Dear Vvvvellows,
a warm welcome to the workshop of

Video Tracking

NODE10
FORUM FOR
DIGITAL ARTS

NOVEMBER, 15th - 20th 2010
FRANKFURTER KUNSTVEREIN
GERMANY

Video Tracking Workshop at node10

Christian Engler (wirmachenbunt) & Frank Langer (frank)

Chris Engler teaches vvvv at the Muthesius Academy of Fine Arts & Design since 2004. He offers an introduction to v4 every semester and supports advanced users in disciplines such as generative animation, motion sensing and interaction design. The students are coming from all kinds of departments: Fine Arts, Industrial Design and Interior Design.
As part of his job at the University, he developed not just the very first dome projection system with vvvv (ICH²) but also a neat Multitouch Table called Future Ocean Explorer.

And last but not least, he runs a design studio in Hamburg called wirmachenbunt.
http://www.wirmachenbunt.de/

Frank Langer worked for 3 years as broadcast cameraman and got interest in interactive video. At university he dived into video tracking, gestures and lighting, which he completed with his graduation on Digital Film Production Techniques.
Graduation work was done with V4 and kindly supported by Meso / Max Wolf. His particular interest covers the field from light->capture->algorithm->interaction with image.
Frank lives and works in Cologne as Interaction Designer for ag4 mediafacade.

http://www.lightinsphere.de
http:// lightinsphere.tumblr.com

we are

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Christian Engler (wirmachenbunt) & Frank Langer (frank)

Lighting

Capturing

Transmitting

Calculating

Presenting

Recognising

Analysing

Interacting

overview

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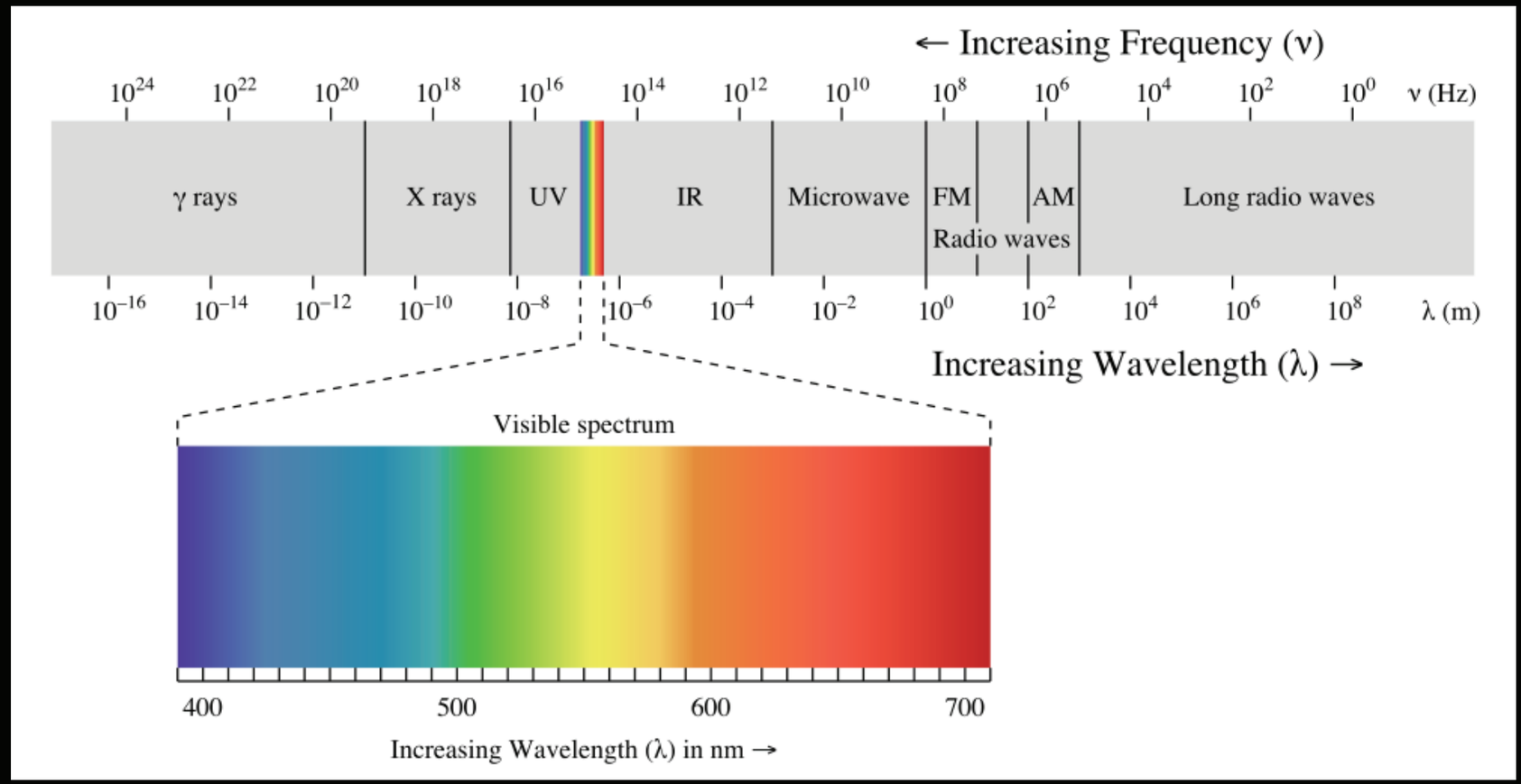
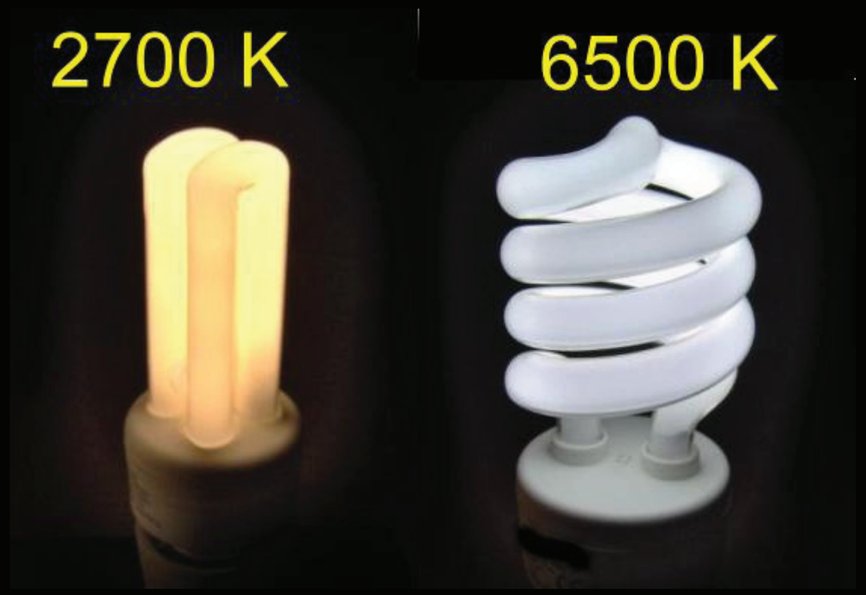
Lighting

Color	Wavelength
violet	380–450 nm
blue	450–475 nm
cyan	476–495 nm
green	495–570 nm
yellow	570–590 nm
orange	590–620 nm
red	620–750 nm



http://en.wikipedia.org/wiki/Visible_light

light basics

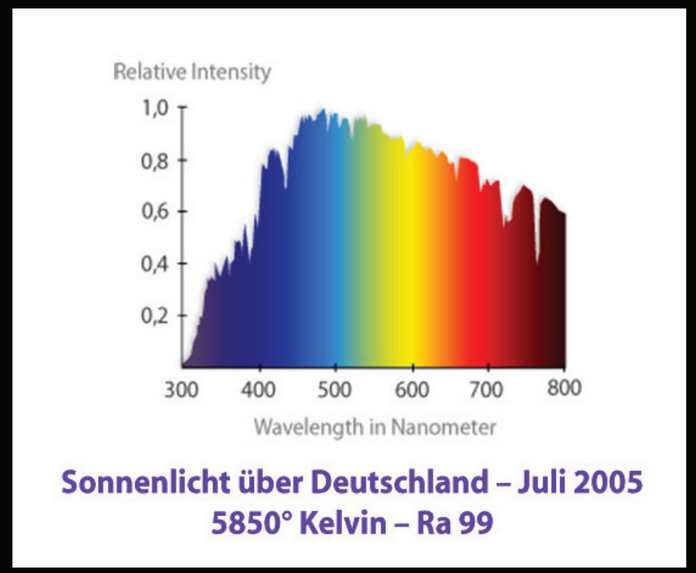


http://de.wikipedia.org/w/index.php?title=Datei:Farb.Temp.jpg

http://de.wikipedia.org/w/index.php?title=Datei:Whitebalance4.jpg

color temperature

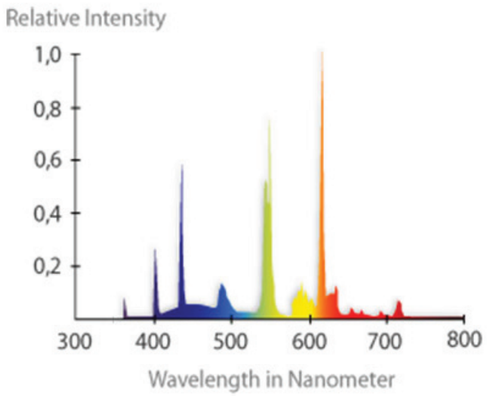
sunlight



Sonnenlicht über Deutschland – Juli 2005
5850° Kelvin – Ra 99

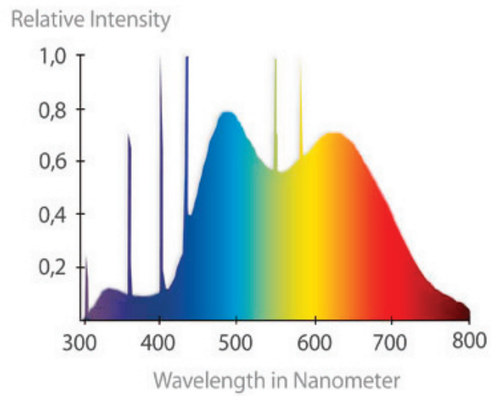
http://www.lifelite.de/spektralanalyse_leuchtstoffroehren.php

