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Chromaticity measurement of airport navigation lighting using integrated colour sensor

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Abstract

The paper presents an analysis of using a TCS3430 light colour sensor to verify the chromaticity of navigation lighting installed at airports. These measurements can help determine the correct operation of the tested lamp using of specialised measuring devices. The emitted light colour is critical for pilots during flight operations such as take-off, landing and taxiing, especially in low visibility conditions. Chromaticity standards (in CIE1931 colour space) are specified in the relevant regulations of the European Union Aviation Safety Agency (EASA) and the International Civil Aviation Organisation (ICAO), and require regular inspection of each light point (both in-pavement and elevated lamps). Tests were carried out for various types of aviation navigation lighting lamps. The stability of measurements and possibilities of visualization on the chromaticity chart were assessed. The article also presents software that allows for quick verification of the operation of a given lamp, intended for airport maintenance services.

1. Introduction

The average intensity of the main beam and colour of the light emitted by aeronautical ground lights plays a crucial role in aviation safety. The International Civil Aviation Organisation (ICAO) [1] and the European Union Aviation Safety Agency (EASA) [2] have established regulations covering the quality of this lighting [3] and requirements for chromaticity and light intensity [4]. These standards ensure that the light emitted by these systems is easily distinguishable by pilots, even under poor visibility conditions [5]. Figure 1 shows an example of an in-pavement navigation lighting lamp on an airport runway.

Regular inspection of chromaticity is necessary to maintain compliance with the ICAO and EASA regulations [6]. These measurements can be performed using dedicated equipment such as spectrophotometers or colorimeters which provide accurate measurements of colour parameters [7]. By regularly conducting such assessments, airports can identify any deviations from required colour standards and take corrective action to ensure aviation safety [8].

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Fig. 1. Airport taxiway centreline in-pavement lamp.

Changes in colour can occur due to a variety of factors, including ageing of the lighting system, environmental factors, and even changes in the composition of the surrounding air. Regularly measuring chromaticity is crucial for airports to comply with ICAO and EASA regulations and to make sure that pilots can easily recognise the colour of the navigational lighting system. [9]. The ICAO has established specific requirements for the chromaticity of the instrument landing system (ILS) which depend on the category of the system. One of the criteria for the ILS category is the navigation lighting system that plays a key role in guiding the aircraft during landing

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operations. ILS in Category I requires a relatively rare verification of the chromaticity of lighting and navigation, however, with the increase in aviation standards up to Category III, a frequent, reliable, and unambiguous checkout is required to enable aviation operations in limited visibility conditions [2, 10].

The EASA chromaticity standards have been defined in the International Commission on Illumination (CIE) 1931 colour space. This colour space is a standard that describes the perception of colour by the human eye. It was developed by the CIE in 1931 and is also known as the CIE XYZ colour space [11]. The colour space is based on the trichromatic theory of colour vision which states that the human eye has three types of colour receptors: red, green, and blue. The CIE1931 colour space defines a set of three colour coordinates, X, Y, and Z, that represent the amount of red, green, and blue light that is needed to produce a given colour. The CIE1931 colour space is often used as a reference for colour measurement and is widely used in the fields of colour science, colorimetry, and colour management. It has been adopted by many organisations, including the International Organisation for Standardisation (ISO) and the Society of Motion Picture and Television Engineers (SMPTE), as a standard for colour measurement and calibration. Figure 2 shows an example chart of the EASA regulations regarding the colours of navigation lighting.

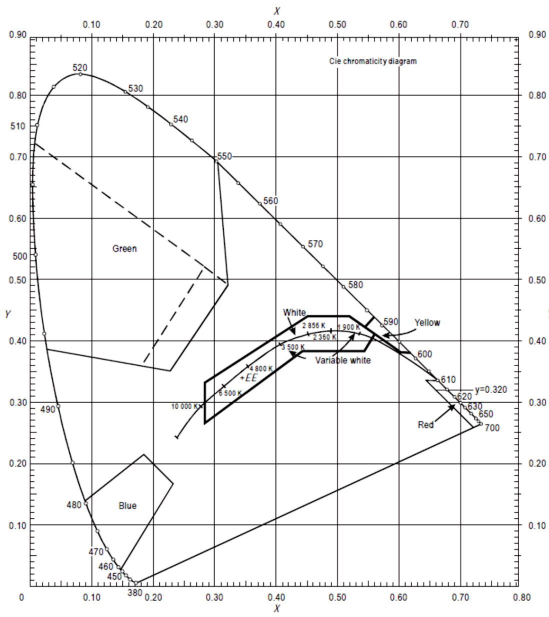

Fig. 2. Colours for aeronautical ground lights [2].

