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INDOOR DAYLIGHTING FREQUENCIES COMPUTED AS A FUNCTION OF OUTDOOR SOLAR RADIATION DATA.

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ABSTRACT

We present a numerical method leading to the determination of the occurence of illuminances at any location in a room. Specific contributions of diffuse and direct light are fully taken into account. The display of light distribution, which uses isochronic curves, appears to be particularly versatile.

CALCUL DE L'OCCURENCE DE LA LUMIERE NATURELLE DANS UN LOCAL EN FONCTION DE DONNEES DE RAYONNEMENT SOLAIRE.

RESUME

Nous proposons ici une méthode numérique permettant de déterminer les fréquences d'occurence d'éclairements naturels en tout point d'un local. Les contributions spécifiques de la lumière diffuse et directe sont prises en compte. La production de cartes isochrones, et non isolux, s'avère particulièrement pertinante dans l'analyse de systèmes d'éclairage naturel.

RECHNUNG DER HÄUFIGKEIT DES TAGESLICHTES IN EINEM RAUM GEMÄSS DEN DATEN DER SONNENSTRAHLUNG.

Wir bieten eine numerische Methode an, die Häufigkeit der natürlichen Beleuchtungen in jedem Punkt eines Raumes bestimmt. Es werden die spezifischen Beiträge des unbestimmten und ds direkten Lichtes dazu berechnet. Die Produktion isochronen sondern nicht isoluxen Karten bestätigt sich als besonsters treffend in der Analyse der natürlichen Beleuchtung.

1. INTRODUCTION

A few years ago, the Lighting Research Program of Ecole Nationale des Travaux Publics de l'Etat, located near Lyon, France, has produced a set of numerical techniques to compute, as precisely as possible, indoor illuminances as a function of outdoor luminous conditions [1]. The technique, which attempts to precisely simulate the physics of light propagation, has considerably more potential than scale model analysis. However, it did not account for long term perfor-

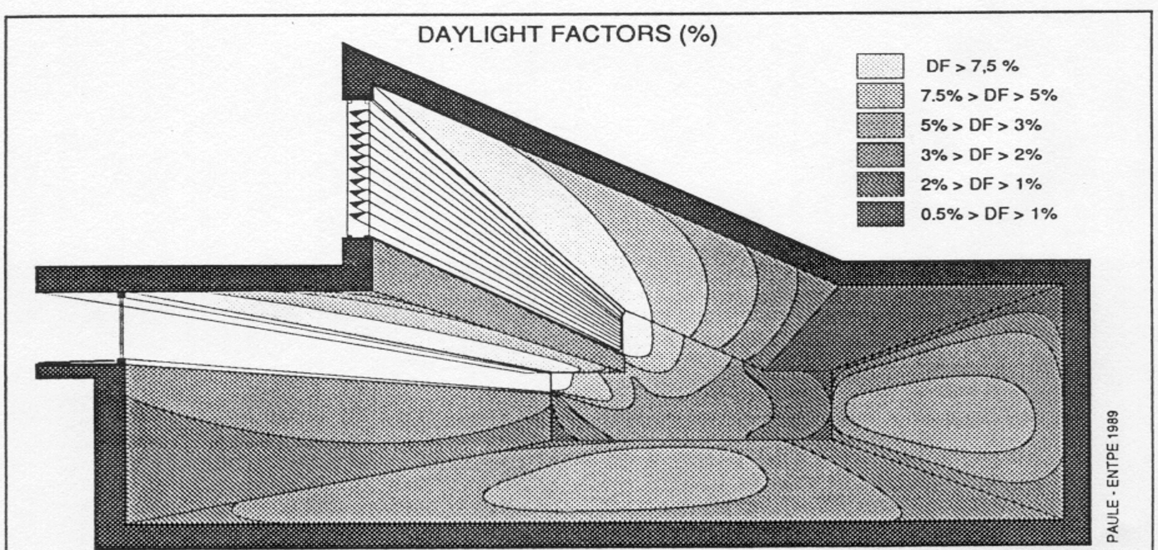

figure 1 :
Example of isolux curves obtained with the spatial model
Exemple de tracés isolux obtenus avec le modèle spatial.
Beispiel isoluxen linien mit dem geometrischen vorbild-berechnet.

mance of daylighting techniques. We propose here an evolution toward this aspect in including time related information.

