THE UNIVERSITY OF CAMPINAS

ARTS INSTITUTE

Unseen Photography

X-ray photography as artworks

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Fotografia Oculta
Fotografia de raio-x como obra de arte

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Abstract: Following the transformations of contemporary art and technology in the 21st century, this project is the prelude to the process of exploring new possibilities of artwork using X-rays. X-ray technology has been used until now, especially for the technical aspects of analysis, restoration, and authentication. This work uses X-ray images as artistic expressions. It explores electromagnetic waves beyond the visible part of the spectrum, discovering the Unseen Photography. Therefore, the original work is consciously created to be X-ray scanned afterwards, and together, the work and the X-ray photographs form an artistic unity of the final artwork.

Keywords: Photography; X-ray photography; Contemporary Art; pigments; art

Resumo: Acompanhando as transformações da arte contemporânea e da tecnologia do séc. XXI, este projeto é o prelúdio do processo de exploração de novas possibilidades de trabalhos artísticos utilizando raio-x. A tecnologia de raio-x é usada até hoje principalmente como aspecto técnico de análise, restauro e autenticação. Este trabalho utiliza imagens de raio-x como expressividade artística. Explora diferentes faixas do espectro eletromagnético além da visível, em específico a faixa dos raios-x, revelando a Fotografia Oculta. Sendo assim, a obra original é criada conscientemente para ser escaneada em raio-x depois, e juntas, obra e fotografia de raio-x, se tornam uma unidade artística do trabalho.

Palavras-chaves: Fotografia; X-ray photography; Arte Contemporânea; pigmentos; arte

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“However, the metaphor is similar: what we call works of art, according to Heidegger, are nothing more than appearances that present us with the truth of things (or people, or the cosmos), as long as we understand the word <<truth>> as a desiccation or an unhidden. The disclosure brings back from oblivion what is hidden. Truth (in Greek aletheia) is what is not-forgotten, what is not-lost, what is not-hidden and, therefore, what appears before our eyes with the luminosity of evidence is true.

Félix de Azúa

1. Introduction

Art was together with science when it was born (Schulz, 2021). In its history, photography was first presented in the scientific/academic scope of the academy of science. To then conquer its space, not without resistance, in the area of arts. After the discovery of the X-ray in 1895, it began to be used by artists in partnership with scientists to analyze works of art (Mantler, 2000, Kajiya, 2012, Balbino, 2018, Rizutto, 2019). The project begins a research process into the use of X-ray technology to create contemporary works of art. It proposes uses and technical possibilities of a potential tool. As a result, the final work presented is the prelude that materializes and concretizes a new study of X-ray images.

The development of technology allows new ways of creating. Analog photography uses photographic film and photographic paper composed of a thin layer of gelatin that contains crystals of light-sensitive silver salts (the silver halides). In common X-ray (analog radiography), radiographic films composed of silver salts (AgBr, AgI) that are sensitized by X-ray photons[2] that were not absorbed by the object that was between the X-ray tube and the radiographic film.

Seeing that analog cameras developed and became digital, radiographic films are also gradually being replaced by digital detectors. The digital sensor allows, as well as the digital camera, a greater amplitude of image quality (in the case of measuring the energy frequencies of the photons) and possible imaging manipulations.

The study is composed of three parts. First, the methodological process shows the relation between photography and X-rays and their use in the area of arts. The second is the process of development and technical research. Third, the poetical and creative elaboration that gives life to the final work.

The construction of technical research starts with the creation of test paintings that compose the image library of the visible layer (the painting) and the unseen layer (the X-ray). Artistic expression goes from the visible spectrum to other levels of depth. The painting and X-ray set forms part of the work as a unit, the visible and the hidden.

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[2] photon: excess energy from the passage (quantum leap) of an electron from one shell to another. It is the smallest unit of what we call light. Photon is light. (Salles, 2016, p.49)

2. Objectives

This project aims to research X-ray photography for the purpose of artistic creation in the area of contemporary arts. It thus permeates the involved concepts and technical aspects to discover if it is possible to use the technique in a creative way and how to do it. This monograph records the technical/creative process, considering this the beginning of the artist's discovery of the X-ray technique and its use in a poetic way. Photography is a structural basis for its similarities in technical and creative terms.

The use of X-ray and X-ray spectral imaging equipment for artistic creation guides the project as a whole. As a result, works and their experiments resulting from the technical research and development of the proposal are presented. The images of the visible and invisible spectrums make up the work as a unit. Here is the mapping of discovering, doing and all the pertinent questions of the artist's process, which is the beginning of her dialog with this technique.

3. Methodology

The methodology starts with specific research on the X-ray technique in the area of physics, understands the context and its different uses in art, performs different imaging tests with X-ray equipment in cooperation with the technicians of the company InsightArt, and finally the execution of the poetic proposal.

The project begins the search for X-ray photography by researching aspects of the area of physics, unraveling technical issues of radiography and X-ray spectrometry. Then, it studies the X-ray equipment, together with distance training carried out by the company InsightArt’s specialist. The unveiling of the technique follows recognizing the different uses of X-rays in art, bringing references from photographers and radiologists who use X-ray imaging creatively.

The fundamental activity of the human psyche or the soul is the creation of images (Jung, 1991). During the project development, the artist explores imagination during the creation of the work that will not be possible to see until it is scanned. The use of test paintings and their results as X-ray photography support and solidify the process of creating the works.

Painting and photography make a solid base and reference for the technical and creative process, establishing connections with the X-ray technique under development through the equipment. Execution and analysis happen simultaneously, considering that the work established by one influences the process of the other. Finally, the artist exhibits the project phases, her discoveries, and final artwork. Moreover, the artist presents her documentation of process and technique drawing up conclusions on the relationship among artistic creation, technology exploration, and her final artworks.

4. Brief digression on photography and x-ray

4.1. Photography

Photography helped people in the 19th century to see the world with different eyes and induced artists to irreversibly advance their explorations and experiments; as a result, artists found themselves impelled to explore other regions (Gombrich, 2013, p.403). In terms of photography, the development happened in a way that technical exploration followed technology. From daguerreotypes to analog photography and digital, we kept expanding boundaries without modifying the intention; the aesthetic expression remains (Salles, 2016, p.16), keeping focus on creation and idea.

Fig. 1 - Edward Weston

The difficult inclusion of photography as an artistic expression in the transition to the 20th century and its resulting presence in Contemporary Art expand its possibilities of

action and visuality. The limits that photography reaches today with the works of David Hockney and Danny Bittencourt were preceded by the modern photography of Cartier Bresson, Edward Weston, Geraldo de Barros and Moholy Nagy. The possibilities achieved allow photographic images and performances that go beyond the imagination and the pure representation of reality.

Fig. 2 - Dani Bitencourt

4.2 Relationship between visible light and X-ray

James Clerk Maxwell showed that a ray of light propagates in the space as electric and magnetic fields; in other words, it is an electromagnetic wave. It was therefore understood that optics, the study of visible light, is a branch of electromagnetism (Halliday, 2013). Called Maxwell's Rainbow, physics has established a large spectrum of electromagnetic waves. In the case of photography, we work in photographic cameras essentially with a very small part of this spectrum, the Visible Light.

X-ray was discovered in 1895 by Wilhelm Conrad Röntgen. It is an entrant form of high-energy electromagnetic radiation. The X-ray wavelength is very small, between 10 nm and 10 pm, corresponding to energies between 124 eV and 124 keV.

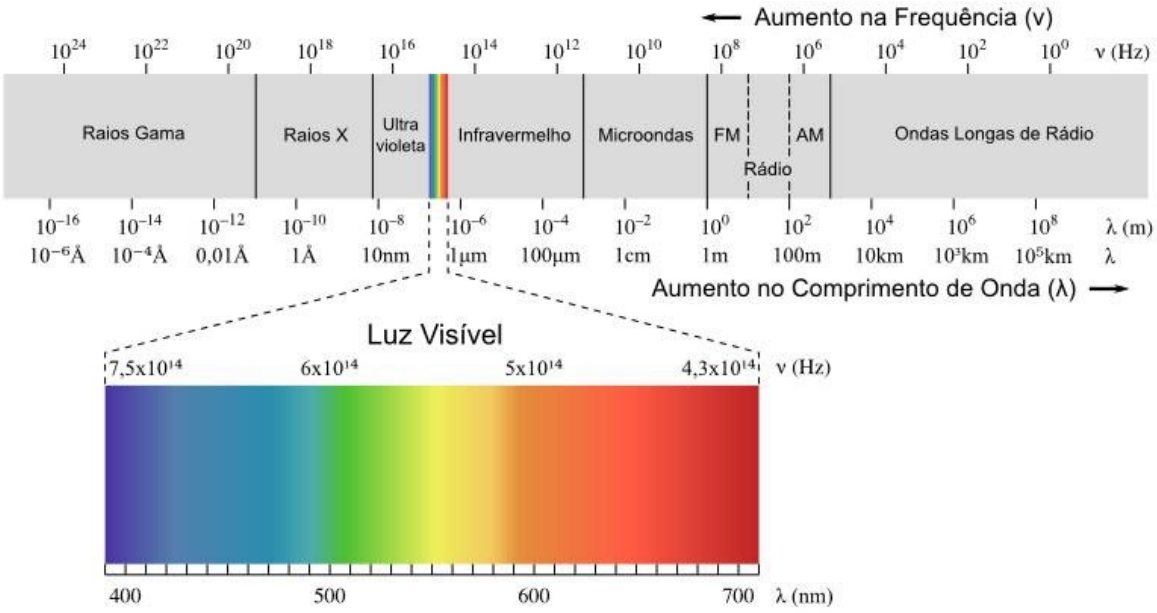

Fig. 3 - Electromagnetic spectrum

The X-ray image generation principle is as follows: light emitted by an X-ray tube passes through an object. The object projects an X-ray spectrum shadow. The shadow is detected by an image sensor, revealing the internal structure of the sample.

