An Introduction to the "Non-Destructive Guillotine" ("NDG") Book Scanner

Fri 22 April 2016

Posted in Tutorials || book-scanning, archiving, darktable, bookscan-software, cameras, ocr, non-destructive-guillotine ⇄ **10 min. to read**

In short: I introduce a new portable, single-camera book scanner design. The scanner is small enough to fit into a backpack when disassembled, and can be re-assembled in under 10 minutes. It does not require any power tools to construct; the only required tools are a tape measure, a PVC cutting tool, and scissors. A full list of parts, sizes, and prices are below, along with a video explaining the scanner's construction and use.

This is a long post; thus, I've added a **Table of Contents with links** here:

Background / Introduction

Just after finishing my under graduate course at the University of San Francisco, I began a project to **digitally archive** all of my university notes and textbooks in order to have them on hand in the future without having to take them with me physically. Having found out about a community of enthusiasts led at the time by a gentleman named Daniel Reetz (http://wwwdanreetz.com/) at DIYBookScanner.org (http://diybookscannerorg), I built my first book scanner, modeled loosely after the

"Scribe" scanner that the Internet Archive (https://archive.org/) was using at the time (http://dltj.org/article/internet-archive-scanning-gallery/). My build was documented in a post (http://diybookscannerorg/forum/viewtopic.php?f=14&t=464&p=4192#p4192) on the DIYBookScanner forums. That was in 2010.

Goals of this Design

Last fall, I became interested again in building a readily-available scanner for books. I was writing a lar ge paper at the time, and it was useful to scan and OCR (https://en.wikipedia.org/wiki/Optical_character_recognition)sections of library books in order to search through their text using a computer; this ability saved me considerable time when looking through lar ge passages for relevant sections.

> *Gloss: Though I'm not a lawyer or legal scholar, to my understanding after reading substantially on the topic, scanning and otherwise processing a library book is legal in the USA, as long as the scan isn't retained past the loan period.*

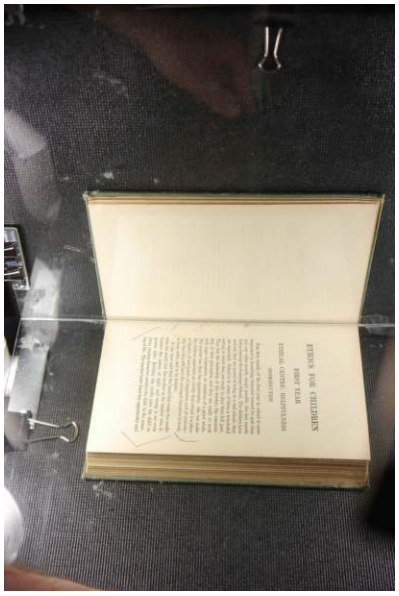
I built a new scanner in November 2015 (which will be the subject of future posts). In February and March, I became interested in **building a smaller version, with thr ee goals:**

> It needed to be **inexpensive to build** (preferably for less than $100 in parts, plus the cost of a single camera).
>
> It needed to be able to **fit into a backpack** or other small carrying case (my November 2015 build was over-engineered and is too large to fit into even a suitcase).
>
> Preferably, it needed to be able to be **built without power tools.** Although I have a tool collection now, when I was an undergraduate, I only had access to a power drill (no circular saws, drill presses, etc.). Thus, building a scanner as an undergraduate was made difficult mostly by my inability cut materials such as wood without help.
>
> > *Gloss: I did learn through this process, however, that hardware stores will often cut plywood for a small fee.*
>
> I wanted this build to be accessible to my younger self – something, for example, that **a group of students living in dormitories or studio apartments could build and share.**

For the past several months, I've been reading about the developments of the DIY Book Scanning (http://diybookscannerorg) community with these goals in mind. T oday, I am excited to introduce a new scanner design.