fluorescent



Gewöhnliche Leuchtstoffröhre
4200° Kelvin – Ra 83

special fluorescent



LifeLite® Vollspektrum Tageslicht Leuchtstoffröhre
5800° Kelvin – Ra 96

color temperature

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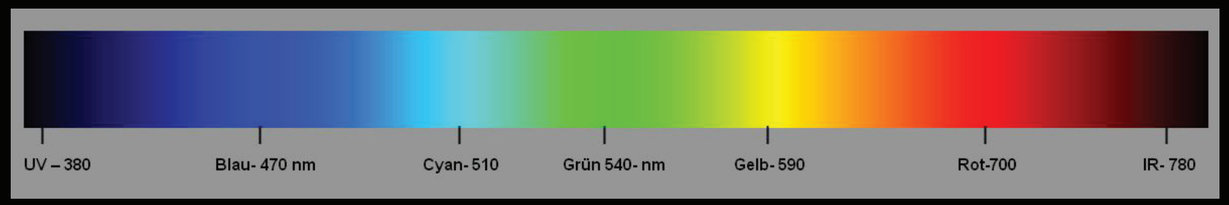
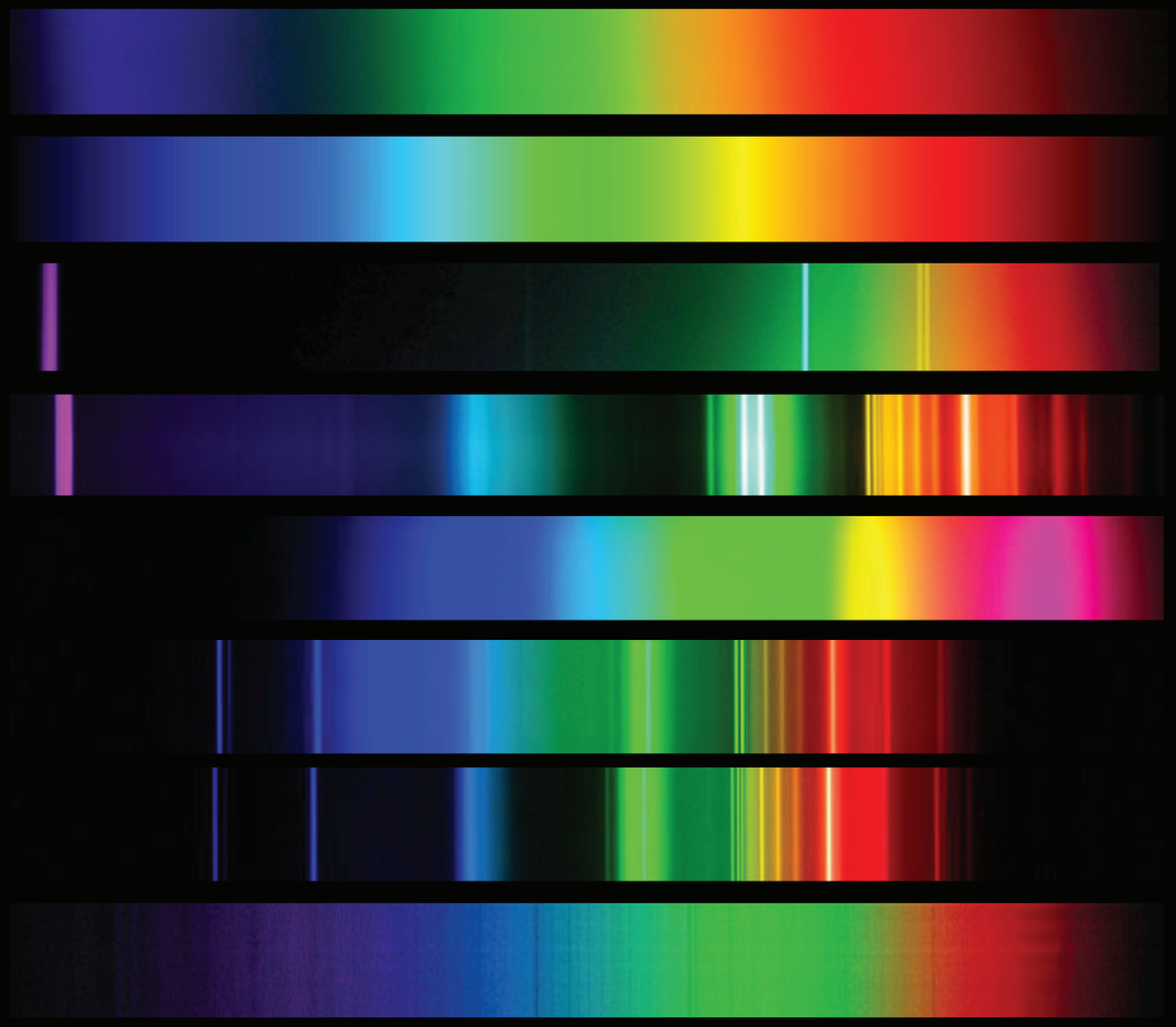


