Abstracts

A Merit Function for Automated Mirror Design

Steven Doyle, David Corcoran and Jon Connell

In earlier work we described how an evolution strategy could be used to automate the design of luminaire reflectors. In particular, a merit function specific to this evolutionary design method was presented. In this paper, we outline how the merit function was developed, the problems encountered during the development process and how they were overcome. Results are presented for the test problem, of generating a mirror design, which produces a desired light distribution at a single target plane. The merit function is also applied to the more difficult task of matching target distributions at parallel planes.

A Metric for Judging Acceptability of Direct Luminaires In Computer Offices

Naomi Johnson Miller, FIES, Peter R. Boyce, PhD, FIES and Peter Y. Ngai, FIES

Computers are now ubiquitous in offices, as is poor computer screen visibility, caused by reflections of office luminaires that obscure text and graphics. Past efforts to identify photometric properties of recessed luminaires which are predictive of this reflected glare have produced metrics too complex for the practitioner to apply, or work well only when applied to a specific size and type of luminaire.

This research looked at subjective responses to combinations of three computer screen types and ten recessed parabolic luminaires, at two typical angles of reflection. Subjects evaluated the luminaires based on interference with screen visibility and as viewed directly. Data analysis shows that there is a main effect of computer screen type and luminaire type on the acceptability of a luminaire for computer screen viewing. Computer screens exhibiting negative contrast displays, high display luminance, low specular reflectance and low diffuse reflectance produce higher levels of acceptability than those with two or more of the opposite characteristics.

In exploring luminaire type on acceptability, many luminaire characteristics were tested. Louver shielding angle proved to be the best predictor, and, when less than 30 degrees (as measured in the 0 degree luminaire plane), it corresponded to the luminaires rated as poorest for both direct view and reflected view. Luminaires with a louver shielding angle greater than 40 degrees received the higher ratings.

Subjective response both in direct and reflected view is strongly related to the luminous intensity of a luminaire, at the angle from which a VDT user will see its reflection in the computer screen. Higher values produce lesser ratings. Specifically, acceptability is related to the luminaire's luminous intensity raised to the power of 0.4, which closely resembles equations developed to relate luminance and brightness. Although luminous intensity cannot be measured directly, it is defined as a product of luminaire luminance and its projected area, and may be a simple metric that demonstrates the important trade-off between luminance and area in the acceptability of a direct luminaire. This metric is especially convenient to apply because luminous intensity (candlepower) is a common feature of standard photometric reports.

The result of this research is a recommendation that luminous intensity limits can be used to predict acceptability of a recessed interior lighting system in offices with computer screens.

Long-Term Performance of Screwbase Compact Fluorescent Lamps

Conan O'Rourke and Mariana G. Figueiro, MS

Over the past several years, screwbase compact fluorescent lamps (SCFLs) have been promoted as replacements for incandescent lamps in interior and exterior luminaires. One commonly quoted benefit for SCFLs is longer life. The lamp industry uses the three-hour-on/20-minute-off switching cycle to determine rated lamp life. However, in residential applications, lamps are switched on and off at different rates and lamp life for SCFLs depends on how frequently they are switched. An experiment was conducted to investigate the effects of different operating cycles on the life of SCFL products.

Data for 11 different SCFL products from six different manufacturers operating in six different cycles are reported. This paper discusses performance characteristics of SCFL and factors affecting fluorescent lamp life. Differences between SCFL products and linear fluorescent lamps are also discussed.

Lumen Effectivness Multipliers for Outdoor Lighting Design

Ian Lewin, Ph.D., FIES, L.C.,

There has been considerable technical activity in recent years concerning spectral effects produced by light sources and their influence on visibility under low light level conditions. In general, there is a growing body of knowledge that appears to confirm that certain spectral distributions are more effective than others in creating visual benefits.

No agreed-upon technique has been adopted by the IESNA to take spectral factors into account in practical lighting design. Because of the large potential impact that the research findings may have upon safety, security and energy use, it is essential that methodology be developed to put the information to use.

This paper will review the results of various researchers and indicate that there are two different

forms of research from which factors can be developed to apply to lighting design: brightness matching and visual performance testing. These will be compared.

The concept of "Lumen Effectiveness Multiplier," LEM, will be proposed. Values of LEM can be derived by two different methods, depending on which form of research data is used.

Chosen values of LEM for a particular design situation are dependent upon numerous factors. These include the nature of the visual task, the light level, the location of the task and lamp spectral distribution. The paper will review such factors.

The paper will also address questions of when and how these factors should be used.

The aim of the work is to establish a basic framework for understanding, evaluating and applying research data on the subject. This may lead ultimately to an IES design practice to take lamp spectral effects at low light levels into account during the design procedure.