2. OBJECTIVES :

The general objective is to provide some capability to compare daylighting techniques on the base of long term performances. We found that daylighting systems are "natural light luminaires" which provide light in an unsteady way. But we are interested to know how many hours (per day, per month, per year) they provide the minimum useful amount of light. It is therefore necessary to compute the occurence of illuminances at all indoor locations for a given fraction of time beetween 9 a. m. and 5 p. m. for instance.

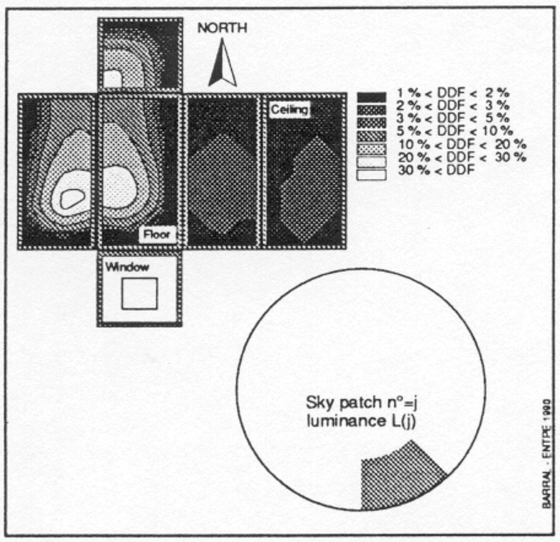

figure 2 :
Répartition des facteurs de lumière du jour relatif à un élément de ciel donné.
DDF distribution on indoor surfaces for a given shy patch.
Verteilung der Tageslicht quotienten, die für eine Himmelmasche berechnet werden.

3.METHOD

3.1. Directionnal daylight factor

It was established [3], that access to occurence of illuminance at each indoor location requires information on the occurence of the sky luminances and of direct sunlight in various parts of the sky vault.

Using our detailed spatial model, we can compute indoor illuminance distribution E (i,j) at all locations P(i) inside a building for either a point source (the sun direction v(j)) or a sky patch of constant luminance (given solid angle Ω_i). An example is shown on figure 2. This sky patch provides its own contribution Evd(j) to the horizontal external illuminance Evd. We can define a Directionnal Daylight Factor DDF(i,j) in each location P(i), relatively to a sky patch of constant luminance.

For n sky patches [1<j< n], we define, for each of the m locations indoor [1<i<m], m x n Directionnal Daylight Factors:

$$DDF\,(i,\,j) = \frac{E(i,\,j)}{Evd\,(i)} \times 100 \qquad \text{DDF in \%}$$

3.2 Sky data production

Diffuse Light : Statistics on luminance distributions of the sky vault are not currently available, although an international effort has been initiated to provide more information on this topic [4]. However, correlations have been proposed [5] to establish most typical sky luminance distribution as a function of more spread climatic information: global and diffuse irradiances, location of the sun in the sky, latitude, dry bulb and wet bulb temperature.

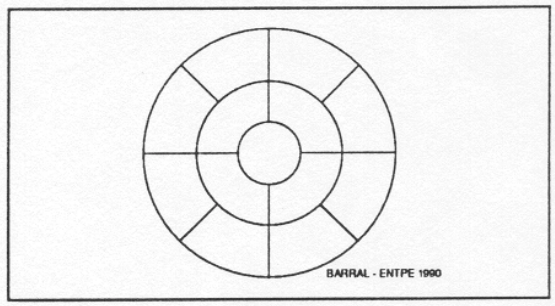

figure 3 :

Division du ciel en 13 mailles utilisée pour le diffus

Division of the sky vault in 13 patches for computations related to diffuse light.
Zerteilung des Himmels in 13 Maschen im Fall des unbestimmten Lichtes.

We used this algorithm to produce hourly average skies: luminance distribution of the sky vault at an hourly step. To minimize the amount of data, we propose to use in this first approach a number of sky patches limited to 13 (see figure 3). A test showed that for most geometries the difference in the value of DDF's is negligible between a 13 patch sky and a 5180 patch sky under overcast conditions.

Direct Sunlight : Figure 4 shows another processing of irradiation data which produces equivalent sky luminances due to sunlight alone. The model requires 72 sky patches which are dependant on the latitude of the place.

