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Use of telemetry X-ray techniques in large-size pictorial works

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Abstract: In recent years, with the rise of digital technologies and the concurrent demise of related analog instrumentation, researchers in the field of cultural heritage have faced significant new challenges implementing digital solutions.

Specifically, this shift has prompted the use of new protocols for the application of radiology in the study of art works. However, due to this change, there has been a return to using older film formats, which is one of the problems that has already been solved using an industrial-type analogical system that allowed large-format X-ray support, and that was able to adapt to almost any surface.

Therefore, this study attempts to rectify the limits of digital X-ray techniques by using telemetry X-ray techniques. At the Laboratory of Documentation and Registration (IRP, or Institute for the Heritage Restoration), based at the Universitat Politècnica de Valencia (UPV), Spain, mobile telemetry X-ray equipment has been designed and implemented to allows the adaptation of large-size pictorial works.

Keywords: pictorial works, X-ray, radiology, telemetry X-ray techniques, large size paintings.

El uso de radiografía telemétrica en obras pictóricas de gran tamaño

Resumen: En los últimos años, con el auge de las tecnologías digitales y la desaparición simultánea de la instrumentación analógica, los investigadores en el ámbito del patrimonio cultural se han enfrentado a nuevos e importantes retos en el desarrollo de soluciones digitales.

En concreto, este cambio ha llevado a la utilización de nuevos protocolos para la aplicación de la radiología en el estudio de las obras de arte. Sin embargo, debido a este cambio, ha habido un retorno a la utilización de los antiguos formatos de película, problema que había resuelto utilizando un sistema analógico de tipo industrial que permite el apoyo de rayos X de gran formato, y que fue capaz para adaptarse a casi cualquier superficie.

Por lo tanto, este estudio trata de rectificar los límites de las técnicas de rayos X digitales mediante el uso de técnicas de rayos X junto con el empleo de las placas telemétricas. En el Laboratorio de Documentación y Registro (IRP, o Instituto de Restauración del Patrimonio), con sede en la Universitat Politècnica de Valencia (UPV), España, se ha diseñado un equipo de radiografía telemétrica móvil que permite su adaptación a obras pictóricas de gran formato.

Palabra Clave: pintura de caballete, rayos X, radiografia telemétrica, gran formato.

A utilização de radiografia telemétrica em obras pictóricas de grande formato

Resumo: Nos últimos anos, com o aparecimento das tecnologias digitais e o desaparecimento, simultâneo, da instrumentação analógica, os investigadores da área de património cultural têm-se confrontado com novos e importantes desafios para o desenvolvimento de soluções digitais.

Concretamente, esta alteração tem suscitado a utilização de novos procedimentos quanto à aplicação de radiologia no estudo de obras de arte. No entanto, por causa desta alteração, tem havido um regresso aos antigos formatos de película, questão que tinha sido resolvida, utilizando um sistema analógico de tipo industrial que permite um suporte de radiografia de grande formato, capaz de se adaptar a, praticamente, qualquer superfície.

Deste modo, este estudo tem como objetivo rectificar os limites das técnicas de raios X digitais, usando técnicas de raios X juntamente com placas telemétricas. No Laboratório de Documentação e Registo (IRP ou Instituto de Restauración del Patrimonio), com sede na Universidade Politécnica de Valência (UPV), em Espanha, foi desenhado um equipamento de radiografia telemétrica portátil que permite a sua adaptação a obras pictóricas de grande formato.

Palavras-chave: pintura de cavalete, raios X, radiografía telemétrica, obras de grande formato.

Introduction

In the application of X-rays to study internal structure of art works, we have used an adapted the research of Arturo Gilardoni (Gilardoni, 1994).

Commercially available radiographic plates are not commonly adapted to cultural assets. During the past few years, industrial X-rays have allowed us to adapt and obtain X-rays of large-size pictorial works. In the Museo del Prado, Carmen Garrido pioneered work in this area (Garrido, 1984).