Fig. 4 - X-ray fundaments - InsightArt collection

We admit, for these two cases (camera and human eye), that both a photographic image and an image seen by our eyes originate from absolutely similar systems (Salles, 2016, p.32). The same happens with the X-ray imaging system. Simplifying the process, the X-ray tube is equivalent to the light source. On the opposite side of this source, we have a sensor that captures “shadows” from the analyzed objects.

The shadow would be the energy absorbed by the object. The sensor works in the same way as the camera sensors and the brain. It interprets the information generating an image. In the case of X-ray spectral imaging, the detector (X-ray camera) records the remaining photons (X-ray light) that were not absorbed and passed through the object. Thus, the internal image of the object and its different internal structures are revealed. The light source in the camera and the human eye is normally ambient (sunlight) or artificial and now comes from inside an X-ray tube.

4.3 Examples of visible light and X-ray in art

Currently, X-ray imaging techniques (e.g. radiography and tomography) are commonly used as a scientific tool. They are used to solve problems in different areas, such as medicine, materials science and art. In the field of visual arts and archeology, it is used for pigment analysis, authentication and restoration (Mantler and Schreiner, 2000).

It is possible to find currently uncommon uses, such as the photographer Hugh Turvey, the medical radiation physicist Arie van't Riet, Nick Veasey and others, all exploring the boundaries between art and science.

Turvey has been an artist in residence since 2009 at the British Institute of Radiology (BIR - The British Institute of Radiology) and has been working since 1994 in London with xograms. The logic of Turvey's work is similar to other photography techniques, such as the photograms, also called rayograms, by Man Ray (Fig. 5 left).

Ray placed simple objects on top of photographic paper and exposed this composition to light (Kemp, 1974), resulting in the image of the shadow of the object in the same logic of cyanotype (Farber, 1998) and other historical photography techniques.

In 2021, the exhibition of Gertrudes Altschul took place at the São Paulo Museum of Art (MASP). German photographer who settled in São Paulo in the 40's and learned the technique of Man Ray during experiments she performed as a member of the FCCB (Foto Cine Clube Bandeirante). Daisies (Fig. 6) is the result of the composition made on the spot, with flowers placed directly on the paper.

Fig. 5 - Left: Man Ray Photogram
Fig. 6 - Right: Gertrudes Altschul. Margaridas, circa 1959 - Comodato MASP Foto Cine Clube Bandeirante, C.00102

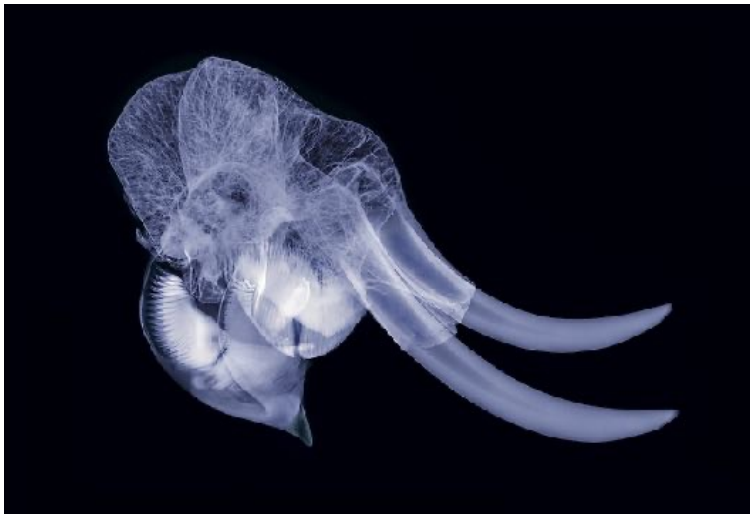

Fig. 7 - Hugh Turvey

X-ray photographer Hugh Turvey works with practices made with large sheets of B/W X-ray light-sensitive film and submit these objects to radiation light, thus, possessing the record of the photons that were not absorbed by the object (X-ray shadow). Fig. 7 shows the X-ray of an elephant's head, an image composed of layers of X-rays, which were overlapped and arranged to better translate the idea behind the photographer's intentions.

> *"The scanners are layered and combined to produce a grayscale image of approximately one gigabyte. Coloring is where you can input depth back into the image and control the eye's path over the image." (Turvey, in an interview for National Geographic).*

The X-ray photographer reports on his website that the technical manipulation of the xogram involves “overexposure, multiple exposure, chemical processing, filtering, mechanical probe, physics, a few happy accidents, photography, attempting and failing, and hand coloring.” Characteristic procedures in common with analog and digital photography.

Radiologist physicist and artist Arie van’t Riet uses X-ray in another way. His knowledge in radiology led him to experiment, using images and coloring them digitally to create scenes of nature such as those in Figs. 8 and 9.

Fig.8 - Arie van’t Riet
Fig. 9 - Arie van’t Riet

In the book “*A ideia-imagem*”, Filipe Salles defines scientific photography as the “function of serving as a direct extension of the eyes, recording in images, subjects that in another way, could never be seen, nor shared and sometimes not even imagined” (Salles, 2016, p.165). This definition fits what is the work on in this project. Ernest Gombrich wrote in his references about art that “the conciliation artist-photographer will grow in importance in the coming years” (Gombrich, 2013, p493)

4.4 Beyond photography, engraving

The results found in the project allowed us to bring relationships with other artistic images, such as engraving. The textures, contrast, lights and shadows of engraving open a parallel with X-ray images resulting from the project.

Figures 10 and 11 are part of the series of engraving prints called “Transparecer”, made by artist Rafaela Bermond in 2018. The artist uses the Brazilian photographer Sebastião Salgado and the works “Mulher” (2001) and “Portrait of a man” (1995-1996) by artist Luise Weiss as a reference. At the end of the project, engraving and X-ray photography will be presented side by side, bringing parallels and observations between the two universes.

Fig. 10 - Rafaela Bermond, Transparecer, 2018, wood engraving on paper, 19 x 35 cm[3]

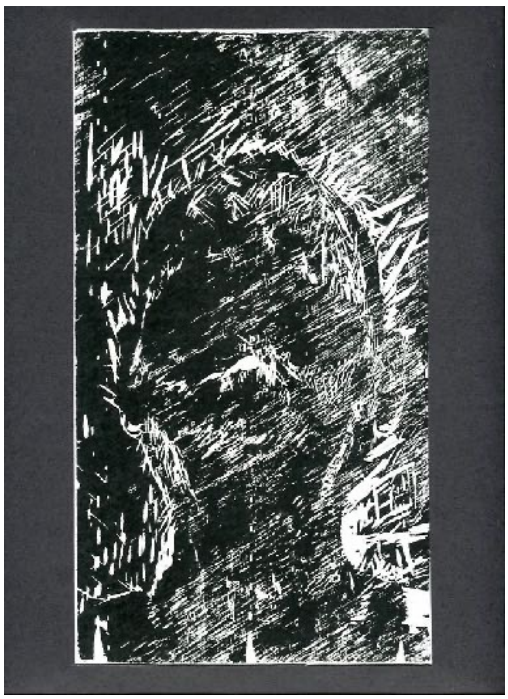

Fig. 11 - Rafaela Bermond, Transparecer, 2018, wood engraving on paper, 19 x 35 cm

[3] https://www.rafaelabermond.com

5. Art and technology

5.1 X-ray spectral imaging and RToo 3D

Classic X-ray imaging systems measure the intensity of X-rays that pass through the inspected object. That is, the light emitted by the X-ray tube that is not absorbed by the object passes through it, and the resulting information is read.

The equipment used in the project, Rtoo 3D, has the possibility of measuring the energy of photons, separating them into multiple frequencies, allowing the differentiation of materials (pigments) in the object. The scan is based not only on the overall attenuation of X-rays but also on their elemental composition, resulting in an X-ray spectral image. Fig.12 is composed of different bands of the electromagnetic spectrum. The first column is the visible spectrum, and the following are images of different frequencies, digitally colored to better understand the image.

RToo is built by a partnership of three companies: ADVACAM, Radalytica and InsightArt. In partnership with universities and laboratories led by CERN (European Organization for Nuclear Research), ADVACAM develops the detector (Widepix 1x5 MPX3 Si or CdTe) that is very sensitive, has low noise in the images and has a high dynamic range (enabling image processing to widen the image range). It converts each photon received from the X-ray tube in isolation into a signal and can calculate the energy of each photon.

In cooperation, Radalytica uses such detectors that are very limited in size and creates a way to use them on a large scale, whether on three-dimensional or two-dimensional objects, using cooperative robot systems (UR-5 from Universal Robots) that allow the entire system to work synchronously at different sizes. In the partnership, InsightArt applies this technology in works of art, mainly for art analysis, restoration, and authentication, as in the example of Fig. 12, a case study of a work signed by Vincent Van Gogh.

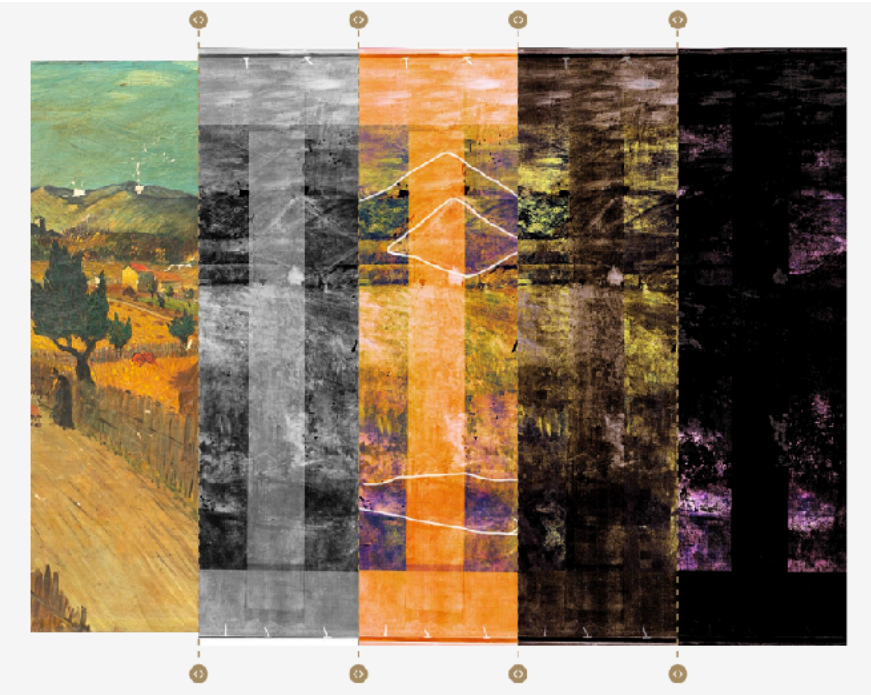

Fig. 12 - InsightArt's spectral X-ray image - La Crau with a View of Montmajour[4]

In addition to the spectral imaging, the possibility of an angled image, using flexible robots, allows us to make a three-dimensional view from different angles. Thus, it is possible to create the path and angle for capturing the image in the same way as with photographic cameras.

