Eric Dubois

Visual Communications from Broadcast TV to Telepresence

Electronic Visual Communications

- From

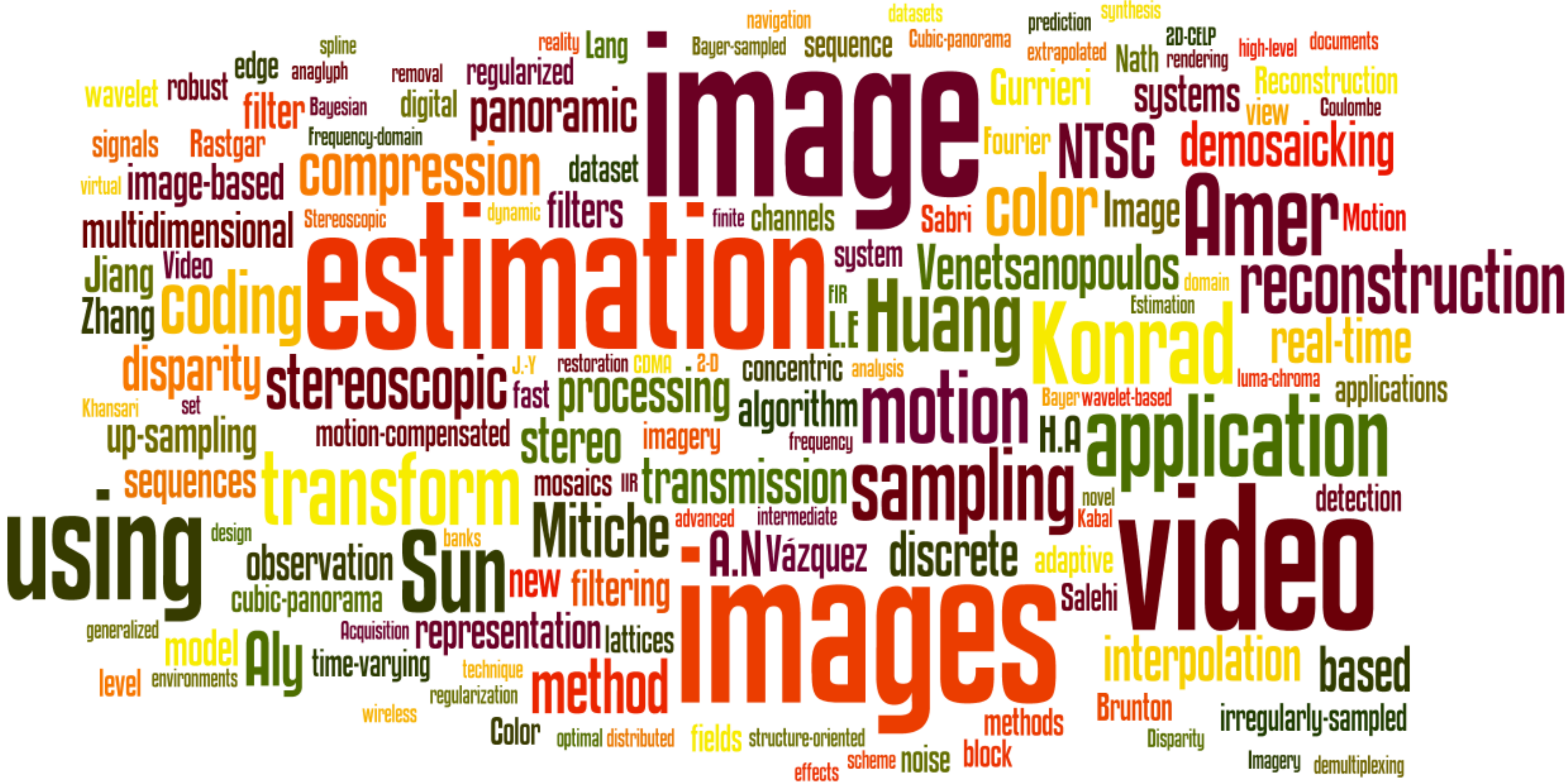
Electronic Visual Communications

- To

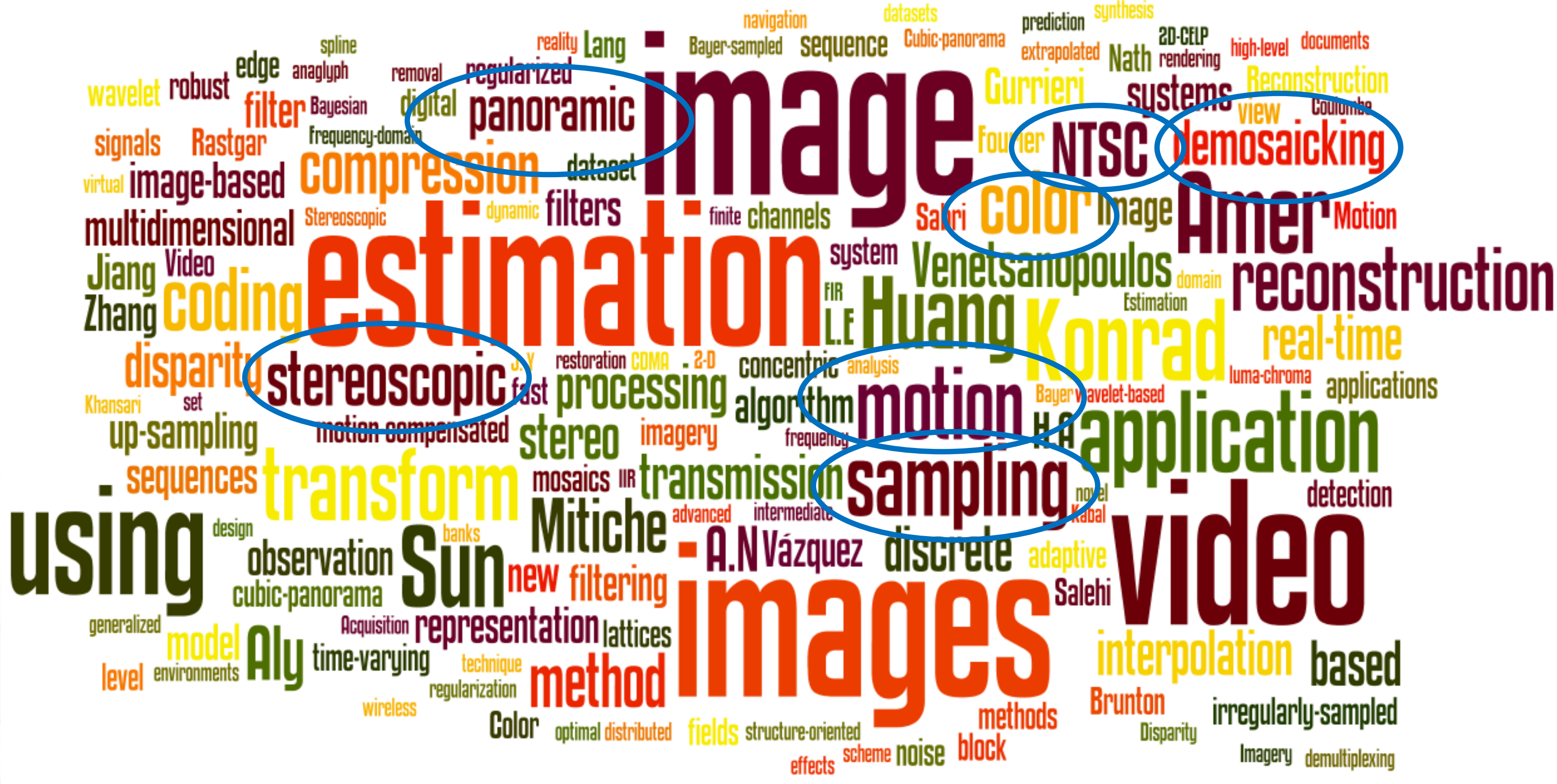
My trajectory

- 1972-1974 M.Eng. Electrical Engineering, McGill University
- 1974-1977 Ph.D. Electrical Engineering, University of Toronto
- 1977-1998 Professeur, Institut national de la recherche scientifique (INRS), INRS-Télécommunications.
- 1998-2013 Professor, School of Electrical Engineering and Computer Science, University of Ottawa.

What have I worked on?



What have I worked on?



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Who have I worked with?

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Some topics I have worked on

- Two-dimensional filtering, multidimensional filtering
- Video sampling theory
- Spatiotemporal NTSC video analysis
- Motion estimation, motion compensated processing
- Anaglyph, stereoscopic imaging
- Color spaces
- Color filter arrays, demosaicking for digital cameras
- Omnidirectional imaging, panoramas

My Introduction to Two-Dimensional Signal Processing

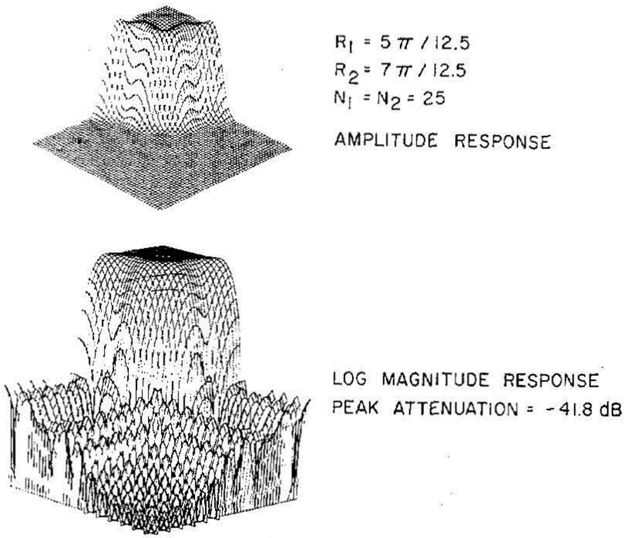


Fig. 3. Amplitude and log magnitude response of a typical low-pass filter for a transition width of $R_2 - R_1 = 2\pi/12.5$.

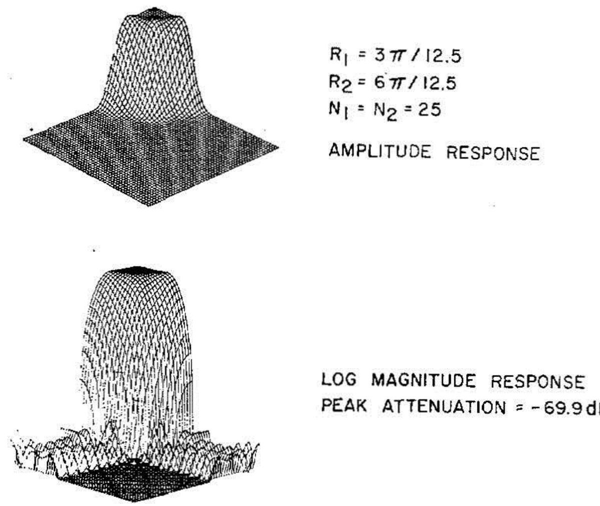
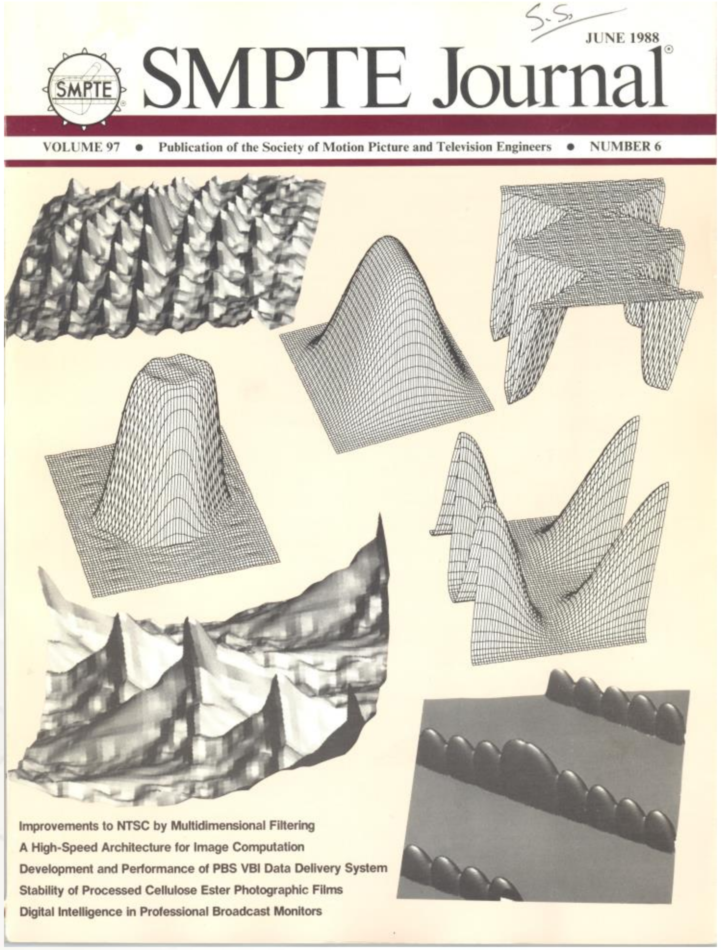


Fig. 4. Amplitude and log magnitude response of a typical low-pass filter for a transition width of $R_2 - R_1 = 3\pi/12.5$.

From J.V. Hu and L.R. Rabiner, "Design techniques for two-dimensional filters," *IEEE Trans. Audio and Electroacoustics*, vol. AU-20, June 1972.

Society of Motion Picture and Television Engineers – Best paper award 1988



Still doing that

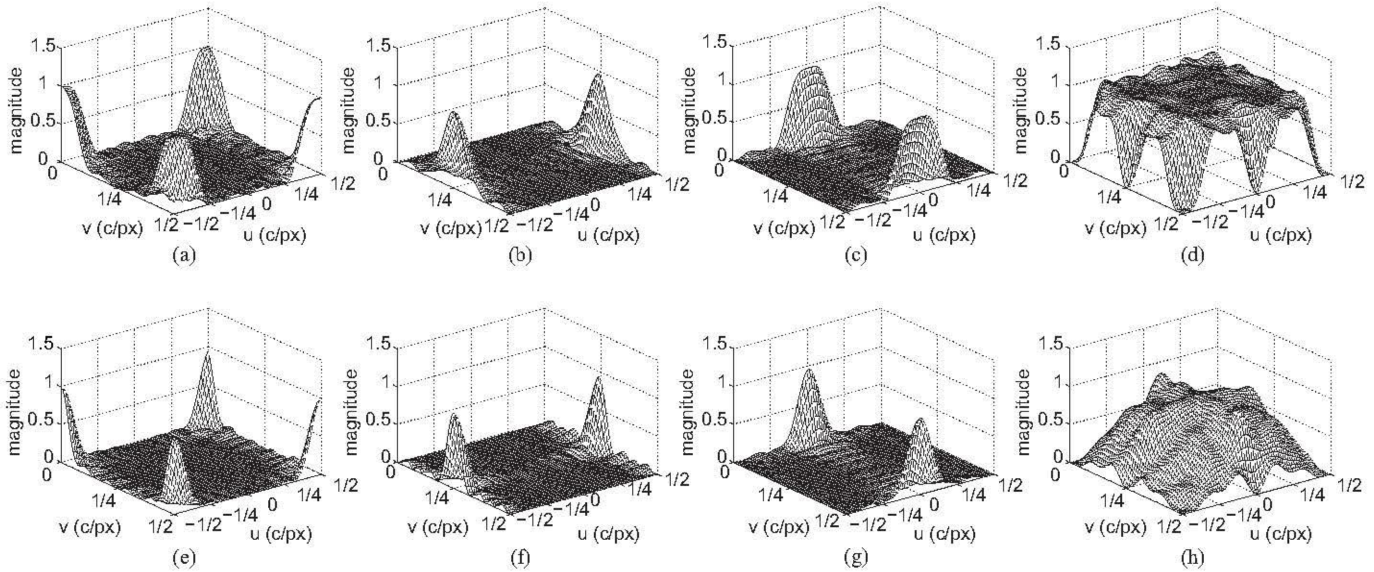


Fig. 3. Perspective view of frequency responses of typical 11 × 11 sized filters. (a) h_1, (b) h_{2a}, (c) h_{2b}, (d) h_L for noise-free CFA. (e) h_{1N}, (f) h_{2aN}, (g) h_{2bN}, and (h) h_{LN} for noisy CFA ($\sigma_A = 10$).

