

Computer Graphics

Lecture - 07

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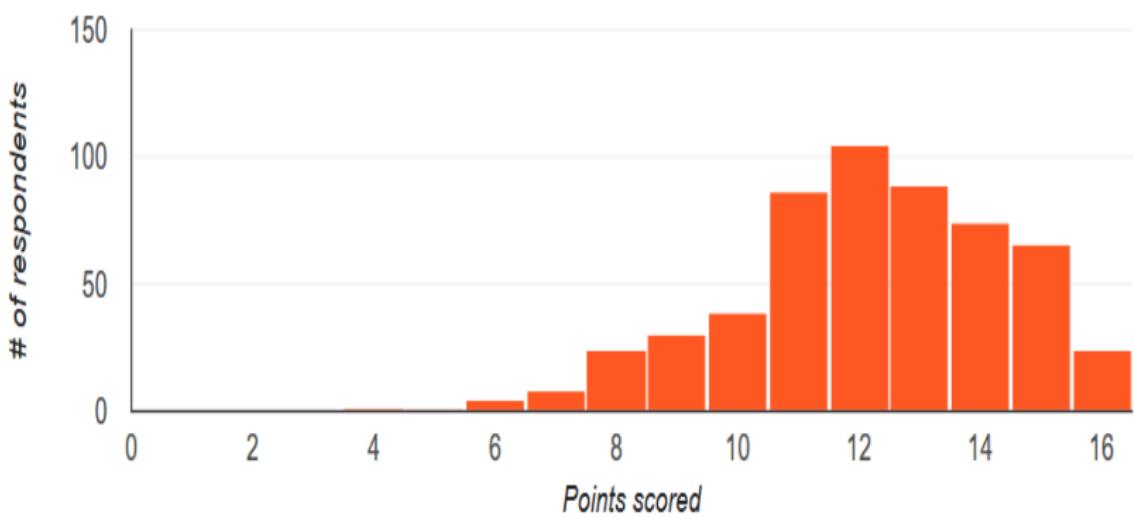
March 23, 2019

Average
12.19 / 16 points

Median
12 / 16 points

Range
4 - 16 points

Total points distribution



1 Color Models

- RGB Color Model
- CMYK
- HSL and HSV

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- Kernel
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OpenCV and BGR

- OpenCV always use BGR
- Try saving the images we made last lecture

RGB Color Model

- Additive Color Model
- R, G, B, Magenta, Cyan, Yellow

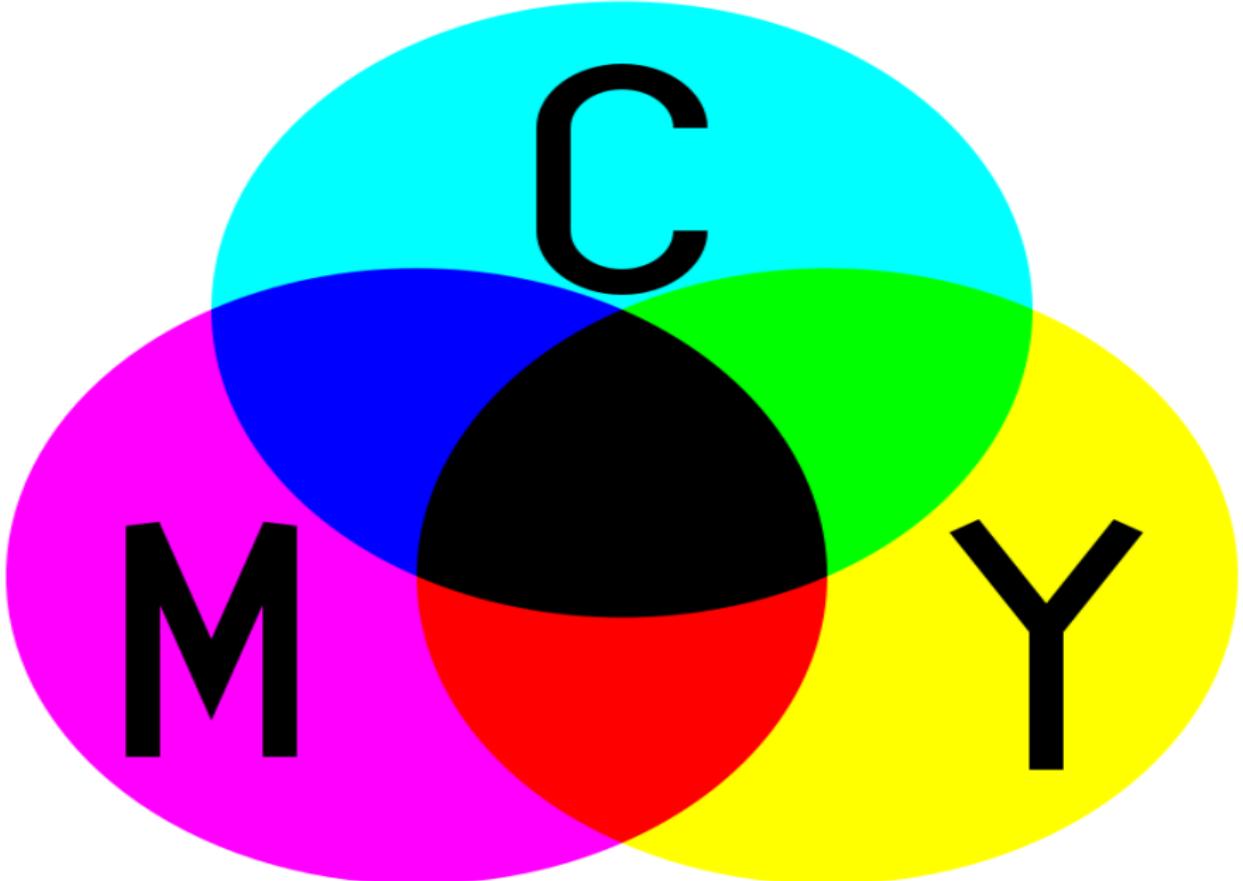
R

G

B

CMYK Color Model

- Subtractive Color Model
- Printers
- Black is preferred as a standalone, because $C + M + Y =$ Brown, not really Black in Printers

A graphic design featuring four overlapping circles forming a square. The top circle is light blue and contains a black outline of the uppercase letter 'C'. The bottom-left circle is magenta and contains a black outline of the uppercase letter 'M'. The bottom-right circle is yellow and contains a black outline of the uppercase letter 'Y'. The middle circle, which overlaps all three, is black and contains a red outline of the uppercase letter 'V'.