Fig. 13 - RToo 3D - courtesy of Radalytica and InsighArt[5]

[4] https://insightart.eu/gallery/case-study/

[5] https://www.radalytica.com

The equipment works as follows: there are two robot arms: the first one carries an X-ray tube, and the second carries a detector. The set X-ray tube and detector, thanks to robots, can rotate freely around the sample. The robots move synchronously so that both the tube and detector always remain in the same relative position to each other, regardless of the circumstances.

The equipment contains:

- Detector: **Widepix 1x5 MPX3 Si or CdTe.** Based on a Medpix3 chip with two energy (wavelength of measured X-rays) discrimination thresholds per pixel (55 μm).
- A pair of **Universal Robots - UR-5 robots.**
- X-ray tube: **Oxford Instruments Apogee** (50 kV, 1 mA)

The equipment is used inside an enclosure, with radiation safety certification issued in the Czech Republic, the United Kingdom and other countries.

5.2 X-ray spectral imaging analysis

The research explored the image processing software of the company InsightArt that accompanies the RToo 3D equipment. It considers that the result obtained in the scanner is a RAW photograph, which will be processed and exported. So the software intermediates this image with a lot of information, and we can select different frequencies to generate the result of it. The InsighArt team of technicians offered one of the test paintings carried out by Jiří Lauterkranc for the initial study of the software and the possibilities of the equipment to understand the correlation between painting and spectral images.

Fig. 14 Test Painting - InsightArt's collection

Figures 15 and 16 are images at different X-ray frequency (energy) responses, made for the study of the software and understanding of the tool and the different layers of the X-ray.

Fig. 15 - Images 1 & 2 - artist's collection
Fig. 16 - Images 3 & 4 - artist's collection

The differences are due to the energy calibration that selects the frequency response for a specific type of pigment to which the software will show the image. The calibration shown above (Fig. 15 and Fig. 16) was not rigorous, just a free trial in the software. Using a common image editing software, we can assign a color to each image of each specific frequency response, as shown in Fig. 17 and Fig. 18.

Fig. 17 - Images 1 & 2 - artist's collection
Fig. 18 - Images 3 & 4 - artist's collection

Fig. 19 is the result of combining images from different frequency response, which results in a new combination with colors that complete each other, and when working on the opacity in the overlap, we find details and color mixtures. The image in Fig. 19 on the left is the combination of the two images in Fig. 18, and Fig. 19 on the right is the combination of the two images in Fig. 17.

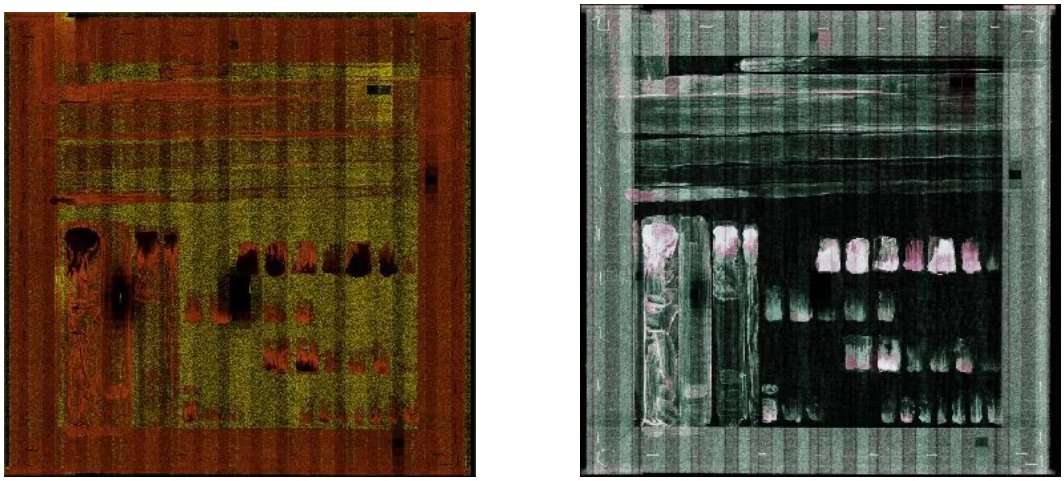

Fig. 19 - Artist's collection

Note that there are differences in layers and types of pigments that are scanned. Fig. 19 reveals the imperfections of the brushstroke, the paint rhythm, the material that has pigment and which does not. It is possible to identify the frame behind the painting and the staples.

Explorations to reveal the hidden details of each brushstroke become visually and aesthetically compelling and interesting. Combining layers with simple colors results in color mixing and blending. The image quality and grain texture of X-ray photography resemble the most sensitive films of analog cameras and the ISO sensitivity in digital cameras, parameters used as an aesthetic option in photography.

5.3 Robots in art

The use of robots for creation in art is not new. Founded by Andrea Anner and Thibault Brevet, AATB is a studio based in Switzerland and France. The team explores the idea of nonindustrial robotics.

They experiment with the use of industrial robotic systems and industrial automation systems for creative development in design, film and visual arts. In Fig. 20 and Fig. 21, the process and the result of the painting carried out by the AATB for Atelier Luma at the World Economic Forum Davos are presented, respectively, using the robotic arm as an intermediary.

Fig. 20 - AATB for Atelier Luma at World Economic Forum Davos - © Joana Luz

Fig. 21 - AATB for Atelier Luma at World Economic Forum Davos - © World Economic Forum: Christian Clavadetscher-LR

Anner and Brevet work with different types of systems and robots; in this project, they use Universal Robots robots[6]. Robots were originally developed thinking primarily about helping the industry. In the same way that European artists explore the possibilities of using equipment in a nonindustrial way, this project explores the use of the robot system to create photographs in art. However, it is worth mentioning that it is not the focus of this project to discuss this field, which in itself is a project and an entire research.

[6] https://www.universal-robots.com acesso em 28 de novembro, 2021

6. X-ray technique in art

Until now, we acknowledge some techniques and possible ways to create art using X-ray. Among them, the possibility of working with different pigments, thicknesses, supports, and tools in the two-dimensional scope was chosen.

The easel painting using acrylic paint begins the practical research of this project, since the main interest is in the pigment of each paint, considering that the pigments used are the same in all methods, with the exception of a few cases (Mayer, 2015). The choice of acrylic paint is based on the artist's familiarity with the technique and ease of handling to create layers, since the drying time between them is shorter.

Below you will find a brief description of each of these processes and images that exemplify the different components of technical research, always working on the relationship between visible and invisible layers of the electromagnetic spectrum.

6.1 Pigments

By the understanding of pigment as:

> *“a colored and finely divided substance, which pass its coloring effect to another material, either when well mixed with it, or when applied to its surface in a thin layer. When a pigment is mixed and ground in a liquid medium to form a paint, it does not dissolve, but remains dispersed or suspended in the liquid.” (Mayer, 2015)*

Each paint has a range of pigments; some are pure, others are a mixture, and a color can contain only one or a combination of pigments (Mayer, 2015). The chemical composition, purity of pigments and pigment composition of each ink vary. ASTM - American Society for Testing and Materials - standardizes the names of pigments, facilitating the manufacturing process. Thus, in each tube of paint, it is possible to find its pigment composition, such as titanium white, composed of the pigment PW6 (pigment white 6). Each acronym is followed by a number representing the type of pigment.

For the project, a selection of paints and a cataloging of pigments were made to analyze and gain greater control and understanding of the final results. With the knowledge of

the chemical composition of the paint, we were able to draw conclusions and different possibilities of the work. In the appendix Table 1 is found in the fifth edition of the Artist's Manual, referring to the classification of pigments, and Table 2 shows the list of pigments used in the project and their respective formulas and chemical classification.

6.2 Test paintings

Inspired by the test painting used by Balbino (2019), 3 different works were created: RB00121 (Fig. 24), RB00221 (Fig. 28), and RB00321 (Fig. 30). The base canvas for the works selection is the same.

Fig. 22 - Painting RB00121 - detail - artist's collection

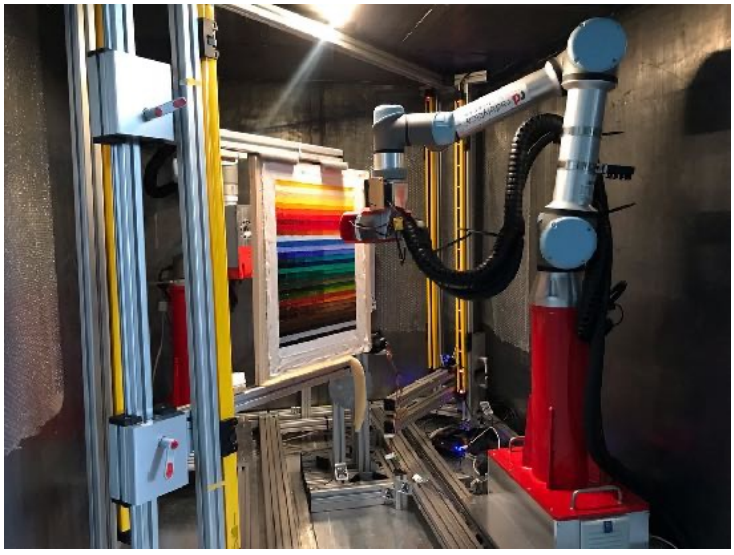

Fig. 23 - Painting RB00121 been scanned - artist's collection

The horizontal lines of the RB00121 painting (Fig. 24) were constructed in the same order as the pigments in Table 2. The horizontal lines vary the pigment, and the columns vary the thickness of the paint. Fig. 25 shows the X-ray of the RB00121 painting. It can be seen that in terms of the amount of matter in each one, some colors become dark in the X-ray, and others become lighter.