From G. Jeon and E. Dubois, "Demosaicking of noisy Bayer-sampled color images with least-squares luma-chroma demultiplexing and noise level estimation," *IEEE Trans. Image Process.*, vol. 22, Jan. 2013

Fourier Analysis 101

Jean-Baptiste Joseph Fourier (21 March 1768 – 16 May 1830)

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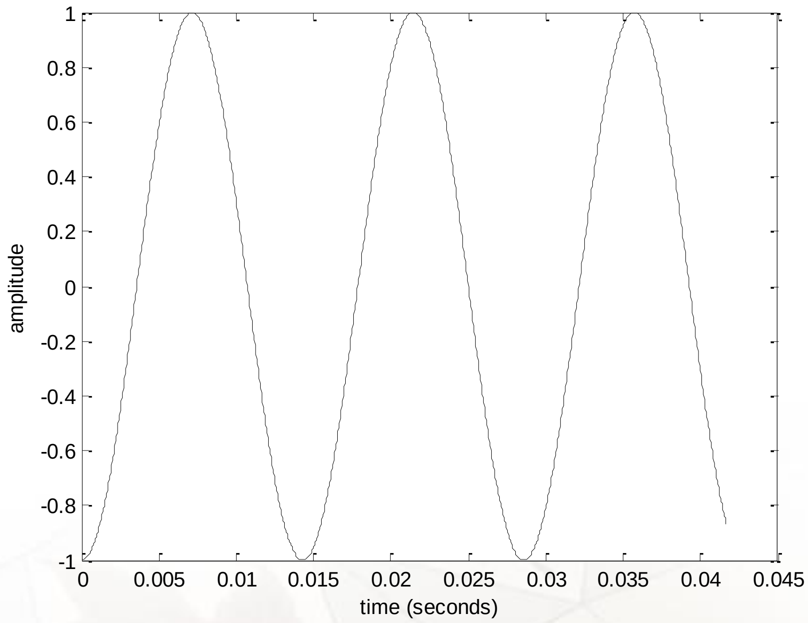
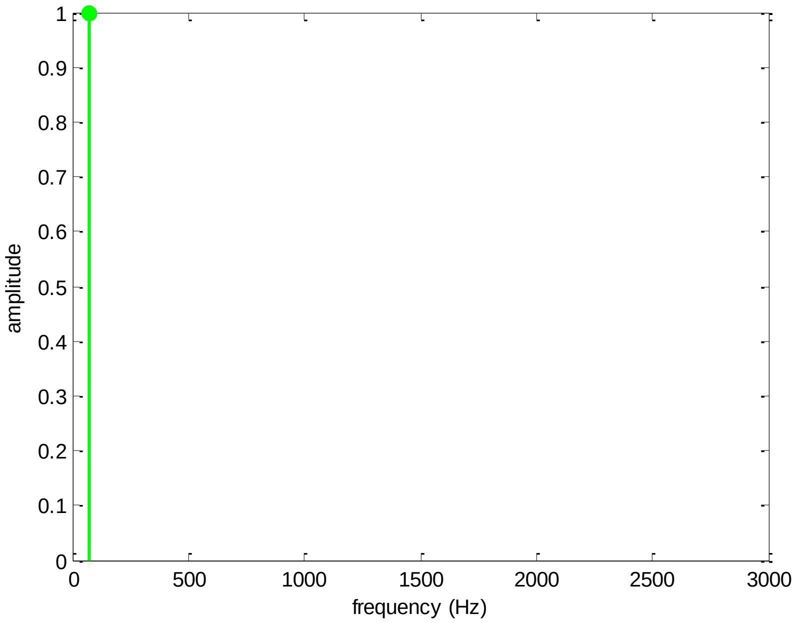
Sine waves and Frequency

- A signal is an entity that carries information such as speech, audio, images, video and so on.
- Signal processing is a major branch of electrical engineering and computer science.
- Fourier found that any signal can be created by adding up sine waves of different frequencies and amplitudes.
- The frequency of a sine wave is the number of oscillations per second, measured in Hertz (Hz).
- Fourier analysis refers to finding out the frequencies and amplitudes needed to construct a particular signal.
- Fourier synthesis refers to actually constructing a signal from these sine waves.

Low frequency sine wave (70 Hz)





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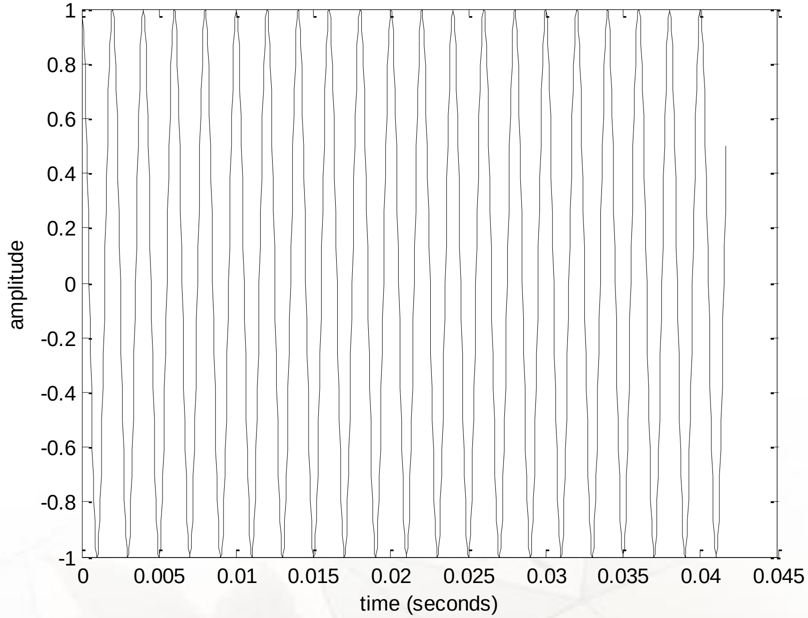
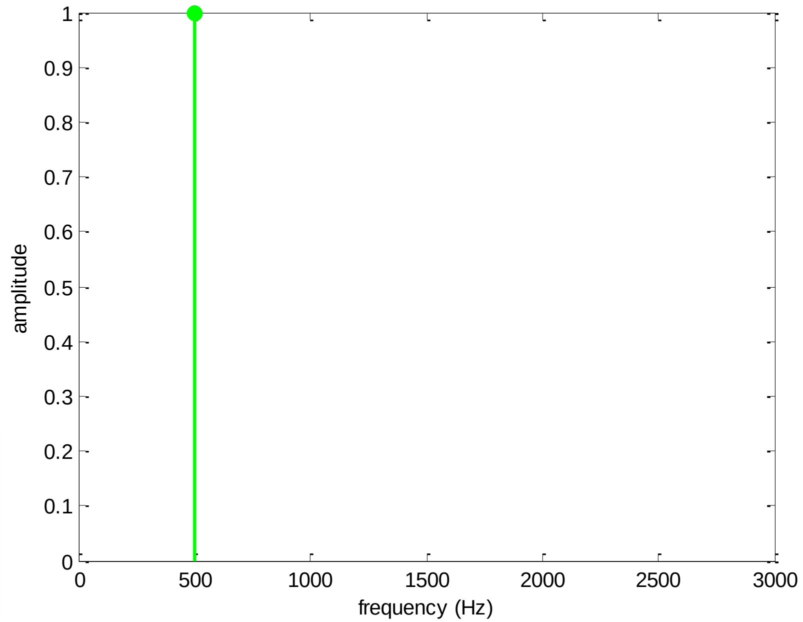
Medium frequency sine wave (500 Hz)





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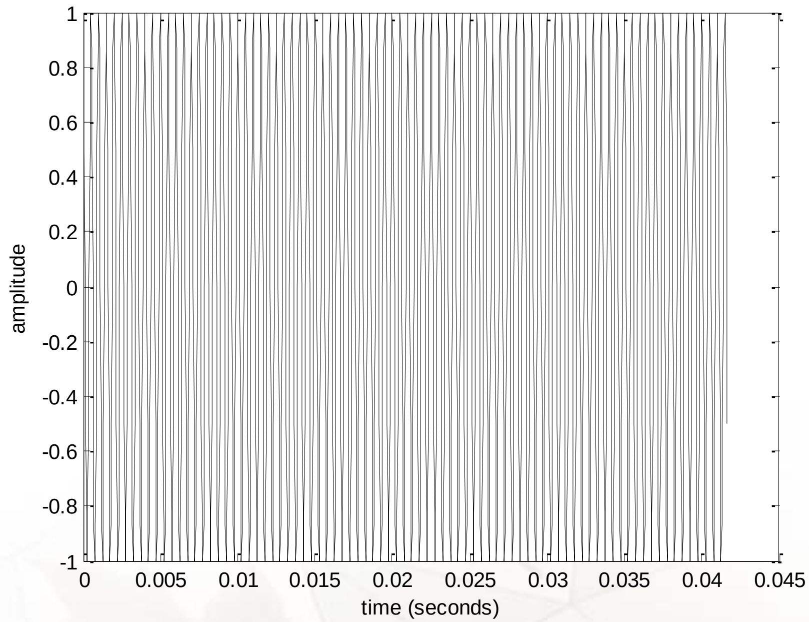
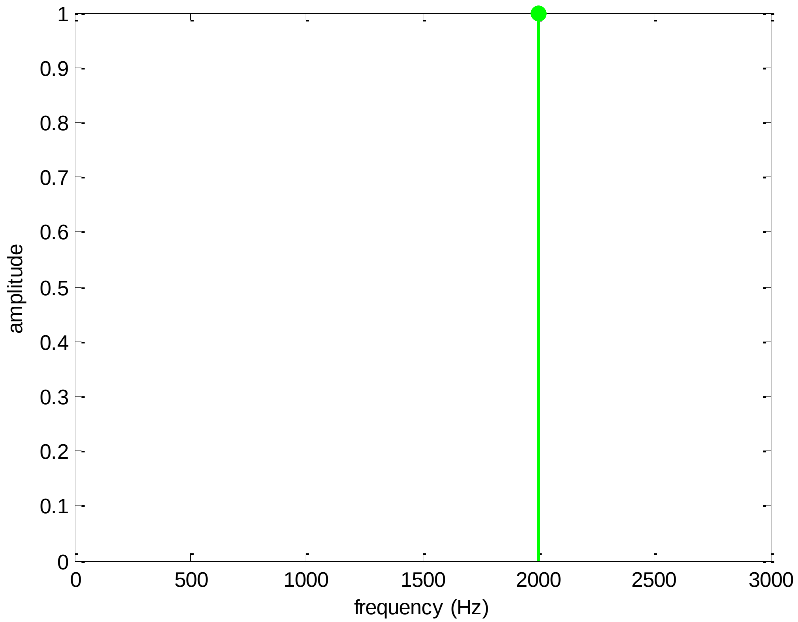
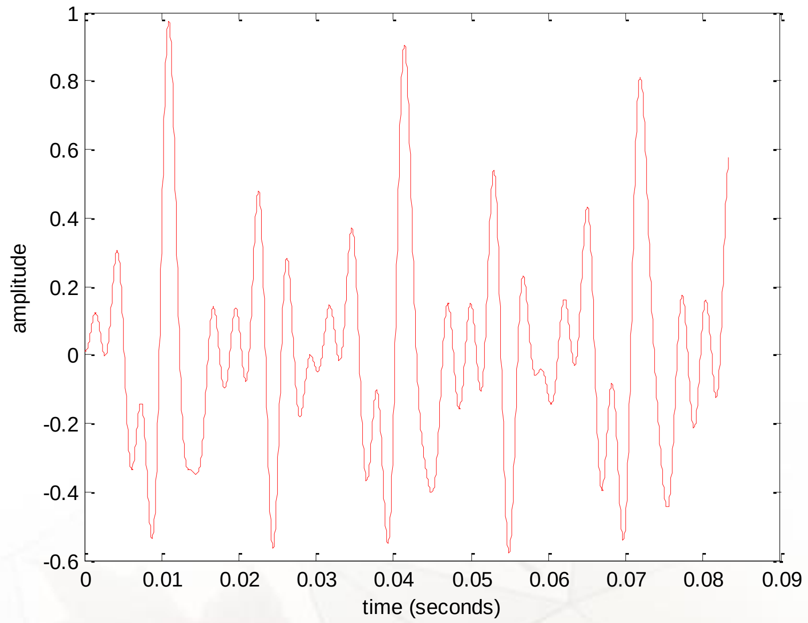
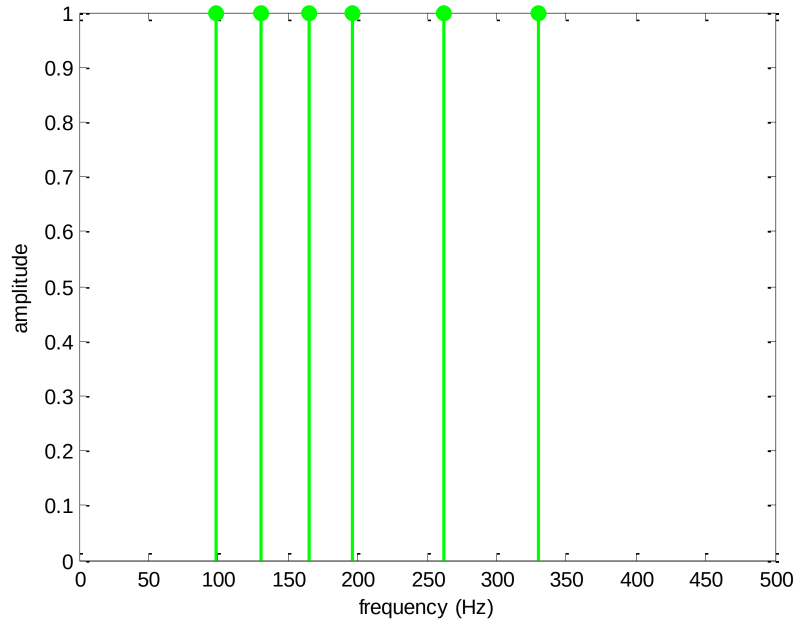
High frequency sine wave (2000 Hz)



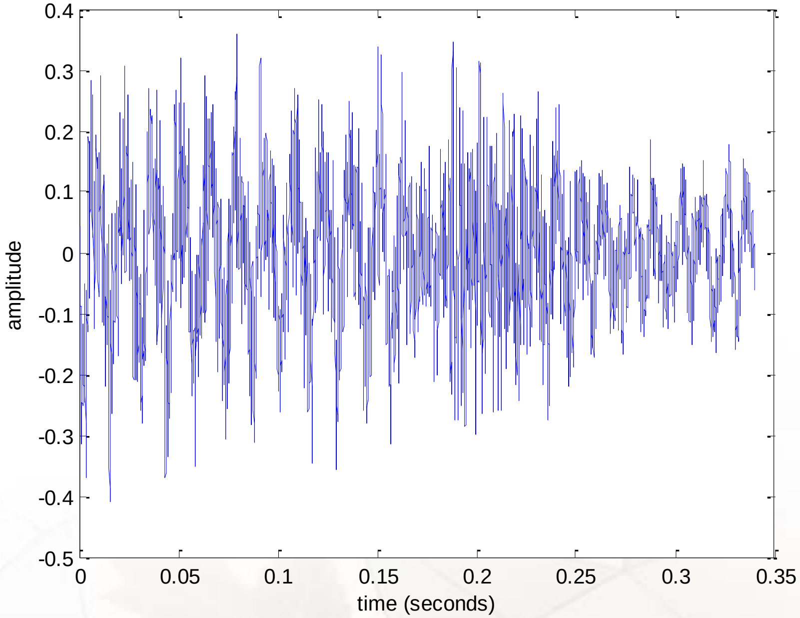


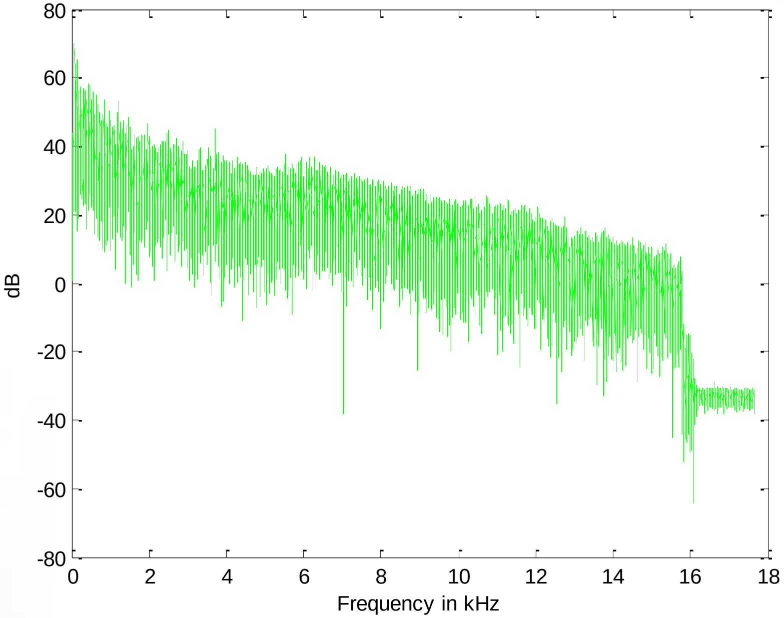
More complex tone (C chord)





Musical phrase (name that tune)

