Digitization of Choirbooks in Guatemala

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Figure 1: Digitization of Guatemalan polyphonic choirbook with do-it-yourself (DIY) book scanner.

ABSTRACT

This paper presents the details about the digitization of a Guatemalan polyphonic choirbook, part of a larger collection held at the Archivo Histórico Arquidiocesano de Guatemala (AHAG). The digitization of this music book is the first step in a larger project that will result in images and symbolic scores semi-automatically retrieved from those images using music-encoding technologies, with the goal of preserving and increasing access to this repertoire. The AHAG does not have the resources to digitize this choirbook collection, as it does not have its own digitization and conservation departments. Moreover, given the books' large size and status in a special collection, there was no digitization equipment in Guatemala suitable for the task. In this paper, we present the details of outsourcing the conservation task, the design of a do-it-yourself book scanner, the digitization workflow, and other recommendations for similar projects where the resources to conduct the digitization are not readily available within the archive.

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CCS CONCEPTS

• **Information systems** → **Digital libraries and archives**; • **Applied computing** → **Sound and music computing**; **Digital libraries and archives**.

KEYWORDS

digital imaging, cultural heritage, preservation, music books, Guatemala, DIY book scanner

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1 INTRODUCTION

The Archivo Histórico Arquidiocesano de Guatemala (Archdiocesan Historical Archive of Guatemala, AHAG) in Guatemala City contains a collection of six polyphonic choirbooks, known by the siglum GuatC. These are old books of large dimensions (average folio size of 30 cm x 45 cm—except for the sixth book which is smaller) containing handwritten music on paper folios. These music books were used in the Guatemala City's Cathedral between c. 1600 and c. 1800. While they were copied in the seventeenth and eighteenth centuries, they contain mostly sixteenth-century polyphonic music written in mensural notation (used in Europe c. 1280–1600). These books document a continuous performance tradition of sacred choral music from the Renaissance through the 1800s. The collection includes works by composers from both Europe and the Americas, resulting in a corpus that allows for studying the transmission of music from Europe to Latin America.

Although the first four choirbooks (GuatC 1–4) have been inventoried [1, 16, 20] and a general overview of the repertoire and history of the whole collection has been provided [15], access to the musical contents of these sources—with the notable exception of the transcribed fourth choirbook [1]—is difficult. There are poor-quality digital images of some of the books (GuatC 1–3) made from microfilms, but pages are cropped or missing, and access to the books on site requires special permission from the AHAG. While modern transcriptions and performances of some of this music have been done by Guatemalan musicologists [2, 10–14], these efforts only cover a small fraction of the corpus.

While the AHAG has scanned some of its historical documents, there are complications to consider for the digital imaging of the GuatC collection. Given the antiquity, physical size, and binding of these books, special equipment and care are necessary for their digitization. Regarding the equipment, according to various digitization guidelines (including FADGI's [9]), these books should be digitized from above with a book scanner of the appropriate dimensions and with no glass/plastic platen to flat the pages. In this paper, we provide the details about how I digitized the first of these choirbooks.[1]

2 BACKGROUND

The first step in this kind of project is to ask permission from the archive holding the item to be digitized. I contacted Guatemalan musicologist Omar Morales Abril, who has studied music sources in the AHAG, on 19 July 2018, asking for his advice on how to approach the archive about this project. He referred me to the AHAG's archivist Alejandro Conde, to whom I spoke over the phone on August 18th of the same year. He advised me to ask permission from the AHAG authorities to do a pilot project with only one of the choirbooks and, depending on the results of the pilot, in the future I could approach them for permission to work with the full collection. I wrote a letter to the chancellor of the Ecclesiastical Curia of Santiago de Guatemala and director of the AHAG, father Eddy René Calvillo, asking permission for the pilot project on 23 October 2018. The request was approved eight days later, on October 31st.

I traveled to Guatemala on November 03–11 and visited the AHAG. There were no conservation and digitization departments on site, so these tasks needed to be outsourced. Through a series of contacts, I found the *Centro de Rescate, Estudios y Análisis Científico del Arte* (*CREA*), a non-profit organization focused on the conservation and restoration of Guatemalan religious heritage that does paper conservation. I presented the project to CREA's lead conservator, and they did an evaluation of the conservation state of the six choirbooks. I received CREA's full conservation report by the end of November and, based on the report, I chose to digitize the first choirbook (GuatC 1).

