UNIVERSITY OF CALIFORNIA

Santa Barbara

Into The Technicalities of Photography:

An EXIF Data Exploration

A Master's Project submitted in partial satisfaction of the requirements for the degree

MASTER OF SCIENCE

in

MEDIA ARTS AND TECHNOLOGY

by

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September 2016

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ACKNOWLEDGEMENTS

For my master’s project, I have explored Photography and Data Visualization, two important fields of study I pursued while at MAT. I owe a thank you to my committee for encouraging me to conduct research that challenged my knowledge and skill at the intersection of the two fields. I would like to thank my Committee Chair Professor Legrady for motivating me and for providing an artist's perspective on the project. I am also very grateful to Professor Höllerer for his encouraging words and for helping me create a user study for this research. Professor Turk was very generous with his insightful feedback, which greatly enhanced the clarity of the project.

I would also like to thank all my MAT colleagues their continuous support over the years. They have provided me with very valuable critique for my project. I would like to thank the UCSB Photography Club and its members for igniting my newfound passion for photography. Thanks to my user subjects for taking out their valuable time to be a part of the user study.

Above all, I am grateful to my family for instilling me good values, respect for knowledge and for their endless support.

ABSTRACT

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"Photo" is derived from the Greek word "phos" which means light. Photography is the art and science of capturing this light to create images using optical-mechanical and other light-sensing mechanisms. The image created is a representation of the scene that is governed by the camera's technical parameters.

Today all modern digital cameras along with the image have the ability to capture the image metadata (also known as EXIF). In the recent years, there has been significant interest in the scientific research community to analyze aesthetics using pixel-based image processing algorithms.

However there has been no scientific research in analyzing metadata to understand photographic aesthetics, especially from a photographer's point of view. "Into the technicalities of Photography" explores image aesthetics using this EXIF data. The approach analyzes four EXIF tags: Focal Length, Shutter Speed, Aperture and ISO.

I propose to analyze this data to understand if sets of selected images when collectively examined reveal photographer's aesthetic preferences. The research presented aims to visualize and organize images as actionable data for better understanding of light, exposure and perspective, which I believe is useful for all photographers.

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1. Introduction

The presented work is a result of theoretical examination and EXIF data exploration of digital images. The research presents a new approach to image study, which is not content based but instead uses the camera's technical parameters (embedded in the image) as a source.

Modern digital photography has evolved at an extremely fast pace in the recent years. High performing sensors, coupled with quality optical lenses have allowed photographers to capture and share increasingly detailed images. At the same time, these high-resolution cameras make photography very unforgiving for someone unaware of the technicalities involved. This attention to technical detail comes with practice and evolves over time. I believe that skilled photographers eventually adopt a certain image aesthetic that defines their images. Image aesthetics are a combination of visual aesthetics and technical aesthetics. Hence "aesthetic" [19] isn't just based on color, context, content and composition but also includes "technical gestalt" which is a result of the camera and lens parameters (i.e. Aperture, ISO, Shutter Speed and Focal Length). From my experience as a professional photographer I have learnt that brilliant images are not just a result of content composition but also technical execution.

The goal of my research is to understand the photographer and their technical aesthetic preferences. The underlying assumption is that every photographer eventually develops a technical gestalt resulting in consistent work that is irrespective of the subject or composition. In other words we tend to develop certain habits for controlling the camera settings, which has a profound effect on the final image. These settings are stored as image metadata (also known as EXIF). For example, for the same scene illumination, photographers may setup the camera differently resulting in very different images. Conversely, if a photographer selects a certain subset of images from an image set based on their preferred aesthetic preferences; I believe that there will be certain degree of correlation between the EXIF data. Understanding and visualizing this relationship will help photographers make informed decisions while creating consistent work.

To collect relevant data, I conducted a user study with local Santa Barbara photographers and correlated my survey findings with the data gathered by an image selection application. The user study consists of a pre user study, image selection, and a post study questionnaire. The data from the user study was combined to create online interactive visualizations, which visually demonstrate every photographer's unique perspective, image preferences and its correlation to EXIF information.

1.1 Problem Statement

In the recent years, there has been significant interest in the scientific research community to analyze aesthetics using image processing algorithms. However there has been no scientific research in analyzing metadata to understand photographic aesthetics, especially from a photographer's point of view. The goal of this project is to understand a photographer's aesthetic preferences by analyzing and visualizing image metadata.

Theoretically, I am interested in understanding how photographers technically analyze a scene[12] and use this knowledge to create consistent work. I believe that a single image doesn't represent a photographer, but several images can reveal their aesthetics preference. The objective of this project is achieved through the means of a user study where images selected by the photographer are spatially reorganized using the EXIF data. Using this method, the EXIF data can be visualized in a meaningful manner to understand the photographer's image aesthetics.

1.2 Relevance of Research

Most of the computer vision and image classification techniques created today are primarily content based. Classification of Images based on metadata has been presented in the form of industry patents[21][39]. However the knowledge obtained from this research has no direct benefit to the photography community.

Technically, "Into the Technicalities of Photography" explores the aesthetic connection of photographs with photographers using metadata and user survey data as its sources. The methodology presented, if successful, can be used directly for self-evaluating photographers and creating recommendation systems for camera gear sellers.

2. Literature Review

The relevant readings for my field of study spanned texts by photographers, philosophers and academic research papers published in established journals.

2.1 Towards the Philosophy of Photography - Vilem Flusser

Towards the Philosophy of Photography[17] describes the importance of the technical image and its importance in the society. Photographs are means of visual communication. Cameras creating photographs act as a transmission channel that converts light into information. The photographer's goal is to encode this visual information that maybe social, cultural or political, into a technical image.

"Technical images are difficult to decode for a strange reason. To all appearances, they do not have to be decoded since their significance is automatically reflected on their surface

- just like fingerprints, where the significance (the finger) is the cause and the image (the copy) is the consequence."

Further, the philosopher proceeds to describe the camera and its relationship with the photographer. Although (after a nearly hundred years) one may argue with his statements, but his reasoning and stating the motivations of photographer stays true. Even the very best of photographers cannot completely understand how a camera works. Yet, they learn how to control it. Paraphrasing Flusser, a photographer is successful when he can correctly redirect their intentions to the camera and capture the image as per their intentions. Conversely, a good image is the one in which the "human spirit" wins over the "cameras program".

"No photographer, not even the totality of all photographers, can entirely get to the bottom of what a correctly programmed camera is up to. It is a black box."

Despite the complexity of a camera, they are surprisingly easy to operate. There is a high possibility that the operator who presses down on the shutter button has no knowledge of what happens within the camera to create an image. With the inclusion of cameras in mobile phones, the importance of this knowledge is further lost as creating images becomes easier and decoding them becomes harder. The importance of decoding images has been lost as the viewer is aware of how they are created and assume they know its significance.

2.2 Aesthetics of Photography

Since the introduction of the digital camera, the photographic process has become an electronic one instead of a mechanical one. The images created by it are a close representation of reality, which has diminished its status as an art form. As Professor Chong-ho Yu correctly points out in his article "Aesthetics of Photography"[40], it is more likely that the viewer will not be curious to know which brushes or paint was used to create a painting. However, they are more likely to raise questions like, *"What lenses did you use? What film is that? Did you retouch it on the computer? There is also this misbelief that better camera gear results in better photographs, which is not true. One must keep in mind that it is not the camera gear but the photographer who is the artist. However, it is possible that the technical information can enrich the aesthetic experience, especially for those who are familiar with the photographic process."*

Consistent work is achieved with experience and achieving mastery over the art, not by luck. In photography, even though one may assume that aesthetics has no correlation with the technical information, it can indicate whether the work was an act of control or an act of chance.[40]

2.3 The Decisive Moment-Henri Cartier Bresson

Henri Cartier Bresson[7][8], one of the most famous street photographers, describes his photographic journey in his book "The Decisive Moment"[9]. In the book, he introduces the term "picture story", an image that is capable of telling an entire story. Such an image is the result of a "joint operation of the brain, the eye and the heart". The objective of this joint operation is to capture the event that is in the process of unfolding, and to communicate impressions.

According to Bresson the key ingredients for a successful picture story are:

- **Composition**: *"In a photograph, composition is the result of a simultaneous coalition, the organic co-ordination of elements seen by the eye."*
- **Subject**: *"Subject does not consist of a collection of facts, for facts themselves offer little interest. Through facts, however, we can reach an understanding of the laws that govern them, and be better able to select the essential ones which communicate reality."*

- **Color**: *"Black and white photography is a deformation, that is to say, an abstraction. Color photography brings with it a number of problems which are hard to resolve today, and some of which are difficult even to foresee, owing to its complexity and its relative immaturity."*
- **Technique**: *"Technique is important only insofar as you must master it in order to communicate what you see. Your own personal technique has to be created and adapted solely in order to make your vision effective on film. But only the results count, and the· conclusive evidence is the finished photographic print."*
- **Customer**: *"We photographers, in the course of taking pictures, inevitably make a judgment on what we see, and that implies a great responsibility."*

In particular, Bresson approach to technique resounds with the texts by Flusser

*"It came to maturity due to the development of easily handled cameras, faster lenses and fast fine-grain films produced for the movie industry. The camera is for us a tool, not a pretty mechanical toy. In the precise functioning of the mechanical object, perhaps, there is an unconscious compensation for the anxieties and uncertainties of daily endeavor. In any case**, people think far too much about techniques and not enough about seeing**. It is enough if a photographer feels at ease with his camera and if it is appropriate to the job, which he wants it to do. **The actual handling of the camera, its stops, its exposure-speeds and all the rest of it, are things that should be as automatic as the changing of gears in an automobile**."[9]*

Although Bresson emphasizes on "seeing", he recognizes the importance of superior technical handling of the camera to achieve artistic vision. Its importance is paramount in photojournalism where no retakes are possible, as the moment has passed.