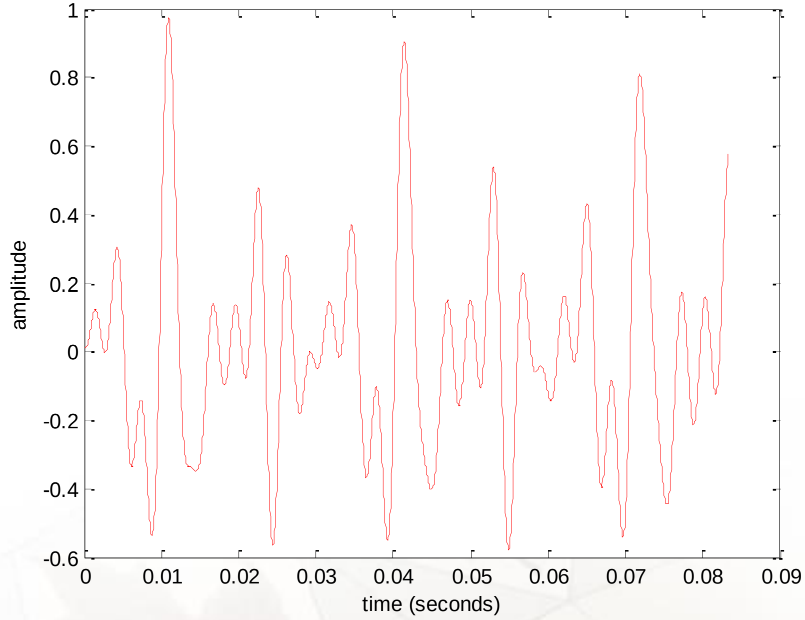


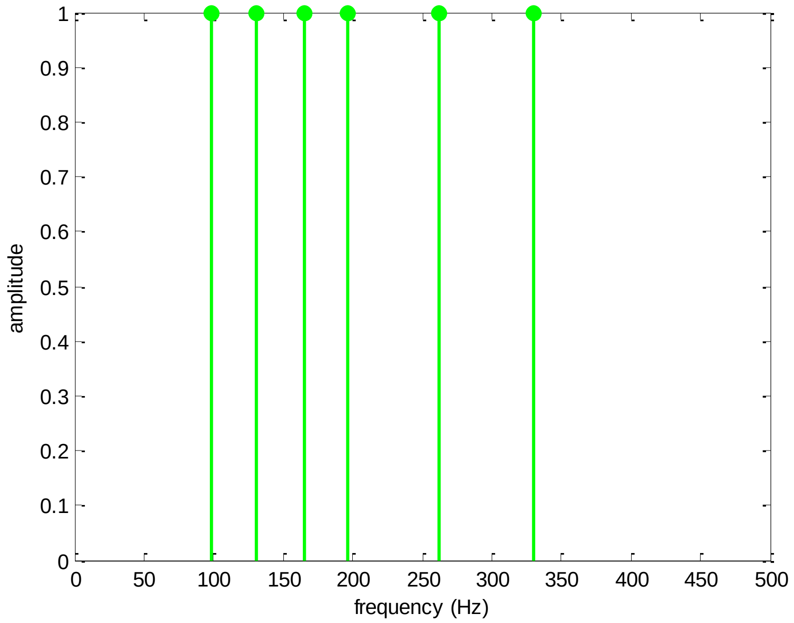


What is a filter?

- A filter is a device that typically removes some of the frequencies in a signal, and lets others pass through.
- For example, a filter that lets the low frequencies through and removes the high frequencies is called a low-pass filter.
- Other examples are high-pass filters, band-pass filters and band-stop filters.
- The filter is described by its frequency response.
- Let's see some examples for the audio signals.

More complex tone (C chord)





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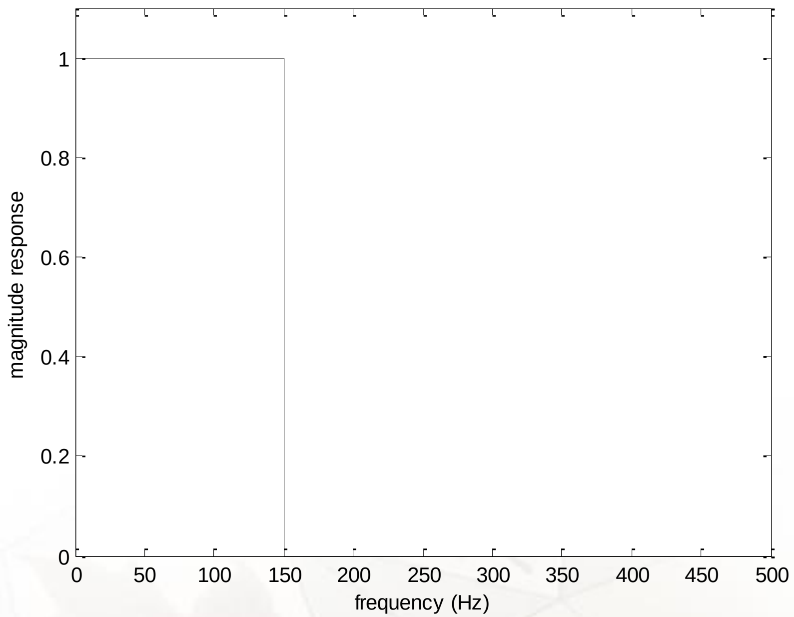
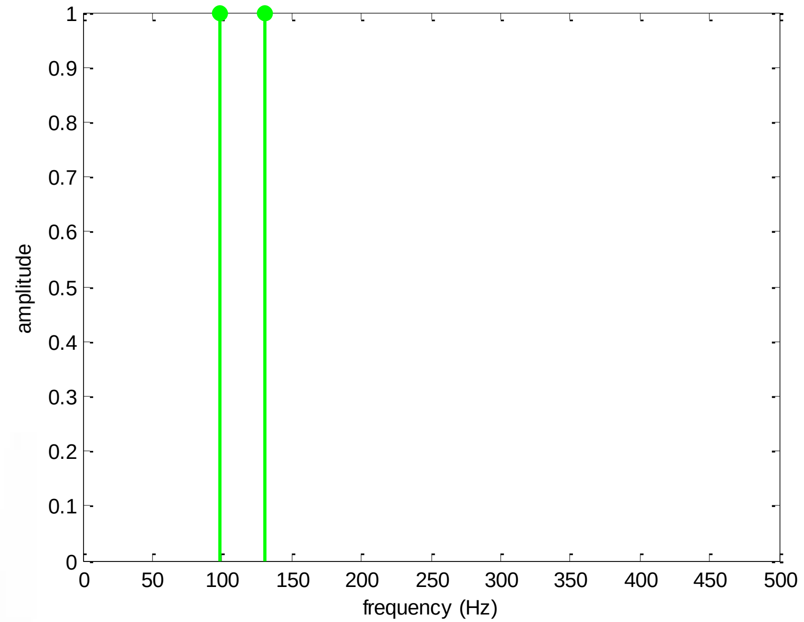
Low-pass filter



Frequency response



Filter output

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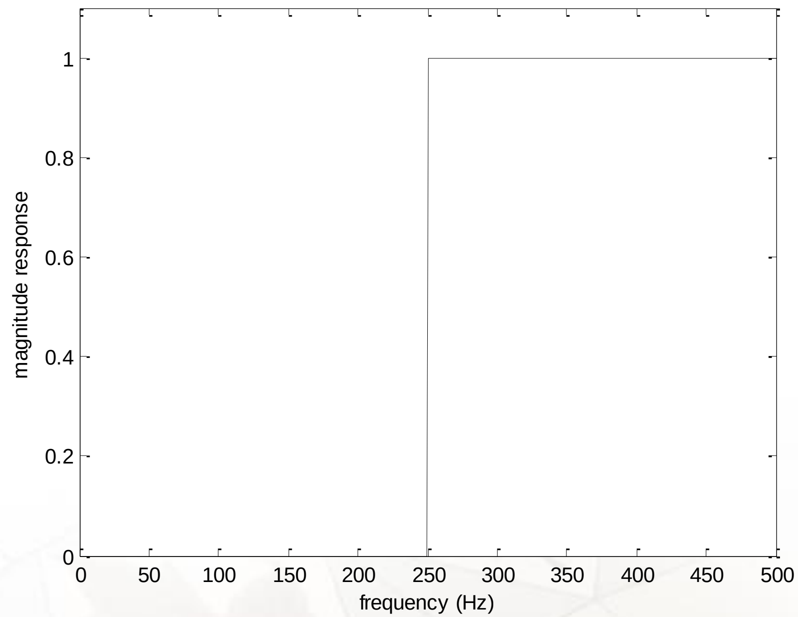
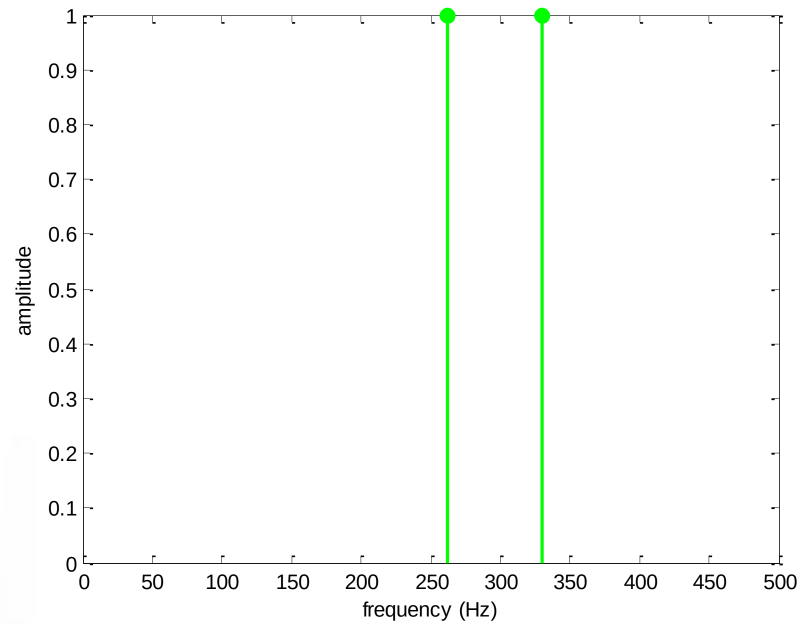
High-pass filter



Frequency response



Filter output

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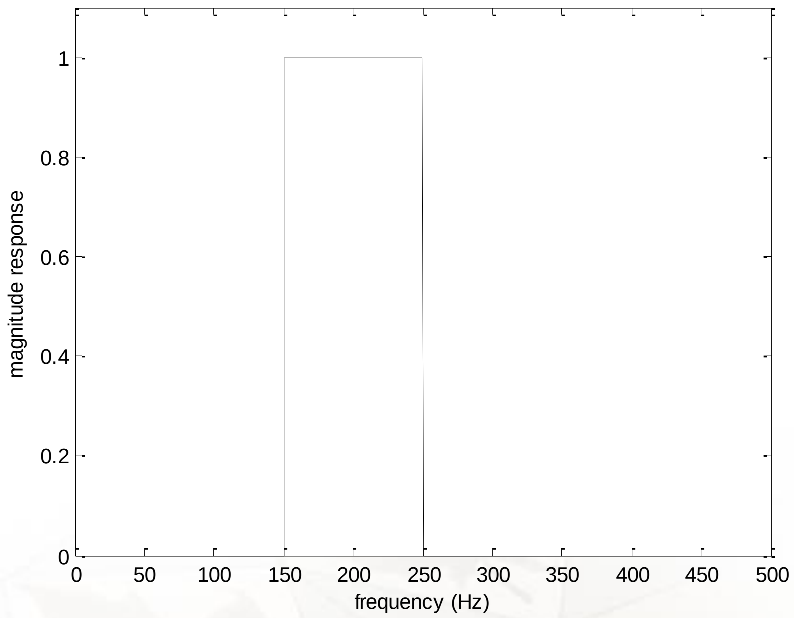
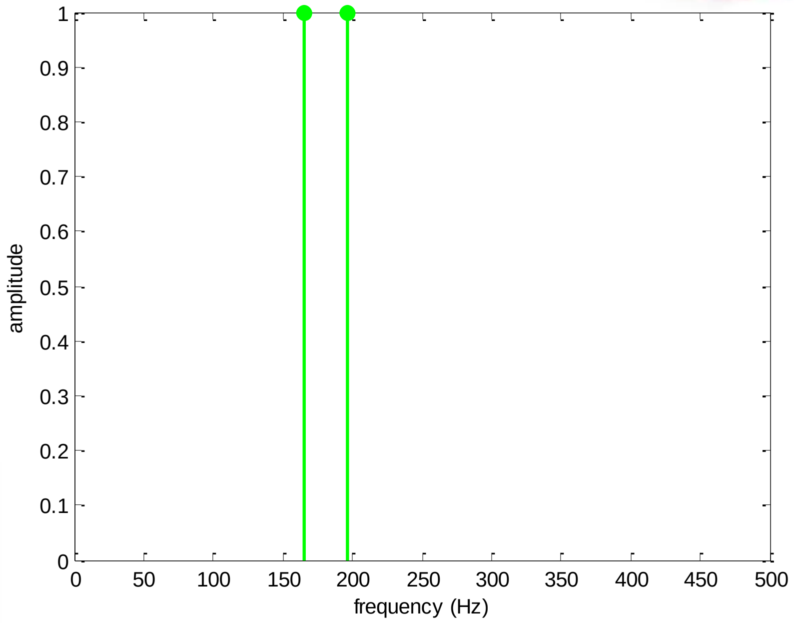
Band-pass filter

