DIAL-Europe: New Functionality's for an Integrated Daylighting Design Tool

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ABSTRACT

The European project DIAL-Europe started in April 2000 and intends to enhance and to enlarge the capabilities of the LesoDIAL software. The aim of this "Swiss" tool was to give architects relevant information regarding the use of daylight, at the very first stage of the design process. DIAL-Europe focuses on European standards and climatic data. Further, a Heating & Cooling evaluation module and an Artificial Lighting module will be added. The objective of the Heating & Cooling module is to indicate the implications of the user's design on heating and cooling energy and on thermal comfort. The objective of Artificial Lighting module is to develop a tool that will give an estimation of illuminance values on the work plane and provide guidance on qualitative aspects and visual comfort as well as on switching control and integration with daylight based on generic light sources and luminaires. Furthermore, the scope of the examples of simulated rooms will be increased in order to allow the user to compare their design with more similar cases. This paper will present the state of achievement and give an overview of the first version of the DIAL-Europe software, which will be available at the beginning of 2002.

1 INTRODUCTION

Artificial lighting represents a major part of the overall energy consumption in non-residential buildings. However, more daylight conscious architectural solutions and the introduction of innovative daylighting systems and efficient lighting controls can displace a considerable part of this electricity consumption by utilising the natural resources offered by daylight. Therefore in October 1993 the Solar Heating and Cooling Programme of the International Energy Agency initiated Task 21 (IEA SHC 2002).

The main objectives of Task 21 were to advance daylighting technologies and to promote daylight conscious building design. Through selected Case Studies the Task demonstrated the viability of daylighting designs under various climatic conditions emphasising system performance regarding energy savings and user acceptability. The Task was to focus on those daylighting systems and strategies which can be applied in new and existing buildings with a high aggregate electricity saving potential such as offices, schools, commercial, and institutional buildings. Systems and strategies were tested and performance evaluated through studies in laboratory facilities, by computer simulations, as well as in Case Study buildings. The performance assessment covered visual, architectural and environmental aspects, including user acceptance of the systems.

In the development of lighting calculation tools the early design phase is increasingly taken into account. During this design phase essential and often irreversible decisions regarding the natural lighting of a building are made. Moreover, in this phase the architect often still works and decides alone, without advice of any other design expert (Erhorn and De Boer 2000).

The primary objective of one of the subtask "Daylighting Design Tools" is to develop a tool which, by being compatible with the design approach of architects, will assist in the early design of windows in buildings, and lead to better energy and environmental performance. One of the deliverables of this subtask was LesoDIAL (Paule et al. 1998). After Task 21 was finished in 1999 the group working on LesoDIAL decided to improve their tool, including all relevant European climates, other environmental factors associated with windows, (such as heat loss, overheating risk and glare), and artificial lighting design and its integration with daylight. Therefore the European project DIAL-Europe was initiated in 2000. It is a three-year project that will end in April 2003.

2 LESO-DIAL

The Swiss Leso-DIAL tool allows non-specialists in lighting engineering to carry out easily and reliably daylighting calculations by means of a qualitative description procedure of the relevant input data. Parameters and expert terms most often used only by design specialists can be used as input data. Alternatively, standard design values are provided, such as daylight factors, illuminance values, etc., for various room geometries. However, the user is not left alone with the results he or she gained from these calculations. Based on a set of expert rules (using fuzzy logic) the results are interpreted and recommendations on how to improve the lighting situation are suggested (Erhorn and De Boer 2000).

The program consists of five modules: *Allocation, Description, Evaluation, Comparison,* and *Lexicon.* The first module, Allocation, corresponds to the first stage of the design process. In this module the main activities that will take place in the room are selected. Following the Swiss standards (ASE 1989) the user is simply asked to select the main activity that will take place in the room after which the required illuminance level can be shown.

The second module, Description, represents the second stage of the design process. In this module the photometry and geometry of the room are described, only handling graphic and linguistic items. Thanks to fuzzy-logic algorithms, one can describe parameters even if they are not precisely known. The principles of these rules are explained in (Paule et al. 1998) and one example is given in this paper in paragraph 3.2.2 .

The third module, Evaluation, evaluates the design. Daylighting autonomy and daylight factors on the work plane are calculated. The algorithms and methods used are described in (Paule et al. 1998). Only calculations with overcast sky are executed. In contrast with classic simulation programs, Leso-DIAL elaborates on the outcomes aiming to optimise the design in the diagnosis area of the tool. Possible weak points in the design are pointed out.