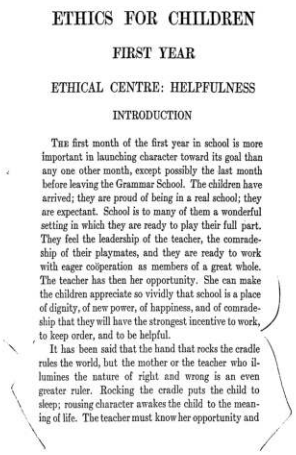
Our goal is to take an original image like this:

> *Gloss: All images in this post have been downsized to make them easier to download; the original images are higher-quality.*



(/images/2016-04_Guillotine_Book_Scanner_Introduction/Scan_Examples/original_page_image.jpg)

...And turn each page into an image like this:



ETHICS FOR CHILDREN

FIRST YEAR

ETHICAL CENTRE: HELPFULNESS

INTRODUCTION

The first month of the first year in school is more important in launching character toward its goal than any one other month, except possibly the last month before leaving the Grammar School. The children have arrived; they are proud of being in a real school; they are expectant. School is to many of them a wonderful setting in which they are ready to play their full part. They feel the leadership of the teacher, the comradeship of their playmates, and they are ready to work with eager colperation as members of a great whole. The teacher has then her opportunity. She can make the children appreciate so vividly that school is a place of dignity, of new power, of happiness, and of comradeship that they will have the strongest incentive to work, to keep order, and to be helpful.

It has been said that the hand that rocks the cradle rules the world, but the mother or the teacher who illumines the nature of right and wrong is an even greater ruler. Rocking the cradle puts the child to sleep; rousing character awakes the child to the meaning of life. The teacher must know her opportunity and

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Scan_Examples/processed_page_image.jpg)

This post is about the hardware portion of that process. The software portion primarily involves two free packages, **ScanTailor** (http://scantailor.org/), which came out of the DIYBookScanner community; and **Darktable** (http://www.darktable.org/), which can edit photos as batches (i.e., can apply the same transformations to all photos in a sequence). Further software recommendations are briefly discussed below .

I call the scanner documented below the **"Non-Destructive Guillotine" ("NDG").** In the design, a plexiglass or acrylic platen comes down vertically to separate the left and right pages of a book, then folds out to press both sides flat. A camera then takes a photograph of both pages at once. Put dif ferently, the scanner use s a **single camera** (unlike many book scanners, which use two cameras) to take **intentionally-keystoned** (https://en.wikipedia.org/wiki/Keystone_effect) photographs of each two pages in a book, held open at a 90-degree angle to one another (thus, each page is 45 degrees of f from the camera). The scanner features a trolley system to lower the camera as the book is scanned, causing the keystoned pages at every point of the book to stay in the same spatial relationship with the camera. This allows the photographs of all pages to be de-keystoned in a batch, using software such as Darktable (http://www.darktable.org/). In addition to hardcover books, **the scanner also works well with paperback books and magazines.**

> *Gloss: Many two-camera scanners have difficulty with paperback books, since the bindings are tight and therefore tend to cause the books to shut as soon as the pressure holding their pages open is released.*

Licensing of the Design and this Documentation

I am releasing the **scanner design into the Public Domain (or its near est equivalent internationally) via the [Creative Commons CC0 dedication]http s://creativecommons.org/publicdomain/ zero/1.0/ "CC0 dedication"),** following Daniel Reetz' advice (http://www.diybookscanner.org/archivist/?page_id=839) on the topic. This write-up and the video below are released under a **Creative Commons Attribution-Shar eAlike 4.0 license** (https://creativecommons.org/licenses/by-sa/4.0/); if you would like to arrange a dif ferent license arr angement to re-use these materials, please contact me () to make an arrangement.

Following my goals, the scanner is **small enough to fit into a backpack** when disassembled, and can be re-assembled in under 10 minutes. It **does not require any power tools to construct;** the only required tools are a tape measure, a

PVC cutting tool, and scissors. **A full list of parts, sizes, and prices ar e below, along with a video explaining the scanner's construction and use.**

