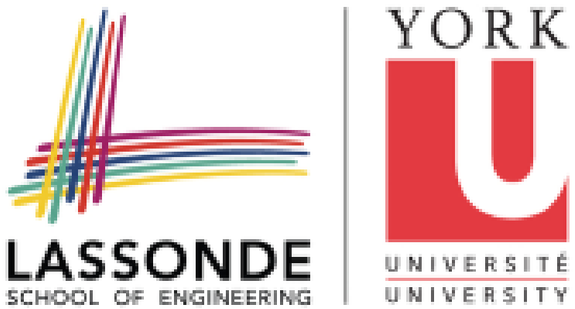
EECS 4422/5323: Computer Vision
Camera Processing Pipeline

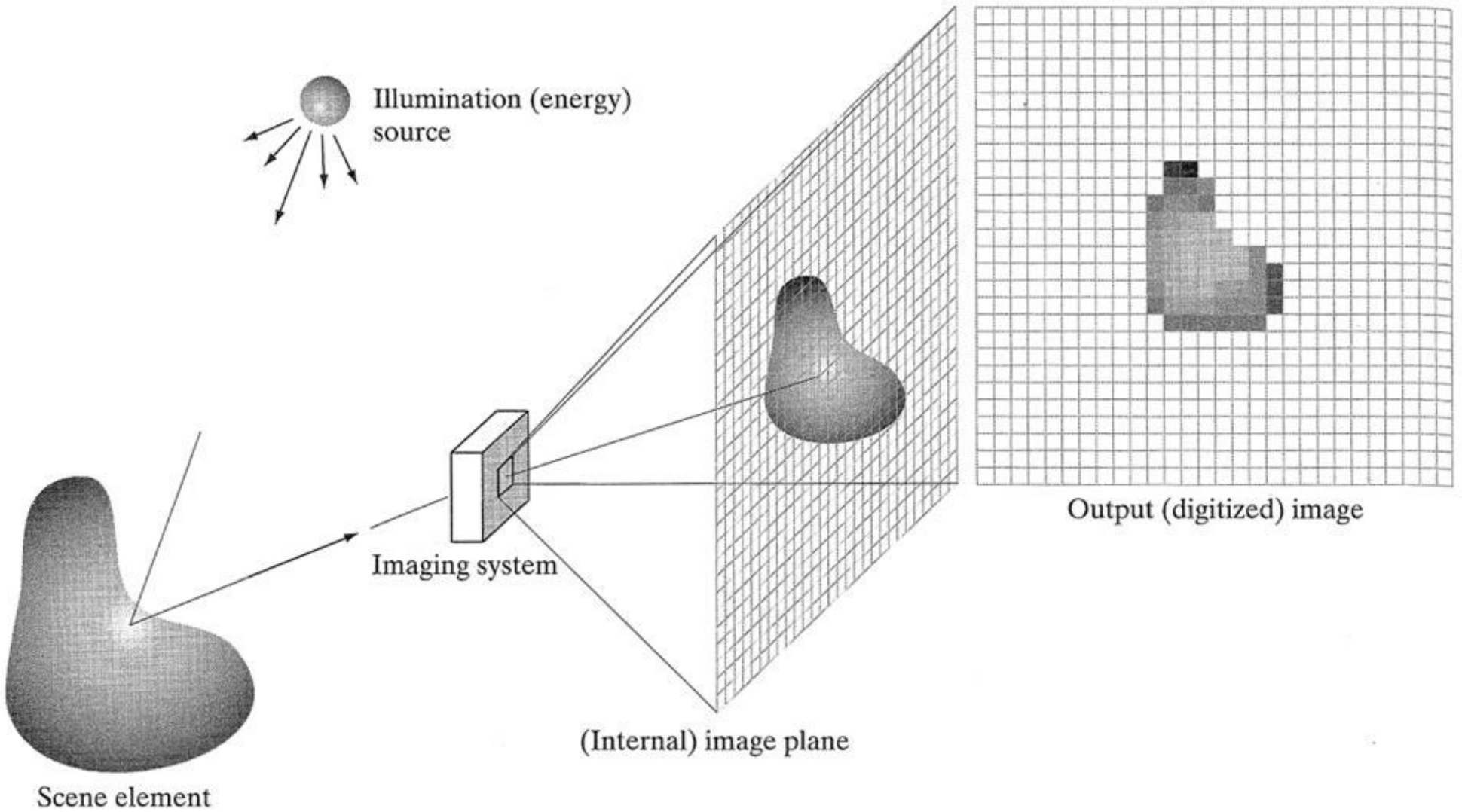
Hakki Can Karaimer

Lab session #1: September 2017



DEPARTMENT OF
ELECTRICAL ENGINEERING &
COMPUTER SCIENCE

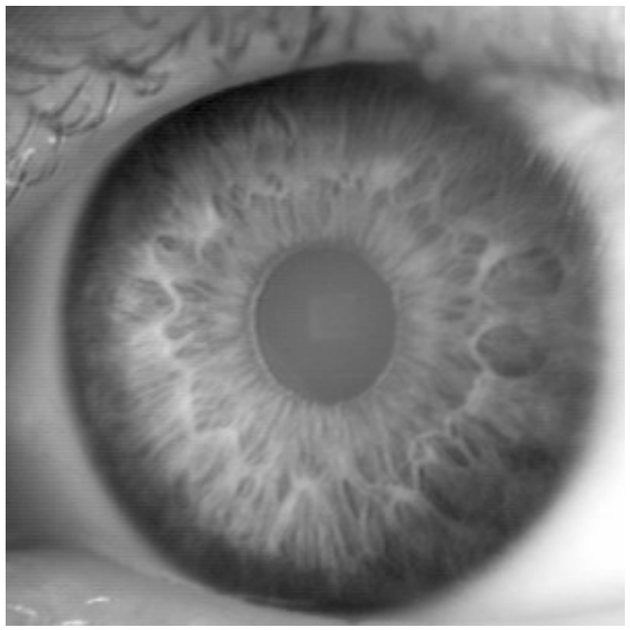
Camera = light measuring device

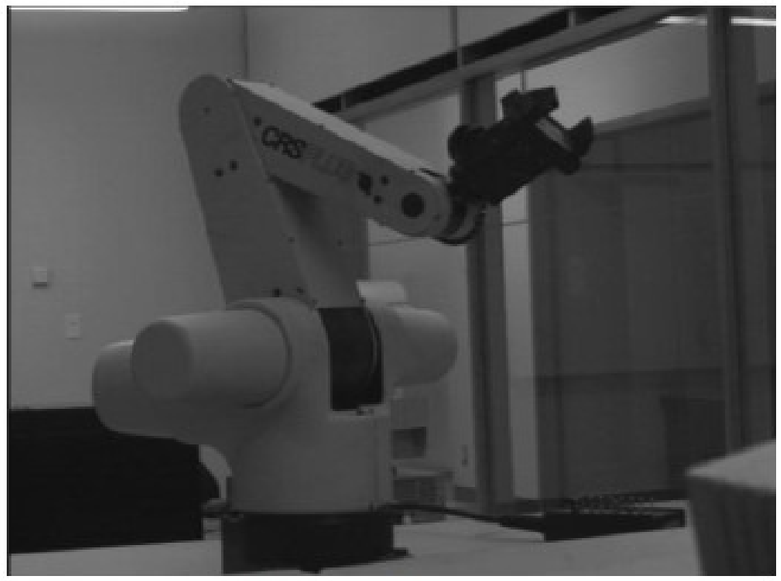


Simple models assume an image is a "quantitative measurement" of scene radiance.

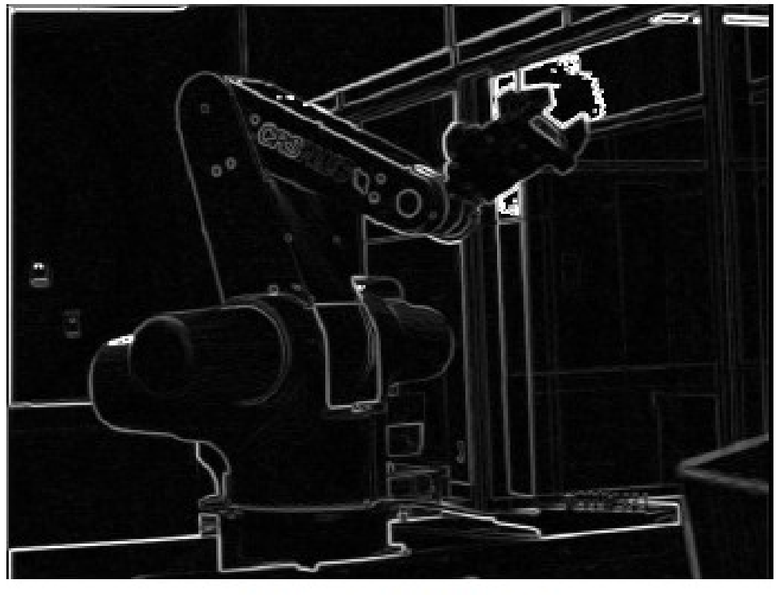
Figure from Digital Image Processing, Gonzales/Woods

Camera = light measuring device

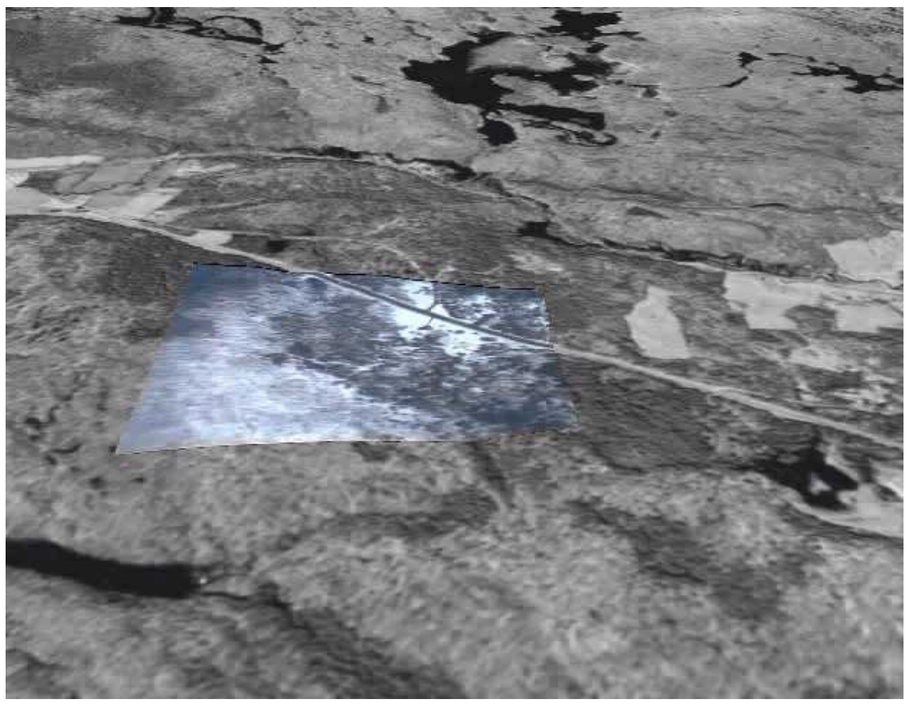




Source image



Edges detected



Light-measuring device?