2.4 Academic Research Papers & Patents

The Image Processing community today uses a similar set of attributes to gauge image aesthetics. Optimizing Photo Composition[27] for example focuses on image composition and measure aesthetics based on known visual guidelines. These guidelines include Rule of Thirds, Visual balance & Diagonal Dominance and are used to compute aesthetic scores. Based on these aesthetic scores the image is retargeted in 6 dimensional space. These include 4 degrees in cropping the frame and two degrees in selecting the target frame. Creating a "tighter frame" for better composition may lead to enhanced aesthetics but at the same time photographers may argue that such a methodology is counter productive and fails to convey the complete story.

Studying Aesthetics in Photographic Images Using a Computational Approach [13] describes a new methodology where photos are evaluated based on exposure, color and rule of thirds. The method extracts low-level features based on established observations that include common intuition, rules of photography and general trend observed in ratings. Such a computational aesthetic model can be helpful for photographers understanding compositional quality. However the paper creates a correlation between photographs and their ratings not the individuals who are rating them. The images are treated purely as pixels and the EXIF tags are not incorporated into the study.

In this digital age, understanding, cataloging, archiving and retrieving photographs is a tremendous technical challenge and it is important to consider the approaches undertaken by leading software and imaging companies. This research often leads to patents, some of which are mentioned below.

Camera meta-data for Content Organization[36], employs a system based on EXIF and image analysis to classify the contents of the image. The patent describes a decision tree to categorize subject data. Each node of the decision tree is a classification function to decide whether the classifier should be assigned. These classifiers are designed understand the content and context of the image, not aesthetics.

Using Camera metadata to classify images to scene type classes[39] utilizes a combination of metadata and histogram distributions to classify images into possible lighting scenarios (scenes).

Knowledge discovery for better photographs [38], utilizes data mining to classify high dimensional metadata into possible scene types. The initial metadata based classification is combined with histogram analysis for scene classification for certain types of photographs. The method presented aim at understanding images not photographers.

The work presented below applies the knowledge I gained to create a system for understanding photographers through visualizing metadata of selected images.

3. Methodology

The above readings ranged from technical research papers, art journals and essays by historic photographers who shaped the field. This has lead to an interdisciplinary research of photographic techniques and exploring imaging data to understand photographer aesthetics. The tools used to create this project include Processing, C++/Openframeworks, Javascript (D3).

3.1 Exploratory Approach

Goal

The initial goal of the prototype was to create a tool that could analyze a set of images and visually cluster it based on the EXIF data. The images would be organized as a Self-Organizing Map in 2 dimensions and in a 3 dimensional grid using K-Means clustering algorithm. The initial prototype of the project was designed as an installation where clustering algorithms were used to classify the images based on the metadata.

Dataset

The MIR Flickr dataset[1] [26] is a dataset created for image research by Flickr and released in 2008. This dataset includes 25000 images along with tag words and the respective metadata. Certain images had incomplete metadata; these images were removed for consistency. The final image data set was reduced to ~10000 images.

Application Design

The prototype was designed as a standalone interactive installation. The images were clearly laid out in a grid. When images were selected they would be highlighted and associated EXIF data would be displayed on a relative scale. The images collectively were run through a K-means algorithm to create 6-10 clusters of images. They were then arranged in a 3 dimensional space where the three axis corresponded to the parameters of the exposure triangle: ISO, Shutter Speed and Aperture. A color was assigned to each image based on the cluster it was assigned to. However image organization in 3D space lead to poor legibility, since images are 2 dimensional. Moreover, designing meaningful interactions proved to be hard, as the metadata cannot clearly presented in relation with the rest of the images.

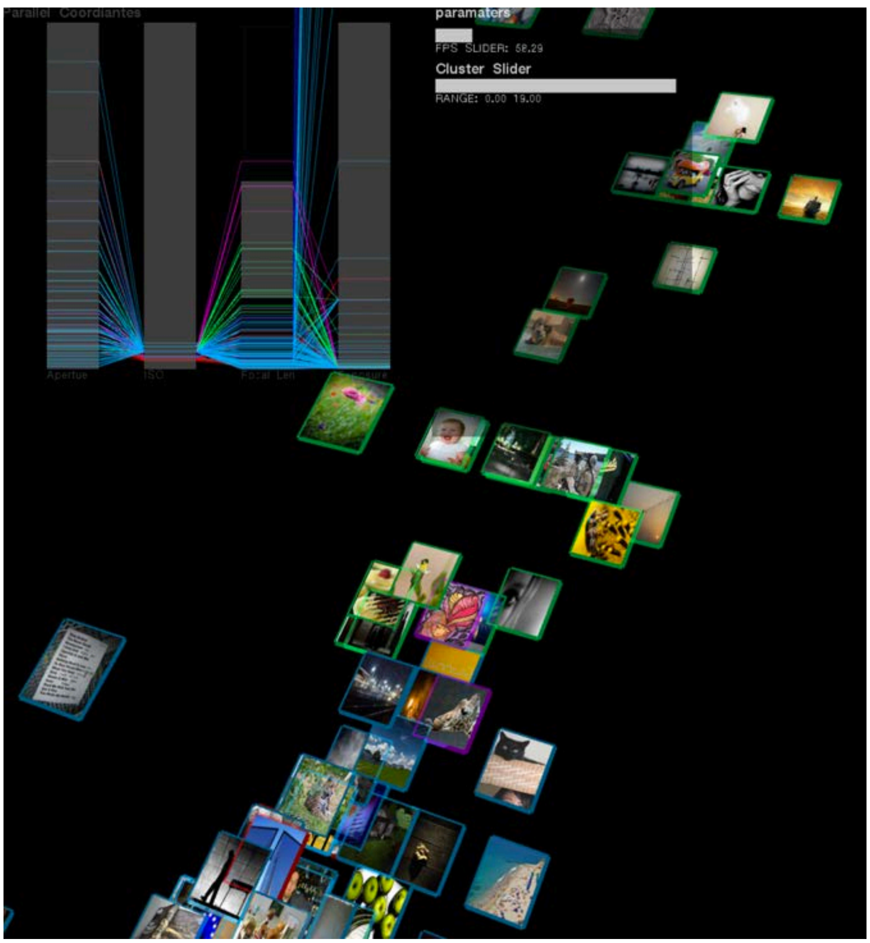

Figure 1. Image organization in 3D space with K-means clustering. The border color around the image represents the cluster it belongs to.

The prototype however successfully showed a possible image organization scheme and correlations between clustering metrics and the emerging clusters. The following visualization was the Self Organizing Map for reorganizing images in a 2D space and visually grouping images with similar EXIF data together.

The Self-Organizing Map[23][24] is an unsupervised machine learning technique, which enables multivariable data to be organized in 2D space. The training dataset was the entire set of ~10000 images and the selected images were placed on the map based on the output. This method solved the problem on dimensionality in the previous approach. Moreover EXIF information can be visually examined and arranged in a meaningful manner. The concept prototype visualized the normalized weights of the nodes in the network. However this visual was difficult to understand, as the images were not brought back into context.

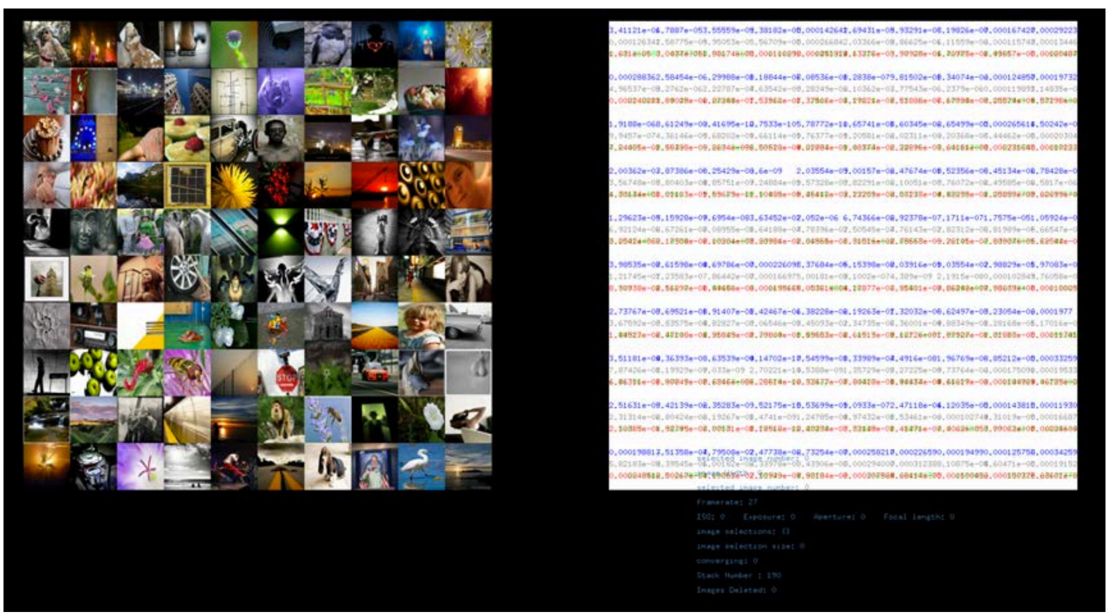

Figure 2.Self-Organizing Map prototype for EXIF Data

Failures

- The images in the dataset were inconsistent, not all images were interesting or aesthetically pleasing.
- The digital photography and its community has changed and evolved over the 9 years since the creation of the dataset. This meant that any current research conducted would be biased and inaccurate.
- Although the prototype was successful in establishing relationship between the images, the method failed short of understanding photographers and visualizing their preferences.
- Visualizations were difficult to understand and draw conclusions.