Designed Appearance Lighting — Revisited
Martin Moeck

Lighting design students need tools to help them turn lighting effects they can perceive with their mind's eye into hardware layouts that will achieve those effects. In such a top-down approach, students would learn to assemble luminance patterns into a finished, appearance-based design concept. A suitable software tool could then support the process of turning the design concept into a hardware layout.

This paper describes a tool, which fulfills some of these requirements. It decomposes an architectural scene into individual architectural elements. Using computer graphics, each element is rendered separately as a lambertian emitter with its inter-reflected component in an otherwise dark environment. A final luminance map is composed through superposition and scaling of the individual images. This luminance map determines the subsequent placement and aiming of luminaires, and is conceived as an extension of lighting design concept drawings.

Multi-Objective Optimization of Spectra Using Genetic Algorithms
Neil H. Eklund and Mark J. Embrechts

This paper applies genetic algorithms (GAs), a powerful general-purpose biologically motivated optimization technique, to the multi-objective problem of spectrum optimization. Two objectives, color and efficiency, are addressed using real spectra, although the addition of other objectives (e.g., color rendering, color temperature) is relatively straightforward.

The direct application of the method presented is to transform the spectrum of newly developed lighting technologies to have desirable color properties while maximizing efficiency. Other applications of this methodology include the design of a filter for the input of a fiberoptic system such that the color at the end of a given length of fiber has particular properties (e.g., appears "white"), while the efficiency of the system is minimally affected.

The principal findings described in this paper are the implementation of an efficient multi-objective fitness function tailored to this problem, and a method for speeding convergence of the GA by "smoothing the chromosomes."

An algorithm, data and results from several approaches are presented.

Application Efficacy
Mark S. Rea and John D. Bullough

The primary measure of success in achieving lighting energy efficiency has conventionally been improvements to the luminous efficacy of lamps. However, in architectural lighting, some specifiers recognize that the most effective lamp and luminaire combination for a given application is often not the one with the highest lamp luminous efficacy. The widespread use of tungsten halogen sources in display and downlighting applications, despite the low lamp luminous efficacy of these technologies relative to others, suggests that lamp luminous efficacy is only partially related to the effectiveness of a lighting installation.

The purpose of this paper is to suggest a new measure of efficacy for lighting applications that is, first, based upon the lamp and luminaire combination rather than, as usually considered, solely on lamp luminous efficacy.

Second, and more importantly perhaps, this new measure is concerned specifically with delivering light where it is needed in the most energy efficient manner. It will be argued that the proposed metric, termed application efficacy, which can be approximated by the maximum luminous intensity (in candelas) from a luminaire per unit power (in watts), is a practical and general measure that helps ensure the most energy efficient luminaire will be employed for a given application.

The Effects of Changing Occupancy Sensor Time-out Setting on Energy Savings, Lamp Cycling, and Maintenance Costs
Dorene Maniccia, Allan Tweed, Andrew Bierman and Bill Von Neida

Most commercial lighting installations utilize occupancy sensors as an energy and cost-effective lighting control strategy. Despite their widespread use, minimal independent information exists about the effect of changing time-out settings on switching frequency, lamp life, lamp calendar life and energy and relamping costs. Consequently, this leads to confusion in the industry

about the appropriate time-out setting for applications.

To garner information about these effects, 180 spaces, representing five applications (offices, restrooms, break rooms, conference rooms and classrooms), were monitored for occupancy and lighting operation for a two-week period between February and September 1997. Baseline occupant switching behavior and occupancy patterns were established, and the effects of installing occupancy sensors with 5-, 10- 15- and 20-minute time-out periods were modeled using data for 158 rooms. Lamp cycling and time-on and time-off frequencies were examined to determine the tradeoffs between time-out setting and annual energy costs and savings, lamp life, and lamp calendar life for each application.

The following conclusions were reached from this analysis:

- The percentage of time spaces are occupied varies by application and will impact potential savings from occupancy sensors.
- Despite increased relamping costs and decreased lamp life due to frequent switching, installing occupancy sensors saves lighting energy and reduces overall costs.
- For classrooms, private offices and restrooms, installing occupancy sensors provides a reasonable payback for the analyzed time-out settings.
- Because the cost differences are minimally different for classrooms, private offices and restrooms, the longest time-out setting should be considered to minimize false offs and assure occupant satisfaction.
- For break rooms, installing occupancy sensors provides a reasonable payback if the five-minute time-out setting is used; however, shorter time-out settings increase the likelihood of false offs and increases the possibility of user dissatisfaction
- For conference rooms, installing occupancy sensors provides a reasonable payback if the 5-, 10- or 15-minute time-out settings are used.

