CODYRUN: Artificial lighting simulation for visual confort and energy saving optimization

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CODYRUN: ARTIFICIAL LIGHTING SIMULATION SOFTWARE FOR VISUAL COMFORT AND ENERGY SAVING OPTIMIZATION.

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ABSTRACT

This paper reports a method about artificial lighting simulation. More precisely, we present a case study with software simulation. The software used is 'CODYRUN', a powerful tool developed by the PIMENT laboratory. This software has been developed by the building physics team of the PIMENT laboratory since 1993. It has been completed with a specific model dealing with artificial and natural lightning in 2009. The goal of this study is to analyse, with CODYRUN, the indoor artificial lighting repartition and optimization. In this way, we will be able to appreciate the quantity/quality of this repartition, and find a better solution if needed. Beyond this particular case, the method can be used in every other study configurations to find the artificial lighting repartition. Considering that, a succinct presentation of the newest CODYRUN lighting functionalities and applications is made. Moreover, we explain briefly how these are implemented.

The case study is a classroom located in a tropical island called 'La Réunion' (Indian ocean). The initial set-up is a classroom-typical light disposal. After simulation, mean artificial lighting values of 433 lux with an inadequate distribution is found. More precisely, it evolves between two hot spots of 794 lux in the centre of the room and 66 lux in the corners. This means, considering visual comfort, only 45% of the work plan is adequately lit. After correction, the distribution is much better. The new mean artificial lighting level has risen to 500 lux but with a better homogeneity. In this new configuration, there is no real hot spot, and the lighting level evolves between 550 lux and 250 lux, respectively at the centre of the room and in the corners. Considering visual comfort, 91% of the working plan surface is now adequately lit. So we improved the lighting quality by 46%.

Thus, this tool induces a good prediction of light distribution and allows optimising it, which means making a better choice considering economy and comfort of occupants (with good lighting, there will be no need for additional devices).

Key Words: CODYRUN, optimization, artificial lighting, simulation, comfort.

INTRODUCTION

Nowadays, in western countries, human beings spend most of their time in buildings. In order to provide quality lighting, leading to a good visual comfort in function of the activities, it is important to take care of the light intensity and distribution in the building. For this purpose, both natural and artificial light need to be taken into account and their evolutions all day/month/year long. These functions have been included in the software CODYRUN, which can thus be used to optimise natural and/or artificial light distribution.

CODYRUN is a research building-simulation software allowing to understand and predict complex configurations behaviour. Thus, it induces a good prediction of light distribution and allows optimizing it. The present paper presents the software and its application in an analysis and optimisation case study.

SOFTWARE PRESENTATION: CODYRUN

CODYRUN is a powerful building numerical simulation tool developed by the PIMENT laboratory. This software has been developed at the PIMENT laboratory building physics team by Harry BOYER [1] since 1993. Initially specialized on thermo-aerolic heat transfer, several models were implemented throughout the years improving the software capacities. Detailed elements of algorithm and validation of this software are presented in several papers [2,3]. CODYRUN philosophy is based on semi-detailed models, which allow to get precise results with low computational costs. Due to its numerous applications in the fields of thermal comfort and energy consumption, it is an appreciated research and predictive tool.

In 2009, a specific model dealing with artificial and natural lightning has been added. According to Fakra [4], this model is more precise than current software references such as RADIANCE, SUPERLITE or LESO-DIAL. It was validated following BESTEST procedures and successfully confronted to experimental data.

More precisely, considering the model, the light study is performed on a virtual horizontal surface called 'work plan'. This surface is located at a specified height from the floor. The work plan is simulated by a variable number of points specifically distributed in a plan, called grid. Each point corresponds to a location where the light intensity is researched, computed.

$$E_{glo,P} = \frac{I_{S,P}}{d_{SP}^2} \cdot \cos(\alpha) \cdot (1 + \rho()) \tag{1}$$

In artificial lighting, for one source, the direct and diffuse radiations are expressed and summarised by the equation (1). Where 'E' is the global artificial lighting at a position P (in lux), 'I' is the light intensity of the source S into P direction (in Cd), 'd' is the distance SP (in m), 'ρ' is the averaged walls reflection coefficients and 'α' is the angle between the work plan normal and the SP light segment.

CASE STUDY

The case study is a classroom located in a tropical island called 'La Réunion' (Indian ocean). The initial set-up is a classroom-typical light disposal (Fig. 1). The aim of this study is to appreciate the quantity/quality of the light distribution, and find a better solution if needed. This study focuses only on artificial light, but the same study could be done for natural light or a combination of both in function of the day time (etc.).

Nota: Beyond this particular case, the following method can be used in every other study configuration to find the artificial lighting distribution.

Hypothesis

Simulations are made on an work plan localised at 0.85 m from the floor. Artificial sources are considered Lambertian, punctual and isotropic. The grid discretisation has a regular pattern, the distance between two nodes is the same following x or y axes, $\Delta x=\Delta y=0.2$m.