Light-measuring device?

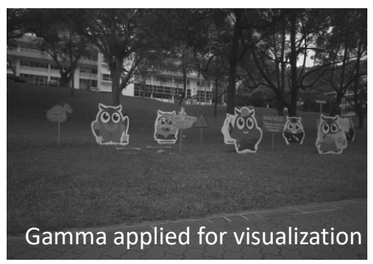
Samsung S6

HTC One M9

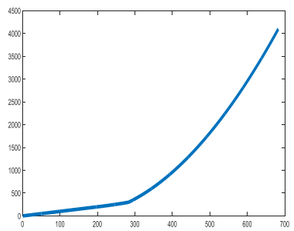
LG G4

Google Camera App
All setting are the same

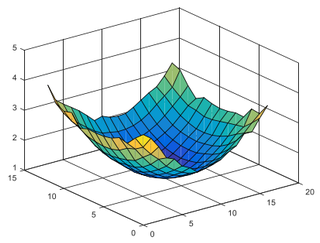
Stages of the camera imaging pipeline and associated parameters



1- Reading raw Image



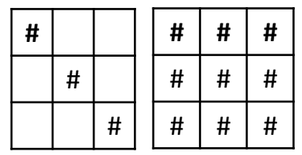
2- Black light subtraction, linearization [Values or 1D LUT]



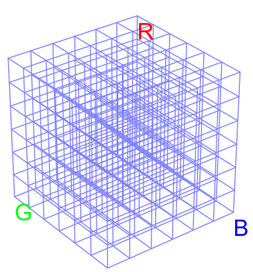
3- Lens correction [2D Array(s)]

4- Demosaicing [Func]

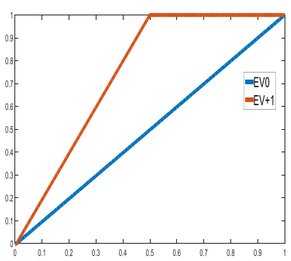
5- Noise reduction [Func]



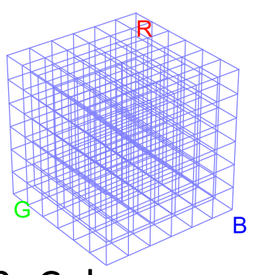
6- White-balancing & colour space transform to CIE XYZ [MATs]



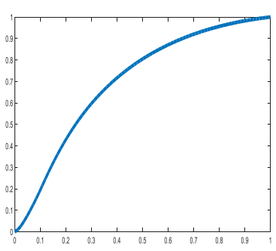
7- Hue/Sat map [3D LUT]



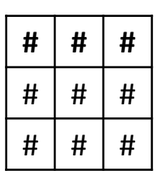
8- Exposure curve [EV value or 1D LUT]



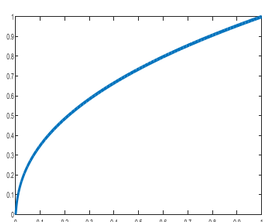
9- Colour manipulation [3D LUT]



10- Tone curve application [1D LUT]

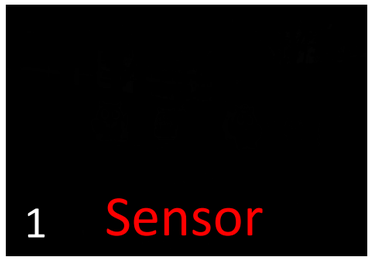


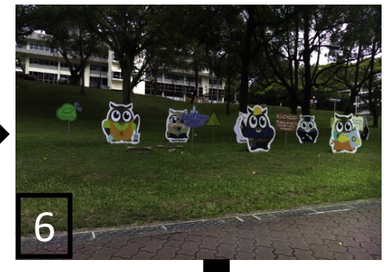
11- Final colour-space conversion [Mat]

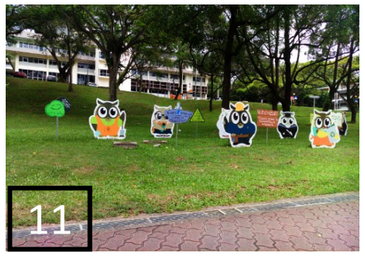


12- Gamma curve application [1D LUT]

Intermediate images for each stage





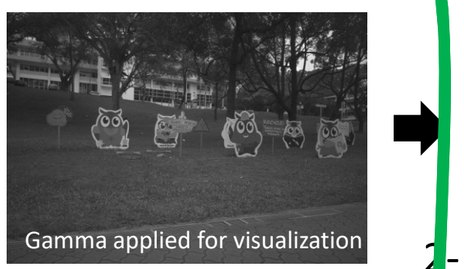


Digital cameras

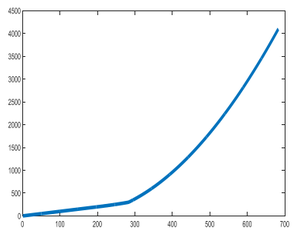
- Digital cameras are far from being light measuring devices
- They are designed to produce visually pleasing photographs
- There is a great deal of processing (photofinishing) happening on the camera

The goal of this lab session is to discuss common processing steps that take place onboard consumer cameras

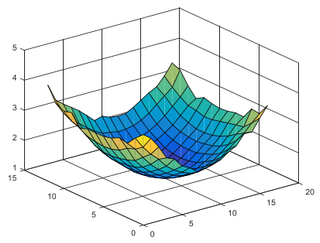
Stages of the camera imaging pipeline and associated parameters



1- Reading raw Image



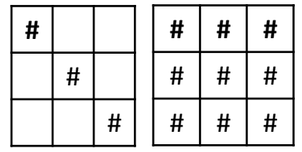
2- Black light subtraction, linearization [Values or 1D LUT]



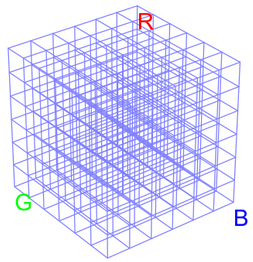
3- Lens correction [2D Array(s)]

4- Demosaicing [Func]

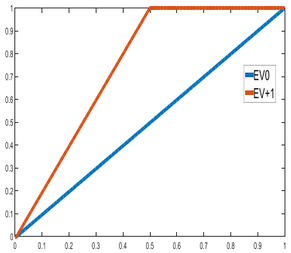
5- Noise reduction [Func]



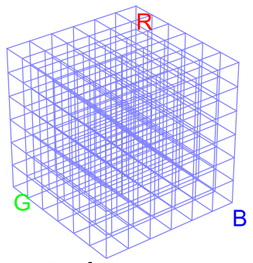
6- White-balancing & colour space transform to CIE XYZ [MATs]



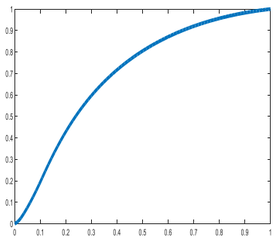
7- Hue/Sat map [3D LUT]



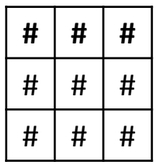
8- Exposure curve [EV value or 1D LUT]



9- Colour mani-pulation [3D LUT]



10- Tone curve application [1D LUT]



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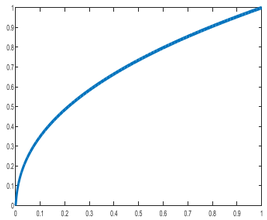
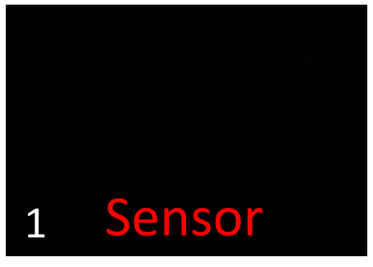
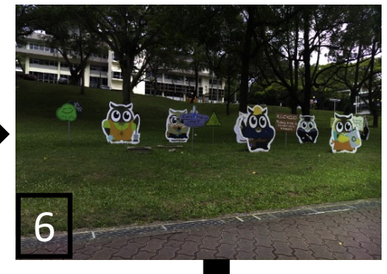
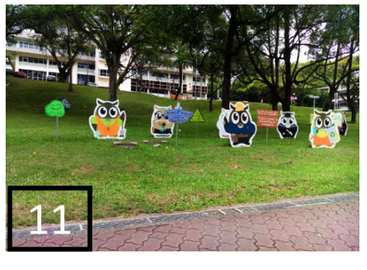


12- Gamma curve application [1D LUT]

Intermediate images for each stage

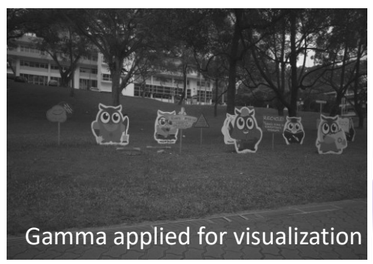






Reading raw image

Stages of the camera imaging pipeline and associated parameters



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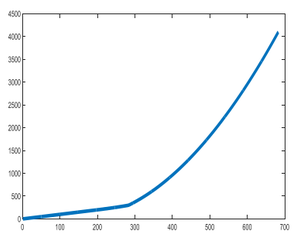
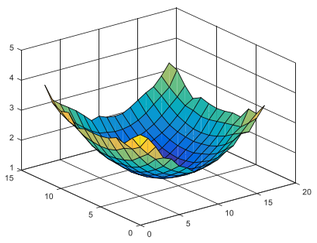


