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Hacia una nueva medición de niveles de luminosidad en ambientes interiores mediante el uso de una Red de Sensores Inalámbricos

Towards a new measuring luminosity level in indoor scenarios by using Wireless Sensor networks

Para uma nova medida de níveis de luminosidade em ambientes interiores através da utilização de uma rede de sensores sem fio

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Resumen

El dispositivo electrónico comúnmente usado para medir el nivel de luminosidad en ambientes interiores y exteriores es el luxómetro; no se encontraron antecedentes investigativos relacionados con el uso de una red de sensores inalámbricos (WSN del inglés *Wireless Sensors Network*) para medir el nivel de iluminación en el interior de salas de clase. Con base en lo anterior, el objetivo de este artículo es medir los niveles de luminosidad en el interior de aulas de clase de educación superior mediante una WSN en la banda de frecuencia ISM de 2.4 GHz. La recolección de datos se realizó durante el verano en dos aulas de clase, ubicadas en el primer y cuarto piso. Para medir la luminosidad se utilizó el método de los lúmenes para que los módulos configurables estuvieran distribuidos uniformemente en el interior de las salas de clase a una altura de un plano de trabajo de 0.80 m del nivel del suelo. Los resultados promedios del valor de luz detectado por cada sensor representaron el nivel de luminosidad y fueron comparados con valores existentes en la norma ISO-8995, en la que se recomienda que la luminosidad mínima en aulas de educación superior debe ser de 500 lux. Los resultados muestran que los escenarios de pruebas escogidos presentan una luminosidad máxima de 981 lux y mínima de 859 lux. Las aulas poseen una luminosidad superior a la recomendada por la norma ISO-8995 y no presentan sombras molestas porque tienen una iluminación natural y artificial adecuada.

Palabras clave: WSN, método de la cuadrícula., luminosidad.

Abstract

The electronic device commonly used to measure the level of brightness inside and outside surfaces is the light meter. There are not investigative records related to the use of a Wireless Sensors Network (WSN) to measure the level of lighting in classrooms inside. The objective of this article is to measure the levels of brightness in the inside of classrooms though of WSN in the band ISM frequency of 2.4 GHz. Data collection was performed during the summer in two classrooms. These classrooms are located on the first and fourth floors. To measure luminosity was used the lumens method so that the configurable modules were uniformly distributed inside of classrooms at a height of a work plane of 0.80 meters from the ground level. The average results of light value detected for each sensor represented the luminosity level. These results were compared with recommended values in the ISO-8995 norm, where it is recommended that the minimum lighting in classrooms must be 500 lux. The results show that the test scenarios have a maximum luminosity of 981 lux and a minimum of 859 lux. The classrooms have a higher luminosity than the recommended by ISO-8995 and they do not present annoying shades because they have adequate natural and artificial lighting.

Key words: WSN, method of lumens, luminosity.

Resumo

O dispositivo eletrônico comumente usado para medir o nível de luminosidade em ambientes internos e externos é o medidor lux; nenhum fundo investigativo foi encontrado relacionado ao uso de uma rede de sensores sem fio (WSN) para medir o nível de iluminação dentro das salas de aula. Com base no acima, o objetivo deste artigo é medir os níveis de luminosidade dentro das salas de aula de ensino superior usando uma WSN na banda de freqüência ISM 2,4 GHz. A coleta de dados foi realizada durante o verão em Duas salas de aula, localizadas no primeiro e quarto andares. Para medir a luminosidade, utilizou-se o método dos lumens para que os módulos configuráveis fossem uniformemente distribuídos nas salas de aula a uma altura de um plano de trabalho de 0,80 m do nível do solo. Os resultados médios do valor da luz detectado por cada sensor representaram o nível de luminosidade e foram comparados com os valores existentes no padrão ISO-8995, o que recomenda que a luminosidade mínima nas salas de aula de ensino superior seja de 500 lux. Os resultados mostram que os cenários de teste escolhidos possuem uma luminosidade máxima de 981 lux e mínimo de 859 lux. As salas de aula possuem uma luminosidade superior à recomendada pelo ISO-8995 e não apresentam sombras irritantes, porque possuem uma iluminação natural e artificial adequada.

Palavras-chave: WSN, método de grade., Luminosidade.

