WILL IT REALLY BE SOFT AND CALM, MY LUMINOUS AMBIENCE?

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ABSTRACT: The intake and distribution of natural light in interior spaces are imagined early in architectural design: placement of openings, orientations and inclinations, depth of spaces, etc. are defined during the first sketches. However, existing design aid tools are ill adapted to this early phase where the building is not completely defined.
In order to help overcome these difficulties, we propose to use the models of buildings in design. They are placed under an artificial or natural sky. Inside images are displayed via micro-cameras on a computer screen. The software computes correspondence between points of the image and luminance levels in the actual models. Knowing luminance in every point of the interior envelope, the software we are developing, analyses the luminous ambience on the image. The main contribution of this work lies within ambience analysis on images, expressed in qualitative and quantitative terms. For example, the result of the analysis of a field of vision is "calm and clear ambience" or "tense and rather dark", etc. Definitions of such qualitative terms, based on previous works, are shown to users along with related quantitative and reference data.
These methods help the use of natural light, hence of renewable energy. It allows good use of the natural luminous flux: to have enough but not too much (avoiding visual discomfort and overheat). It also allows architects to follow the aesthetic evolutions of the ambiences they imagined.

Conference Topic: Computer Simulation Tools
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1. CONTEXT and PROBLEM

The purpose of this work is to propose improvements for a design aid method of luminous ambience in daylighting.

1.1. Architectural Design

The way natural light is taken and distributed in interior spaces is decided very early in architectural design: the placement, orientations and slopes of openings, etc., are defined during the first sketches. However, existing tools for design aid are ill adapted to this early phase of design where the building is not completely defined. Architects also have a real problem of control of luminous ambience: lacking natural light leads to unnecessary energy consumption and lowers the pleasantness for users (pleasantness due to natural light); excess and poor distribution of natural light leads to visual discomfort and summer overheat which also increases energy consumption for cooling. Moreover, architects are also preoccupied by the esthetical aspect of ambience.

1.2 Indicators

During the design of a building, architects do not have enough indicators to create efficient, comfortable, pleasant and energy-saving ambience. Moreover, the existing indicators are given in a quantitative language which is not directly connected to architectural intentions which are expressed in a qualitative manner [1]. It is therefore very difficult to take them into account during the design of ambience. During the design, an architect may think of a calm and padded ambience [2] or a radiant ambience [3], etc. Once the building is built, users may feel these ambiences. But we may also measure the luminance levels in these spaces and compare these measures to the expressed architectural intentions (calm, radiant…). Some works [4] have already built links between quantitative measurements and qualitative expressions and we continue these works to enrich these interpretations of qualitative expressions via quantitative data.

Existing indicators are defined in norms, regulations and expert rules. Illuminance levels are defined in norms [5].

However, luminance and chromaticity distribution are not defined in these norms via quantitative expressions, it is only partially studied in some books [6, 7]. This norm [5] requires the calculation of UGR which is rather difficult for architects during the design phase. Moreover, UGR does not study the whole interior envelope but only discomfort coming from luminaries. The analysis of luminance distribution on the whole interior envelope provides information on discomfort (mainly due to too strong contrasts). The publications about luminance contrasts generally focus on workspaces, especially on the work surface [6, 7] and its relations to environment. Other types of space are seldom studied.

In addition to this question of performance and comfort, necessary indicators for architectural design should focus on the value of a luminous ambience due to visual pleasantness, esthetical and architectural value of the space (subjective criteria of the architects). Quite naturally, some indicators should also reflect energy savings due to natural and artificial lighting. Energy consumption due to lighting is directly linked to illuminance levels [8] but also to the distribution of luminance and chromaticity.

1.3 Data

To analyse an ambience, existing or in design, architects need to compare these indicators to the state of the current ambience and to his/her intentions. In order to perform this comparison, it is necessary to collect data on the luminous ambience. Collecting these data is a difficult process, generally out of reach of the architect. There are 4 main methods to collect these data (distribution of illuminance, luminance and chromaticity) on a luminous ambience:

a. Computer simulation.
b. Physical simulation.
c. Use of luminance calibrated camera in situ.
d. Measurements in situ.