C

M

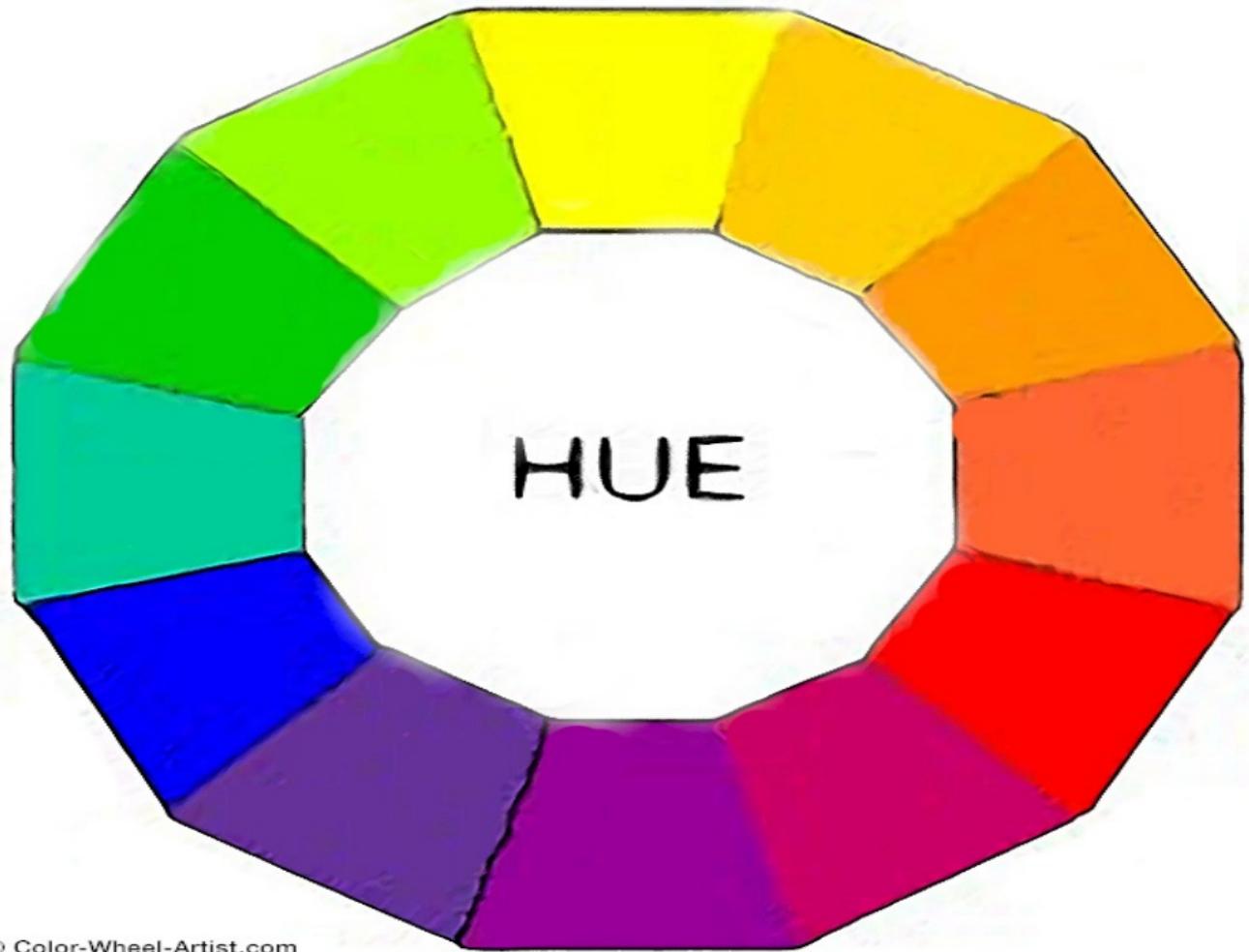
Y

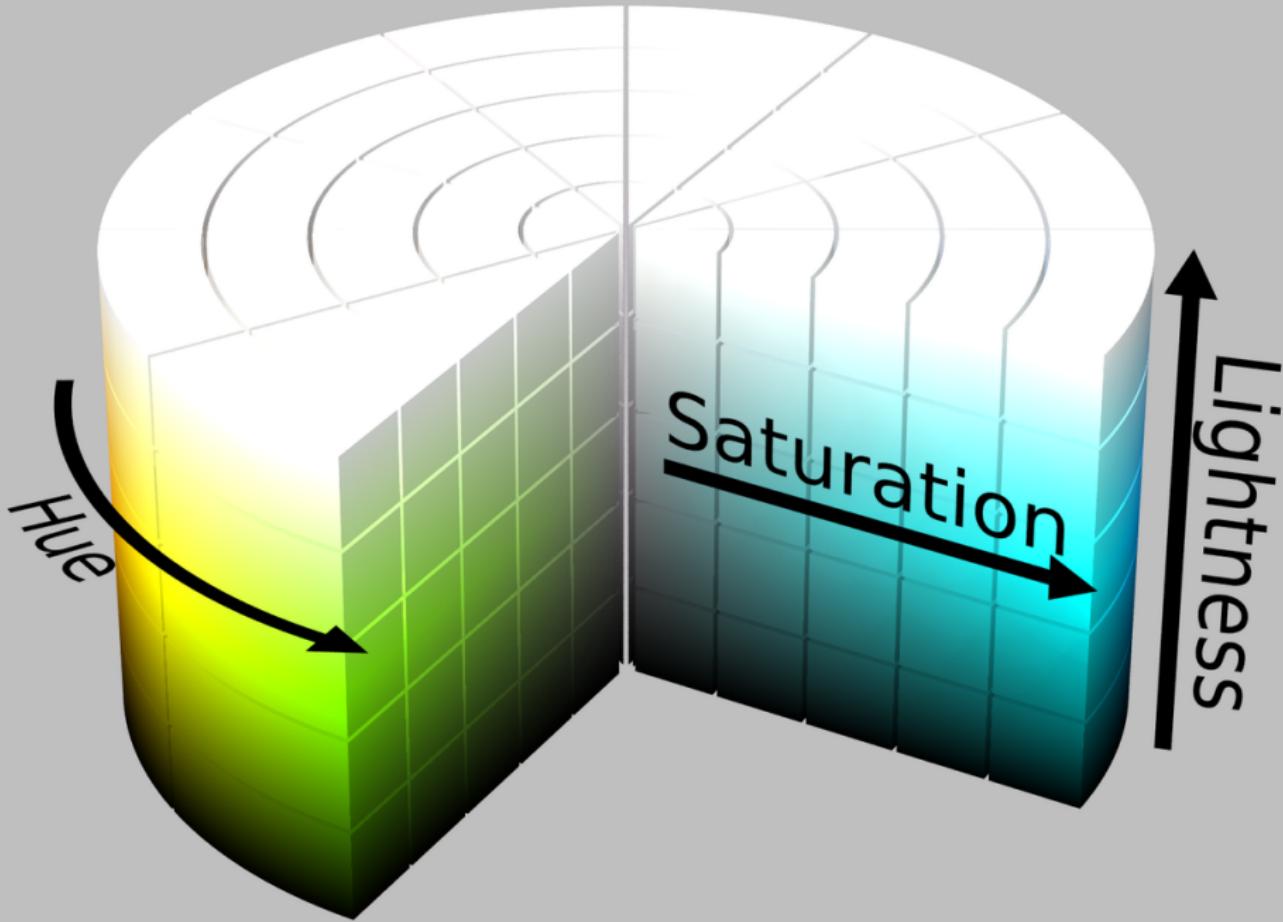
HSL and HSV - 01

- **HSL:** Hue, Saturation, Lightness
- **HSV:** Hue, Saturation, Value
- Alternative representations of the RGB color model
- Designed in the 1970s by computer graphics researchers to more closely align with the way human vision perceives color-making attributes.
- Hue: Color Appearance Parameter - Simply: Color

HSL and HSV - 02

- In these models, colors of each hue are arranged in a radial slice, around a central axis of neutral colors which ranges from black at the bottom to white at the top.
- The HSV representation models the way paints of different colors mix together, with the saturation dimension resembling various shades of brightly colored paint, and the value dimension resembling the mixture of those paints with varying amounts of black or white paint.
- The HSL model attempts to resemble more perceptual color models such as the Natural Color System (NCS) or Munsell color system, placing fully saturated colors around a circle at a lightness value of $1/2$, where a lightness value of 0 or 1 is fully black or white, respectively.