The chromaticity requirements for airport lighting differ depending on the type of lamp and its location. The equations describing the limits of individual colours in the CIE1931 colour space, shown in Fig. 2, are as follows [2]:

- Red:
  - Purple boundary: $y = 0.980 - x$
  - Yellow boundary: $y = 0.335$
- Yellow:
  - Red boundary: $y = 0.382$
  - White boundary: $y = 0.790 - 0.667x$
  - Green boundary: $y = x - 0.120$
- Green:
  - Yellow boundary: $x = 0.360 - 0.080y$
  - White boundary: $x = 0.650y$
  - Blue boundary: $y = 0.390 - 0.171x$
- Blue:
  - Green boundary: $y = 0.805x + 0.065$
  - White boundary: $y = 0.400 - x$
  - Purple boundary: $x = 0.600y + 0.133$
- White:
  - Yellow boundary: $x = 0.500$
  - Blue boundary: $x = 0.285$
  - Green boundary: $y = 0.440$
    $y = 0.150 + 0.640x$
  - Purple boundary: $y = 0.050 + 0.750x$
    $y = 0.382$
- Variable white:
  - Yellow boundary: $x = 0.255 + 0.750y$
    $y = 0.790 - 0.667x$
  - Blue boundary: $x = 0.285$
  - Green boundary: $y = 0.440$
    $y = 0.150 + 0.640x$
  - Purple boundary: $y = 0.050 + 0.750x$
    $y = 0.382$

To verify navigation lighting parameters, specialised devices are used, including measurement platforms [4] and drones [12, 13]. In particular, the focus has so far been on the intensity [14, 15] of the lamps (decrease can be caused by damage to the lamp prism). However, presently, more and more importance is placed on checking airport areas [16] and the chromaticity of light emitted by airport navigation lighting.

The issue of chromaticity measurement using integrated electronic sensors is being studied in scientific publications. The key issue is a correct measurement in a specific colour space or correct conversion. The method for calculating and specifying light source chromaticity using the CIE2015 10° colour matching functions (CMFs) is presented in Ref. 17. This article provides methodological recommendations to increase the evidential value of laboratory-based psychophysical experiments investigating the effect of light source spectral power distribution on the subjective evaluation of the colour appearance of scenes. The article does not analyse the use of specific electronic systems.

The chromatic verification of the light sources was also made in Ref. 18 which focused on LED sources. For the CIE1931 colour space, the values of illuminance and correlated colour temperature (CCT) were determined. The measuring apparatus consists of a spectrophotometer and recommended sphere geometries which require disassembly of the tested light source to obtain measurement results.

In Ref. 19, the authors presented a microprocessor system for capturing, processing and colour management that allows the colours of any non-self-luminous object. During the experimental tests, a TCS3414CS colour sensor was used. The study of the colour space did not refer to international standards and requirements, and the colour obtained was not categorised within the limits set in the CIE1931 colour space.

A mobile solution for chromaticity evaluation is a smartphone-based system that allows to approximate colour regions on the CIE1931 x, y chromaticity diagram [20]. The tests were limited to assessing the chromaticity of the measurement scene, and then lighting to the selected setting.

In the previous papers, the authors proposed a measurement matrix for testing in-pavement navigation lighting lamps operation quality [21] and a system for testing those lamps with automatic selection of the colour of the emitted light using an AS7262 sensor used at the Poznań-Ławica Airport [22].

The aim of this paper was to determine the correct operation of the tested aeronautical ground lights by verifying their chromatic characteristics using the TCS3430 light colour sensor. Such solution allows to build a mobile chromaticity measurement system.

2. TCS3430 tristimulus colour sensor

The TCS3430 sensor is a highly advanced component used in a variety of colour sensing and ambient light sensing applications. The sensor operates in the visible light spectrum with the range from 380 nm to 780 nm and has a very high sensitivity to light, enabling it to detect even small variations in the spectral output of different light sources. The sensor uses a combination of photodiodes and an on-chip filter to accurately measure the intensity of light at different wavelengths. The sensor has a dynamic range making it suitable for use in a range of lighting conditions. The filter used in the sensor ensures that it is capable to accurately measure the intensity of light at different wavelengths, while also providing a high degree of noise reduction [23].