In the column on the far right, where a thin and uniform layer of paint was made, the difference between the pigments is barely noticeable. In the column on the extreme left, where there was a thick layer of paint, we can see the difference in the pigments in the X-ray.

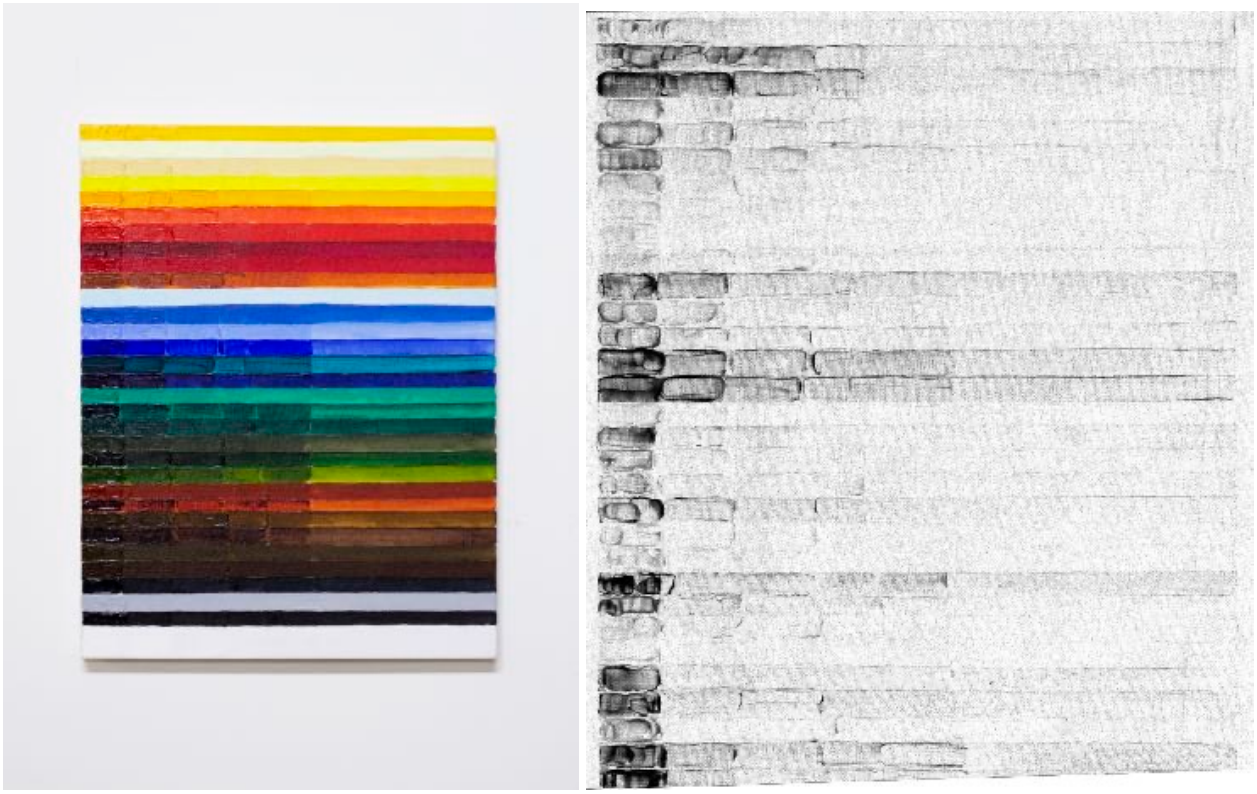

Fig. 24 - Left: Painting RB00121 - artist's collection
Fig. 25 - Right: Positive X-ray RB00121

Some colors, such as yellow napoles 47 (third line) of compositions PW6 (TiO2) and PY42 (Fe_2O_3•xH_2O), have iron oxide, and dark yellow 51 (first line) of compositions PY74 ($C_{18}H_{18}N_4O_6$), PO13 ($C_{30}H_{18}FeN_3O_6$•Na) and PW6 (TiO2) has nitrous iron. Both have the same chemical element in their composition but have different structures, resulting in differences in the X-ray.

Dark colors in the visible spectrum are very light in the X-ray spectrum, but this is not the rule; what varies is the chemical composition of each pigment that determines the shade

of gray in the X-ray. A posteriori can be analyzed in detail by observing Figures 24 and 25 and comparing them with the data in Table 2 of pigment composition.

The results found by scanning the visible spectrum color palette allowed the creation of a grayscale palette in the X-ray. Fig. 26 shows the order of pigments in Table 2, and Fig. 27 shows the organization of the same image but in grayscale scaling.

Dark scale: 121, 131, 84, 63, 113, 83, 154, 110, 47, 70, 46; medium: 51, 108, 85, 33, 79, 126, 124, 72, 73, 122, 75; and lighter: 166, 130, 59, 58, 11, 88, 95, 118, 69.

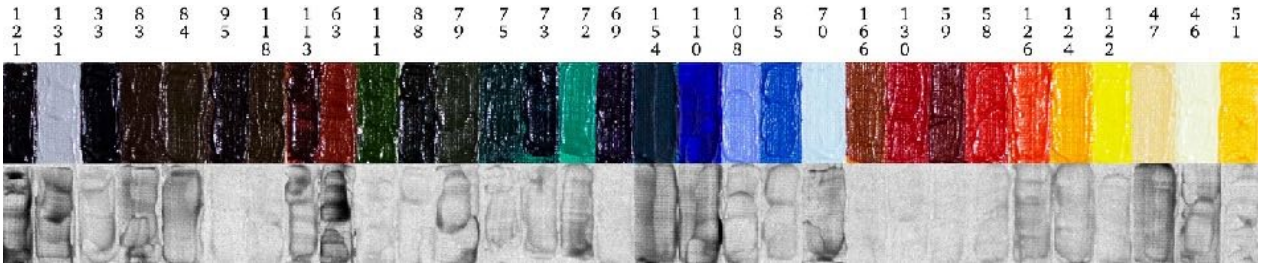

Fig. 26 - Chromatic scale of painting RB00121

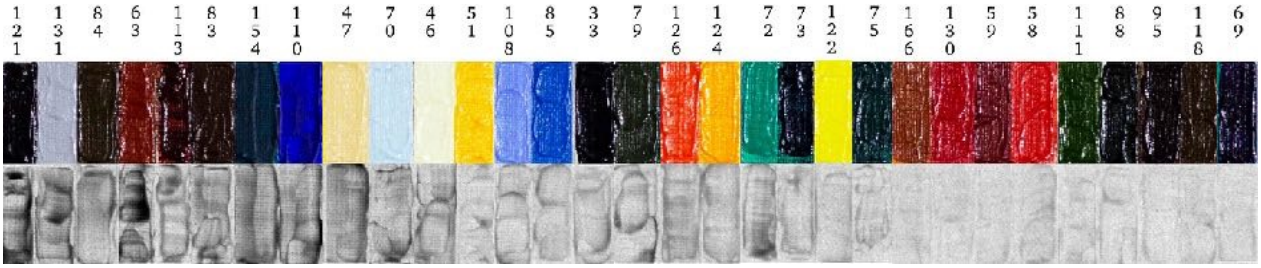

Fig. 27 - Grayscale of painting RB00121

6.3 Thickness

The difference in the pigments is only noticeable in the first column (Fig. 25), where the pigments were placed thickly (approximately 2 mm), and as the ink thickness decreases, the information captured by the equipment decreases. Thus, all the pigments used have an insignificant amount of matter, which, when spread and deposited in a non-thick way, generates little or no difference in the X-ray. Therefore, any painting performed in the visible spectrum with a thin layer of pigment will not interfere with the X-ray image.

The scanner of painting RB00321 was unnecessary (Fig. 28). The vertical and horizontal lines are both very thin layers, so it would show little or no results on the scanner.

Fig. 28 - Painting RB00321 - artist's collection

6.4 Layers

The RB00221 paint was built in 2 layers. The first layer was painted with titanium white (PW6). With 4 vertical columns, from left to right: the first with thin thickness and random brush strokes vertically, the second with thick layers of brush strokes marked horizontally, the third with thick and random strokes vertically, the fourth with an even layer and unmarked strokes. In Fig. 29, it is not possible to perceive the difference described, but Fig. 30 is notable.

Fig. 29 - Left: Painting RB00221 - artist's collection
Fig. 30 - Right: X-ray of painting RB00221 - artist's collection

The goal here was to be able to see how each pigment allows you to visualize the lower layer. In fact, this materialized, and there was little or no interference from the upper pigment in the visualization of the lower layer. In the result obtained, we noticed that, as the results of the RB00121 painting revealed to us, very thin layers of paint appear very

little on the X-ray. It was also possible to conclude that for any thick layer of titanium white (PW7) made under any color, the image to be revealed on the X-ray is the white layer, not the visible layer.

6.5 Textures: supports and tools

The canvas allows us to visualize the material's own texture (Fig. 31), which can be an aesthetic option to create texture in the image. For the following explorations of new textures, the canvas (from the test paintings) was replaced by wood, the brush by the spatula, and the smooth surface by the engraving.