legend



led 3000k Warm White

halogen

fluorescent 1

fluorescent 2

common bulb 2700K

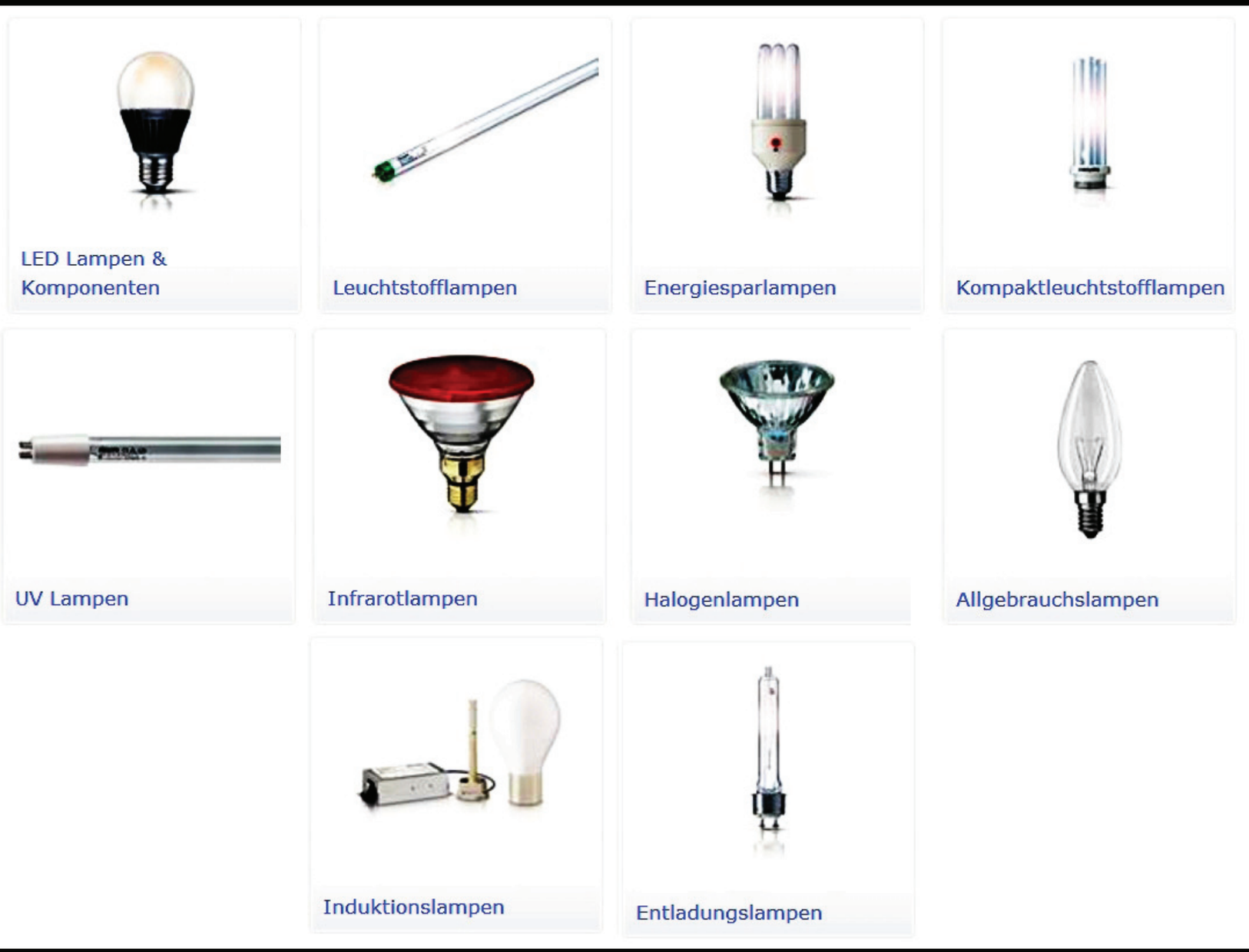
compact fluorescent lamp 5800K

compact fluorescent lamp 2700K

sun light

http://astro.uni-tuebingen.de/~grzy/SPEKTROGRAPHIE.html

color temperature

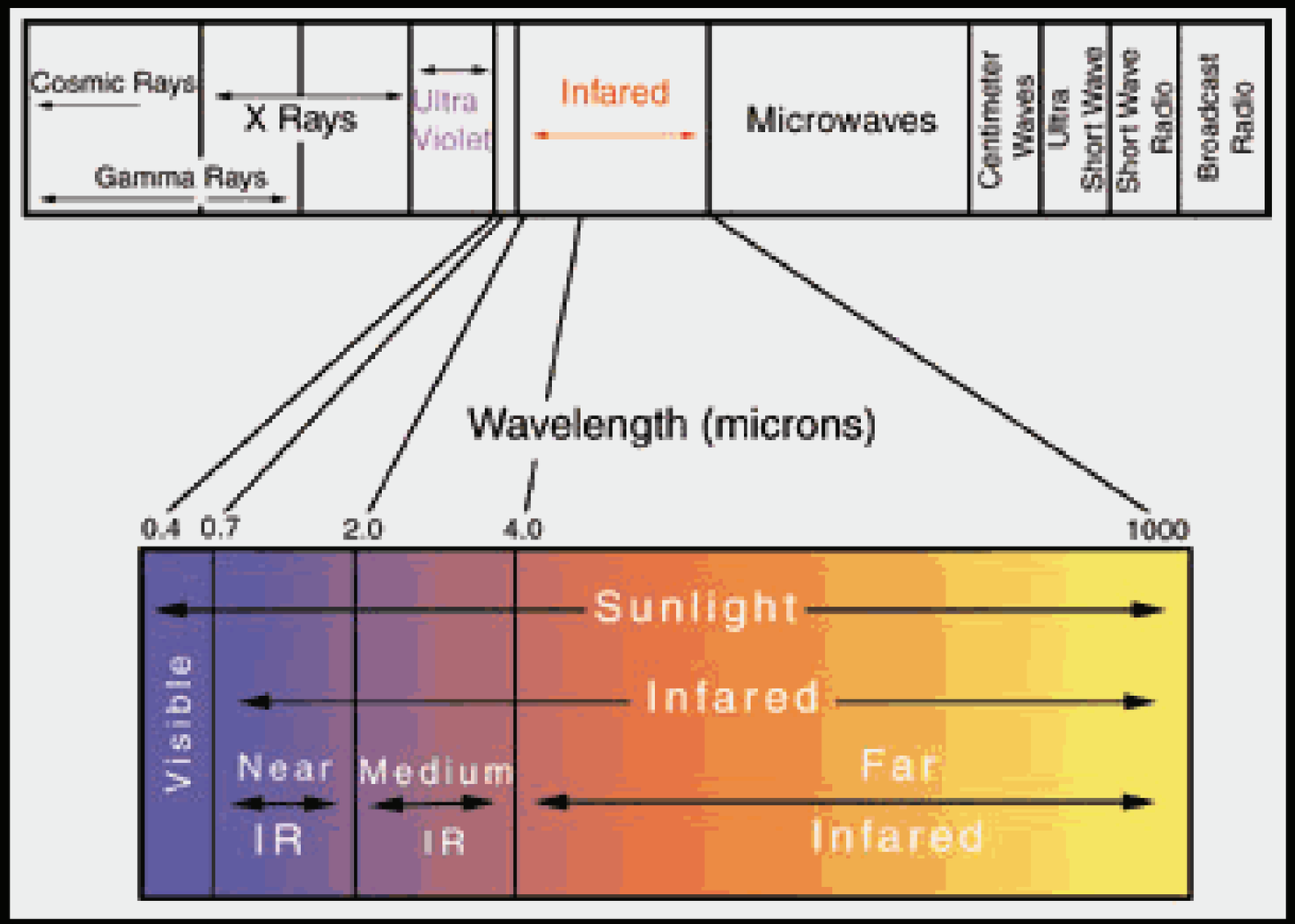


http:/www.philips.com

lamp variety

infrared

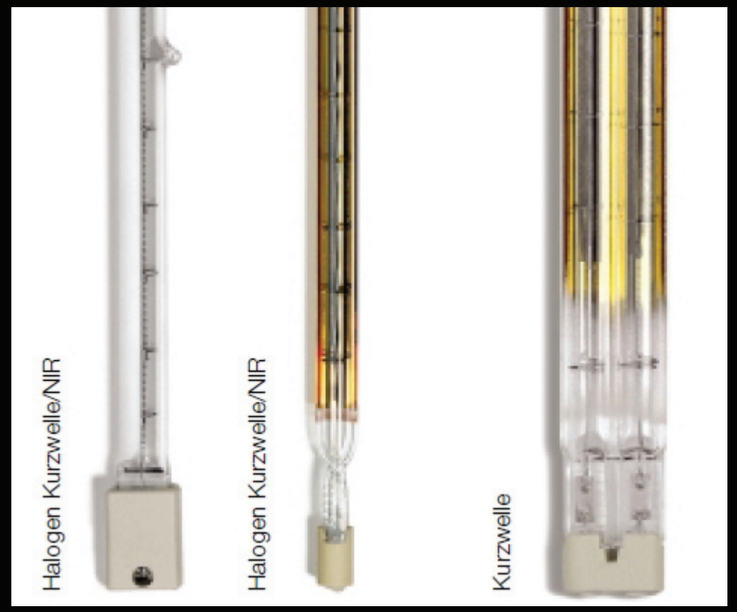
visible



http://www.watershed.net/About-Saunas/

infrared light

IR lamp
industry IR lamps



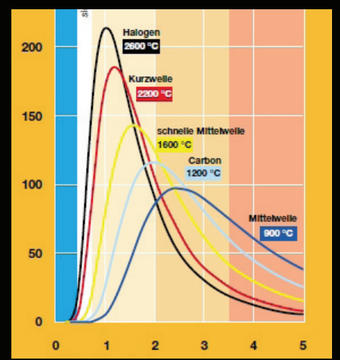
http://www.heraeus-noblelight.com

IR lamp
health lamp

http://www.philips.com

common bulb (!)
radium

http://www.radium.de



infrared lamps

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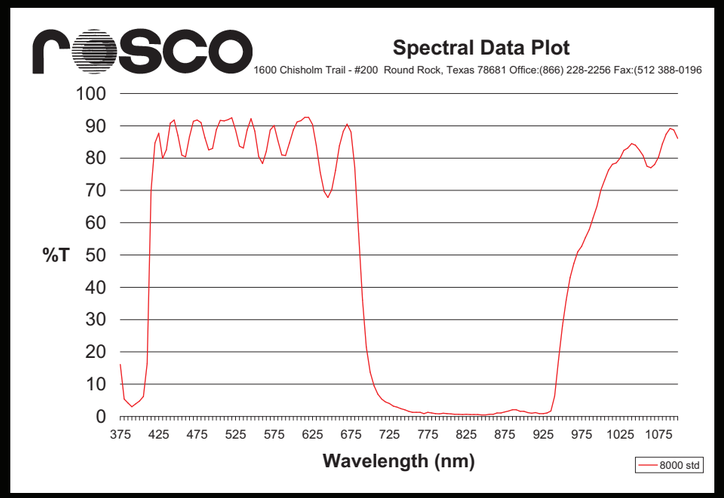
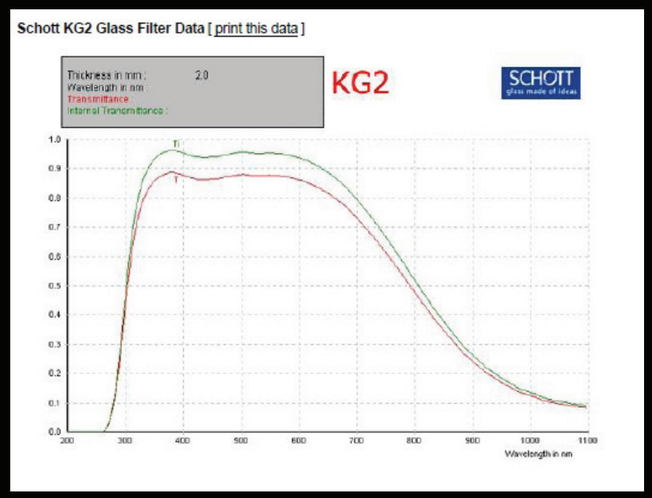
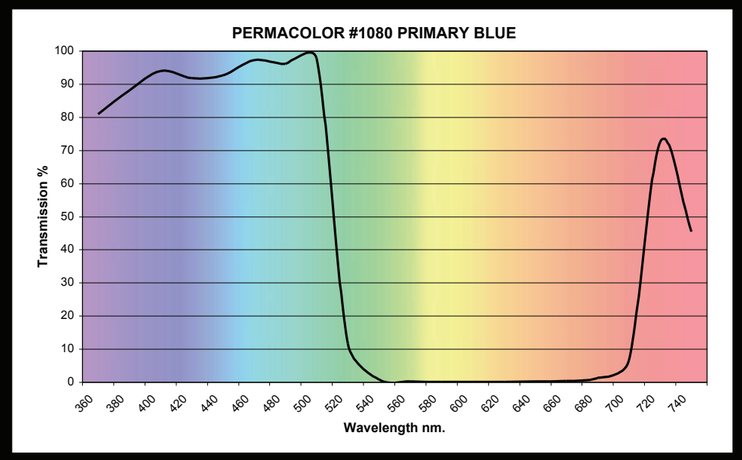


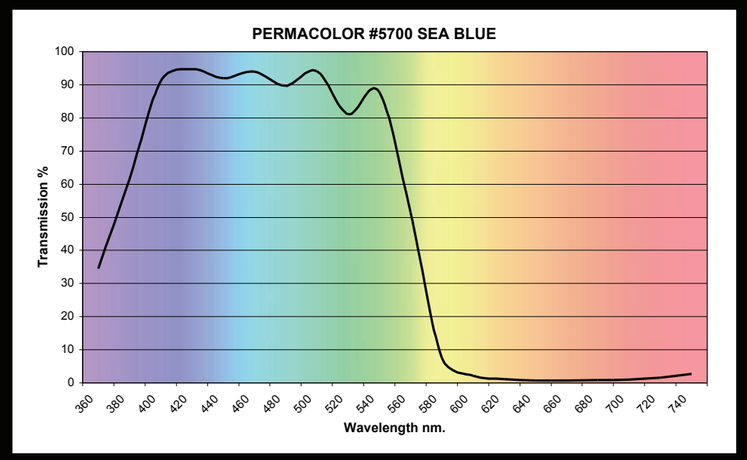
rosco hot mirror



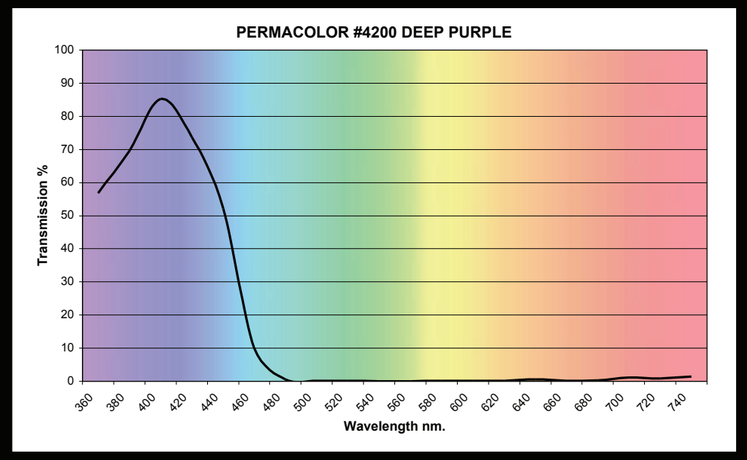
schott heat filter



rosco permacolor 31080



rosco permacolor 35700



rosco permacolor 34200

infrared filter

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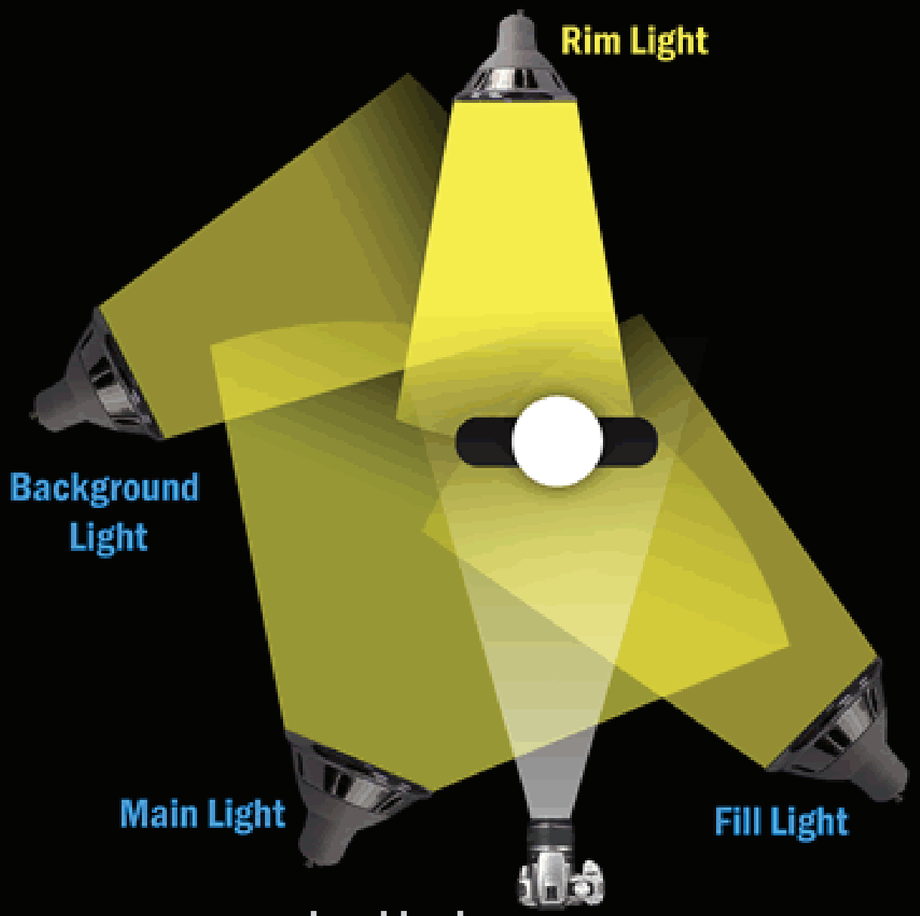
background light

http://www.shortcourses.com/



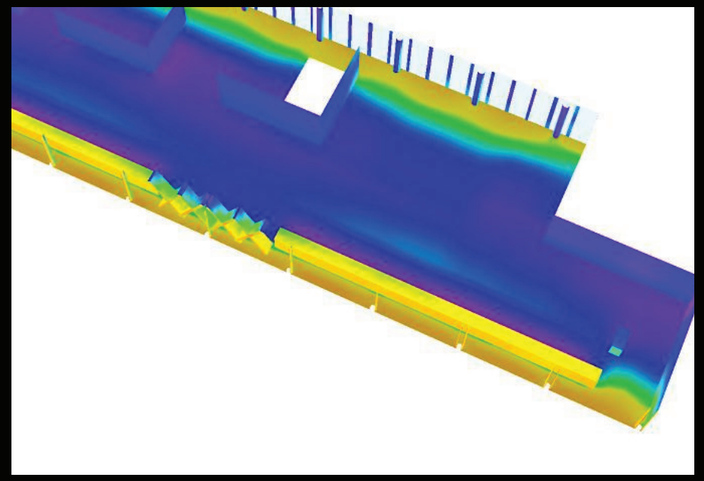
fill light

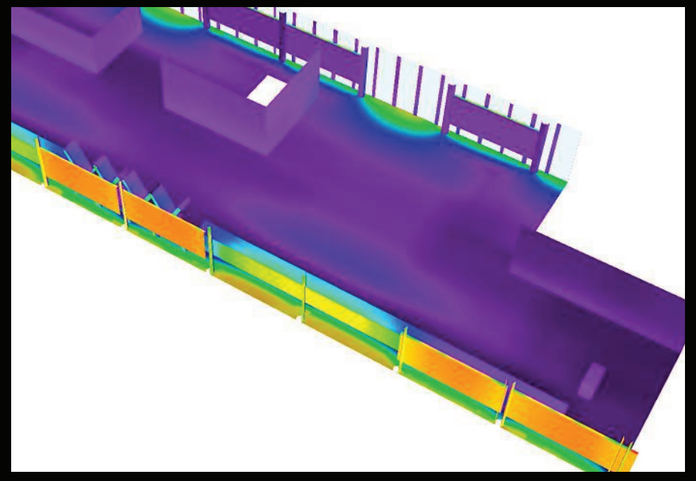
mainlight

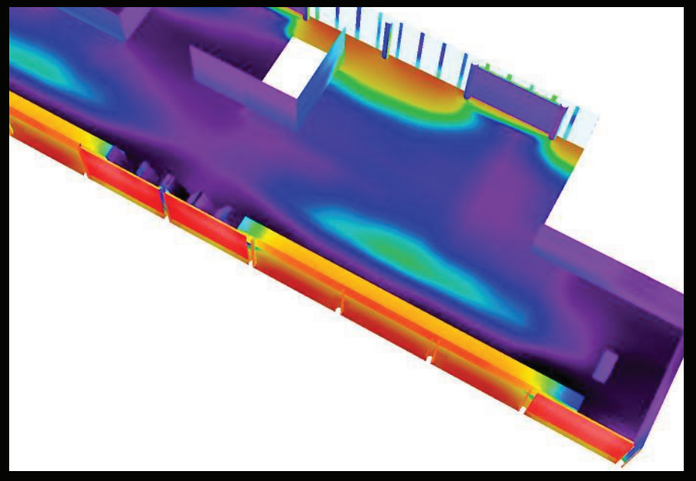
rimlight

light position

all pics april sunlight 18h







calculation of sun light direction,
intensity, contrast, glares,
at certain places on specific dates

