

## SCYTHE AND SEW: A TOOL FOR CREATING AND ANALYZING MEANINGFUL PATTERNS OF LIGHTING SIMULATION DATA

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### ABSTRACT

This paper presents "Scythe and Sew", a software environment for analyzing lighting simulation data. It provides a spreadsheet like infrastructure for manipulating high-dimensional simulation results. It allows users to both import and create lighting simulation data, or patterns, into a workspace for inspection. A composition area allows the user to perform algebraic operations on the patterns to obtain new insight into the data. This framework allows for a range of lighting assessments including comparing model performance under two standard skies, to a lighting requirement, and at two geographic regions. Various examples are illustrated.

### INTRODUCTION

In 1991, Sumption et. al, created the visionary film *Lightscaapes* to explain multidimensional aspects of lighting performance (Sumption, Haglund et al. 1991). *Lightscaapes* shows how the dynamic nature of daylight interacts with a representative floor of a modern high-rise office building. It illustrates "flows" of light rising and falling according to diurnal, seasonal, and climatic cycles of daylight. IT also shows how the flows "submerge" solid blocks of lighting requirements. When the blocks are under the flows there is ample light, otherwise, additional electricity needs to be used. The contribution of electric light is also shown as another undulating layer, responsive to dimming controls. In sum, the video examined lighting from a holistic perspective, taking into account both day lighting and electric lighting systems.

Since then, a number of interactive systems have been written to visualize some of the complexities that *Lightscaapes* raised. For example, (Mahdavi and Berberidou-Kallivoka 1994) describe how 2D performance graphs of daylight factors could be drawn according to interactive model specification. The system described in (Papamichael, La Porta et al. 1997) shows quantitative performance graphs on demand for both daylight and electric light. (Cheng and Pat-Yak Lee 2001) show a variety of ways of visualizing photorealistic images of daylit spaces using both animation and simultaneous viewpoints. [Bund and Do 2003] allow a user to interact with a

3D architectural model and obtain shading performance graphs on demand. Space Series [Glaser and Ubbelohde 2002] facilitates efficient display and interaction of planar daylight data. It allows a user to interactively explore a large, variable data space through tessellation, brushing and linking, and magic brushing.

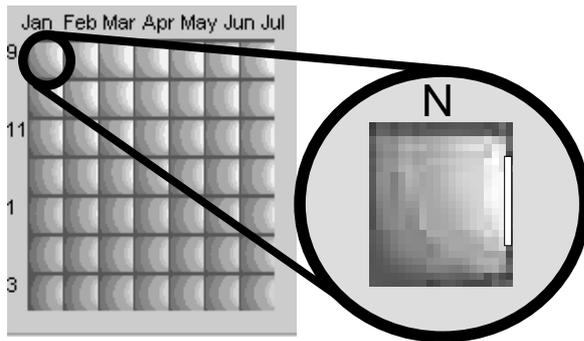
In all these programs, though, there is no explicit support for comparison or manipulation of simulation results. Instead, they rely on visual inspection or other programs to assess lighting performance. We propose *Scythe and Sew*, an environment for dynamically interacting with multiple sources of simulation data.

### SIMULATION FRAMEWORK

#### **Patterns**

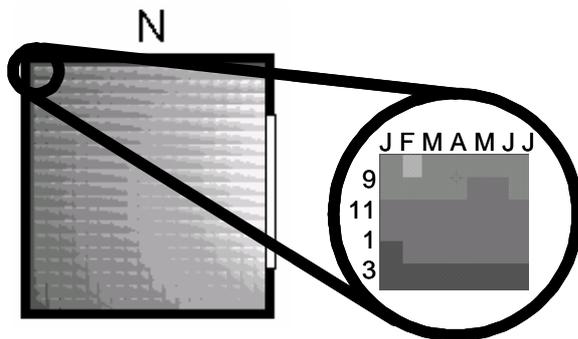
*Scythe and Sew* works with *patterns* as a unit of analysis. Patterns are a way of viewing simulation results that have both three spatial (x, y, z) and two temporal (time of day, day in year) dimensions. They are collections of *slices* or 2D plots of data., providing a window into the larger five dimensional information space. Slices typically are a lighting performance graph of a surface at a single moment in time or calendar of values across a single point in space. A workplane illuminance graph at 9am on January 3<sup>rd</sup>, for example, would constitute a slice. The opposite is also a slice—a single point on the workplane can be charted across the day and year. Although patterns are multidimensional, they may be constant along certain intervals. Patterns are discussed in detail in (Glaser and Ubbelohde 2002) (but note the terms "pattern" and "slice" have replaced "slice" and "cell" respectively).