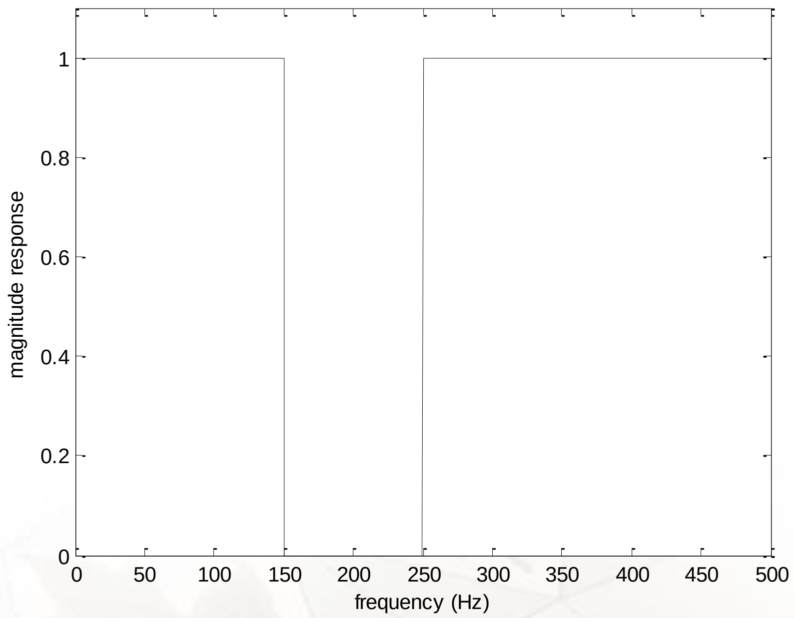


Frequency response

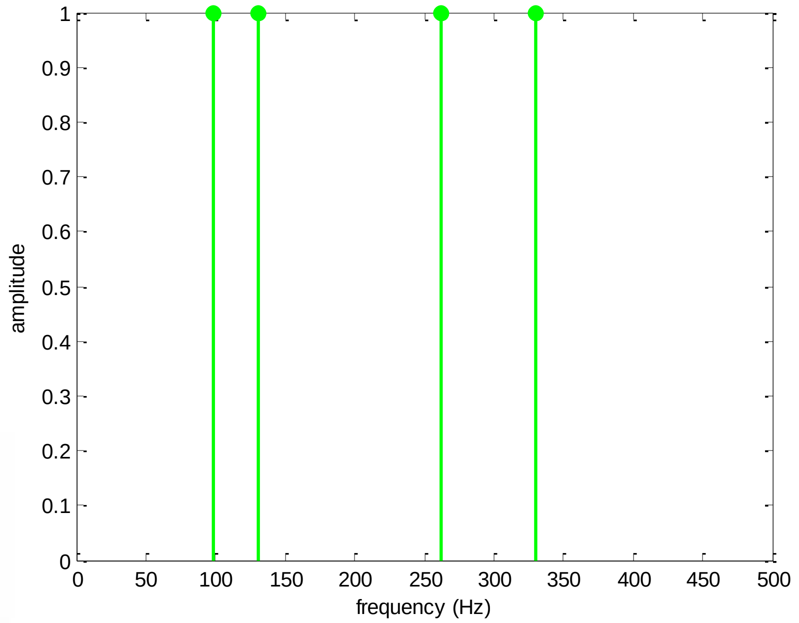


Filter output

Band-stop filter

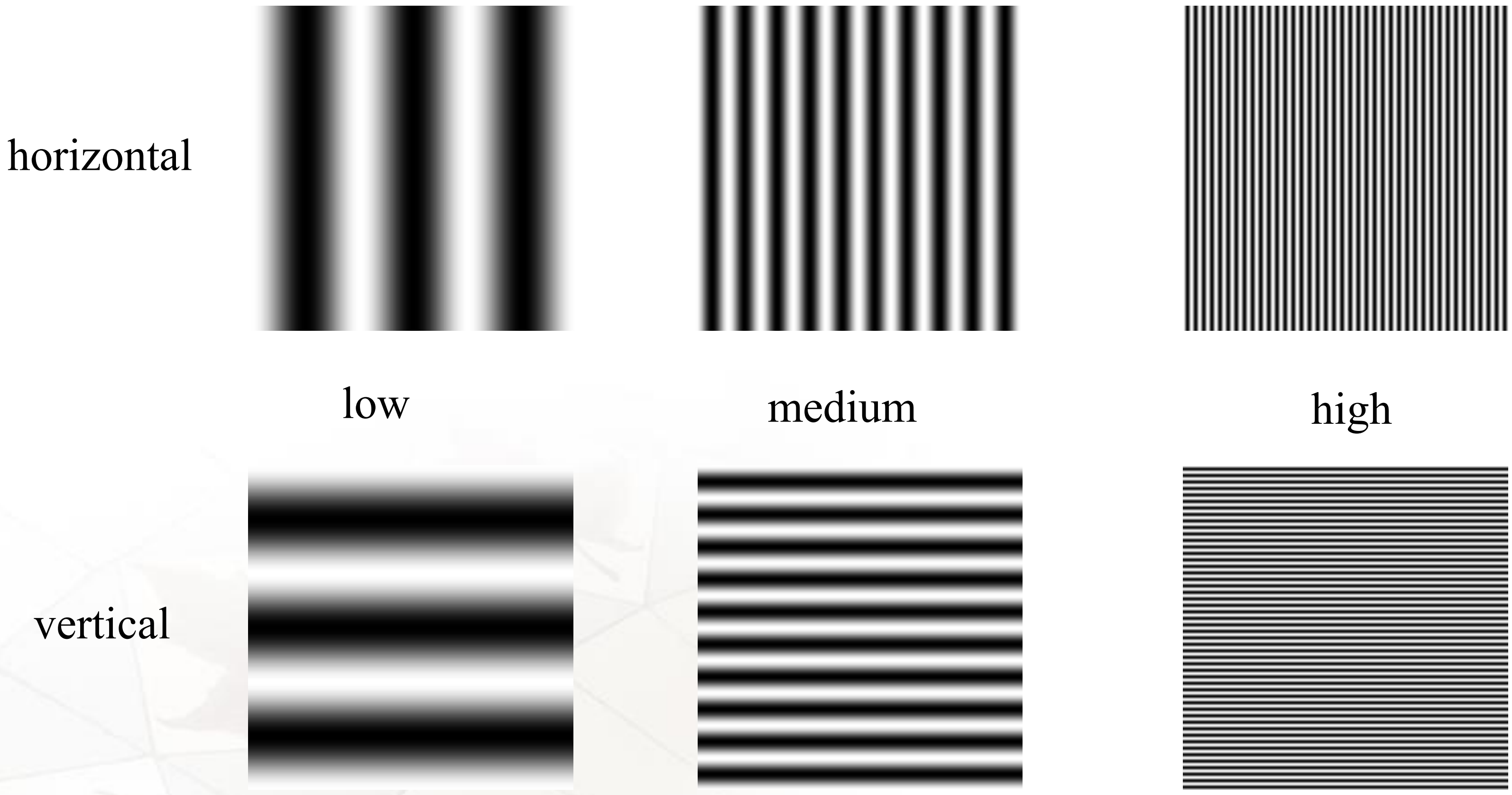


Frequency response

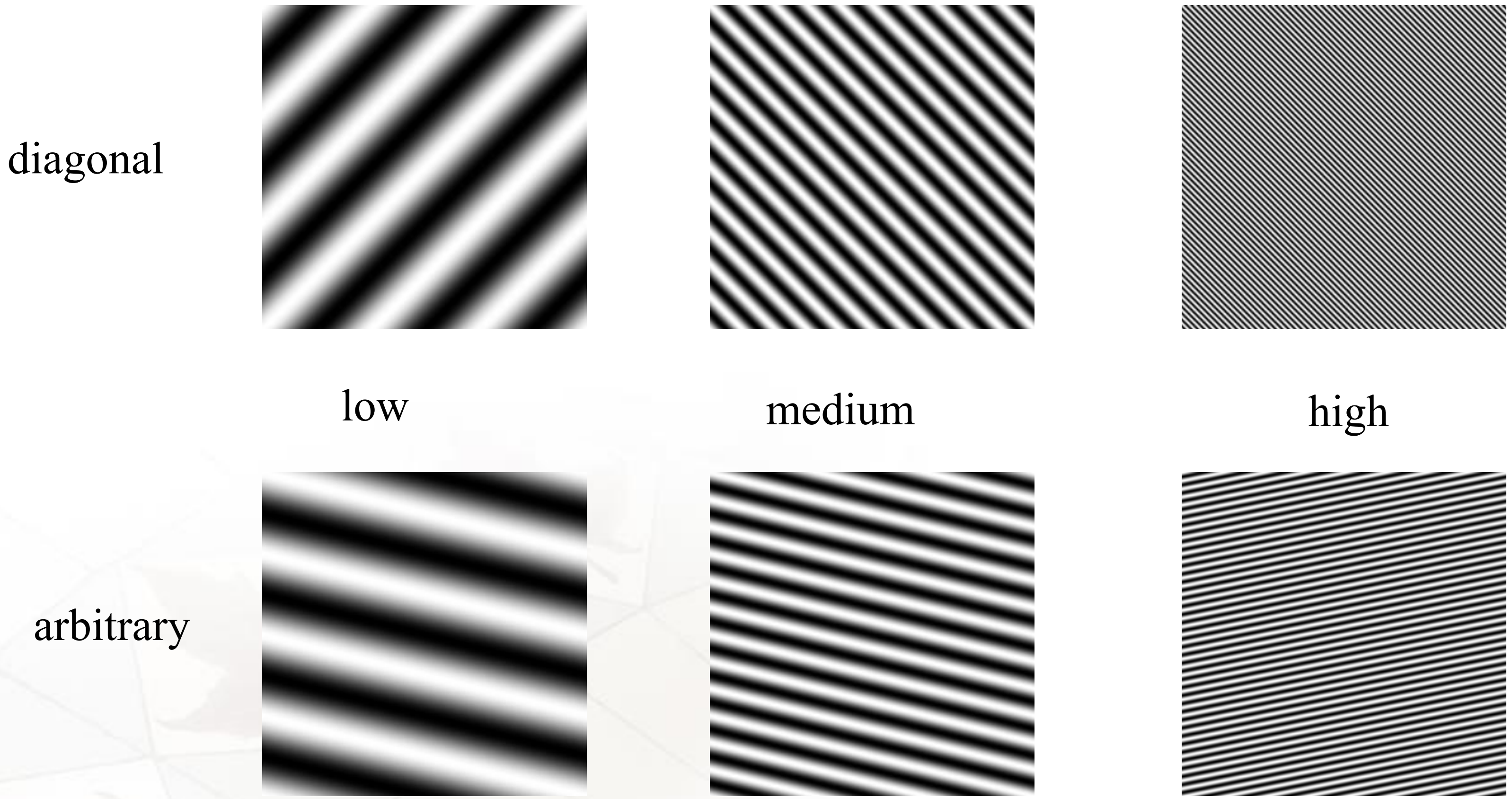


Filter output

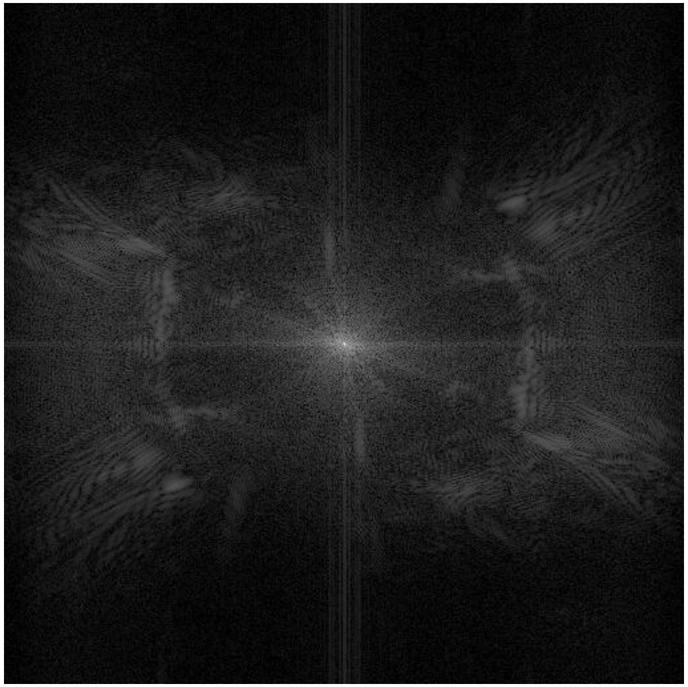
Spatial frequencies



Spatial frequencies



Frequency Spectrum



First Application: NTSC decoding

- NTSC: National Television System Committee
- Extended black and white to color in the 1950s in a compatible fashion.
- The video signal was viewed as a one-dimensional signal.
- The main problem was separating the color from the black and white information.
- Using a two –dimensional representation, better solutions could be found.
- Three-dimensional representations were even better.

NTSC One-dimensional spectrum

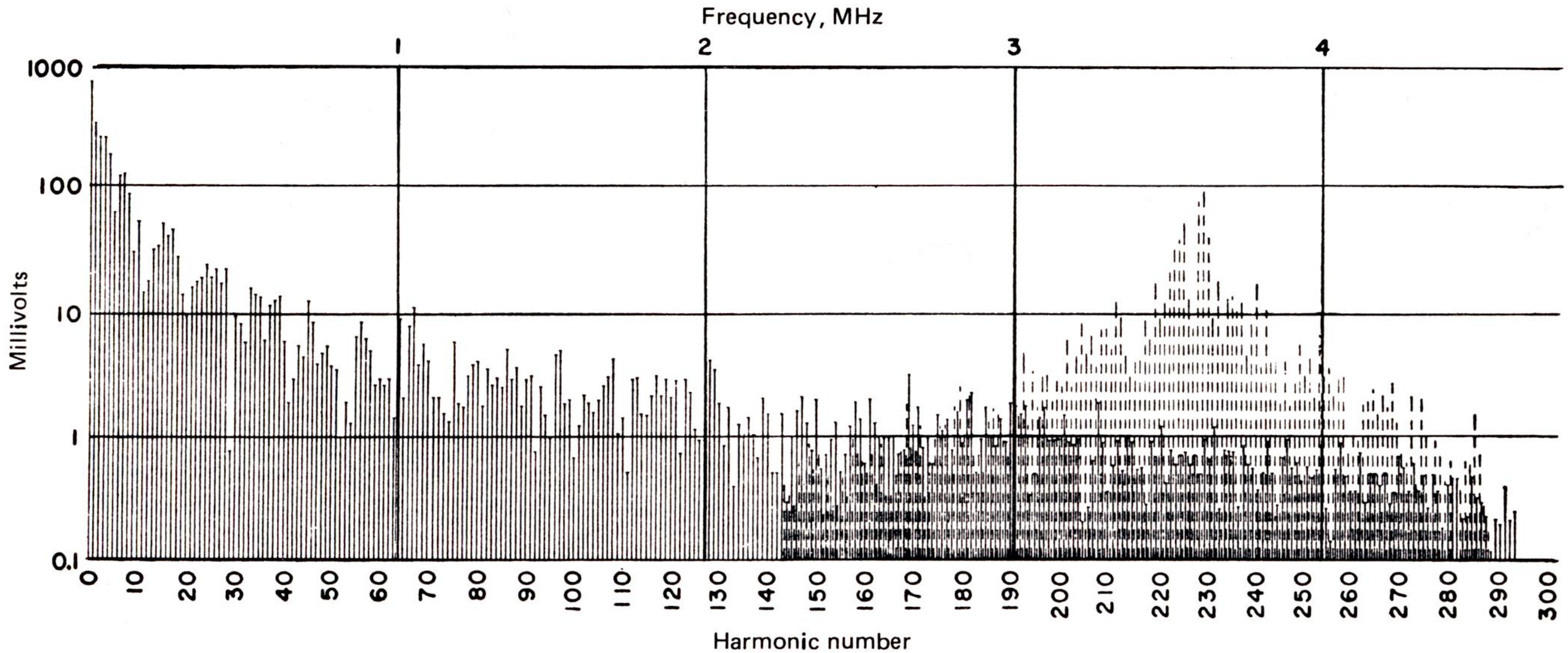
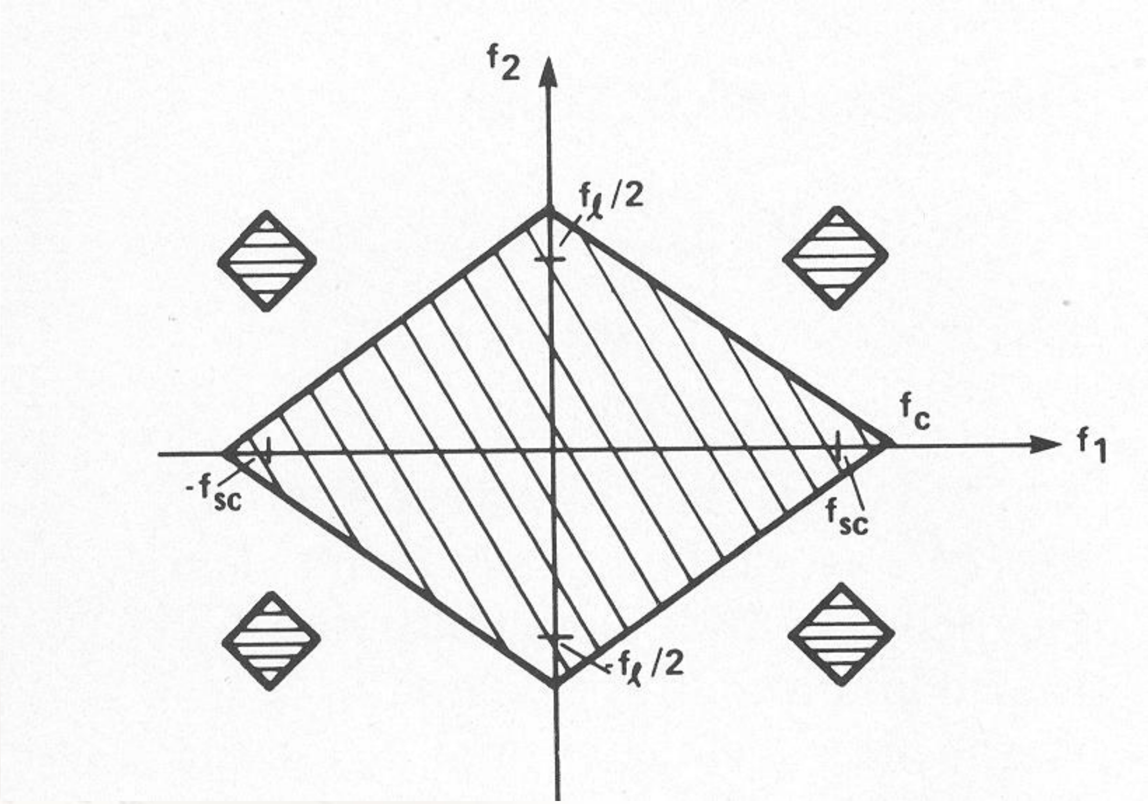


FIG. 5-18 Measured luminance-chrominance spectrum of color-bar-chart signal. (*From Fink.*[3])

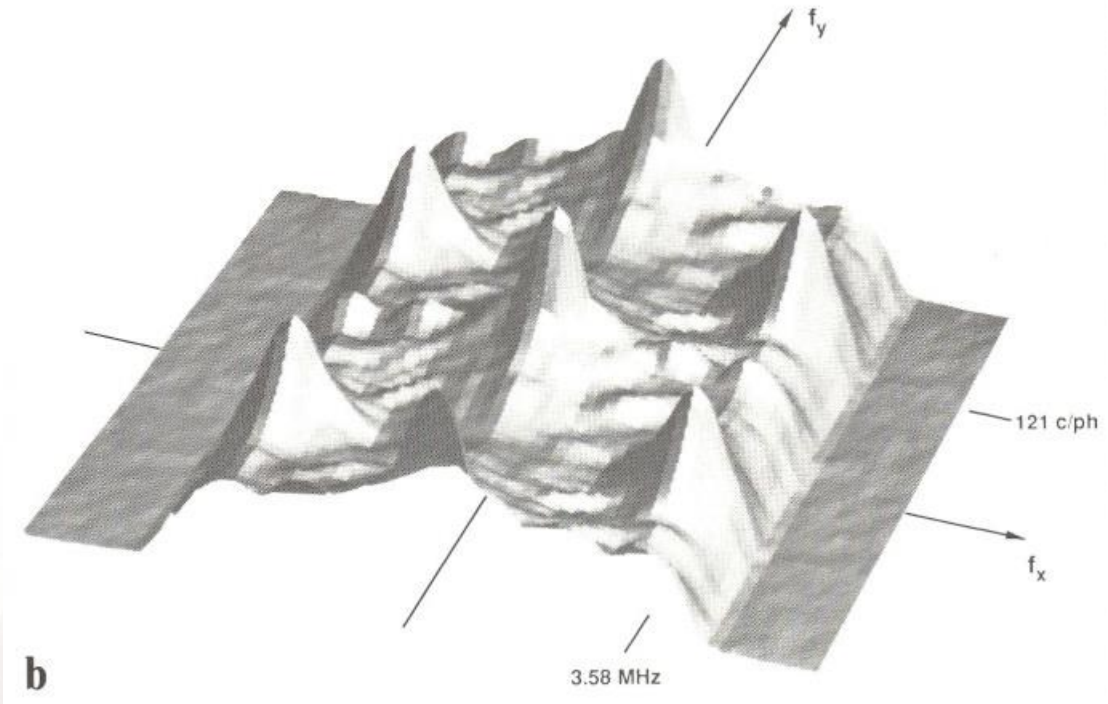
From the Television Engineering Handbook, 1986.