In recent years, commercially-available industrial X-ray films supplied in 'daylight packaging' were used to adapt to the surface of all kinds of art works and allowed oversize X-radiographies to be obtained. Initially, to conduct a complete X-ray examination of a large-size pictorial work, assembled X-radiography had to be performed. This approach has the disadvantage of producing x-radiographs with different gray scale densities. This introduced a difficulty that affects the understanding of such register. The ability to build a complete surface register for a single radiographic exposure presents the advantage that the gray scale shown in the registration was homogeneous.

In 2000, the X-ray analysis service developed a methodology that sought to optimize all factors involved in obtaining quality X-rays and remove some of the subjectivity present in the selection of exposure time. The system was based on the measurement of the radiation dose, which was collected in the same plane of the X-ray and the level of blackening or optical density obtained (Madrid, 2000).

Beyond this, we faced a new challenge of adapting these strategies to new materials and equipment for obtaining radiographic records.

This is the reason why we have been interested in existing possibilities in this field, such as direct radiography or digital radiography plates, with the latter being preferred. There were several reasons that aided us in making this decision, but the most important was the ease of adaptation of this system to the traditional one. The work presented here provides evidence for this (Figure 1).

Since the acquisition of indirect digital radiography equipment (Computed Radiology, CR) by this laboratory, a number of adjustments in relation to the voltage and the exposure time have been carried out to interpolate the integrated dose data and adapt the level of blackening obtained in digital recording. This has improved the possibilities of the digital system, which consists of a dynamic range that allows radiography with a smaller quantity of integrated dose.

Once this question was remedied, the problem of obtaining digital large-format radiographs was tackled. The basis for the improvement and design of a mobile wall telemetric X-ray device system is detailed below.

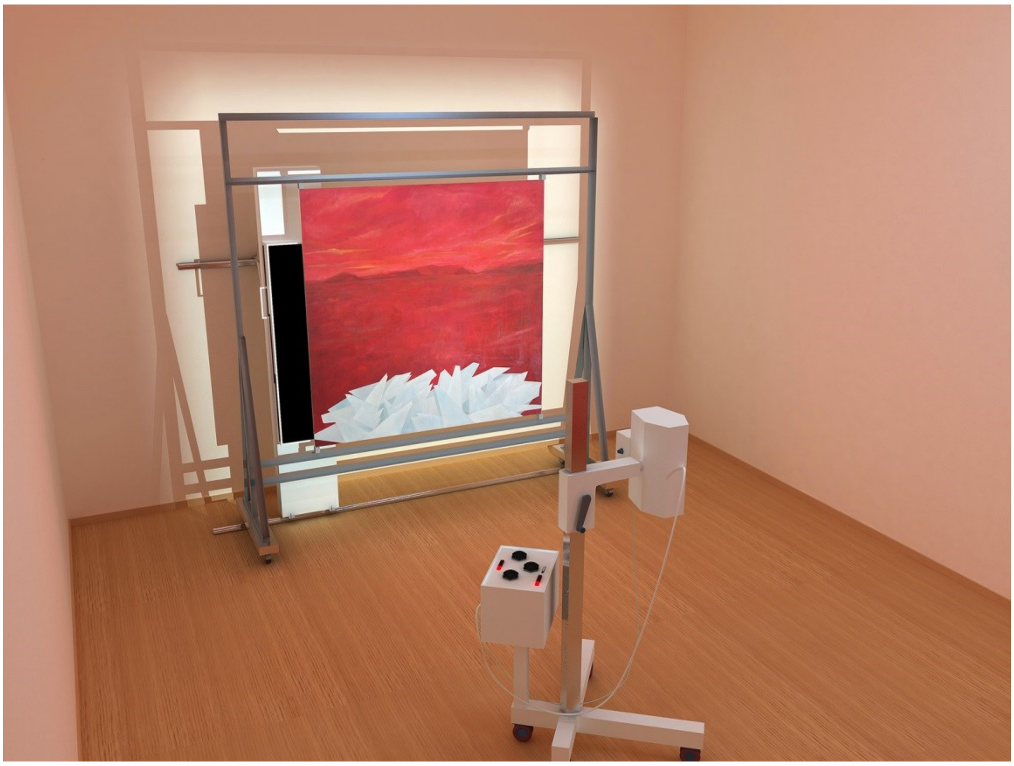

Figure 1: Virtual image of the study.