- http://www.dial.de/
- http://www.relux.biz/

light calculation

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Capturing

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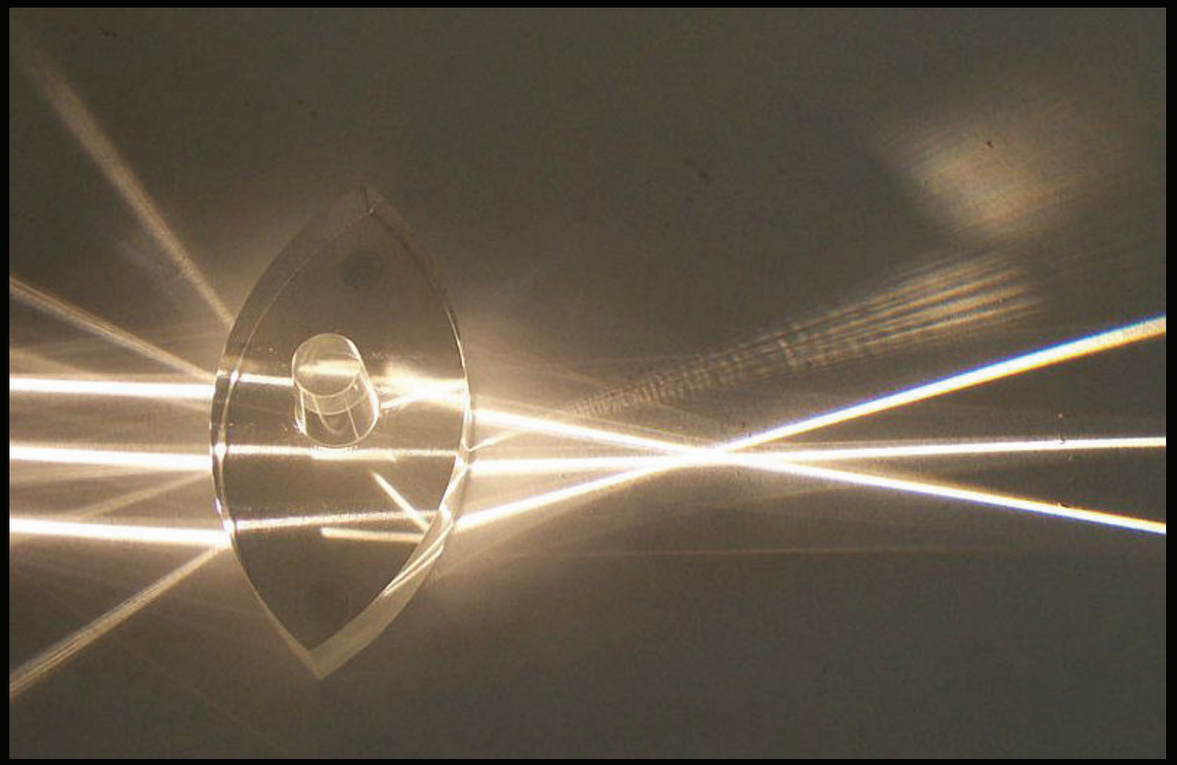

http://en.wikipedia.org/wiki/File:Large_convex_lens.jpg

http://www.flickr.com/photos/tambako/

optics

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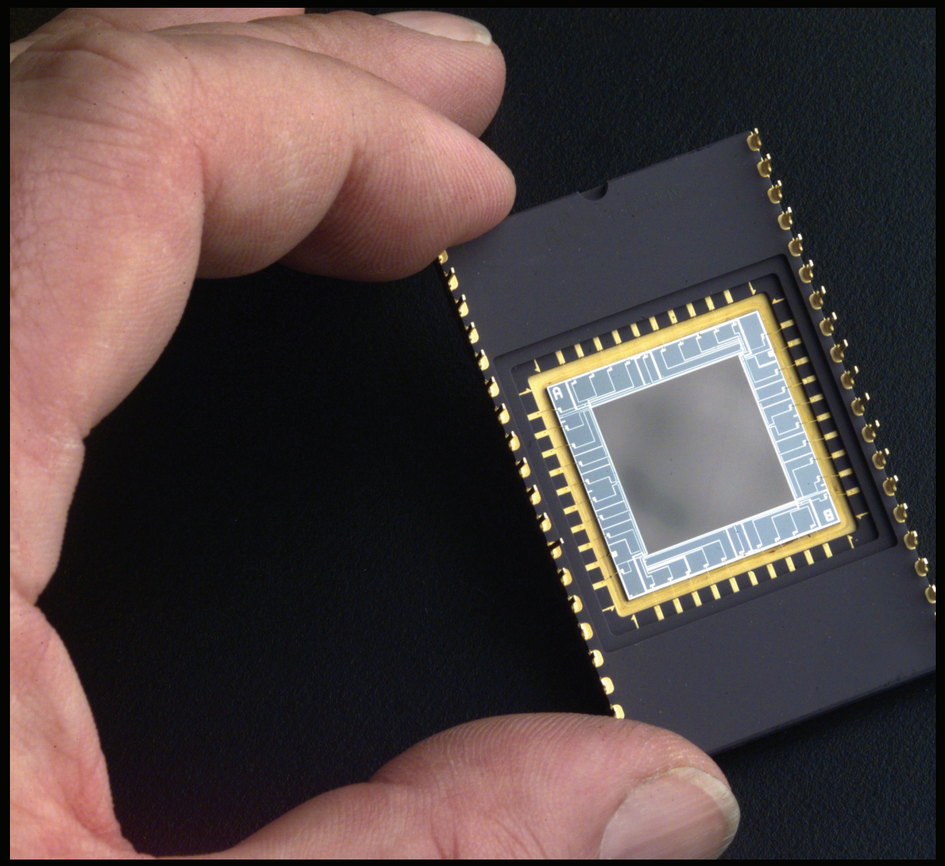
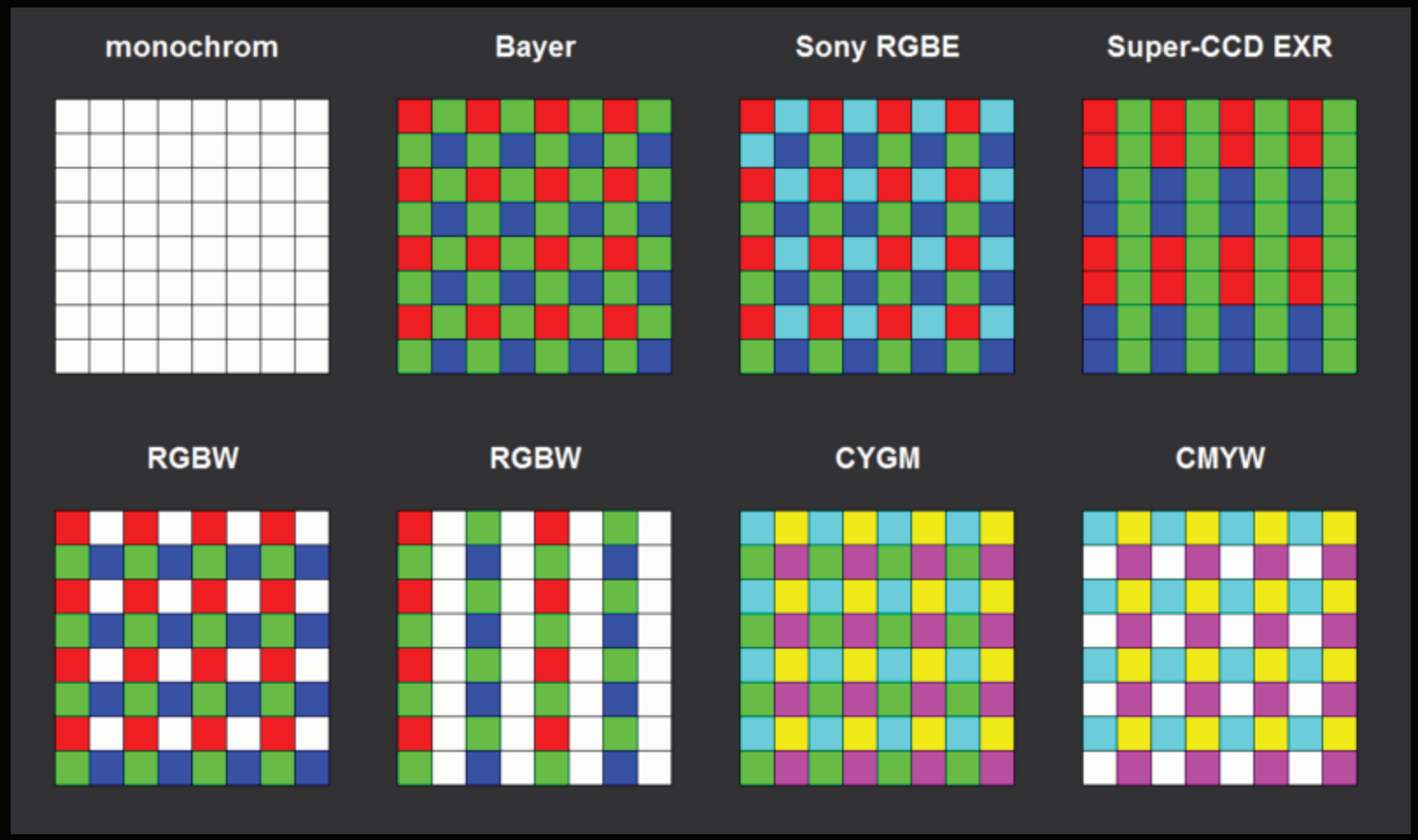


http://de.wikipedia.org/wiki/Datei:CCD.jpg



http://de.wikipedia.org/wiki/Datei:CFA_Pattern_fuer_quadratische_und_rechteckige_Pixel.png

One chip is dedicated for each color (RGB), whereas a single chip cam uses a color pattern to capture all 3 colors with one chip only - at cost of quality.