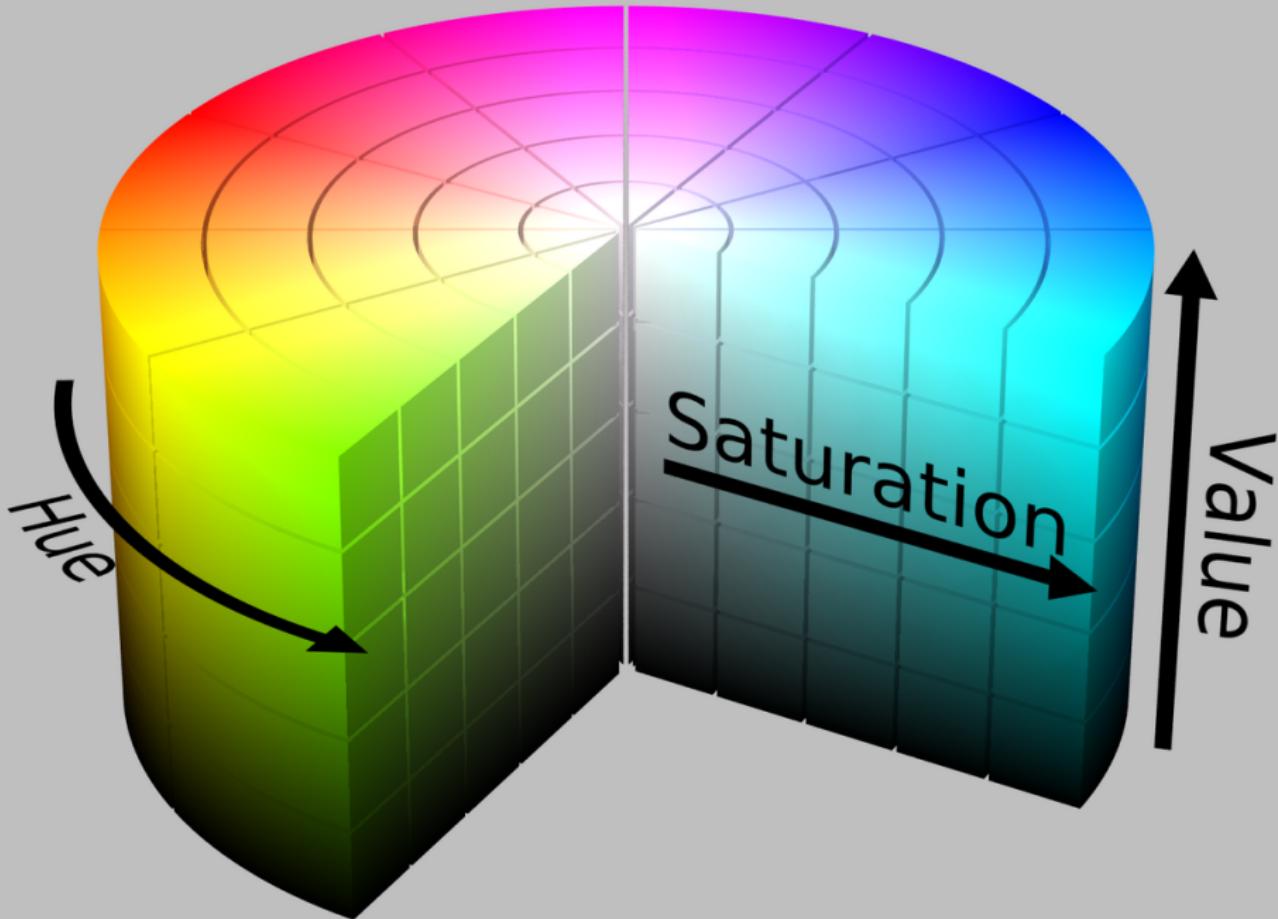


Image Processing

- In computer science, digital image processing is the use of computer algorithms to perform image processing on digital images.
- As a subcategory or field of digital signal processing, digital image processing has many advantages over analog image processing.
- It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing.
- Since images are defined over two dimensions (perhaps more) digital image processing may be modeled in the form of multidimensional systems.

History - 01

- Many of the techniques of digital image processing, or digital picture processing as it often was called, were developed in the 1960s at the Jet Propulsion Laboratory, Massachusetts Institute of Technology, Bell Laboratories, University of Maryland, and a few other research facilities, with application to satellite imagery, wire-photo standards conversion, medical imaging, videophone, character recognition, and photograph enhancement.
- The cost of processing was fairly high, however, with the computing equipment of that era.
- That changed in the 1970s, when digital image processing proliferated as cheaper computers and dedicated hardware became available.

History - 02

- Images then could be processed in real time, for some dedicated problems such as television standards conversion.
- As general-purpose computers became faster, they started to take over the role of dedicated hardware for all but the most specialized and computer-intensive operations.
- With the fast computers and signal processors available in the 2000s, digital image processing has become the most common form of image processing and generally, is used because it is not only the most versatile method, but also the cheapest.
- Digital image processing technology for medical applications was inducted into the Space Foundation Space Technology Hall of Fame in 1994.

Tasks - 01

- Digital image processing allows the use of much more complex algorithms, and hence, can offer both more sophisticated performance at simple tasks, and the implementation of methods which would be impossible by analog means.

Tasks - 02

In particular, digital image processing is the only practical technology for:

- Classification
- Feature Extraction
- Pattern Recognition
- Projection

Classification - 01

- the problem of identifying to which of a set of categories a new observation belongs, on the basis of a training set of data containing observations (or instances) whose category membership is known.
- Examples are assigning a given email to the "spam" or "non-spam" class, and assigning a diagnosis to a given patient based on observed characteristics of the patient.
- Classification is an example of pattern recognition.

Classification - 02

- In the terminology of machine learning, classification is considered an instance of supervised learning, i.e., learning where a training set of correctly identified observations is available.
- The corresponding unsupervised procedure is known as clustering, and involves grouping data into categories based on some measure of inherent similarity or distance.

Feature Extraction - 01

- In machine learning, pattern recognition and in image processing, feature extraction starts from an initial set of measured data and builds derived values (features) intended to be informative and non-redundant, facilitating the subsequent learning and generalization steps, and in some cases leading to better human interpretations.
- Feature extraction is a dimensionality reduction process, where an initial set of raw variables is reduced to more manageable groups (features) for processing, while still accurately and completely describing the original data set.

Feature Extraction - 02

- When the input data to an algorithm is too large to be processed and it is suspected to be redundant (e.g. the same measurement in both feet and meters, or the repetitiveness of images presented as pixels), then it can be transformed into a reduced set of features (also named a feature vector).
- Determining a subset of the initial features is called feature selection. The selected features are expected to contain the relevant information from the input data, so that the desired task can be performed by using this reduced representation instead of the complete initial data.

Pattern Recognition

- The field of pattern recognition is concerned with the automatic discovery of regularities in data through the use of computer algorithms and with the use of these regularities to take actions such as classifying the data into different categories

Projection

- 3D projection is any method of mapping three-dimensional points to a two-dimensional plane.
- As most current methods for displaying graphical data are based on planar (pixel information from several bitplanes) two-dimensional media, the use of this type of projection is widespread, especially in computer graphics, engineering and drafting.

Image Noise

- Image noise is random variation of brightness or color information in images, and is usually an aspect of electronic noise.
- It can be produced by the sensor and circuitry of a scanner or digital camera.
- Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector.
- Image noise is an undesirable by-product of image capture that obscures the desired information.

Image Processing Techniques

Some techniques which are used in digital image processing include:

- Anisotropic diffusion
- Image Editing
- Image Restoration
- Partial Differential Equations
- Pixelation

Anisotropic Diffusion

- Also called Perona–Malik diffusion
- Technique aiming at reducing image noise without removing significant parts of the image content, typically edges, lines or other details that are important for the interpretation of the image.

Image Editing

- Illustrated in a stand-alone section

Image Restoration

- The operation of taking a corrupt/noisy image and estimating the clean, original image.
- Corruption may come in many forms such as motion blur, noise and camera mis-focus.
- Image restoration is performed by reversing the process that blurred the image and such is performed by imaging a point source and use the point source image, which is called the Point Spread Function (PSF) to restore the image information lost to the blurring process.
- Image restoration is different from image enhancement in that the latter is designed to emphasize features of the image that make the image more pleasing to the observer, but not necessarily to produce realistic data from a scientific point of view.

Pixelation - 01

- In computer graphics, pixelation (or pixellation in British English) is caused by displaying a bitmap or a section of a bitmap at such a large size that individual pixels, small single-colored square display elements that comprise the bitmap, are visible.
- Such an image is said to be pixelated (pixellated in the UK).
- Early graphical applications such as video games ran at very low resolutions with a small number of colors, resulting in easily visible pixels.

Pixelation - 02

- The resulting sharp edges gave curved objects and diagonal lines an unnatural appearance.
- However, when the number of available colors increased to 256, it was possible to gainfully employ anti-aliasing to smooth the appearance of low-resolution objects, not eliminating pixelation but making it less jarring to the eye.
- Higher resolutions would soon make this type of pixelation all but invisible on the screen, but pixelation is still visible if a low-resolution image is printed on paper.

Image Editing

- Image editing encompasses the processes of altering images, whether they are digital photographs, traditional photo-chemical photographs, or illustrations.
- Traditional analog image editing is known as photo retouching, using tools such as an airbrush to modify photographs, or editing illustrations with any traditional art medium.
- Graphic software programs, which can be broadly grouped into vector graphics editors, raster graphics editors, and 3D modelers, are the primary tools with which a user may manipulate, enhance, and transform images.
- Many image editing programs are also used to render or create computer art from scratch.

Basics of Image Editing

- Raster images are stored in a computer in the form of a grid of picture elements, or pixels.
- These pixels contain the image's color and brightness information.
- Image editors can change the pixels to enhance the image in many ways.
- The pixels can be changed as a group, or individually, by the sophisticated algorithms within the image editors.
- Note: It is easier to rasterize a vector image than to vectorize a raster image.
- Vector images can be modified more easily, because they contain descriptions of the shapes for easy rearrangement.
- Also Scalable, being rasterizable at any resolution.

Automatic Image Enhancement - 01

- Camera or computer image editing programs often offer basic automatic image enhancement features that correct color hue and brightness imbalances as well as other image editing features, such as red eye removal, sharpness adjustments, zoom features and automatic cropping.
- These are called automatic because generally they happen without user interaction or are offered with one click of a button or mouse button or by selecting an option from a menu.

Automatic Image Enhancement - 02

- Additionally, some automatic editing features offer a combination of editing actions with little or no user interaction.
- Note the following image, here the Gaussian Filter (will be illustrated later) removes the pros on the hand
- Those are considered "at least for Gaussian Filter - Noise" and they can be removed

Befor



after



Image Editors Features - 00

- Listed below are some of the most used capabilities of the better graphic manipulation programs.
- The list is by no means all inclusive.
- There are a myriad of choices associated with the application of most of these features.