The fourth module, Comparison, gives access to a case-studies database to compare the user's design with existing rooms that have been monitored and stored earlier. Leso-DIAL will scan the database in order to find a case-study that matches the user defined design as good as possible.

The fifth module, Lexicon, contains about 100 terms of the daylighting vocabulary, presented in a richly illustrated way. At every point in Leso-DIAL the user can get access to this lexicon to retrieve an explanation on the terms he or she does not understand.

The aim of LesoDIAL software was to give architects relevant information regarding the use of daylight, at the very first stage of the design process. Among the features that made this program successful, one can notice its very intuitive interface and velocity. Another interesting point is the possibility to simultaneously access calculation facilities (evaluation module), detailed information on lighting (lexicon) and visualisation of existing or simulated case studies (comparison module). Furthermore, the "diagnosis" facility based on fuzzy logic rules proved to be a very efficient mean to guide the user towards an "optimal" design (Paule et al. 1998). These characteristics all will remain in the new DIAL-Europe tool.

3 DIAL-EUROPE

DIAL-Europe is a three year project funded by the European Community. The first year of the project was used to work on making the interface more user-friendly. The screen size has been improved. The number of openings to be possibly taken into account has grown from 6 to 10 per room face. The possibility to describe vertical fins has been implemented. There is also now greater flexibility for the user with regard to specifying figures outside the range ordinarily used within DIAL-Europe. For example, regarding reflectance values, the software warns the user if they are choosing a figure outside what is recognised as 'normal' but the user is then able to confirm its choice. Details such as these, coupled with many other refinements, make the tool more user-friendly, and will help enlarge its applicability in both industry and education.

Four functionalities will be added to Leso-DIAL during the DIAL-Europe project:

- European climatic data;
- Artificial lighting module;
- Heating & Cooling module;
- Extension of the case studies database.

In this paragraph these four topics will be explained further, based on (Paule 2002).

3.1 **European Climatic Data**

3.1.1 *Overall objectives*

The overall objective of this functionality is to develop and extend the algorithms used in DIAL to improve the daylight autonomy prediction, and to also take into account sunny skies, shading devices and advanced daylight systems. Additional objectives include the selection, development and application of visual comfort criteria and the specification of diagnosis criteria.

3.1.2 *Climatic data*

Meteorological data from Meteonorm (Meteotest 2002) has been used to adapt the daylight autonomy calculation to a large number of locations throughout Europe. The calculation is based on the external horizontal diffuse illuminance. Polynomial functions describing the cumulative probability for outdoor diffuse illuminance to reach a given level are obtained for each location (see Figure 1). These new algorithms have been implemented in DIAL-Europe. Data from approximately 150 cities in 16 European countries are available, and the countries covered so far include: Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the UK.

Thanks to these functions, the annual daylighting sufficiency is estimated, based on daylight factor values and with respect to the required indoor illuminance. A validation work has started to see whether extreme latitudes and sunny climates can be handled using the same method.

The implementation of orientation factors, based on the European Daylighting Atlas data, is considered to adapt the result to the facade orientation.

3.1.3 *Calculation*

BRE simplified algorithms have been implemented in the software. These algorithms allow the program to take into account the contribution of ground reflection in both open outdoors and atrium cases.

The calculation grid has been modified from 9x9 in Leso-DIAL to 12x12 in DIAL-Europe. This increases the precision of the calculation and leads to a better knowledge of the maximum and minimum values of the light distribution. The mean value of both daylight factor and daylight sufficiency is then more precise.

3.2 **Artificial lighting module**

3.2.1 *Overall objectives*

The overall objective of this functionality is to develop an artificial lighting design module which would be compatible with the level of input and output detail in the daylighting tool. Guidance will be provided on qualitative aspects and visual comfort, switching controls and integrate them with daylight.

3.2.2 *Achievements*

Work has been undertaken on the development of generic lamps and luminaires for offices, hospital wards, and schools. For generic lamps, Table 1 has been generated. Depending on the preferred colour temperature, colour rendering and shape of the source (line or point) possible sources will be presented to the user of DIAL Europe.

It is envisaged that the user will be able to specify the light distribution required within their room, the colour of the light and the type and location of the luminaires. After the user has selected the source and luminaire of his or her preference, s/he can determine how many luminaires must be positioned of this type and also the distance between floor and luminaire. Additional luminaires of another type can be selected, after which the design loop will be repeated.