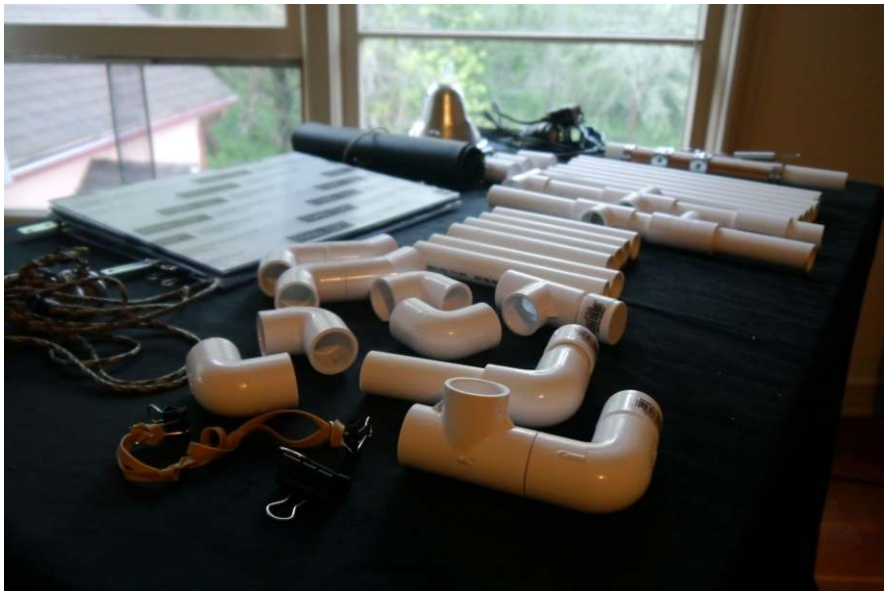
This scanner design is one of many; see the DIYBookScanner webiste (http://diybookscannerorg/) for alternative designs and discussion. DIY Book Scanner enthusiasts, and the website's original founder Daniel Reetz, spent years building this community and conducting research into inexpensive book scanning technology . The scanner design shown here, while original, has been inspired by many posts in the community's website's forums, especially including **Mr. David Landin** (https://wwwyoutube.com/watch?v=ns3jGFbJvXI), who was possibly the first member of the community to use PVC for the major part of a build.

Building the Scanner

Hardware

Overview of the Parts

> *Gloss: Do note that in the photos and video below, the vertical arm holding the camera trolley is (in the build shown) at a slight angle. Ideally, this arm would be straight up and down. Correcting this is a matter of re-arranging the PVC pipe and fittings on the top back assembly (i.e., the row of pipe and fittings on the back, top side of the scanner); it has subsequently been corrected in my scanner.*



(/images/2016-04_Guillotine_Book_Scanner_Introduction/Table_of_Parts_at_Angle.jpg)

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Table_of_Parts_1.jpg)

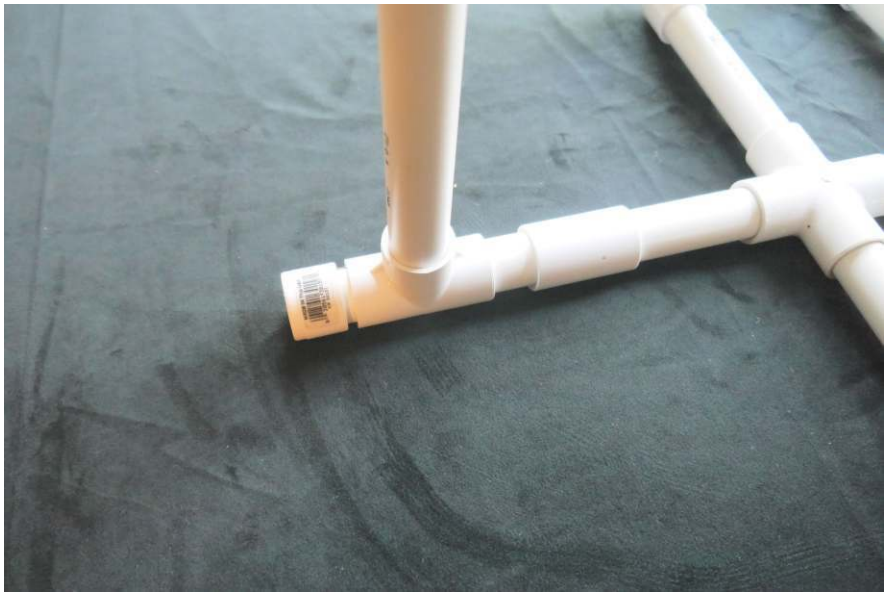
(/images/2016-04_Guillotine_Book_Scanner_Introduction/Table_of_Parts_2.jpg)

The Bare Frame

Gloss: Scanner Frame Front Angle

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Scanner_Frame_Front_Angle.jpg)

Gloss: Scanner Frame Front of Base Detail



(/images/2016-04_Guillotine_Book_Scanner_Introduction/Scanner_Frame_Front_of_Base_Detail.jpg)

Gloss: Scanner Frame Left-Side Angle

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Scanner_Frame_Left-Side_Angle.jpg)

Gloss: Scanner Frame Rear Top Detail

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Scanner_Frame_Rear_Top_Detail.jpg)