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Introduction

Recent technological advances and application demands have enabled Wireless Sensors Network (WSN) to become an emerging area of research in wireless and distributed networks (Potdar, Sharif, & Chang, 2009). In addition to the above, the WSN has a great interest in the potential to serve in diverse applications for the control and monitoring of physical phenomena, considering that they are ready to be implemented at low cost and with unprecedented flexibility (Mottola & Picco, 2011). Thus, in Pulido et al., (2012) work lines are presented that address different aspects of research, development and innovation in the WSN area; for example, the development of a computer tool that allows data capture of cardiovascular variables (heart rate and regularity of heart rate) in patients and thermal monitoring for safety and energy efficiency applications. With regard to what was previously proposed in Archila Córdoba & Santamaría Buitrago (2013), it is possible to consult works carried out in relation to WSN, such as monitoring cattle herds through WSN, detecting forest fires, monitoring natural environments, applications for defense, as well as medical applications in patient observation.

The electronic device commonly used to measure brightness indoors and outdoors is the luxometer Crespo, Sánchez, & Vásquez (2015). In Coelho, Peterlini, & Gonçalves (2010) the authors present a register of the distribution of relative levels of illuminance within building models using a series of points in a grid. On the other hand, in Fernández, Peteira, Cabrera, & Durán (2008), the authors used luxometers to investigate the effect of light intensity on populations of pests causing damage to coffee crops. Finally in Jácome & Quinga (2014), the investigation of the measurement of the amount of light in administrative areas of a Higher Education Center is carried out.

In this context, there is no antecedent of research related to the use of a WSN to measure the level of illumination inside classrooms of Higher Education, therefore, the objective of the present article is to measure the levels of luminosity existing in the interior of classrooms of higher education study centers, through the use of WSN. To obtain the average luminosity level, data were collected from four test scenarios, using the method of measuring the lumens, which consists of dividing the interior into several equal square areas. The network of configurable modules will be uniformly distributed in the center of each area at a height of a work plane at 0.80 m from the ground level (Monteoliva & Pattini, 2013; Secretaría de Trabajo y Previsión Social, 2008), so that these sensors will be responsible for collecting information to perform a comparative analysis of the luminosity level.

Materials and methods

The acquisition of data through the use of a WSN was carried out inside two classrooms located inside the campus of the University of the Armed Forces ESPE, from 12:00 to 14:00 during the summer in July . In that month the average temperature was 22 degrees Celsius. Figure 1a shows the classroom located on the first floor and Figure 1b shows the classroom on the fourth floor, in the first there is less presence of sunlight and in the second, larger, which influences the level of luminosity in each interior environment. The test scenarios are of equal dimensions, the details are presented in Table 1 and have similar characteristics: they have beige walls, two windows and eight fluorescent tube lamps as can be seen in Figure 1a and Figure 1b. Currently installed luminaires are shown in Figure 2. The lamps are Sylvania fluorescent lamps (Havells Sylvania, 2017), widely used in institutions that require a high luminous flux and provide uniform illumination over the entire work area.

Figure 1. Escenarios de prueba.

(a) (b)

Source: Elaboración propia.

Figure 2. Luminaria actual instalada.

Source: Elaboración propia.

The lumens method was chosen for its simplicity to obtain the average value of illumination in indoor environments; this form of study is based on a grid of measurement points, so it is necessary to divide the interior of the classroom into zones of equal size and place the node in the center of each area at a height of 75cm ± 10 cm above the soil level to measure the average illuminance that influences each of the numbers of measurement points (Secretariat of Labor and Social Welfare, 2008).

There is a relation to establish the number of measurement points, for which it is necessary to calculate the area index (IC) using Equation 1 and the data of Table 1, in Monteoliva & Pattini (2013) this formula is denominated Points of Grillado.

$$IC = \frac{a \times b}{h \times (a + b)} \qquad (\mathbf{1})$$

Table 1. Dimensiones de los escenarios de prueba.

Datos	Símbolo	Dimensión [m]
Ancho	a	7.10
Largo	b	9.70
Altura de la luminaria respecto al suelo	H	3.90
Altura de la luminaria respecto al plano de trabajo	h	3.10

Source: Elaboración propia.

The relationship mentioned to calculate the minimum number of measurement points is expressed in Equation 2, where IC is rounded to the nearest integer.

