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Sensor array for the analysis of the lighting situation in an intelligent industrial hall

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Abstract

In this paper, the possibility of using a multi-channel color sensor to identify artificial light and daylight for use in an intelligently illuminated industrial hall is investigated. First, an overview of intelligent lighting systems is given and the experimental setup is explained. Due to the large amount of data, the processing of large data sets is then highlighted. On the basis of the data collected, it will then be shown that it is possible to distinguish between daylight and artificial light using multi-channel colour sensors.

Index Terms: *intellogent lighting, smart lighting, color sensor, daylight, adaptive illumination*

1 Introduction

Due to the increasing digitalization and connectivity of all areas of life, terms such as "Internet of Things" or "smart" have become an integral part of today's technological discussions. Small, networked electronic components provide the technical basis for a "smart" environment. They collect information about their environment and can interact with it and the user. On the basis of this information it is possible to increase user comfort. In the field of interior lighting, such "smart" concepts for increasing user comfort are currently still in an early stage of development. Commercially available systems currently offer basic options for adjusting brightness and colour temperature via smartphone applications, for example. There are also individual products that offer brightness control. All these systems have in common that the user must actively intervene and the lighting cannot adapt adaptively to the spectral properties of the room.

2 Definition of an intelligent lighting system

The first step is to define the properties of an intelligent lighting system. Looking at common definitions shows two essential approaches: purely technical and involving people.

2.1 Technical definition

Heppelmann and Porter identify three main components of an intelligent lighting system: physical components, smart components and connectivity components [1]. Physical components represent all electrical and mechanical elements of a lighting system that are essential for its function. Such functions, which represent specific product properties through sensors, smartphone applications etc. and extend the basic function of the luminaire, are referred to as smart components. The provision of communication to smartphones or a higher-level building management system is represented by connectivity components.

2.2 Biological-technical definition

In contrast to the purely technical definition, the biological-technical definition according to Khanh et al. also considers the effect of light on humans and their interaction with the intelligent lighting system. For example, the system must be able to set the optimum lighting situation for the user. Visual, non-visual and individually adaptable parameters must be taken into account.

3 Research Topics

It is currently necessary to know the spectral properties of a room within the framework of a light installation. This requires either the spectral measurement of a room or knowledge of all components such as wall paint, furnishings, etc.. Based on these spectral data, the lighting of the room can now be adjusted accordingly. However, both variants require a considerable amount of time or technology. For this reason the idea of an intelligent lighting system exists. It is able to adapt dynamically within the room according to its target specifications. For this purpose, the luminaires need information about the room and the current spectrum of the area to be irradiated. In addition to this, however, information such as room occupancy, temperature and current weather data is also required. The latter provide information on the influence of outdoor light on the lighting system. For space and cost reasons, a compact and simple sensor system for recording room data is required. This work is intended to investigate to what extent multi-channel colour sensors are suitable for distinguishing between daylight and artificial light.

4 Test setup

For the experiment, a small factory hall was equipped with an intelligent lighting system. Sensor arrays were installed at various positions within the hall for this purpose. Figure 1 shows the positions of the sensor arrays inside the hall. In the following, sensor array 1 is examined as an exemplary example.