Digitization equipment and personnel were harder to find. I looked for book scanner options at different institutions, including the National Library, University Libraries, private archives, and digitization services recommended by the former institutions. However, no suitable option was found. Unlike libraries in developed countries, Guatemala's National Library has not carried out any digitization work on its collections as they do not have the equipment nor the budget for such an enterprise. I had better luck in the private sector (University libraries, private archives, and digitization services). However, none of their book scanners were large enough for the manuscripts. The *Centro de Investigaciones Regionales de Mesoamérica* (*CIRMA*), a private institution that holds the microfilms of some of the music assets of the AHAG, had a high resolution camera that could be used as part of a Do It Yourself (DIY) book scanner—the use of this camera would have resulted in images of a resolution higher than 400 ppi. Unfortunately, given how expensive this camera is, they were not allowed to lend it to other institutions.

Given the lack of suitable digitization options, we decided to make our own DIY book scanner by building or borrowing all the parts (see Section 3). I was not able to find a professional photographer with experience in digitization of special collections, as suggested in various digitization guidelines [9] and institutions with experience in digitization of cultural heritage material (e.g., Bibliothèque et Archives nationales du Québec). Instead, I contacted a professional photographer who had previously worked with CIRMA on the digitization of one large item. He helped me set up the camera parameters prior to digitization, while I handled the manuscript myself during the actual process.

3 DIY BOOK SCANNER DESIGN

The final setup of my DIY book scanner is shown in Figure 2, with its three main parts built or borrowed:[2]

- **Book cradle.** The book cradle was built out of wood by German Thomae (my father, who has experience in carpentry) in Guatemala.
- **Camera.** A Nikon D750 camera was borrowed from the Marvin Duchow Music Library (McGill University). The camera has a 24.3-effective-megapixels image sensor, which, given the dimensions of the manuscript pages (18 x 12 square inches), allows for an image resolution of 300 ppi (with no interpolation), an adequate archival resolution value according to the FADGI specifications.[3] The camera included a AF-S Micro NIKKOR 24-85 mm f/3.5-4.5G ED VR lens.
- **Lights.** Two natural-light LED panels were borrowed from the DDMAL Lab (McGill University).[4]

The DIY book scanner was designed following the advice of the McGill Library, the Bibliothèque et Archives nationales du Québec (BAnQ), and the Digital Image Archive of Medieval Music (DIAMM)—institutions with experience in the digitization of special collections, cultural heritage materials, and music manuscripts, respectively—and various digitization guidelines [3, 4, 7–9]. Their recommendations include:

- Bring the digitization equipment to the source item rather than transporting the item itself, avoid unbinding bound

[1] When using the pronouns "I/me/myself" in this paper, it refers to the first author.

[2] Information about book scanner rigs and other ideas on how to build your own book scanner rig can be found online [18].

[3] According to FADGI, a 300 ppi resolution falls into their 3-star digitization projects which result in very professional images that can serve various uses (including OCR), while the 400 ppi resolution falls into their 4-star digitization projects that represent state-of-the-art image capture [9, p. 9, 18]. On the other hand, DIAMM recommends a 400 ppi resolution as its baseline [7].

[4] https://ddmal.music.mcgill.ca

books, and use the appropriate scanning technology [8, p. 36–37].

