

High Speed LiFi Light Communication (LC) Using Color Space Modulation

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Soo-Young Chang [SYCA]

and

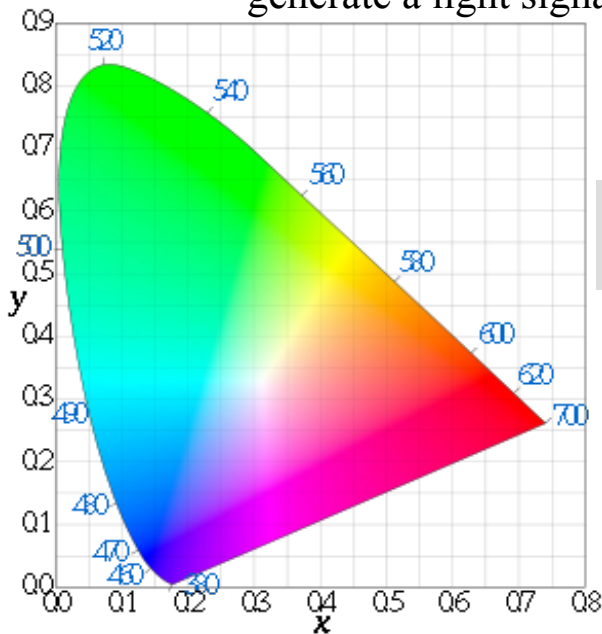
Jaesang Cha [SNUST]

CONSIDERATIONS FOR HIGH EFFICIENT MODULATION FOR LIGHT SIGNALS

- Need of brightness control or not
 - Need superior brightness for optical wireless communications?
 - It is more desirable for performance not to be affected by brightness control.
- Dependency of light source characteristics
 - Is a modulation technique applied not dependent on technical characteristics of LEDs or other light sources deployed?
- Not (or negligibly) affected by background noise or not
 - Offsetting the impact of background light sources
 - Stable data transmission should be achieved even if the background noise is strong.
 - Offers high robustness to background light
- Data speed
 - Low to high data rates to be realized: adaptive to the amount of information delivered
 - **Adaptiveness to various data rates is important.**

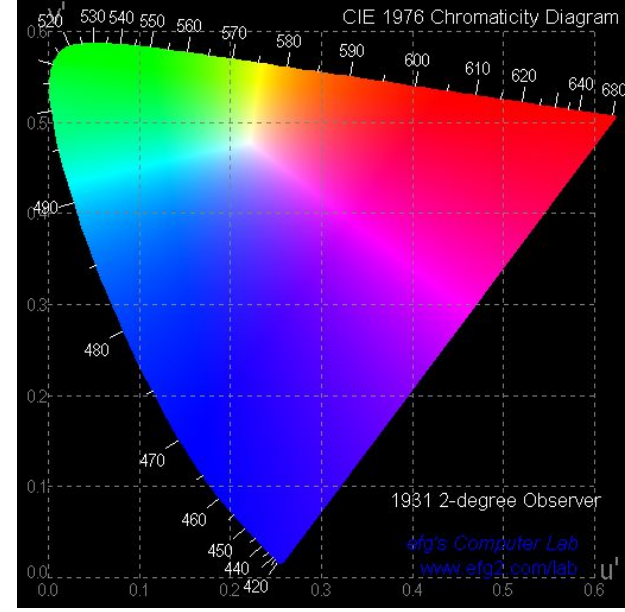
COLOR SPACES UTILIZED FOR LC MODULATION

- Light color spaces
 - Light color spaces can be defined.
 - A point in a color space represents a color of light.
 - Linearity and uniformity work in the space for mixing multiple light signals to generate a light signal having a specific color.



1931 CIE xy
Color space

1976 CIE $u'v'$
Color space



ONE COLOR SPACE: CIE 1931 COLOR SPACE

The CIE xy chromaticity diagram and the CIE xyY color space

- The outer curved boundary is the spectral (or monochromatic) locus, with wavelengths shown in nanometers.
- The concept of color can be divided into two parts: brightness and chromaticity.
- The Y parameter is a measure of the brightness or luminance of a color.