The TCS3430 sensor is designed to be compact and energy-efficient, with a low power consumption of just 0.45 mW in full operation. It is housed in a small surface-mount package which makes it easy for integration into the range of sensing and control systems. The sensor is also capable of operating in a wide temperature range, from −40 °C to 105 °C, making it suitable for use in demanding environments. One of the key features of the TCS3430 sensor is its ability to compensate for the effects of temperature and aging on photodiodes [23]. This ensures that it maintains accuracy and reliability under a wide range of environmental conditions. This feature makes it an ideal choice for use in adverse environments, such as industrial or outdoor settings. The sensor is also capable of adjusting the intensity of lighting based on ambient light levels, making it a valuable tool for reducing energy consumption and light pollution in indoor lighting applications. The sensor can measure ambient light levels and adjust the lighting, accordingly, making the lighting system more efficient and environmentally friendly. Table 1 shows the electrical and optical parameters of the TCS3430 sensor [23].

The TCS3430 light spectrum sensor can play a crucial role in the supervision of airport navigation lighting, ensuring that the lighting works optimally and meets the required standards for safety and visibility by measuring the spectral output of different light sources used in the navigation lighting system. Figure 3 shows the block diagram of the TCD3430 chromaticity sensor.

Figure 4 shows the spectral response of the TCS3430. It has five channels: X, Y, Z, IR1 (Far Red LED) and IR2 (IR LED). By combining the readings from all four

Table 1.
Electrical and optical parameters of the TCS3430 sensor [23].

Parameter	Min.	Max.	Units
Supply voltage	−0.3	2.2	V
Digital I/O terminal voltage	−0.3	3.6	V
Output terminal current	−1	20	mA
Channel X (Warm White LED)	58	90	counts/(μW/cm^2)
Channel Y (Warm White LED)	56	70	counts/(μW/cm^2)
Channel Z (Warm White LED)	6.5	14	counts/(μW/cm^2)
Far Red LED	90	180	counts/(μW/cm^2)
IR LED	90	230	counts/(μW/cm^2)

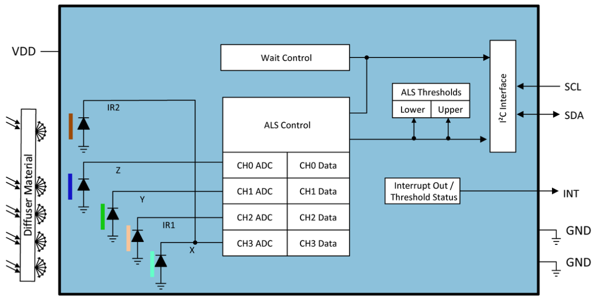

Fig. 3. TCS3430 block diagram [23].

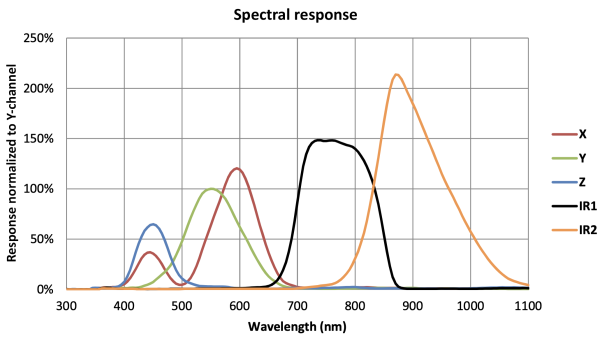

Fig. 4. TCS3430 spectral response [18].

photodiodes, the TCS3430 can accurately determine the colour of the light. The spectral response of each photodiode in the TCS3430 is carefully designed to match the response of the human eye to different colours [24].

The sensor provides colour information in the form of XYZ coordinates, which represent the tristimulus values of the light. However, to plot these colours on a chromaticity chart, it is necessary to convert the XYZ coordinates to the (x, y) coordinates in the CIE1931 colour space. It is based on tristimulus theory which states that any colour can be represented as a combination of three primary colours: red, green, and blue. The (x, y) coordinates in this colour space represent the chromaticity of the colour, which is the hue and saturation of the colour, but not its brightness.