- If the book cannot be opened flat, the cradle should hold it open at an angle to avoid putting pressure on the book spine. The book scanner options I consulted in BAnQ and the McGill Library used a 110° angle.
- Keep the camera perpendicular to the page.
- Light should mimic natural daylight, avoid flash and natural light [7].
- Keep the lights at an angle (approximately 45°) to avoid reflections on the camera lens, and have the same amount of lighting on each side of the page to be digitized.
- Avoid the use of a platen to flatten the pages.[5]
- Use black felt for neutral background and a stack of pieces of black cardboard to position the color patch at the same height as the digitized page.[6]
- Use a color, grey-scale, and dimension targets. I did not have enough space for both the color and grey-scale target, so I chose to include the color target because I was taking color photographs. However, Julia Craig-McFeely (DIAMM's project director) indicates that the grey-scale target is more important than the color one. A suggestion for including both targets is to cut the color and grey squares into smaller squares [9, p. 73]; however, I could not do this because I borrowed the targets.
- Take the images at the highest quality one can afford and use file formats with no compression or lossless compression for master files (e.g., TIFF and JPEG2000)—access files can be created later in a lossy format (e.g., JPEG). RAW is also considered appropriate for master files [4, p. 18]. I took the master images as NEFF, the raw format used by Nikon cameras, and generated a second master copy in TIFF using Nikon's Capture NX-D software. Master files should not be retouched [9, p. 20].
- The recommended resolutions are 300 ppi or 400 ppi and the suggested bit-depth for color images is 24 or 48 bits (this is, 8 or 16 bits per color channel) [9, p. 18–20]. I took the images at the highest quality possible with the camera I was lent. The images were stored with 300 ppi, with a size of 4016 x 6016 pixels, and using a 24 bit depth.

The cradle had two configurations, the facing-up V-shape configuration (see Figure 3) and the open-at-one-side configuration (see Figure 4), which is the one I ended up using as shown in Figure 2. Both configurations allow the book to open at a 110° angle. The facing-up V-shape configuration has the advantage that one can use two cameras to photograph two pages of the book at once. However, this means finding two cameras of the same resolution and using the same parameters to guarantee that the images of recto and verso pages have the same quality. It also makes it hard to keep the camera perpendicular to and at a constant distance from the photographed page if one does not have a scanner rig with rails

[5]This is even more important in parchment since, as pointed by Craig-McFeely, the ink sits on top of the surface and can be lift when removing the platen.

[6]This was suggested by DIAMM's photographer Lynda Sayce. To keep the color patch at the same level as the photographed page when using a platen, Sayce suggested pasting the patch below the platen (so that any shadow/color projected by the platen affects the page and reference target similarly).

Figure 2: DIY book scanner setup with the cradle opened on one side, the camera held perpendicular to the page with a copystand, and natural-light LED panels on each side for even distribution of the light over the page.

or adjustable mounts on which to place the cameras. In my case, I only had a tripod, which would make this very difficult. Moreover, without a glass or plastic platen, it is difficult to keep the pages flat in this V-shape configuration.

In the open-at-one-side configuration, though one can only photograph one folio at once, there were several advantages. In this configuration it is easy to **(1)** set the camera perpendicular to the page being digitized using a copy stand (or a combination of a sturdy tripod and horizontal arm [19]), **(2)** maintain a constant distance between the camera and the page while moving through the pages of the book, **(3)** keep the page flat, and **(4)** provide an even distribution of the light on the page when using two sources of light, with one at each side. If you are interested on building your own book cradle, the parts and dimensions of this one are listed in Appendix B together with some diagrams showing their placement.

4 THE DIGITIZATION WORKFLOW

As indicated in [3, p. 10], preparation of the material for digitization includes conservation assessment and treatment. GuatC 1 was already approved to undergo digitization by CREA conservators (in the report of November 2018), and the book received conservation treatment on January 7th (2019) to prepare it for digitization the next day. Digitization experts from BAnQ and the McGill Library indicated that the camera parameters (including operations like white balancing) should be set by a professional photographer before each

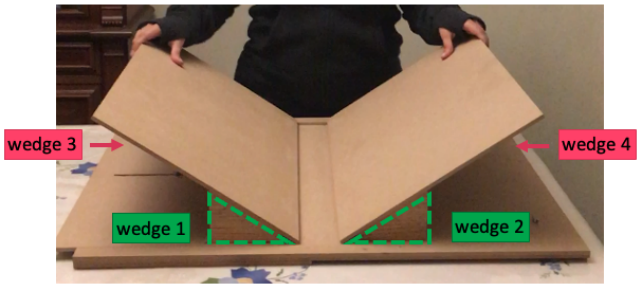

Figure 3: V-shaped book cradle facing-up configuration. It includes two doors, one of them movable to fit the book spine. Each door is held by a pair of wedges at a 35° angle, allowing to open the book at 110° (angle between the doors).