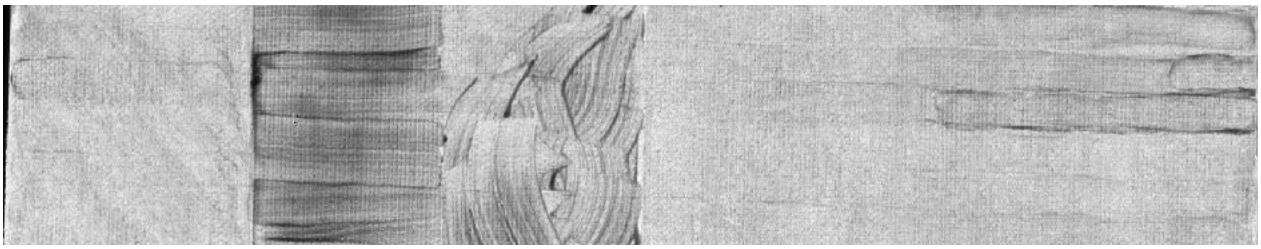

Fig. 31 - detail painting RB00221 - artist's collection

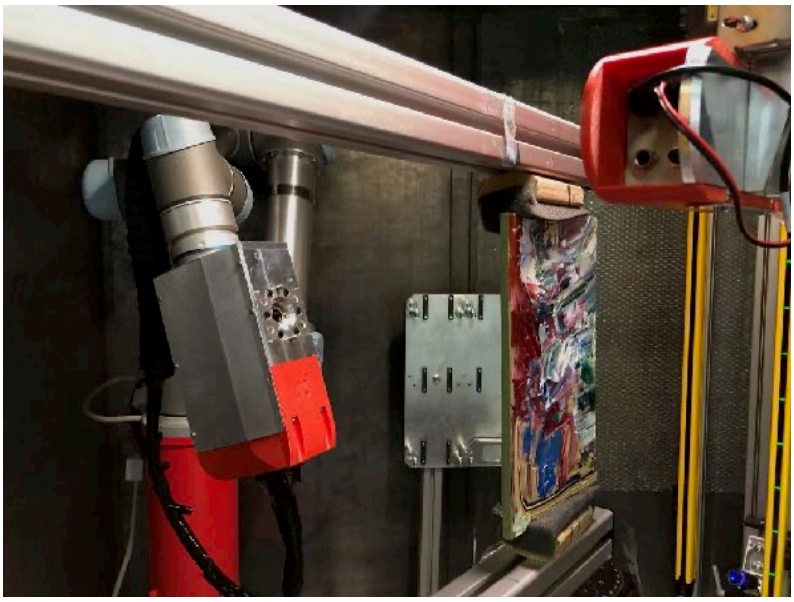

Fig. 32 - Scaner RToo 3D with painting RB00421 - artist's collection
Fig. 33 - Painting RB00421 - artist's collection

The first new painting (Fig. 33) was made following the movement of abstract painting, thinking about highlighting areas of light and dark brushstrokes and areas of plain color. Therefore, exploring possible X-ray images that could result from the spontaneous execution of a painting.

In the result of the scanner, we can verify new elements not mentioned before: objects. The paint, for having a plastic texture, plus the creation of creases and holes in the wood, made it possible to hide small objects in the mass of paint deposited. To test this possibility, we used small shells (Fig. 36 and Fig. 37) and a shirt button (Fig. 38).

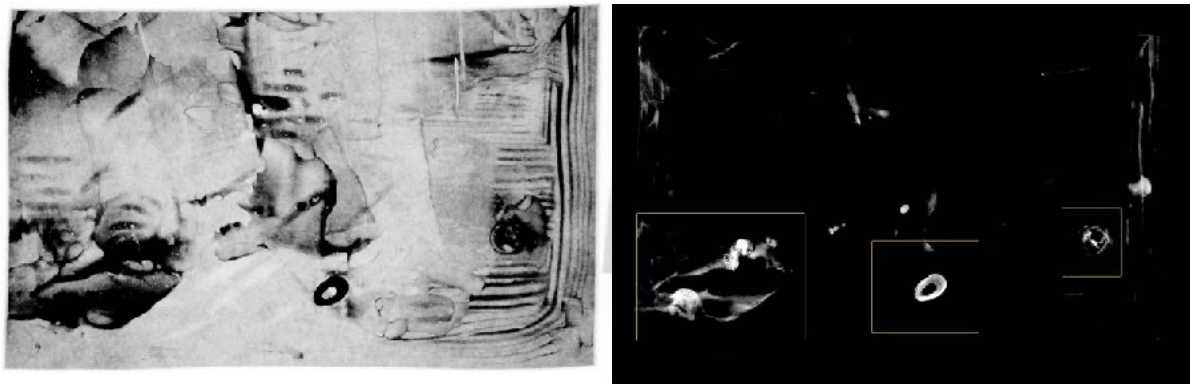

Fig. 34 - Left: X-ray of painting RB00421 - artist's collection
Fig. 35 - Right: detail from the X-ray of painting RB00421

Fig. 36 - detail RB00421

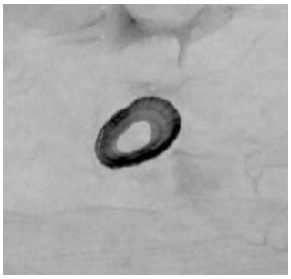

Fig. 37 - detail RB00421

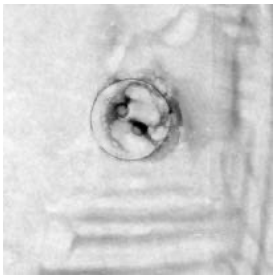

Fig. 38 - detail RB00421

Another space explored in term s of layers was to think of wood as an object that can be used for woodcuts. In Fig. 39, we can see in the first column the negative X-ray photograph, in the second column the wood carving layer, in the third column the positive X-ray photograph and in the fourth column the image of the visible layer.

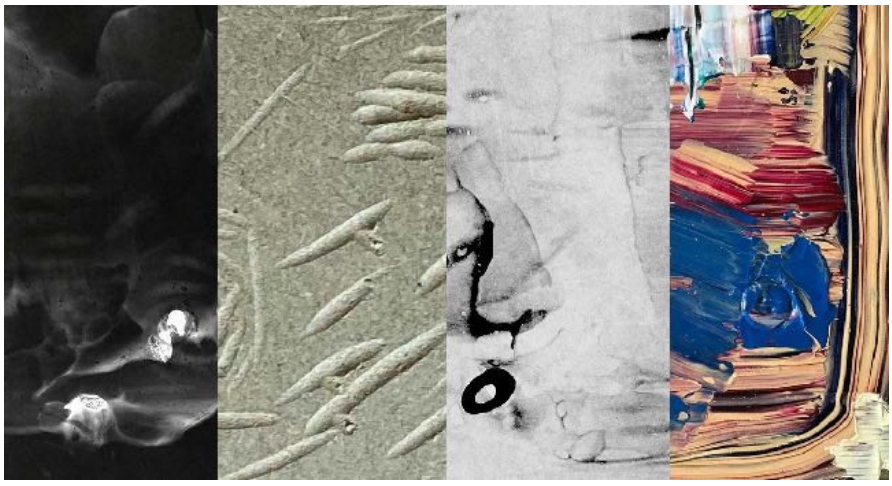

Fig. 39 - RB00421 paint layers

7. Poetics

The creation of the project's works is born from a hybrid place, from the combination of photography and painting techniques. Technological development makes it possible to advance within the technique and create a third work, mixed. Resulting from a symbiosis of two worlds that have long been intertwined, they are established and materialized in a hybrid work. The dialog between pictorial image and photographic image is taken to a third level, that of creating a work that uses both universes to materialize itself.

The use of technology breaks the conflicts, paradigms and ties between the processes of painting and photography. There are thus two strong elements, one from each universe. Time, conquered and unveiled by photography; and space, conquered by painting. Photography thus reveals the layers of painting. As final works, two themes present in both universes are shown, abstraction (Fig. 40) and portrait (Fig. 42).

7.1 Relationship between photography and painting

> *“Photography has, in its essence, the eminent possibility of perpetuating a state of light that occurred in a time, which is short enough to freeze our perception in an instant, thus being able to evoke the emotional memory of what witnessed the scene, as well as to translate the emotion of that moment, arousing in those who were not present a similar emotion.” (Salles, 2016, p.124)*

The registry through painting and a posterior photography serve as an extension of memory and visuality. We feel the need to eternize and perpetuate emotions, events, and people through images. It represents the mentality of those who want to be remembered and those who want to figure about the past and present (Woodford, 1983).

The different possibilities of creating images to express the idea behind the work in photography are similar to the different uses of color and texture adopted by painters. The relationship between painting and photography since the 19th century to the present, is intertwining. As photography often becomes a reference for painting, and painting inspires photography.

Susan Woodford, in reference to the work of Jackson Pollock, says that “its intention is to reveal the creative activity and the pure physical energy of the artist, to inform the observer of the action of both his body and his spirit when he undertakes the work of producing a painting.” Thus, both the abstraction explored by Jackson Pollock and the photographer Edward Weston (Fig. 1) and the formality explored by Sebastião Salgado and Candido Portinari surround the scopes of the human psyche and its ability to create.

7.3 A third space: expansion

The “archetype can be both an image and an emotion. […] When archetypal images are stripped of their specific emotional charge, life escapes them and they become mere words” (Jung, p.101). The image is not just consciousness, expression and mind; it is emotion. A portrait of someone you love, someone you know or yourself, a painting or abstract photography are full of sensations, emotions, feelings and ideas.

In the text written by Prof. Maurício Lissovsky (2001), he develops two concepts about photography. One of **urgency** and one of **eternity** are materialized with the photographs of Cartier-Bresson and Edward Weston, respectively. Within the discussions of the place of photography as a representation or not of reality, representation of representation raised by Salles, there is a way out with the idea of **expansion**. This project thus surrounds, creates, and proposes images following the space of Rubens Fernandes Jr ’s concept of Expanded Photography[7] (2002). Moreover, this project is entering and revealing the hidden through the X-ray.