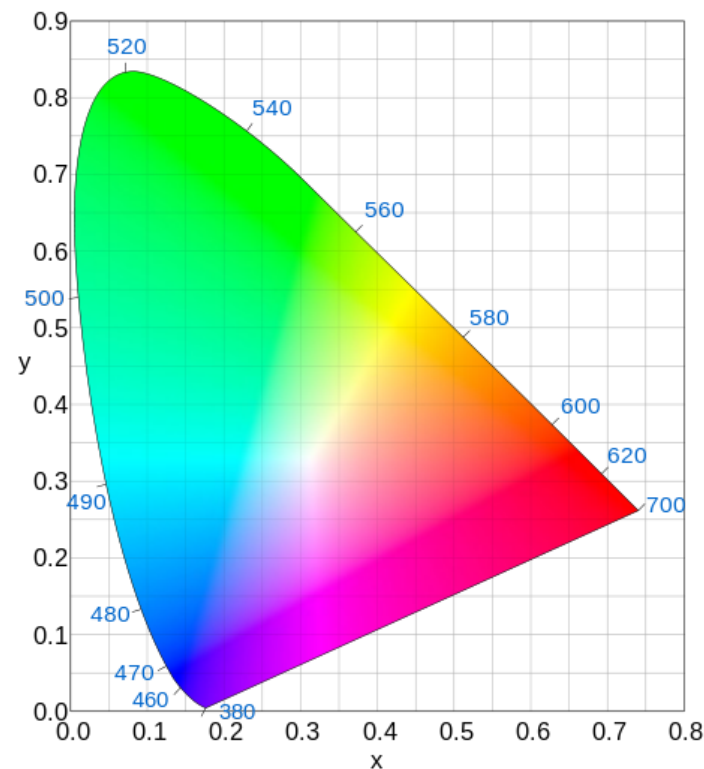
$$x = \frac{X}{X + Y + Z}$$

$$y = \frac{Y}{X + Y + Z}$$

$$z = \frac{Z}{X + Y + Z} = 1 - x - y$$

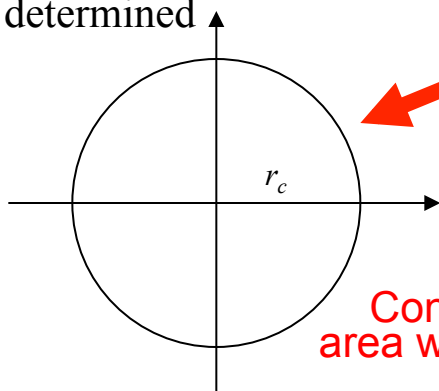
$$X = \frac{Y}{y}x$$

$$Z = \frac{Y}{y}(1 - x - y)$$

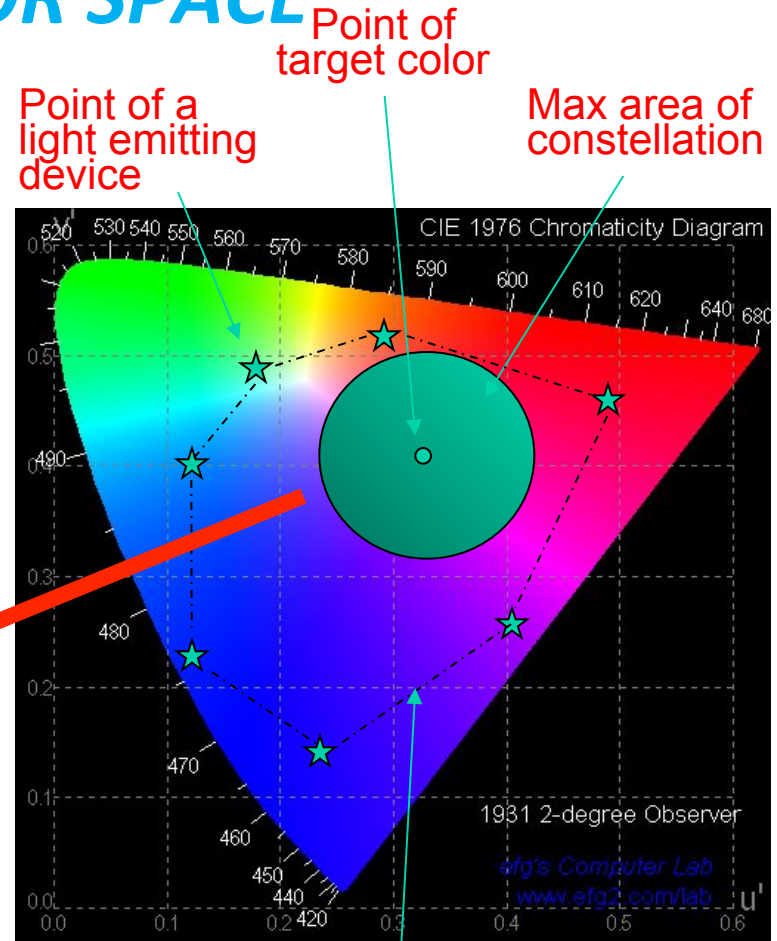


UTILIZATION OF CONSTELLATION ON A COLOR SPACE

- Maximum area of constellation is determined by two factors:
 - Point of a target color visible to human eyes: this point becomes the origin of constellation.
 - Gamut formed by primary color points which represent points of light emitting devices used.
- Maximum constellation area determined



Constellation area with radius r_c



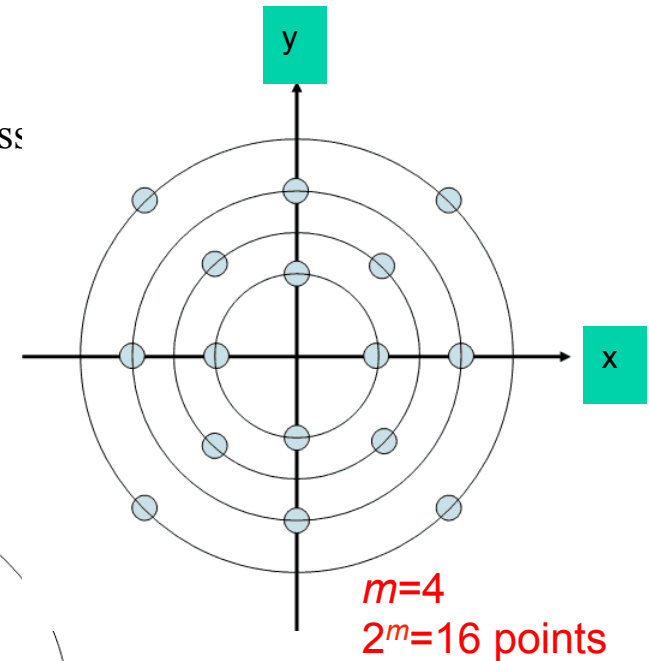
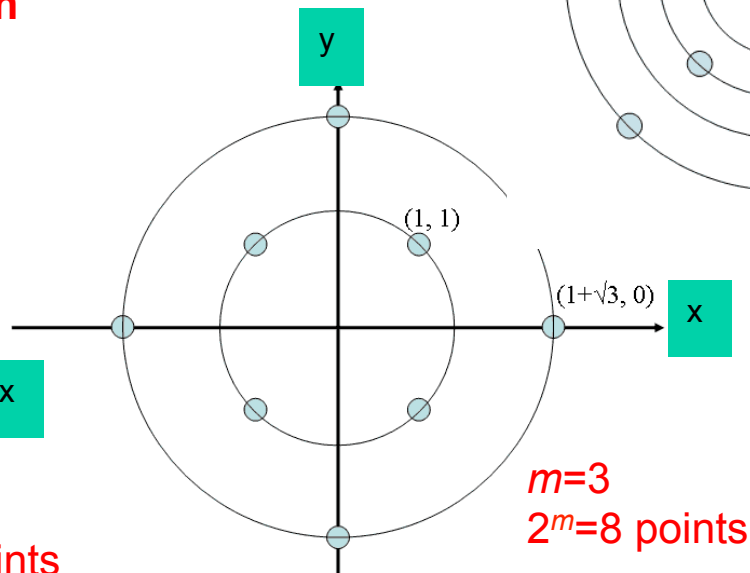
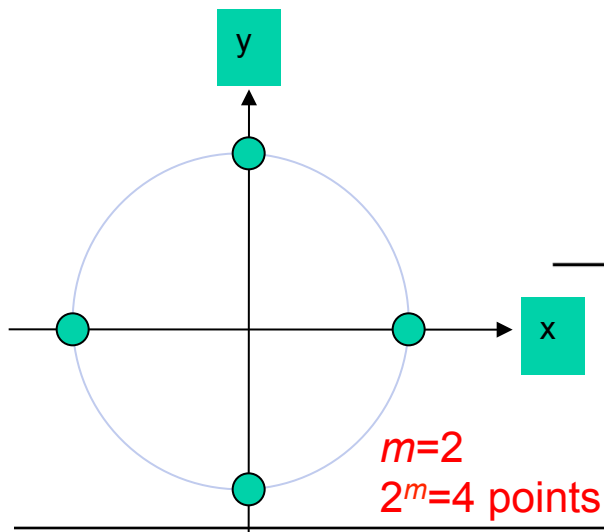
Gamut formed by seven light emitting devices

