

Cloud-based RAW image editing

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Abstract —

Context/Background RAW images are used by photographers to improve the quality of their images, specifically when editing, to avoid the compression problems associated with JPEGs. Editing these files is traditionally done on a high-spec machine, capable of processing images with large resolutions. In the field, this can be difficult. When used for websites, the work-flow is typically to edit a RAW file and export as one file format (generally JPEG, which loses some quality), and then uploaded to a content management system where the output image is automatically edited and resized, reducing the quality further. Editing these RAW files without requiring the user to use a high spec machine is therefore ideal, by creating a web service for RAW editing.

Aims The main aim of this project is to test the feasibility of a Cloud-based RAW image editor.

Method A render server back-end will first be implemented as an API, taking in an input as a JSON object, and then processing the image, and then a JavaScript client shall be created to interface with this API.

Proposed Solution A web application, using a Java server with dcraw and custom image processing code to process RAW images, communicating over a socket.io interface, and a web front-end that allows users to interface with the render server.

Keywords — RAW image editing, dcraw, cloud image editing

I INTRODUCTION

Many photographers use a file format (or rather, a family of very similar file formats) called RAW, which rather than compressing the image and conducting some image manipulation on the camera, store the RAW camera sensor data outputted by the camera sensor, for later processing and editing by a computer. These files can be much larger than the compressed image, but provide a far greater degree of control over the captured image, when compared with a compressed JPEG, along with an increase in quality. A RAW file essentially acts as a digital negative, as the image can be edited constantly without losing any quality between edits. (Verhoeven 2010)

A Project Aim

The aim of this project is to produce a Cloud-based RAW image photo editor, both as an API (allowing potential image rendering headlessly), along with a full RAW image editor interface via a web browser. The image photo editor should be able to read at least DNG and NEF files, and allow contrast, colour and exposure adjustment, along with noise reduction, haze removal, and auto correction options. Furthermore, this system should be multi-user, allowing more than one user to edit RAW photos at a time through the web interface, each with their own individual collection of images.

B Deliverables

The project will have the following deliverables:

#	Name	Description
1	Render Server	This will be a web application server that takes a JSON string as an input, renders the image with settings defined in the JSON string, and sends the output back to the user. This shall provide an interface to the clients so that they can use this render server.
2	Client-side front-end	This will be a web based interface that allows the user to edit RAW photos in their web browser. It will allow the user to upload/select images that they want to edit, and then to edit the RAW images (providing a preview when settings are changed). Essentially, this will wrap the render server API, and also provide it's own functionality. This will be in the form of HTML, CSS and JavaScript files providing the user interface and most of the core functionality, along with some helper server-side methods.
3	Project Report	This will be a report containing information about the entire project, all the way through the design, build and testing phases. It's contents shall include an evaluation of the prototype, how effective it is, and how it can be improved through technology changes/further improvements.

II DESIGN

This section outlines the design of the system, starting off with the specification of what such a system needs to have, followed by further research, options for designing different components of the system, along with some information on implementation detail. Furthermore, details on architecture are outlined here.

A Requirements

Table 1 shows the functional requirements of the project, which define the functional elements of the system being produced.

Table 2 show the non-functional requirements of the project, which don't directly relate to the functionality of the system, but are performance based attributes that ensure the system will be more likely to succeed at the aims.

Number	Requirement	Priority
FR-01	Allow the user to edit the exposure of a RAW image	High
FR-02	Allow the user to adjust the colour saturation and hue	Medium
FR-03	Allow the user to export their edits to several popular file formats: JPEG, PNG, and TIFF	Medium
FR-04	Store the render settings of a given RAW file (as specified by the user), to allow for the image to be re-rendered and re-edited without losing quality	High
FR-05	Have the ability to edit user specified files (i.e. users can specify which file to edit, rather than using a hard-coded file within the system)	High
FR-06	The client interface should have the ability to zoom in and out of the preview image, to help aid editing	Low
FR-07	Allow the user to apply automated image enhancement algorithms to the image to find the best parameters for each image	Low
FR-08	Allow the user to set their own white balance	Medium
FR-09	Allow the user to apply gamma correction to their RAW image	Medium
FR-10	Allow the user to control the highlights of the image	Low