To convert the XYZ coordinates from the TCS3430 sensor to the (x, y) coordinates in the CIE1931 colour space, it is necessary to normalise the XYZ values by dividing each by the sum of all three values. This gives the relative amounts of each primary colour that make up light [25]. Next, equations (1) and (2) should be used to calculate the (x, y) coordinates:

$$x = \frac{X}{(X + Y + Z)} \tag{1}$$

$$y = \frac{Y}{(X + Y + Z)}, \tag{2}$$

where $X, Y,$ and Z are the normalised tristimulus values.

When the (x, y) coordinates are calculated, they can be plotted on a chromaticity chart to visualise the colour. The chromaticity graph is a two-dimensional graph that shows all possible chromaticities in the CIE1931 colour space. To obtain correct results in the largest possible spectrum of lamps, it was decided to set the gain factor at 1, which gives the possibility to carry out tests at close range, thus eliminating the risk of rapid saturation of the sensor.

3. Software for chromaticity analysis of airport navigation lighting

The authors have also prepared a software for automatic data conversion, drawing a measured point, and finally comparing it to the applicable standards used in aviation. The user enters the data received from the sensor in the form of *XYZ* coordinates, selects the colour standard that the tested lamp should meet, and the system determines whether the standard has been met and draws a chromaticity graph with a point provided by the user to visualise the data. The system generates a chromaticity chart, in which standards for individual colours have been applied, defined by the equations in the EASA document [2].

The authors decided to generate a chromaticity plot based on the 2-deg (x, y) chromaticity coordinates of CIE1931 provided by the Colour & Vision Research, Institute of Ophthalmology, University College London [26]. These coordinates allowed for the most accurate generation of the chromaticity diagram (every 1 nm of the visible light wave in the range from 360 to 830 nm). Figure 5 shows the user interface with the visualisation of the measurement obtained.

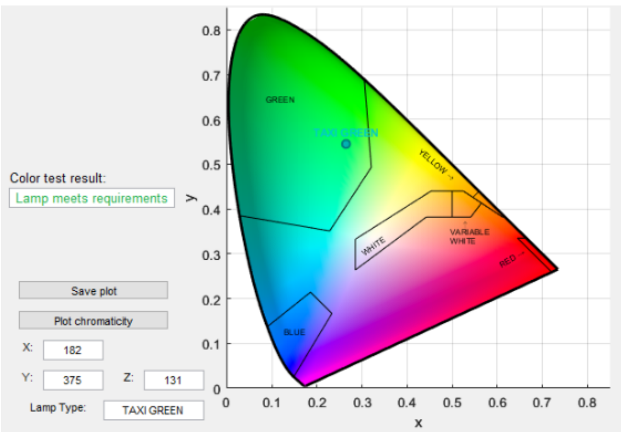

Fig. 5. Graphical user interface of the prepared software.

4. Colour measurements of in-pavement aeronautical ground lights

As part of the work, tests were carried out using the TCS3430 sensor and in-pavement airport navigation lamps. 10 measurement series were carried out, each with 1000 measurements at each distance from the light source. Measurements were carried out according to the requirements of international institutions (EASA, ICAO), that is at the maximum power of a given light point (current 6.6 A) – 48 W or 40 W halogen bulbs [27, 28]. Statistical parameters such as standard deviation and median were also calculated. Table 2 shows the electrical and optical parameters of in-pavement aeronautical ground lights. The results indicate a small scatter of data for measurements made at different distances from the light source. This indicates that the measurements were made correctly, considering the geometrical relationships defined in the standards, including the angular setting in relation to the main beam of the emitted light. The mean values obtained in the measurements are presented in Table 3. It can be observed that measured values are strongly depended on distance between light source and sensor, although the measurement range of TCS3430 covers all investigated distances. An additional remark is that the standard deviation is also not a significant value in each case.

Table 2.
Electrical and optical parameters of in-pavement aeronautical ground lights [27, 28].

Lamp type	Power of the light source [W]	Colour	Average intensity [cd]	Horizontal distribution [degrees]	Vertical distribution [degrees]
TDZ	48	White	5800	−12 to +12	0 to 16
RCL_White	48	White	5800	−12 to +12	0 to 16
RCL_Red	48	Red	870	−12 to +12	0 to 16
TAXI_GREEN	40	Green	442	−18 to +18	0 to 12
TAXI_YELLOW	40	Yellow	663	−18 to +18	0 to 12

The applied sensor ensures the repeatability of the measurements [18]. The tests were carried out on five types of colours of lamps built into the airport areas (Fig. 6):

- TDZ – touchdown zone lamp (white),
- RCL_White – runway centreline lamp (white),
- RCL_Red – runway centreline lamp (red),
- TAXI_GREEN – taxiway centreline lamp (green),
- TAXI_YELLOW – taxiway centreline lamp (yellow).