Method a and b are laboratory methods, whereas c and d are performed in situ. Only methods a and b may be used during the design and all 4 methods may be used for an existing space.

a. Computer simulation

A virtual image of the luminous ambience contains quantitative information on all points of the space. Whatever software is used, there are always approximations in the algorithm, in the details of the geometry and in the characteristics of materials. These approximations have an impact on the quality of the results. However, simulation brings a great comfort compared to in situ methods because of the total control over the environment.

b. Physical simulation

A model of the space is built and placed in an artificial sky. There is of course a great problem of precision in the geometry and in materials. The sky is also an approximation of an actual sky. However, this also gives a degree of freedom: a simulation remains possible even if all the details are not defined, in particular if they are unknown (as we are during the design, not in the end). Moreover, once the image is captured on a computer using calibrated cameras, one has measures for all points of the image. The environment is also completely controlled and qualitative and quantitative results are immediately visible.

c. Use of luminance calibrated cameras in situ

As in physical simulation, a digital camera with a large scale of grey levels is used. The method consists in calibrating the camera according to luminance levels (a grey level corresponds to a defined luminance level) to obtain an in situ record on which luminance distribution is shown as it appears on site. Qualitative and quantitative results are immediately visible. However, the method is submitted to the availability of the chosen climatic conditions. Moreover, the precision of the recording of very high or very low luminance levels is difficult and depends on the quality of the recording device.

d. Measurements in situ

In situ measurements do not make approximations; one gets the actual luminous conditions and actual materials. From this point of view, the results are more precise and reliable. However, the method is quite heavy: the exterior luminous flux changes over time and it is often necessary to stop the measurements and to wait for more favourable conditions. Moreover, chosen points must be targeted very precisely on the walls which is difficult. Finally, measured points are only a fraction of the points available in the field of vision, hence data on all points remain unknown.

To conclude, we can say that laboratory methods are less precise. However, these are the only available during the design and, if the building exists, it is best to work in situ. The work presented here aims at improving method b, use of physical simulation. The paper now presents the calibrating method and the analysis of calibrated images.

2. METHODS and RESULTS

2.1 Image calibration methods

We use micro-video-cameras and a software we wrote to analyse luminous ambience in models of spaces. Micro-cameras bring images of the chosen fields of vision to the software. In order to study the luminance levels inside the models and present them on the image, it is necessary to calibrate the images, that is to find the correspondence between the colour (grey level) on the image and the luminance level in the model.

To do this calibration, we choose different points in the model and we measure the luminance level with a luminance-meter. The points are chosen in order to represent the whole variety of luminance levels within the model, from the lowest to the highest. For the same point on the image, we record the grey level. When we use a colour camera, we transform the RGB colour level in grey level using the classical formula: $Y=R*0,299+G*0,587+B*0,114$, where Y is the grey level and R, G and B the colour components (for details, see for example [9]). Hence, we have for all measured points the correspondence between the grey level on the image and the luminance level in the model. Every non-measured grey level is then calculated via a simple linear approximation from the two measured luminance levels associated to the closest grey levels. Hence the more measured points we have, the better the quality of the values on the image. Finally, we take several estimated points and verify that their estimated luminance level is very close to the actual one. We call the set of couples (grey level, luminance level) the LUT. This LUT depends only on the settings of the camera (aperture) and of the software (colour balance, gain). Therefore, to a setting of camera corresponds a LUT that may be used whatever the model or the climatic conditions.

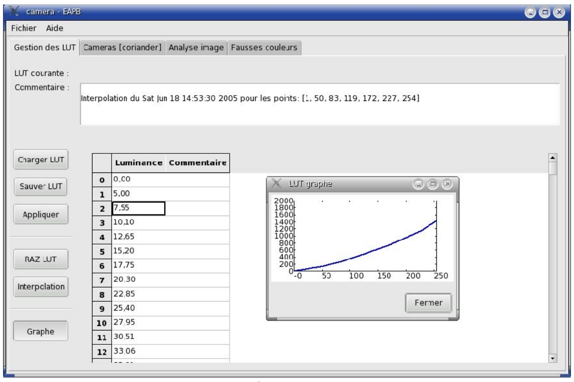

Figure 1. Initial screen of Ljubicam with the LUT and the associated graph

This calibration is validated by subsequent measurements, using the luminance-meter on several additional points (different from those used for the interpolation). The difference between measured and calculated luminance levels is under 1%.

Figure 2. Image of the inside of a model made by students from the 2nd year studio of architect B. Paurd

Once this calibration phase is finished, we can acquire all the fields of vision we need to study the model. All the images are acquired in JPEG format. Analysis can start.

The first analysis is to study luminance levels on the image. Luminance levels for every point is available. Clicking on a point immediately displays the corresponding luminance level. It is therefore easy to detect interesting contrasts, gradual ranges of luminance, etc.