2- Black light subtraction linearization [Values or 1D LUT]



3- Lens correction [2D Array(s)]

4- Demosaicing [Func]

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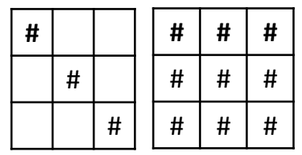
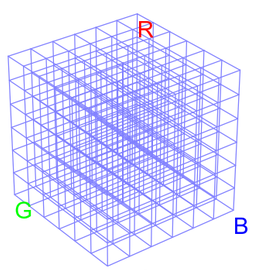
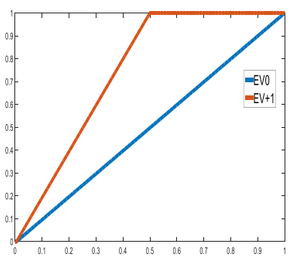


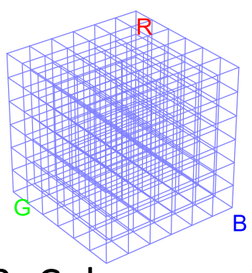
6- White-balancing & colour space transform to CIE XYZ [MATs]



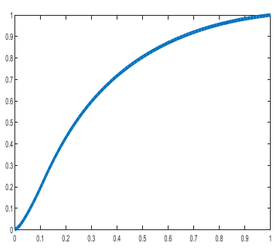
7- Hue/Sat map [3D LUT]



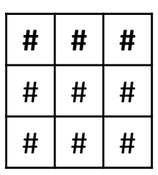
8- Exposure curve [EV value or 1D LUT]



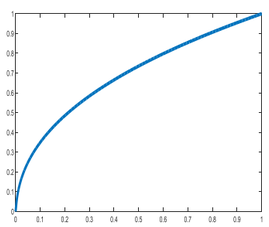
9- Colour mani-pulation [3D LUT]



10- Tone curve application [1D LUT]

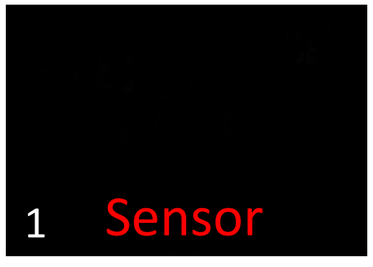


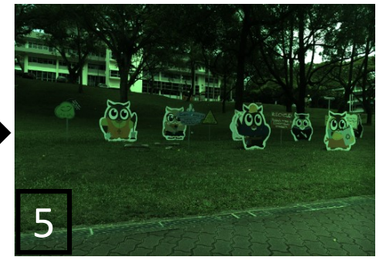
11- Final colour-space conversion [Mat]

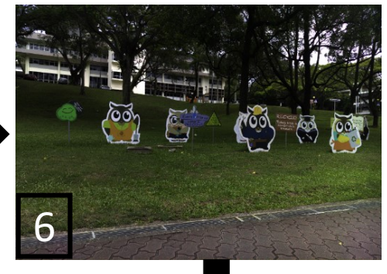


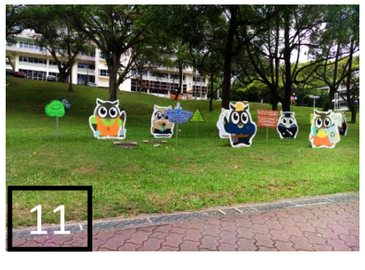
12- Gamma curve application [1D LUT]

Intermediate images for each stage

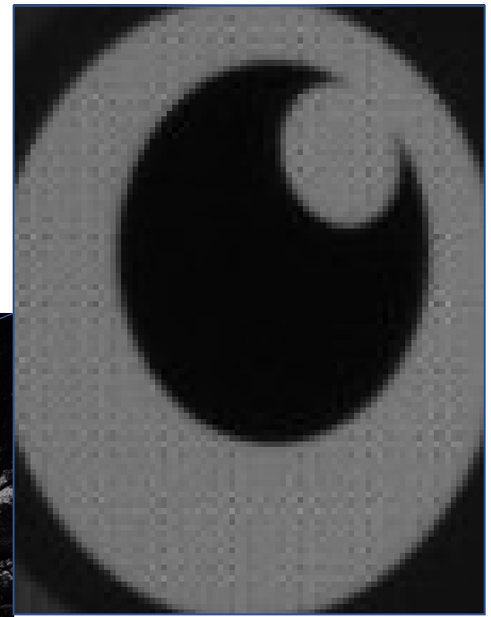








Black light subtraction linearization



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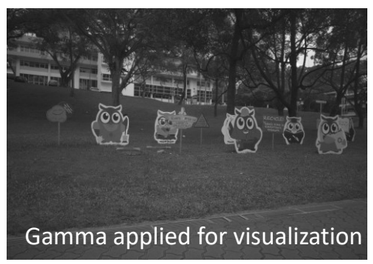

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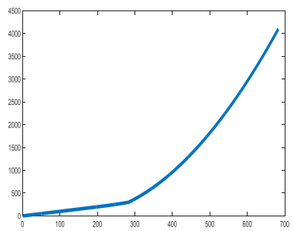

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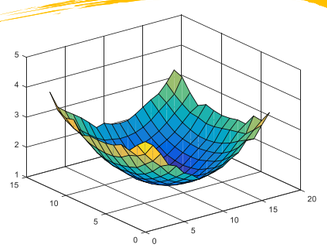

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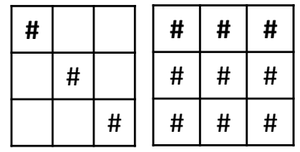

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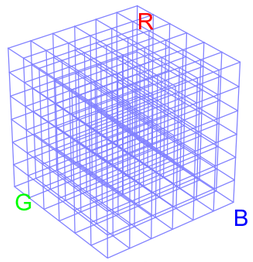
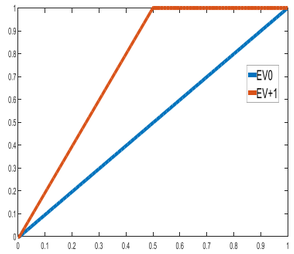
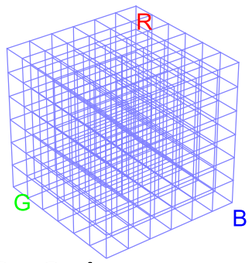


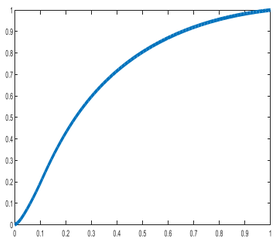
7- Hue/Sat map [3D LUT]



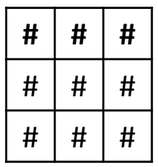
8- Exposure curve [EV value or 1D LUT]



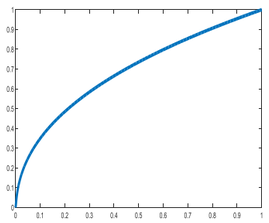
9- Colour mani-pulation [3D LUT]



10- Tone curve application [1D LUT]

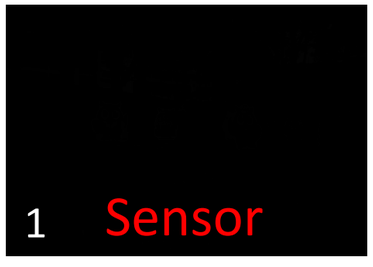


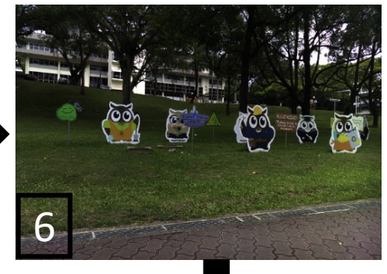
11- Final colour-space conversion [Mat]

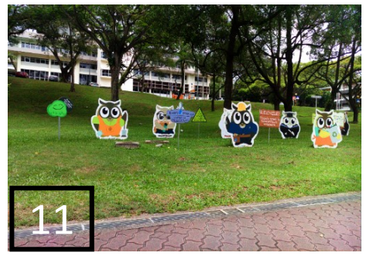


12- Gamma curve application [1D LUT]

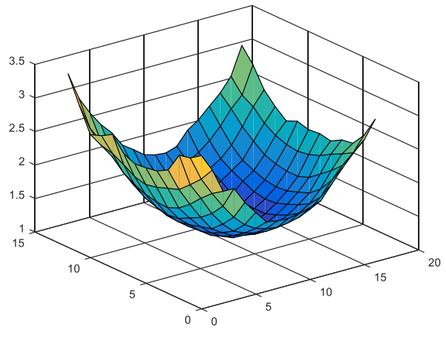
Intermediate images for each stage





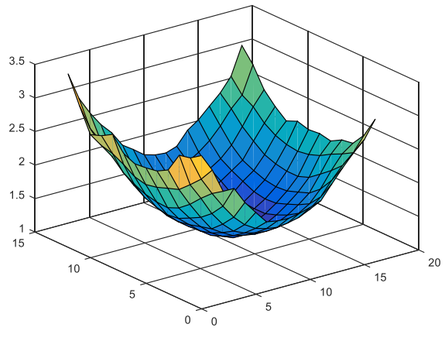


Lens correction (vignetting)

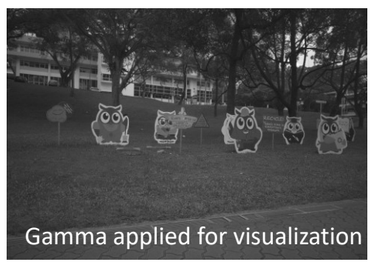


Lens correction (vignetting) – before

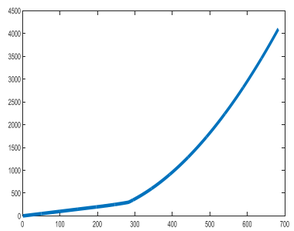
Lens correction (vignetting) – after



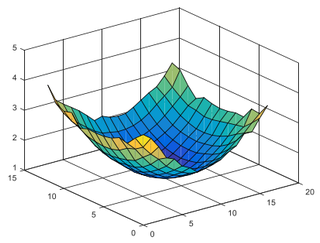
Stages of the camera imaging pipeline and associated parameters