Table 1: Functional Requirements

Number	Requirement	Priority
NFR-01	The system should be able to cope with at least 2 users simultaneously using the system	High
NFR-02	The system should allow the editor controls to be hidden, to show the preview image on its own	Medium
NFR-03	The render server should provide a preview within 15 seconds of changing a parameter	Low
NFR-04	The user interface must be accessible through a web browser	High

Table 2: Non-Functional Requirements

B Proposed Extensions

B.1 Quality of Service Improvements

Client Side Preview Rendering The system itself renders the RAW images entirely on the client side, directly from the RAW file. However, the time taken for a render request to be sent, and the preview to be returned from the server can be quite a long time. Currently, the user will just be required to wait, but an improvement can be made where simple operations can be carried out on the client side, using the previous preview image as the starting image, and therefore there will be a gradual speedup due to the lack of network traffic or having to run computationally extensive tasks on the entire RAW file (simply a compressed version of the preview).

B.2 Additional Features

Image Haze Removal In images, it's possible that haze can creep into the image from background sources. In order to combat this, single image haze removal can be implemented to remove haze using an automatic algorithm. Several different algorithms exist, some using colour attenuation, others using

By using colour attenuation prior (using the colour attenuation information already known about the image), we can use the difference between the brightness of the image and the saturation, in order to estimate the amount of haze present at a particular point. This can then be used to produce a map of the depth of an image, from only one image, and then by applying the atmospheric scattering model in reverse, the haze-reduced image can be yielded. This also has much better running time compared with other similar algorithms, which is more suited to our system (as we need to reduce the time taken to render images as much as possible). (?)

C Architecture

As the system is fairly large, it's important to break it down into individual pieces. These are:

C.1 Client Interface to Render Server Communication

There are several options for communicating between the user interface and the render server.

Representational State Transfer (REST) A Representational State Transfer system would work by sending a request to the server, requesting an image be rendered. This initial request will be replied to with a job number, which will be quoted in further communications. From here, future requests will be made over a regular interval, requesting the information for the specified job. If this job is finished, the result will be returned, but otherwise further requests will need to be made. This is the process of polling.

The XMLHttpRequest object in JavaScript, used to make AJAX requests, was designed by Microsoft in 1999, and later adopted in the 2000s. This method is definitely the most compatible with browsers, being compatible with Edge, Chrome, Firefox, Internet Explorer 7+, Opera, and Safari. (Mozilla 2017)

However, this method does require making many requests and connections to the server, coupled with code to regularly poll at an interval until done. While this will work, it's not the

#	Description
1	The user makes a request to the reverse proxy. Behind this contains the web application server, along with static file hosting (to avoid having to use Python to deal with the transfer of files). Furthermore, a request will be made occasionally to save the current render settings, which will be passed to the Django App to save the render parameters alongside the image itself in the database.
2	If the user requests the raw static files, such as the web editor, or image picker, the django app checks they are logs in, and then passes a header to the reverse proxy to serve the static files.
3	The django app provides user accounts and authenticated routes, along with managing the storage of images, and their associated meta-data (such as render settings). No static content is directly rendered on this server, but AJAX requests are made, which return JSON, or session cookies (in the case of authentication).
4	In order to store user accounts, or associate image files with image objects and associated data, a database is used. This is a necessary data store, in order to store the appropriate data needed for auth and image management.
5	When the user uploads an image, it goes through the Django web app, and immediately is uploaded to the file storage server (in our case, OpenStack Swift). This is a central store to allow access from both Django and the render server, without needing to store files directly on a file system, as we can therefore scale Django instances without needing to deal with where files are being stored. If one django instance goes down, the files will still exist.
6	Through the HTML, CSS, and JS editor web application, the client shall interface with the render server directly via Socket.IO. Commands will be sent that request a render job, along with the render parameters needed.
7	If the render server doesn't have the RAW file cached, it will go off through the reverse proxy to the file storage server, and download the RAW file. Also, in the event an export job is selected, then the output of the render server shall be transferred to the file storage server.
8	Finally, files can be downloaded/uploaded through the reverse proxy by connecting it with the file storage server. This is done in the NGINX config.