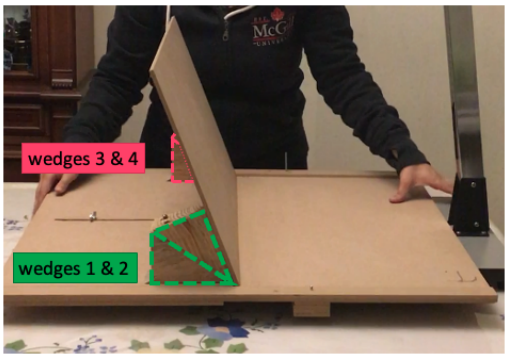

Figure 4: Book cradle open-at-one-side configuration. The right door has been removed, leaving only the left (movable) door. This door is held at a 70° angle by a pair of two 35° wedges stacked together, holding the book opened at 110°.

imaging session.[7] However, not having a digitization expert on site made this task impossible. As I conducted two digitization sessions per day for four days, having the professional photographer check the camera parameters prior to each of these sessions would have meant having him come to the AHAG on eight different occasions for less than an hour each. Instead, we hired the photographer to set the camera parameters to be used during the entirety of the project on the first day, and to come the following two mornings to check if everything was working as expected and to answer any questions.

On day one of the digitization process, the photographer positioned the camera in the copystand arm (at 50 cm) and determined the zoom based on the distance between the camera and the manuscript (setting it to a focal length of 44 mm).[8] Considering that I was conducting the digitization on my own, the photographer set the camera to shoot in one of its automatic modes, Mode A (Aperture-Priority Auto). In mode A, one only needs to set the camera's aperture and, based on this value, the camera automatically adjusts the shutter speed. The photographer set the aperture by testing different f-numbers, taking a photo of one folio with each value, and checking which f-number made the corners of the page (the areas that are the farthest from the camera) look better defined. He also set the camera to perform auto white balancing.

Since the photographer was not available to check the camera parameters prior to each session, I kept these and all other imaging conditions constant during the whole digitization project. I used the same room to photograph the whole manuscript and kept its lighting conditions constant by maintaining the room lights off and the wooden doors of the window closed (avoiding any external sources of light), and only used the two LED panels as the light source, whose locations remained fixed (I marked the location of the legs of the light stands on the floor).

To take the photos, I connected the camera wirelessly to my laptop and used tethering software (DslrDashboard).[9] Shooting tethered—i.e., shooting from an external device such as a computer, tablet, or phone—allowed me to review the photos on my laptop a few seconds after shooting, which is much more efficient than evaluating the photographs in the camera's monitor, especially when the camera is placed high up in the copystand. The tethered application also allowed me to press the shutter button on my laptop rather than trying to reach the shutter button of the camera, which is important to avoid introducing unwanted vibrations when taking the photograph.

I photographed all the versos first, turned the book around, and photographed all the rectos. I came up with a small series of steps for digitizing each folio to make the process as consistent as possible:

(1) Turn the page.
(2) Place the snake weight on top of the page that is on the door side so that it does not fall over the page to be photographed (see Figure 1).
(3) When photographing a verso, change the piece of paper that denotes the number of the folio (see the piece of paper with the printed verso number at one side of the color patch in Figure 5).[10] I omitted steps 3 and 7 when photographing rectos, since the number is included at the top of the folio for rectos.
(4) Quickly review the previous picture taken (previous folio), which should be uploaded on the computer by then. This inspection consists of quickly evaluating whether the picture is in focus, and looking for shadows.
(5) Press focus on the app, which uses the auto-focus function of the camera.
(6) Shoot from the app.
(7) In the case of a verso, check once again that I used the right printed number.
(8) And repeat.

As I moved through the pages of the book, eventually the stack of pieces of cardboard holding the color patch projected a shadow over the photographed page. When a shadow appeared in the image

[7] Although some parameters such as white balance can be corrected lossless when images are saved in RAW format.
[8] The photographer indicated that ideally one would set first the focal length (maintaining its value close to the len's median focal length) and then position the camera. However, we were limited by the length of the copystand arm.
[9] https://dslrdashboard.info/
[10] The use of these pieces of paper with the printed number for verso pages was the photographer's idea.