Image Editors Features - 01

- Selection
- Layers
- Image Size Alteration
- Cropping an Image
- Cutting out Part of an Image from the Background
- Histogram
- Noise Reduction
- Removal of Unwanted Elements
- Selective Color Change
- Image Orientation
- Perspective Control and Distortion
- Lens Correction
- Enhancing Images

Image Editors Features - 02

- Sharpening and Softening Images
- Selecting and Merging of Images
- Slicing of Images
- Special Effects
- Stamp Clone Tool
- Change Color Depth
- Contrast Change and Brightening
- Gamma Correction
- Color Adjustments
- Dynamic Blending
- Printing
- Image Warping
- Morphing

Selection - 01

- One of the prerequisites for many of the applications mentioned below is a method of selecting part(s) of an image, thus applying a change selectively without affecting the entire picture.
- Most graphics programs have several means of accomplishing this, such as:
 - a marquee tool for selecting rectangular or other regular polygon-shaped regions,
 - a lasso tool for freehand selection of a region,
 - a magic wand tool that selects objects or regions in the image defined by proximity of color or luminance,
 - vector-based pen tools,

Selection - 02

- as well as more advanced facilities such as
 - edge detection
 - masking
 - alpha compositing
 - and color and channel-based extraction.
- The border of a selected area in an image is often animated with the marching ants effect to help the user to distinguish the selection border from the image background.

Layers - 01

- Another feature common to many graphics applications is that of Layers,
- which are analogous to sheets of transparent acetate (each containing separate elements that make up a combined picture),
- stacked on top of each other,
- each capable of being individually positioned, altered and blended with the layers below,
- without affecting any of the elements on the other layers.

Layers - 02

- This is a fundamental workflow which has become the norm for the majority of programs on the market today,
- and enables maximum flexibility for the user while maintaining non-destructive editing principles and ease of use.
- Layers example

User Manual

—

STOP



C A P T U R E

USER MANUAL



Image Size Alteration

- Image editors can resize images in a process often called image scaling, making them larger, or smaller.
- High image resolution cameras can produce large images which are often reduced in size for Internet use.
- Image editor programs use a mathematical process called resampling to calculate new pixel values whose spacing is larger or smaller than the original pixel values.
- Images for Internet use are kept small, say 640×480 pixels which would equal 0.3 megapixels.
- Different Image Size Alteration Algorithms will be presented InchALLAH later

Cropping an Image

- Digital editors are used to crop images.
- Cropping creates a new image by selecting a desired rectangular portion from the image being cropped.
- The unwanted part of the image is discarded.
- Image cropping does not reduce the resolution of the area cropped.
- Best results are obtained when the original image has a high resolution.
- A primary reason for cropping is to improve the image composition in the new image.





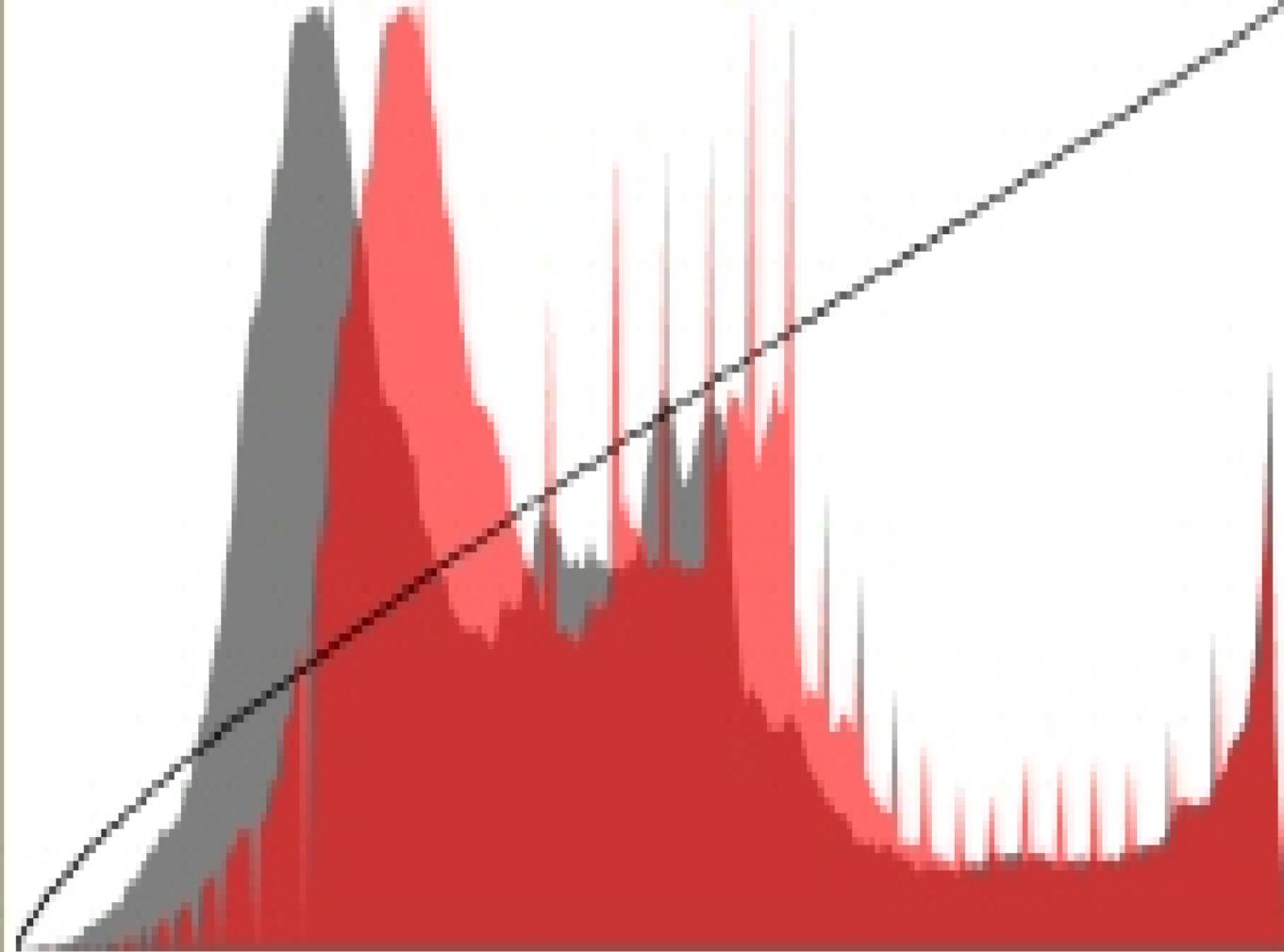
Cutting out a Part of an Image from the Background

- Using a selection tool, the outline of the figure or element in the picture is traced/selected, and then the background is removed.
- Depending on how intricate the "edge" is this may be more or less difficult to do cleanly.
- For example, individual hairs can require a lot of work.
- Hence the use of the "green screen" technique (chroma key) which allows one to easily remove the background.

Histogram

- Image editors have provisions to create an image histogram of the image being edited.
- The histogram plots the number of pixels in the image (vertical axis) with a particular brightness value (horizontal axis).
- Algorithms in the digital editor allow the user to visually adjust the brightness value of each pixel and to dynamically display the results as adjustments are made.
- Improvements in picture brightness and contrast can thus be obtained.





Noise Reduction - 01

- Image editors may feature a number of algorithms which can add or remove noise in an image.
- Some JPEG artifacts can be removed; dust and scratches can be removed and an image can be de-speckled.
- Noise reduction merely estimates the state of the scene without the noise and is not a substitute for obtaining a "cleaner" image.

Noise Reduction - 02

- Excessive noise reduction leads to a loss of detail, and its application is hence subject to a trade-off between the undesirability of the noise itself and that of the reduction artifacts.
- Noise tends to invade images when pictures are taken in low light settings.
- A new picture can be given an 'antiqued' effect by adding uniform monochrome noise.





Selective Color Change

- Some image editors have color swapping abilities to selectively change the color of specific items in an image, given that the selected items are within a specific color range.

Before



After



Image Orientation

- Image editors are capable of altering an image to be rotated in any direction and to any degree.
- Mirror images can be created and images can be horizontally flipped or vertically flopped.
- A small rotation of several degrees is often enough to level the horizon, correct verticality (of a building, for example), or both.
- Rotated images usually require cropping afterwards, in order to remove the resulting gaps at the image edges.