The 'lumen method' is being used to estimate the illuminance level of artificial lighting. Calculation routines have been implemented to evaluate illuminance levels on each of the room faces (including work plane). A first tool has been embedded in the lexicon in order to allow the user to see the influence of the position, the number and the distribution of a selection of luminaires.

In addition to this, more than 50 diagnostic 'expert rules' have been developed that will help the user to select artificial lighting components. The rules are built as IF-THEN statements and either generate lines in the 'diagnosis' field of DIAL-Europe, or select the most suitable generic lamp or luminaire.

Table 1: **Possibilities of colour temperature & colour rendering index for artificial lighting sources.** *Very small Series

Colour temperature Colour rendering index	Extra warm white (< 2900 K)	Warm white (2900 - 3300 K)	Neutral white (3300-5000 K)	Cool white (> 5000 K)
Fair (50 - 80)	Fluorescent	Fluorescent High intensity discharge	Fluorescent High intensity discharge	Fluorescent
Good (80 - 90)	Fluorescent Compact fluorescent High intensity discharge	Fluorescent Compact fluorescent High intensity discharge	Fluorescent Compact fluorescent High intensity discharge	Fluorescent
Exact (90 - 100)	Fluorescent Compact fluorescent* Incandescent lamp	Fluorescent Compact fluorescent* Tungsten halogeen	Fluorescent Compact fluorescent* High intensity discharge	Fluorescent

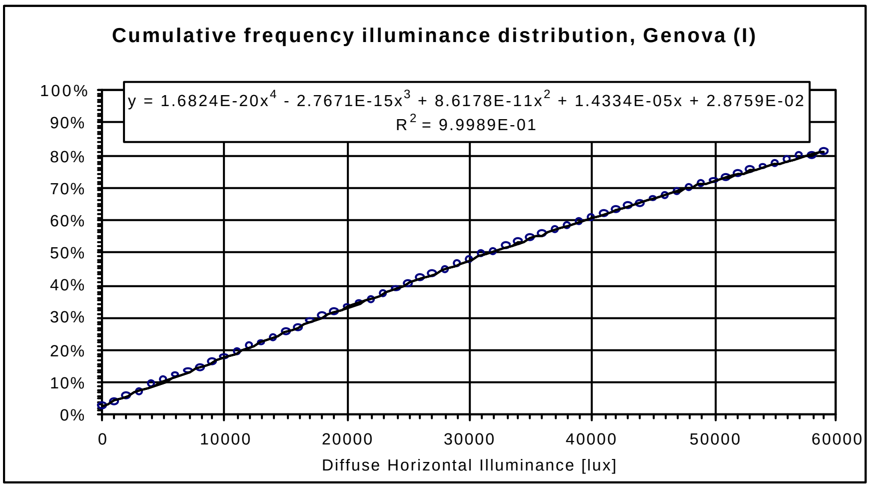

Figure 1: **Example of polynomial function used to calculate daylighting autonomy, (Meteotest 2002)**

3.3 **Heating & Cooling module**

3.3.1 *Overall Objectives*

The overall objective of this functionality is to indicate the thermal implications (heating and cooling energy and thermal comfort) of the proposed design with a level of input and output detail compatible with the daylight tool.

3.3.2 *Achievements*

Following a detailed analysis of the Admittance Method and the Free-floating Internal Temperature Method, it was decided to programme and implement a simple 3-node resistance network method (RNM) into the tool, in order to calculate the overheating risk. The model takes into account the solar gain, lighting gain, climate data and ventilation rates within the room, as well as its thermal mass and occupancy pattern. Users of the software will then be warned of the overheating risk of their design.

Tests are currently being carried out on the RNM to check its validity.