The data from the TCS3430 sensor in the form of *XYZ* have been normalised and transferred to the space compatible with the CIE1931 colour space in the form of (x, y) coordinates. Table 4 shows the coordinates after conversion. Such operation allows to obtain values independent from the measurement distance. In particular rows, the values are at the same level now.

Table 3.
Data from the TCS3430 sensor of the tested in-pavement aeronautical ground lights (XYZ coordinates).

Lamp type		Distance from lamp [m]																	
		0.5			1.0			1.5			2.0			2.5			3.0		
		Mean	Standard deviation	Median	Mean	Standard deviation	Median	Mean	Standard deviation	Median	Mean	Standard deviation	Median	Mean	Standard deviation	Median	Mean	Standard deviation	Median
TAXI_YELLOW	X	3473	1	3473	850	0	850	380	0	380	222	0	222	140	0	140	98	0	98
	Y	2787	1	2787	690	0	690	296	0	296	173	0	173	110	1	110	75	0	75
	Z	145	0	145	35	0	35	15	0	15	9	0	9	6	0	6	4	0	4
TAXI_GREEN	X	525	1	525	182	1	182	75	0	75	45	0	45	28	0	28	22	0	22
	Y	1127	2	1127	375	1	375	161	0	161	98	0	98	60	0	60	46	0	46
	Z	396	1	396	131	1	131	62	0	62	38	0	38	23	0	23	17	0	17
TDZ	X	27826	7	27824	10687	2	10687	4173	1	4173	2346	0	2346	1261	1	1261	772	0	772
	Y	25063	6	25062	9590	2	9590	3808	1	3808	2139	0	2139	1150	0	1150	693	0	693
	Z	5323	1	5323	217	1	2127	831	0	831	472	0	472	195	0	195	82	0	82
RCL_White	X	36100	20	36099	10261	3	10261	4445	1	4445	2534	2	2535	1439	2	1439	982	2	982
	Y	31755	17	31753	8997	3	8997	4021	1	4021	2225	2	2225	1292	1	1292	882	1	882
	Z	6923	3	6922	1966	1	1966	871	0	871	481	0	481	283	0	283	192	0	192
RCL_Red	X	15358	3	15359	4705	1	4705	2244	1	2244	1466	0	1466	857	0	857	427	0	427
	Y	8130	2	8130	2465	1	2466	1167	0	1167	803	0	803	453	0	453	227	0	227
	Z	447	0	447	136	0	136	65	0	65	43	0	43	24	0	24	12	0	12

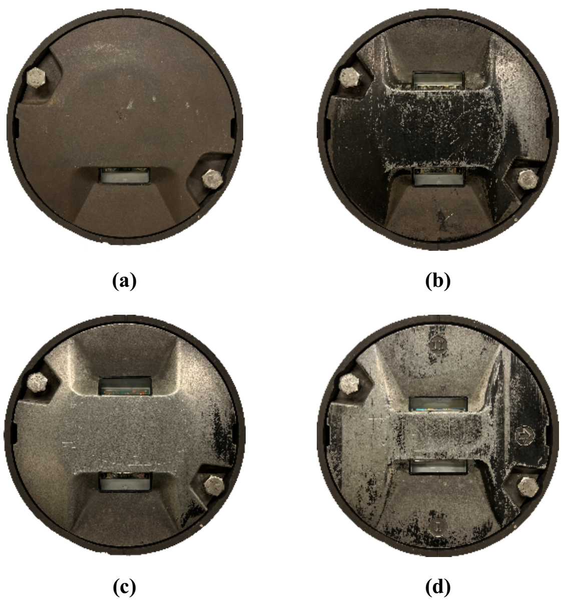

Fig. 6. In-pavement aeronautical ground lamps: touchdown zone (a), runway centreline white-white (b), runway centreline white-red (c), taxiway centreline green-yellow (d).

Table 4.
Normalised TCS3430 sensor data from in-pavement navigation lighting converted to CIE1931 (x, y) coordinates.