An Analysis of The Energy and Cost Savings Potential of Occupancy Sensors for Commercial Lighting Systems

Bill Von Neida, Dorene Maniccia and Allan Tweed

Occupancy sensors are promoted as one of the most energy-efficient and cost-effective lighting control technologies. Despite widespread promotion, however, minimal independent information exists about their comparative energy savings potential in different spaces, the coincidence of savings with peak demand, or the impact of sensor delay periods on energy savings. This lack of information leads to end-user uncertainty and specification risk, which has hampered market penetration.

To garner information about energy and cost savings potential, 180 spaces representing five applications (offices, restrooms, break rooms, conference rooms and classrooms) were monitored for occupancy conditions and lighting operation for a two-week period between February and September 1997. Baseline occupant switching and occupancy patterns were established, and the effects of installing occupancy sensors with 5-, 10-, 15- and 20- minute timeout periods were modeled using data for 158 rooms. The results of this analysis support the following conclusions:

- Energy savings were significant for all room types ranging from 17-60 percent. This is due to the findings that most spaces are infrequently occupied (averaging 18 percent of the time), and that occupants in both public and private spaces are not diligent about turning off the lights, leaving lights on 11-48 percent of the time.
- The majority of energy use, and the predominant energy savings potential was found during normal business hours, not after hours or on weekends. These findings clarify the role of sensors vs. time-based controls to capture potential savings.
- Although the majority of energy use and waste occurs during the weekday, the sensor's largest contribution to savings is generally not coincident with a typical building's peak load period, or with typical electric utility peak billing periods.
- Sensor tuning for time-out periods from 5-20 minutes accounts for between 6-13 percent of the total savings potential. These findings have significant implications for understanding the trade-offs between savings and occupant complaints when commissioning sensors.

Lighting and Sustained Performance: Modeling Data-Entry Task Performance

Neil H. Eklund, Peter R. Boyce and S.N. Simpson

This paper describes an experiment undertaken to determine the effect of different lighting and print conditions on the sustained performance of a repetitive, self-placed, data-entry task. Twenty-four subjects worked for almost four hours at a data-entry task in one of three identical, private, windowless offices. All three offices were lighted by a similar fluorescent, parabolic lighting installation. In total, task performance measurements were taken for 60 combinations of illuminance, print size and luminance contrast. One other variable was examined: the décor of the office. All the subjects worked in the office when it was completely devoid of colored décor and also when it was colorfully decorated.

The performance of the data-entry task, measured as work speed for correct data-entry, was used to construct an empirical model of task performance. This model can be used to quantify the changes in the amount of work done on the data-entry task in a fixed time, for changes

in illuminance, print size and luminance contrast. This, in turn can be used as part of a cost-benefit calculation.

The Relative Visual Performance (RVP) model, developed by Rea and Ouellette,[7] shows close agreement with the measured mean work speeds. The Visual Performance (VP) model of Adrian and Gibbons[10] does not. As for the effect of décor, the subjective ratings showed that the subjects noticed the change in décor and considered the chromatic interior more attractive and interesting. However, décor did not make any difference to the performance of the data-entry task.

Modeling of Urban Light Pollution: Seasonal and Environmental Influence

Alberto J. Cabello and Carlos F. Kirschbaum

The urban light pollution is a specific characteristic of a city. The spectral and photometric parameters of the sky glow are closely linked with several aspects of the urban site and nearby areas. Those aspects include population, climate variations, urban and architectural design, types of lamps mounted in luminaires, geographical location, vegetation, economic activity, industrial profile of neighbor areas, seasonal ambient pollution, materials used in buildings, streets and other built areas.The paper informs about partial results obtained through the estimation of main characteristic factors of the light pollution of a city placed at the North-Western area of Argentina. The investigation project includes other Latin American and European cities. The study aims at building up a knowledge base where private and governmental planning institutions can access information about the state of illumination, light pollution and energy waste on transportation networks and urban lighting The current research stage is dedicated to estimating the lighting characteristics of the most relevant urban surfaces such as roads, pedestrian ways and building facades, as well as spectral diffuse reflectance of the main kinds of vegetation.

Performance Evaluation of the Inspection Lighting Systems in Industrial Auto Plants

Mojtaba Navvab, Ph.D., FIES. and Yoshiaki Uetiani, Dr. Eng.

Modern industrial auto plants, with new machinery and assembly configurations, will require specialized integrated lighting systems to ensure adequate illumination without reflected glare. A series of on-site detailed measurements were conducted in order to study the performance of three different inspection lighting systems in industrial applications. Some of the extreme conditions were simulated using computer and/or full-scale simulations. The objective of these on-site studies was to understand how the geometry of the tasks and luminance of the lighting system affect the visual quality and quantity of the working area.

Since the eye of the industrial worker operating in the dynamic mode and in realistic visual work situations is seldom still, eye movements will produce transient adaptive effects. There are differences between the local luminance encountered at various points in the visual field and the luminance of the task background. Exposure to the changing pattern of luminance is to be expected in industrial lighting environments. Data from these studies provide the basis for calculation of task visibility, luminance and highlights under actual lighting conditions. The results have shown that related indices provide a more adequate physical correlation for the lighting system comparisons for inspection lighting systems in industrial auto plants.