In order to make luminance distribution more immediately readable, the software can display false colour images. To create them, a colour palette is defined. Intervals of luminance levels are selected and a colour is associated to each of them. The set of colours and the intervals is called a palette. The false colour image is built by replacing the real colour by the corresponding one in the palette (via the grey level associated to a luminance level). Colour information on the image is therefore simplified.

This allows making more obvious some groups of luminance on the image. As it is very simple to modify the palette, hence the colour, it is possible in real time to show a particular part of the image with more or less precision. The following pictures show the same image with two different palettes. It is quite clear that some zones are more detailed and show different information.

Figure 3 and 4 are false colour images of Figure 1. The palette of Figure 3 is designed to simplify the image to show the main luminous areas. Figure 4 increases considerably the information on darker and brighter parts. It enlightens the interest of false colour images, which make immediately visible specific parts of the images. Naturally, actual luminance levels are still readable on the image simply by clicking on points.

This software runs under the system Linux. It is being developed using Open Source software. It uses languages Python and WxPython and Coriander for image acquisition. We use digital camera Marlin F-145C. These industrial cameras have the advantage to have no "embedded Image enhancer" designed to "improve" the image but which make analysis meaningless (as with most cameras). With this kind of industrial camera, images and measurements are repeatable, and this is a major requirement.

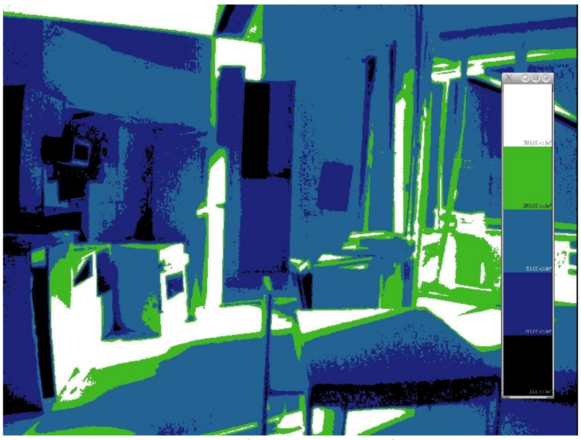

Figure 3. The image of Figure 2 in false colour with a palette simplifying the image

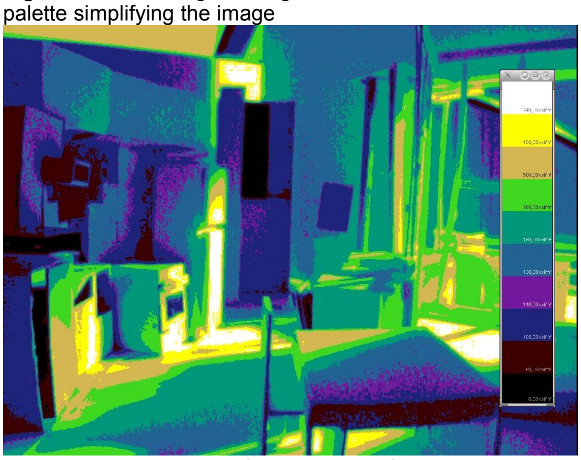

Figure 4. The image of Figure 2 in false colour with a palette enhancing brighter and darker parts

We are working on the improvements of this method by calibrating the system independently from the model studies. This will naturally accelerate the model studies. The pre-calibration consists in: luminance levels of a number of points will be measured on samples of various grey levels with a luminance-meter. These points will also be transmitted as grey levels via the camera system using various settings of the camera: aperture, gain, etc. Because of these settings, for a given point, different grey levels may be obtained on the computer screen. However, for a given set of settings, the same grey level will always correspond to the same level of luminance. That way, a large number of Lut will be defined for various camera and system settings. For model studies, the users will choose appropriate settings for the camera. Hence the Lut will be automatically associated. Hence the correspondence between grey and luminance levels will be automatically defined.

2.2. Analysis of calibrated images

These analyses have been inspired by [3, 10]. They are based on the results of previous works [4, 11] and improved upon the results of [13]. This part of the work and the software are still in progress. We show here the first results. We present the analysis of calibrated images on an example: the model of the university library of Nanterre, built by Edouard Albert in 1965 (modelled by our students during our course on sustainable architecture, see Figures 6 and 7).