Two-dimensional NTSC spectrum



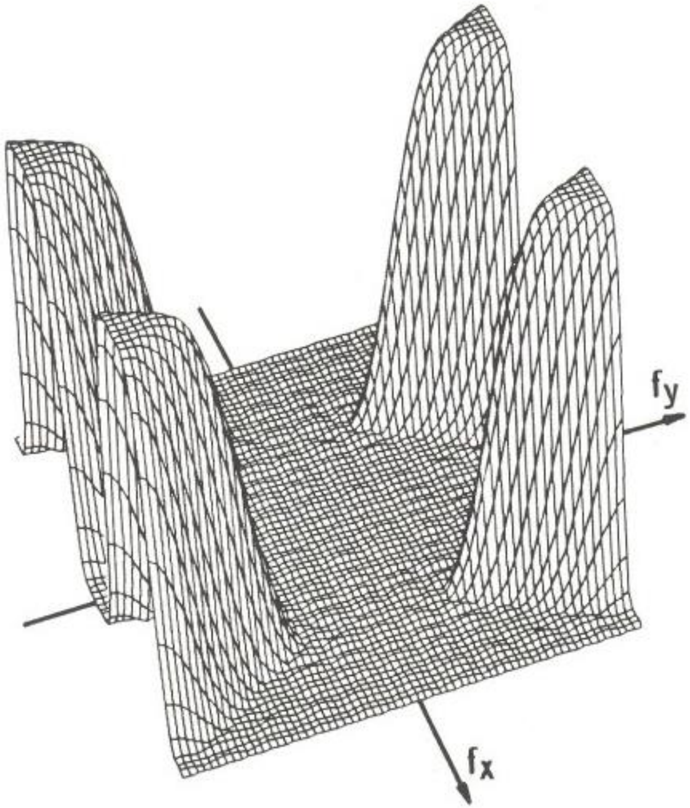
From **E. Dubois, M.S. Sabri, and J.-Y. Ouellet,** "Three-dimensional spectrum and processing of digital NTSC color signals," *SMPTE J.*, vol. 91, pp. 372-378, April 1982.

Measured Two-dimensional NTSC spectrum



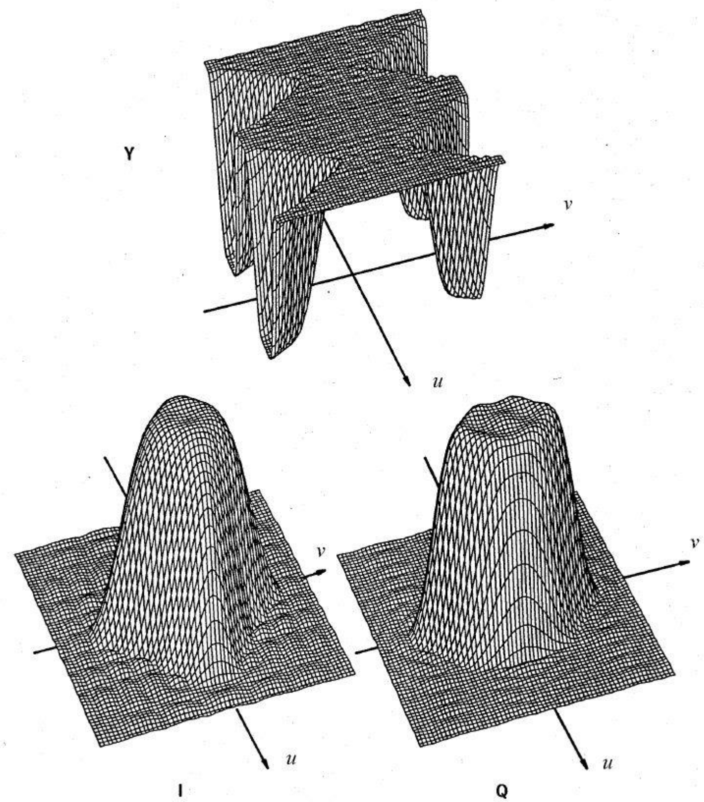
From **E. Dubois and W.F. Schreiber**, "Improvements to NTSC by multidimensional filtering,"*SMPTE J*., vol. 97, pp. 446-463, June 1988.

Chrominance band-pass filter



From **E. Dubois and W.F. Schreiber**, “Improvements to NTSC by multidimensional filtering,”*SMPTE J*., vol. 97, pp. 446-463, June 1988.

Two-dimensional NTSC prefilters



From **E. Dubois and W.F. Schreiber**, “Improvements to NTSC by multidimensional filtering,”*SMPTE J*., vol. 97, pp. 446-463, June 1988.

Test image

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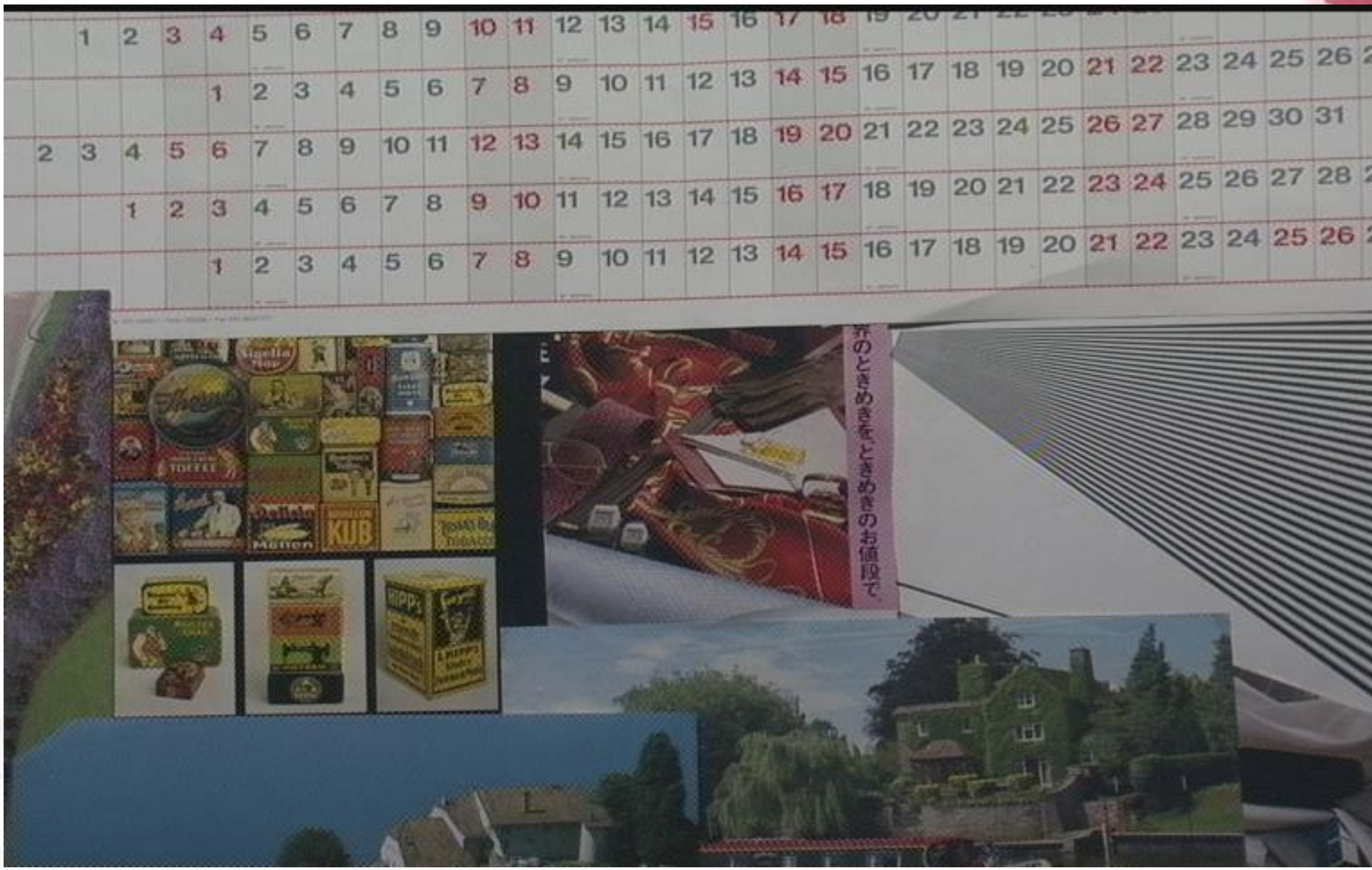
Conventional NTSC

Enhanced NTSC



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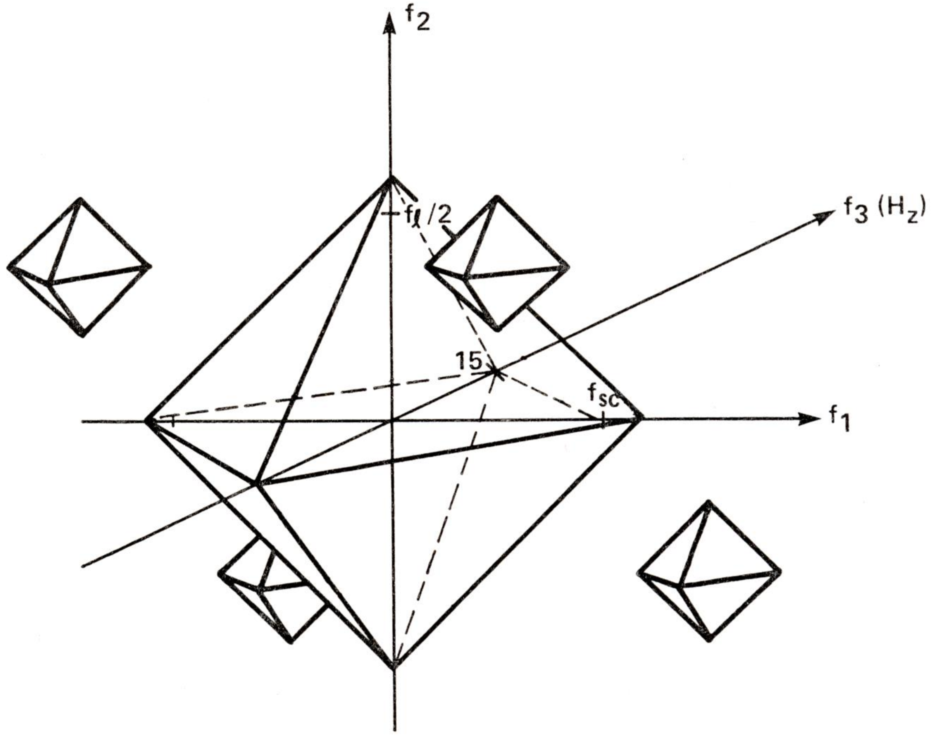
Three-dimensional NTSC spectrum



From **E. Dubois, M.S. Sabri, and J.-Y. Ouellet,** "Three-dimensional spectrum and processing of digital NTSC color signals," *SMPTE J.*, vol. 91, pp. 372-378, April 1982.

Second application: Demosaicking for digital cameras

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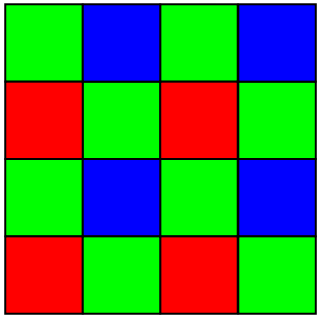
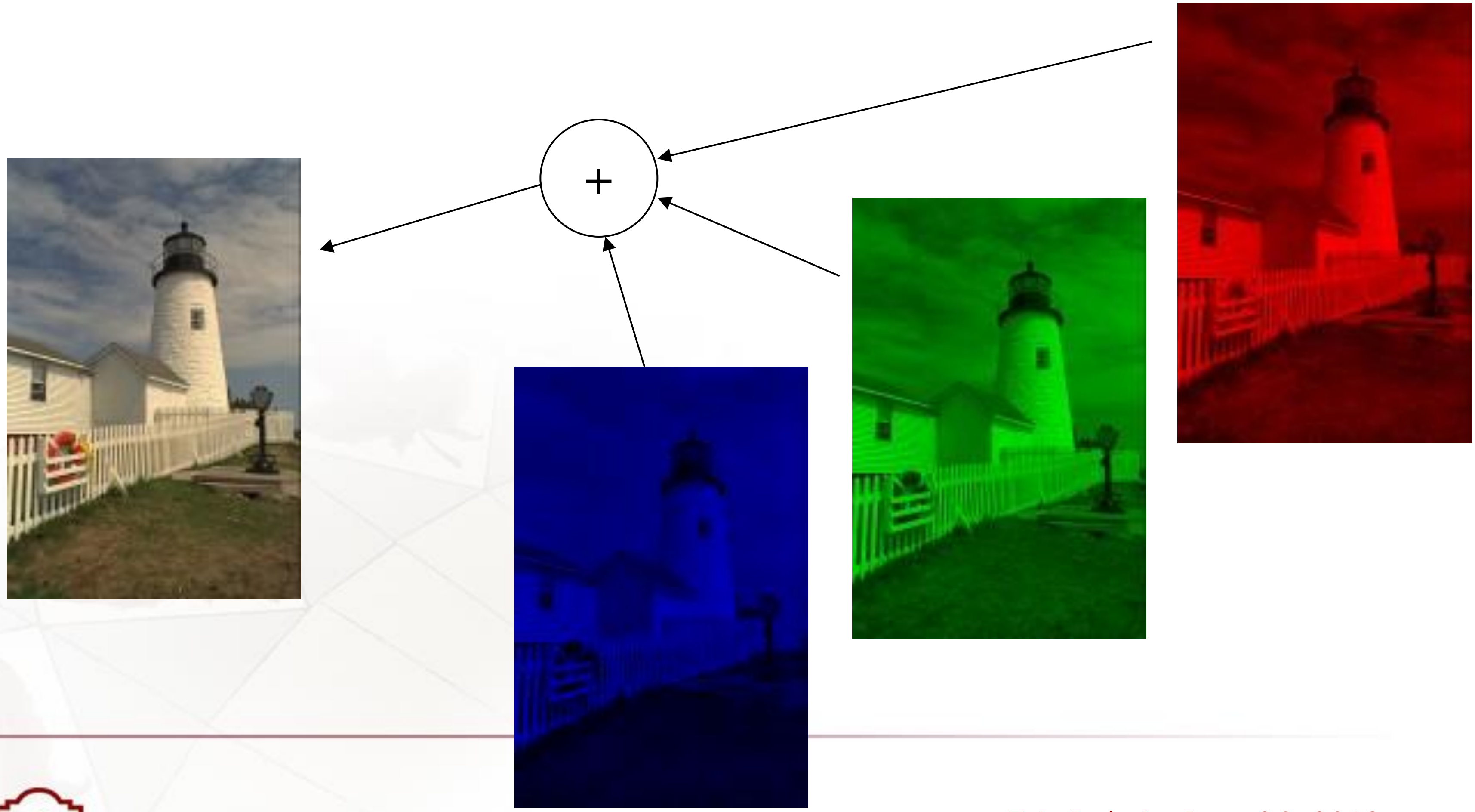
Problem Statement

- ***Problem***: Most digital color cameras capture only one color component at each spatial location. The remaining components must be reconstructed by interpolation from the captured samples. Cameras provide hardware or software to do this, but the quality may be inadequate.
- ***Objective***: Develop new algorithms to interpolate each color plane (called demosaicking) with better quality reconstruction, and with minimal computational complexity.