http://en.wikipedia.org/wiki/CCD_sensor

chip

USB

FireWire

GigE-Cam

W-Lan Cam

CCTV Fixedcase

cam types

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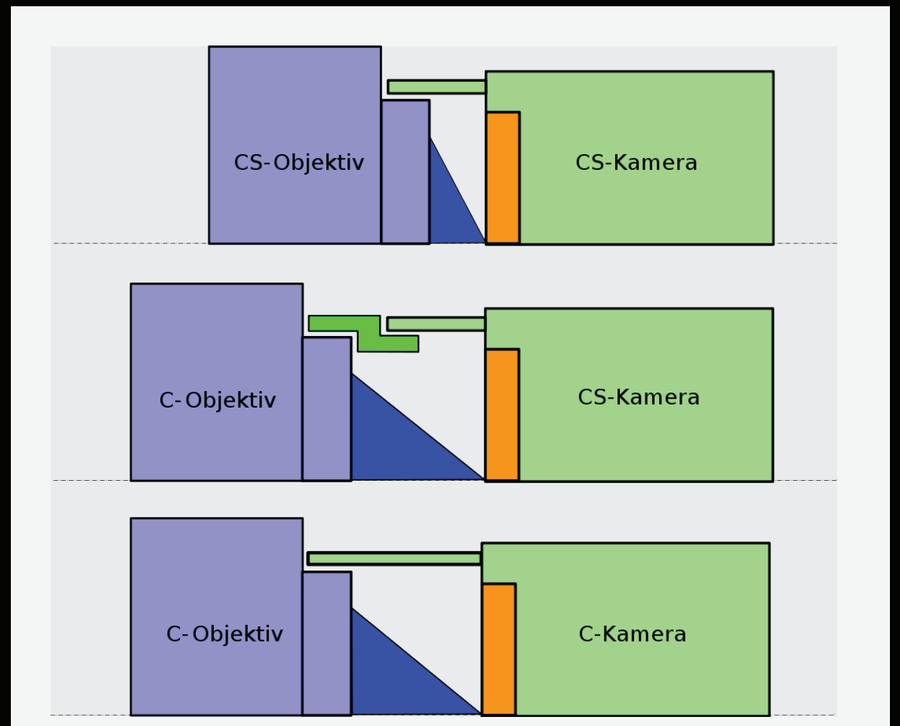


de.wikipedia.org/wiki/C-Mount

cs- / c-mount

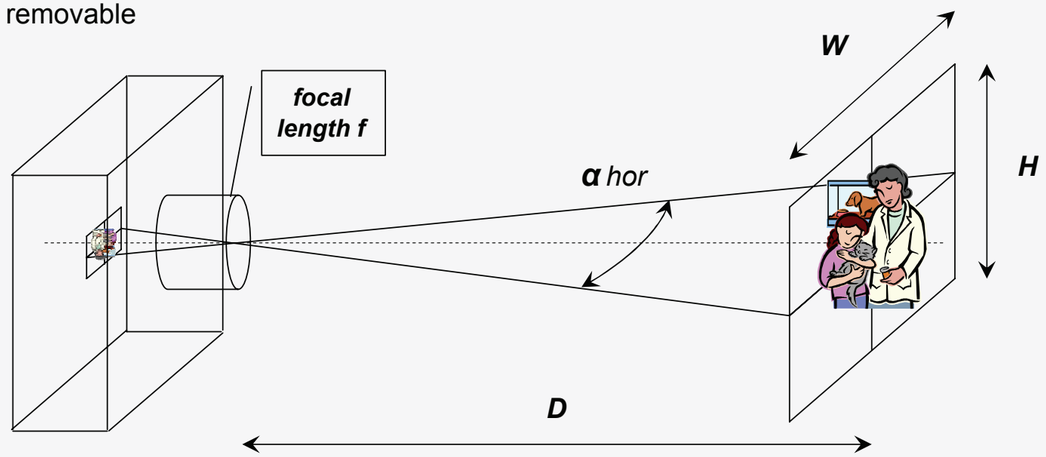
Having two values of the triangle

-dof / focal length
-image width / angle
-chip size / diameter

can give you the missing one.

Viewing angles for **unibrain** Fire-i Board camera

Lens is M12x0,5 removable



Lens focal length	Horizontal viewing angle	Vertical viewing angle	Diagonal viewing angle	Size of the reality for D = 0,5 m (see note)		Size of the reality for D = 5 m	
f	***α hor***	***α vert***	***α diag***	***W***	***H***	***W***	***H***
(mm)	(°)	(°)	(°)	(m)	(m)	(m)	(m)
2,10	80,95	65,24	93,70	0,853	0,640	8,53	6,40
2,50	71,27	56,52	83,72	0,717	0,538	7,17	5,38
3,00	61,70	48,26	73,49	0,597	0,448	5,97	4,48
3,60	52,93	40,94	63,78	0,498	0,373	4,98	3,73
4,00	48,26	37,14	58,50	0,448	0,336	4,48	3,36
4,30	45,25	34,71	55,03	0,417	0,313	4,17	3,13
6,00	33,26	25,25	40,94	0,299	0,224	2,99	2,24
8,00	25,25	19,07	31,28	0,224	0,168	2,24	1,68
12,00	16,99	12,78	21,15	0,149	0,112	1,49	1,12
16,00	12,78	9,60	15,94	0,112	0,084	1,12	0,84

Note : each lens has a minimum object distance, that may be longer than 0,5 m

http://www.unibrain.com

optic choice

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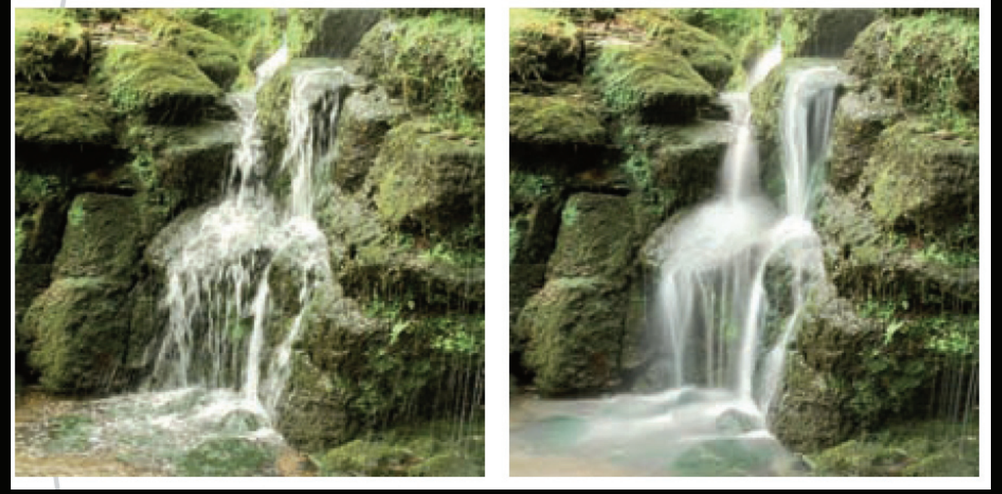
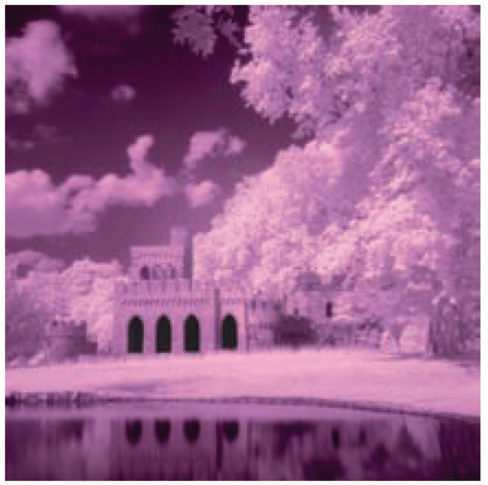
Close up-filter

ND-filter





IR-filter

Pol-filter

b+w www.schneiderkreuznach.com

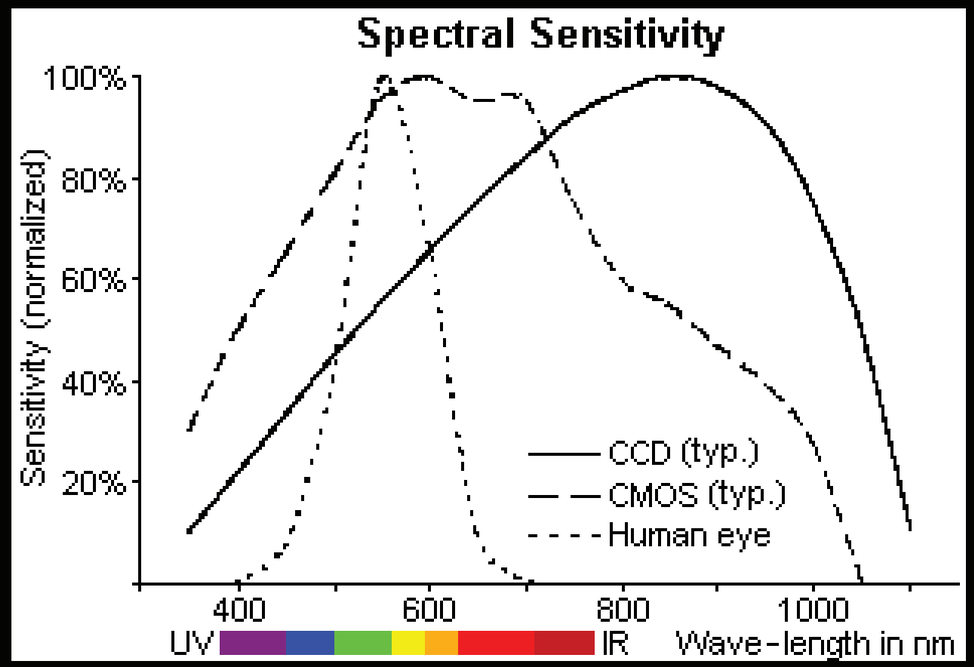
optic choice

CCD

high sensitivity in NIR (max > 650 nm)
better colours,
better contrasts,
especially at low or bright lights

CMOS

closer to human vision (max > 550 nm green)
small housings
specific ROI/areas can be addresses on chip
thus capable of ultra high fps for small areas



http://www.fen-net.de/walter.preiss/d/slomoinf.html

- Daniel Göhring - http://bib.drgoehring.de/goehring02ccdvscmos.pdf
- http://www.fen-net.de/walter.preiss/d/slomoinf.html

ccd vs cmos

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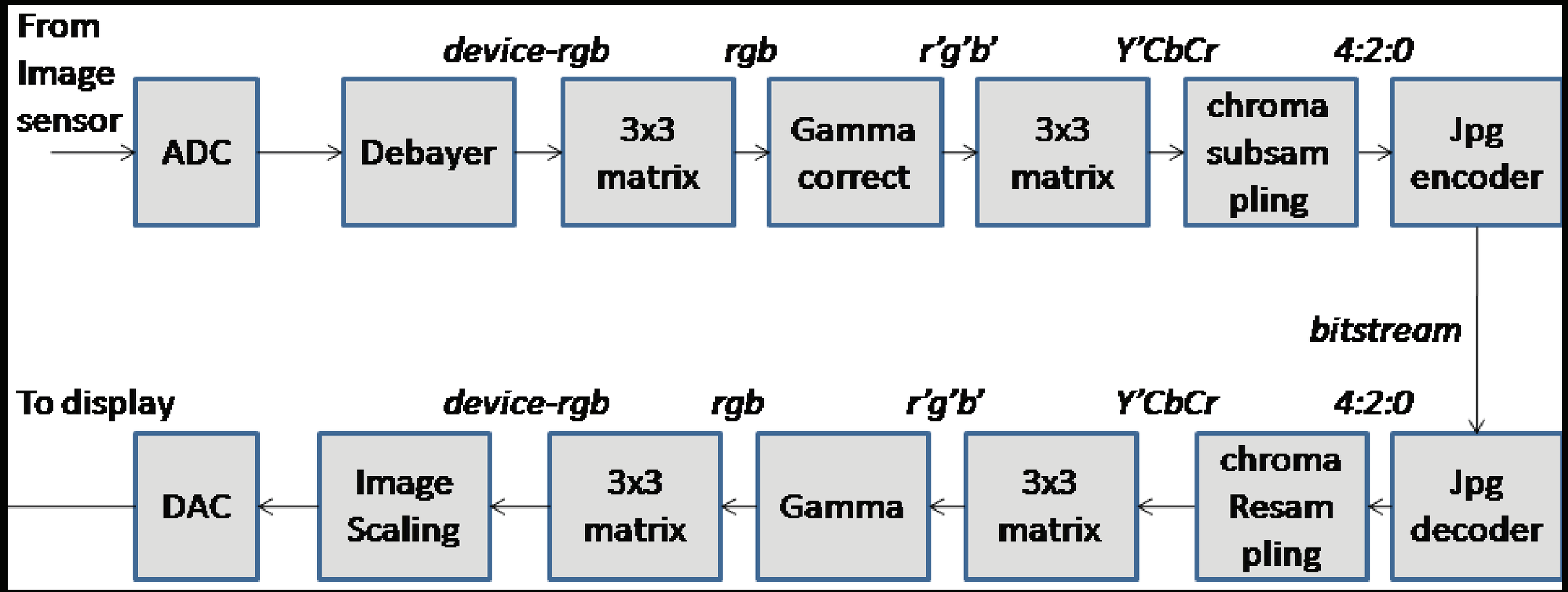
Transmitting