1- Reading raw Image



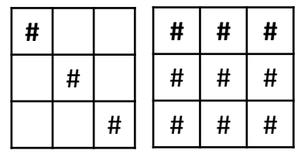
2- Black light subtraction, linearization [Values or 1D LUT]



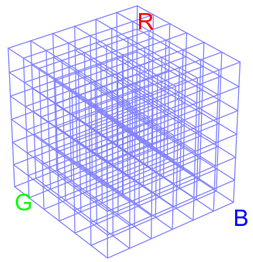
3- Lens correction [2D Array(s)]

4- Demosaicing [Func]

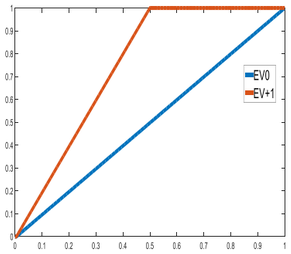
5- Noise reduction [Func]



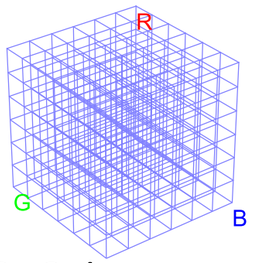
6- White-balancing & colour space transform to CIE XYZ [MATs]



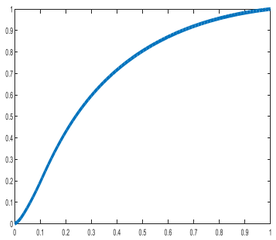
7- Hue/Sat map [3D LUT]



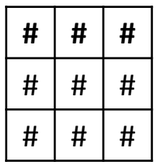
8- Exposure curve [EV value or 1D LUT]



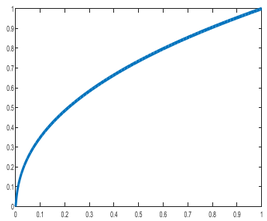
9- Colour manipulation [3D LUT]



10- Tone curve application [1D LUT]

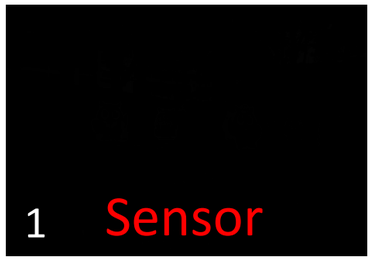


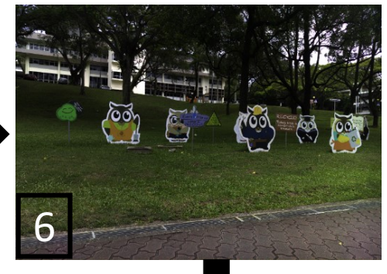
11- Final colour-space conversion [Mat]

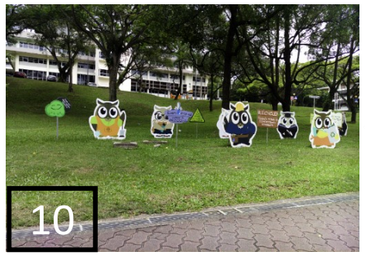


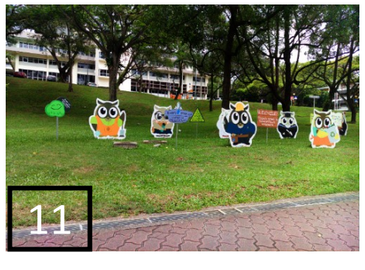
12- Gamma curve application [1D LUT]

Intermediate images for each stage

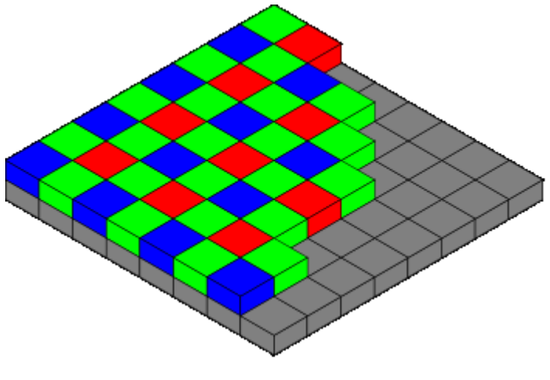




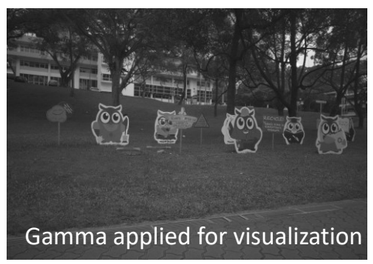




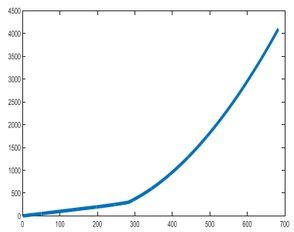
Demosaicing



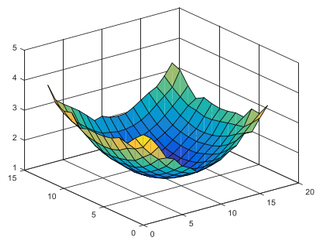
Stages of the camera imaging pipeline and associated parameters



1- Reading raw Image



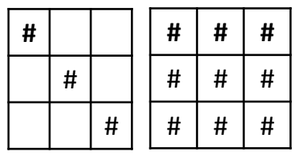
2- Black light subtraction, linearization [Values or 1D LUT]



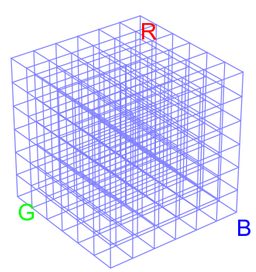
3- Lens correction [2D Array(s)]

4- Demosaicing [Func]

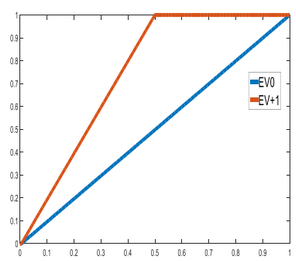
5- Noise reduction [Func]



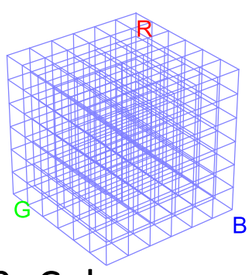
6- White-balancing & colour space transform to CIE XYZ [MATs]



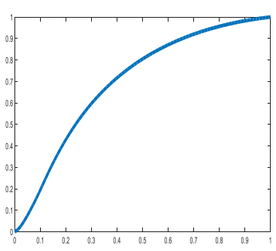
7- Hue/Sat map [3D LUT]



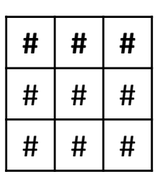
8- Exposure curve [EV value or 1D LUT]



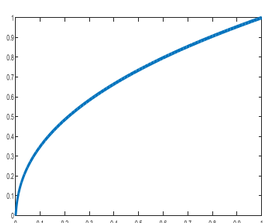
9- Colour manipulation [3D LUT]



10- Tone curve application [1D LUT]

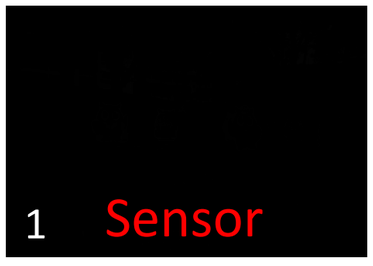


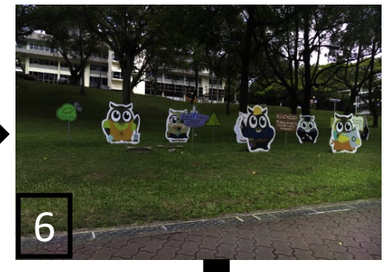
11- Final colour-space conversion [Mat]

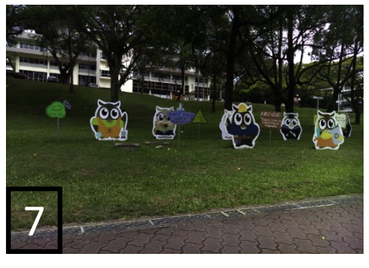


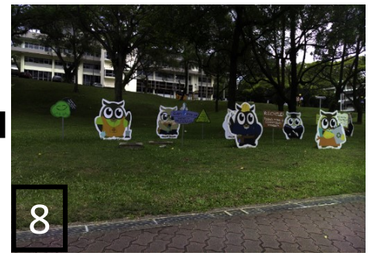
12- Gamma curve application [1D LUT]

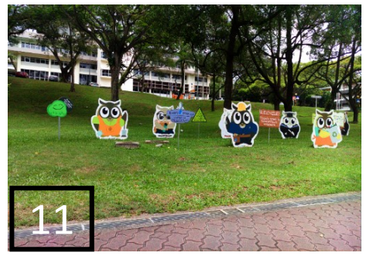
Intermediate images for each stage



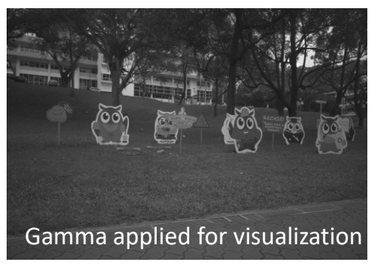




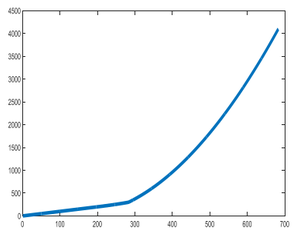




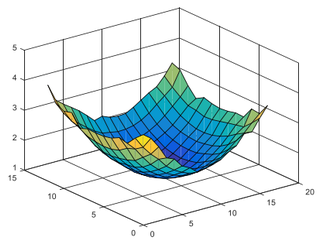
Stages of the camera imaging pipeline and associated parameters



1- Reading raw Image



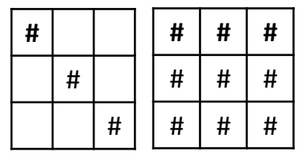
2- Black light subtraction, linearization [Values or 1D LUT]