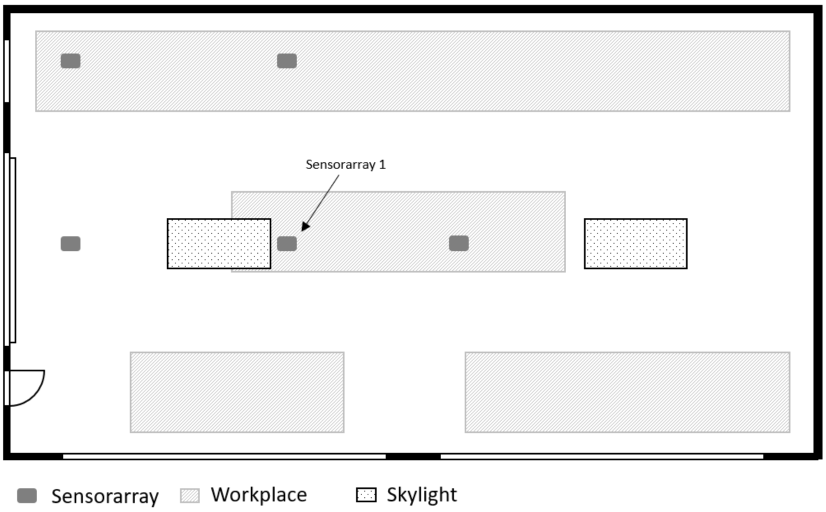

Figure 1: Positioning of the sensor arrays within the industrial hall

Each sensor array contains a 6-channel color sensor AS7262 [2], a Grideye IR sensor AMG8833 with 8x8 pixels [3] as well as a sensor for the acquisition of environmental data such as temperature, air pressure, humidity and air quality BME680 [4]. The sensor array is shown in Figure 2.

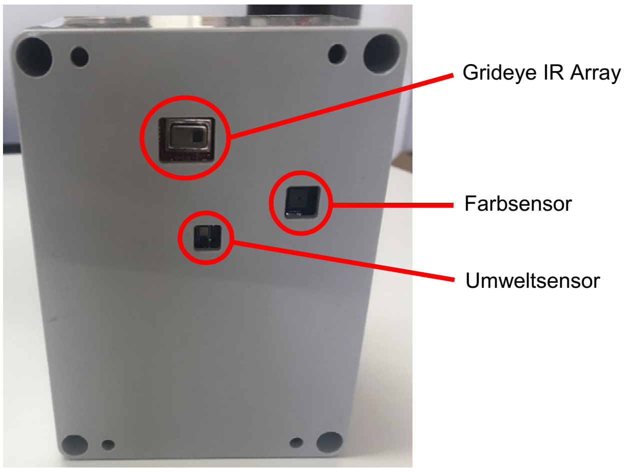

Figure 2: Underside of the sensor array

The respective sensor data are recorded and preprocessed by an ESP32 microcontroller. The microcontroller transmits the data via WiFi to a local edge computer. The Edge Computer has four tasks: Query of the weather data, processing and filtering of the sensor data, control of the lighting system and communication to a cloud. A server cluster at the TU Darmstadt is chosen as the cloud. All sensor and weather data are continuously stored in a Cassandra database running in the cloud [5].

5 Data evaluation

In order to obtain a usable data situation, data were recorded over a period of three months in the context of this work. This resulted in a total data set of 170 GB in CSV and JSON format [5]. Therefore, the collected data had to be aggregated and filtered first. The processing and visualization of the data was performed in Python 3.7 and Pandas.

Figure 3 shows an example of a line with a total of 145 million lines. This is formatted as a JSON file. JSON is a hierarchical, text-based representation of key/value pairs and is used especially in machine to machine communication as a file format.


```
{
  "index": "0",
  "mac": "B4E62DAC56A5",
  "room": "werk3",
  "time": "1557391580.1747217",
  "partition_id": "2735",
  "luminaires": "",
  "name": "None",
  "sensors": {
    "gas_resistance_env": "48.375",
    "humidity_env": "35.497",
    "pressure_env": "972.53003",
    "temperature_env": "26.87"
  }
}
```


Figure 3: Raw data from database dump

First, all irrelevant key/value pairs and the JSON hierarchy are removed from the data record to simplify further processing with pandas. In the following step, the data was revised with regard to storage efficiency and readability. The Unix timestamp was translated into a readable date format and the MAC address was renamed to the name of the array. Finally, the data types of the respective measured values were reduced to the smallest possible data type. Thus, the data set could be reduced from 170 GB to about 50 MB without any relevant loss of information. The finished data set can be seen in Figure 4.


```
{
  "mac": "Node01",
  "time": "2019-05-09 10:46:20.654758",
  "gas_resistance_env": "48.375",
  "humidity_env": "35.497",
  "pressure_env": "972.53003",
  "temperature_env": "26.87"
}
```