The Full Scanner

Gloss: Full Scanner Front Angle

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Full_Scanner_Front_Angle.jpg)

Gloss: Full Scanner Left-Side Angle

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Full_Scanner_Left-Side_Angle.jpg)

Gloss: Full Scanner Right-Side Angle

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Full_Scanner_Right-Side_Angle.jpg)

Gloss: Full Scanner Rear Angle

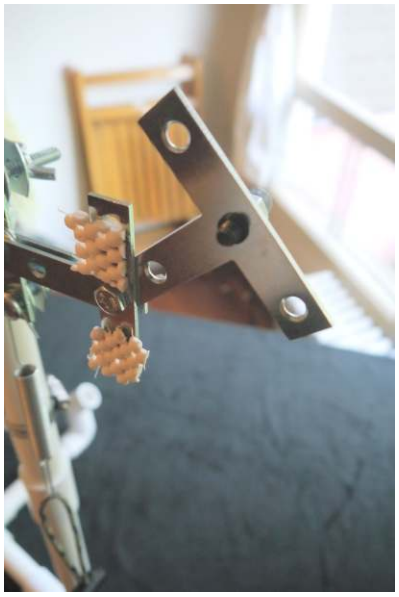
(/images/2016-04_Guillotine_Book_Scanner_Introduction/Full_Scanner_Rear_Angle.jpg)

Camera Mount

Gloss: Camera Mount and Trolley

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Camera_Mount_and_Trolley_1.jpg)

Gloss: Camera Mount Detail



(/images/2016-04_Guillotine_Book_Scanner_Introduction/Camera_Mount_Detail.jpg)

Gloss: Camera Trolley Detail 1

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Camera_Trolley_Detail_1.jpg)

Gloss: Camera Mount and Trolley Detail 2

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Camera_Mount_and_Trolley_Detail_2.jpg)

Cradle

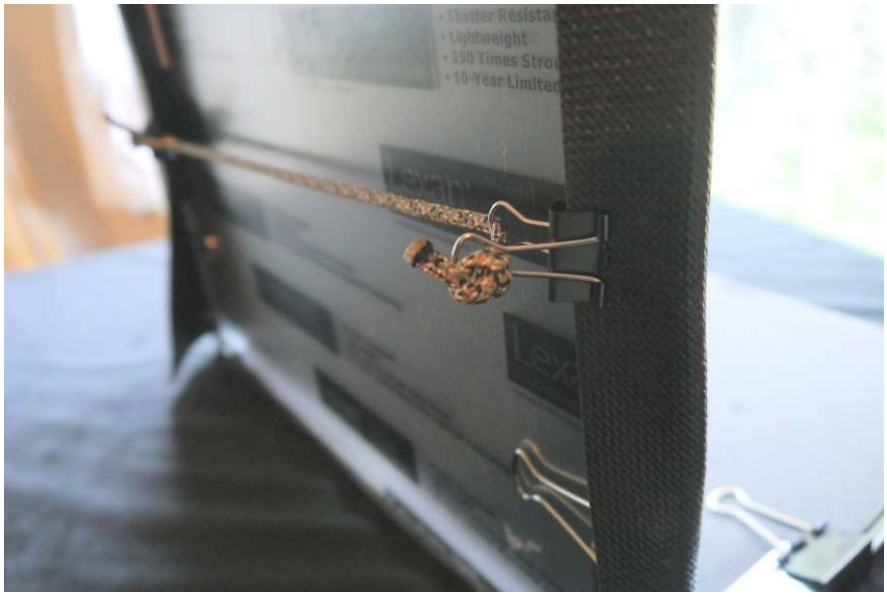
Gloss: Cradle Front Angle

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Cradle_Front_Angle.jpg)

Gloss: Cradle Rear Angle

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Cradle_Rear_Angle.jpg)

Gloss: Cradle Rear Angle Drawer Liner Attachment Detail



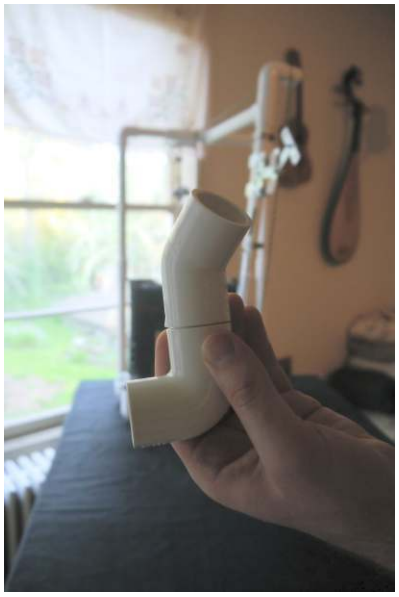
(/images/2016-04_Guillotine_Book_Scanner_Introduction/Cradle_Rear_Angle_Drawer_Liner_Attachment_Detail.jpg)