Lamp type		Distance from lamp [m]					
		0.5	1.0	1.5	2.0	2.5	3.0
TAXI_ YELLOW	x	0.54	0.54	0.55	0.55	0.55	0.55
	y	0.44	0.44	0.43	0.43	0.43	0.42
TAXI_ GREEN	x	0.26	0.26	0.25	0.25	0.25	0.26
	y	0.55	0.54	0.54	0.54	0.54	0.54
TDZ	x	0.48	0.48	0.47	0.47	0.48	0.50
	y	0.43	0.43	0.43	0.43	0.44	0.45
RCL_ White	x	0.48	0.48	0.48	0.48	0.48	0.48
	y	0.42	0.42	0.43	0.42	0.44	0.43
RCL_ Red	x	0.64	0.64	0.65	0.63	0.64	0.64
	y	0.34	0.34	0.34	0.35	0.34	0.34

Figure 7 shows a point with marked measurements, in an illustrative way, five lamps are in one graph. Due to the graphical visualisation of the data, it is possible to easily distinguish the types of lamps and check the correctness of the reproduced colours. All tested in-pavement lamps meet the standards contained in international regulations.

Figure 8 shows the dependence of the (x, y) coordinate values (CIE1931 colour space) on the distance from the light source. In the case of in-pavement lamps, the maximum values in the sensor were not exceeded, that is why it is possible to measure from a distance of 0.5 m. The observed waveforms are linear, which leads to the conclusion that the measurement system is resistant to environmental changes and can be made independently of the distance from the tested lamp during the measurements.

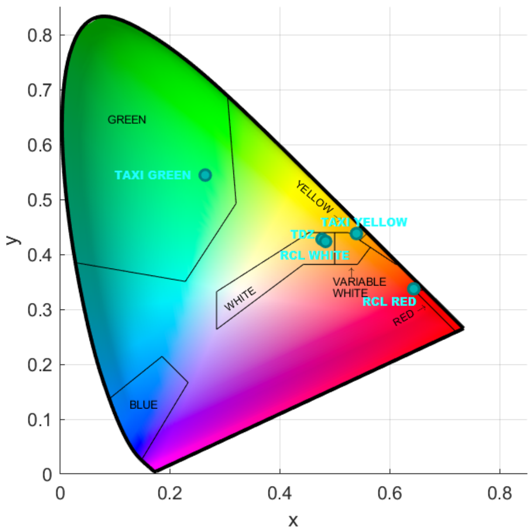

Fig. 7. Chromaticity chart of in-pavement airport navigation lighting system.

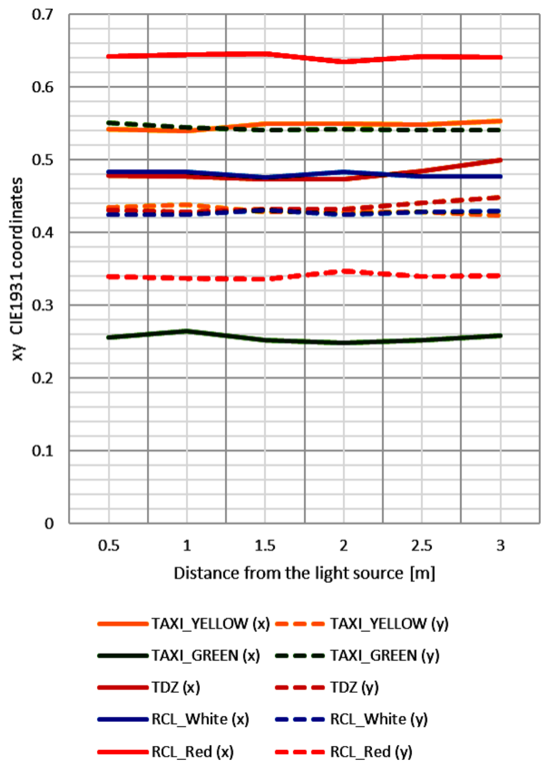

Fig. 8. Graph of the CIE1931 x, y coordinates of the tested in-pavement lamps as a function of the distance from the light source.