The existing lighting systems and their configurations are compared. The specific design characteristics are evaluated against the current guidelines. The on-site measured data show that these systems provide safe and adequate illumination for these inspection areas, but they provide different qualities of light with respect to glare within their luminous work environment.

A Comparison of Visual Performance Under High and Low Color Temperature Fluorescent Lamps

Mojtaba Navvab, Ph.D., FIES.

Over a two year period, two sets of 101 subjects each were tested for word reading and letter acuity under two different fluorescent lighting systems. Subjects' word reading acuities were evaluated in a test room while they were seated at a desk in normal reading posture, and they read unrelated words of progressively diminishing size with the words placed in a horizontal or nearly vertical position. The lighting in the room was provided by either an equal number of low color temperatures or high color temperature fluorescent lamps in the conditions of fully lighted surround or dark surround. Because of the equal number of lamps, task luminance was always at least 50 percent higher under the low color temperature lamps. In spite of this large bias favoring the low color temperature lighting, word reading acuity was highly significantly better under the high color temperature lamps for the fully lighted surround condition. No significant differences in acuity occurred in the dark surround condition. Spectrally driven pupil size changes are conjectured as the mechanism responsible for the observed effects.

Recommended Daylight Conditions for Photosensor System Calibration in a Small Office

Soo-Young Kim and Richard Mistrick

Photosensor-controlled dimming systems for the electric lighting system in a private office were analyzed to determine the optimum sky and blind conditions under which to calibrate these systems. Computer simulations were performed for three commercially available photosensor products in both a north and south-facing room.

The daylight conditions included clear glazing, horizontal blinds and blinds oriented at a 45-degree angle, which were tested under an IESNA clear, partly cloudy and overcast sky throughout the day at different times of the year.

An optimum calibration condition was determined for each combination of room orientation and photosensor system using the full set of tested daylight conditions. From this "preferred" setting, we determined the best sky, solar position and blind conditions at which to perform photosensor control system calibration. Horizontally oriented blinds under clear or partly cloudy skies generally provided the best possible calibration conditions to achieve a near-optimum calibration setting. A 45-degree blind setting also provided a good calibration condition when the daylight levels were sufficiently high. Calibrations performed with clear glazing only (no blinds) generally provide very poor performance and should not be used when blinds are also likely to be applied.

In addition, correlation coefficients between workplane illuminance and photosensor signals show that sensors that received less direct light from the window provide slightly better performance when a space is exposed to all possible conditions. Finally, all three sensors that were tested provided very similar energy savings when calibrated at their optimum setting.

A Lamp Life Predictor for Frequently Switched Instant-Start Fluorescent Systems

Nadarajah Narendran, Tao Yin, Conan O'Rourke, Andrew Bierman and Nishantha Maliyagoda

Although T8 fluorescent lamp life is typically rated at 20,000 hours, it can significantly vary depending on the ballast product. The current industry practice for testing fluorescent lamp life requires these lamps to be subjected to three-hours on / 20-minutes off cycle, which is also known as the standard cycle for life testing. This method requires more than two years of testing, which is expensive and also delays the development of new products. Therefore, researchers have been trying to expedite the procedure for lamp life testing by increasing the switching frequency. However, none of these attempts have shown much promise for correlating the lamp life on faster cycles to the lamp life on the standard cycle.

Alternatively, researchers have been trying to correlate certain starting and operating electrical parameters of the lamp-ballast system to lamp life. As an example, it has been shown that the ratio of the hot cathode resistance to cold cathode resistance correlates well with lamp life for rapid-start ballast fluorescent systems. Instant-start ballasts comprise a larger market share than rapid-start ballast. A literature survey shows that, at the present time, there is no such parameter available for predicting lamp life of instant-start systems.

It is also shown in literature that within a range, lamp life shortens with increasing switching frequency. At very fast switching frequencies, such as the five-minutes on / five-minutes off cycle, the major portion of the electrode damage takes place due to starting, which ultimately leads to lamp failure. At standard operating cycles, the electrode damage takes place during starting and operating periods.

To predict lamp life on any switching cycle, one has to know the amount of electrode damage that takes place due to starting and the amount of electrode damage that take place due to normal operation. This study deals only with starting effects. The goal of this initial study is to analyze the starting electrical properties and identify a parameter that correlates well to high-frequency switching life, which provides insight to the amount of electrode damage that takes place during starting. It is shown here that the time integrated value of the lamp voltage over the starting period, $\int_0^{start} V dt$, correlates well with high-frequency switching life for the lamps tested.

The details of the experimental study and the results are explained in this manuscript.