Lighting Arm

Gloss: Lighting Arm Mountpoint Detail 1

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Lighting_Arm_Mountpoint_Detail_1.jpg)

Gloss: Lighting Arm Mountpoint Detail 2



(/images/2016-04_Guillotine_Book_Scanner_Introduction/Lighting_Arm_Mountpoint_Detail_2.jpg)

Gloss: Lighting Mount Detail

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Lighting_Mount_Detail.jpg)

Platen

Gloss: Platen Corner-Brace Detail

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Platen_Corner_Brace_Detail.jpg)

Gloss: Platen Counterweight Detail

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Platen_Counterweight_Detail.jpg)

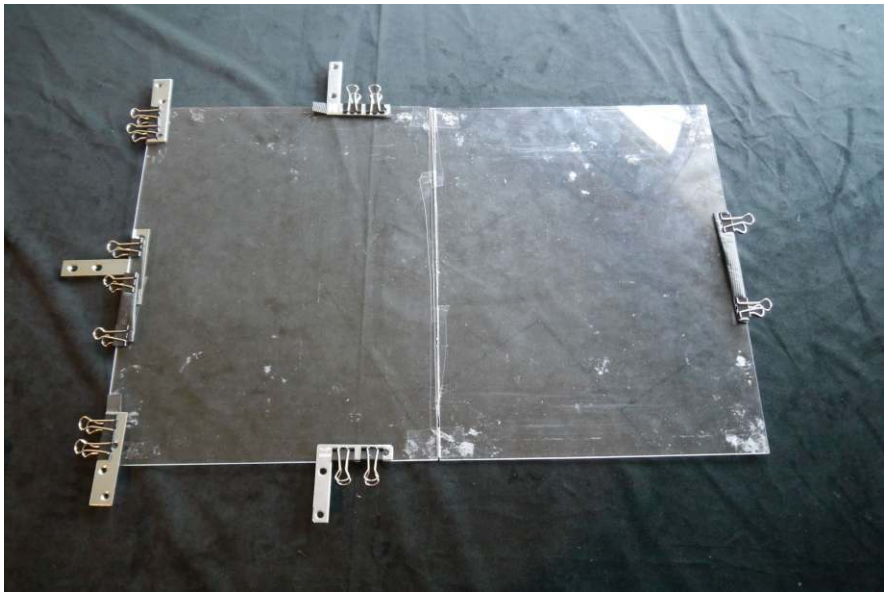
Gloss: Platen Front-Side Detail

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Platen_Front-Side_Detail.jpg)

Gloss: Platen Top Detail

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Platen_Top_Detail.jpg)

Gloss: Platen Unfolded



(/images/2016-04_Guillotine_Book_Scanner_Introduction/Platen_Unfolded.jpg)

Pulley and Counterweight

Gloss: Pulley and Counterweight

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Pulley_and_Counterweight.jpg)

Gloss: Pulley and Counterweight Paracord Meeting-Point Detail

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Pulley_and_Counterweight_Paracord_Meeting-Point_Detail.jpg)

Gloss: Rubber Band Detail

(/images/2016-04_Guillotine_Book_Scanner_Introduction/Rubber_Band_Detail.jpg)

Video Tutorial on the Scanner's Design, Construction, and Use

I've recorded a video that explains the scanner in more depth (click to view):

Software

As mentioned above, **I recommend using Darktable (http://www.darktable.org/) to batch-de-keystone the images (first the left pages, and then the right pages).** Darktable allows any series of corrections or transformations made to one image to be **saved as a "Style" (https://www.darktable.org/usermanual/ch02s03s08.html.php) and re-applied to any other images.** I manually de-keystone and sharpen one image for its left page, save the "style" and re-apply it to all other photos taken from the book scanner, and then export the resulting images. I then repeat the process for the right pages in the original photographs.