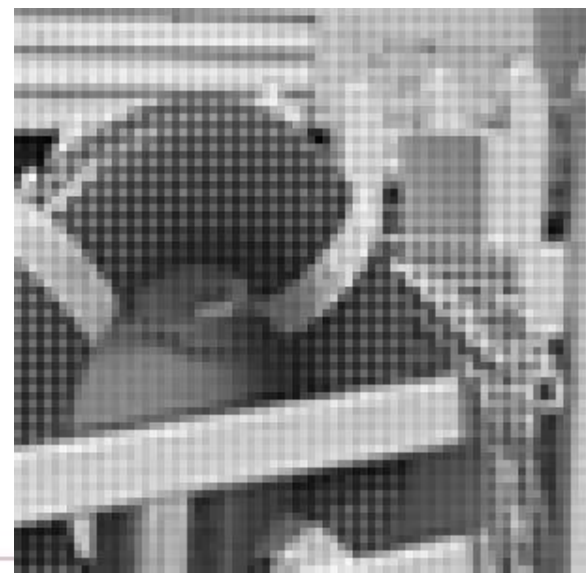


Construction of color image from color planes



Lighthouse original

Lighthouse
Bayer CFA image



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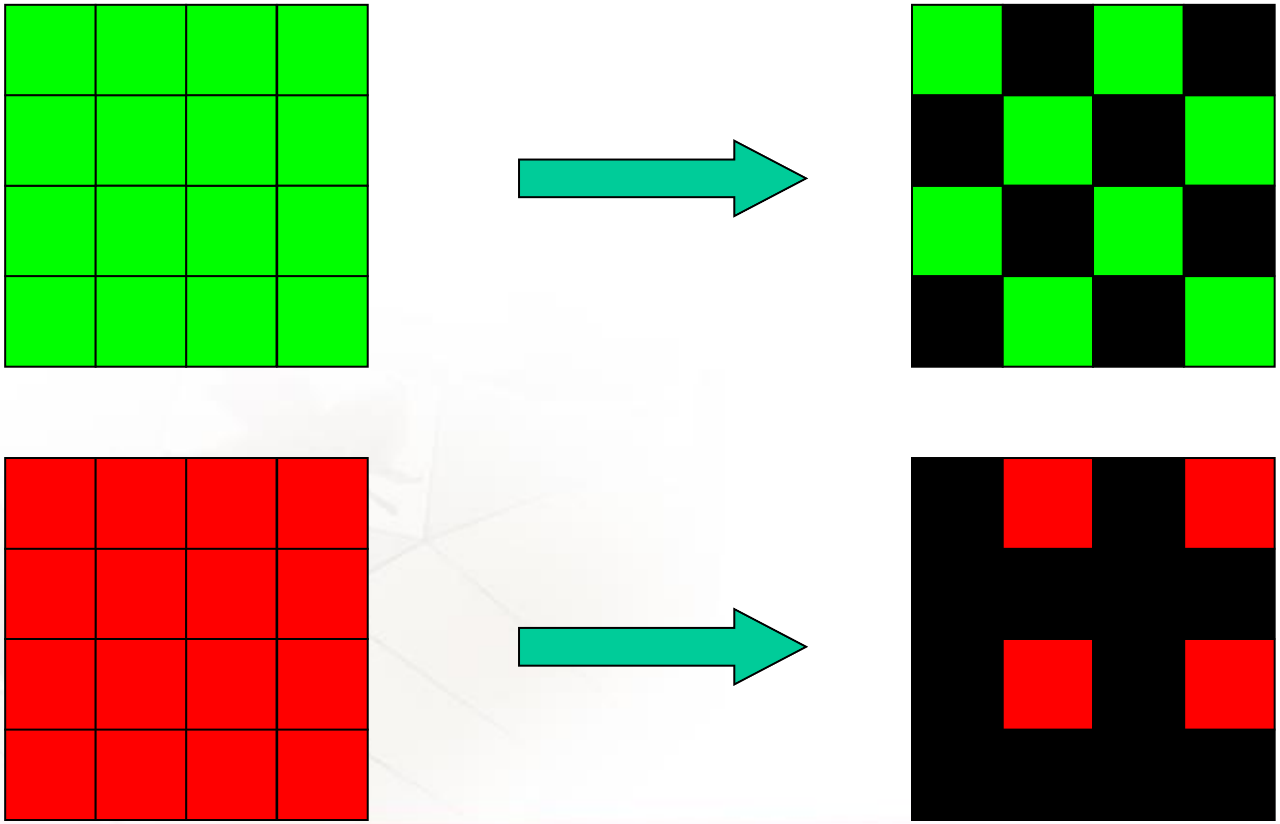
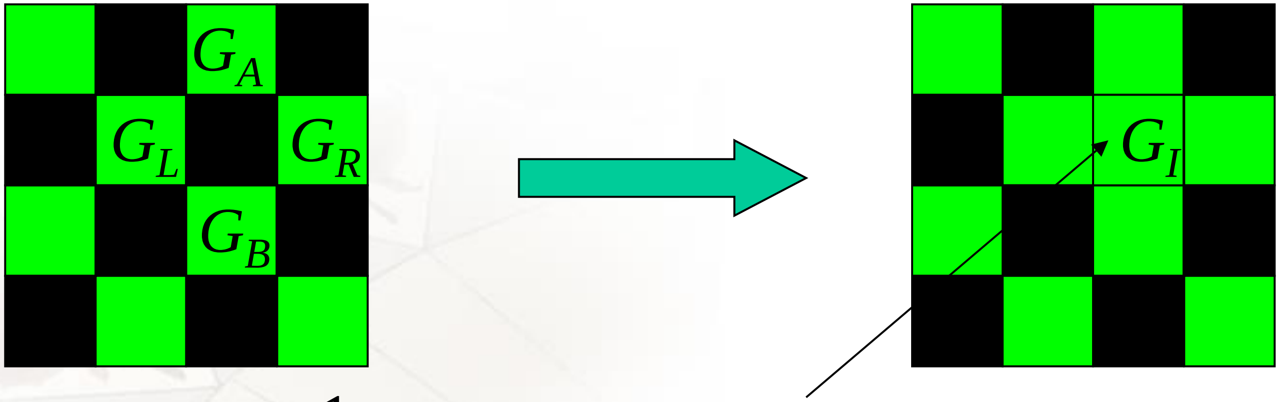
Formation of Color planes



Color plane interpolation

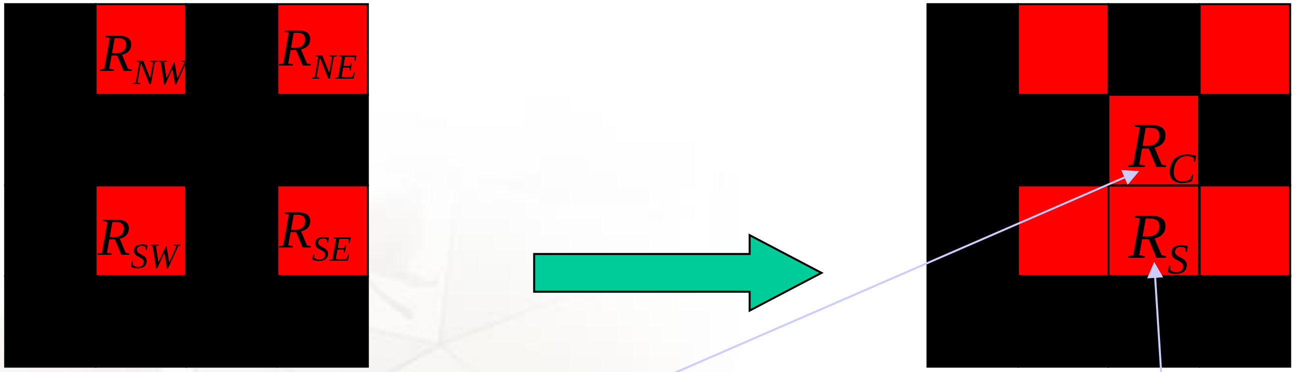
Green channel: bilinear interpolation



$$G_I = \frac{1}{4}(G_L + G_R + G_B + G_A)$$

Color plane interpolation

Red channel: bilinear interpolation



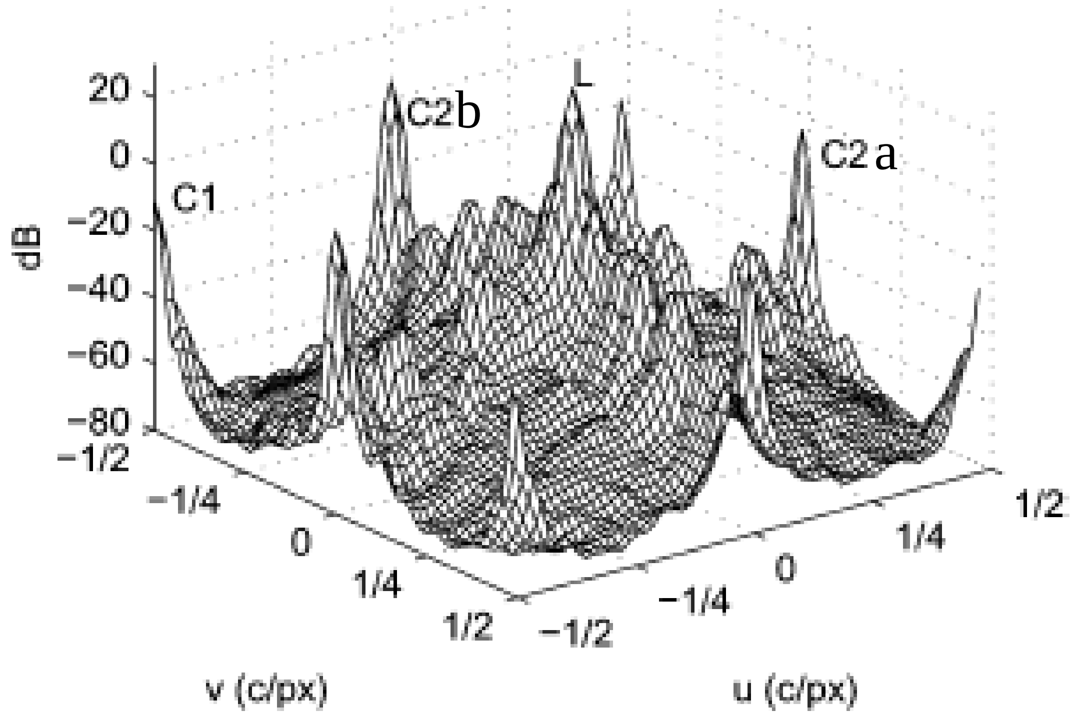
$$R_C = \frac{1}{4}(R_{NW} + R_{NE} + R_{SW} + R_{SE})$$

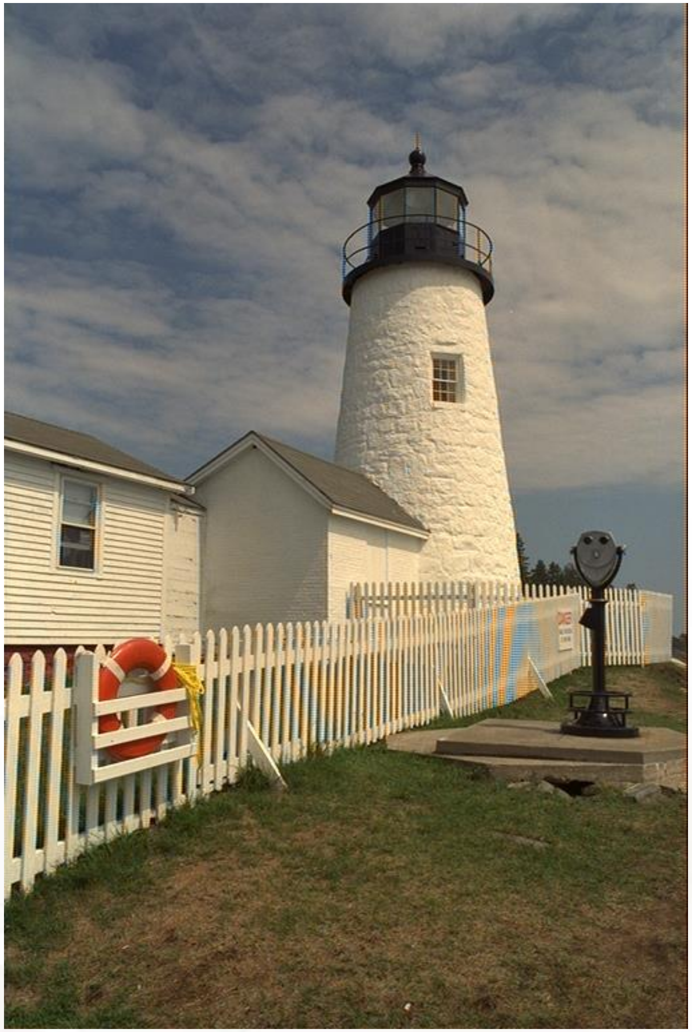
$$R_S = \frac{1}{2}(R_{SW} + R_{SE})$$

Lighthouse
Interpolated color image

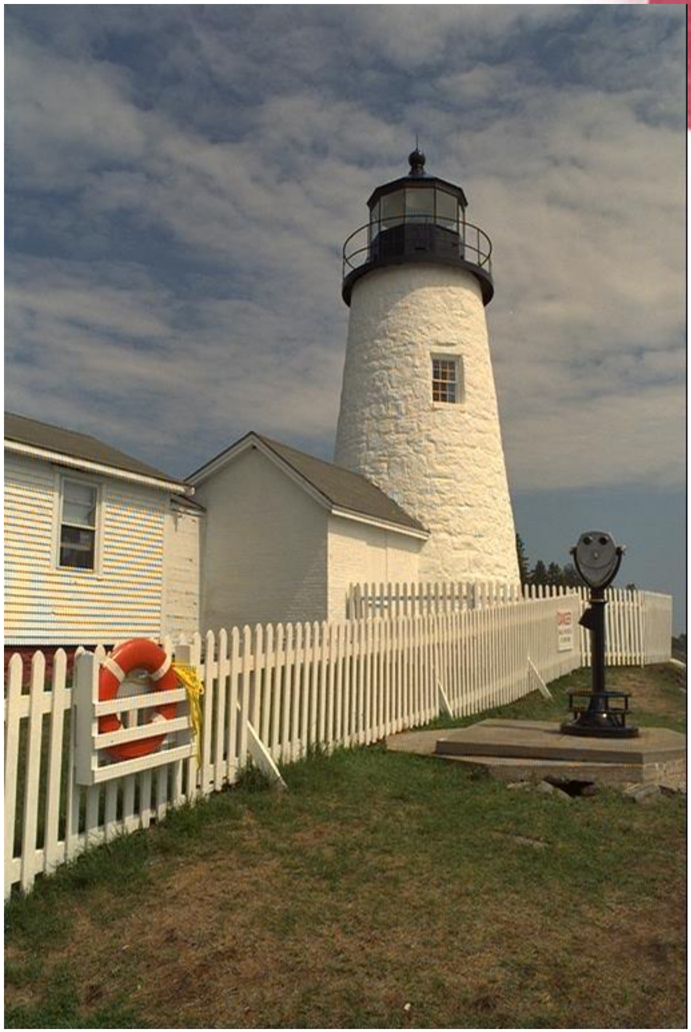
Lighthouse original

Spectrum of CFA signal



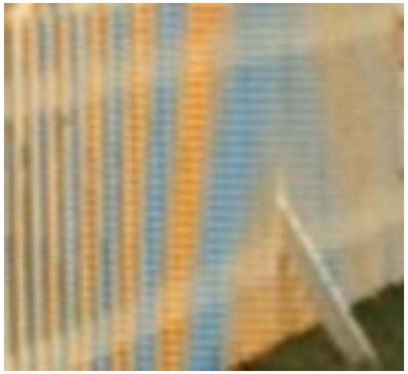


Using C2a only



Using C2b only

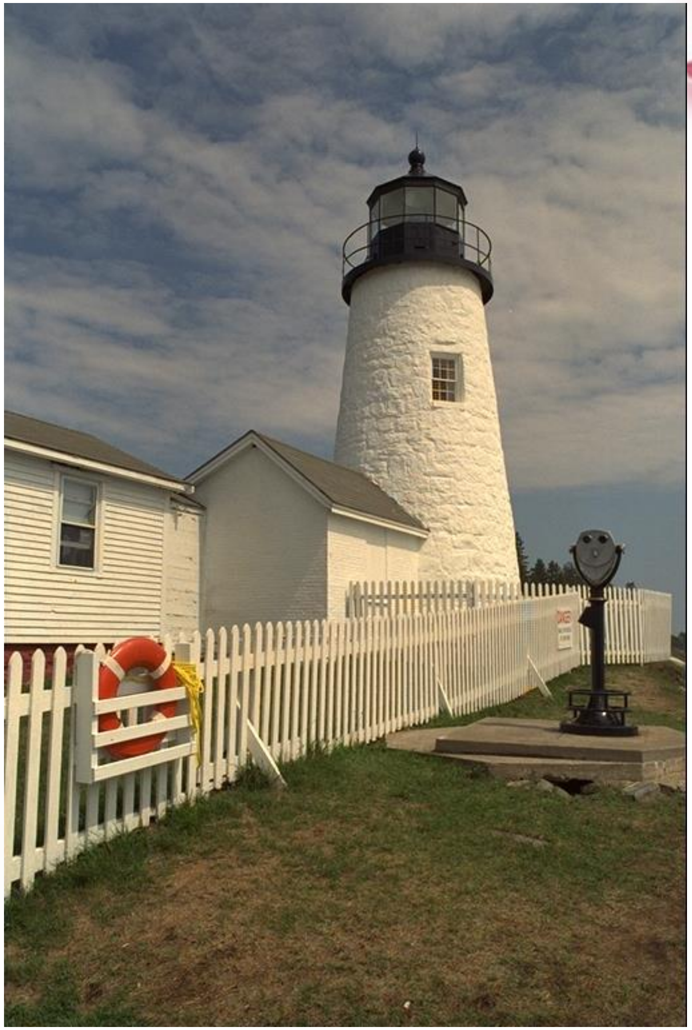
Demosaicking using C2a only or C2b only -- details

Original	From C2a only	From C2b only
		
		

My Contributions

- I recognized that the C2 component appears twice.
- We can reconstruct the signal with either of them.
- Typically at each location at least one of them will give a good reconstruction.
- We need a genie to tell us which to use at each location.