Description

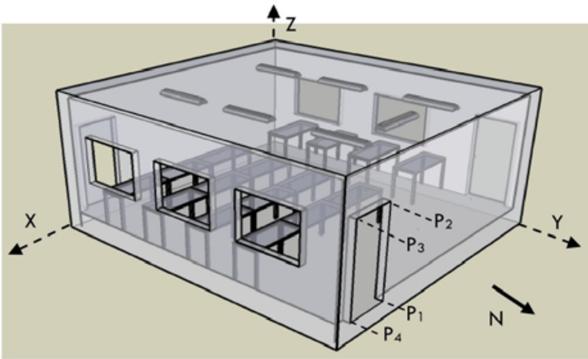

Figure 1: Classroom presentation and light disposal.

The classroom has seven neon lights. L1 to L6 are lighting the student desks (~1300 Cd) and L7 is lighting the blackboard (~950 Cd). The L1 to L7 intensities were found by measurement, they are expressed into Table 1, for localisation see Figure 2. After classroom description in CODYRUN, the simulation can be run.

Light Position	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**
Intensity (Cd)	1290	1370	1350	1148	1164	1372	955
Utilisation	Desk	Desk	Desk	Desk	Desk	Desk	Board

Table 1: Measured light intensities.

RESULTS AND DISCUSSION

Real set-up simulation

After simulation, a mean artificial lighting level of 433 lux with an inadequate distribution is found (Fig. 2). More precisely, it evolves between two hot spots of 794 lux in the centre of the room and 66 lux in the corners. Around 50% of the work plan is lit by more than 500 lux as imposed by the European norm (NF/EN 12464-1), whereas 5% shows a lighting level below 300 lux (next to the borders).

This light distribution implies a correct lighting distribution on 45% of the work plan leading globally to a bad visual comfort (both too much or not enough light).

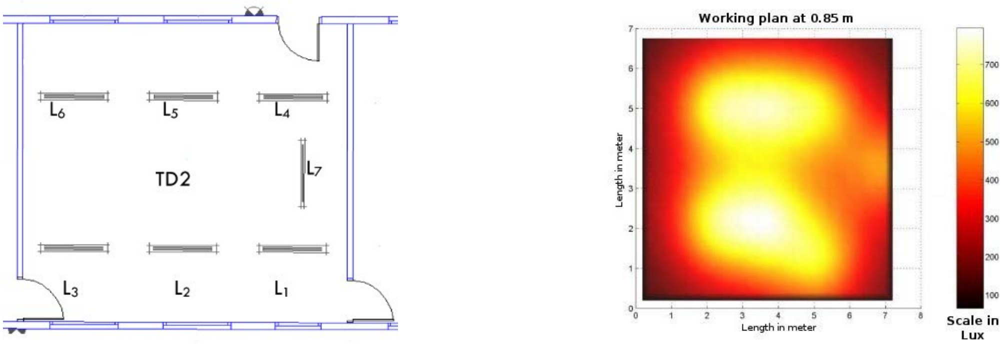

Figure 2: Classroom real light disposal and intensities distribution.

Optimization simulation

Considering the real light disposal intensities distribution and values, another light distribution was proposed in order to get a relatively homogeneous intensity throughout the classroom. Several methods could be used to get a new sizing. Here the main idea was a better distribution of the light, so the sizing is based on the global intensity conservation. In this case, nine identical lights of 1767 Cd (Fig. 3) were chosen.

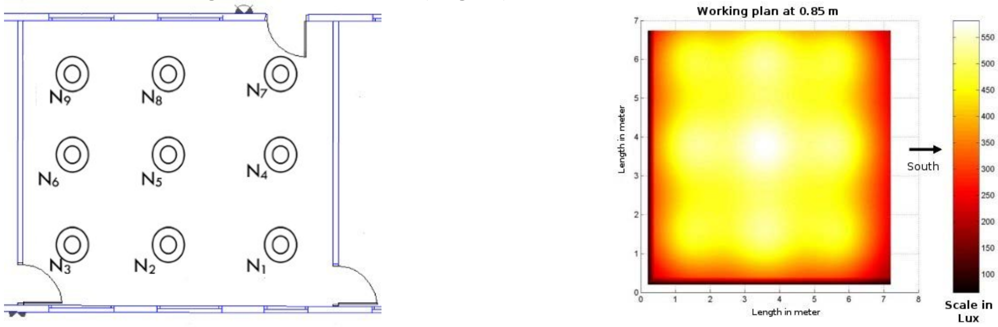

Figure 3: Optimized classroom light disposal and intensities distribution.

Corrected light disposal simulation gives a better distribution. The new artificial lighting mean rose from 433 to 500 lux but with a better homogeneity. In this distribution, there is no real hot spot, and the lighting evolve between 550 lux and 250 lux, respectively at the centre of the room and in the corners. Considering visual comfort, 91% of the working plan surface is adequately lit. So we improved the lightning quality by 46%.

CONCLUSION

CODYRUN allowed us to diagnose a classroom's artificial lighting in intensity and distribution. This predictive tool could also simulate another configuration to find a better light disposal, improving significantly visual comfort and lighting quality (+46%). Similar diagnostics could be performed for natural lighting or a time evolving mix of both natural and artificial lighting.

Considering the thermo-aerolic model implemented in CODYRUN, the light and thermal models can be coupled to get simultaneously an energy, thermal and visual study in the same simulation.

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