Table 3: Architecture Diagram, Explained.

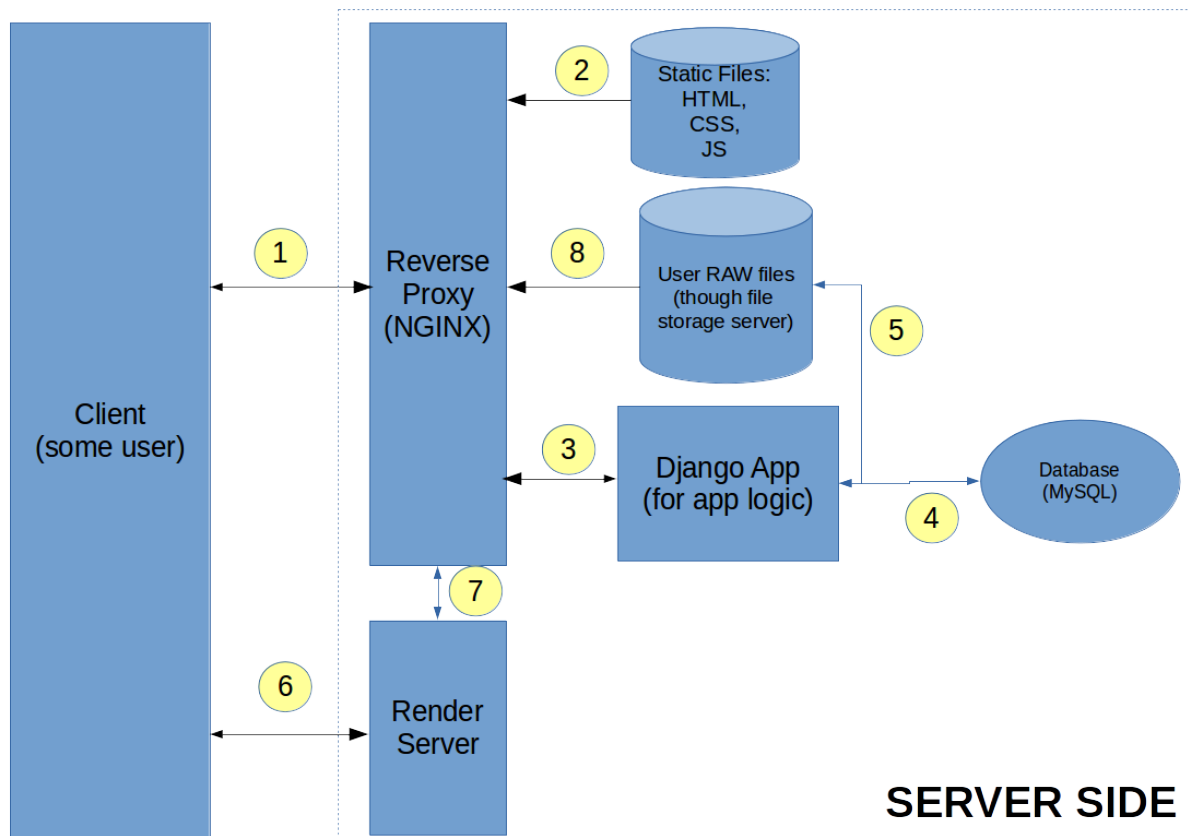


Figure 1: A diagram showing the architecture of the system. Explanation of this diagram can be found in Table 3

most optimal solution, and the code produced from this would be more complex (code could be needed to issue jobs, recall jobs, and to ensure that the person who requests the result of a job is actually allowed to see the result of the job).