Perspective Control and Distortion

- Some image editors allow the user to distort (or "transform") the shape of an image.
- While this might also be useful for special effects, it is the preferred method of correcting the typical perspective distortion which results from photographs being taken at an oblique angle to a rectilinear subject.
- Care is needed while performing this task, as the image is reprocessed using interpolation of adjacent pixels, which may reduce overall image definition.
- The effect mimics the use of a perspective control lens, which achieves a similar correction in-camera without loss of definition.

Scan



Next

Back



90°



Save

Amazing

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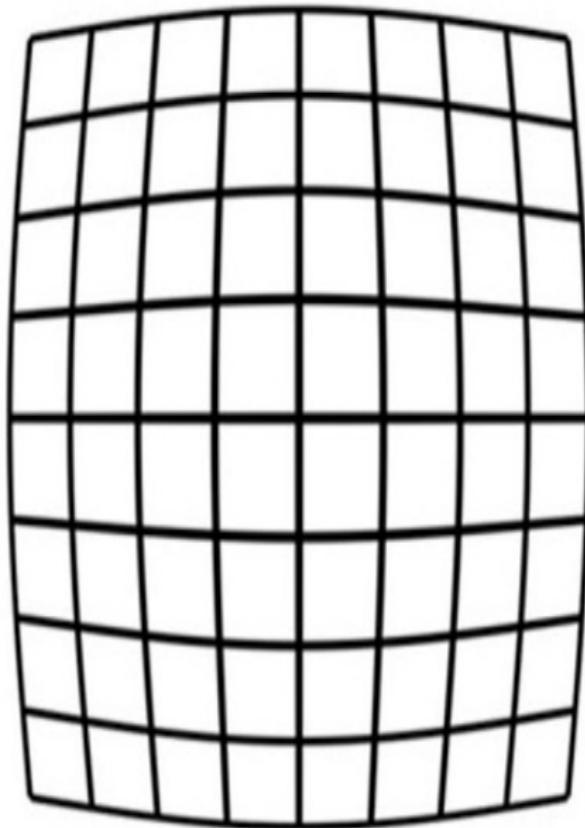


Lens Correction - 01

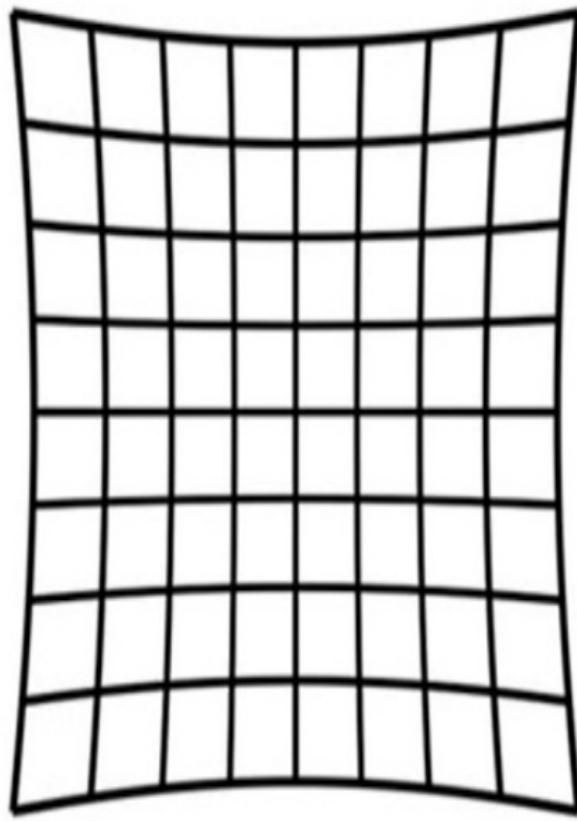
- Photo manipulation packages have functions to correct images for various lens distortions including pincushion, fisheye and barrel distortions.
- The corrections are in most cases subtle, but can improve the appearance of some photographs.

Lens Correction - 02

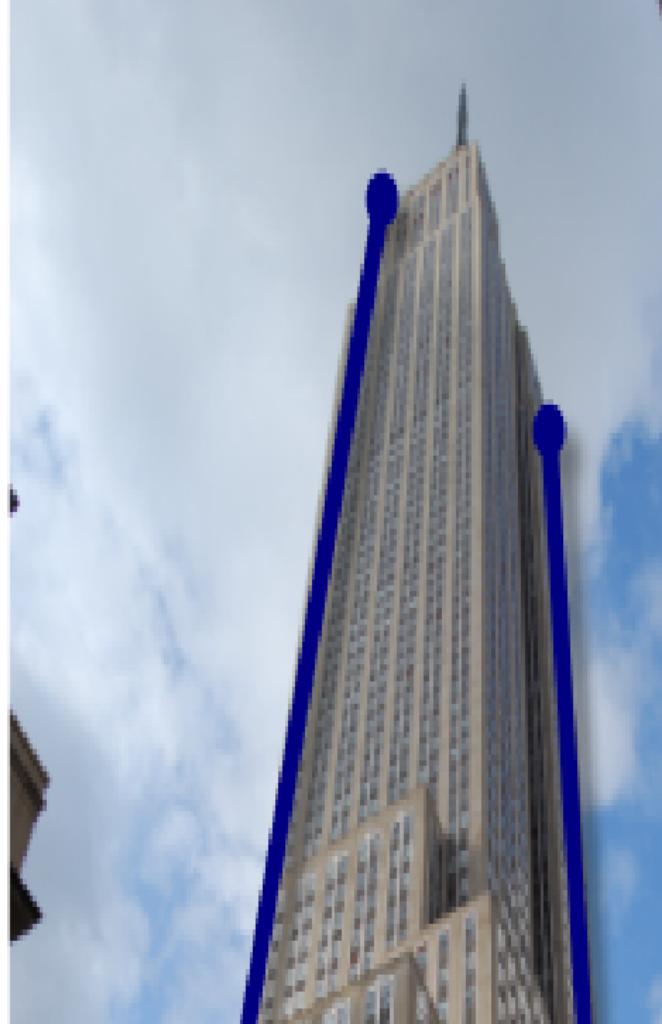
- Barrel Distortion: a type of defect in optical or electronic images in which vertical or horizontal straight lines appear as convex curves.
- Pincushion Distortion is the exact opposite of barrel distortion – straight lines are curved outwards from the center.
- This type of distortion is commonly seen on telephoto lenses, and it occurs due to image magnification increasing towards the edges of the frame from the optical axis.



Barrel Distortion



Pincushion Distortion











Enhancing Images

- In computer graphics, the process of improving the quality of a digitally stored image by manipulating the image with software.
- It is quite easy, for example, to make an image lighter or darker, or to increase or decrease contrast.
- Advanced photo enhancement software also supports many filters for altering images in various ways.
- Programs specialized for image enhancement are sometimes called image editors.

Contrast - Side Note 01

- Contrast is defined as the separation between the darkest and brightest areas of the image.
- Increase contrast and you increase the separation between dark and bright, making shadows darker and highlights brighter.