This means that 72 Directionnal Sunlight Factors are needed, for the direct component.The directionnal Sunlight Factor (DSF) is exprersed by :

$$DSF\,(i,\,j) = \frac{E(i,\,j)}{Evsh\,(i)} \times 100 \qquad \text{DSF in \%}$$

with:

E(i,j) = indoor illuminance in P(i) for sunlight alone.
Evsh(j) = external horizontal illuminance resulting from sun only in the jth patch.

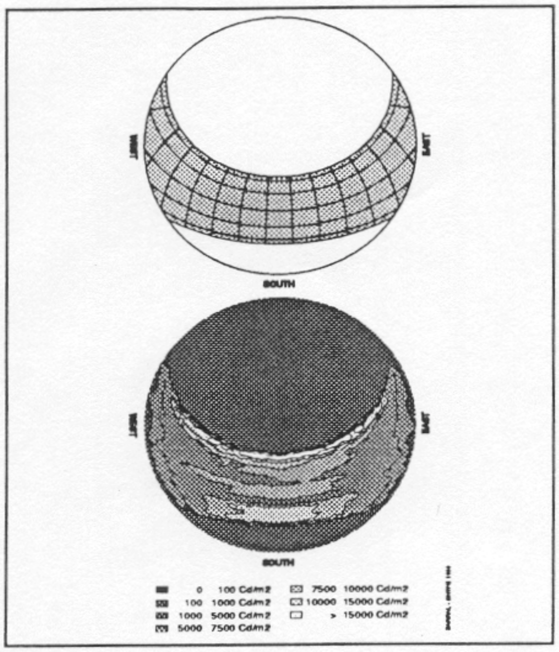

figure 4:
Division du ciel en 72 mailles utilisée pour la lumiere en provenance du soleil.
Division of the sky vault in 72 patches for direct sunlight.
Zereilung des Himmels in 72 Maschen im Pall des Sonnenlichtes.

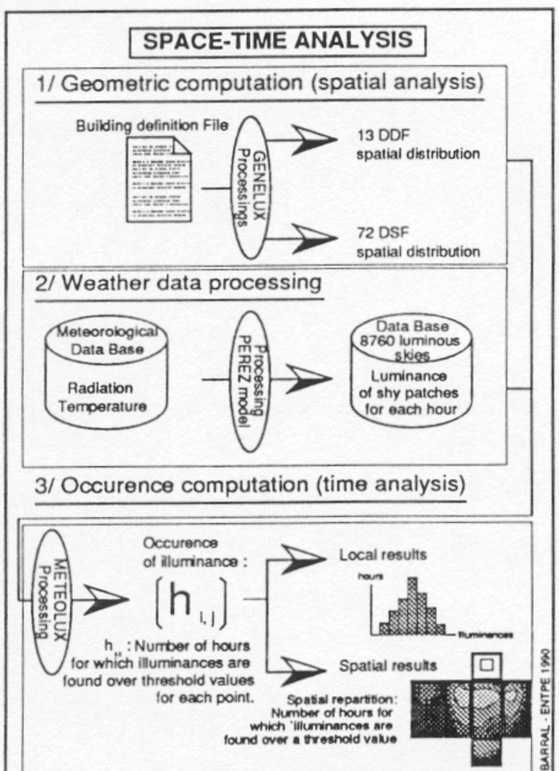

figure 5:
Schéma de principe de l'environnement numérique.
General schema of the numerical processing.
Zeichnung der numerischen Verarbeitung.

3.3. Numerical integration

The steps are described on figure 5. The firt step of the method is purely geometric and produces DDF and DSF values on indoor surfaces for the two sets of sky patches: that is a total of 85 Directional Daylight factor sets.

The second step is the production of hourly information on daylight availability by processing of climatic data. We produce for each hour, 13 values of luminance of the sky vault, and one value of luminance corresponding to the sky patch which includes the sun.