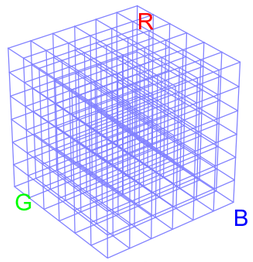
3- Lens correction [2D Array(s)]

4- Demosaicing [Func]

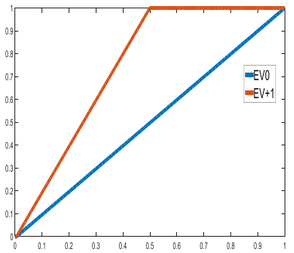
5- Noise reduction [Func]



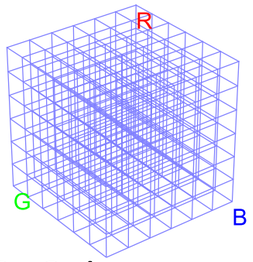
6- White-balancing & colour space transform to CIE XYZ [MATs]



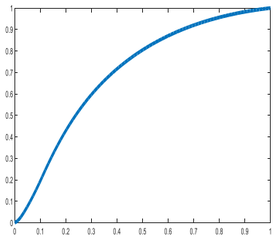
7- Hue/Sat map [3D LUT]



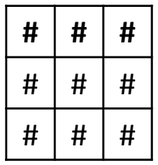
8- Exposure curve [EV value or 1D LUT]



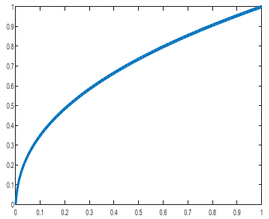
9- Colour manipulation [3D LUT]



10- Tone curve application [1D LUT]

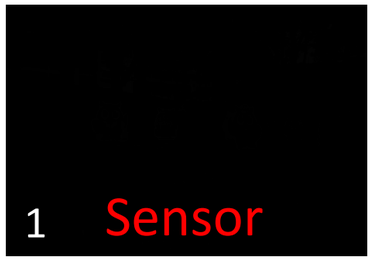


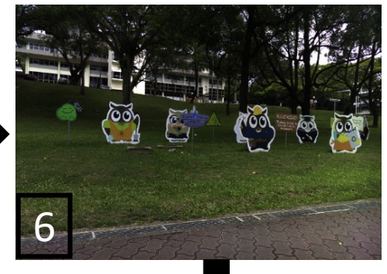
11- Final colour-space conversion [Mat]

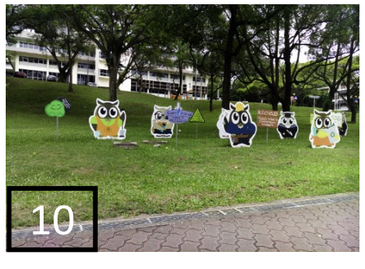


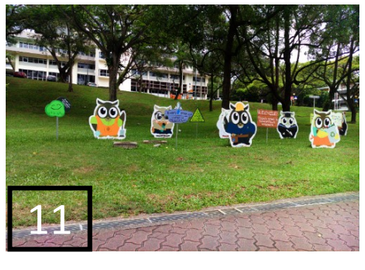
12- Gamma curve application [1D LUT]

Intermediate images for each stage









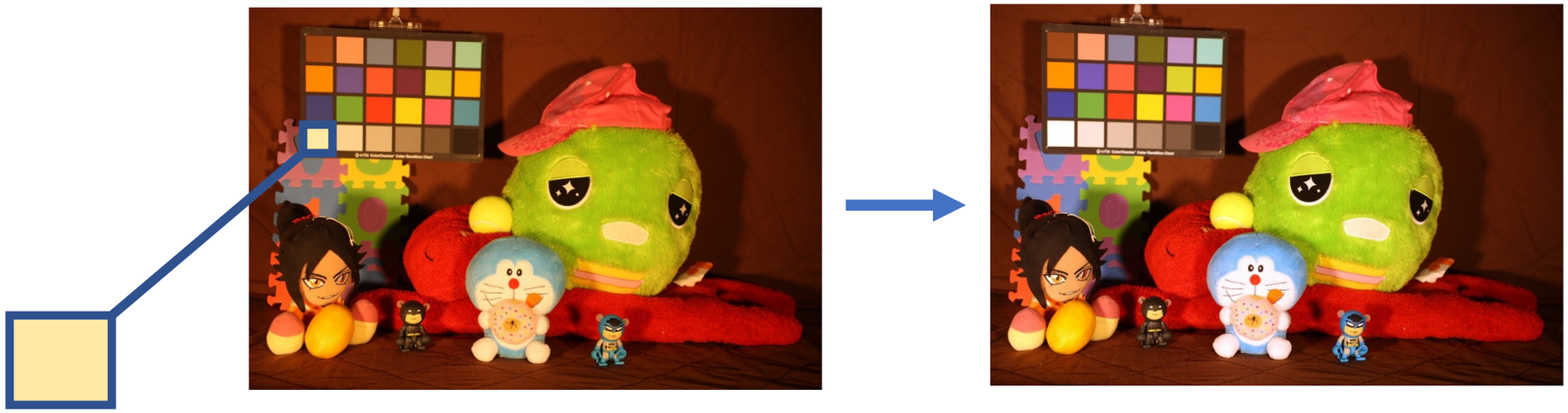
White balancing & color space conversion

Colour cast correction

- If we can observe the colour of the illumination, we can correct it with a simple diagonal matrix.

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} R_{white}/R & 0 & 0 \\ 0 & G_{white}/G & 0 \\ 0 & 0 & B_{white}/B \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

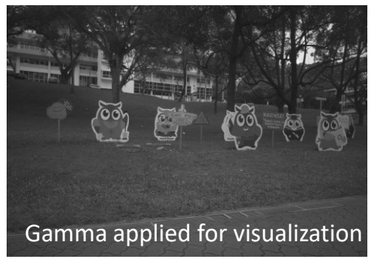
- This is known as “white-balance” since it ensures white is corrected



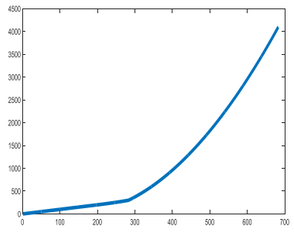
Illuminant’s colour

After the illuminant is divided out, we are sure about white is correct.

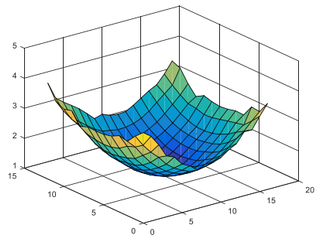
Stages of the camera imaging pipeline and associated parameters



1- Reading raw Image



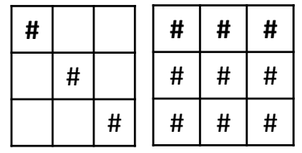
2- Black light subtraction, linearization
[Values or 1D LUT]



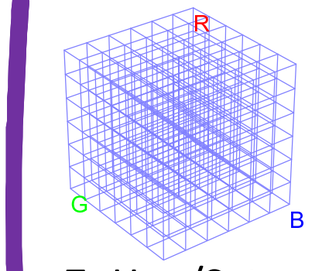
3- Lens correction
[2D Array(s)]

4- Demosaicing
[Func]

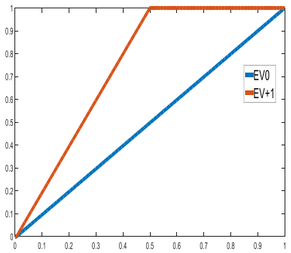
5- Noise reduction
[Func]



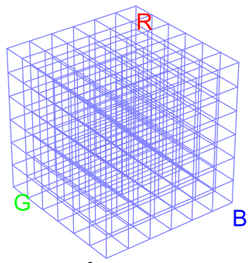
6- White-balancing & colour space transform to CIE XYZ [MATs]



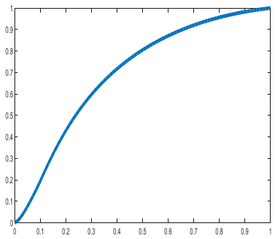
7- Hue/Sat map
[3D LUT]



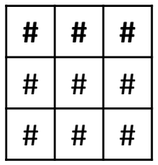
8- Exposure curve
[EV value or 1D LUT]



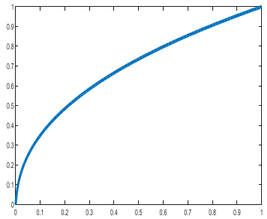
9- Colour manipulation [3D LUT]



10- Tone curve application [1D LUT]

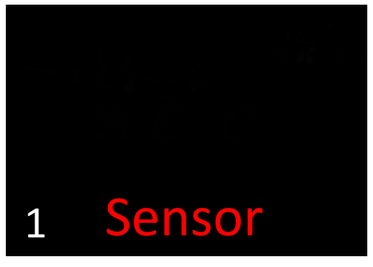


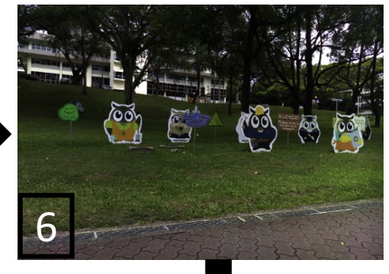
11- Final colour-space conversion [Mat]

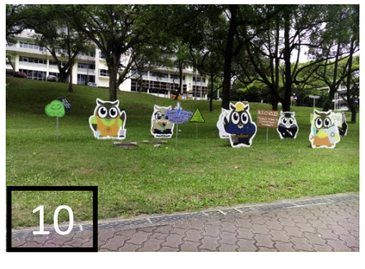


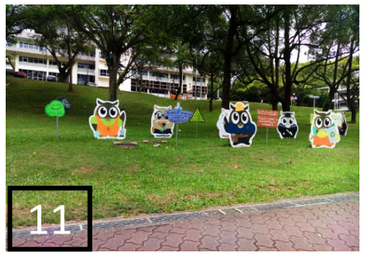
12- Gamma curve application [1D LUT]