Figure 4: Filtered and preprocessed data set

6 Discussion

Figure 5 shows the sensor response of the 450nm channel of the color sensor over 24 hours of one of the installed sensor arrays. These indicate the measured irradiance in μW/cm². The data were averaged to T=60min to make a first qualitative statement. For the further consideration the 450nm channel is used as an example. There are three striking characteristics: On weekdays the sensor responses increase about one hour earlier compared to the weekend, the brightness curves of individual days show a strong variability (see Sat-Sun) and in the afternoons the curves are similar.

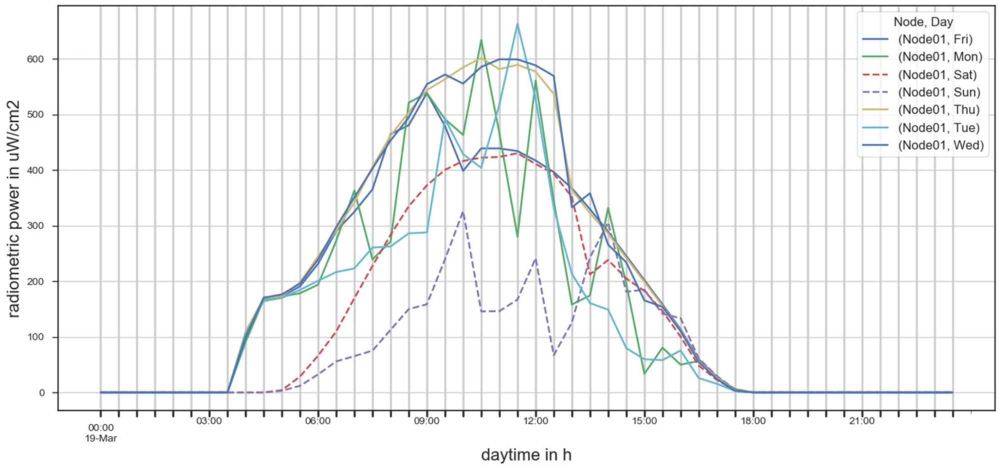

Figure 5: Sensor return values of the 450nm color channel of the AS7262 color sensor over T=60min averaged for the daily courses of the weekdays Monday - Sunday

6.1 Time-delayed increase of sensor responses

On weekdays, sensor responses show a comparatively abrupt increase each day at the exact same time. On the other hand, the sensor response increases continuously on weekends. A comparison of the maxima of the individual sensor responses shows a difference of approx. E=150μW/cm² between working days and weekends. This difference can also be determined at the beginning of the day. Thus the conclusion is obvious that the artificial lighting is switched on at this time. This has an influence of approx. 15% of the total irradiance. An inquiry with the owner of the industrial hall confirmed this assumption.

6.2 Variations in the brightness curve

The days Tuesday, Wednesday and Saturday show in the measurement a brightness curve correlating to the time of day. On the remaining days, on the other hand, significant fluctuations can be observed as shown in Figure 6. As these occur both on weekdays and at weekends, therefore under pure daylight as well as under mixed light, external influences can be assumed. One possible cause can be changing weather conditions, especially the degree of cloud coverage. The verification of this hypothesis will be carried out in the context of a further work.