Web Socket Web Socket allows for two way communication between a browser and a server. It acts in a similar way to traditional TCP socket communication, only it incorporates the origin based security model used within web browsers. By using web socket over REST, opening multiple HTTP connections is not needed, as a single connection is maintained at all times. (Melnikov & Fette 2011)

Socket.io Socket.io is an implementation that relies on both REST and Web Socket. If the browser supports web socket, then it is utilised, but in the event that the user's browser does not support new web socket technologies, then it defaults to using REST, and automatically polls regularly for information. This way, we get the best of both options shown above, in such a way that the code itself remains fairly tidy (as the polling nature of REST is abstracted away from our system).

C.2 Render Server

The render server takes instructions given to it (with accordance to our API), and generates the output image based on the RAW image supplied, and the appropriate settings.

One of the first considerations is how to parse RAW files.

dcraw Dcraw is an executable that allows the processing of RAW image files.

Dcraw itself can then be used to convert to other formats, one being the uncompressed TIFF format, giving us a very high quality image that can then be adjusted. Our system isn't merely a wrapper for dcraw in this instance, but extends the features supplied by dcraw.

Despite being an executable, it's written using only standard C libraries, and therefore it's fairly portable, not requiring any dependencies (aside from compiling with a C compiler of course, if no binaries are downloaded). (Coffin 2017)

According to the man-page, the executable contains commands to set RAW exposure, export as TIFF, set saturation level, set white balance, set colourspace, set gamma curve and flip the image. (Coffin 2015)

libraw LibRaw is a C++ library based on dcraw, that is designed as a library rather than just an executable.

LibRaw would be used when loading RAW images, processing them, and then from this, the image can be processed using custom routines (i.e. converting the libraw format to a matrix representation, and then using that matrix representation to carry out some manipulation).

While LibRaw has many useful features, the documentation is somewhat limited.

ImageMagick ImageMagick is a library that can be used to process any images, not just RAW. While it can read RAW image files, it also has many more features, including many feature that we don't need/want to implement ourselves for the purpose of this project. As such, I believe while ImageMagick is a good option, it's a bit too heavy for our use.

C.3 Client-side Interface

The page design of the interface shall follow the design in D. The goal of the client side interface is to allow adjustment of the image parameters, and show a preview whenever a parameter is changed.

To display the image, an HTML5 Canvas will provide a large amount of control to how we can display the image, allowing for features such as zooming, and drawing. This can't be achieved using a standard HTML image.

D User Interface

A sidebar should be used as the main interface for adjusting image parameters. This sidebar should be able to be hidden, showing the image fully underneath. When the sidebar is in the expanded state, the preview image should be displayed fully on screen.

The user interface design is shown in Figure ??

Within the sidebar, clicking on a navigation item will display a new submenu. If the item is a parameter adjustment, updating the value in the menu will also update the value that is sent to the render server to generate a preview.

E Implementation Information

Each individual module of the system requires different technologies in order to produce an overall system.

Client-side Interface For this, HTML5, CSS3 and JavaScript (with jQuery to provide extra functionality) are ideal, as HTML5 can be used to create the user interface, with CSS3 providing styling and some basic animation to improve the UX. Using JavaScript with jQuery, it allows us to keep track of the state of the editor, and transmit and receive information between client and render server with help of some library. jQuery is useful for interfacing with the DOM (the webpage itself, and it's components), allowing us to specify events, and functions to run on particular events, along with template loading and various other functionalities.

As this is mostly static content, only a few web services needed for image selection/ maintaining user uploaded RAW files, a web server like Apache/NGINX can be used to serve these static files, using server side scripting only to determine whether a user is authenticated, and if so forwarding headers can be used to serve the static file without needing to serve static files through the scripting language itself, which is much slower

NGINX is what I'd recommend in this situation because unlike Apache, NGINX isn't configured out of the box for dynamic content, but Apache is configured to use PHP out of the box.

User account based RAW file management In order to select and upload images, a method of specifying users, and their uploaded images needs to be created. This will require a database, to store the user information (username, password), pointers to the images (image URL, and user associated with each image), along with some server side scripts to manage authentication, dealing with file uploads, and maintaining collections of images (listing all images associated with a user).