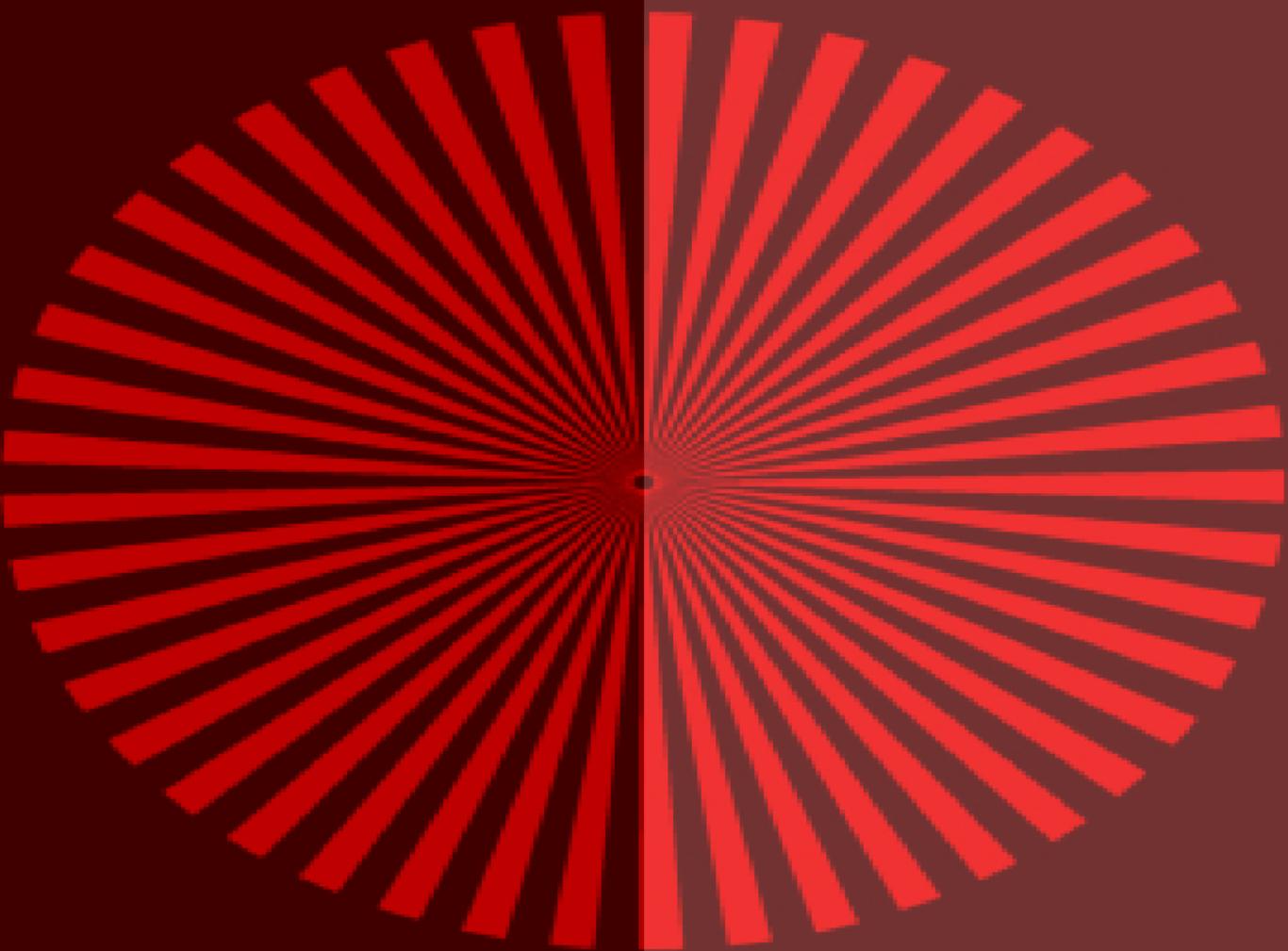
Brightness vs. Contrast - Side Note 02

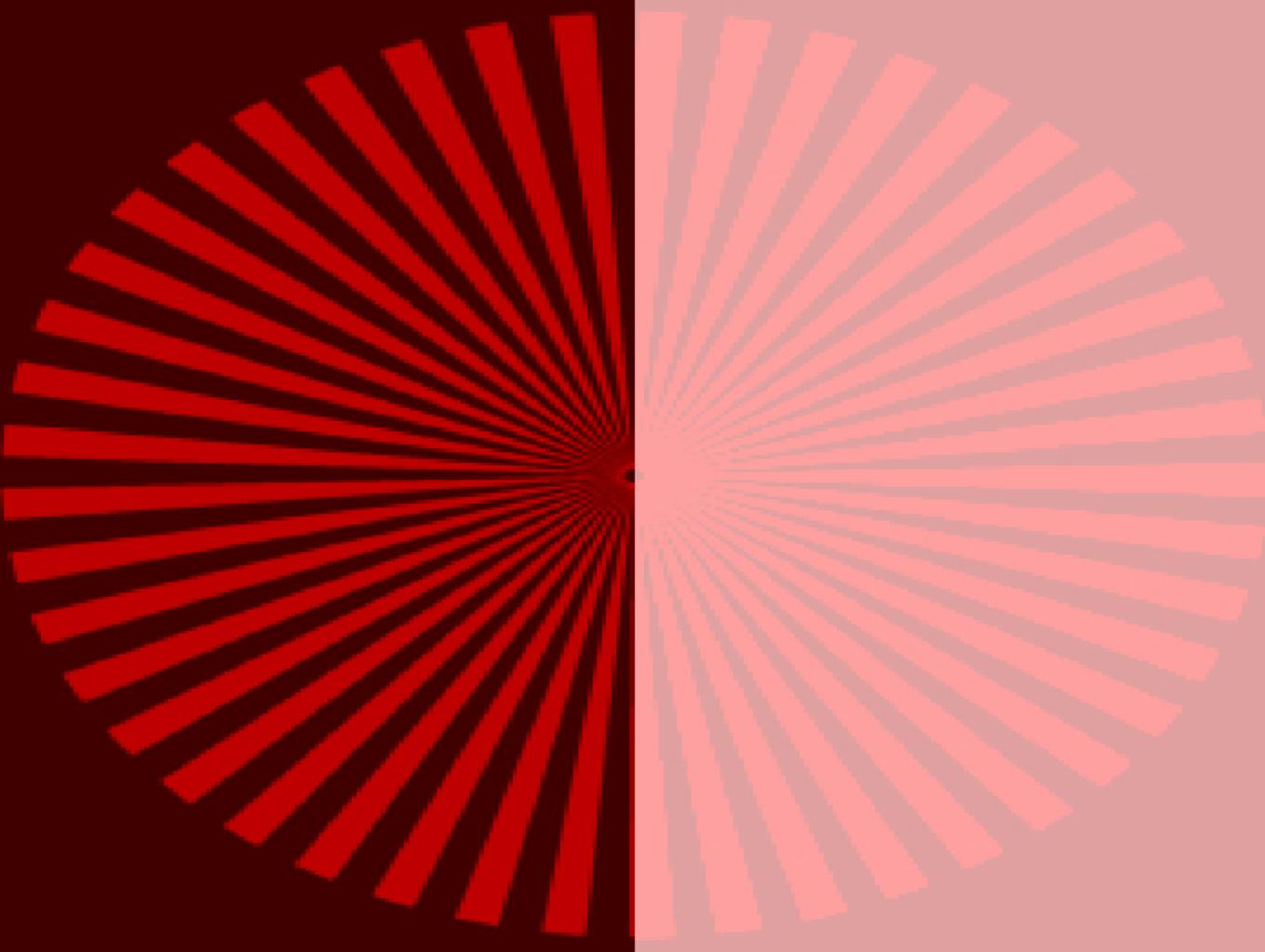
- Brightness refers to the overall lightness or darkness of the image.
- Increasing the brightness every pixel in the frame gets lighter.
- Contrast is the difference in brightness between objects in the image.
- Increasing the contrast makes light areas lighter and dark area in the frame becomes much darker.