Laboratory equipment and its adaptation to the telemetric X-ray mobile system

These studies were performed using TRANXPORTIX 50 ® General Electric Company equipment. This equipment has a 3 kV X-ray tube and a 2.3 mm focus, with a 2mm aluminium filter to control the absorption of the X-ray beam, which allows it to work at very low voltages, from 20 to 110 kV. Additionally, the intensity range is also appropriate for this type of study, owing to fixed values of current intensity of 10 and 20 mA. A light collimator centers and locates the beam system of the irradiated area, to which a marker system has been adapted to ensure an effective irradiation area.

The facility also has an indirect radiography CR workstation. Set in concrete, with an AGFA ® CR 30-X digitizer, this is one of the most versatile instruments used for this type of work. The CR 30-X combines with the image identification software and quality control AGFA® NX. This station processes the digital images obtained with the indirect digital system through the CR MDT4.0T chassis, also from AGFA®, in a format of 35 × 43 cm2 and a pixel matrix size of 3480 × 4248 pixels2.

These chassis are mounted on an installation dedicated to telemetric X-rays, which facilitates an X-ray effective area of 126 × 33 cm2. The telemetric X-ray system, or the CR Easylift® using its commercial name, from AGFA, permits the superimposition of three chassis in the same plane, and offers an effective area of X-ray. These three plates are mounted in a mobile freight car, which can move in a vertical plane from 0 (e.g. level position) to 230 cm of the maximum height (Figure 2).

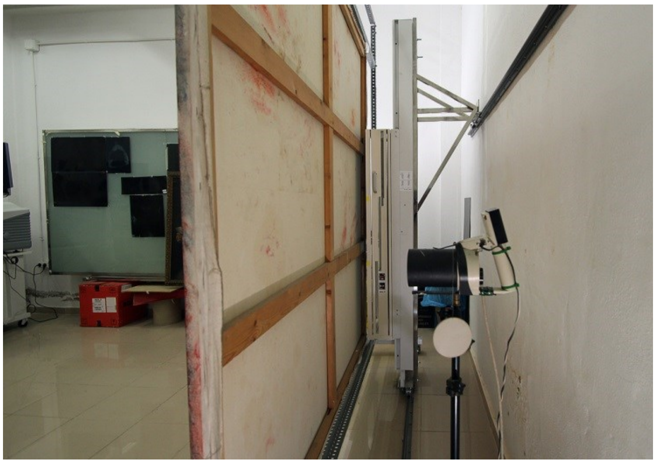

Figure 2: Location of devices.

To make this system more efficient, the IRP Laboratory of Documentation and Registration has built a mobile structure that supports the telemetric X-ray device with two rails. One rail is placed on the wall and the other on the ground. A Teflon-coated roller system ensures smooth displacement movement of the whole system.

The measurements of the rails are 300 cm, which are predefined by the film-to-focus distance that is tangential to the wall. This measurement is the maximum one that the source can be placed at, and we can cover all the area generated by the displacement in the horizontal axis of the mobile system. Including the two movements, one in the horizontal plane of 300 cm and the second in the vertical plane of 0–230 cm, the plate has an area of approximately 7 m2. In the rail system, we have adapted some objects that help the positioning of the system along the route followed.

Likewise, the constant need for loading and unloading of the chassis by hand has been taken into account, which is why the structure has been separated by 70 cm from the vertical rail, to maintain accessibility.

A mobile stretcher has been built to hold the paintings, which anchors the artwork by the upper and lower parts. The material used for holding the artwork is high-density polyurethane foam, which is transparent to radiation.