While any web framework would work with this, I've chosen to use the Python programming language with the Django web framework, as database queries can be made using the built-in Object Relational Mapper (ORM), that automatically writes SQL queries for the specified database back-end (e.g. MySQL, PostgreSQL), based on defining models as Python classes (inheriting the `django.models.Model` class).

Furthermore, Django contains built-in authentication, and built in methods to create users, login, and managing sessions. These two features simplify the creation of the server side scripts for user account based RAW file management.

For the interface, rather than sticking to server side generated pages, serving a JavaScript based interface for this means the files can all be stored on the static file server used for the editor, and therefore AJAX requests can be made to the server to get the information needed, and load them onto the page. This avoids having to generate an entire page just for a few pieces of information. This JavaScript code shall make a request to get a list of the images (encoded as JSON, along with their associated urls). When a user clicks on the URL, the image picker loads

up the editor, passing the URL to the image to edit (through GET variables). This way, there is less reliance on the entire server side framework.

In order to ensure all of this works, a database is needed. Django officially supports three databases: PostgreSQL, MySQL, Oracle and SQLite. SQLite is file based, and while it's ok for single user apps, for multiple users it won't scale well.

MySQL is far better for applications, implementing most (but not all) of the SQL functionality. However, it doesn't perform as well with concurrent users on write operations (e.g. writing new images into the database), or writing the associated image settings to the database. Furthermore, features are missing like full text search.

PostgreSQL is the most advanced, being fully standards compliant, and it has concurrency features built in to avoid using read locks. It's extensible, and allows for features like full text search. However, it can potentially be slower for primarily read based operations compared to MySQL, and as setup complexity for Postgres is far higher, it might not be the best tool for our project. (Tezer 2014)

Therefore, for this part of the system, Django shall be used alongside MySQL.

Render Server While lower level programming languages might be useful for image processing, the requirement of linking this with web technologies means that a language such as C or C++ is not as ideal.

Java is a better choice, as there are libraries available to provide web services (REST), along with Web Socket implementations, along with Socket IO. Furthermore, Java contains some libraries within the language that allow for image manipulation, most notably BufferedImage related features such as ConvolveOp, image resizing, and various other standard features build in. This is useful, as rather than starting completely from scratch, the custom image processing routines can build on the built in Java implementations, and create more advanced algorithms using them.

While Java doesn't support loading TIFF into BufferedReader using ImageIO directly, an extension exists online, in the form of TwelveMonkeys. No RAW image loading library exists within Java, but an executable such as ddraw or rawspeed can be used to generate a file that can be read within Java, while retaining the quality (e.g. uncompressed TIFF). This can be done using ProcessBuilder, and ideally writing a library to do this.

As this system will likely use a large amount of external dependencies, a dependency management tool like Apache Maven should be used, to both manage dependencies from an external source (e.g. GitHub, Maven Repositories), and also to build the system.

Overall, the render server system will be made up of several different components, each confined to their

Account Management Server As this system needs to be used by multiple people, we need to have some record of users, and their associated images.

Rather than rendering each page dynamically, we can instead use JavaScript to make AJAX requests, fetching the data needed, and this way, we don't need to render whole HTML web pages. In terms of back-end technology, it doesn't matter too much what is used, as it won't be used too much, but in my case I'll be using Node.JS with an Express server, simply because it's easy to deploy and install dependencies ("npm install" can be run to install dependencies in one