Learning

- Creating of an unbiased and up to date dataset with consistent images.
- Including a user study to understand photographers along with their image selections.
- Creating a simple user-friendly approach where the data can be quickly processed and visualized.
- Parallel Coordinates for visualizing multiple dimensions.

3.2 The Photographer Centric Approach

The new approach towards image study was focused more on photographers metadata based aesthetic preferences and its correlation with user data. The data created was used to create web based data visualizations that served as powerful learning tools for technical image analysis. This was the result of a more thoughtful and meaningful approach based on the learning from previous prototype.

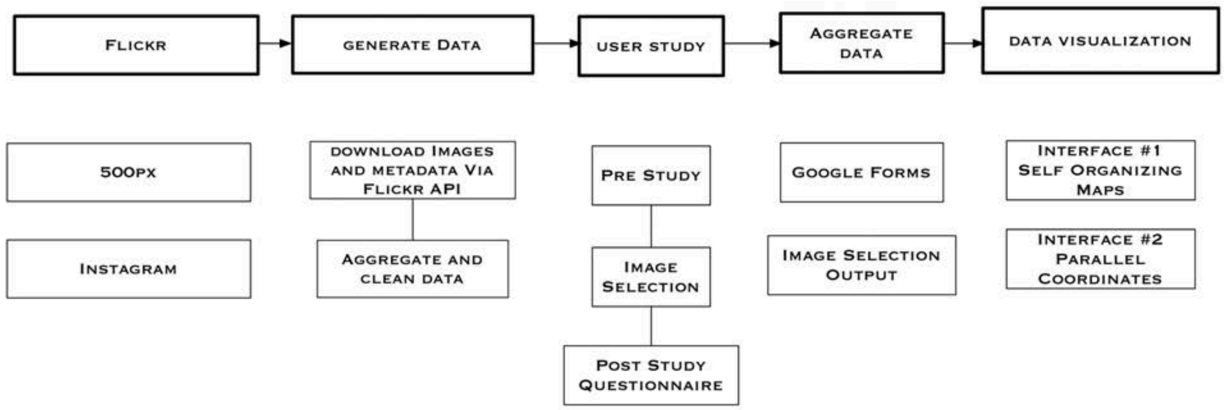

Figure 3. Workflow for the photographic centric approach

3.2.1 Create a New Image Dataset

For the image selection process the new dataset needed to be sufficiently large and include all necessary metadata. Several APIs of popular social image based social media sites that were considered and evaluated. These included Getty, Google, Yahoo, Instagram, 500px & Flickr. Although Instagram is currently the most popular image sharing application, the image resolution is limited and the EXIF information is stripped down for privacy. The final image-set was created using Flickr REST API as it provided complete metadata tags if available and visually aesthetic images.

The new image data set was created using Flickr's interestingness API[3][32]. According to Flickr the image interestingness is calculated by a combination of factors including views, comments, shares and likes[16]. However the actual working of the algorithm is a well-kept secret. The result of Flickr interestingness is a set of 500 images daily that are part of the Flickr Explore page. Generally speaking the images are aesthetic, consistent and of high resolution. 250 interesting images were downloaded for each day starting Jan 01 2016 and May 21 2016 resulting in a total of over 40000 images. The image metadata suggests that the images were taken with various imaging devices. Moreover not all images had complete metadata. Such images were removed from the set. According to the data certain images were "trending" for multiple days and featured on the interestingness list for multiple days.

The images were downloaded monthly over multiple days to not exceed Flickr's API quota. The Interestingness API was used to retrieve a list of 250 image IDs per day. For each image ID, a query was run to download the image in 3 formats [Large Square (150p), Medium (500p), Large (1024p)] and a separate query to download the EXIF data. The responses were acquired as JSON files and relevant data (Focal Length, ISO, Shutter Speed, Aperture) was retrieved from the files. The 35 mm equivalent of focal length was used to ensure consistency in data. The images were discarded if the required metadata was absent. Finally the metadata was concatenated into one file for faster processing.

3.2.2 User Study Application

Purpose

The purpose of the application was to provide a way to serve the Flickr image data set to the user study subject, to store the image selections and provide immediate visual feedback after the study. The application was created in C++/ Openframeworks for fast processing and quick prototyping. It was a derivative of the previous prototype but with intuitive interface design.

Interface Design

Perception of color in images may change based on background color which may affect user selections. To remove any color bias the visual elements of the interface were monochromatic. The application can be split primarily into two main interfaces:

1. The Selection Interface

- The selection interface is the first interface of the app that is characterized by a large 8*8 image grid.
- The images can be selected by clicking on them (appear with a green border). A larger version is displayed on the top right corner on mouseover.
- A control panel to save data and tweak interface parameters.

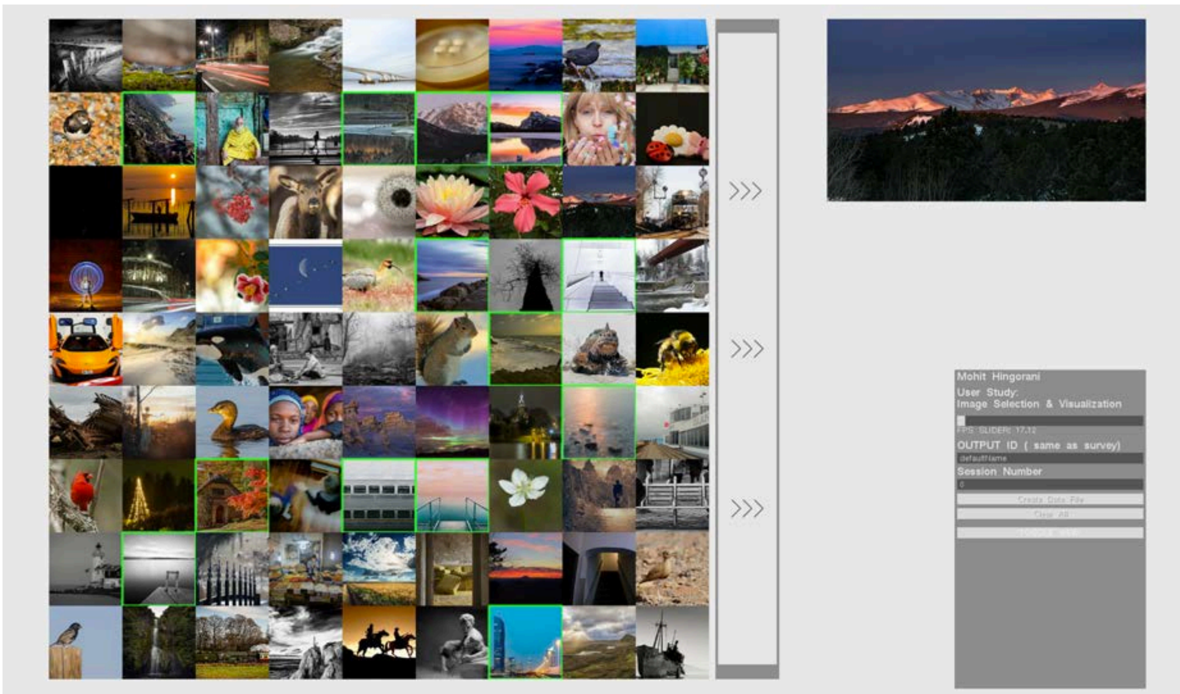

Figure 4.User Interface for selecting images. Images are presented in a grid and are selectable onclick. During the user study the users were asked to select images that matched their own aesthetic sense. A typical user would study around 800 images in 10 minutes and select ~35 images.

2. The Evaluation Interface

- The evaluation interface is similar in design to the selection interface.
- The key component of this interface is the parallel coordinate system
- The Parallel coordinate system consists of 4 axes to map the 4 EXIF parameters.
- Highlighting an image highlights its corresponding EXIF information.

- Conversely, modifying the parallel coordinate system removes the images that do not fulfill the criterion.