The results indicated that nine measurement points are required; this can be corroborated according to table A1 of Official Mexican NORM NOM-025-STPS-2008 (Secretaría del Trabajo Y Previsión Social, 2008).

$$Número\ mínimo\ de\ puntos\ de\ medición = (IC + 2)^2 \qquad (\mathbf{2})$$

Initially we proceeded with the programming of 10 Memsic CrossBow modules: 1 USB model MIB520 gateway (MEMSIC Inc, 2017b) that provides an interface for programming and data communication and nine MPR2400 model nodes (MEMSIC Inc, 2017a), these sensor nodes have the characteristics shown in Table 2; Also for the acquisition of data, nine MTS310 sensors (Crossbow Technology Inc., 2006) are required to be coupled to the MPR2400 nodes, these sensors were considered because they can measure light. To achieve this, we worked with a laptop with Windows XP Professional operating system, Intel Pentium 4 processor working at 2.60 GHz with 1GB RAM to run the software MoteConfig (Ali, Drieberg, & Sebastian, 2011, Border, 2012) for the programming of the nodes and MoteView for the real-time monitoring and the analysis of the readings of the sensors (Parbat, Dwivedi, & Vyas, 2010; Turon, 2005).

Table 2. Características de los nodos MPR2400 de *CrossBow Memsic.*

Parámetro	**Valor**
Procesador	Atmel ATMega 128L, 8 bit
Velocidad (MHz)	8-16
RAM (Kbytes)	4
Radio Gama de frecuencia (GHz)	2,4 a 2,48
Tx / Rx	TI - CC 1000/2420
Tasa de datos (Kbps)	38,4 / 250

Source: Elaboración propia.

For MoteConfig software, a different identifier for each node (Node ID), an identifier for the network (Group ID), the 2.4 GHz ISM frequency band is chosen. nodes and in the coordinator are shown in Table 3, so that a sensor node is put into operation as Gateway or fixed node.

Table 3. Parámetros de configuración de los nodos sensores.

Parámetro	**Valor**
NODE ID (Gateway)	0
NODE ID (nodos)	1/2/3/4/5/6/7/8/9
GROUP ID	110
RF Power	31
RF Channel	CHANNEL_15

Source: Elaboración propia.

Then, according to the calculations previously made, we placed in each grid of measurement points the nine nodes and a Gateway within the classroom. Figure 3 shows the proposed scenario for measuring the luminosity level and Figure 4 shows the location of three fluorescent tube lamps inside classrooms.