The pattern shown in *Figure 1* is of a rectangular room with a single East window in San Francisco, CA. It shows daylighting distributions for a period between January and July from 9am to 3pm. It is sampled 7 times a day, one day a month. Each slice records 19x21 equally spaced data points inside of the room. The sensors are all at workplane height. This representation shows both diurnal (top to bottom) and seasonal (left to right) variations of daylight.



**Figure 1.** An example of a pattern. A slice of data from January at 9am is highlighted.

Each pattern is implemented as a set of vectors and bounds inside of the multi-dimensional simulation space, collectively referred to as the *view* of the pattern. Modifying the *view* allows multiple representations of the same data. *Figure 2* depicts a pattern using the same simulation data as *Figure 1*, but with a different *view*, yielding a different pattern. This view shows how light is distributed across the space with temporal variations. The temporal variations are the same as the axis shown in *Figure 1*. This gives the graph variations within each slice of data.



**Figure 2.** A time in space pattern. It shows calendars inside of space.

### Operators

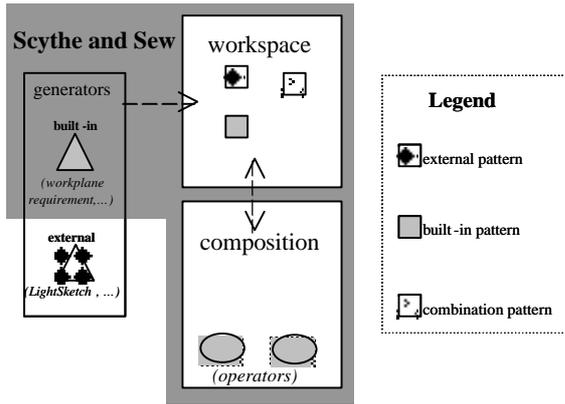
Although patterns are useful for seeing data, they are often not always ends in themselves. Architects often like to compare within, between or among building scenarios. For example, they may want to assess worst versus best-case scenarios for daylight availability. In this case, the simulation results could be subtracted between scenarios to find an answer. Alternatively, an architect may want to get a sense of the average amount of daylight a building receives also through computation. In these cases, simple algebraic operations can be used to answer these questions.

### Manipulation

Scythe and Sew allows users to manipulate patterns of data in a flexible way. Patterns can be joined together through algebraic operations in a composition area to create new combination patterns. These new patterns, in turn, can be further manipulated and analyzed. Hence, the environment takes a spreadsheet like approach of managing data. Scythe and Sew, though uses units of analysis that are sympathetic to the multidimensional aspects of daylight.

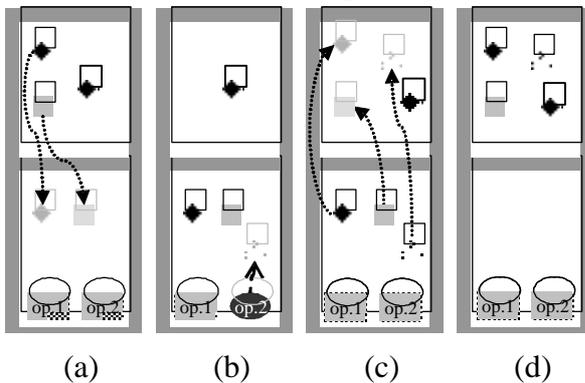
*Figure 3* is a conceptual diagram of Scythe and Sew. It consists of generators and two main interface regions. The generators create patterns for the workspace and composition areas. There are both external and internal generators. External generators are either computer programs or raw data files as in the case of measured data. We are using LightSketch [Glaser et al. 2003] to create datasets from day lit and electric lighting sources. Internal generators are built into the Scythe and Sew program for creating simple masks. Currently, the only implemented mask is a constant for managing illuminance requirements. Together these generators form a vocabulary for lighting analysis.