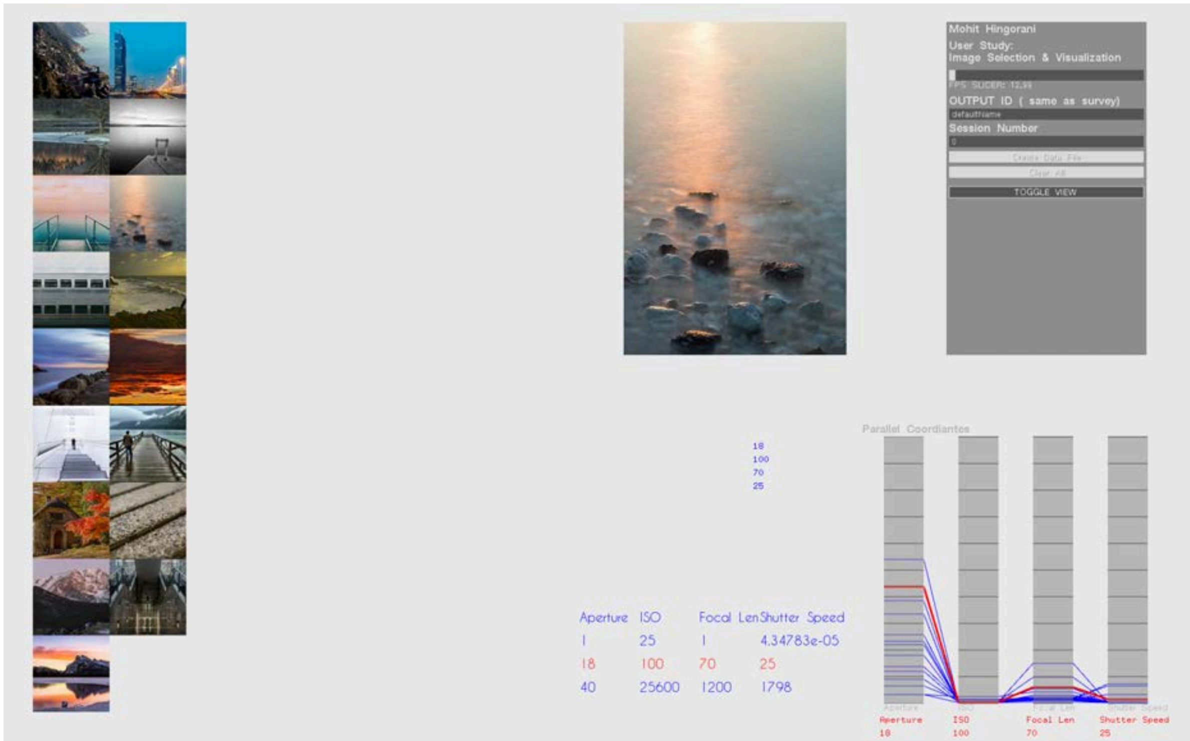

Figure 5.User Interface for reviewing images during user study. The selected images can be individually studied using the parallel coordinates.

The visualization and interface serves as a tool for the photographer to technically analyze the images they selected.

3.2.3 User Study

The complete user study included three phases:

- Pre User Study
- Image Selection and evaluation
- Post Study Questionnaire

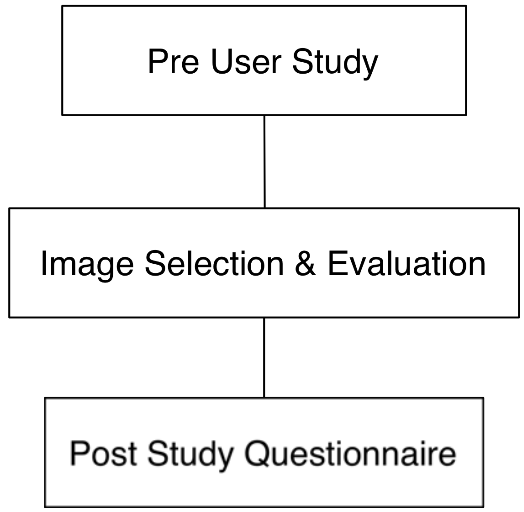

Figure 6.User Study Workflow

Pre User Study

The pre user study was designed to understand the photographer's experience, equipment preferences and knowledge. The use of Likert scale ensured a quantitative response to qualitative questions ensuring consistency and transparency.

1. How long have you been pursuing photography?
2. What is camera system do you currently use? (Multiple Option)
3. How many lenses do you currently use?
4. What kind of lenses do you prefer: Zoom v/s Prime How do you hold your camera?
5. Camera Orientation: Portrait v/s Landscape
6. Focal lengths used most often (Multiple Option)
7. What is your favorite Focal Length? enter "none" if you have no preference
8. How do you expose your photographs: Exposure Compensation
9. Have you "formally" studied photography?
10. How would you define your photography genre? (Multiple Option)
11. Is photography your full-time profession?
12. How often do you post-process your photographs
13. How familiar are you with EXIF Data
14. On a scale of 1-7 how important is technical knowledge of photography

15. On a scale of 1-7 how would you rate your technical knowledge of photography
16. On a scale of 1-7 how important is composition?
17. On a scale of 1-7 how would you rate your composition skills
18. Since the study involved a self-evaluative component the post study questionnaire was both qualitative and quantitative in nature.

Post Study Questionnaire

1. Are there any interesting aspects of photography in this user study that stood out to you? Mention any observations/takeaways here. (Short note)
2. Would you consider this user study to be useful to photographers (Scale 1-5)
3. Did you learn more about your shooting style? (Short note)
4. Will this user study affect your shooting style in the future (Scale 1-5)
5. Any recommendations to improve the study? (Short note)

3.2.4 Data Aggregation

The pre and post user study was conducted with Google Forms and the data was aggregated and exported as a CSV file. The user image selections were saved as text files from the application (later converted to CSV). The metadata and the images were saved along with the selections for faster retrieval. Through the use a unique key the Google form data and the image selection were successfully compiled for data visualization.

4. Data Visualization

The above compiled data created a unique multi-dimensional dataset for creating interactive data visualizations. The goal of the data visualization was to correlate the two data sources and highlight the diversity of technical preferences created by purely selecting images (without knowing the EXIF). At the same time the visualizations had to be compact and adapted for the web.

4.1 Interface # 1 Self-Organizing Maps

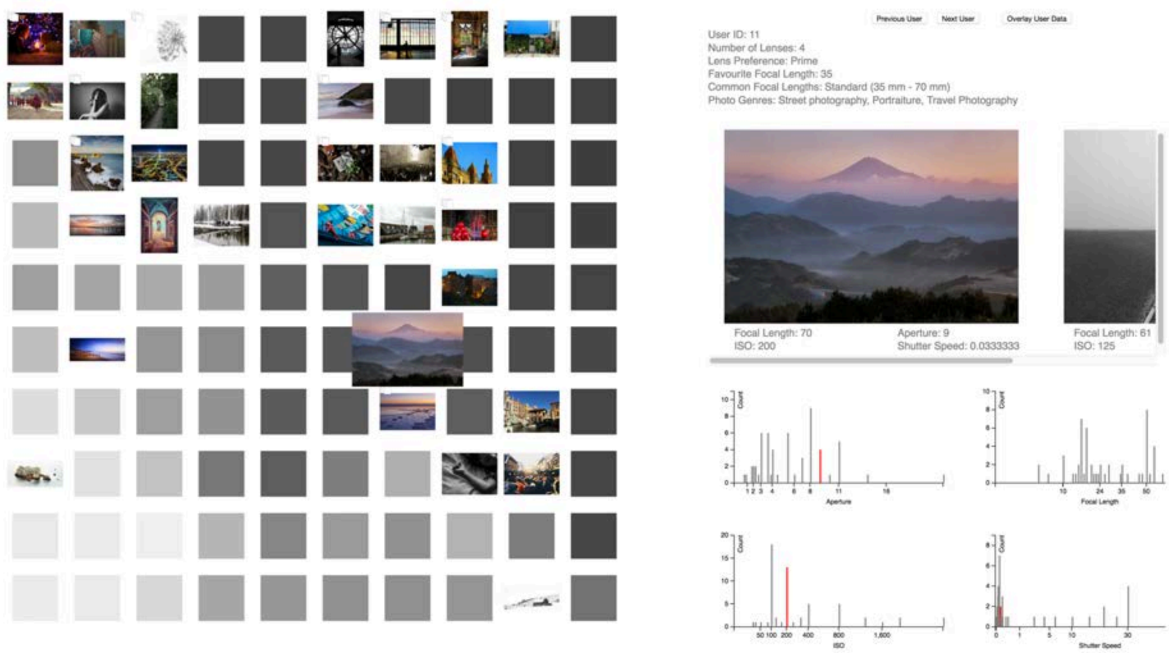

Figure 7. Self-Organizing Map Interface: Images selected by the user are reorganized based on its EXIF data. Individual histograms visualize EXIF distribution

Self-Organizing Map[23][24] is an artificial neural network for visualizing multi-dimensional data. Images can be organized visually in a meaningful manner using this method to create groups of images with similar EXIF data.

It is divided into two parts: training and mapping.