A radiation monitor completes the equipment. This device, a Ram Ion ® (Rotem Company) ionization chamber, has an auto-ranging system. We have used it for dose-integrated measurements.

Current X-radiography protocol

The work protocol is summarized by the following:

- obtain pre-exposure measurements;
- characterize the points for mural radiography obtained with telemetry X-rays;
- execute the mural radiography;
- edit assembled X-radiography with an image-processing program.

The first phase, involving obtaining dosimetric measurements, permits the evaluation and adjustment of the exposures. From a sequence of shots, with some fixed exposure time values, the relationship of integrated dose and the slope of its equation relating to time of exposure is determined (Madrid, 2000). In this way, we ensure that the radiography will obtain the best level of optical density (Table 1).

Once fixed, the different parameters of the exposure sequences, such as the voltage, the current, the distances between the focus and the register, and the exposure times, establish a grid of points that mark the different positions of the location of the slide-wagon that carries the chassis. The distribution of these points should ensure a minimum area of overlap between one plate of the telemetric X-rays and another plate.

At this point, each of the wall radiography shots can be taken. These are then downloaded in a sequence of X-rays that the computer, through the image identification program and quality control AGFA® NX, presents in a single image. These sequences, or telemetric radiographs, are transferred to an image program capable of reading the Dicom system, where they are later assembled into a full image mosaic in TIFF format (Figure 3).