The two main interface regions, the workspace and composition area, are used to view and manipulate patterns. The workspace area is where patterns originate. Here a pattern can be resized or have its data values inspected. In the composition area, the user can manipulate the patterns. Patterns can be joined together through algebraic operations such as average and difference to create new patterns. These new patterns, in turn, can be further manipulated and analyzed and the results brought back to the workbench.



**Figure 3.** A conceptual diagram of the major components of Scythe and Sew.

Figure 4 is a conceptual diagram of Scythe and Sew’s workspace and composition areas in use. In a) two patterns from the workspace are dragged into the composition area. One pattern is generated from an external program such as LightSketch while the other an internal generator like a lighting requirement level. In b) an operator, such as difference, is selected and a new combination pattern is generated from the two patterns in the composition area. In c) all the patterns are brought back to the workbench area and d) are available for inspection.

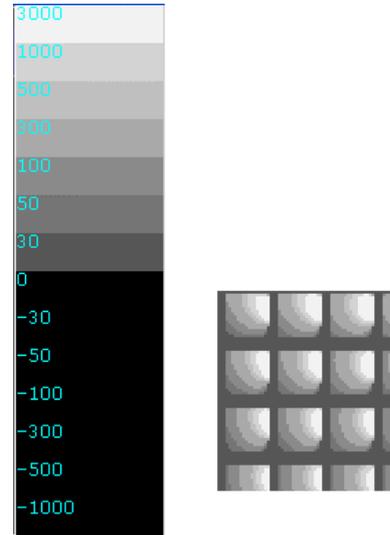


**Figure 4.** This storyboard illustrates how patterns can be manipulated across workspace and composition areas. Dotted arrows represent a user-initiated drag and drop; dashed arrow the creation of a new pattern after button press.

### Color maps

Color maps consist of colors and the numerical scales to which they correspond. Scythe and Sew uses them to paint the data onto the screen, allowing users to quickly visualize lighting quantities that vary over both time and space. Color maps can also represent negative lighting values that appear when operations are performed on simulation data. By utilizing different color maps for the positive and negative scales, users can easily identify which portions of a composition are below zero and which are above

zero. The color maps built into Scythe & Sew utilize standard color schemes, including grayscales, heated body, and rainbow scales. Both positive and negative scales have independently controlled color maps. These scales are mapped onto numerical scales in various ways, including linear and logarithmic maps. Figure 5 illustrates the color map used for charts in this paper<sup>1</sup>.



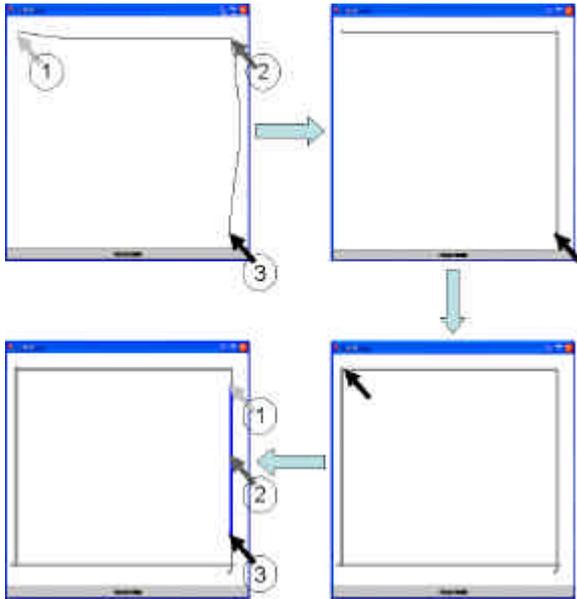
**Figure 5.** Grayscale color map with units in Lux. Positive Lux are lightly shaded, while negative values are black.

### DISCUSSION

This section illustrates how Scythe and Sew can be used to analyze a range of lighting analysis problems. It shows how this tool can be used to assess different sky models, site conditions, and electric lighting integration consequences. The program LightSketch is used to generate the architectural models and datasets used by Scythe and Sew. It should be noted that Scythe and Sew is an intermediary program and the validity of its data is limited by the simulation source, in this case LightSketch.

