National Technical University of Athens

Lighting Laboratory

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EVALUATION OF IMAGE SENSORS FOR LIGHTING CONTROL APPLICATIONS

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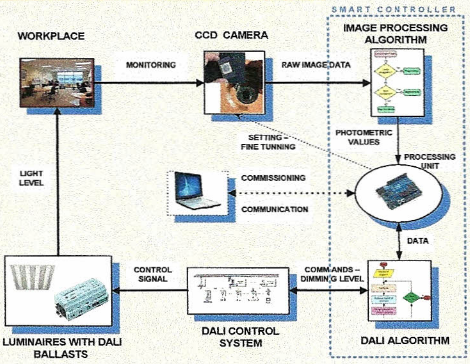
WHY A CCD SENSOR INSTEAD OF THE CONVENTIONAL? – LIGHTING CONTROL OF THE FUTURE

Some of the conventional closed loop photosensor problems are that the placement on the working plane (wp) is not effective, the sensitivity to reflectances from the wp, the detection of IR as incident light, the weakness of the control algorithms, the commissioning and users inconvenience due to failure operation.

The new system, with the image (CCD) sensor, overcomes many of the above problems. The sensor placed anywhere on the ceiling and aims to the control zone. The sensor calibrated in order to convert the images of the room to real luminance images (using image-processing routines). IR filters placed on the lens and protect the sensors function. Finally the installed luminaires are dimmed individually at the appropriate light level through a multi-signal output.

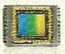
LIGHTING CONTROL AND IMAGE SENSORS



Block diagram of a lighting control system with image sensor

Image sensors technical specifications

	Active pixels	Fill factor	Quantum eff.	Well capacity	Dynamic range	Dark current	Readout noise	Power cons.
	Mp	%	%	e-	db	e/s	e-	W
CCD 1	1.4	100	62	16000	68.5	0.05	6	20
CCD 2	4.2	100	55	40000	76.5	0.5	7	21
CCD 3	1.4	100	62	18000	69.5	0.05	7.5	12
CMOS 4	1.3	40	26	63000	59	70	70	0.35
CMOS 5	2.2	42	62	13500	60	125	13	0.6
CMOS 6	1.3	40	53	13700	64	21	30	0.2



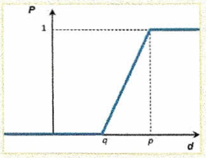
- ✓ Number of active pixels ⇨ Number of the sensor pixel that is sensitive to light.
- ✓ Fill factor ⇨ Percentage of each pixel that is sensitive to light.
- ✓ Quantum efficiency ⇨ Measure of the efficiency with which incident photons are detected.
- ✓ Well capacity ⇨ Capacity of the well in which the electrons are collected.
- ✓ Dynamic range ⇨ Ratio of the pixel's saturation level to its signal threshold.
- ✓ Dark current (noise) ⇨ Unwanted charge that accumulates in the sensor pixels due to natural thermal processes that occur while the device operates at temperatures above absolute zero.
- ✓ Readout noise ⇨ Noise of the on-chip amplifier which converts the charge into a change in analogue voltage.
- ✓ Power consumption ⇨ Necessary power that the sensor requires in order to function.

MULTICRITERIA ANALYSIS - PROMETHEE II

The PROMETHEE procedure is based on pair wise comparisons. The aggregated preference indices and outranking flows must be defined.

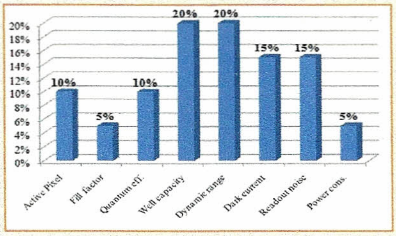
$$\pi(b,a) = \sum_{j=1}^{k} P_j(b,a) w_j \qquad \pi(a,b) = \sum_{j=1}^{k} P_j(a,b) w_j$$

Preference function



According to the multicriteria method Promethee II type V preference function is best suited for quantitative criteria

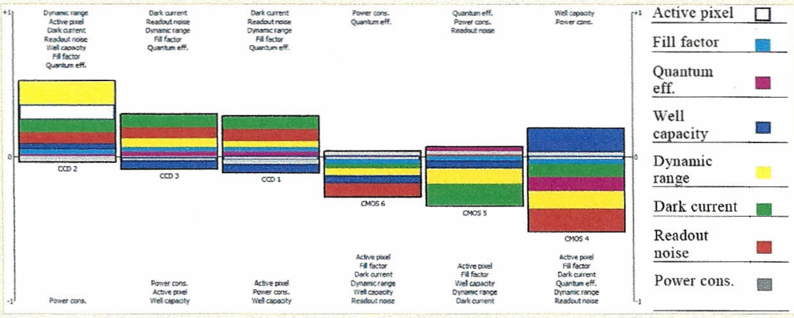
$$P(d) = \begin{cases} 0, d \le 0 \\ \dfrac{d-q}{p-q}, 0 \le d \le p \\ 1, \quad d > p \end{cases}$$



$$\sum_{j=1}^{k} w_j = 1$$

Technical specifications weights for Promethee II method

EVALUATION OF SENSORS USING PROMETHEE II



Promethee II complete ranking

Promethee II ranking with φ(α), φ+(α) and φ-(α) scores

Sensor	φ(α)	φ+(α)	φ-(α)
CCD 2	0,4869	0,5421	0,0552
CCD 3	0,2081	0,3176	0,1094
CCD 1	0,1649	0,2997	0,1347
CMOS 6	-0,2480	0,1422	0,3903
CMOS 5	-0,2825	0,1318	0,4143
CMOS 4	-0,3294	0,2192	0,5487

- ✓ For each sensor the bar is drawn with as many slices as the number of criteria.
- ✓ Each slice corresponds to the contribution of the criterion to the φ net flow score of the action taking into account the weight of the criterion.
- ✓ The sum of the positive slices minus the sum of the negative ones is equal to the φ net flow score of the sensor.

CONCLUSIONS

- ➢ CCD 2: Only negative the power consumption .
- ➢ CCD 3 & 1: Increased power consumption vs CMOS, lower resolution and well capacity vs CCD 2.
- ➢ CCD 1, 2, 3: Better image quality (high efficiency &low noise levels) vs CMOS.
- ➢ CMOS 6: Lower power consumption but bad fill factor, noise, dynamic range, active pixel.
- ➢ CMOS 5: is the CMOS sensor with the lower noise levels.
- ➢ CMOS: Intrinsic advantages (low power consumption, high quantum efficiency) with low weight for the method.
- ➢ CMOS: Some technical specifications (low cost, high speed imaging, integration capability) are not included in the ranking method because they do not affect the lighting control system.

CCD advantages

- High efficiency
- Low noise levels
- Well capacity
- Dynamic range

⇨ CCD sensors are selected between the upper three selections of the method ranking

CMOS advantages

- Low power consumption
- High quantum efficiency
- Low cost, high speed imaging…

⇨ CMOS appears to be a good solution in lighting control with wireless sensors network due to their low power consumption