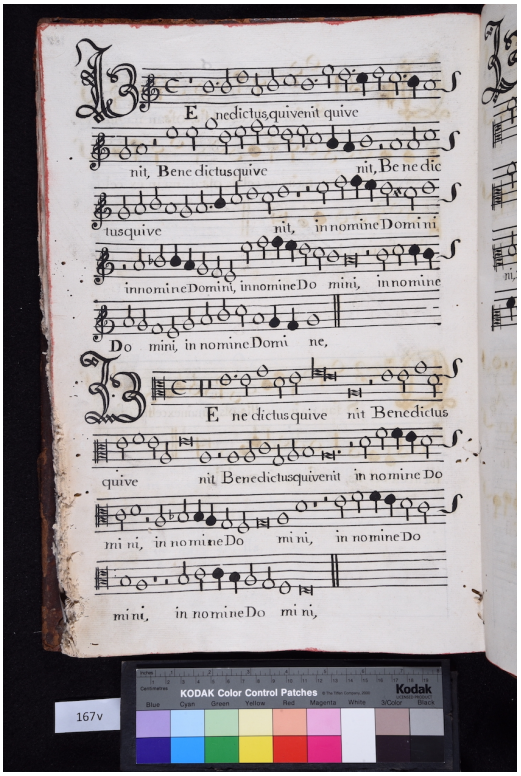

Figure 5: Example of the photograph of a verso folio. ***AHAG, Archivo Catedralicio, Sección Litúrgica.***

at the bottom of the page, I removed a cardboard from the stack. Similarly, as I moved through the pages, the photographed folios started getting farther from the camera—which can be seen in the photographs when the black felt area gets bigger. To keep the distance between the camera and the folio constant, I lowered the camera 0.5 cm—the smallest unit of the copystand arm—after going through approximately the same distance in terms of folios.

As I started getting closer to the end of the book, two issues emerged. First, most of the pages were on the door side of the cradle (rather than on the horizontal plane) and they would tend to fall, because the snake weight was no longer enough to hold them in place. To solve this and to stop the book from closing abruptly, I increased the angle of the opened book by moving the cradle door. The second issue concerned the page to be photographed, which tended to curve more. To solve this, I lifted the book spine by cutting two pieces of the black felt, rolling each of them into a conic shape, and inserting each cone below one end of the spine (always under the black felt sheet). This helped give support to the spine and to flatten the page that lay on the horizontal surface of the cradle by raising the spine and gutter.

The computer application tethered to the camera I was using to shoot got stuck from time to time. My solution was to switch to a mobile tether application (Nikon's Wireless Mobile Utility, WMU) that I had installed on my phone to continue the process, keeping the camera parameters unchanged. It is always important to test the equipment beforehand—imitating the on-site conditions as close as possible—and have alternatives to be prepared for issues.[11] However, there are ways to avoid this problem with the tethering application: **(1)** Use the camera's official tethering software to avoid compatibility issues, **(2)** connect the camera using a cable rather than wirelessly to avoid connectivity issues (you might need to buy a long cable, as the data cable that comes with the camera tends to be short), and **(3)** save your images on an external hard drive to avoid any memory issues generated by storing the images in the computer.

This was my first time shooting with the computer tethered to the camera, and while I took advantage of the program's preview and remote shooting functionalities, further exploration of the software would have been beneficial since there are options for adding comments (useful for keeping track of the verso numbers), changing the file path for storing the images (better to save them in an external hard drive), and adding stars (useful for selecting the preferred image from a set of photographs of the same folio).

The whole process took seven business days (approximately a week and a half). Day one, as indicated before, was for conservation treatment and for me to check which configuration of the cradle worked better with the choirbook. Day two was for setting up the book scanner and camera parameters and testing the workflow to find any issues. Days three to six were spent on photographing the folios. The photographer helped me during one of those days to photograph the book's covers and spine. And the seventh day was for re-shooting any folio that presented issues (e.g., a tilted color patch or a small detached piece of paper covering some of the text or music content). Ignoring the test shots from day two, I took a total of 580 photographs to digitize the folios, and discarded around 187 of these.