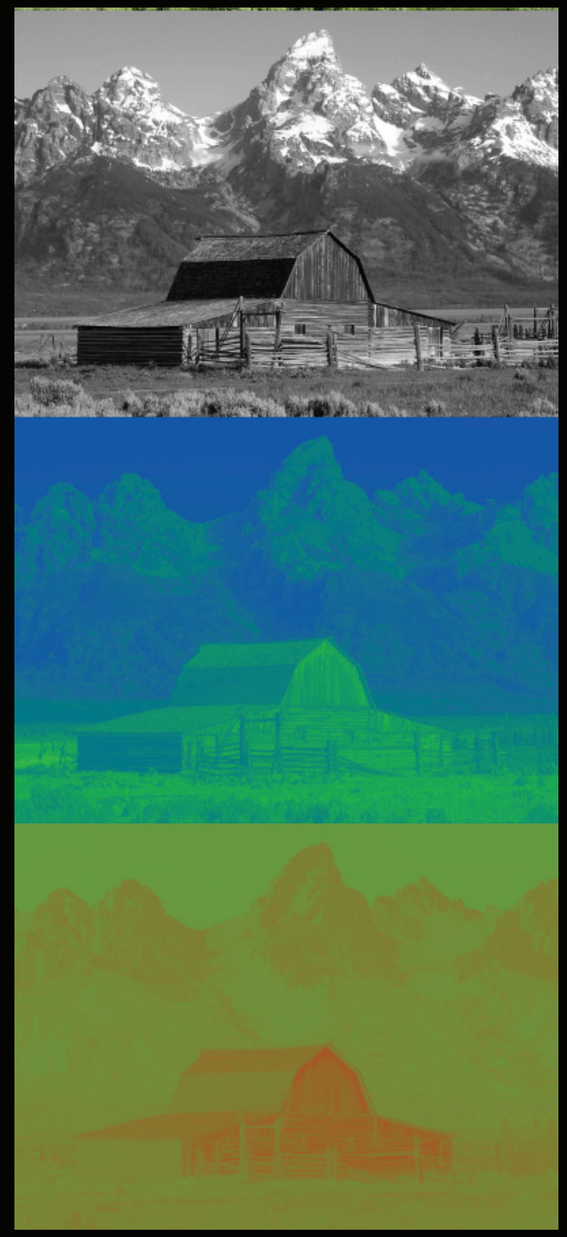
http://en.wikipedia.org/wiki/File:Image_pipeline2.png

image pipeline

Historically, YUV was used for a specific analog encoding of color information in television systems, as there still were BW telies. While YCbCr was used for digital encoding, nowadays both is just called YUV.

http://en.wikipedia.org/wiki/YUV

http://en.wikipedia.org/wiki/File:Barn-yuv.png



yuv / y'cbcr colormodels

RGB to YUV Conversion

$$Y = (0.257 * R) + (0.504 * G) + (0.098 * B) + 16$$

$$Cr = V = (0.439 * R) - (0.368 * G) - (0.071 * B) + 128$$

$$Cb = U = -(0.148 * R) - (0.291 * G) + (0.439 * B) + 128$$

YUV to RGB Conversion

$$B = 1.164(Y - 16) + 2.018(U - 128)$$

$$G = 1.164(Y - 16) - 0.813(V - 128) - 0.391(U - 128)$$

$$R = 1.164(Y - 16) + 1.596(V - 128)$$

quelle:http://www.fourcc.org/fccyvrgb.php

yuv / rgb conversion

4:4:4 (R'G'B' (no subsampling))

-HDCAM SR can record 4:4:4 R'G'B' over dual-link HD-SDI.

4:2:2

-AVC-Intra 100
-Digital Betacam
-DVCPRO50 and DVCPRO HD
-Digital-S
-CCIR 601 / Serial Digital Interface / D1
-ProRes (HQ, 422, LT, and Proxy)
-XDCAM HD422

4:2:1

-very few software or hardware codecs use this sampling model

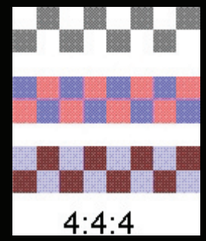
4:1:1

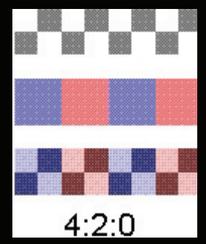
Initially, 4:1:1 chroma subsampling of the DV format was not considered
to be broadcast quality and was only acceptable for low-end and consumer applications
-DVCPRO (NTSC and PAL)
-NTSC DV and DVCAM
-D-7

4:2:0

-MPEG
-PAL DV and DVCAM
-HDV
-AVCHD and AVC-Intra 50
-Apple Intermediate Codec
-most common JPEG/JFIF, H.261, and MJPEG implementations
-VC-1

http://en.wikipedia.org/wiki/Chroma_subsampling

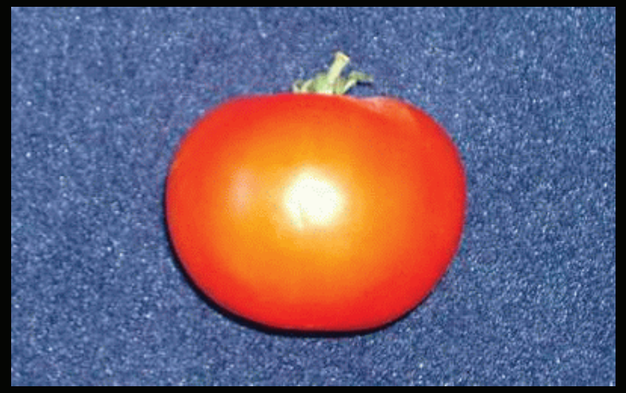




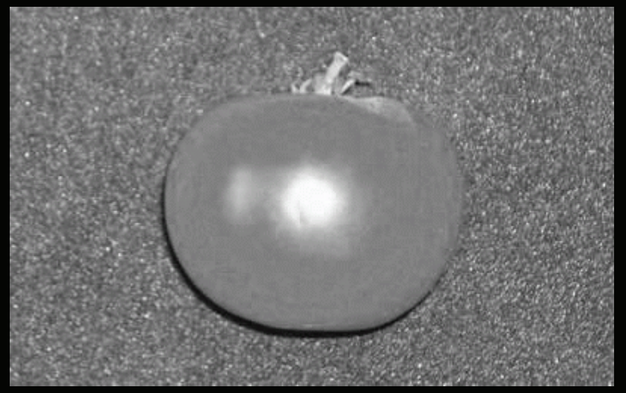
http://en.wikipedia.org/wiki/
File:Chroma_subsampling_ratios.svg

yuv - conversion rates

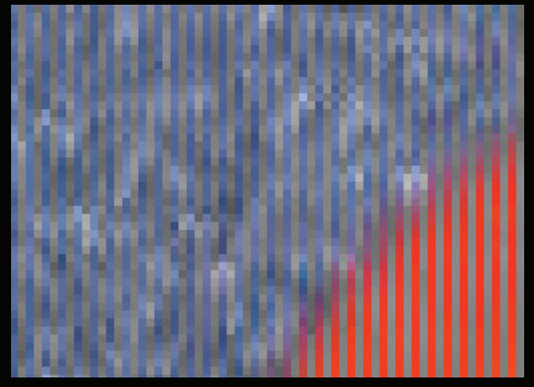
Original



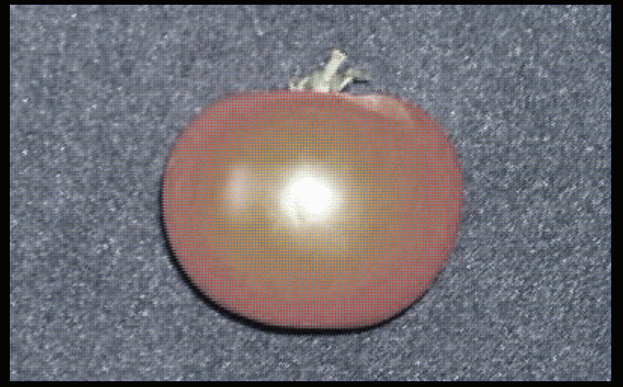
Luminance



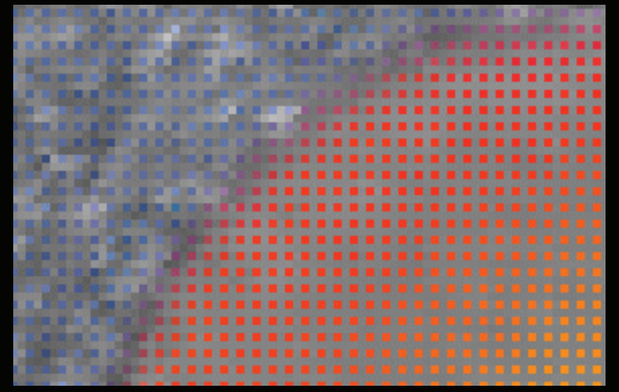
YUV 4:2:2



YUV 4:2:2



YUV 4:2:0



YUV 4:2:0

http://www.cine4home.de/knowhow/ChromaUpsampling/ChromaUpsampling.htm

yuv - chroma upsampling

-FireWire 400 (1394a) 100, 200 or 400 Mbit/s bandwith
(ca. 12, 25 or 50 MByte/s)
-integrated Power for devices (8 bis 33 V DC, 1,5 A), only 6-pol
-parallel data transmitting in both directions (fullduplex)
-4,5 m max. distance between two device (at 400 Mbit/s)
-max distance with in-line-connection max. 72m
-paketorientiated datatransfer
-fast isochrone mode
-writes data directly in PC memory without interaction of CPU
-IDs can assigned to Firewire ports

FireWire was designed for high performance, particularly in time-sensitive applications such as audio and video.