#	Description
1	JSON string passed from server to file manager, to download/ensure the file is in the local cache.
2	If the file doesn't exist in cache (test using random number generator seed) download it from the file storage server.
3	Write the file to local cache if downloaded, using an aliased filename. Update the URL to this filename in the JSON string.
4	Pass the updated JSON string to the operation manager.
5	Pass the JSON String to the component dealing with rendering of RAW using DCRAW.
6	Parse JSON string, find the properties to modify within DCRAW and use the JDCRAW library to set up the executable.
7	Execute the instructions set up with the ddraw executable.
8	File will be read from the local cache, and processed by the executable.
9	The output of ddraw will be written back to the local cache, as a TIFF file (for compatibility with Java/Adams processor)
10	Pass the new rendered URL (the URL of the tiff file) back up to JDCRAW library
11	Pass the URL up to the ddraw manager, and update the JSON string accordingly for the next processor in the pipeline.
12	Ensure the changes to the JSON string are reflected in the operation manager.
13	Pass the updated JSON string to the Adams Processor
14	Based on the operations defined in the JSON string, read the TIFF file (generated by DCRAW), and call the appropriate custom subroutines to process the image. These routines are written in Java, and are the custom written methods to create the advanced functionality.
15	Write the output of Adams to a file, and pass the URL back up to the Adams processor
16	Pass the JSON string up to the operation manager.
17	If an export grade image is needed, save the export file to the file storage server, and update the JSON string.
18	Export the appropriate information, including a base64 encoded preview of the image, and export URL if needed.