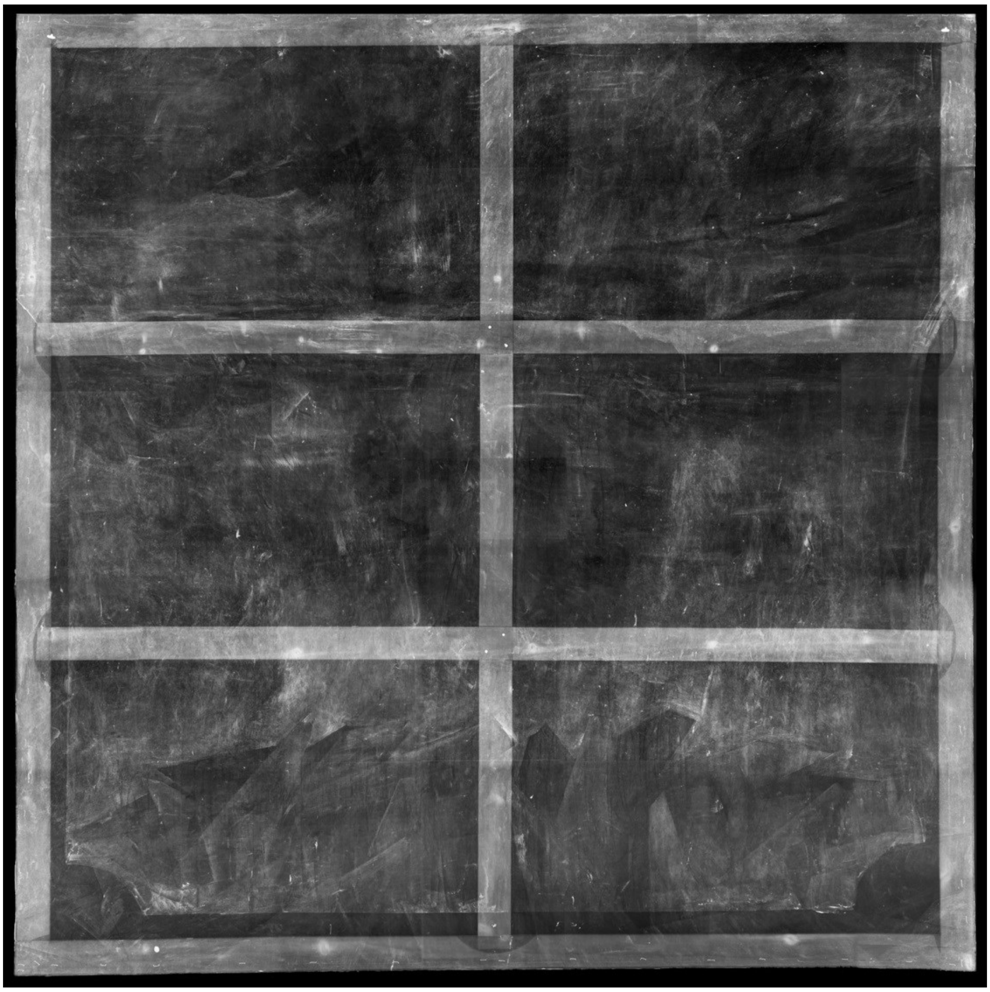

Figure 3: X-rays of the "Equinox" by Rosa Martinez.

Table 1. Measurements of doses in the telemetric X-ray.

Nº Telemetric	Dose (microSv)
1	19.50
2	23.10
3	19.00
4	19.00
5	23.00
6	24.00
7	21.00
8	17.00
9	19.00
10	19.00
11	16.00
12	18.00
13	22.68
14	22.10
15	17.40
16	21.50
17	17.00
18	20.00
19	21.00
20	18.00
21	15.00
22	23.00
23	20.00
24	20.00
25	19.00
26	12.00
27	22.00
28	16.00
29	19.00
30	17.00
31	16.00
32	20.00
33	16.00
34	17.00
35	20.00

"Equinox" by Rosa Martinez: practical application

An artwork by Rosa Martinez, which belongs to the Polytechnic University of Valencia Art Heritage Fund, was chosen to test the practical application of this system. The canvas "Equinox", made in acrylic, has dimensions 200 cm2. This kind of work not only presents a problem for undertaking X-ray studies due to its size, but also presents a challenge in optimizing the optical density due to the pictorial technique. Because the constituent materials of this painting have a very high degree of contrast among the different materials is needed so in the radiograph (Figures 4, 5).

To cover the whole 200 cm2 area, the beam of X-rays had to be displaced by a total of 500 cm. This distance ensured an area of irradiation of over 25% of this painting. In this type of study, it is important to have a margin in the irradiation zone because the X-ray beam does not radiate the whole perimeter in a uniform manner (Madrid, 2006). The grid that was established to determine the different points of execution of the assembled X-radiography constitutes a mosaic of 35 plates of mural X-rays, composed of 7 columns and 5 rows, ensuring an overlap area of 5 cm on its horizontal dimension and 10 cm in its vertical dimension.

The sequence of exposures was performed with the following parameters: 62 kV voltage, 20 mA current, and 5 s of exposure, for all exposures. The readings of integrated dose had a mean value of 19.12 μSv and a standard deviation of 2.69 μSv.

The 35 wall X-ray plates were processed using commercial digital image processing software, capable of reading Dicom files. By means of a similar point locating system, we have adapted each one of the files until complete registration is obtained.

Figure 4: "Equinox" by Rosa Martinez.

Figure 5: Back of the painting.

Conclusions

Taking into consideration all the information revealed in our study, we can summarize the most significant conclusions.

Through the practical application of this study, it has been demonstrated that the transition towards a new technology, in this case, the application of digital X-rays, is an opportunity to revise and improve conventional installations.

Digital X-ray analysis has been developed to an optimum quality using plates through a simple work protocol adaptation.

The post-processing control of digital X-ray films improves the likelihood of contrast adjustment improvement. This is a fundamental aspect in work using a low X-ray absorption technique.

The digital system presents advantages due to its versatility in obtaining registration and provides a considerable cost reduction for this type of study.

This study has been able to set up substantial points of improvement for future research. On one hand, the automated movement of the CR Easylift® over the rails allows to maximize radiographed area as well to minimize loss zones between the various plates. On the other hand, the digital data treatment will enhance the adjustment resulting from exposure log mediate (LgM) related to the digitalization process of the plate.

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