- Training:

- The EXIF data for the data set is first normalized.
- All nodes in the map are initialized.
- The map is trained using the normalized EXIF data.
- For every input the closest node is calculated using the Euclidian Distance.

$$D = \sqrt{\sum (V_i - W_i)^2}$$

Figure 8. Euclidian Distance between EXIF data vector and the weight of the node

- The weight of the node is updated based on the input vector and the learning rate
- The weight of the neighboring nodes is updated based on their radius from the Best Matching Unit (BMU).

$$W_f = \alpha * \sqrt{(d/r)} * (V_t - W_i)$$

Figure 9. Updated node weight based on the sample vector and the distance radius from selected node

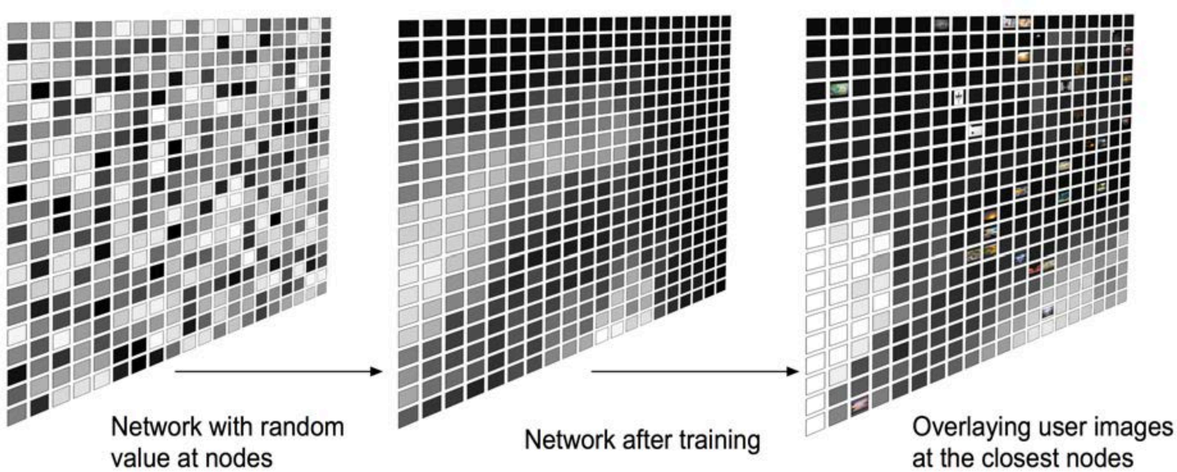

Figure 10. Training the Self Organizing Map and visualizing images selected during the user study by user

- Mapping
  - The selected images from user study are individually mapped for every user.

- For every image selected by the user the closest node is calculated using Euclidian Distance between the weight of the node and the image vector.
- The image is superimposed on the closest node for visualization
- If multiple images map to the same node an icon is placed on top of the node indicating it.

- U-Matrix: The U-Matrix[34] is a representation of the self-organizing map depicting the distance between neighboring neurons. The distance for each node is the mean of the Euclidian distance between the weight of the selected node and its neighboring nodes. The distances are mapped to gray scale to indicate distance between the EXIF data.

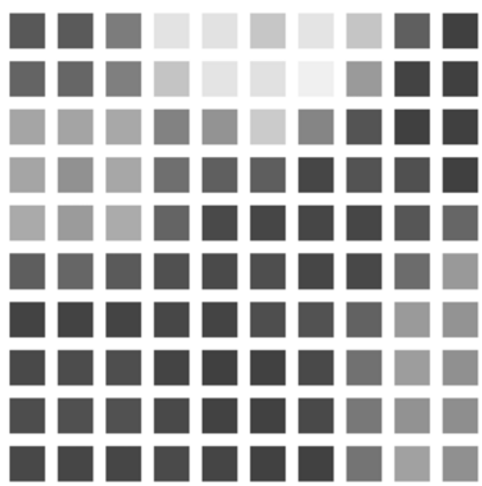

Figure 11. U-Matrix: the color of the node represents the mean Euclidian distance between its weight and the weight of its 4 neighbors

- Histogram: The image data for every user is aggregated based on individual EXIF parameters. The data is represented as individual histograms to clearly show the distribution of the EXIF data. The x-axis represents the value of the EXIF parameter while the y-axis represent the number of Images. Median values from the entire image set as well as data from the user study is overlaid on the histograms to provide further insight to the photographer.

4.2 Interface #2 Parallel Coordinates

The purpose of this interface is to visualize and interact with user study data to study general trends and observations. The interface consists of two interactive parallel coordinate systems.

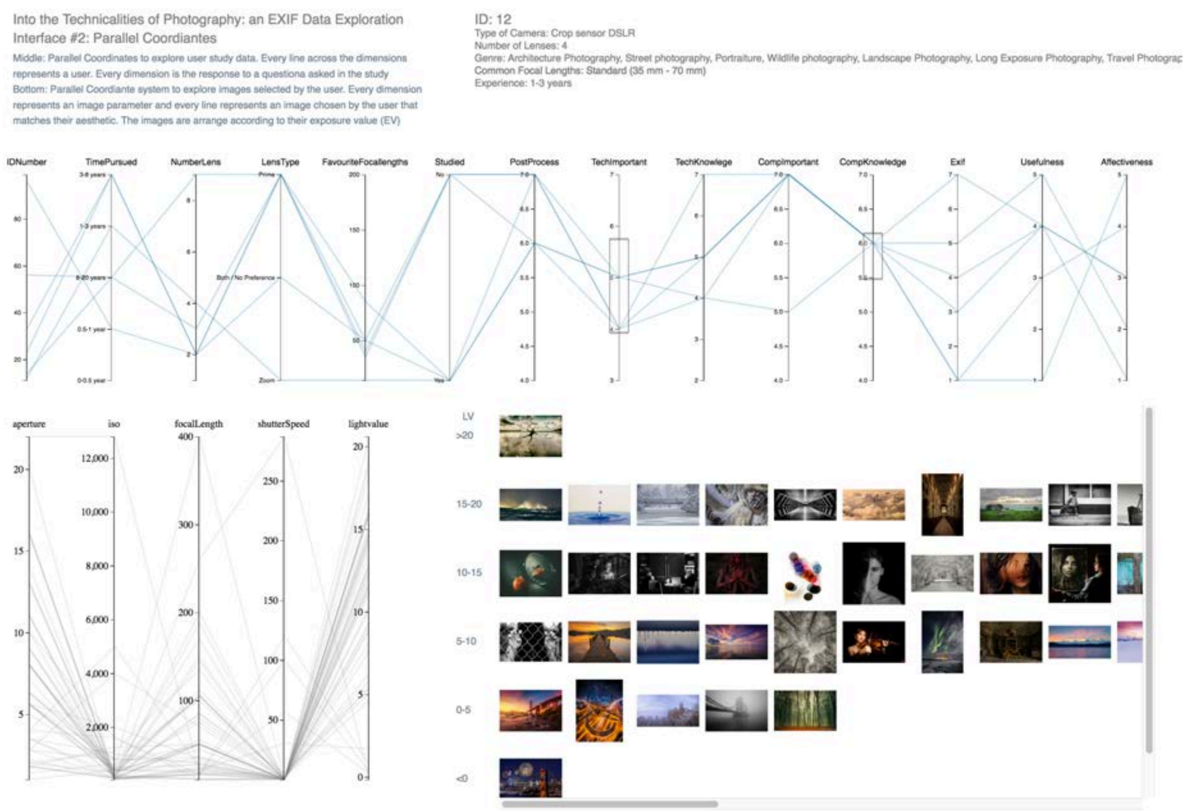

Figure 12. Parallel Coordinates. The purpose of this interface is to explore user study responses to understand general trends. EXIF data for the selected user was displayed with the images ordered by their light value.

In the user study coordinates, each dimension on the Y-axis represents the response from the user study questionnaire. Every line across the X- axis represents a user through their responses. The dimensions can be brushed to show only the users who satisfy criterion limits. This is useful for identifying general trends within users. Every user can be individually selected using mouseover. Highlighting a user displays a second set of parallel coordinates[25] and the images that were selected during the user study. The dimensions of the parallel coordinates include the 4 EXIF parameters as well the calculated light value of the image. A line represents every image across this parallel coordinate system.

Light value

The light value[4] is a number (between -20 and 20) that represents the scene illumination of the image. The light value at ISO/ASA 100 is also referred to as Exposure value. The concept was invented in the 1950's to simplify the understanding of exposure by combining shutter speed, aperture and ISO.

$$EV_{100} = log_2(aperture^2 / \ shutterspeed)$$

$$EV_{ISO} = EV_{100} + log_2(ISO/100)$$

Figure 13. Exposure value (EV) is a measure of scene illumination described by the aperture and shutter speed at ISO 100. Light value is Exposure Value adjusted for ISO speed.

The images are categorized according to their corresponding light value. This visualization aims to create a link between the EXIF settings of selected images and the distribution of their scene illumination preferences.

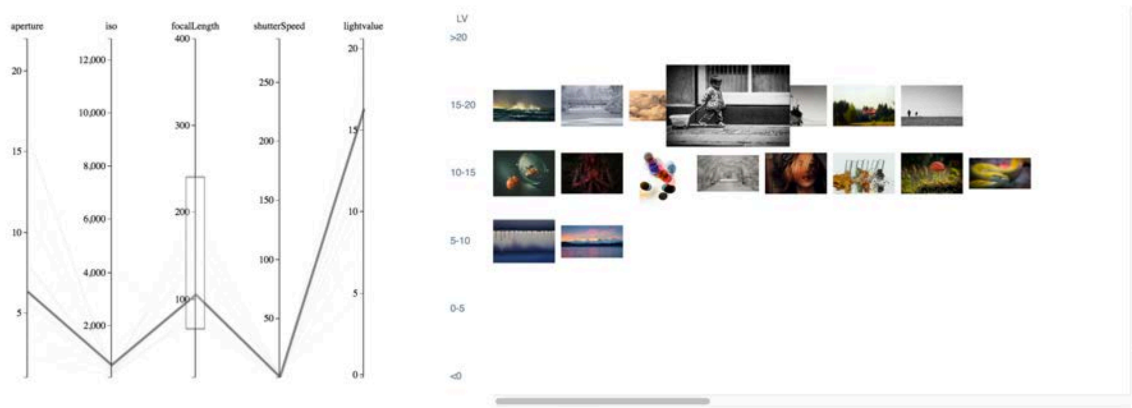

Figure 14. Parallel Coordinates to visualize the user's selected image metadata. The images were categorized based on their light value.