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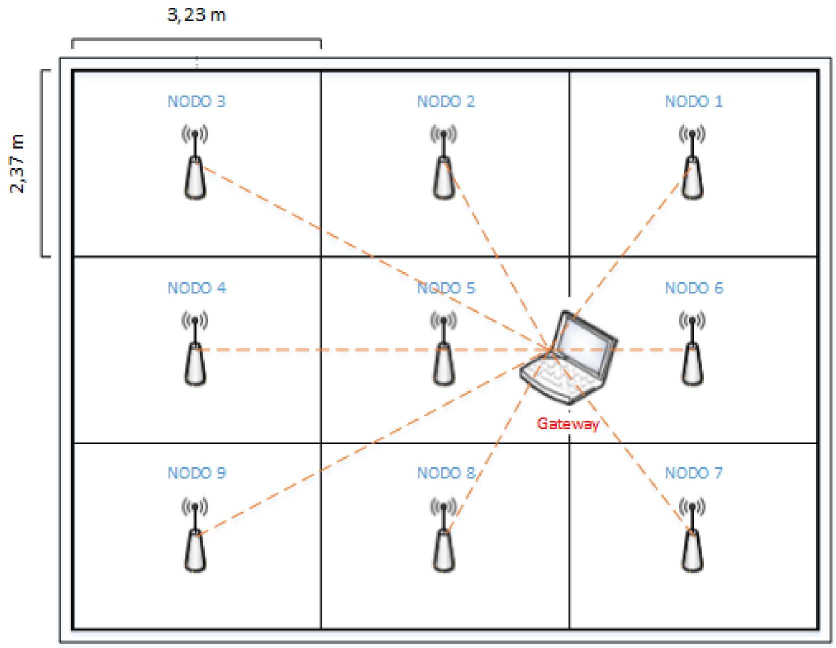
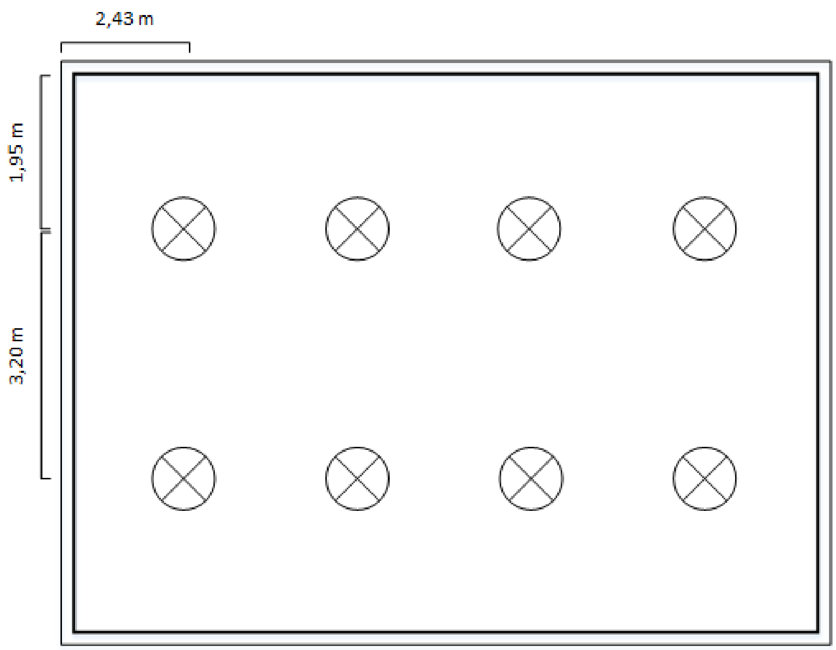
Figure 3. Escenario de diez nodos desplegado en Interiores.



Source: Elaboración propia.

Figure 4. Ubicación de las lámparas en el interior de las aulas de clase.



Source: Elaboración propia.

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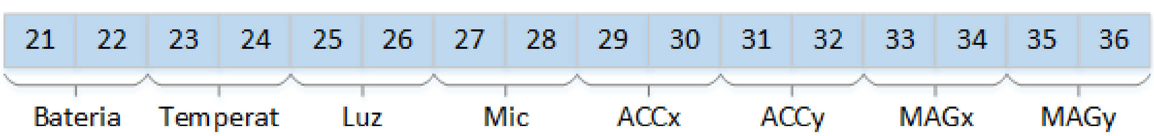
To perform the connection process between the MoteView Interface and the WSN, the MoteView software was run and Acquire Live Data was selected. After doing so, the interface of the MoteView Software can automatically recognize the nodes, thus obtaining the link between the sensor network and the monitoring application on the computer. The nodes sent data using the Xmesh routing protocol developed by Crossbow for wireless networks (Teo, Singh, & McEachen, 2006). For the data collection, four scenarios were considered where the lighting factors of the classroom were modified, where: Scenario 1 corresponds to data collection when the curtains are open and the lamps are on; Scenario 2 when the curtains are open and the lamps are off; Scenario 3 at the time the curtains are closed and the lamps on and Scenario 4 having the curtains closed and lamps off.

Finally, after collecting data in each test scenario and after completing the data acquisition period for 20 minutes, the file with .txt extension, generated by MoteView software, was exported. The file contains the distribution of the physical magnitude Bytes of the MTS310 sensors within the Sensor Data packet as shown in Figure 5.

Figure 5. Distribución de Bytes de magnitudes físicas en el paquete Datos del sensor MTS310.



Source: Elaboración propia.

A two-digit hexadecimal number represents each Byte in the data frame, so it needs to be converted to decimal numbers or raw units (Crossbow Technology Inc., 2006; Vivanco, 2008). The 26-25 bytes represent the magnitudes of the light, so the software will be displayed in engineering units and these units are equivalent to the lux, unit of the illumination level of the International System whose symbol is lx. Finally, the analysis of the acquired data is done through the MATLAB Tool.

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Analysis of results

In this section we analyze the results obtained when performing the WSN indoors, the average results of the level of luminosity detected by each sensor in each of the proposed scenarios can be seen in Table 4 and Table 5 of the classrooms located on the first and fourth floors respectively.