Table 4: Render Server Steps Description

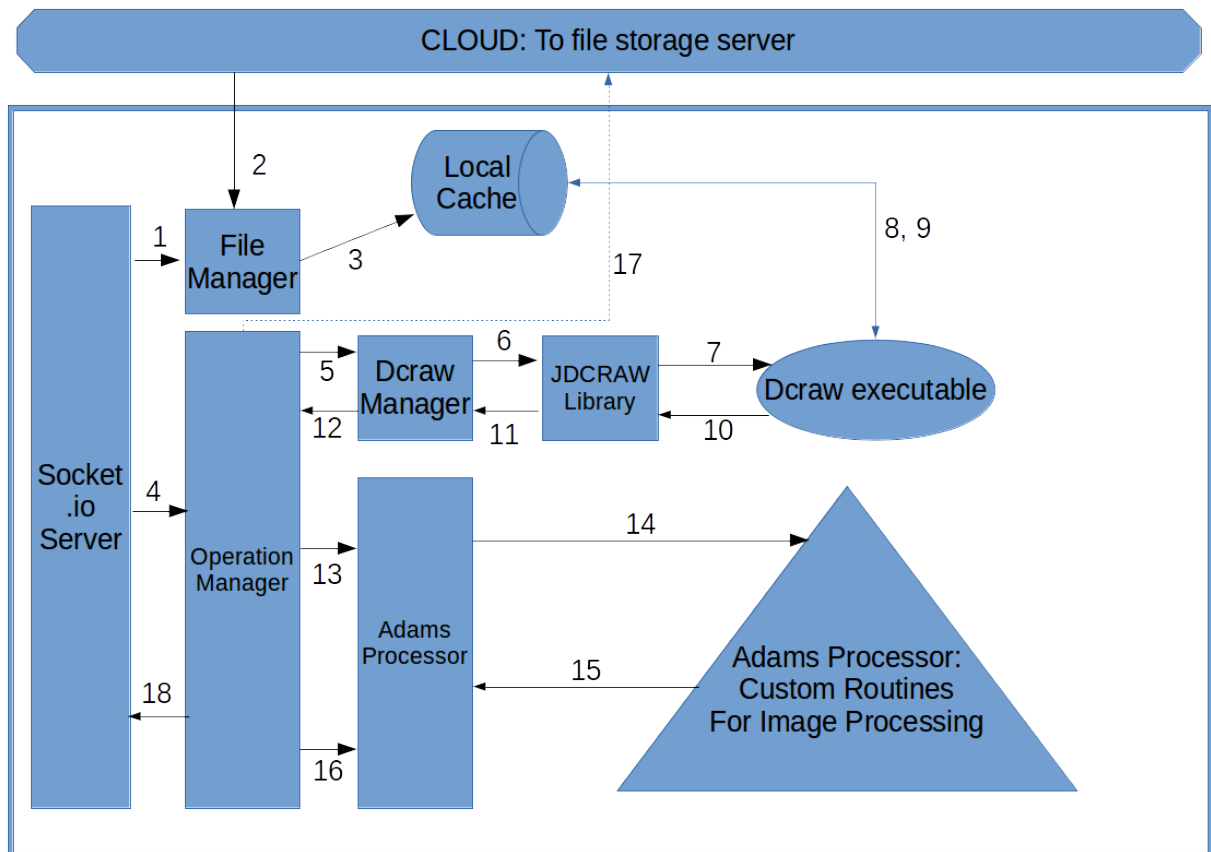


Figure 2: A diagram showing the structure of the render server components

command), and it can also connect to a database to provide services such as login, and records of individual files.

File Storage Server As the user is required to upload files, and the files that are exported need to be stored somewhere (not on the render server local disk) to be accessed, it's important we have a centralised store.

Ideally, this file storage server should be interchangeable, allowing the user to change where the files are stored (only requiring it to be accessible by using a URL).

There are a few options on the public cloud for use with this system, namely Amazon's S3, and other storage services. However, as this prototype will initially be employed on a private cloud, I shall use a service called OpenStack Swift, which allows the storage of files. Furthermore, as this links in as a Django storage backend, and APIs already exist to tie Django in with Swift, this makes the implementation easier. As this will be separate from the web services server, and also separate from the render server, any loss of either of these will cause the files to remain online, and also allows for more user account management servers and more render servers to be placed online, fetching and writing files to this file storage server.

Distributed System Management As this system consists of several smaller systems, it's important that these are managed. For each smaller component, a Docker container can be created,

containing the configuration between each one. From here, Docker Compose can then be used to manage the entire system, bringing everything online, opening ports, and building everything automatically.

This requires us to create a Dockerfile per system (one for the render server, one for the client front-end). This Dockerfile specifies the image to build from, along with instructions that need to be run, and files that should be shared, to make that container work. Rather than customising an individual image, this customisation can be done by building on existing images, saving time without needing to start again from scratch. (Kent 2014)

F Evaluation

In order to measure the success of the system, a mixture of user based tests and system based metrics will need to be taken.

As this is a software product, the underlying server will need to be constant to avoid biased results. Therefore, for the tests, a computer shall be used as the server with the following specs:

- Processor: Intel i7-7700k at 4.2GHz
- Memory: 16GB DDR4-3000 RAM
- Storage: 1TB WD 7200RPM hard drive
- Operating System: Ubuntu 17.10

The amount of file storage here isn't as important, but as we are using a hard drive, file caching might be slightly slower than if using an SSD.

The system will be deployed using Docker Compose, with the configuration scripts shown in the GitHub repository.

F.1 System-based Metrics

Three different images per camera shall be used within the system to test compatibility with other camera manufacturers. Canon, Nikon, Pentax and Lecia camera RAW formats shall be tested.

In order to measure usability (along with the human based experiment), the system shall be used by several different users, and for each, the time taken to submit a preview, and then get the preview displayed on the screen shall be tested, as this figure gives us an indication in the delay between modifying parameters and having the updated image displayed on screen.

F.2 User-based tests

While metrics can give us an indication into the usability and usefulness of the system, it's also important to test the system with users.

The first test shall be carried out with individual users. This first test shall consist of the following simple steps:

1. Log into a given user account
2. Create a new album

3. Upload a new image to that album
4. Open the image for editing in the editor
5. Set the exposure to a specified value
6. Adjust colour settings
7. Use the built-in automated features
8. Export the fixed image as PNG for download

The users selected for this shall be mixed between experienced photographers (i.e. those who are familiar with using current RAW editing software such as Lightroom and Darktable), and people who haven't used any RAW editing software before. The time taken for the users to carry out the instructions shall be measured, along with their comments on the ease of use of the system through a survey. The use of the time metric allows us to see how easy the system is to become familiar with and to use, while the survey allow us to compare the user's experience and how they found the software to use.

A sample of 10 people shall be used for the live demo, which while it isn't a very large sample size, any sample size larger than this would make the tests difficult to carry out due to the requirement of external application hosting.

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