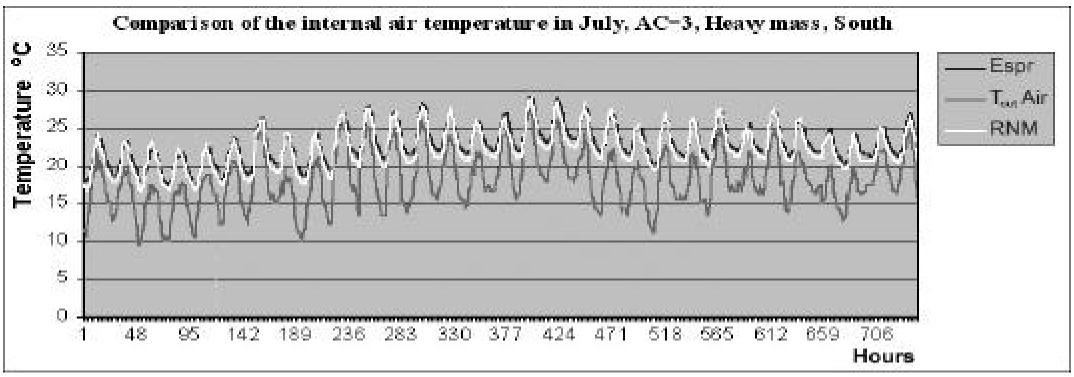

Figure 2: **Initial comparative results between the RNM and ESP-r methods**

Table 2: **Example of decision table used to build the linguistic diagnosis**

		Overheating Risk		
		Acceptable	High	**Very High**
Shading Coefficient (g)	**Medium**	-	-	***COULD***
	High	-	COULD	SHOULD
	Very High	COULD	SHOULD	MUST

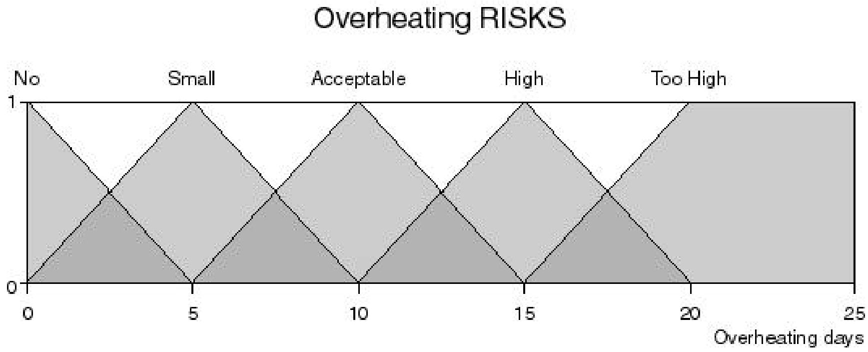

Figure 3: **Example of fuzzy set used to describe the overheating risk as a function of the number of overheating days**

Comparisons are being made with the results from ESP-r, for the analysis of energy and mass flows, on light, medium and heavyweight rooms. Users will be able to specify the room type by selecting from a set of images within the software. This makes the choice between heavy, medium and lightweight building types much easier for the non-expert.

Initial comparative results between the RNM and ESP-r are very favourable as can be seen from Figure 2.

Expert rules, based on fuzzy logic statements will be implemented to prompt the user to optimise the design. Figure 3 shows an example of a fuzzy set that could be used to describe the overheating risk as a function of the number of overheating days. Table 2 shows the different linguistic items (verbs) that are used to qualify the strength of the incentive message delivered to the user. The idea is to use those kind of fuzzy sets to build fuzzy rules such as shown in table 2, and that might be expressed as follow:

- IF Overheating Risk is «**Very High**»
- AND Shading coefficient is «**Medium**»
- THEN The user ***COULD*** reduce the g coefficient of the shading device**.**

Many other parameters as orientation, glazing ratio, shading device and ventilation strategy, etc. will be used in this optimisation process to reduce the overheating risk.

3.3.3 *Sunny skies, shading devices*

Modelling work has been carried out using Radiance in order to provide information on shading devices and advanced daylighting systems. A standard room has been modelled incorporating four different types of shading device: overhangs, light-coloured louvres, non-specular light shelves and diffusive blinds. This work has produced utilisation factors for input into the daylighting software element of the tool.

3.4 **Case Studies Database**

3.4.1 *Overall Objectives*

The overall objective of this functionality is to increase the scope of the examples of real buildings and to develop and refine the criteria for their selection and the quality of their description and analysis. Also covered within this functionality is the generation of a range of simulated case studies, both to fill in 'gaps' in the real database and to illustrate parametric series for key variables.

3.4.2 *Achievements*

The selection of parameters and experiments have been completed as scheduled and work on the 2-year long period of simulations has commenced. The initial simulations, using Adeline and Radiance, have focussed on atria, with 162 cases being modelled. The atrium being simulated has been chosen from a real building from the Daylight Europe project. This was done in order get realistic proportions, materials and colours. Parameters are varied within each case and the results obtained show renderings, geometrical and photometric data for the room, daylight factors and daylight autonomy as well as graphical information about the room. An example is given in Figure 4.