Table 4. Nivel de luminosidad promedio en lux por sensor y escenario de prueba del aula ubicada en el primer piso.

	Escenario 1	Escenario 2	Escenario 3	Escenario 4
Sensor 1	938	912	907	855
Sensor 2	944	920	910	857
Sensor 3	937	916	912	856
Sensor 4	938	921	913	859
Sensor 5	943	918	908	861
Sensor 6	945	917	911	863
Sensor 7	939	921	909	859
Sensor 8	940	923	910	860
Sensor 9	943	919	906	862
Promedio	**941**	**919**	**910**	**859**

Source: Elaboración propia.

Table 5. Nivel de luminosidad promedio en lux por sensor y escenario de prueba del aula ubicada en el cuarto piso.

	Escenario 1	**Escenario 2**	**Escenario 3**	**Escenario 4**
Sensor 1	983	961	953	894
Sensor 2	979	959	959	893
Sensor 3	982	963	952	900
Sensor 4	985	964	958	896
Sensor 5	981	963	958	901
Sensor 6	980	958	957	897
Sensor 7	978	960	955	898
Sensor 8	983	962	950	902
Sensor 9	981	963	950	894
Promedio	**981**	**961**	**955**	**897**

Source: Elaboración propia.

Figure 6 and Figure 7 represent the luminosity level in lux of the classroom of the first and fourth floor respectively and compare the results obtained in each test scenario, we can see that there is greater luminosity in Scenario 1. Scenario 2 and Scenario 3 they present a similar but lower luminosity level in comparison to Scenario 1 because in these scenarios the state of lamps and curtains was modified, finally. The lower brightness value compared to the previous scenarios is in Scenario 4. These data obtained indicate that the level of luminosity detected by the sensors varies when the natural and artificial light is modified within the classrooms.

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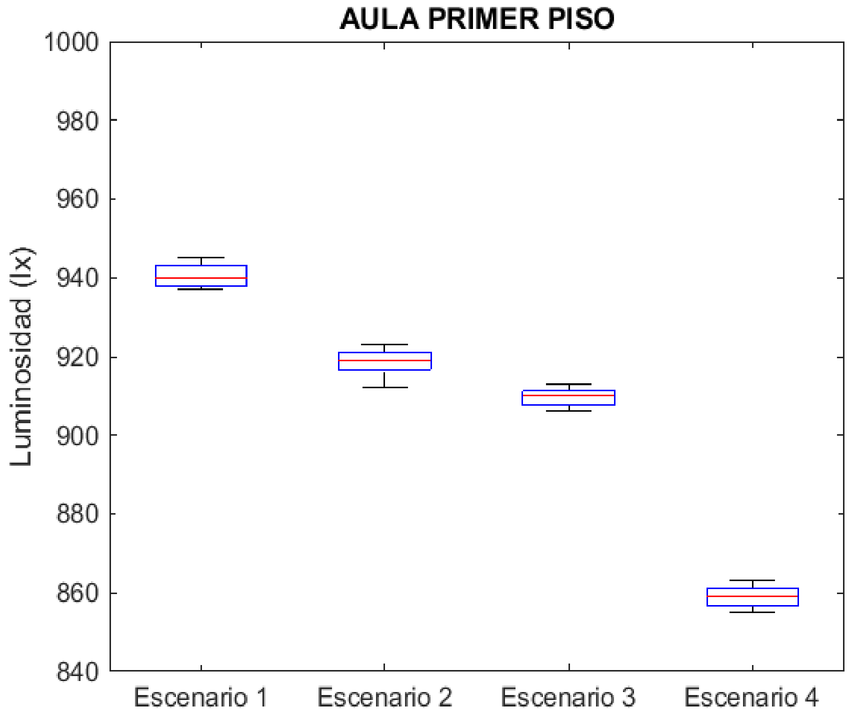
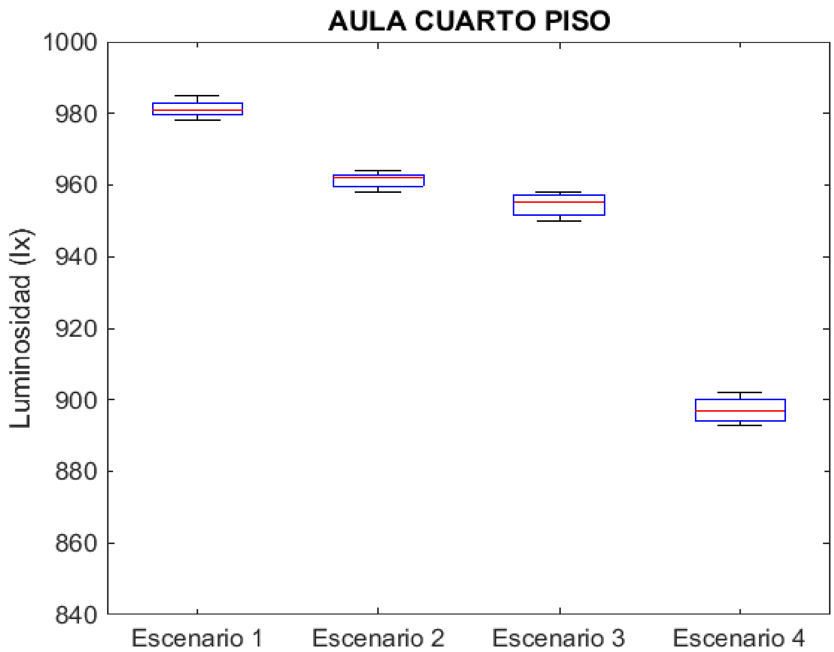
Figure 6. Nivel de luminosidad promedio por escenario de prueba del aula ubicada en el primer piso.