Our system use the following criteria to analyse:

First level criteria :

- C1.1: links between luminance contrasts and qualitative expressions as presented on Figure 5:

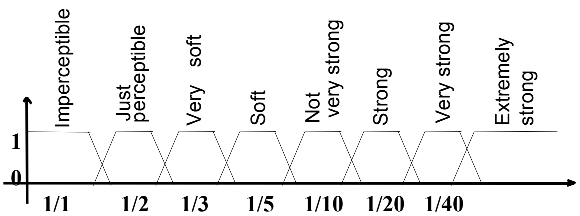

Figure 5. Qualification of luminance contrasts classes for day vision in an interior space [11]

There are several methods to compute luminance contrasts. The AFNOR (French Institution for Norms) has proposed to calculate contrast C as C= L1/L2 or C= (L1+L2)/ L2, where L1 is the luminance at point 1 and L2 the luminance at point 2. Other methods exist to calculate contrast. They may respond to various needs. For example, Peli in [12] proposed a definition for contrasts. He proposed methods, which calculate contrasts by introducing some fuzziness, that is the progressive disappearance of the separations between 2 luminous areas (clearly defined at the beginning). With this method, the notion of gradual range of luminance is confounded with the notion of contrast.

The two formulas from AFNOR are simple and the meaning is immediately understandable by architects. Peli's and many other approaches are more complicated but interesting and rely upon a good mathematical background. One can notice that, for Peli, the notions of contrast and gradual range are confounded and that is not usable in the reality of buildings.

In this first level of criteria, we use formula C=L1/L2. Despite its drawbacks, it is simple and of immediate understanding and we believe in a design aid tool the significance of the first results should be immediately and easily understandable by architects.

- C1.2: visual comfort thresholds in workspaces, as defined in [6,7], are directly related to luminance contrasts thresholds in the following way:

A contrast below 1/3 is very comfortable; a contrast from 1/3 to 1/10 is comfortable; from 1/10 to 1/20 is rather comfortable; above 1/20 is little comfortable; from 1/40 to 1/50 is the limit for discomfort but still bearable; above 1/50 a contrast is considered as uncomfortable.

Second level criteria (in this paper, only the criteria that are meaningful for our example are presented):

- C2.1: if contrasts on the field of vision are lower than 1/4 with some close to 1/4 on large surfaces (contiguous or not), then the ambience is very calm. In daylighting, lower contrasts are rare due to the presence of the sky in the field of vision. For example, ambiences in Alvar Aalto's architecture are considered as calm and well-lit; we measured that contrasts on large surfaces are very often at a maximum of 1/6 (see for example, Pension Bank in Helsinki) and higher only punctually.

- C2.2: if contrasts reach 1/40 on a significant part at the limit between two surfaces (contiguous or not) of different luminance levels, then there is a tension.

This kind of criteria was designed from 2 different types of works: comfort is defined in dictionaries as the absence of psycho-physiological tension which may come from exterior stimuli (acoustic, visual, etc.) see [6, 7], hence the limit between comfort and discomfort shows the appearance of tension for subjects. On the other side, when asked, people with heavy architectural background (architects, teachers and last year students) often interpret as tense ambiences with strong luminance contrasts. For example, ambiences in the architecture of Tadao Ando (who often uses strong contrasts) are often qualified as tense, theatrical and even dramatic.

In order to better analyse these characteristics due to contrasts, the notion of surface size is very important. We are currently working on the way to take it into account in the study of contrasts and gradual ranges of luminance.

- Library Room Description

Current space:

The room has a double orientation, south-east and north-west. The glazed surface is large, around 1/5 of the floor surface.

The floor is made of clear wood, walls and ceiling are also clear, cream-coloured. Reading tables were not produced for the model. In the initial model, students tried to represent faithfully the surfaces of the actual space, see Figure 6.

During the visits in the library, students expressed the subjective feelings about the luminous ambience. In short, this gives an ambience: well-lit, calm but a bit dull, with no character.

Renovated space:

One of the students' proposals for the renovation of the space was: to keep the high illuminance level, to keep a calm and padded ambience to make the ambience more elegant and more attractive. This was translated in: make a very clear ceiling, to lighten the walls up to white with nearly black window frames and make the floor very dark (nearly black), see Figure 7.

The two models were placed in our artificial sky (Moon and Spencer), the images, the false colour images and the computer analysis of the luminous ambience were obtained, see Figure 6 to 9.