Intermediate images for each stage



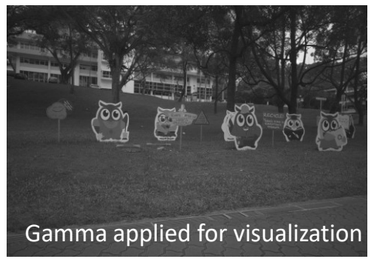




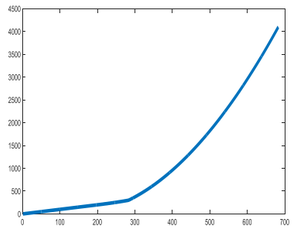


Hue/Sat map application

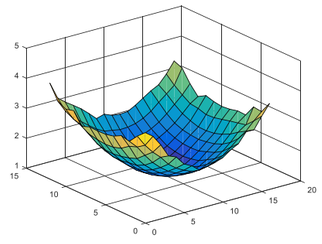
Stages of the camera imaging pipeline and associated parameters



1- Reading raw Image



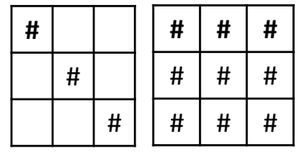
2- Black light subtraction, linearization
[Values or 1D LUT]



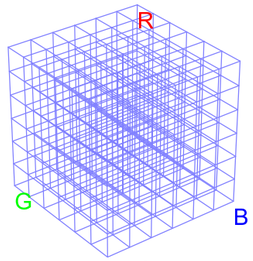
3- Lens correction
[2D Array(s)]

4- Demosaicing
[Func]

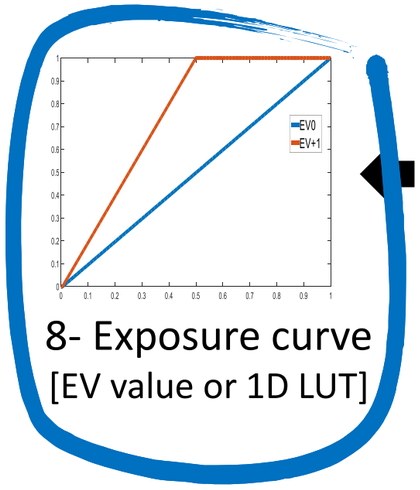
5- Noise reduction
[Func]



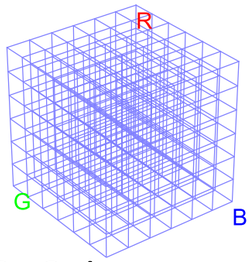
6- White-balancing & colour space transform to CIE XYZ [MATs]



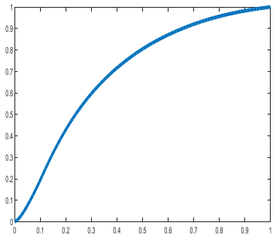
7- Hue/Sat map
[3D LUT]



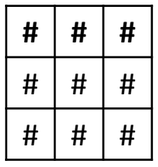
8- Exposure curve
[EV value or 1D LUT]



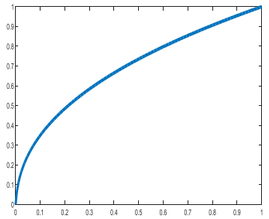
9- Colour manipulation [3D LUT]



10- Tone curve application [1D LUT]

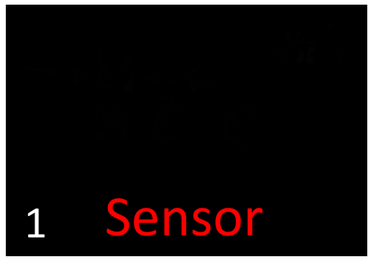


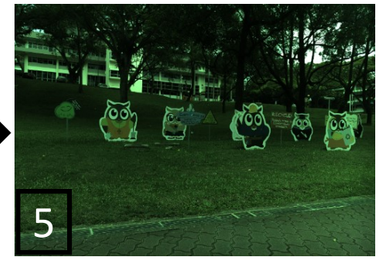
11- Final colour-space conversion [Mat]

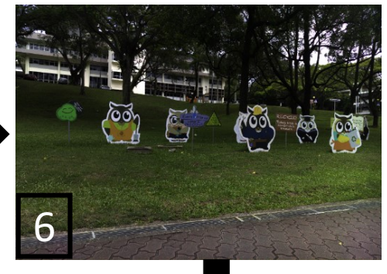


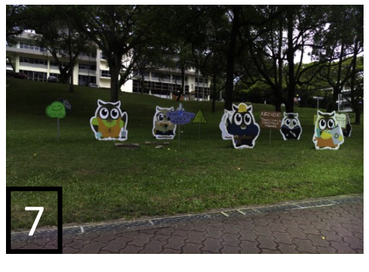
12- Gamma curve application [1D LUT]

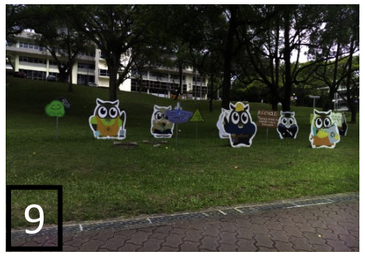
Intermediate images for each stage

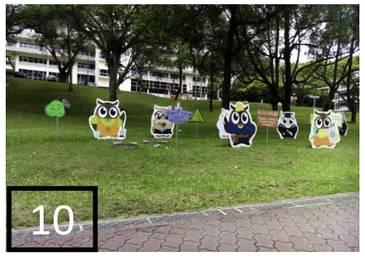


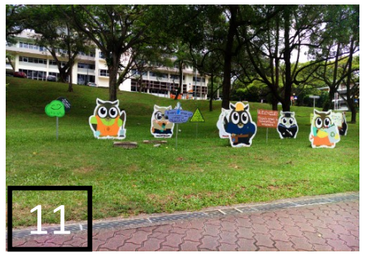






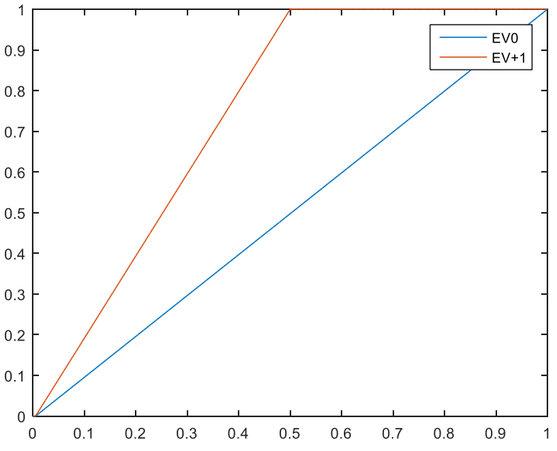




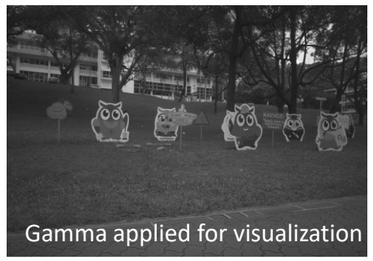


Exposure curve application

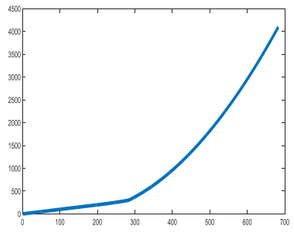
EV+1



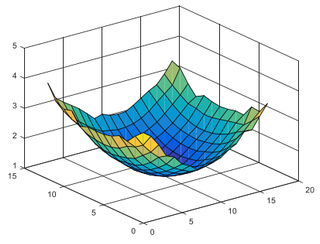
Stages of the camera imaging pipeline and associated parameters



1- Reading raw Image



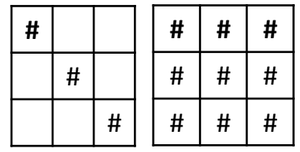
2- Black light subtraction, linearization
[Values or 1D LUT]



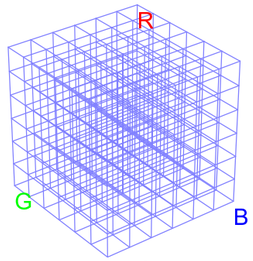
3- Lens correction
[2D Array(s)]

4- Demosaicing
[Func]

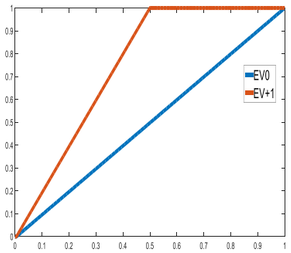
5- Noise reduction
[Func]



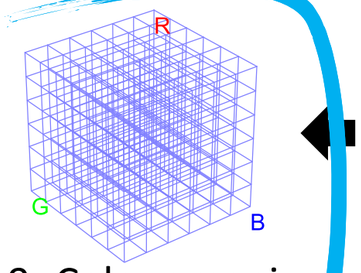
6- White-balancing & colour space transform to CIE XYZ [MATs]



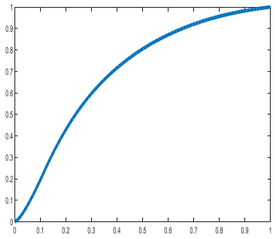
7- Hue/Sat map
[3D LUT]



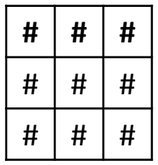
8- Exposure curve
[EV value or 1D LUT]



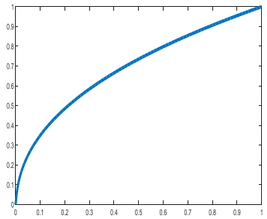
9- Colour manipulation [3D LUT]



10- Tone curve application [1D LUT]

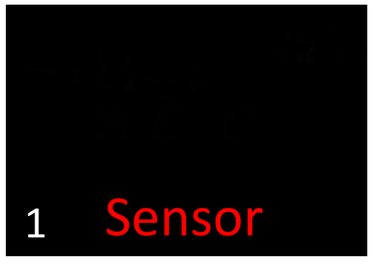


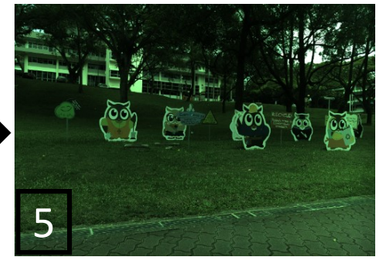
11- Final colour-space conversion [Mat]