Source: Elaboración propia.

Figure 7. Nivel de luminosidad promedio por escenario de prueba del aula ubicada en el cuarto piso.



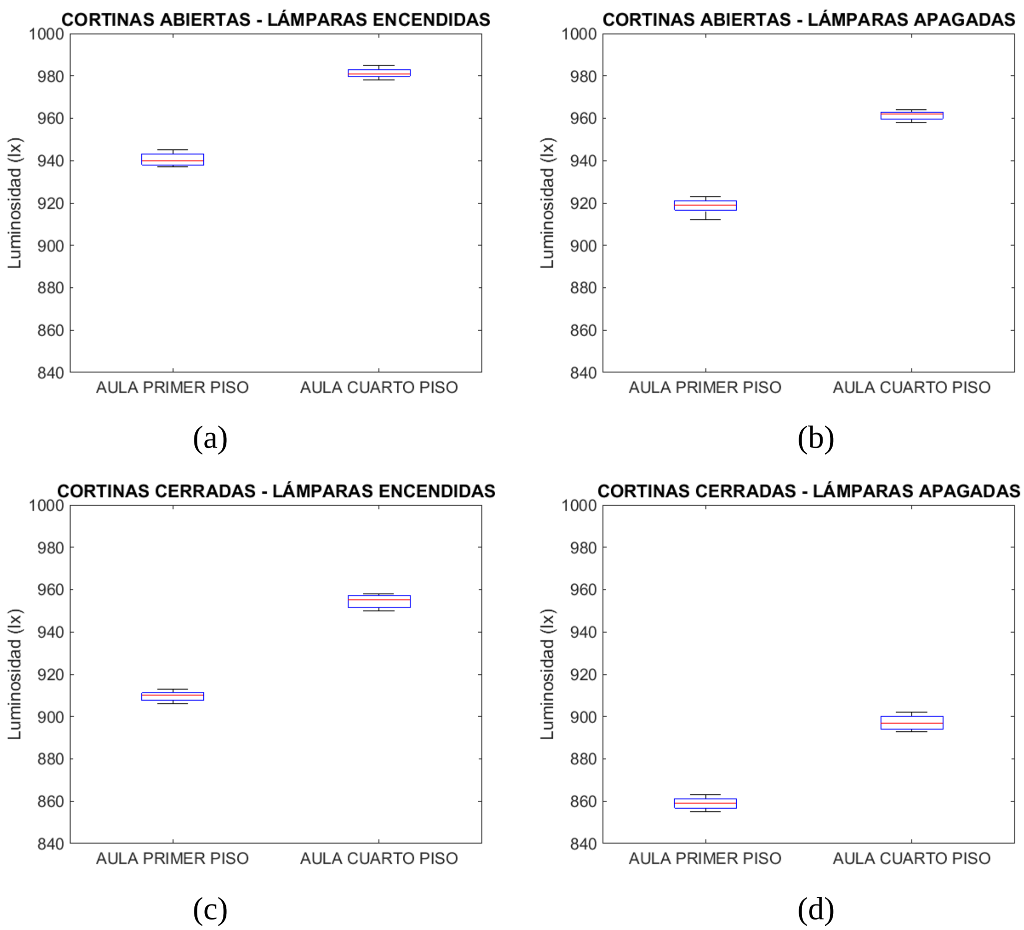
Source: Elaboración propia.