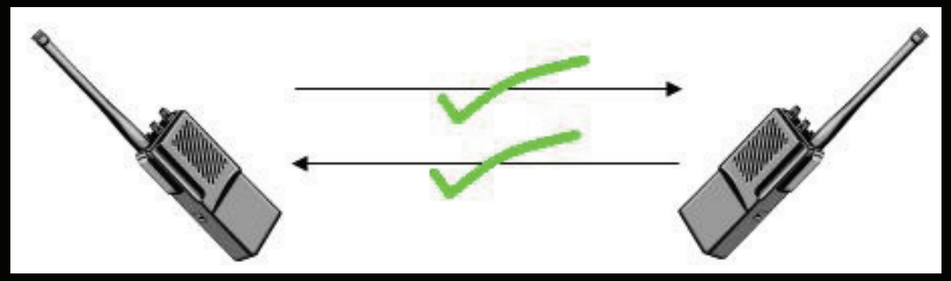
firewire

-A high-speed (USB 2.0) rate of 480 Mbit/s (~57 MB/s)
-USB 2.0 maximum cable length is 5 metres (16 ft) - 25m
-Maximum permitted hubs connected in series is five - 15m
 4.4 V to 5.25 V bei (500 mA)
-half-duplex
-Big performance gains can be achieved when
 attaching USB devices in different controllers
-paketorientiated datatransfer
-verfifies incoming data and ask for anew if broken (like TCP)
-complex protocol with handshake, eof, needs CPU power
-IDs cant assigned to Usb devices, so cams can shift each time

USB was designed for simplicity and low cost

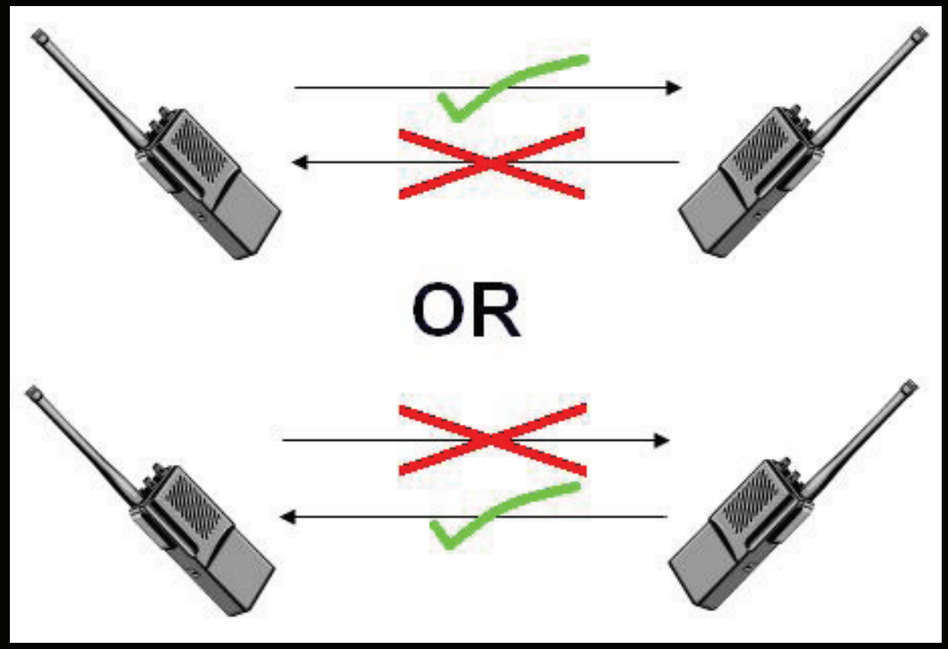
-Gigabit 1,000 Mbit/s or 125MB/s,
-FastEthernet 100 Mbit/s or 11.6 MB/s,
-Ethernet 10 Mbit/s or 1.16 MB/s
-allows long distances depending on quality of cable
-protocol is important as well as hardware like switches, cables
-UPD is fast and pushy, but has no error control
-TCP has error control, but has latency
-needs CPU power

ethernet



full duplex allows communication in both direction simultaneously

FireWire & Ethernet (depends on settings, hardware and protocol)



half duplex allows one direction at one time only

USB & WLAN

http://en.wikipedia.org/wiki/Duplex_(telecommunications)

duplex

	ratio	px	sum pixel	8bit, RGB, 25 fps, 4:2:0	8bit, Y 25fps, raw
VGA	4:3	640×480	307200px	90MB/s	60MB/s
miniDV	4:5	720×576	414720px	122MB/s	81MB/s
SVGA	4:3	800×600	480000px	141MB/s	94MB/s
XGA	4:3	1024×768	786432px	230MB/s	153MB/s
cam 720p	16:9	1280x720	921600px	270MB/s	180MB/s
WXGA	16:10	1280x800	1024000px	300MB/s	200MB/s
SXGA	4:3	1280×1024	1310720px	384MB/s	256MB/s
UXGA	4:3	1600×1200	1920000px	563MB/s	375MB/s
1080i/p	16:9	1920x1080	2073600px	608MB/s	405MB/s
WUXGA	16:10	1920×1200	2304000px	675MB/s	450MB/s

http://en.wikipedia.org/wiki/Pixel

resolution bandwith

LAN

Ethernet	1.16 MB/s
FastEthernet	11.6 MB/s,
Gigabit	125MB/s,

WLAN

802.11	0.25 MB/s
802.11a	6.75 MB/s

PC

PCI Express 1.0	250 MB/s
PCI Express 2.0	500 MB/s
AGP 4x	1,067 MB/s

USB

USB 1.1	1.5 MB/s
USB 2.0	60 MB/s

Firewire

FireWire 100	12 MB/s
FireWire 200	25 MB/s
FireWire 400	50 MB/s
FireWire 800	98 MB/s

http://en.wikipedia.org/wiki/List_of_device_bandwidths

common bandwiths

307200px (640*480px)
*8 (256colors)
* 3 (RGB)
= 7 372 800bits/s *25fps
= 184 320 000 bits/s
= 180000kB/s = 180MB/s
/ 2 (4:2:0 YUV) = 90MB/s

In short:
24 * 25 / 2 / 1024000 = 90MB/s (8bitRGB*fps/YUV rate/kb/s to MB/s)
8 * 25 / 1024000 = 57 MB/s (8bitBW*fps (raw) /kb/s to MB/s)

90MB/s vs 57 MB/s? USB 2.0 only got 60MB/s?
Solution: Its a single chip webcam, its using a bayer colour filter in front of chip.
Thus its a third of 90MB/s / 3 = 30MB/s for 25fps.
But colours are strongly compressed and sort
of unreliable, not good for color tracking

Creative Live Ultra:
CCD-Sensor
640 x 480px @ 30fps
USB-2.0

example calculation

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Calculation

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RGB Red Green Blue
8bit per Channel = 256 Colors
10bit, 16bit, 32bit is possible but
lacks of output devices

24 bit per Pixel
16.8 million colors (“Truecolor”)
Pixel spatial distribution
Histogram channel distribution

image in computer

RGB is standard
RGBA extended standard
different color modells possible,
but only for calculation internally
Output (Monitor, Beamer, LCD) work in RGB model

common is
HSV - Hue, Saturation, Value
HSL - Hue, Saturation, Luminance
CMYK - Cyan, Mangenta, Yellow, Kontrast (used for print)
Lab - Ligthness, a = Green-Mangenta, b = Blue - Yellow
Greyscale - Greycolors

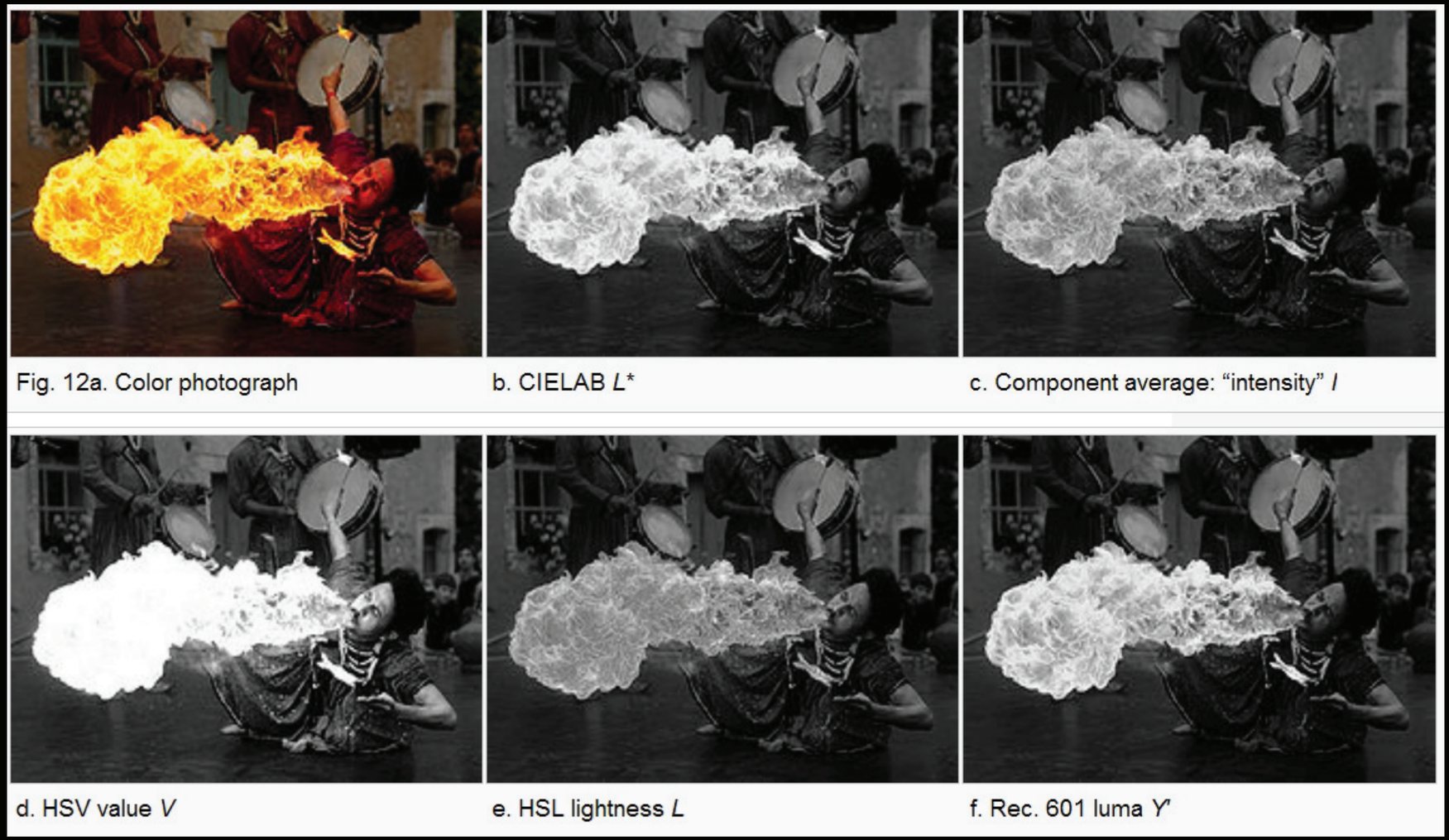


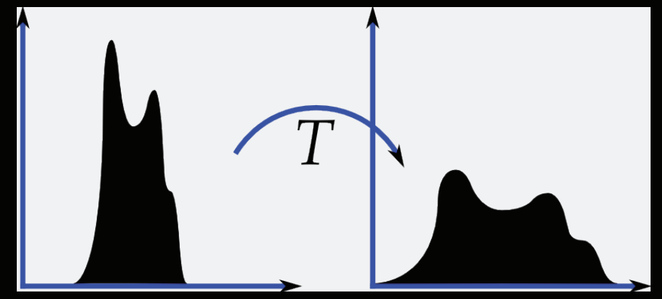
Fig. 12a. Color photograph
b. CIELAB *L**
c. Component average: “intensity” *I*
d. HSV value *V*
e. HSL lightness *L*
f. Rec. 601 luma *Y'*

http://en.wikipedia.org/wiki/Color_model

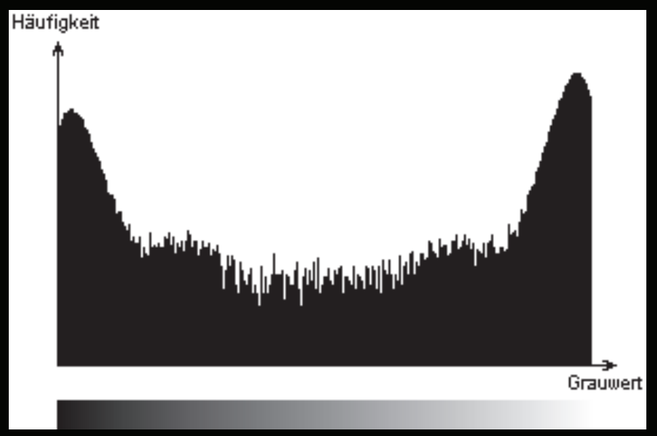
Every colormodel has its purpose,
so might be useful to convert into different color space