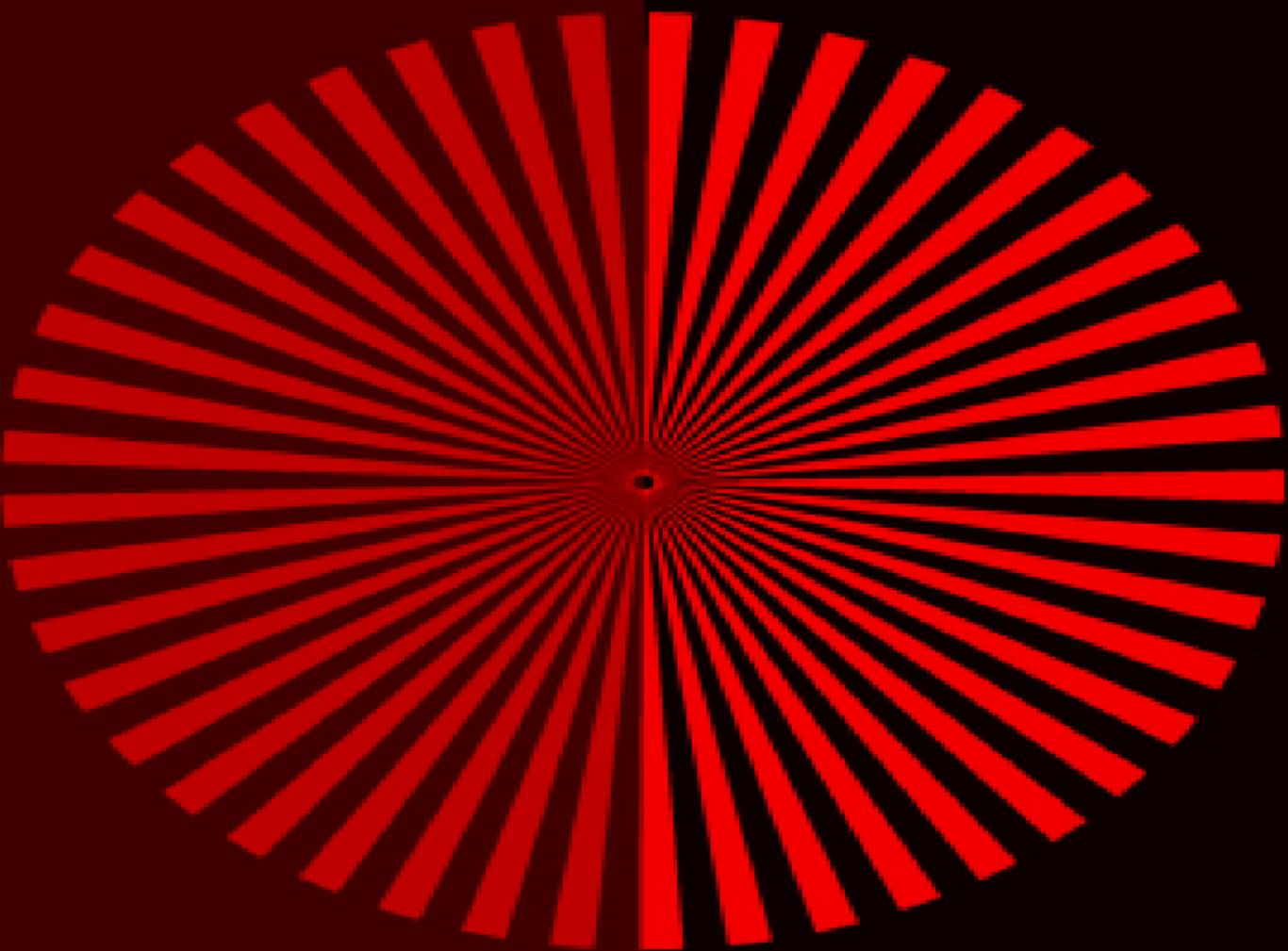
Brightness vs. Contrast - Examples

Following Images - in order:

- Increase Brightness
- Extreme Brightness
- Increase Contrast







Sharpening and Softening Images - 01

- Graphics programs can be used to both sharpen and blur images in a number of ways, such as unsharp masking or deconvolution.
- Deconvolution will be discussed later, in kernels and Gaussian filter.
- Blur: It is a widely used effect in graphics software, typically to reduce image noise and reduce detail.
Mathematically, applying a Gaussian blur to an image is the same as convolving the image with a Gaussian function.



Original

StDev = 3

StDev = 10



HOW TO BLUR FACES

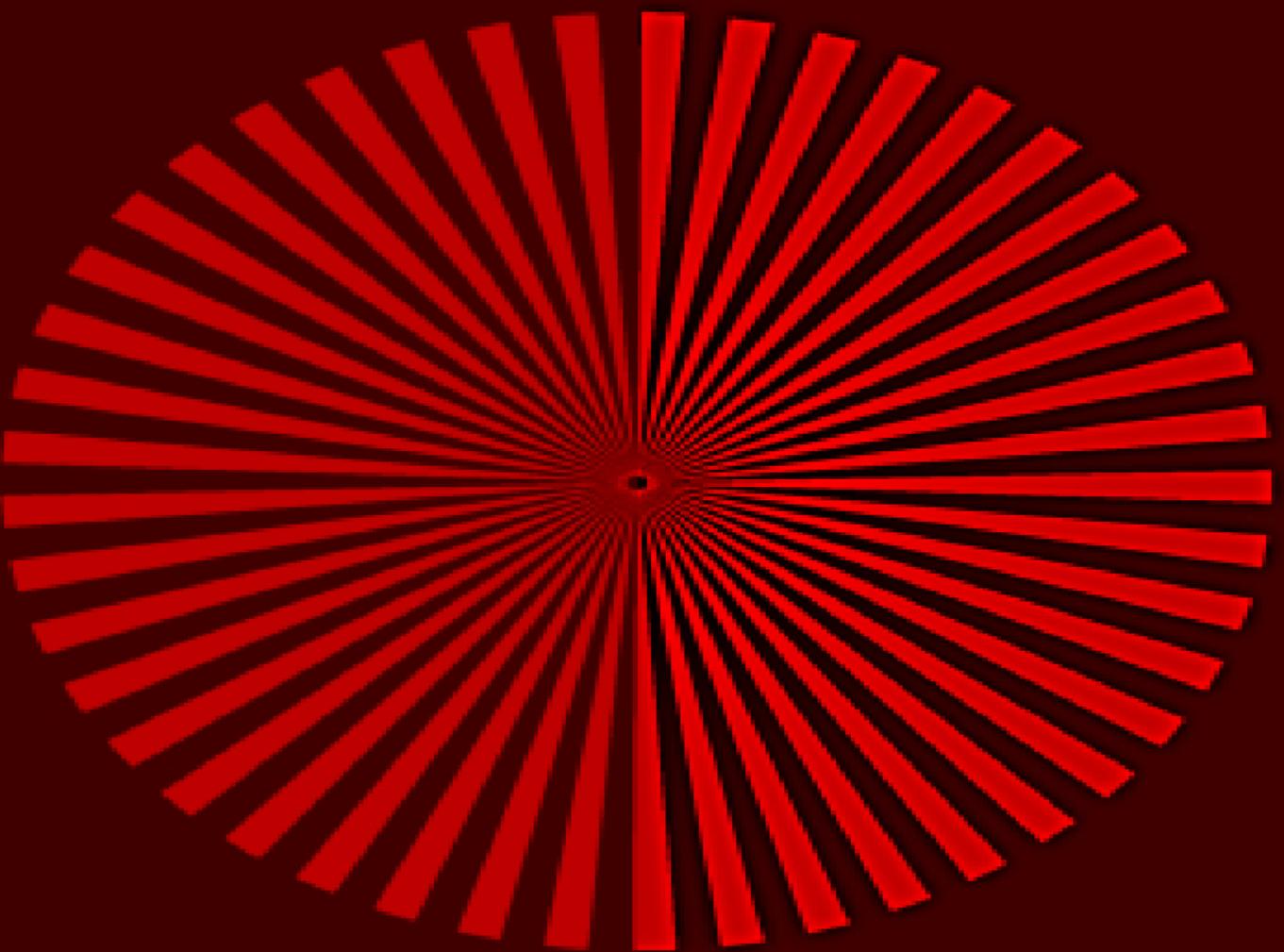


Sharpening and Softening Images - 02

- Portraits often appear more pleasing when selectively softened (particularly the skin and the background) to better make the subject stand out.
- This can be achieved with a camera by using a large aperture, or in the image editor by making a selection and then blurring it.
- Edge enhancement is an extremely common technique used to make images appear sharper, although purists frown on the result as appearing unnatural.
- Another form of image sharpening involves a form of contrast.

Sharpening and Softening Images - 03

- This is done by finding the average color of the pixels around each pixel in a specified radius, and then contrasting that pixel from that average color.
- This effect makes the image seem clearer, seemingly adding details.
- It is widely used in the printing and photographic industries for increasing the local contrasts and sharpening the images.





Selecting and Merging of Images - 01

- Many graphics applications are capable of merging one or more individual images into a single file.
- The orientation and placement of each image can be controlled.
- When selecting a raster image that is not rectangular, it requires separating the edges from the background, also known as silhouetting.
- This is the digital analog of cutting out the image from a physical picture.
- Clipping paths may be used to add silhouetted images to vector graphics or page layout files that retain vector data.
- Alpha compositing, allows for soft translucent edges when selecting images.

Selecting and Merging of Images - 02

- There are a number of ways to silhouette an image with soft edges, including
 - selecting the image or its background by sampling similar colors,
 - selecting the edges by raster tracing,
 - or converting a clipping path to a raster selection.
- Once the image is selected, it may be copied and pasted into another section of the same file, or into a separate file.
- The selection may also be saved in what is known as an alpha channel.

Selecting and Merging of Images - 03

- A popular way to create a composite image is to use transparent layers.
- The background image is used as the bottom layer, and the image with parts to be added are placed in a layer above that.
- Using an image layer mask, all but the parts to be merged are hidden from the layer, giving the impression that these parts have been added to the background layer.

Selecting and Merging of Images - 04

- Performing a merge in this manner preserves all of the pixel data on both layers to more easily enable future changes in the new merged image.
- Photomontage of 16 photos which have been digitally manipulated in Photoshop to give the impression that it is a real landscape

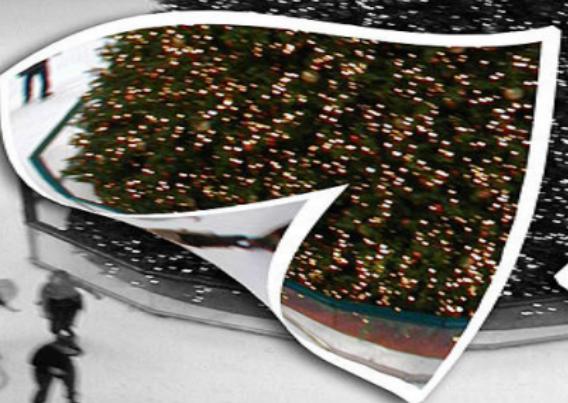


Slicing an Image

- A more recent tool in digital image editing software is the image slicer.
- Parts of images for graphical user interfaces or web pages are easily sliced, labeled and saved separately from whole images so the parts can be handled individually by the display medium.
- This is useful to allow dynamic swapping via interactivity or animating parts of an image in the final presentation.
- Image slicing is a technique for creating a web page (or a component of a web page, like a header or navigation menu) visually in Photoshop.