> *“Anyway, the universe got bigger: before we thought our eyes could cover everything that existed; today we know that what we see is only a tiny fraction of the light that is known to exist” (Salles, 2016, p.48*)

X-ray photography is the opposite of Cartier-Bresson's objective instant photography. Expands time and reality, reveals the hidden. It plays with the temporal sensation of the expansion of what is visible and that travels in time, shelters the unconscious and the conscious so that it becomes material.

[7] PHD thesis by PUC/SP

We must remember that we are not just what is portrayed, the physical aspect. Art speaks of the inexpressible, "[…] the photograph of the subjective instant […] no longer predominates the aspect of the single instant, but the expansion of time, the moment that expands in its dimension, to translate a timeless condition" (Salles, p.127). We recognize ourselves as a society for what we perceive not only through the senses but also through what is beyond.

> "*Art thus has a function that we could call knowledge, "learning" (aprendizagem). Its domain is that of the irrational, the unspeakable, of sensibility: a domain without clear boundaries, very different from the world of science, logic, theory. Fruitful domain, because our contact with art transforms us. Because the artistic object brings within itself, skillfully organized, the means of awakening in us, in our emotions and reason, culturally rich reactions, which sharpen the instruments we use to apprehend the world around us*." (Jorge Coli, 2003)

7.4 The Art piece: "Unseen Photography"

As a result of all the technical research carried out, the series of X-ray photographs called "Unseen Photography" (*Fotografia Oculta*) was created. The conclusion of the work becomes powerful and symbolic also considering the current context of its realization, the COVID-19 pandemic.

The work, as it is carried out with equipment that is geographically located in the Czech Republic, must be in part done in Brazil and completed in the Czech capital, Prague. On one hand, the work expresses the mystery, the whirlwind of feelings and elements that present themselves and that were previously hidden, as the years 2020 and 2021 have revealed to all humanity. On the other hand, it shows affection, kept at a distance mediated by a screen, by mail, and by the affection that remains.

The situation generated by the pandemic has given new meaning to the concepts and affective relationships prevented by isolation. The physical distance becomes even more latent, but it is shortened due to the infinite technological resources. The project reveals the long-distance relationships created, maintained and expanded in this period.

Fig. 40 opens the door to our imagery of X-ray photographs. Here, combinations of X-ray spectrometry images, digitally colored and layered, are used. Fig. 41 reveals the details of the image that show the objects and the carvings in the wood as explained in section 6.5.

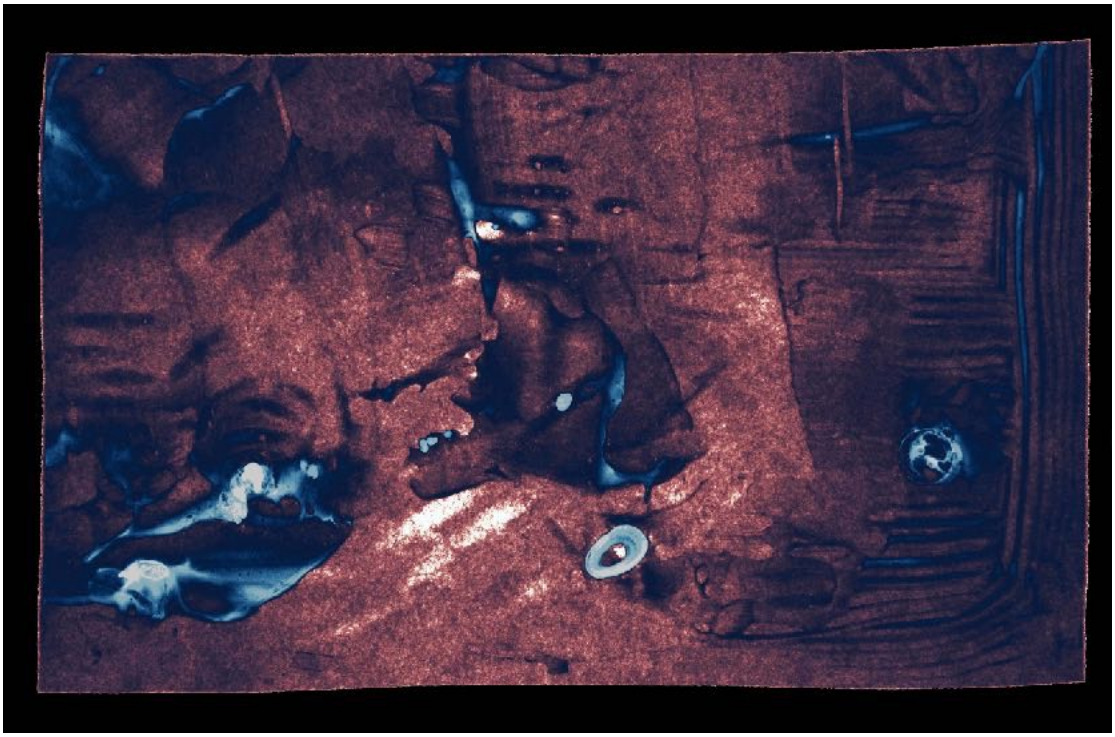

Fig. 40 - X-ray of Painting RB00421

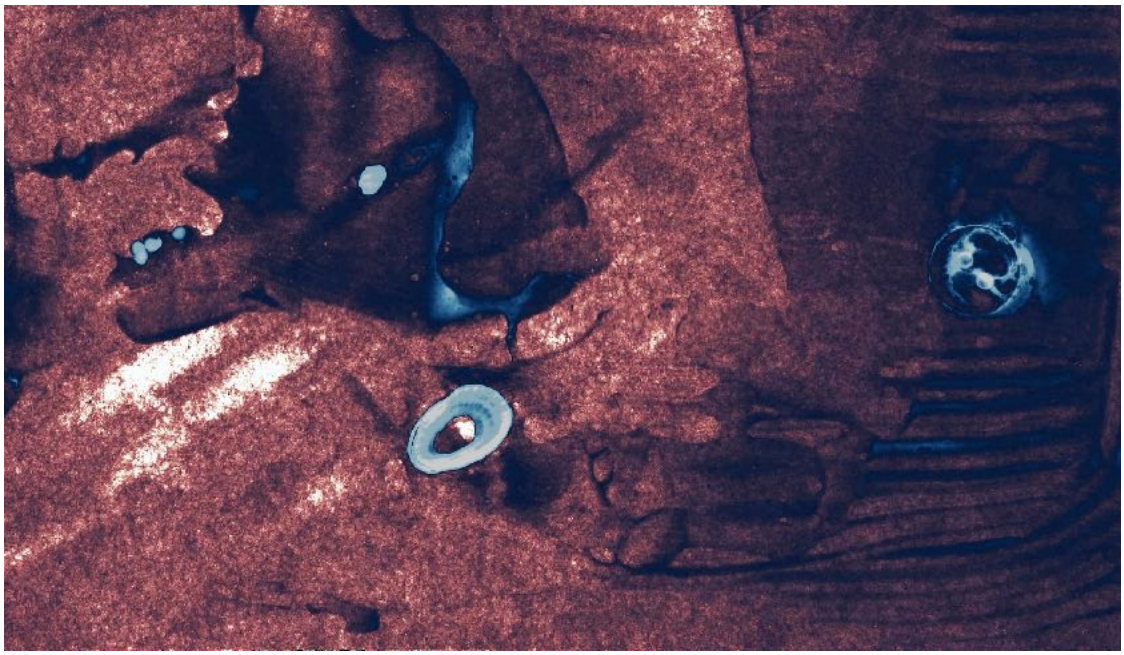

Fig. 41 - detail X-ray of Painting RB00421

The differences between the painting shown in Fig. 33 and the result achieved through X-ray photography are shown. The traces of the wood carvings (in strong white) are exposed, and the hidden objects are highlighted, revealing subjective and hidden aspects of the image. The eye wanders from one side to the other, possessing a rhythm of reading and movement through brushstrokes, marks, notches and tones.

Fig. 42 shows the other side of the project, the portrait. In the visible layer, the expression of sadness and loneliness carries the vacant look of the portrayed. His hair blends into the background almost in an erasure. The X-ray reveals a safe, strong and present posture, a firm and objective look, determined toward the future. In Fig. 42 on the right, the X-ray photography reveals to us the expansion of what it truly is, the framing of what is portrayed by the cell phone.

Fig. 42 - Fig. Works from the series “Fotografia Oculta” - “Unseen Photography” Painting on wood and X-ray photography, 2021. 13x21,4 cm

These characteristics confirm that there is, in what is seen as reality and perceived in this way, another face that is also reality, which shows us another way of seeing the same image.

7.5 Spectral X-ray imaging results

Following the process of coloring the abstract photograph, the results obtained by X-ray spectrometry were used here, separating the images by layers of different frequency response channels, as studied in section 5.2. Fig.43 shows the separation of the different frequency responses and their colorization using common image editing software. Fig. 44 reveals the union of these layers in a single image using transparency between them. Fig. 45 reveals the combination of images in Fig. 43, Fig. 44 and Fig. 42.