colors

histogram (graph presentation)
can be made for different “channels” like RGB, HSV, Luminance, RG chromaticity
counting the number of image pixels in each bin (color value)
provides a compact summarization of the distribution of data/colors in an image
ignores shape of image - can be identical for two images with different objects
color histograms have high sensitivity to noisy interference such as lighting
useful tool for threshold
useful tool for seeing brightness noise
useful tool for brightness distribution /camera aperture



http://en.wikipedia.org/wiki/Color_histogram



http://de.wikipedia.org/w/index.php?title=Datei:Rauschbild-Histogramm.png

histogram

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Recognizing

Kernel based filters use surround pixel values

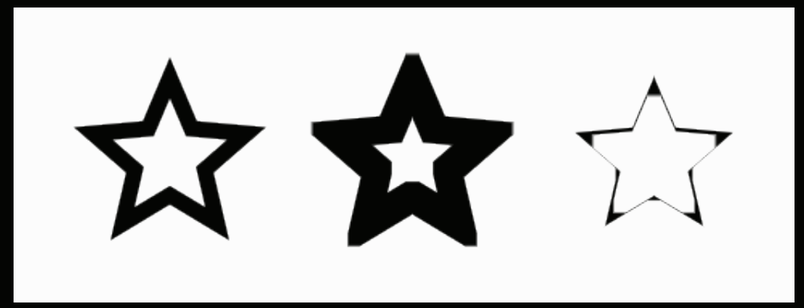
noise reduction:
median, gauss, dilate, erode

edge finding:
high pass. low pass, sobel, canny,
Roberts-Cross, Kirsch-Filter, sharpen

edge enhancement:
erode, dilate, open, close, unsharp

directions:
sobel, feature orientation, difference, optical flow
contrast: prewitt, laplace

pattern:
thinning, thickening, skeletonization, hit-and-miss



http://tavmjong.free.fr/INKSCAPE/MANUAL/html/Filters-Pixel.html

-1	-2	-1
0	0	0
1	2	1

- http://homepages.inf.ed.ac.uk/rbf/HIPR2/wksheets.htm
- http://www.anigators.com/cvision/Filter-o-Rama.html

kernel filter

Pixel based filters can be used to prepare image before recognising foreground.
Basically you can do:

color corrections, color transformation, color replacement

gamma, contrast,

lensdistortion, morph

- http://homepages.inf.ed.ac.uk/rbf/HIPR2/pntops.htm
- http://idlastro.gsfc.nasa.gov/idl_html_help/Contrasting_and_Filtering.html

pixel filter

how to seperate objects from background out of a sequence of frame?

simple way:
take difference of static background frame,
thus we get foreground objects

but how to obtain a static background?

http://www-staff.it.uts.edu.au/~massimo/BackgroundSubtractionReview-Piccardi.pdf

object recognition

background

change of illumination (fast and long-run)
background motion (such as trees, leaves, waves)
when becomes foreground to background (chair, parked car)

object recognition

background substraction

abs(currentFrame-storedFrame) > Threshold

When to store background?
Not adaptive to light changes and shadows
Gets everything different even chairs, cars

object recognition

frame difference

abs(currentFrame-previousFrame) > Threshold

Background is just the previous frame
Its more a motion detection than object detection
Needs high contrasts of frames, best is 5 frames before
Sensitive to threshold

object recognition

average / median background

$medianFrame = F_i + F_{i+n-1} / n$
$abs(currentFrame - medianFrame) > Threshold$

Adaptive to light changes
Will slowly pushes unmoved objects to background (cars, charis)
Memory consuming

object recognition

weighted background

weightedFrame = w*p(x,y) + frame(row,colmn)
abs(currentFrame-weightedFrame) > Threshold

Adaptive to light changes
Adaptive to background motion (trees. leaves)
Will slowly pushes unmoved objects to background (cars, charis)

object recognition

Threshold

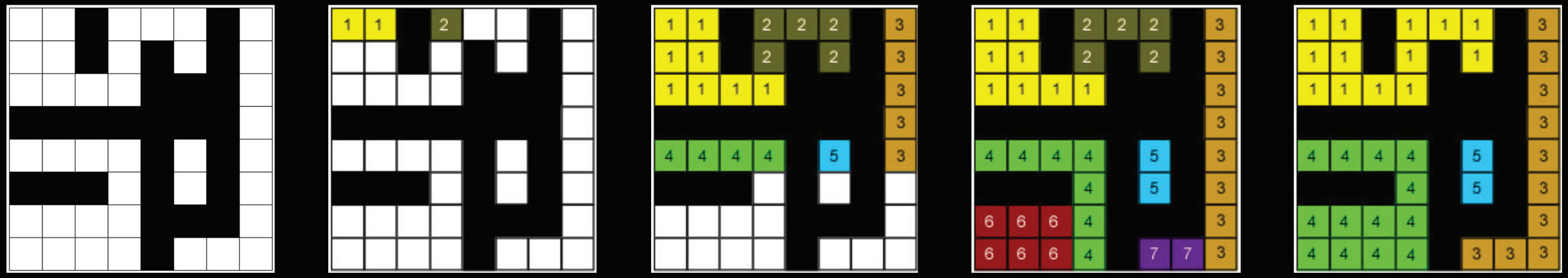
simple Threshold value > Threshold
Bottom-Top Thresold TopThreshold > value > BottomThreshold
Gaussian Threshold value <> GaussianDeviation

Threshold simply puts everything in its range to white = 1.
Usally its applied to a greyscale image and gives you back a binary BW image, where white is object and black is removed parts (BW matte)

Threshold is your gatekeeper, which changes values into 0 and 1. Sooner or later you always use it.

threshold

Blob tracking



Is a iterative algorithm and checks if there are neighbour pixels, that are interconnected.
For blob tracking you need a BW, zero-one image only.
For keeping its IDs in following frame it needs to overlap its blob area.

http://www.aishack.in/2010/03/labelling-connected-components-example/

blob tracking

Color tracking

Looks for a certain colour value in an image.
Usually you define a range rather, than a fixed color.
Color tracking is very sensitiv to lighting change and its wise to have camera bound to fix aperature and white balance.
Best is to convert images to HSL color scheme to get Hue-Colour separated of Luminance and Saturation and go for Hue only. Thus making it less sensitiv to lighting changes.
Take a three chip cam instead of single chip.

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Analysing

How to change tracked data into interaction?

By analysing data:
for the unusual like peaks and extrema,
for specific points like areas,
for a set points and its likelyness

And how to obtain this?

By statistics!

analysing data

Commonly we get data like:
points (X,Y), points (X,Y,Z),
spreads of this points,
and sometimes IDs

We can get out of this:
distance of points, velocity,
heading, area of points,
bounds of spread, center, masses,
mean, median, deviation,
shape of spread

basis data

Sometime its useful to normalise data before analyse it,
because its more stable to different scales.
By normalising you get a relation of all points rather,
than its places in an area. So, you normalise all points, a bin.

```
range (X,Y) = min(X,Y) - max(X,Y)
normalisedPoints (X,Y) = (Points (X,Y) - min(X,Y)) * (1/range (X,Y))

                spread = 0.32,0.73,0.28,0.47,0.49,0.45,0.37,0.28,0.65,0.39
normalised spread = 0.09,1.00,0.00,0.41,0.46,0.37,0.20,0.00,0.82,0.25
```

normalisation

Also important is mean, which gives you the average of all values according to its amount (!)

$$mean = point_{n} (X,Y) + point_{n+1} (X,Y) + \dots + point_{n-1} (X,Y) / n$$

spread = 0.32,0.73,0.28,0.47,0.49,0.45,0.37,0.28,0.65,0.39
mean = 0.45

There are also geometric mean, harmonic mean, etc

- http://www.algebra.com/algebra/homework/Probability-and-statistics/Mean.wikipedia
- http://en.wikipedia.org/wiki/Mean

mean

Another is median, which is often confused with mean.
Median takes the middle value(!) out of a ordered spread.
It doesnt care about the amount, but its spatial distribution.

sort (spread(X,Y))
median = $point(X,Y)_{n/2}$

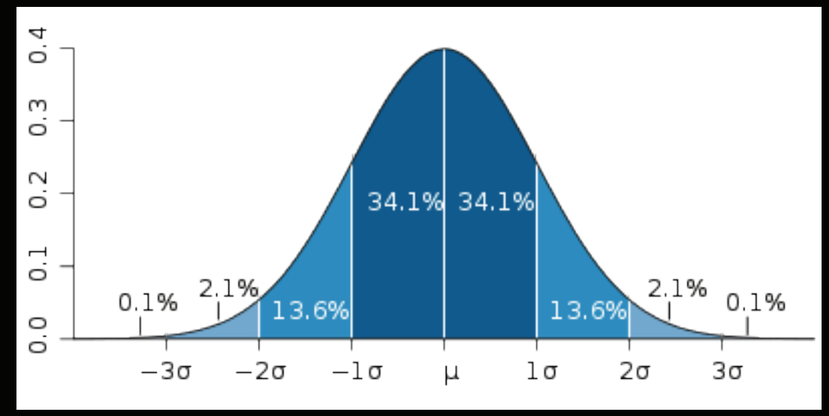
spread = 0.32,0.73,0.28,0.47,0.49,0.45,0.37,0.28,0.65,0.39
ordered spread = 0.28,0.28,0.32,0.37,0.39,0.45,0.47,0.49,0.65,0.73
median = 0.45

There are also quartiles - a quarter of spread

http://en.wikipedia.org/wiki/Median

median

Mister Gauss found a common pattern
the Gauss bell, which describes a
common distribution of values.
But there are some value, which
are a little not the same:
standard deviation.



http://en.wikipedia.org/wiki/File:Standard_deviation_diagram.svg

Thats interesting for us as its the unusual, for what we often look.

There is also variance, root of mean, etc

http://en.wikipedia.org/wiki/Gaussian_distribution

gauss deviation

For digging deeper into statistics check this sites:

- http://www.stats4students.com/guides.php
- http://en.wikipedia.org/wiki/Portal:Statistics
- http://www.algebra.com/algebra/homework/Probability-and-statistics/Mean.wikipedia

statistics

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Interacting

After doing our statistics looking for the unusual or wanted, we can change that into interaction.

Sadly, there isnt a typical way of interaction, which can be described here easily. Its always very special, like tracking is.

But there are keypoints which help you!

First of all think of what you want to tell.
Make a concept, talk with friends about it. If they understand it easily its good, if not you have to adjust it.

Make skribbles, storyboards and flowcharts of interaction.

Think in terms of stories and fun.
Simple and understandable interaction is most fun for audience.

The visuals and atmosphere of your installation influence how the visitor will feel about it. So, make the surface apealing and your audience is using it in a friendly, curious mood.

How is the setting? Can you improve tracking by some changes you need - requirements. Ask for it.

Tracking is about brightness and luminance. You turn that into computer numbers later.

Most algorythm work with greyscale / luminance image only and look for hard contrast. Having that in mind, you should optimize your lighting, camera and aperature, thus it makes computation easier.

How do you handle errors?
Often people look for the borders of systems.
Give it an openess, that encourage people interact.
Let them play, watch it and enjoy.
If it isn’t you desired behaviour, then refine it.

keypoints to interaction

Thank you

for your patience

We hope you enjoyed it
and got inspiration out ouf it

typo Scriptina by Apostrophe http://pedroreina.net/apostrophiclab/0158-Scriptina/scriptina.html
and audimat by Smeltery http://www.smeltery.net/

icons by paradis24434 http://paradis24434.deviantart.com/art/Antique-icons-65361362
and http://icons.mysitemyway.com/free-clipart-icons/1/styled-right-arrow-icon-id/8348/style-id/92/glossy-waxed-wood-icons/arrows/

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