Special Effects - 01

- Image editors usually have a list of special effects that can create unusual results.
- Images may be skewed and distorted in various ways.
- Scores of special effects can be applied to an image which include various forms of distortion, artistic effects, geometric transforms and texture effects, or combinations thereof.
- An example of some special effects that can be added to a picture.



Special Effects - 02

- Using custom Curves settings in Image editors such as PhotoShop, one can mimic the "pseudo-solarisation" effect, better known in photographic circles as the Sabattier-effect.



Stamp Clone Tool

- The Clone Stamp tool selects and samples an area of the picture and then uses these pixels to paint over any marks.
- The Clone Stamp tool acts like a brush so you can change the size, allowing cloning from just one pixel wide to hundreds.
- You can change the opacity to produce a subtle clone effect.
- Also, there is a choice between Clone align or Clone non-align the sample area.
- In Photoshop this tool is called Clone Stamp, but it may also be called a Rubber Stamp tool.



Change Color Depth - 01

- It is possible, using software, to change the color depth of images.
- Common color depths are 2, 4, 16, 256, 65,536 and 16.7 million colors.
- The JPEG and PNG image formats are capable of storing 16.7 million colors (equal to 256 luminance values per color channel).
- Luminance - It describes the amount of light that passes through.

Change Color Depth - 02

- In addition, grayscale images of 8 bits or less can be created, usually via conversion and down-sampling from a full-color image.
- Grayscale conversion is useful for reducing file size dramatically when the original photographic print was monochrome, but a color tint has been introduced due to aging effects.

Contrast Change and Brightening - 01

- Image editors have provisions to simultaneously change the contrast of images and brighten or darken the image.
- Underexposed images can often be improved by using this feature.
- Recent advances have allowed more intelligent exposure correction whereby only pixels below a particular luminosity threshold are brightened,
- thereby brightening underexposed shadows without affecting the rest of the image.

Contrast Change and Brightening - 02

- The exact transformation that is applied to each color channel can vary from editor to editor.
- GIMP applies the following formula:
- Followed by an example of contrast correction

Contrast Change and Brightening - 03

```
if (brightness < 0.0) {  
    value = value * ( 1.0 + brightness ); }  
else {  
    value = value + ((1 - value) * brightness ); }  
value = (value - 0.5) *  
        (tan ((contrast + 1) * PI/4) ) + 0.5;  
// where value is the input color value  
// in the 0..1 range  
// and brightness and contrast are  
// in the -1..1 range.
```



Gamma Correction - 01

- In addition to the capability of changing the images' brightness and/or contrast in a non-linear fashion, most current image editors provide an opportunity to manipulate the images' gamma value.
- Varying the amount of gamma correction changes not only the brightness, but also the ratios of red to green to blue.
- Gamma correction is particularly useful for bringing details that would be hard to see on most computer monitors out of shadows.

Gamma Correction - 02

- In some image editing software this is called "curves", usually a tool found in the color menu, and no reference to "gamma" is used anywhere in the program or the program documentation.
- Strictly speaking, the curves tool usually does more than simple gamma correction, since one can construct complex curves with multiple inflection points, but when no dedicated gamma correction tool is provided, it can achieve the same effect.

Gamma Correction - 03

- A lot of games often include a gamma correction feature when you first start playing the game. It's often some sort of symbol or image on the screen with a sliding bar, where you're supposed to adjust the slider so that the symbol is just barely visible.
- Gamma correction function is a function that maps luminance levels to compensate the non-linear luminance effect of display devices (or sync it to human perceptive bias on brightness).
- Shortly, it is important in adjusting what the computers expect you to see and the display / screen that displays it
- Is Gamma a Brightness? NO

Color Adjustments - 01

- The color of images can be altered in a variety of ways.
- Colors can be faded in and out, and tones can be changed using curves or other tools.
- The color balance can be improved, which is important if the picture was shot indoors with daylight film, or shot on a camera with the white balance incorrectly set.
- Special effects, like sepia tone and grayscale, can be added to an image.

Color Adjustments - 02

- In addition, more complicated procedures such as the mixing of color channels are possible using more advanced graphics editors.
- The red-eye effect, which occurs when flash photos are taken when the pupil is too widely open (so that light from the flash that passes into the eye through the pupil reflects off the fundus at the back of the eyeball), can also be eliminated at this stage.
- An example of color adjustment using raster graphics editor



Dynamic Blending

- Advanced Dynamic Blending is a concept introduced by photographer Elia Locardi in his blog Blame The Monkey to describe the photographic process of capturing multiple bracketed exposures of a land or cityscape over a specific span of time in a changing natural or artificial lighting environment.
- Once captured, the exposure brackets are manually blended together into a single High Dynamic Range image using post-processing software.
- Dynamic Blending images serve to display a consolidated moment.
- This means that while the final image may be a blend of a span of time, it visually appears to represent a single instant.



Printing - 01

- Controlling the print size and quality of digital images requires an understanding of the pixels-per-inch (ppi) variable that is stored in the image file and sometimes used to control the size of the printed image.
- Within Adobe Photoshop's Image Size dialog, the image editor allows the user to manipulate both pixel dimensions and the size of the image on the printed document.
- These parameters work together to produce a printed image of the desired size and quality.
- Pixels per inch of the image, pixel per inch of the computer monitor, and dots per inch on the printed document are related, but in use are very different.

Printing - 02

- The Image Size dialog can be used as an image calculator of sorts.
- For example, a 1600×1200 image with a resolution of 200 ppi will produce a printed image of 8 x 6 inches.
- The same image with 400 ppi will produce a printed image of 4 x 3 inches.
- Change the resolution to 800 ppi, and the same image now prints out at 2 x 1.5 inches.

Printing - 03

- All three printed images contain the same data (1600 x 1200 pixels), but the pixels are closer together on the smaller prints, so the smaller images will potentially look sharp when the larger ones do not.
- The quality of the image will also depend on the capability of the printer.
- Control printed image by changing pixels-per-inch



Image Warping - 01

- Image warping is the process of digitally manipulating an image such that any shapes portrayed in the image have been significantly distorted.
- Warping may be used for correcting image distortion as well as for creative purposes (e.g., morphing).
- The same techniques are equally applicable to video.



Image Warping - 02

- While an image can be transformed in various ways, pure warping means that points are mapped to points without changing the colors.
- This can be based mathematically on any function from (part of) the plane to the plane.
- If the function is injective the original can be reconstructed.
- If the function is a bijection any image can be inversely transformed.

Image Warping - 03

The following list is not meant to be a partitioning of all available methods into categories

- Images may be distorted through simulation of optical aberrations.
- Images may be viewed as if they had been projected onto a curved or mirrored surface. (This is often seen in ray traced images.)
- Images can be partitioned into polygons and each polygon distorted.
- Images can be distorted using morphing.

Image Warping - 04

There are at least two ways to generate an image using whatever chosen methods to distort.

- (forward-mapping) a given mapping from sources to images is directly applied
- (reverse-mapping) for a given mapping from sources to images, the source is found from the image

Image Warping - 05

- To estimate what kind of warping has taken place between consecutive images, one can use optical flow estimation techniques.
- In the news in 2007, a suspected pedophile used the "swirl" effect to hide his face in the pictures he had taken while raping and sexually abusing young children whose "ages appear to range from six to early teens." Interpol trivially reversed the swirl by swirling in the opposite direction to identify and eventually locate the man in Thailand.

Morphing - 01

- Illustrates 2D Image Morphing
- For 3D Morphing, Google Morph Target Animation
- Following image shows Three frames from a morph from George W. Bush to Arnold Schwarzenegger showing the midpoint between the two extremes



Morphing - 02

- Morphing is a special effect in motion pictures and animations that changes (or morphs) one image or shape into another through a seamless transition.
- Morphing means stretching or as part of a fantasy or surreal sequence.
- Traditionally such a depiction would be achieved through cross-fading techniques on film.
- Since the early 1990s, this has been replaced by computer software to create more realistic transitions.