GENERATION OF CONSTELLATION

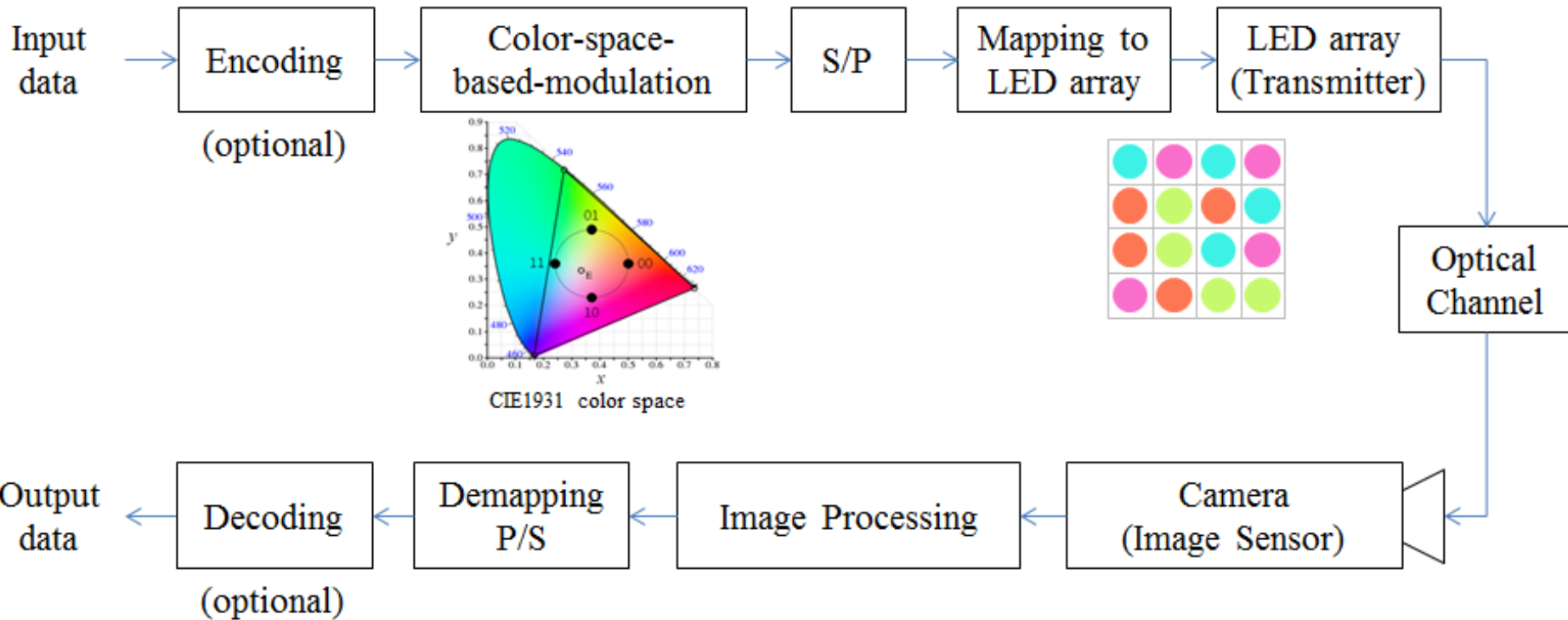
Normalized constellation

Inside a unit circle centered at the origin, 2^m points are arranged so that the distance between any two points is maximized.

Examples of constellation



LC SYSTEM DIAGRAM USING COLOR SPACE MODULATION



Color independent Visual-MIMO tranceiving procedure

CONCLUSIONS

- Color space modulation scheme has some advantages
 - Independent of brightness control
 - Not to be affected by brightness control.
 - Dependency of light source (such as LEDs) characteristics
 - Modulation technique applied is not directly dependent on technical characteristics of LEDs or other light sources deployed.
 - Not (or negligibly) affected by background noise
 - Adaptiveness to various data rates
 - Simple implementation
- This modulation scheme may have better performance than other intensity modulations.
 - Need more simulation results .
- This modulation scheme can be applied to High Rate LC areas as well as other low rate LC areas.