Figure 8 presents a summary of the results obtained with respect to average luminosity by test scenario, comparing the results of the classroom of the first floor with respect to the classroom of the fourth floor.

In panel 8a the average luminosity values of each sensor obtained in Scenario 1 are presented. It can be seen that the median is 941 (lx) and 981 (RU) for the first and fourth floor classroom respectively. However, there is greater variability in the data of first-floor classroom sensors, with an interquartile range of 5.25 and lower variability in fourth-floor classroom data, with an interquartile range of 3.25. In addition, the distribution in both classrooms has positive asymmetry.

Panel 8b shows the average luminosity values obtained in Scenario 2. It can be seen in this figure that for the first floor classroom there is a median of 919 lux, there is greater variability of data, with an interquartile range of 4.25 compared to the fourth-floor classroom with less variability in the data, with an interquartile range of 3.25 and a median of 962 lux. These distributions have negative asymmetry, with at least one luminance measurement of 912 lux and 958 lux corresponding to the classroom of the first and fourth floor.

Figure 8. Comparación de luminosidad promedio del aula del primer y cuarto piso por cada escenario de prueba.



Source: Elaboración propia.

The median brightness of Scenario 3 for the first floor classroom is 910 lux; and 955 lux for the fourth floor classroom, both of which are illustrated by panel 8c. Both distributions have negative asymmetry, with interquartile ranges of 3.5 and 5.75 for the classroom on the first and fourth floor respectively.

In panel 8d corresponding to Scenario 4, it can be seen that in the classroom of the first floor has a median of 859 lux and an interquartile difference of 4.5, while the data of the classroom of the fourth floor present a median of 897 lux and have positive asymmetry, with an interquartile range of 6.25 which means that there is greater variability in the data.

Discussion and conclusion

When the WSN was deployed indoors, greater brightness was found in Scenario 1 than in the other scenarios, with values of 941 lux and 981 lux for the classroom of the first and fourth floor respectively, these values being the most significant. The first floor classroom has a brightness of 859 lux and the fourth floor classroom 897 lux in Scenario 4, these values being below 900 lux which makes them the least significant. Finally, the average brightness values for Scenario 2 and Scenario 3 are between 910 lux and 961 lux, respectively. In all scenarios it can be seen that the fourth-floor classroom is brighter compared to the classroom on the first floor, because there is more light on the fourth floor because it receives more natural light during the day. As in the classroom on the first floor there is not much sunlight, the average luminosity has a lower value.

In the graphic representation of the data there are no outliers, ie there are no values that have been highlighted above or below the other values obtained by the sensors. When comparing the level of luminosity per stage between the classroom of the fourth floor and the classroom of the first floor is that in Scenario 1 there is a difference of 39 lux of luminosity, 42 lux in Scenario 2, for Scenario 3 there is a difference of 45 lux and for Scenario 4 there is a difference of 38 lux. It is concluded that the level of luminosity in the fourth floor classroom is higher by 40 lux on average in each scenario because it receives more natural light during the day, while the classroom on the first floor has little presence of sunlight due to obstacles present in the windows like trees and shrubs that cause shade.

The average luminosity results detected by each sensor in each of the proposed scenarios are expressed in lux. A comparison was made with the values recommended in ISO-8995 which specifies lighting requirements for indoor workplaces, where it recommends that the minimum illuminance in classrooms of higher education should be 500 lux. Thus, it was concluded that the test scenarios chosen are complying with the average illuminance and do not present annoying shadows because they have a good natural and artificial lighting.

Our group is interested in continuing this research line, so that future work will compare the level of luminosity by varying the height of the sensor with respect to the work plane as recommended and will be made in three different time slots; in addition to considering other parameters such as coefficients of use, reflection and maintenance.

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