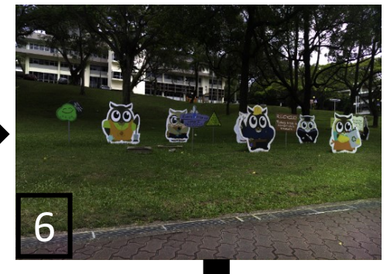


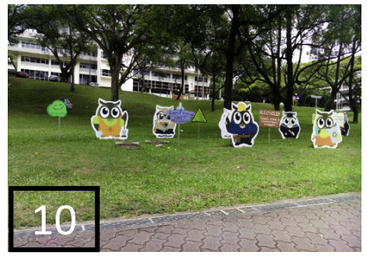
12- Gamma curve application [1D LUT]

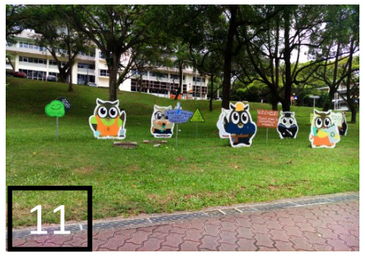
Intermediate images for each stage





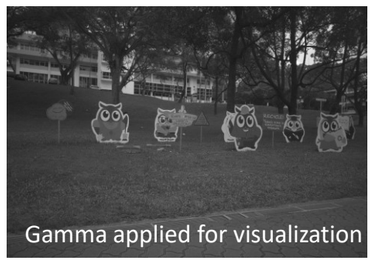




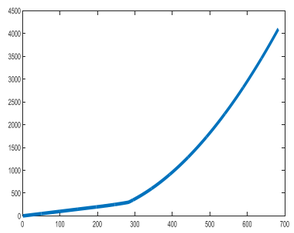


Colour manipulation application

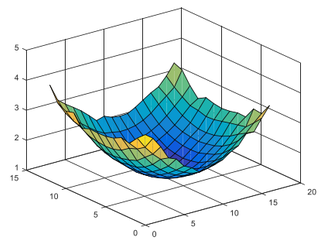
Stages of the camera imaging pipeline and associated parameters



1- Reading raw Image



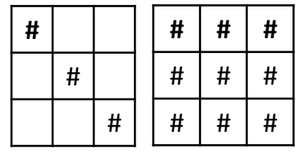
2- Black light subtraction, linearization [Values or 1D LUT]



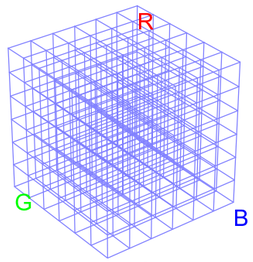
3- Lens correction [2D Array(s)]

4- Demosaicing [Func]

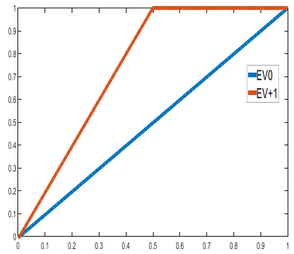
5- Noise reduction [Func]



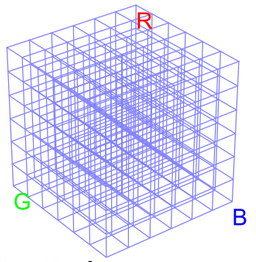
6- White-balancing & colour space transform to CIE XYZ [MATs]



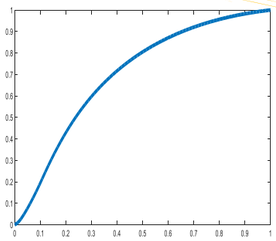
7- Hue/Sat map [3D LUT]



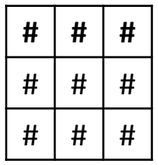
8- Exposure curve [EV value or 1D LUT]



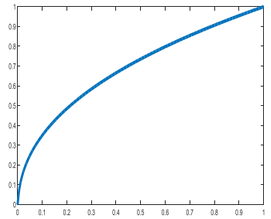
9- Colour manipulation [3D LUT]



10- Tone curve application [1D LUT]

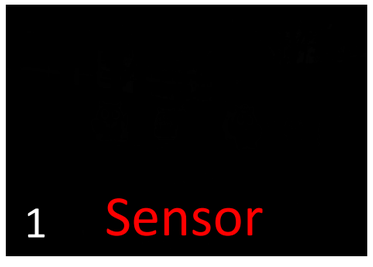


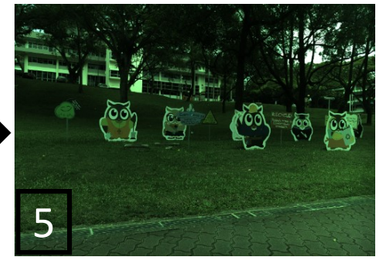
11- Final colour-space conversion [Mat]

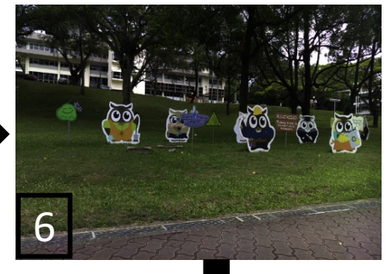


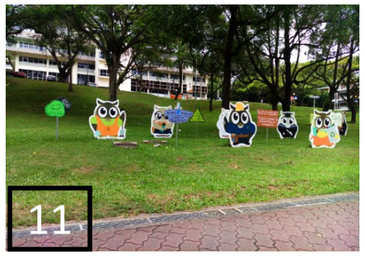
12- Gamma curve application [1D LUT]

Intermediate images for each stage

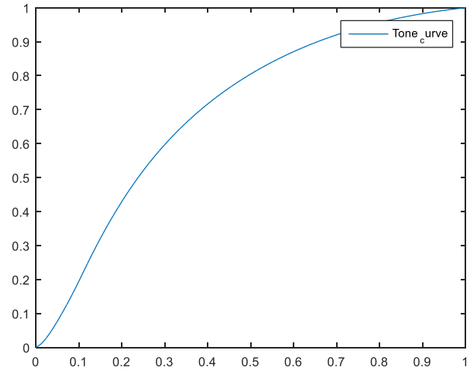




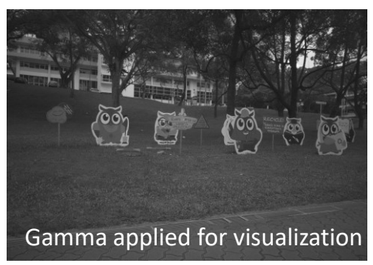




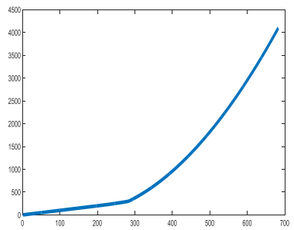
Tone curve application



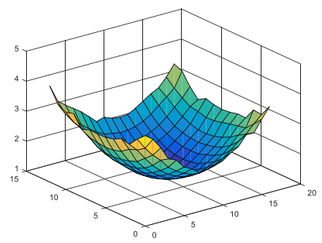
Stages of the camera imaging pipeline and associated parameters



1- Reading raw Image



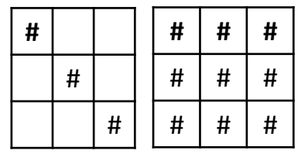
2- Black light subtraction, linearization [Values or 1D LUT]



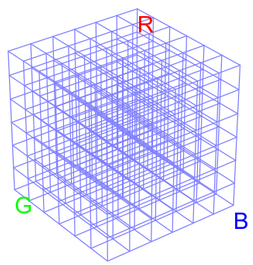
3- Lens correction [2D Array(s)]

4- Demosaicing [Func]

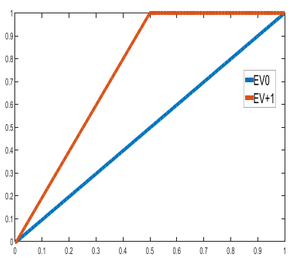
5- Noise reduction [Func]



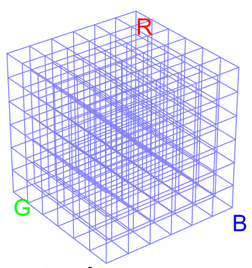
6- White-balancing & colour space transform to CIE XYZ [MATs]



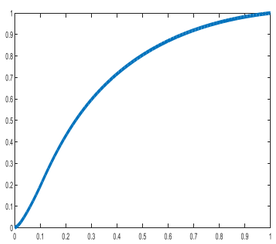
7- Hue/Sat map [3D LUT]



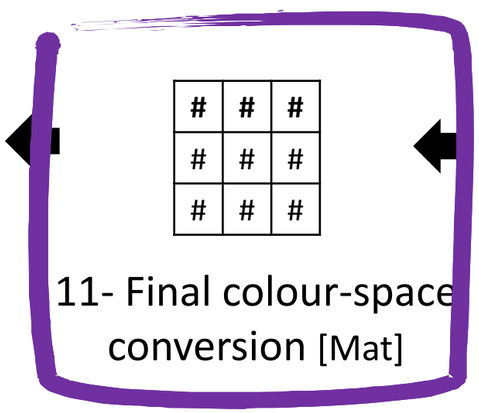
8- Exposure curve [EV value or 1D LUT]



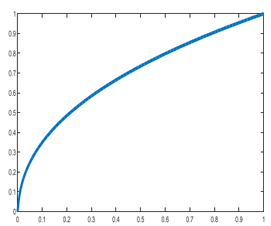
9- Colour manipulation [3D LUT]



10- Tone curve application [1D LUT]