Alternatively, images could be de-keystoned using software written as part of a one-day build by **Yutaka Tsutano,** here (https://github.com/ytsutano/bookscan). The software uses printed glyphs to mark the boundaries of each page, and then uses OpenCV (http://opencvorg/) to split and de-keystone the page images. Since Mr. Tsutano's code was created as part of a one-day build several years ago (one about which Mr. Tsutano has written he would prefer not to continue to develop), I recently forked the code (https://github.com/publicus/bookscan) in order to increase its level of documentation and code clarity. This is still a work in progress, however. I am not a C++ developer, and so see my role as primarily custodial for now (i.e., working on documentation and community-building).

The de-keystoned images can then be passed to ScanTailor (http://scantailor.org/), which will automatically crop and tilt the images, equalize margins, and white-balance correct the images. At that point, the output images can be bound into a PDF with a tool like the PDFToolKit (PDFTK) (https://en.wikipedia.org/wiki/Pdftk). Alternatively, it can be OCRed and then bound with tools such as DjvuBind (https://github.com/strider1551/djvubind) or PDFBeads (https://rubygems.org/gems/pdfbeads/versions/1.1.1).

If you are not running Linux and have access to them, Adobe Acrobat Pro and ABBYY FineReader (https://en.wikipedia.org/wiki/ABBYY) can also be used to OCR PDFs produced from the scanner.

What You'll Need

Parts List

Tools

0	Item	Quantity	Approx. Price Per Unit (USD)	Total Item Price (USD)	Optional Item Price
1	Scissors	1			
2	(Optional, but highly recommended) PVC cutting tool	1	10		10
3	(Optional, but recommended) Pliers (Useful for removing stuck PVC pipe from fittings)	1			
4	Matches/lighter (for sealing cut paracord)	1			
5	(Optional, but recommended) Hacksaw or other cutting tool (for dowel)	1			
6	Clear packing tape	1			
7	Double-sided tape (for attaching drawer material to camera mount)	1			

0	Item	Quantity	Approx. Price Per Unit (USD)	Total Item Price (USD)	Optional Item Price
8			Required Total:	0	

Cradle and Platen

0	Item	Quantity	Approx. Price Per Unit (USD)	Total Item Price (USD)	Optional Item Price
1	Acrylic sheet 11”x14”x3/32” (.093” thick suffices)	4	4.78	19.12	
2	Small (3/4”) binder clips	17	0.1	1.7	
3	Medium (1.25”) binder clips (can replace 4 of these with 6 additional small binder clips) (Alternatively, these can be replaced with an equal number of small (3/4”) binder clips)	5	0.15	0.75	
4	4” Corner brace	2	2.87 / 2 pack	2.87	
5	3” Straight mending plate	2	2.97 / 4 pack	1.485	
6	2.5” 90-degree flat corner brace	2	2.67 / 4 pack	1.335	
7	Roll of black anti-slip drawer liner (non-adhesive) (one 18”x4' roll is plenty)	1	6	6	
8	Rubber bands	3	0.1	0.3	

0	Item	Quantity	Approx. Price Per Unit (USD)	Total Item Price (USD)	Optional Item Price
9	550 nylon paracord (5/32” or 3.9mm) (approx 12 feet) (see cut list for specifics)	15	0.09	1.35	
10	Fishing weights (approx 13 oz. (I have 3x3oz and 2x2oz))	13	1	13	
11	(Optional) 2x mini carabiner (for easy clipping)	2	1	2	
12	Cord drawstring lock	2	0.5	1	
13	(Optional) Fine (220-400)-grit sandpaper and black spraypaint for PVC				5
14			Required Total:	50.91	

PVC and fittings (for structure)

0	Item	Quantity	Approx. Price Per Unit (USD)	Total Item Price (USD)	Optional Item Price
1	3/4” Schedule 40 PVC	~15 feet (see cut list for specifics) (pricing here is for 20 feet, since it's not an expensive part of the build, and it can be useful to have extra in case of mistakes)	2.70 / 10 feet	5.4	
2	Coupler	4	0.35	1.4	
3	Cross	1	1.96	1.96	

0	Item	Quantity	Approx. Price Per Unit (USD)	Total Item Price (USD)	Optional Item Price
4	Tee	5	0.75	3.75	
5	90 angle	8	0.48	3.84	
6	45 angle	2	0.84	1.68	
7	Cap	2	0.46	0.92	
8			**Required Total:**	18.95	