5 FINAL REMARKS

There are many music documents locked in archives around the world, and not all of these archives have digitization and conservation departments. In this paper, we provide a case study of a digitization project conducted under such conditions. The lack of digitization equipment was addressed by building a book scanner, following best practices outlined in various digitization guidelines and recommendations of institutions with experience in digitizing special collections and old music documents. All the parts of the book scanner were either built or borrowed from other institutions. We provide the details for setting up the book scanner, as well as the workflow followed and the issues that emerged during the digitization process. In this project, we have tried to present a realistic solution for the digitization of old music books in an archive that lacks the resources and personnel for this kind of project. We hope this is useful for similar initiatives.

The digitization of the GuatC 1 manuscript described in this paper is the necessary first step in a larger workflow for retrieving symbolic music scores from manuscript images by using music-encoding technologies (including optical music recognition and

[11] Actually, the two configurations of the book cradle were the result of testing the setup at home with a large book from my own collection. This home test made me realize some of the issues with my V-shaped facing-up cradle and camera setup—mentioned at the end of Section 3—and helped me to prepare the cradle to have an alternative configuration, the open-at-on-side configuration, which was the one that I used as it worked better with the actual manuscript when I tested it on site.

automatic voice-alignment and editorial-correction software for mensural notation). These retrieved images and symbolic editorial scores will increase access to and ensure the preservation of this repertoire.

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A ONLINE RESOURCES

- Youtube playlist showing the book cradle configurations, the book scanner setup, and the digitization process: https://www.youtube.com/playlist?list=PLC08PttZdHNBpl8z1MV2U3UZFNBL3jQ5g
- Tools for completing the music-encoding part of the workflow:
  - The **Music Recognition, Encoding, and Transcription (MuRET)** framework is used for performing optical music recognition (OMR) over the retrieved images [17]. https://muret.dlsi.ua.es/muret/#/home
  - The **Measuring Polyphony Editor (MP Editor)**, an online editor for mensural notation, is used for performing the automatic voice-alignment step (over the symbols recognized by the OMR) and to provide editorial corrections [5, 6]. https://editor.measuringpolyphony.org/#/

B BOOK CRADLE DESIGN

This section contains the details for building a book cradle like the one used for this project. Table 1 provides all the parts of the cradle with their dimensions, and Figures 6 to 12 show the position of each of these parts. All parts where extracted from a medium-density fibreboard (MDF) of 4 x 8 square feet and a quarter-inch width.

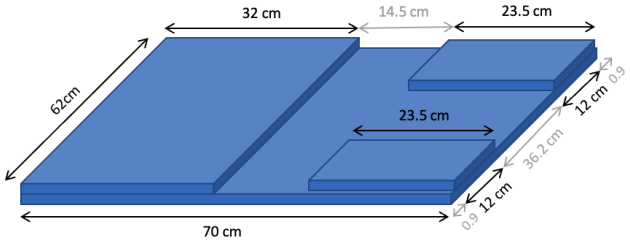

Figure 6: Bottom of the cradle (flipped cradle).

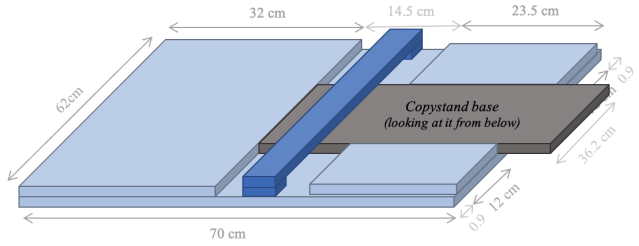

Figure 7: Bottom of the cradle (as in Figure 6) showing the joint bar used to fix the copystand base to the book cradle.

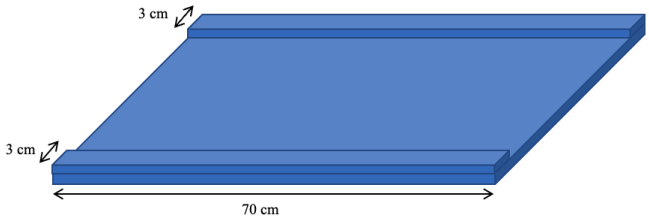

Figure 8: Top of the cradle.

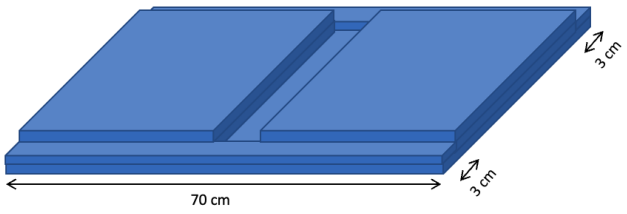

Figure 9: Cradle with doors closed.