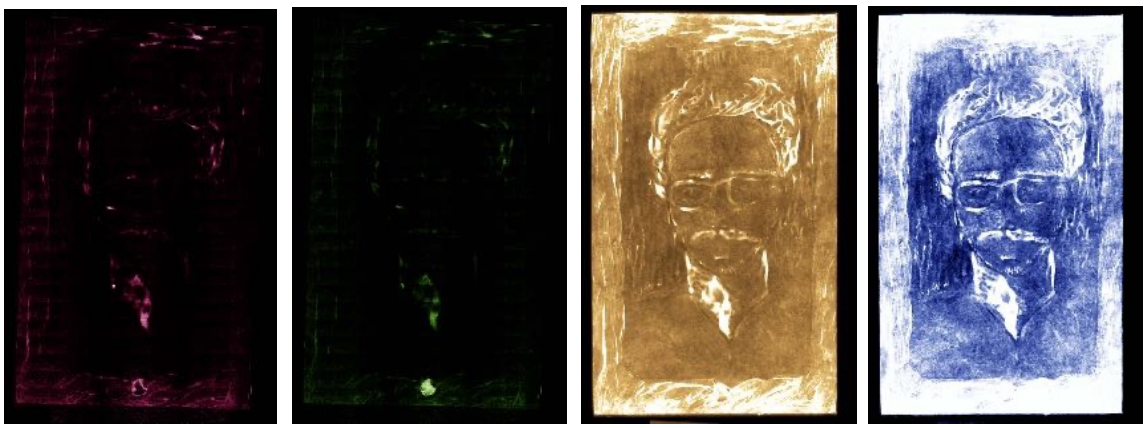

Fig. 43 - Colorization of X-ray layers from Painting RB00521

Fig.44 - Left: Compiled from the images in Fig. 43
Fig.45 - Right: Division of layers of X-ray photograph of Painting RB00521

7.6 X-ray photography and engraving

As previously shown in section 4.4, the X-ray image (Fig. 46) and engraving (Fig. 47) are visualized side by side. A quick comparison of the images reveals the similarities between X-ray photography and wood engraving. At the same time, that the engraving is a two-dimensional print, the X-ray is a three-dimensional scanning system, which explores the entire depth layer and allows a greater range of gray in its result.Therefore, the project inhabits a third space that runs not only through photography and painting but also collides with engraving.

Fig. 46 - Left: Photograph of X-ray Painting RB00521
Fig. 47 - Right: Wood engraving from the "Transparecer" project, Rafaela Bermond

7.7 X-ray layers

The X-ray and the use of Rtoo 3D equipment allow us to scan not only one work but also two at the same time. In Fig. 48, there is another way of exploring the three-dimensionality of the X-ray; the combination of two works at the same time.

In Fig. 48, you can see the details of two wooden boards, pointed out by the yellow arrows, the back one being the abstract painting and the front one the portrait painting. Therefore, a single image was obtained with both images. Thus, in Fig. 49, we can see,

in more detail, that both objects, brushstrokes of abstract painting and the brushstrokes of the portrait appear in the image.

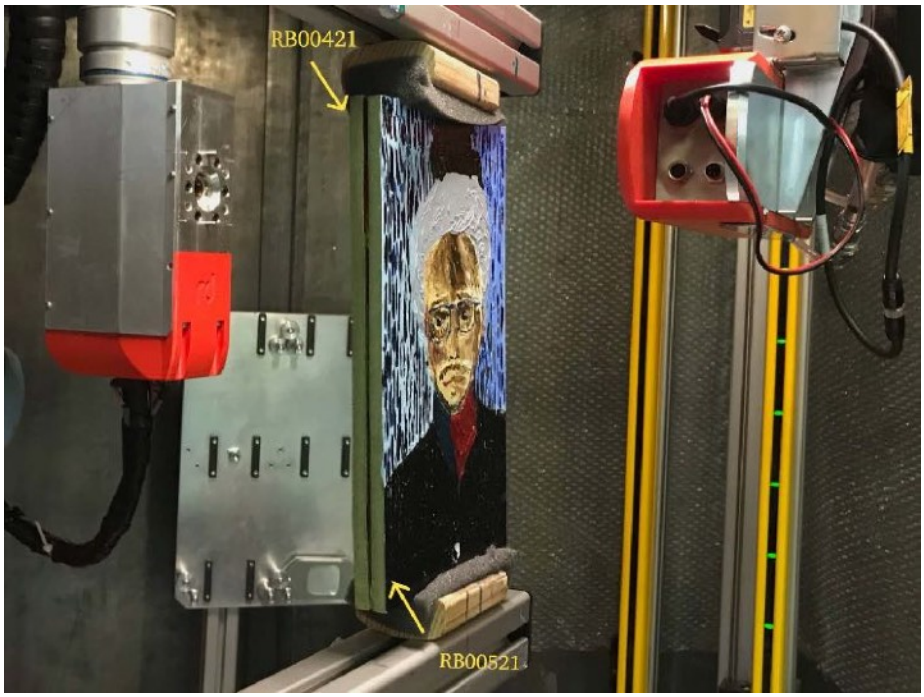

Fig. 48 - Scanner Rtoo 3D with two works together

Fig. 49 - X-ray photograph of Paint RB00421 + RB005218. Exhibition of the work

8. Work exhibition

Fig. 50 - X-ray photo series - “The unseen reality of you”

Fig. 42 shows the first exhibition proposal which brings the portrayed in the visible layer and in the X-ray layer, side by side, showing the differences of the visible and the hidden, of painting and of X-ray photography.

Fig. 50 shows another exposure possibility, which reveals the different layers of the X-ray spectrometry photograph, showing the different frequency response channels of the same image. Bringing the different possibilities of visualization or erasure, relating to the different expressions present in the conscious and unconscious, which are revealed and erased through the energy levels of the X-ray.

Fig. 51 - Exhibition preview - X-ray photography series: “Unseen Photography” 58x40 cm

In the case of prints, X-ray photographs must be printed in Fine Art quality, preferably on cotton paper, and displayed in a traditional way, as shown in Fig. 51 and Fig. 52. Other possibilities could be tested, such as linecular printing, which consists of two images printed at the same time, and the spectator's movement in the work reveals one or another image. The technique is commonly used for printing advertisements or toys, but I believe it has potential in the project, since the presence of the spectator moving in front of the work becomes essential for its complete visualization.

Fig. 52 - Exhibition preview - X-ray photography series: "Hidden Photography" 58x40

In a larger exhibition space, it would also be possible to have the original works on the wall or printed in a large size, allowing the spectator to have an immersion in the space. Upon entering the room, the viewer would be provided with a tablet device that allows him to view the X-ray photograph by pointing the tablet at the wall, as Jeffrey Shaw does in his work Pure Land Ar, 2012 (Fig. 53).

Fig. 53 - Jeffrey Shaw - Pure Land AR[8]

[8] https://www.jeffreyshawcompendium.com/portfolio/pure-land-ar/

9. Conclusion

The recurring transition of artists and scientists between fields resulted in different investigations of creation using other ranges of the electromagnetic spectrum in addition to the visible light band. The development of the project uses X-ray spectrometry scanners to unravel a library of photographic images in the invisible spectrum of a work.

This monograph is the prelude to the process of exploring the X-ray technique used by the artist for poetic creations. It opens up a potential tool for art, both in the field of X-rays and in the use of robots, and invites future explorations of different uses of X-rays for artistic experimentation.

The guiding line of the project primarily studies the technical specificity of X-rays in physics and comprehends technical use of an X-ray imaging equipment. The logic behind creating through photography and painting guides the tests carried out in the project, exploring tests in the two-dimensional scope in the use of pigments, thicknesses, layers, instruments, supports and tools. But also in three-dimensional with the use of objects in the painting and the scanning of two paintings at the same time.

Photography and painting can be considered records that make extensions of memory in terms of physical characteristics or emotional character. Technological advancement allows advancing within the technique and creating a third work, mixed, resulting from a symbiosis of two worlds that have long been interlaced and are established and materialized in a hybrid work.

The series that makes up the work “Unseen Photography” presents the painted portrait and abstract painting together that appeared to the eyes through X-ray photography. Images expand our way of perceived reality.

It is a fact that human culture unveils and expands consciousness and its perception of the world as it discovers space, the unconscious, the mind, and other ways of its own culture and discloses other cultures. This project begins a research project that reveals and proposes the expansion of a potent and expansive creative tool, which explores what is not visible to the senses at first and brings it to the surface, unveiling other levels beyond what is seen with the bare eyes.

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10. Figure references

Fig. 1 < https://edward-weston.com/edward-weston/ > access in 18 June 2021

Fig. 2 < https://dannybittencourt.com/galeria/ > access in 18 June 2021

Fig. 3 <http://admiradoresdafisica.blogspot.com/2012/03/espectro-eletromagnetico.html> access in 18 June 2021

Fig. 4 < InsightArt's collection>

Fig. 5 < https://www.dailyartmagazine.com/10-most-famous-rayographs-of-man-ray/ > access in 18 June 2021

Fig. 6 < Catálogo da Exposição MASP - Gertrudes Altschul: filigrana; organização editorial e curadoria Adriano Pedrosa e Tomás Toledo. São Paulo: MASP, 2021. 224 p., 164 il. >

Fig. 7 < https://www.nationalgeographic.com/photography/article/hugh-turvey-inside-the-life-of-an-x-ray-artist > access in 18 June 2021

Fig. 8 e 9 < https://focusmagazine.nl/2020/09/18/arie-van-t-riet-toont-natuur-rontgenfotos/ > access in 18 June 2021

Fig. 10 e 11 < http://www.rafaelabermond.com> access in 25 November 2021

Fig. 12 < https://insightart.eu > access in 18 June 2021

Fig. 13 < https://insightart.eu > access in 18 June 2021

Fig. 14 < InsightArt's collection>

Fig. 15, 16, 17, 18, 19 <artist's collection>

Fig. 20 e 21 <https://www.aatb.ch/exhibitions/aatb-for-atelier-luma-at-world-economic-forum-davos-2020/ > access in 25 November 2021

Fig. 22 a 46 < artist's collection>

Fig. 47 < http://www.rafaelabermond.com> access in 25 November 2021 >

Fig. 48 a 52 < artist's collection >

Fig. 53 < https://www.jeffreyshawcompendium.com/portfolio/pure-land-ar/ > access in 25 November 2021

APPENDIX

Table 1 - Pigments

Natural Red	NR – Vermelho Natural
Pigment Blue	PB – Pigmento Azul
Pigment Black	PBk – Pigmento Negro
Pigment Brown	PBr – Pigmento Marrom
Pigment Green	PG – Pigmento Verde
Pigment Orange	PO – Pigmento Laranja
Pigment Violet	PV – Pigmento Violeta
Pigment White	PW – Pigmento Branco
Pigment Yellow	PY – Pigmento Amarelo