Lighting

0	Item	Quantity	Approx. Price Per Unit (USD)	Total Item Price (USD)	Optional Item Price
1	Lightbulbs (1600 lumens/120 volts)	2	5	10	
2	(Optional) Clamp light with aluminum reflector (the clamp can be removed)	2	9		18
3	#2 (1" – should fit snugly enough to be tightened around the 3/4" PVC) conduit hangers with 1/4" carriage bolts	2	0.87	1.74	
4	1/4" Wingnuts	2	0.24	0.48	
5	Extension cord with 2 plugin spaces	1	2.5	2.5	

0	Item	Quantity	Approx. Price Per Unit (USD)	Total Item Price (USD)	Optional Item Price
6	1/4"x1/2” long hex bolt	2	0.31	0.62	
7	1/4" hex nut	2	0 (Take from Conduit hanger)	0	
8			**Required Total:**	15.34	

Camera track

0	Item	Quantity	Approx. Price Per Unit (USD)	Total Item Price (USD)	Optional Item Price
1	3/8" x approx. 18" hardwood (e.g., oak) dowel	1	1.44	1.44	
2	#20 Hose clamp (aka “Jubilee clip”) (1/2” band, 3/4”-1 3/4” diameter)	2	0.98	1.96	
3	Extension spring (I used a 2” spring), preferably with hooks on the ends	1	1.6	1.6	
4			**Required Total:**	5	

Camera mount

0	Item	Quantity	Approx. Price Per Unit (USD)	Total Item Price (USD)	Optional Item Price
1	#2 (1" – should fit snugly enough to be tightened around the 3/4" PVC) conduit hangers with 1/4" carriage bolts	2	0.87	1.74	
2	1/4" Wingnut	2	0.24	0.48	
3	3”x3” T-shaped plate	2	2.98 / 2 pack	2.98	
4	1/4"x1/2” long hex bolt	1	0.31	0.31	
5	1/4" Wingnut	1	0.24	0.24	
6	1/4" washers	2	0.2	0.4	
7	1/4"x3/4” long Allen bolt / “socket cap screw/bolt,” with grooved head exterior (to allow thumb-tightening into camera)	1	0.55	0.55	
8	(Optional) 1-2x additional 1/4" hex nut for spacing bolt for camera	2	0 (Take from Conduit hanger)	0	
9	Thin o-ring that fits snugly over the 1/4" bolt for camera (for example, 5/16” Outside Diameter x 3/16” Inside Diameter x 1/16”) (Often comes in pack of 10, which is priced here)	1	2.27	2.27	

0	Item	Quantity	Approx. Price Per Unit (USD)	Total Item Price (USD)	Optional Item Price
10			Required Total:	8.97	
11					

Total Cost (Assuming you do not have any required parts already – if you do have some parts already, the cost decreases)

0	Required Parts	Required + Optional Parts
1	99.17	132.17

Cut List ()

Dowel

0	Purpose	Inches (Approx.)	Number	Total
1	Camera track	9	2	18

Paracord

0	Purpose	Inches (Approx.)	Number	Total
1	Camera trolley	87	1	87
2	Platen counterweight	30	1	30
3	Cradle drawer liner attachment	17	1	17

0	Purpose	Inches (Approx.)	Number	Total
4				**134 (11.17 feet)**

PVC

0	Purpose	Inches (Approx.)	Number	Total
1	Frame height	13	7	91
2	Paracord channel connectors	1.5	3	4.5
3	Hidden/Flush connectors	1.25	3	3.75
4	Lighting support arm	7	2	14
5	Frame width (top)*	5	1	5
6	Frame width (top)*	2	1	2
7	Frame width (top)*	4	1	4
8	Platen counterweight offset (can make longer if desired)	4	1	4
9	Frame width (bottom)*	6	4	24
10	Frame length (bottom)	4	2	8
11	Frame length (bottom)	1.75	1	1.75
12				**162 (13.5 feet)**

	Purpose	Inches (Approx.)	Number	Total
13	* Frame width should be adjusted based on the size of your acrylic sheets and the connection depth of the specific PVC fittings that you purchased (some PVC fittings are slightly deeper than others). The frame should fit around the acrylic sheets, forming a channel through which they can run.			

Conclusion

I'm excited about this new design. I welcome constructive comments and suggestions, either directly (/pages/contact.html) or through the DIYBookScanner community (http://diybookscannerorg/forum/memberlist.php?mode=viewprofile&u=6402&sid=d309f98ddc871a51c50addd2ebbd5148)