5. Colour measurements of elevated aeronautical ground lights

As part of the work, tests were also carried out for elevated airport navigation lighting with the use of the TCS3430 colour sensor. 10 series, each with 1000 measurements at a distance of 0.5 m, 1.0 m, 1.5 m, 2.0 m, 2.5 m, and 3.0 m from the tested light source, were done. Also, in this case, measurements were made at the maximum power of the light sources (current 6.6 A). In the case of the stop bar lamp, there is a bulb with a lower power (45 W) than in the case of approach lamps (150 W) [29]. The light source used affects the intensity of the main beam emitted. Table 5 shows the electrical and optical parameters of elevated aeronautical ground lights. As in the case of in-pavement lamps, the values of the standard deviation and median confirmed the high repeatability and measurement accuracy of the sensor used. The data dispersion was only a fraction of the value obtained throughout the measurement series. The mean values obtained in the measurements are presented in Table 6. Proper measurement is possible from 0.5 m for STOP_BAR, 1 m for APP_Red and 1.5 m for APP_White. Standard deviation is slightly greater than in the case of in-pavement aeronautical ground lights, but values do not exceed 2% of mean value.

Table 5.
Electrical and optical parameters of elevated aeronautical ground lights [29].

Lamp type	Power of the light source [W]	Colour	Average intensity [cd]	Horizontal distribution [degrees]	Vertical distribution [degrees]
APP_White	150	White	22108	−10 to +10	2 to 13
APP_ Red	150	Red	6921	−5 to +9	3 to 13
STOP_BAR	45	Red	309	−10 to +10	1 to 8

The tests were carried out on three types (Fig. 9) of elevated lamps used in airport areas:

- APP_White – approach system lamp (white),
- APP_Red – approach system lamp (red),
- STOP_BAR – stop bar lamp (red).

Also, in this case, the data received from the TCS3430 sensor in the form of XYZ coordinates have been normalised and transferred to the CIE1931 colour space in the form of x, y coordinates. Table 7 shows the coordinates after conversion. According to previous observations (Table 6), the overrange of TCS3430 sensor occurs at a distance of 0.5 m for APP_Red, and 0.5 m and 1 m for APP_White which makes these results unsuitable for consideration.

Table 6.
Data from the TCS3430 sensor of the tested elevated aeronautical ground lights (XYZ coordinates).

Lamp type		Distance from lamp [m]																	
		0.5			1.0			1.5			2.0			2.5			3.0		
		Mean	Standard deviation	Median	Mean	Standard deviation	Median	Mean	Standard deviation	Median	Mean	Standard deviation	Median	Mean	Standard deviation	Median	Mean	Standard deviation	Median
APP_White	X	36805	284	36863	36863	0	36863	18551	81	18528	9415	116	9405	5220	68	5221	3701	31	3698
	Y	35058	2055	35628	36697	609	36863	15789	63	15776	7998	81	7998	4456	57	4449	3166	22	3159
	Z	10167	1698	9787	10271	266	10320	4241	16	4236	2130	29	2128	1180	14	1181	835	7	834
APP_Red	X	36863	0	36863	15695	139	15681	6849	61	6837	3381	43	3357	2044	31	2059	1486	18	1491
	Y	36863	0	36863	8660	82	8630	3767	25	3770	1799	30	1785	1088	22	1098	798	16	806
	Z	36863	0	36863	1338	12	1334	560	5	559	280	3	280	165	1	166	120	2	121
STOP_BAR	X	2688	34	2679	822	4	822	408	5	405	240	1	240	154	1	154	111	0	111
	Y	1381	20	1377	429	2	429	208	4	206	120	1	120	79	0	79	58	0	58
	Z	251	3	251	77	0	77	38	0	38	22	0	22	14	0	14	10	0	10


(a) (b) (c)

Fig. 9. Elevated approach system lamps: White (a), Red (b), and Stop Bar Lamp (c).

Figure 10 shows a point with marked measurements; for illustrative purposes, three lamps are shown in one graph. Due to the graphical visualisation of the data, it is easy to distinguish between types of lamps and check the correctness of the colour reproduction.

It can be noticed that in the case of the Stop Bar and APP_Red lamps (used lamps), they no longer meet the standards regarding chromaticity of the emitted light beam. This may be due to many factors, such as the wear of the halogen bulb light source, as well as the lamp shade which is also a colour filter. It is exposed to direct action of weather conditions, leading to degradation of the structure and physical properties of the lampshade (discolouration, cracks, matting, fading). For this reason, regular and reliable

Table 7.
Normalised TCS3430 sensor data from in-pavement navigation lighting converted to CIE1931 (x, y) coordinates.