- I presented an algorithm that works almost as well as the genie most of the time and gives state-of-the-art performance with relatively low computational complexity.

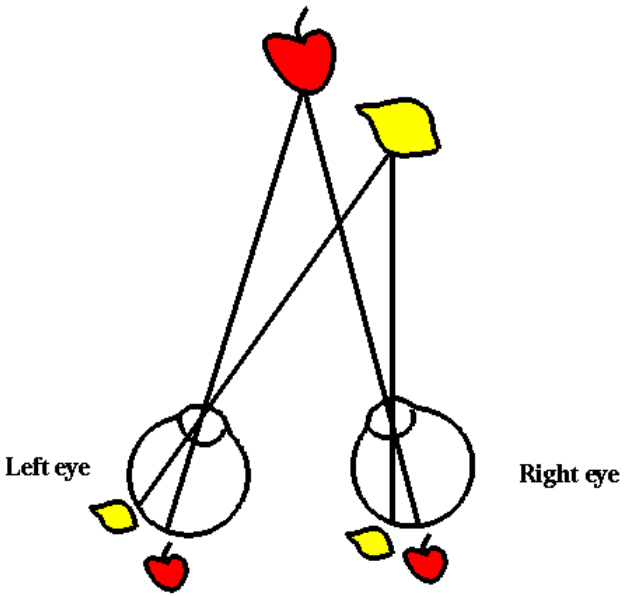


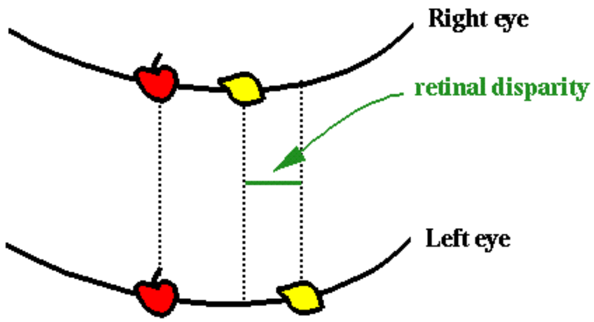
Third Application: Stereoscopic Imaging

Development of a new approach for creating stereoscopic images for colored glasses, called the anaglyph method.

Binocular Vision

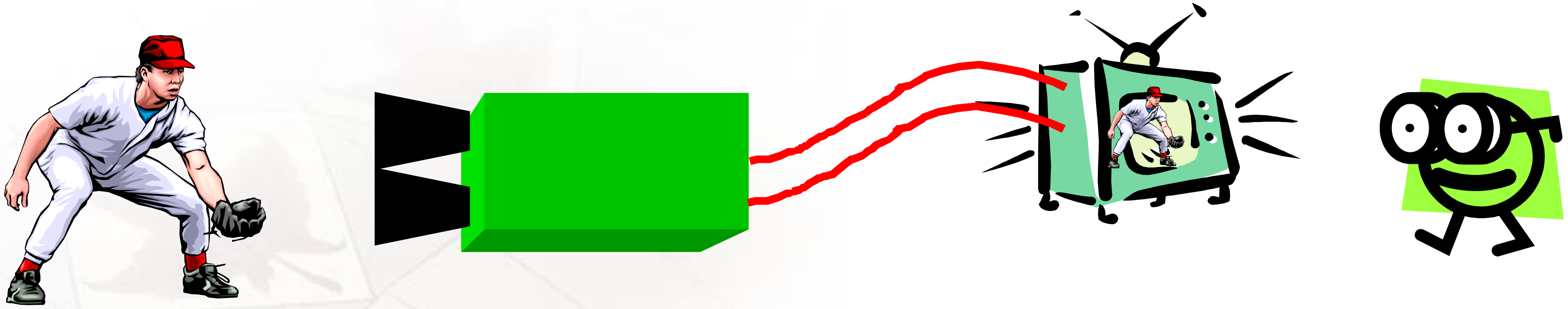
We see the world with ***two*** eyes. Each eye sees a slightly different view of the scene we're looking at. The brain interprets the differences and provides us with the 3D perception of depth.





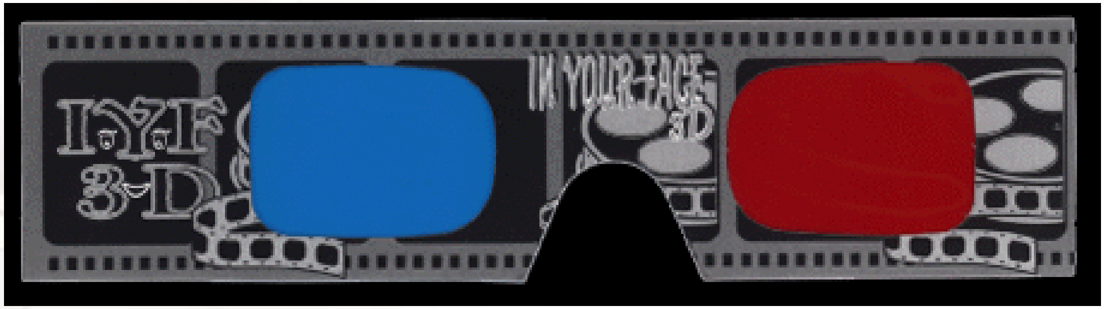
Stereoscopic Imaging

- Form two views of the scene from slightly different points of view -- either with a camera or by computer graphics
- Display the two views with some apparatus that forces the left eye to only see the left view and the right eye to only see the right view



What is 'anaglyph'?

Anaglyph is a method to view stereoscopic images using coloured spectacles. The method was patented in 1891 by Louis Ducos du Hauron, but similar methods had been demonstrated previously by W. Rollmann in 1853 and J.C. D'Almeida in 1858.

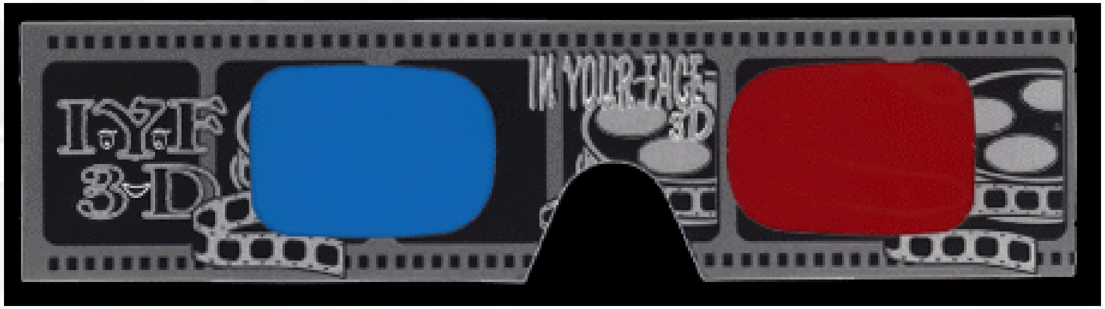


Classical method

For monochrome (no color) stereo images, the left view in blue (or green) is superimposed on the same image with the right view in red. When viewed through spectacles of corresponding colors but reversed, the three-dimensional effect is perceived.

The Anaglyph stereoscopic images in this presentation require the red/blue glasses available in this room to perceive the 3D effect

The red filter goes over your LEFT eye.

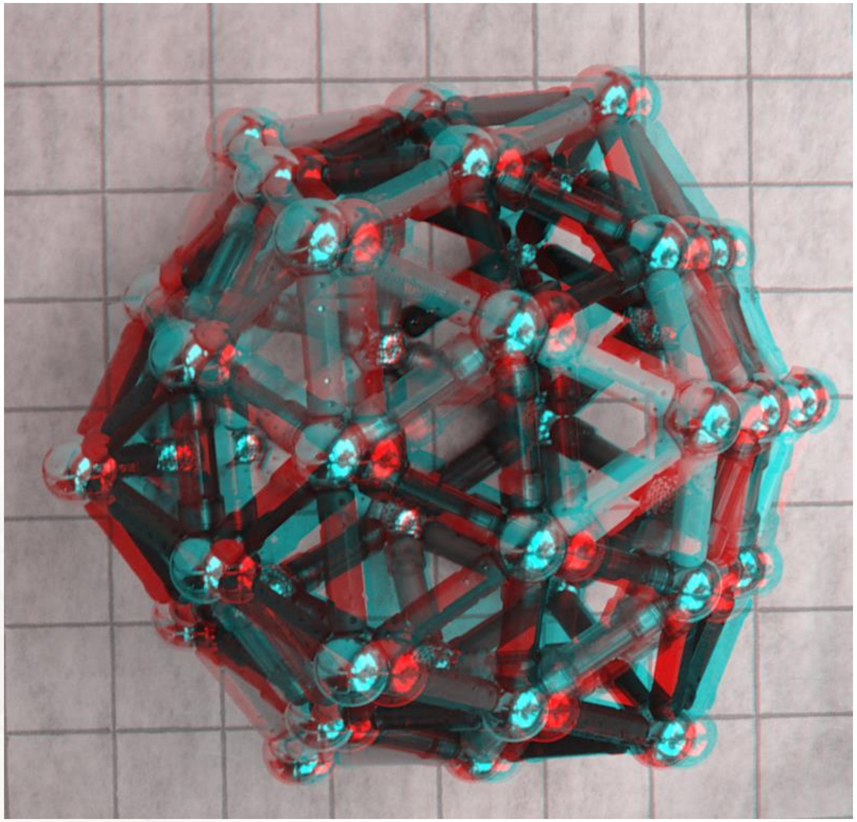


RIGHT LEFT

CAUTION

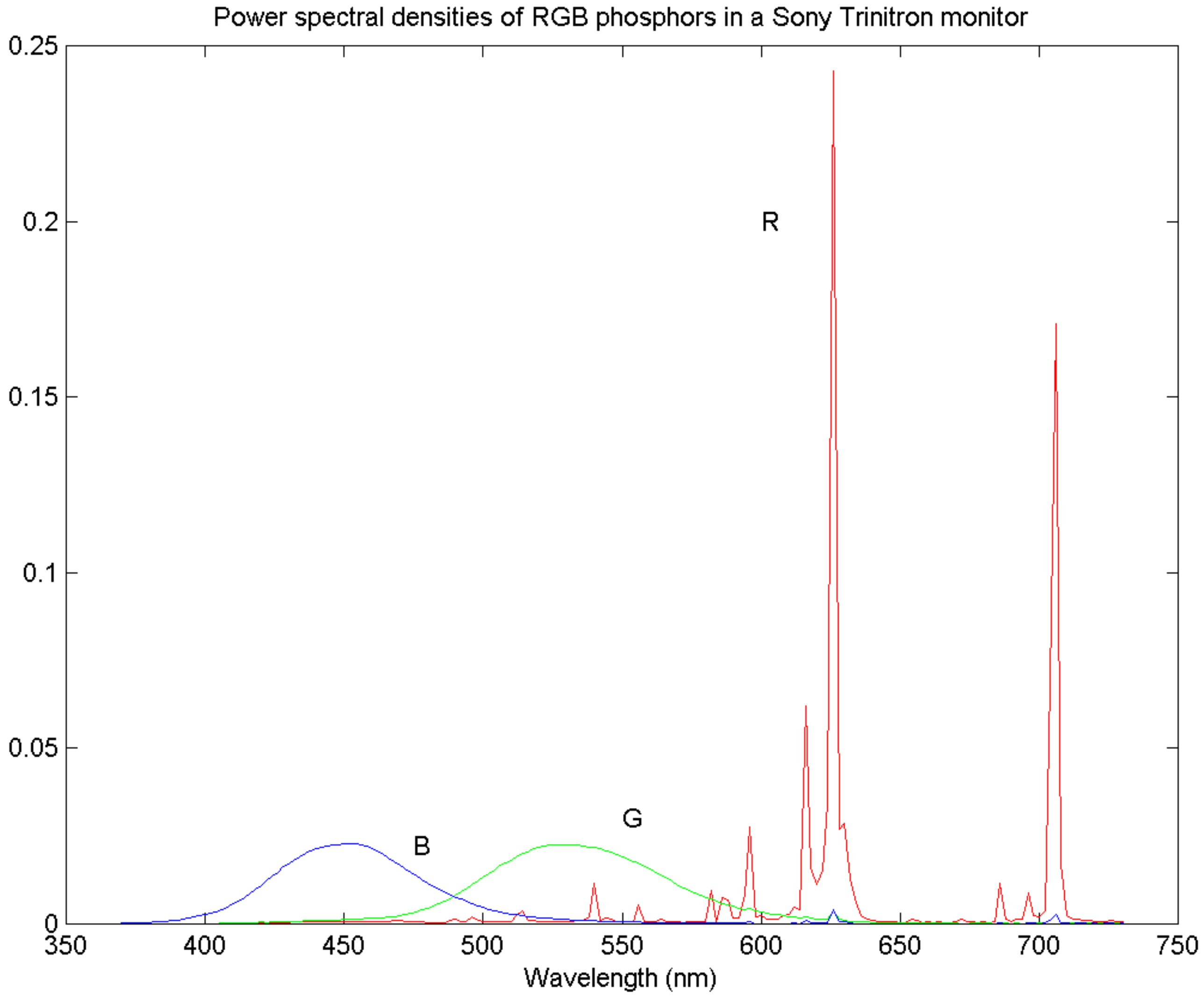
- It is said that about 10% of people don’t perceive the stereoscopic 3D effect.
- Some people may feel queasy when viewing 3D images.
- If you’re in the first group, you may find the images in the presentation rather boring.
- If you’re in the 2nd group please don’t feel obliged to look at the images with the glasses!