6. Observations

Since the data interfaces are explorative every user will have different observations based on their interests. Observational results are presented from exploring with the interface.

- Focal Length and Aperture play a crucial role in image creation. The effect of depth of field and perspective is profound on users according to the user study.
- Shutter Speed is easier to recognize in the SOM image space when movement is captured.
- ISO manifests itself as noise/grain in photos. Harder to detect/gauge as it is textural in nature.

Self Organizing Maps

- Cluster formation is harder to detect with the low resolution SOM (such as this) but generally multiple images pointing to the same node is a good indication.
- Further, if several such multiple image nodes are being formed, these can be classified as a "group".
- Most users at least had one group being created by the images.

- Typically users with multiple groups corresponded with multiple EXIF peaks (especially for focal length).

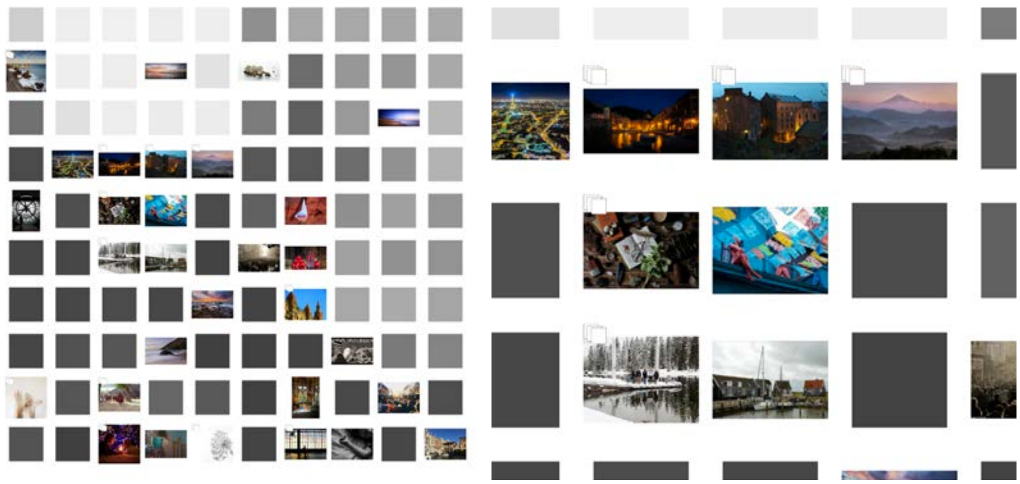

Figure 15. Group formation in Self Organizing Maps

Focal Length

- The histogram reveals the distribution of Focal Lengths of the images the photographers picked out. If there are notable “peaks” in the data, the user can be motivated to use prime lenses of that focal length as they typically are cheaper than their zoom counterparts. For such users the focal length has a strong effect on image aesthetics.
- Conversely, if the distribution is relatively flat the photographer may consider opting for zoom lenses that are relatively more versatile, since perspective (due to focal length) isn’t a strong contributor.
- “Overlay” visualizes additional data about lens preferences. Comparing it with the histogram helps them understand if their selected lens preferences are reflected in the user study. The histogram distribution provides insight to amateur photographers who do not yet have a preference yet.

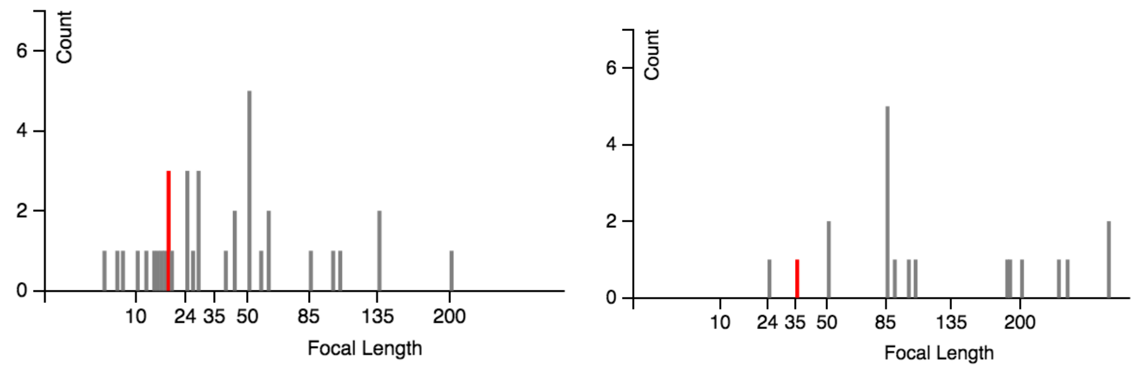

Figure 16. Focal Length distribution for two users

Aperture

- If a “group” of images with low apertures is created it is an indication of a user's aesthetic preference for bokeh. High apertures are typically associated with high depth of field landscape images.
- The overall distribution of aperture reveals the users tendency to select high depth of field (high aperture) or low depth of field ones (low aperture).
- Based on gathered data, one can choose the correct lens that satisfies their needs. Typically faster lenses (lower aperture) are more expensive than their slower counterparts.

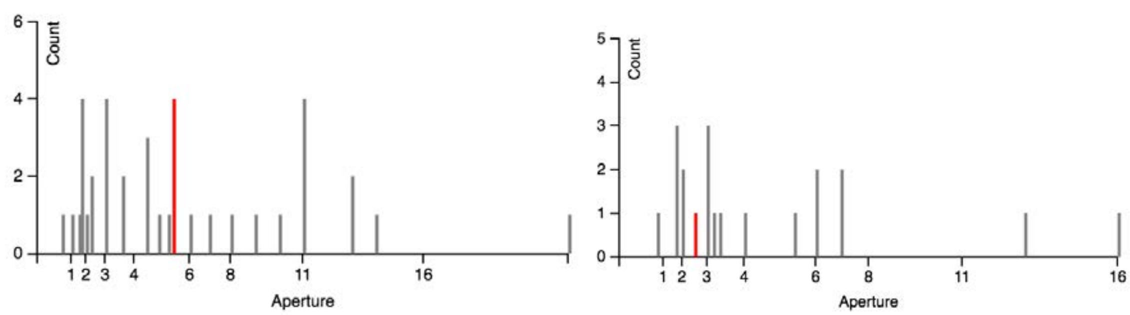

Figure 17. Aperture distribution for two users

ISO

- One of the biggest advantages of Full Frame cameras over the crop sensor is better low light performance. However these cameras are 2x-3x times the cost of their crop sensor counterparts.
- High ISO generally indicates photographs taken in low light, which contributes to its own unique aesthetic (diffused ambient light). In such scenarios users can benefit from full frame cameras.

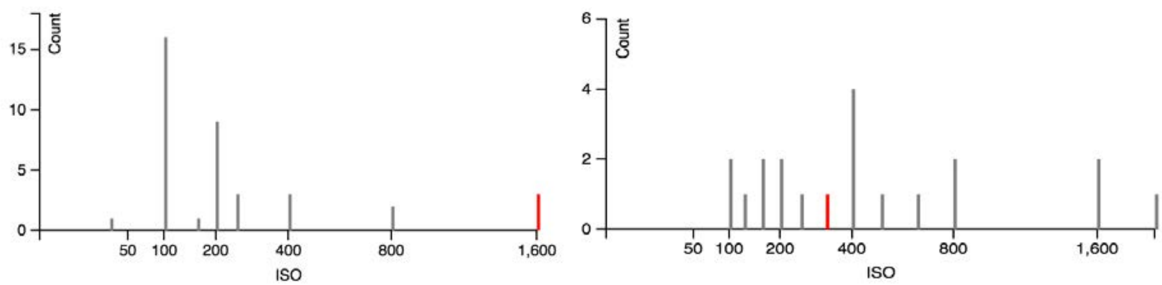

Figure 18. ISO distribution for two users

Shutter Speed

- For very few users, groups of images with similar shutter were observed. Typically the images had similar EXIF data as well.
- Since the range of shutter speed is to the order of 10^6 it was harder to visualize and draw conclusions

User Post Study

- 80% of users agreed that such a study is useful for photographers
- 55% user agreed that the study would have a direct impact on their shooting style