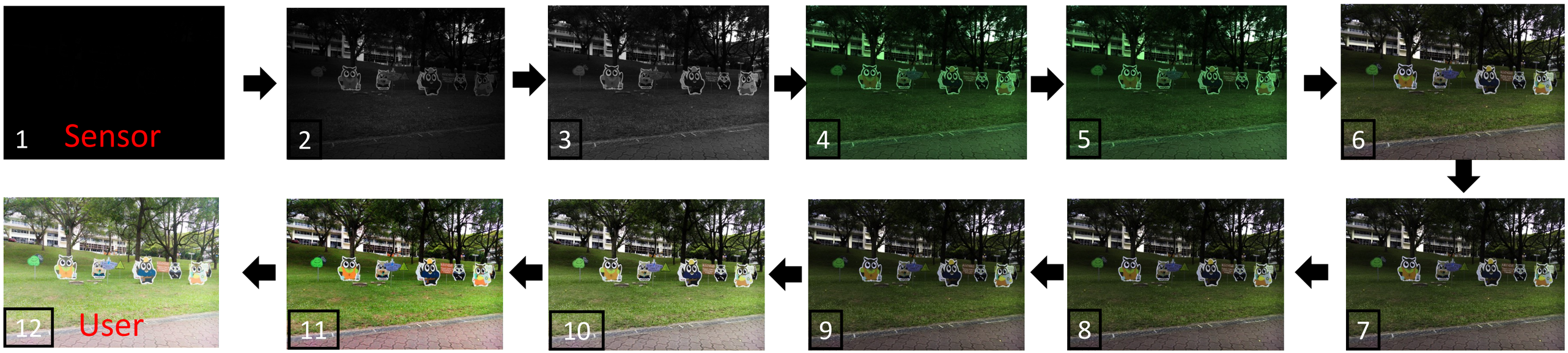


11- Final colour-space conversion [Mat]



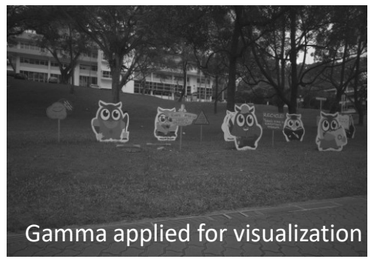
12- Gamma curve application [1D LUT]

Intermediate images for each stage

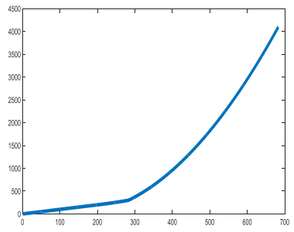


Final color space conversion

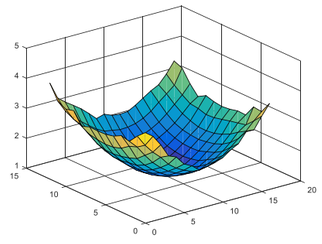
Stages of the camera imaging pipeline and associated parameters



1- Reading raw Image



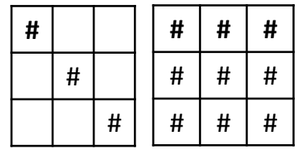
2- Black light subtraction, linearization
[Values or 1D LUT]



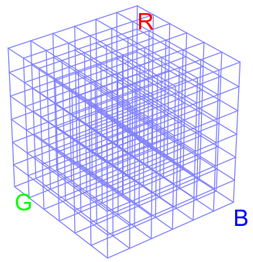
3- Lens correction
[2D Array(s)]

4- Demosaicing
[Func]

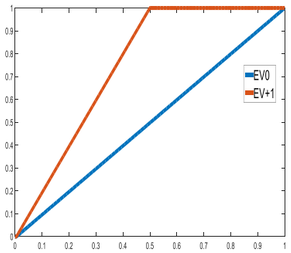
5- Noise reduction
[Func]



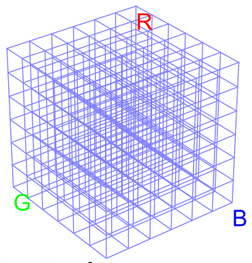
6- White-balancing & colour space transform to CIE XYZ [MATs]



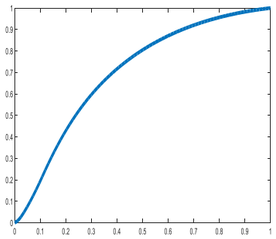
7- Hue/Sat map
[3D LUT]



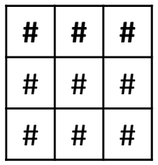
8- Exposure curve
[EV value or 1D LUT]



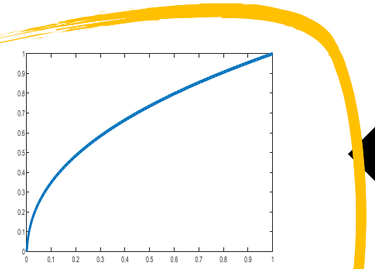
9- Colour manipulation [3D LUT]



10- Tone curve application [1D LUT]

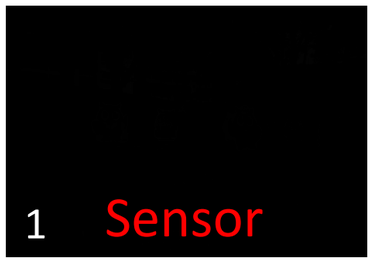


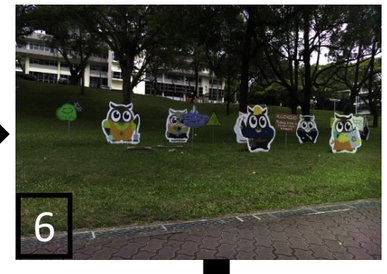
11- Final colour-space conversion [Mat]

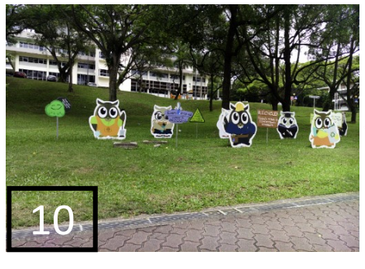


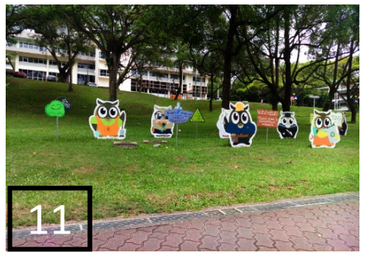
12- Gamma curve application [1D LUT]

Intermediate images for each stage

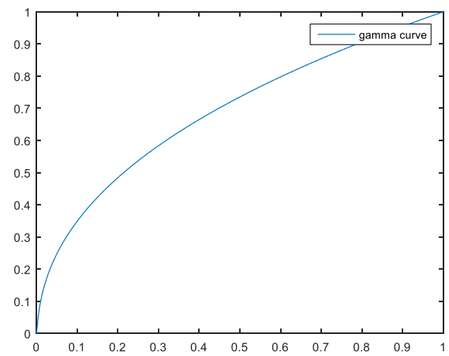




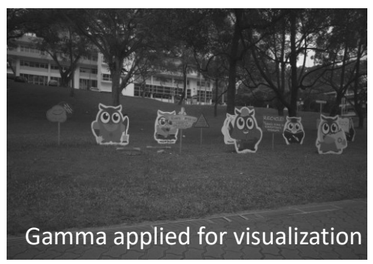




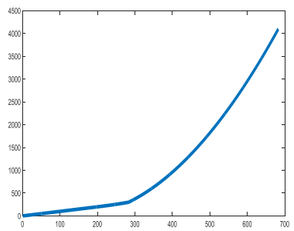
Gamma curve application



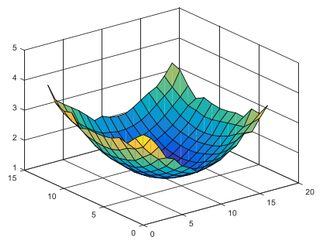
Stages of the camera imaging pipeline and associated parameters



1- Reading raw Image



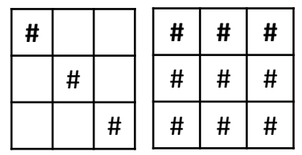
2- Black light subtraction, linearization [Values or 1D LUT]



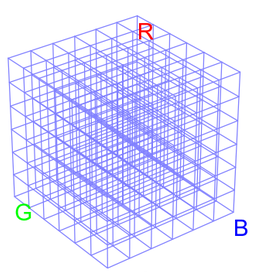
3- Lens correction [2D Array(s)]

4- Demosaicing [Func]

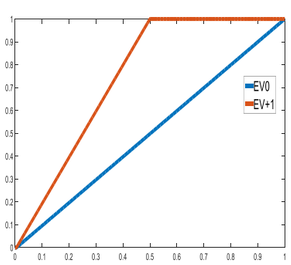
5- Noise reduction [Func]



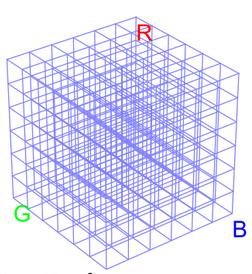
6- White-balancing & colour space transform to CIE XYZ [MATs]



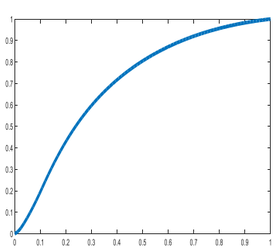
7- Hue/Sat map [3D LUT]



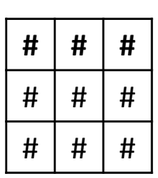
8- Exposure curve [EV value or 1D LUT]



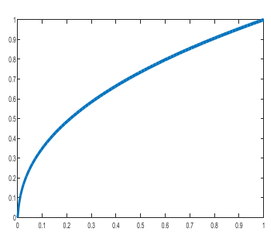
9- Colour mani-pulation [3D LUT]

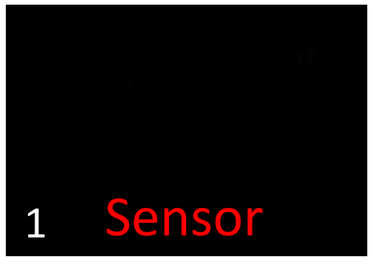
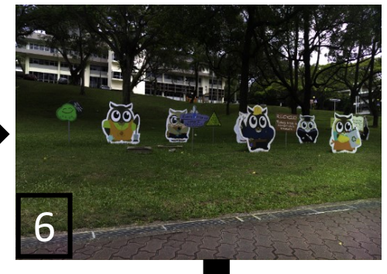
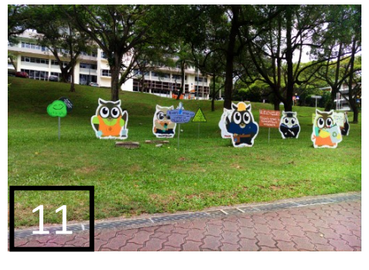


10- Tone curve application [1D LUT]



11- Final colour-space conversion [Mat]



12- Gamma curve application [1D LUT]

Intermediate images for each stage