- QUALITATIVE RESULTS (IMAGES)

Figure 6. Image of the initial ambience

Figure 7. Image of the students' proposal

- QUANTITATIVE RESULTS (FALSE COLOUR IMAGES)

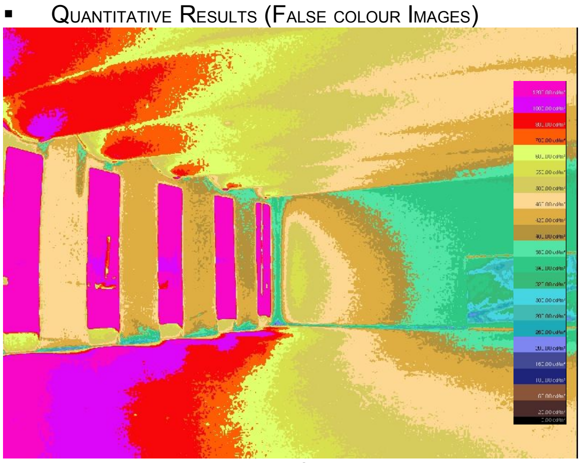

Figure 8. False colour image of the initial ambience

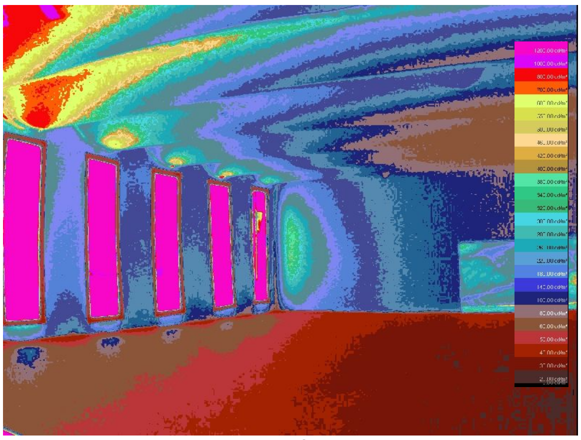

Figure 9. False colour image of the proposal

- THE COMPUTER ANALYSIS YIELDS THE FOLLOWING RESULTS:

Current ambience
Luminance contrasts: very soft
Comfort thresholds: comfortable
The ambience is: very calm

Renovation proposal
Luminance contrasts: Soft to very strong
Comfort thresholds: limit of discomfort
The ambience is: Presence of a tension

- ANALYSIS BASED ON THE ABOVE RESULTS

These qualitative (images), quantitative (false colour images) and the computer analysis results help us to conclude:

The new ambience is very different; contrasts and illuminance are modified.

New very strong contrasts appear: if the reader turns his/her head, he/she will have in his/her field of vision the black floor, the nearly black window frames and the sky outside, which will lead to very strong contrasts.

In the new ambience, the field of vision of a reader in the normal reading position includes white paper, table and the dark floor.

We can deduce that, between the book and the part of the floor which is in the reader's field of vision, a strong or very strong contrast will appear.

We can see that this ambience is close to discomfort with contrasts above 1/40 whereas this space is a workspace. Moreover illuminance levels are lower, the space is not so well-lit.

However, the tension appeared due to the desire to make the ambience less dull and more elegant. The resulting ambience may be less dull and more elegant, but the visual comfort was lessen and this is not appropriate for the use of this space, a library.

Another proposal has to be sought for the renovation of this library.

3. CONCLUSION

The purpose of this work is to improve a method of design aid for luminous ambience in daylighting. We studied the method "physical simulation" which uses a model of the space placed under an artificial sky (or a natural one) and a system of micro-cameras.

We propose a method for image calibration that has been integrated in a computer tool. The results have been validated: luminance levels which appear inside the model are calculated and displayed on the screen with an error under 1%. We now intend to improve the method by pre-calibrating the system (for typical cases), and that would avoid a calibrating just before each model study. This would make studies faster.

Then, we studied the question of the definition of criteria for the analysis of images for calibrated luminous ambience. This work is still in progress. We showed here the first results of this part, which displays information based upon qualitative images and quantitative information. These information are given in terms of comfort/discomfort and the qualitative expressions of the architects.

This method has been used with great benefit during the teachings in the studio of architecture in the Paris-Belleville school of architecture. The system is used during the design, because it provides the opportunity to do a study even if some details of the building remain unknown. Moreover, the installation of a new variant in the model is very easy (a few minutes). Therefore, we immediately have the new images and the results. This ease and speed of use is a fundamental aspect in the design phase.

Moreover, students in architecture (last year students) are very keen on qualitative data (images and expressions) linked to quantitative data. They are interested to see that qualifications have significance in terms of luminance, contrasts and gradual ranges of luminance, etc. This improvement of the significance of qualitative terms makes the understanding of luminous ambience much deeper.

In the second phase of development, we will include more complex criteria for the analysis of luminous ambience. These criteria should take into account the notions of surface and of contiguity of luminous areas. We will also enrich the system with new qualitative terms explained via quantitative terms and automatically calculated by the system. We believe that the system will allow improving the speed of the analysis of luminous ambience, not only for students in architecture, but also in the professional world.

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