming at a new way of looking at historical aerial photographs and ideally unveiling a new dimension in past-landscape studies and dissemination.

The various procedures are all oriented towards the artificial colorization of historical aerial photographs, natively black and white. These “bizarre” trials are intended as ways to promote new approaches to legacy data, with the ultimate goal to simplify or enhance aerial photo-interpretation and involve non-experts in the narration of the past made through photographic documents.

Lastly, artists dealing with historical image colorization admit the intense and time-consuming effort required to achieved a realistic result and a philological reconstruction, involving historical research, comparative materials and interviews with witnesses or experts. Therefore, black and white colorization may be a creative process that can increase focus and attention on what we see (or we don’t see) in historical aerial images.

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KEYWORDS

Color photography; artificial intelligence; image-to-image; remote sensing; air-photo interpretation;

ABSTRACT

Historical photographs, whether taken from the air or from the ground, are usually synonyms of grayscale or sepia prints. From the very beginning of photography, during the first half of 19th century, people were amazed by this new media that could record all aspects of a scene with great detail. Soon though, everybody started wondering why would such an impressive innovation fail to record colors? A process of trials and errors then started (including the most successful and pioneer one, involving the use of potato starch, by Lumière brothers) aiming to add colors to photographs, till the consolidation of new systems (camera and film) capable to collect photographs directly in color. In the past, before and during this innovative approach, native black and white photographs were painted in the effort to give them life. Today, only few methods are available to convert a panchromatic image into a color one, and they need a number of steps and further development to work properly. The paper tries to present different methods to colorize native black and white photographs, based on available automatic or interactive Artificial Intelligence (Machine Learning or Deep Learning) algorithms, on revised remote sensing procedures and on visual tricks, aiming at exploring the possible improvement in readability and interpretation of photographed contests in the usual analytic process of photo-interpretation. At the same time, colorized historical photographs hold different appeal in the general public and have the potential to attract and involve non-experts in the archaeological/historical reconstruction phases.

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