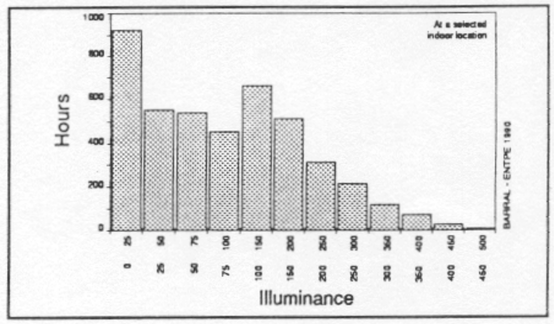

figure 6:
Histogramme des occurences d'éclairement
Illuminances frequencies (hours/class)
Häufigkeit der Beleuchtungen.

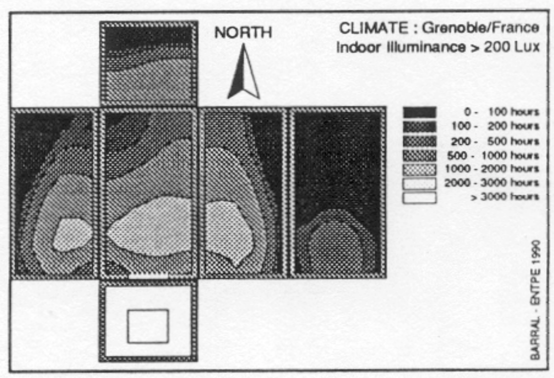

figure 7:
Carte isochrone diffus seul, année entière.
Isochronic curves for diffuse light alone, whole year.
Isochrone Karte, nur unbestimmtes Licht, das ganze Jahrlang.

The third step consists of affecting hour per hour the appropriate illuminance value to each indoor location using the simple one-to-one relationship derived in step #1. It is therefore possible to evaluate the number of hours per month or per year or any period of time for which an indoor illuminance belongs to a given range of interest.

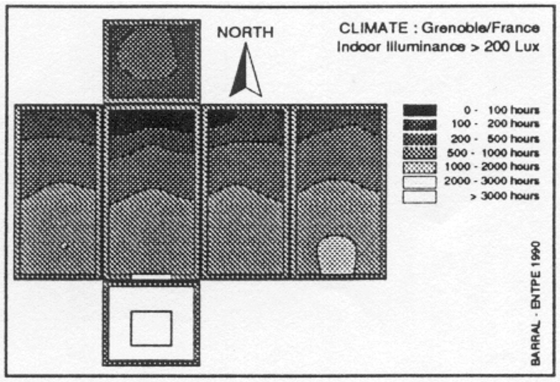

figure 8:
Carte isochrone direct seul année entière.
Isochronic curves for sunlight alone, whole year.
Isochrone Karte, nur direktes Licht,das ganze Jahr lang.

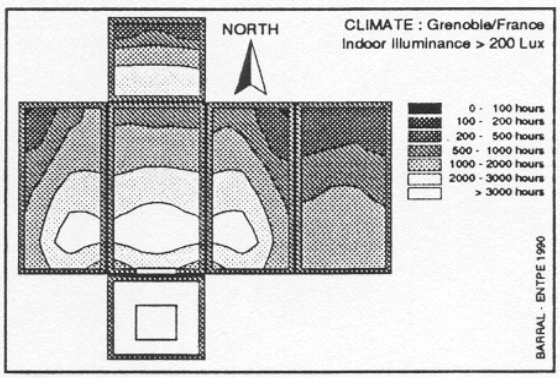

figure 9:
Carte isochrone global (diffus + direct), année entière.
Isochronic curves for diffuse and direct light, whole year.
Isochrone Karte, Gesamtlicht (direkt+unbestimmt), das ganze Jahr lang.

4. RESULTS

Hence the production of a frequency graph (figure 6) or a display using isochronic curves (figures 7, 8, 9). The isochronic curve allows the integration of spatial and time related informations. Extending our initial approach [7] to both the diffuse and the direct component allows for an investigation of either their respective effects (fig. 7 vs fig. 8) or their combined effect (fig. 9).

CONCLUSION

This approach might appear rather complex for designers who are familiar we the daylight factor approach. However, the procedure is easy to manage. It is powerful because it uses a spatial model which is itself very powerful (multiple reflections of light between up to 100000 polygons, simulation of spectral effects, simulation of various material surfaces with a Monte-Carlo technique). It is evolutive: the number of sky patches may be increased. But once the first on-time geometric step is accomplished, the time series analysis requires very little extra computing time.

ADRESSES

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