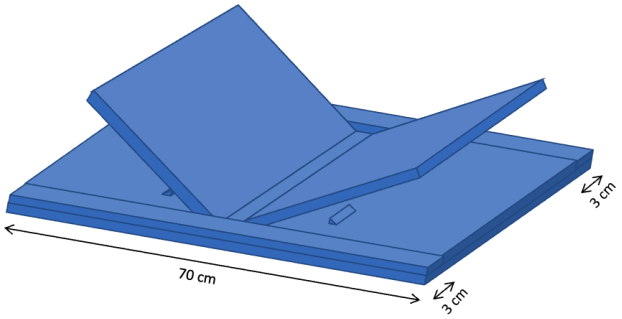

Figure 10: Cradle with both doors open. Wedges are used to keep the doors open (as shown in Figure 3 and Figure 4).

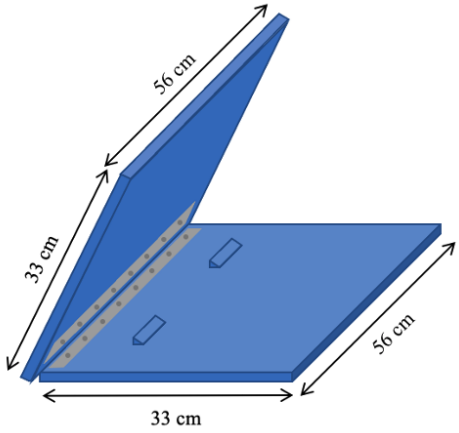

Figure 11: Right-side door. This is a removable door to be slid into the right side of the empty space in the cradle shown in Figure 8. The small triangular pieces work as stops for the wedges that keep the door open.

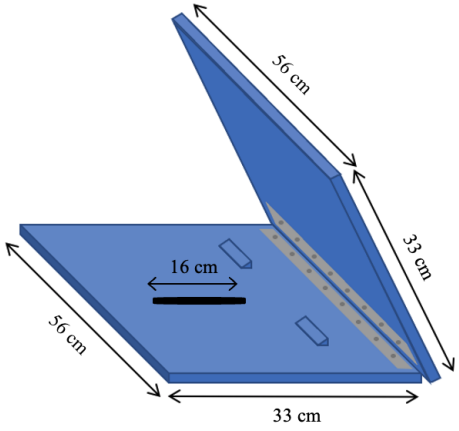

Figure 12: Left-side door. This is a movable door to be inserted at the left side of the empty space of the cradle shown in Figure 8. The large slide hole in the middle of its lower panel allows the door to stay in different positions by using a wing nut (which can be seen in Figure 3 and, more clearly, in Figure 4).

Table 1: Cradle components and their dimensions.

Type of Piece	No. of Pieces	Size (cm)	Description
Base	1	width=62; length=70	The base where the doors rest (largest piece in Fig 6).
Bottom piece A	1	width=62; length=32	Three pieces to fit the base of the copystand in the bottom side of the cradle (Fig 6).
Bottom piece B	2	width=12; length=23.5	
Joint bar A	1	width=62; length=5	Three pieces form the joint bar that fixes the copystand base in the place limited by the three bottom pieces (Fig 7).
Joint bar B	2	width=3.5; length=5	
Lateral guides	2	width=3; length=70	Two lateral guides, pasted on top of the base, to help sliding the doors in (Fig 8).
Door panels	4	width=56; length=33	These four pieces are connected in pairs with a continuous hinge to make the two doors (Fig 11 and 12). The doors are to be inserted in the upper part of the cradle by sliding them in (Fig 9 and 10).
Hinge	2	length=54	Continuous hinge used in each door (Fig 11 and 12).
Wedges	4	height=7.8; length=11.3 (minus triangle's tip of 1.9cm); width=4.5	Each triangular wedge has a 35° angle, given their height and length. The triangles' tip was cut and used to fix the wedge in place (see four small triangular pieces in the doors in Fig 11 and 12 that work as stops for the wedges).