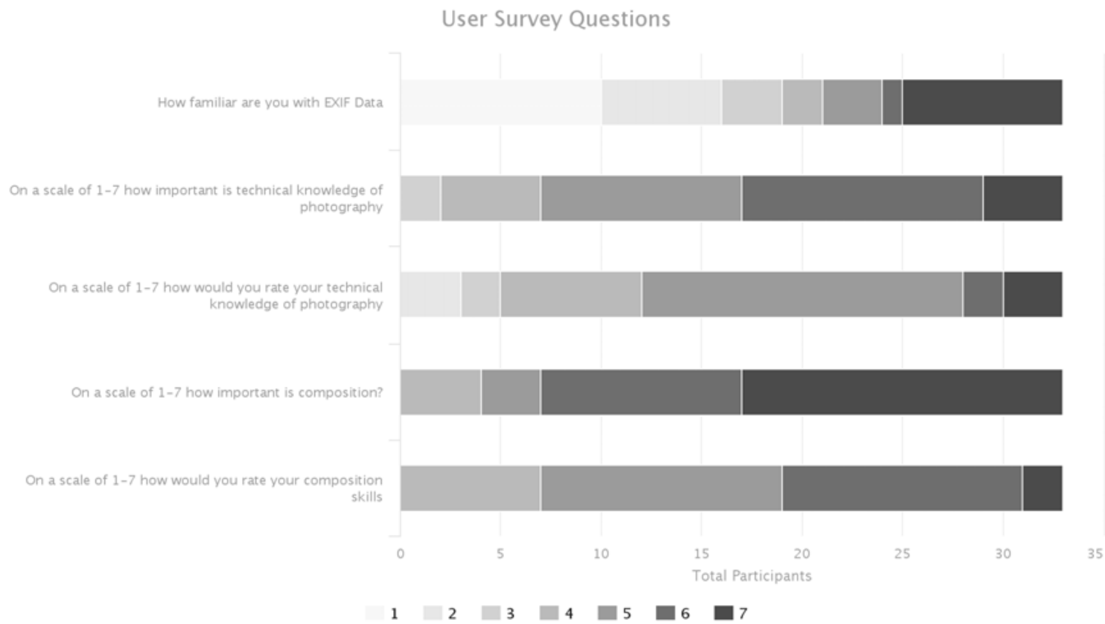

Figure 19. User Study Response: Self Evaluation

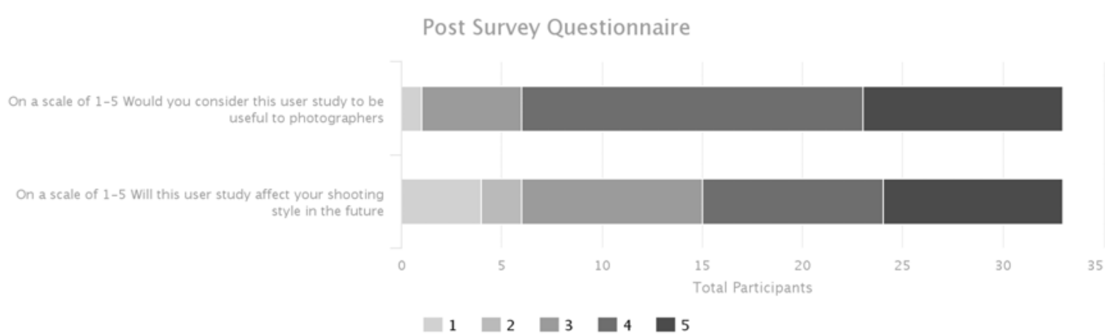

Figure 20. User Study Response: Evaluating the success of the user study

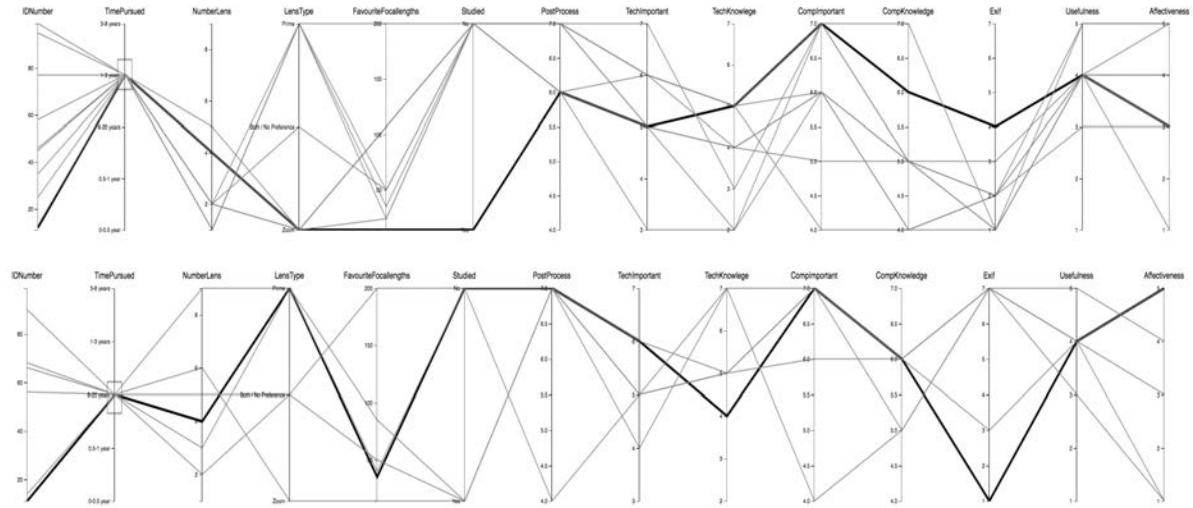

Figure 21. Comparing Experience Groups within user study data in parallel coordinates.

Comparing experience groups in the parallel coordinate interface reveals interesting trends. For example photographers with experience between (1-3 years) and (8-20 years) rated similar compositional knowledge during the self-evaluation but (8-20 years) group rated their technical knowledge to be higher. A similar observation was made for EXIF knowledge, showing its importance with experienced user groups.

6. Conclusion

“Into The Technicalities of Photography” introduces a new methodology to understand technical aesthetics of images. Using two interactive web-based interfaces, user study data, selected images and the EXIF parameters are visualized for photographers to understand technical aesthetics of the images they selected.

From the self-evaluation study it was observed that with experience, the photographer’s technical and EXIF knowledge improves vastly even as they rate their compositional knowledge to be the same. This serves as a clear indication and motivation for photographers to learn more about the camera for creating better images. In order to do so, the interfaces are designed to encourage users to ask questions about the data and freely explore the image space.

The project serves as a test bed for a metadata-based approach towards analyzing photographs for educating photographers to understand how technical parameters and exposure affect overall image aesthetics. This knowledge is often overlooked in practice and is learnt only through experience. The project explores spatial image organization that visually groups similar images together for better understanding. Based on my own learning’s from the project, I envision creating a complete web-based system for photographers to select images, interact with the data and learn about their own technical aesthetic preferences.

7. Future Work

The project presented is the first step towards creating a connection between photographers and technical image aesthetics. The study brings forward a new approach whose possibilities are yet to be fully explored. Since Shutter Speed, ISO and Aperture are interrelated, interactive exposure triangle can serve as a powerful and easy to understand visualization. An Exposure triangle can be represented as a modified ternary plot. Visualizing shutter speed is a challenge that needs to be overcome since traditional scales cannot accurately represent it. The interfaces would have more utility if they could be combined to into a single interface. A possible version would combine the image selection and data visualization into a single website to provide instant feedback to allow self-evaluation for photographers. The acquired knowledge can serve to inform camera equipment vendors to recommend appropriate gear for amateur photographers.

8. Bibliography

[1] A.M.Cox, Clough, P., & Marlow, J. (2008). Flickr: a first look at user behaviour in the context of photography as serious leisure. *Information Research* .

[2] *AI-Junkie*. (n.d.). Retrieved from Kohonen's Self Organizing Feature Maps: http://www.ai-junkie.com/ann/som/som1.html

[3] API, F. (n.d.). *Flickr API*. Retrieved from Flickr API: https://www.flickr.com/services/api/

[4] Ayton, G. (n.d.). Retrieved from http://www.ayton.id.au/gary/photo/photo_exp1.htm

[5] Barthes, R. (1964). *Rhetoric of the Image.*

[6] Campany, D. (2013, April). *Victor Burgin: Other Criteria*. Retrieved from http://davidcampany.com/other-criteriavictor-burgin/

[7] Cartier-Bresson, H. (1958). Famous Photographers Tell How. (H. Cartier-Bresson, Interviewer)

[8] Cartier-Bresson, H. (1971). NY Times. (S. Turner-Seed, Interviewer)

[9] Cartier-Bresson, H. (1952). *The Decisive Moment.*

[10] ChinaPhotoCenter. (n.d.). *ChinaPhotoCenter*. Retrieved from http://chinaphotocenter.com/what-are-the-major-differences-between-the-photography-style-of-eastern-and-western-countries/

[11] CIPA. (2010). *EXIF*. (Camera & Imaging Products Association) Retrieved from http://www.cipa.jp/std/documents/e/DC-008-2012_E.pdf

[12] Collier, A. (2013, December). *Processing EXIF Data*. Retrieved from http://www.exegetic.biz/blog/2013/12/processing-exif-data/

[13] Datta, R., Joshi, D., Li, J., & Wang, J. Z. (2006). Studying aesthetics in photographic images using a computational approach. *European conference on Computer Vision.*

[14] Davies, L. (2016). The Telegraph. (A. Leibovitz, Interviewer)

[15] *EXIF*. (n.d.). Retrieved from https://en.wikipedia.org/wiki/Exif

[16] Flickr. (n.d.). *Flickr Interestingess*. Retrieved from Flickr: https://www.flickr.com/services/api/flickr.interestingness.getList.html

[17] Flusser, V. (1983). *Towards a Philosophy of Photography.*

[18] Goodnight, E. Z. (2011, July 13). *How To Geek*. Retrieved from http://www.howtogeek.com: http://www.howtogeek.com/68085/how-to-use-exif-data-to-learn-from-master-photographers/

[19] Guy, D. (n.d.). *photographic aesthetics*. Retrieved from http://www.photokonnexion.com/3269-2/

[20] Hsueh, M. (2011). *PhotoVis: Visualization of Digital Photograph Metadata .*

[21] Jain, R., & Sinha, P. (2008). *Patent No. US8094948 B2.*

[22] Jeffrey, I. (2009). *How to read a photograph*. Retrieved from The Guardian: https://www.theguardian.com/artanddesign/2009/mar/06/how-to-read-photograph

[23] Kohonen, T. (1990). The Self-Organizing Map. *IEEE* .