Grayscale anaglyph



New Method to Make Anaglyph Images

- Uses the properties of the glasses --- how the two filters affect the wavelengths in the light
- Uses the characteristics of the Human Visual System
- Uses the characteristics of the display device



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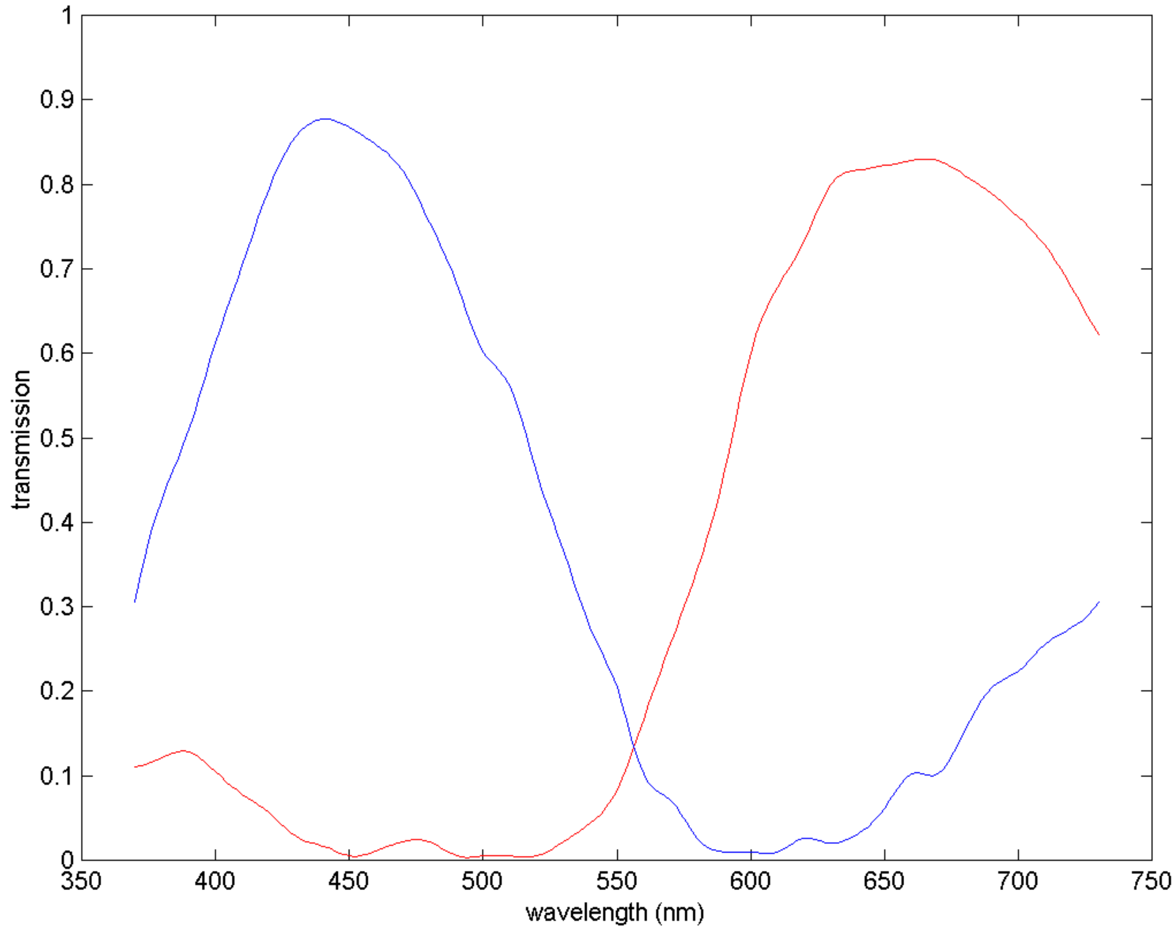
Transmission of red and blue filters



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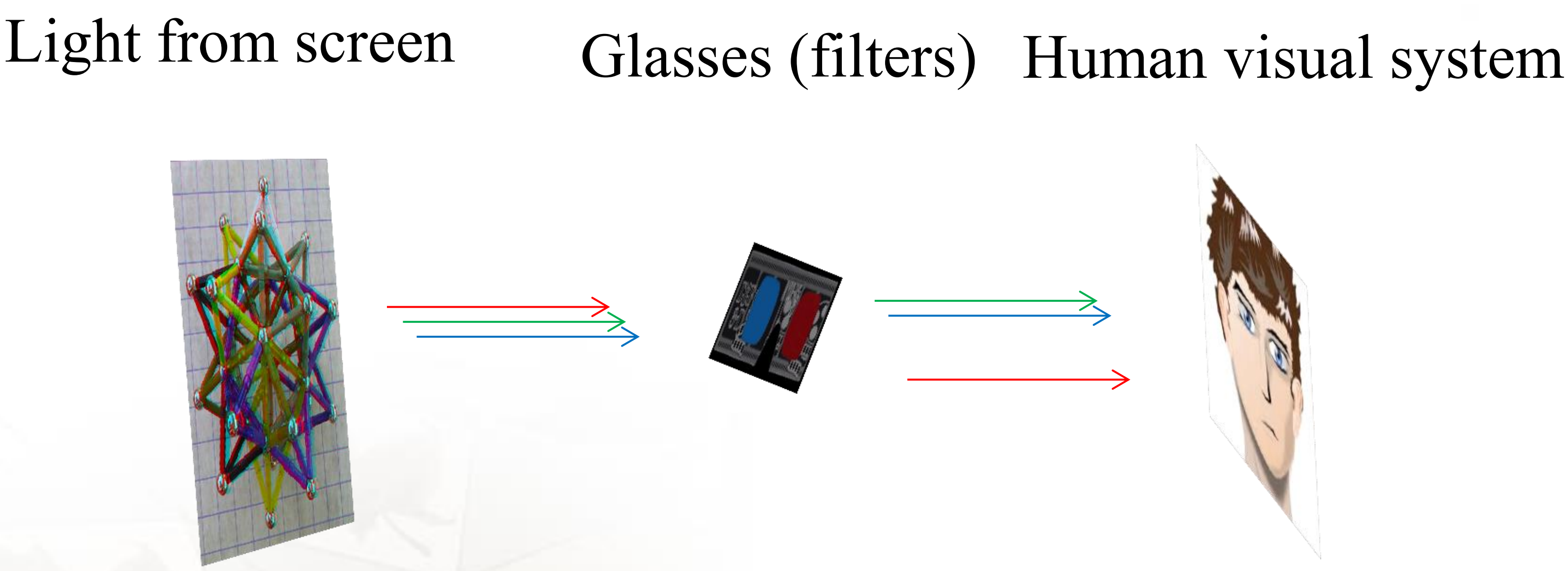
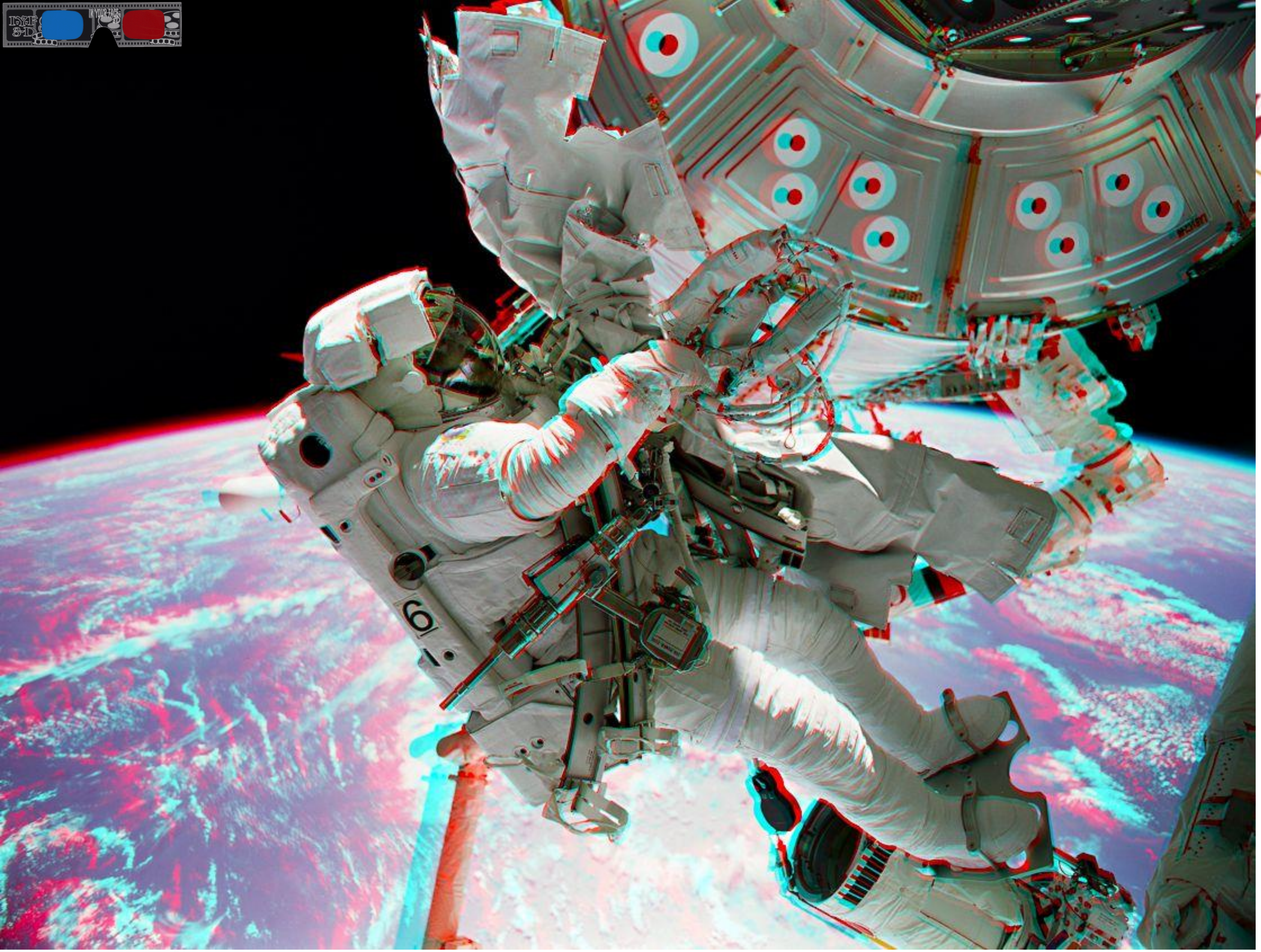
Anaglyph viewing scenario

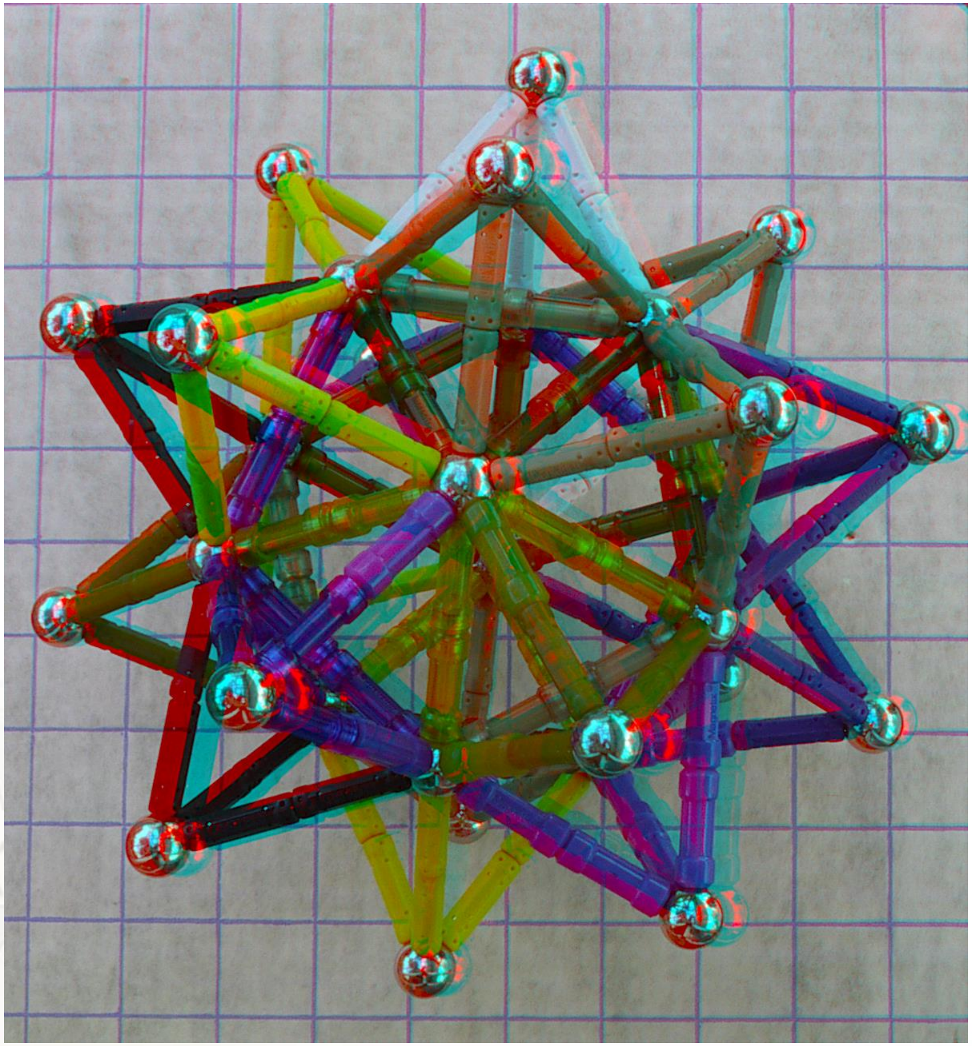


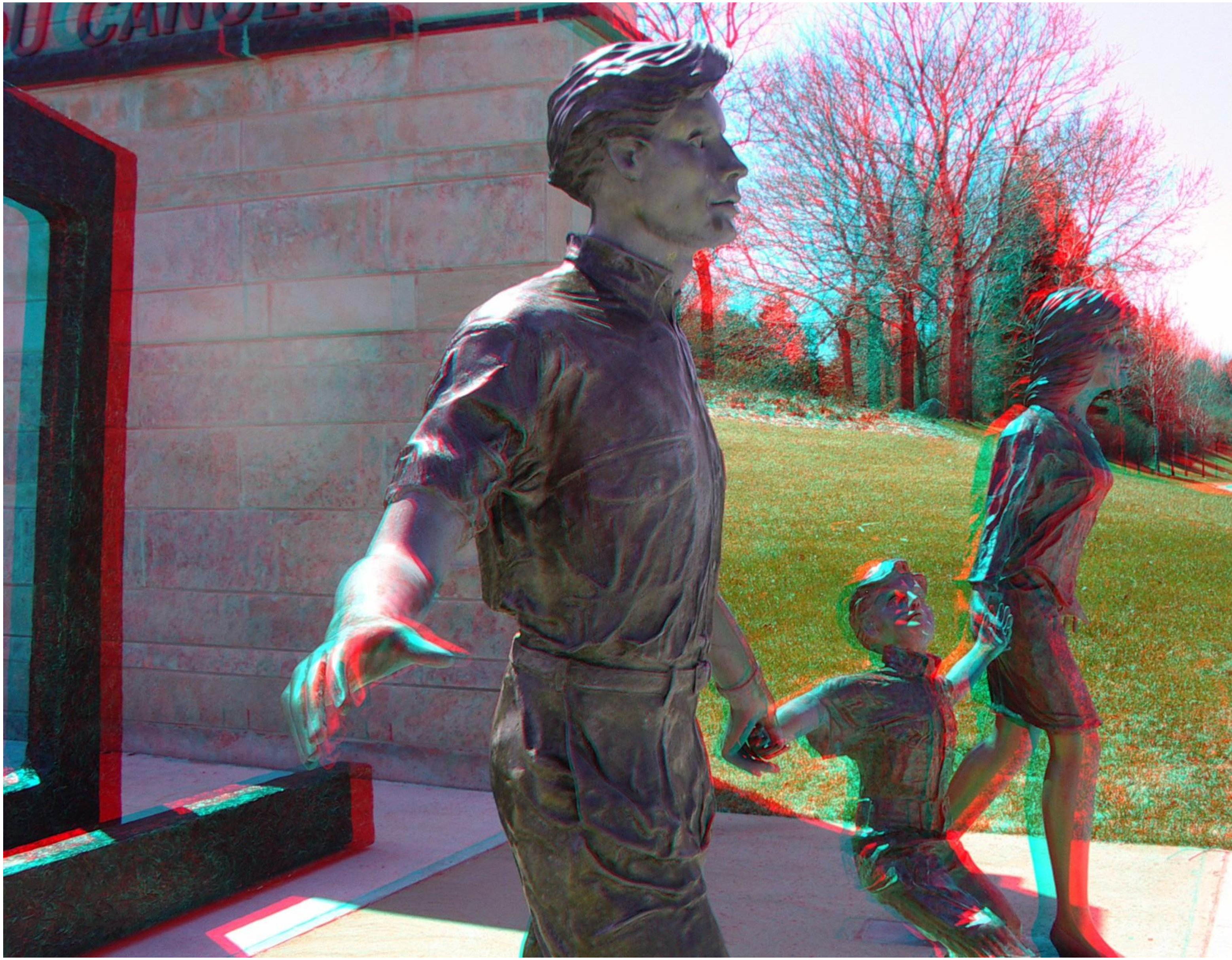
Create the best anaglyph image, such that when passed through the glasses, it gives the viewer the closest rendition to the true stereo pair.


6

[Youtube 3d video]

Star polyhedron





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Stereoscopic panoramas

- Telepresence aims to provide an electronic experience as close as possible to ***being there***.
- We have been working on techniques for virtual navigation in remote real-world environments (Navire project) using omnidirectional images (similar to Google Street View).
- One aspect is stereoscopic omnidirectional imaging.
- Ph.D. student Luis Gurrieri is currently working on this, and I will show some of his results.

Stereoscopic Panoramas

- Living Room
- Lamoureux
- Tabaret

Concluding Thoughts

- Spend a lot of time to choose the best notation to describe the problem.
- Formulate the problem carefully trying to address the fundamental principles.
- Get a bright idea.
- Express your solution in terms of your great notation and your solid formulation.

Acknowledgements

- I would like to thank my many students and collaborators over the past 35 years; I have touched on some of their work here, but of course I could not mention most of it. I am happy to be in contact with most of them on LinkedIn.
- Thanks to NSERC for 35 years of Operating/Research/ Discovery Grant funding. I have had grant #00022 since 1978. Also thanks to BNR and CBC.
- Thanks to Kent Walker of the University's Multimedia Distribution department for replacing the projector in this room within one day.

- And thanks to you for your attention!