The data being prepared in this functionality will enable the user to compare the proposed design with the similar example(s) from the database. The test for similarity will be carried out by fuzzy-logic rules, as it was in LesoDIAL.

4 CONCLUSION

More and more architects demand simple tools to optimise the use of daylighting inside buildings, as early as possible in the design process. There is a real tendency to check daylight availability in buildings during their conception. Where environmental quality "labels" do already exist, for example HQE in France, precise information on daylight is required from designers.

Due to its philosophy for simplicity, rapidity and intuitivety DIAL-Europe is in a very good position to fulfil this demand. Although it is extremely difficult to estimate the direct impact of a design tool, the potential for energy saving from the use of daylight can be readily demonstrated. We can consider that if after one year of availability on the internet 1,000 copies have been distributed, but suppose only 10% of these influenced designers to improve the use of daylight in new medium-sized (2000m2) buildings from 'typical' to 'good'. We will assume that here 'typical' means almost no use of daylight and 'good' assumes a conservative 50% reduction in lighting energy. This estimate comes forward from the policy incorporated in the design tool: for tasks that are executed during the day, electrical lighting only will be designed as additional lighting to the daylight. Further, the design tool will promote the application Daylight Responsive Control [DRC] systems and occupancy sensors. TNO research (Zonneveldt 1991) has presented that the application of DRC systems and occupancy sensors can save up to 60% of the lighting energy for daylit office rooms. The DRC systems will decrease the electricity use with 50% for the window zone of office rooms (depth is approximately two times the window height). An additional 10% of energy saving will be achieved by applying an occupancy sensor, that is dimming the electrical lighting if the occupant(s) of the room has (have) left the room for more than 15 minutes.

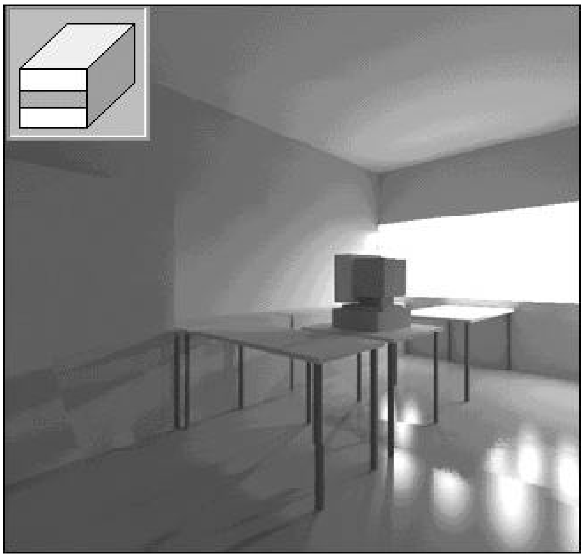

Figure 4: **Example of Radiance simulation rendering used to illustrate case-studies stored in the database**

In a survey of office buildings in the UK, BRESCU (Building Research Establishment Conservation Support Unit) gives typical yearly lighting energy consumption as an average 54 kWh/m2 delivered electricity. Thus, at the end of one year, with 100 copies in active use, we could see potential savings of 100 x 2000 x 54 x 50% = 5.4 GWh/year. Assuming that the approximate cost of electricity is 0.12 Euro/kWh, the value of this saving is 5.4 x 0.12 = 0.65m Euro a year. This compares favourably with the total cost of the project, which stands at 0.7m Euro. Assuming that the savings go on accruing in subsequent years, and that the use of the tool continues as in the first year with 1,000 copies being marketed but only 100 being actively used, then the saving in ten years would be 35.75m Euro. This equates to an electricity saving equivalent to 0.25m tonnes of CO_2.

5 ACKNOWLEDGMENTS

With thank to all the participants of the DIAL-Europe project:
- The Martin Centre for Architecture and Urban Studies University of Cambridge, (UCAM), coordinator.
- Ecole Polytechnique Fédérale de Lausanne (EPFL)
- Fraunhofer-Gesellschaft zur Forderung de angewandten Forschung e.V. (FhG/IBP)
- Netherland Organisation for Applied Scientific Research (TNO).
- ESTIA sàrl

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