[24] Kohonen, T. (1990). *The Self-Organzing Map*. Retrieved from The Self-Organzing Map: http://sci2s.ugr.es/keel/pdf/algorithm/articulo/1990-Kohonen-PIEEE.pdf
[25] Kosara, R. (2010). *Parallel Coordiantes*. Retrieved from https://eagereyes.org/techniques/parallel-coordinates
[26] Lew, M. J. (2008). *The MIR flickr retrieval evaluation*. Retrieved from The MIR flickr retrieval evaluation: http://dl.acm.org/citation.cfm?id=1460104
[27] Liu, L., Chen, R., Wolf, L., & Cohen-Or, D. (2010). Composition, Optimizing Photo.
[28] Marchesotti, L., Perronnin, F., Larlus, D., & Csurka, G. (2011). Assessing the aesthetic quality of photographs using generic image descriptors. *International Conference on Computer Vision.*
[29] Mark Huiskes, B. T. (2008). *The MIRFLICKR Retrieval Evaluation*. Retrieved from The MIRFLICKR Retrieval Evaluation: http://press.liacs.nl/mirflickr/
[30] Miller, M. (2011). *Exposure Triangle*. Retrieved from http://photo.stackexchange.com/questions/6598/what-is-the-exposure-triangle/12441
[31] Nikon. (n.d.). *Understanding Focal Length*. Retrieved from http://www.nikonusa.com/en/learn-and-explore/article/g3cu6o2o/understanding-focal-length.html#!
[32] S., B. D., Caterina, F., Henderson-Begg, James, C., Mourachov, & Serguei. (2006). *Patent No. 20060242139.*
[33] Salgado, S. (2012). The Guardian. (L. Barnett, Interviewer)
[34] Stefanovicˇ, P., & Kurasova, O. (2011). Visual analysis of self-organizing maps. *WSOM 2011* .
[35] Talvala, E. V. (2011). The Frankencamera: Building a Programmable Camera for Computational Photography. *The Frankencamera: Building a Programmable Camera for Computational Photography* .
[36] Tretter, D. R., & Lin, Q. (2001). *Patent No. US 6977679 B2.*
[37] Yang, T. (n.d.). *ShutterDial*. Retrieved from http://www.shutterdial.com/#/
[38] Yen, J., Wu, P., & Tretter, D. (2007). Knowledge discovery for better photographs. *SPIE.*
[39] Yen, J., Wu, P., & Tretter, D. (2006). *Patent No. US 7668369 B2.*
[40] Yu, C.-H. (2004). Aesthetics of Photography. *Art Criticism* .
[41] Zhou, H., Yuan, X., Qu, H., Cui, W., & Chen, B. (2008). Visual Clustering in Parallel Coordinates. *IEEE-VGTC* .
[42]

9. Appendix

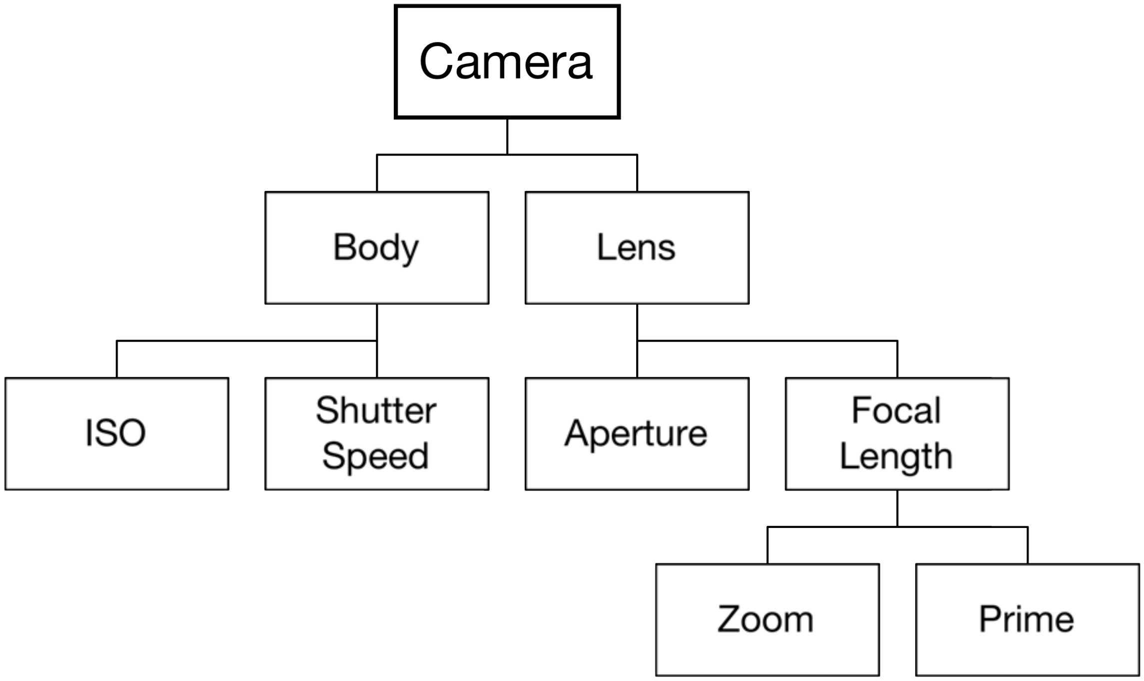

Figure 22. Camera breakdown into its EXIF parameters

- **EXIF**: Exchangeable Image File format is a standard that specifies the formats for images, sound, and ancillary tags used by digital cameras (including smartphones), scanners and other systems handling image and sound files recorded by digital cameras.
- **Shutter Speed**: In photography, shutter speed is the length of time when the film or digital sensor inside the camera is exposed to light.
- **ISO**: ISO, which stands for International Standards Organization, is a measure of the sensitivity of film or a digital sensor to light. The larger the ISO the more sensitive the sensor or film.

- **Aperture**: Aperture is the lens opening that lets light in during the exposure. Unit: F-Stop. The larger the F-number the small the lens opening.

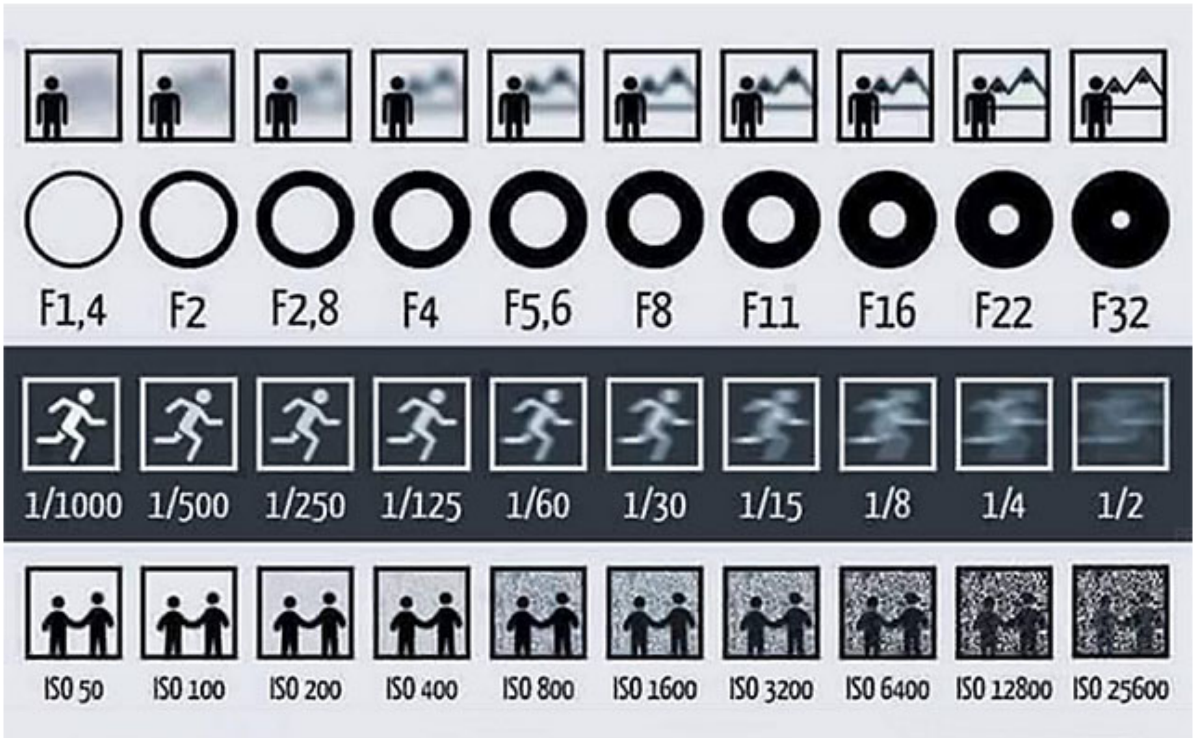

Figure 23.Visual effect of camera parameters on the image (Petapixel)

- **Focal Length**: Focal Length is the calculation of an optical distance from the point where light rays converge to form a sharp image of an object to the digital sensor or 35mm film at the focal plane in the camera. Generally speaking lower focal length refers to lenses, which have a wider field of view, and lenses with high focal length number have a narrow field of view. Focal length is measured in mm.

QR CODE: Link to online prototypes

www.mohithingorani.com/masters-project