Lamp type		Distance from lamp [m]					
		0.5	1.0	1.5	2.0	2.5	3.0
APP_Red	x	0.33	0.61	0.61	0.62	0.62	0.62
	y	0.33	0.34	0.34	0.33	0.33	0.33
APP_White	x	0.45	0.44	0.48	0.48	0.48	0.48
	y	0.43	0.44	0.41	0.41	0.41	0.41
TDZ	x	0.62	0.62	0.62	0.63	0.62	0.62
	y	0.32	0.32	0.32	0.31	0.32	0.32

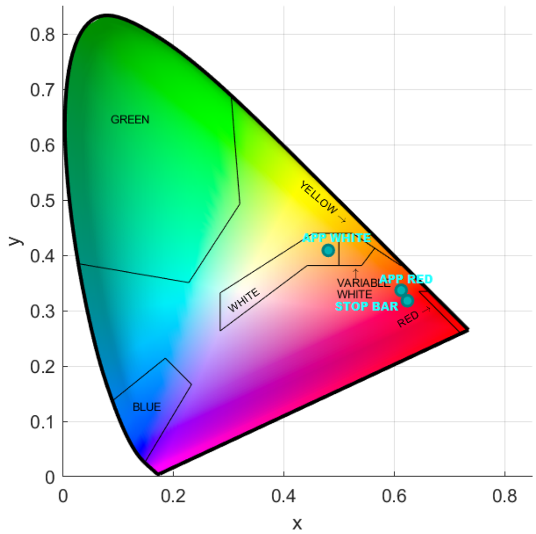

Fig. 10. Chromaticity chart of the elevated airport navigation lighting system.

verification of chromaticity of the lamps is necessary to carry out the maintenance and replacement process on time.

As was mentioned earlier in this section, approach lamps have much more powerful light sources. Figure 11 shows the dependence of the xy coordinates in the CIE1931 space on the distance to the tested lamp. In the case of APP_Red measurements at a distance of 0.5 m and APP_White at a distance of 0.5 m and 1.0 m, the values of individual components were exceeded due to sensor saturation, therefore, the results after conversion at these points are not reliable. It has been established that the minimum measurement distance for the approach lamps is 1.5 m.

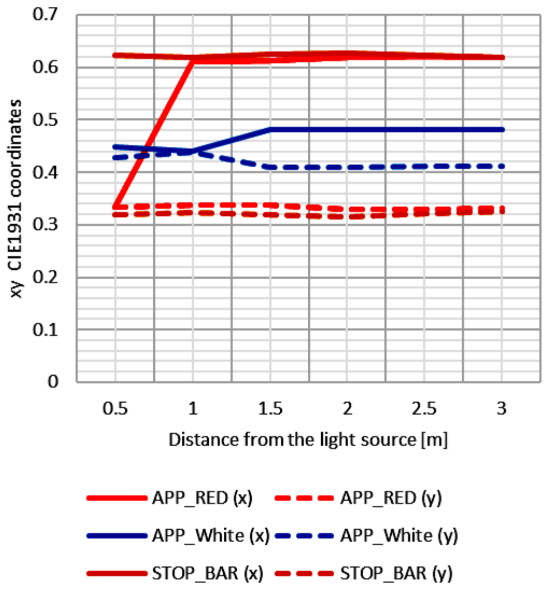

Fig. 11. Graph of the CIE1931 (x, y) coordinates of the tested elevated lamps as a function of the distance from the light source.

6. Conclusions

This paper analysed the possibility of using the TCS3430 sensor in the chromaticity assessment of the airport navigation lighting. The authors prepared software for automatic conversion and visualisation of the obtained measurements, as a result, the user can obtain information about the fulfilment of the chromaticity standard for the selected type of the tested navigation lamp.

Experiments were carried out on seven types of lamps installed in Poznań-Ławica Airport and the influence of the measurement distance from the tested light source was examined. It was found that the measurement of in-pavement airport navigation lamps can be made from a minimum distance of 1 m, and in the case of lamps located above the surface of airport areas, of at least 1.5 m.

The main advantage of TCS3430 is the possibility of obtaining CIE1931 colour coordinates according to EASA standards. Such colour space was not directly possible to analyse with the previous sensor tested, the AS7262. The limitation of the TCS3430 sensor is not sufficient range of given results for each type of tested lamp at the same distance, what results in recommendations for testing in-pavement aeronautical ground lights at a distance of 1 m and 1.5 m for elevated aeronautical ground lights.

The next stage of the authors' work will be the development of the portable microprocessor-based system, so that the user, while making a measurement with no need to enter data, will automatically obtain information on the fulfilment of international standards.

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