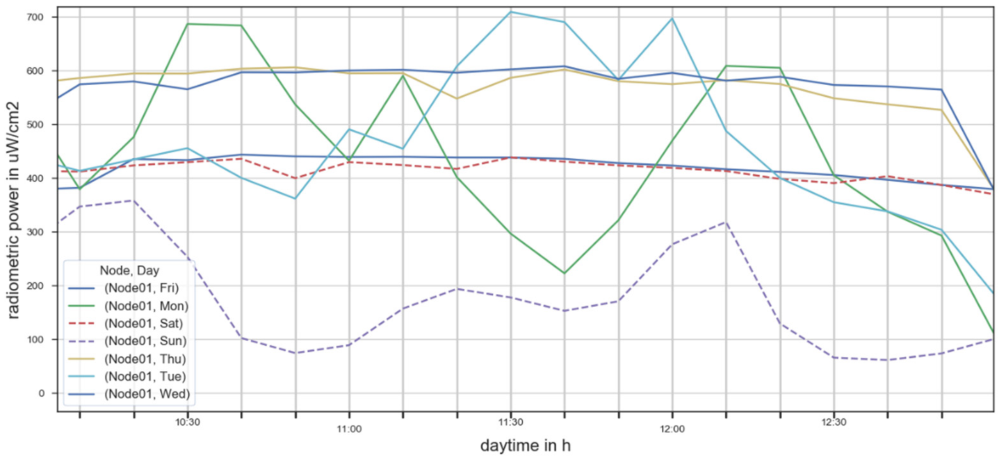

Figure 6: Strong variations of the individual sensor channels

6.3 Adjusting course in the afternoon

Thirdly, a converging course of the sensor responses of all days in the early afternoon can be observed, as shown in Figure 7. The weekdays show a significant reduction of their sensor response by about E=250-300µW/cm². At this point two boundary conditions have to be considered: The shift of the daylight spectrum into the warm white range over the course of the day and the fact that the 450nm channel of the sensor is considered here [6]. Taking these boundary conditions into account, it is assumed that the hall lighting will be switched off in the early afternoon. This was also confirmed after consultation with the hall operators.

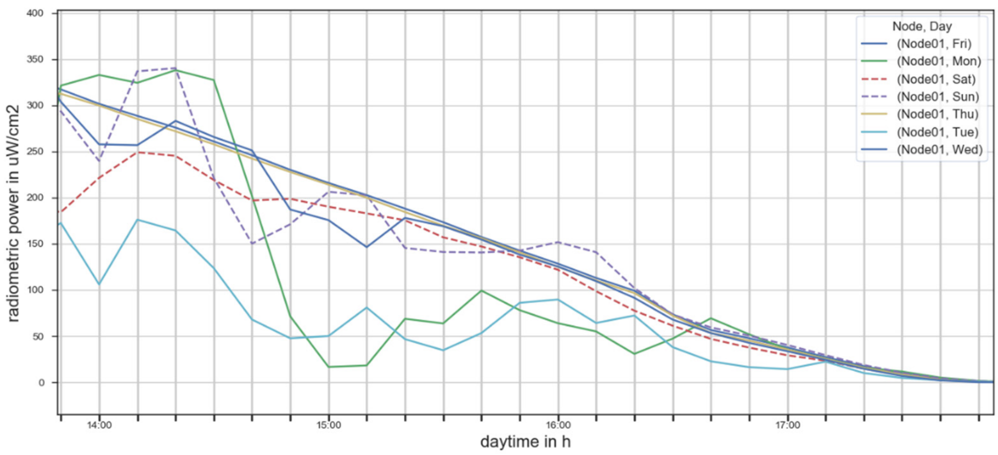

Figure 7: Converging course of sensor responses in the afternoon hours

7 Conclusion and outlook

In the context of this work, an initial evaluation was carried out regarding the use of a multi-channel colour sensor to differentiate between artificial light and daylight in smart industrial hall lighting. Common patterns in the course of the sensor response are shown as a function of the day of the week. On working days, the sensor responses increase with time. A higher irradiance of about E=150µW/cm² is also recorded. The assumption that the hall lighting would be switched on was confirmed after consultation with the hall operator. Similarly, the switching off of the hall lighting could be detected.

In addition, the irradiance recorded during the course of the day fluctuated strongly in some cases. However, the presumption of the influence of the degree of cloud cover was not investigated in the context of this work. This offers a starting point for further investigations. In this respect the correlation between cloudiness and response of the colour sensor should be examined. The sensor responses of the remaining spectral channels should also be examined with respect to the spectral distribution of daylight.

8 References

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