Table 2 - Pigment Composition

Acrylic Paint

Name in Portuguese	Name	Pigment	Brand	n°	Type	Formula	Chemical Classification
Amarelo Escuro	**Dark Yellow**	**PY74**	Corfix	51	Organic Synthetic	$C_{18}H_{18}N_4O_6$	Monoazo
		PO13			Organic Synthetic	$C_{30}H_{18}FeN_3O_6$•Na	Nitrous
		PW6			Synthetic Inorganic	TiO2	Opaque white
Amarelo Brilhante Claro	**Light bright yellow**	**PW6**	Corfix	46	Synthetic Inorganic	TiO2	Opaque white
		PY3			Synthetic Organic	$C_{16}H_{12}Cl_2N_4O_4$	Monoazo
Amarelo Nápoles	**Yellow Naples**	**PW6**	Corfix	47	Synthetic Inorganic	TiO2	Opaque white
		PY42			Synthetic Inorganic	Fe_2O_3•xH_2O	Iron Oxide
Amarelo Cádmio Claro (imit.)	**Light Cadmium Yellow**	**PY3**	Corfix	122	Synthetic Organic	$C_{16}H_{12}Cl_2N_4O_4$	Monoazo
		PY74			Synthetic Organic	$C_{18}H_{18}N_4O_6$	Monoazo
Amarelo Cádmio Escuro (IMIT.)	**Dark Cadmium Yellow**	**PY65**	Corfix	124	Synthetic Organic	$C_{18}H_{18}N_4O_6$	Monoazo
Laranja Cádmio (IMIT.)	**Cadmium orange**	**PY65**	Corfix	126	Synthetic Organic	$C_{18}H_{18}N_4O_6$	Monoazo
		PR112			Synthetic Organic	$C_{24}H_{16}Cl_3N_3O_2$	Monoazo
Laca Gerânio	**Geranium lacquer**	**PR112**	Corfix	58	Synthetic Organic	$C_{24}H_{16}Cl_3N_3O_2$	Monoazo
		PY1			Synthetic Inorganic	TiO2	Opaque white
Carmim	**Carmine**	**PR146**	Corfix	59	Synthetic Organic	$C_{33}H_{27}ClN_4O_6$	Monoazo
		PV23			Synthetic Organic	$C_{34}H_{22}Cl_2N_4O_2$	Oxazine

Acrylic Paint

Name in Portuguese	Name	Pigment	Brand	n°	Type	Formula	Chemical Classification
Vermelho Cádmio Escuro (IMIT.)	**Dark Cadmium Red**	**PR170**	Corfix	130	Synthetic Organic	$C_{26}H_{22}N_4O_4$	Monoazo
		PR23			Synthetic Organic	$C_{20}H_{12}N_2O_2$ & $C_{20}H_{10}Cl_2N_2O_2$	Quinacridone
Vermelho Veneza	**red venice**	**PY83**	Corfix	166	Synthetic Organic	$C_{36}H_{32}Cl_4N_6O_8$	Disazo
		PR112			Synthetic Organic	$C_{24}H_{16}Cl_3N_3O_2$	Monoazo
		PY42			Synthetic Inorganic	$Fe_2O_3•xH_2O$	Iron Oxide
		PR101			Synthetic Inorganic	Fe_2O_3	Iron Oxide
		PBk7			Synthetic Inorganic	C	0
Azul Real	**Azul Real**	**PW6**	Corfix	70	Synthetic Inorganic	TiO2	Opaque white
		PB15.1			Synthetic Organic	$C_{32}H_{16}CuN_8$	Phthalocyanine
		PY74			Synthetic Organic	$C_{18}H_{18}N_4O_6$	Monoazo
Azul Cerúleo	**Célula blue**	**PB29**	Corfix	85	Synthetic Inorganic	$Na_{6\text{-}8}Al_6Si_6O_{24}S_{2\text{-}4}$	Silicate
		PW6			Synthetic Inorganic	TiO2	Opaque white
		PB15.1			Synthetic Organic	$C_{32}H_{16}CuN_8$	Phthalocyanine
		PY74			Synthetic Organic	$C_{18}H_{18}N_4O_6$	Monoazo
Azul Hortensia	**Blue Hydrangea**	**PW6**	Corfix	108	Synthetic Inorganic	TiO2	Opaque white
		PG7			Synthetic Inorganic	Co_2TiO_2	Mixed Metal Oxide
Azul Cobalto	**Cobalt blue**	**PB29**	Graduate	110	Synthetic Inorganic	$Na_{6\text{-}8}Al_6Si_6O_{24}S_{2\text{-}4}$	Silicate
Azul Turquesa	**Turquoise**	**PB15**	Graduate	154	Synthetic Organic	$C_{32}H_{16}CuN_8$	Phthalocyanine
		PG7			Synthetic Inorganic	Co_2TiO_2	Mixed Metal Oxide

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Name in Portuguese	Name	Pigment	Brand	n°	Type	Formula	Chemical Classification
Azul da Prússia	**Prussian blue**	**PB15.1**	Corfix	69	Synthetic Organic	$C_{32}H_{16}CuN_8$	Phthalocyanine
		PV23			Synthetic Organic	$C_{34}H_{22}Cl_2N_4O_2$	Oxazina
		PY74			Synthetic Organic	$C_{18}H_{18}N_4O_6$	Monoazo
Verde Veronese	**Green Veronese**	**PW6**	Corfix	72	Synthetic Inorganic	TiO2	Opaque white
		PG7			Synthetic Inorganic	Co_2TiO_2	Mixed Metal Oxide
		PY74			Synthetic Organic	$C_{18}H_{18}N_4O_6$	Monoazo
Verde Esmeralda	**Emerald Green**	**PG7**	Corfix	73	Synthetic Inorganic	Co_2TiO_2	Mixed Metal Oxide
Verde Inglês	**English Green**	**PG17/ PB15.1/ PY74**	Corfix	75	Synthetic Inorganic	Cr_2O_3	Mixed Metal Oxide
		PB15.1			Synthetic Organic	$C_{32}H_{16}CuN_8$	Phthalocyanine
		PY74			Synthetic Organic	$C_{18}H_{18}N_4O_6$	Monoazo
Terra Verde	**Green Land**	**PG17**	Corfix	79	Synthetic Inorganic	Cr_2O_3	Mixed Metal Oxide
		PY42			Synthetic Inorganic	$Fe_2O_3•xH_2O$	Iron Oxide
		PBk7			Synthetic Inorganic	C	0
Verde de Hooker	**Hooker Green**	**PY83**	Corfix	88	Synthetic Organic	$C_{36}H_{32}Cl_4N_6O_8$	Disazo
		PB15.3			Synthetic Organic	$C_{32}H_{16}CuN_8$	Phthalocyanine
Verde Oliva	**Olive Green**	**PY83**	Corfix	111	Synthetic Organic	$C_{36}H_{32}Cl_4N_6O_8$	Disazo
		PY42			Synthetic Inorganic	$Fe_2O_3•xH_2O$	Iron Oxide
		PG7			Synthetic Inorganic	Co_2TiO_2	Mixed Metal Oxide
		PBk7			Synthetic Inorganic	C	0

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Terra Siena Queimada	**Burnt Si-enna**	**PR101**	Corfix	63	Synthetic Inorganic	Fe_2O_3	Iron Oxide
Vermelho óxido Transpar-ente	**Red Oxide Transpar-ent**	**PR101**	Corfix	113	Synthetic Inorganic	Fe_2O_3	Iron Oxide
Sépia	**Sepia**	**PY83**	Corfix	118	Synthetic Organic	$C_{36}H_{32}Cl_4N_6O_8$	Disazo
		PG7			Synthetic Inorganic	Co_2TiO_2	Mixed Metal Oxide
		PR83			Synthetic Organic	$C_{14}H_8O_4$	Anthraquinone
Marrom de Garança	**Madder Brown**	**PY83**	Corfix	95	Synthetic Organic	$C_{36}H_{32}Cl_4N_6O_8$	Disazo
		PG7			Synthetic Inorganic	Co_2TiO_2	Mixed Metal Oxide
		PR83			Synthetic Organic	$C_{14}H_8O_4$	Anthraquinone
Sombra Natural	**Natural shadow**	**PY1**	Corfix	84	Synthetic Inorganic	TiO2	Opaque white
		PY42			Synthetic Inorganic	$Fe_2O_3•xH_2O$	Iron Oxide
		PR101			Synthetic Inorganic	Fe_2O_3	Iron Oxide
		PBk7			Synthetic Inorganic	C	0
Sombra Queimada	**Burnt Shadow**	**PR101**	Corfix	83	Synthetic Inorganic	Fe_2O_3	Iron Oxide
		PY42			Synthetic Inorganic	$Fe_2O_3•xH_2O$	Iron Oxide
		PBk7			Synthetic Inorganic	C	0
		PY13			Synthetic Organic	$C_{28}H_{12}N_2O_2$	Anthraquinone
Gris de Payne	**Payne Gris**	**PB29**	Corfix	33	Synthetic Inorganic	$Na_{6\text{-}8}Al_6Si_6O_{24}S_{2\text{-}4}$	Silicate
		PBk7			Synthetic Inorganic	C	0

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Name in Portuguese	Name	Pigment	Brand	n°	Type	Formula	Chemical Classification
Gris Neutro	**Neutral Gris**	**PW6**	Corfix	131	Synthetic Inorganic	TiO2	Opaque white
		PBk11			Inorganic, Synthetic Inorganic	$FeO \bullet Fe_2O_3$	Iron Oxide
		PB29			Synthetic Inorganic	$Na_{6-8}Al_6Si_6O_{24}S_{2-4}$	Silicate
Preto de Marte	**Black mars**	**PBk11**	Corfix	121	Inorganic, synthetic Inorganic	$FeO \bullet Fe_2O_3$	Iron Oxide
Branco de Titânio	**Titanium white**	**PW6**	Lefrance & Bourgeois	102	Synthetic Inorganic	TiO2	Opaque white