Figure 8 shows a simple rectangular model with an East window. Its geometry was produced by a few pen strokes using LightSketch. The program generates a 3D model with standard dimensions from the 2D sketch input. LightSketch has links to the Radiance lighting simulation engine and can output both photorealistic images and abstract illumination values. This output can be passed to Scythe and Sew, which draws the lighting values and images onto patterns.

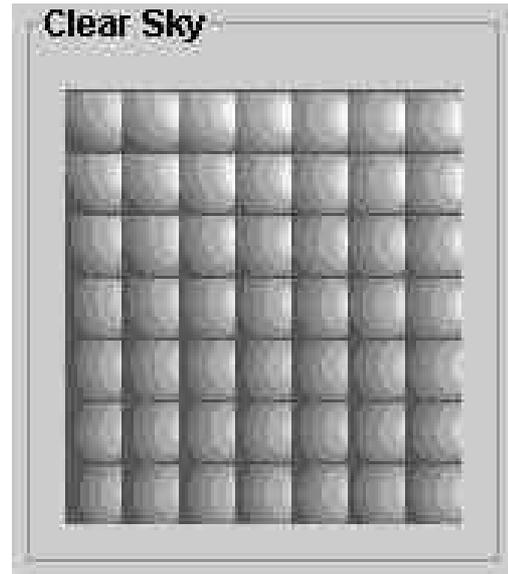
<sup>1</sup> black was used to represent all negative values due to the limited bandwidth of the grayscale colormap.



**Figure 6.** A rectangular model with a single eastern window drawn in Lightsketch. (clockwise from upper left) sketching 2 walls, recognition of walls, drawing 2 more walls, sketching a window

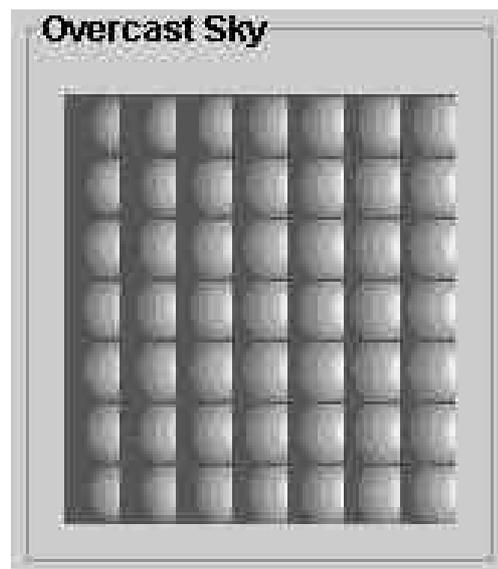
#### Model Performance Under Different Sky Conditions

Figures 7-9 show a sequence describing how Scythe and Sew can compute the differences between simulation results using two sky models. Figure 8 shows simulation results for the model drawn in under CIE clear sky conditions. This pattern initially appears in the workspace area of Scythe and Sew. It shows how the model performs from January to December, 9 am to 3 pm. It can be seen that in the morning, during summer hours, there is an abundance of daylight. Also daylight availability decreases as the day goes on. Seasonal variations appear minor except for the early morning hours.



**Figure 8.** The rectangular model with a single East window simulated under clear skies.

Figure 9 is an image of the same rectangular model under overcast skies. It differs from Figure 8 in at least three main aspects. First, there is visibly less regions of high illuminance in the morning hours. Secondly, the light is spread more evenly in the room. In particular, there is less variation along the north/south axis due to the light source which only varies by altitude. The last observed difference is that the model under overcast sky appears to get brighter towards noon while the clear sky model gets darker. This is due to the sun's visibility to the eastern window only during clear sky conditions. .



**Figure 9.** The rectangular model with a single East window simulated under overcast skies.

Figure 10 is a combination pattern created through Scythe and Sew. It is created in a similar fashion that is demonstrated in Figure 4. Namely the patterns in Figures 6 and 7 are brought to the workspace area and their difference is taken. The automatic titling of the pattern as “x-y” indicates that this is a combination pattern subtracting y from x.

The results show quantitatively how much more light is present during a clear versus cloudy sky. Confirming our observations, it shows that more daylight is available in the mornings for sunny skies (the light regions) and afternoons for overcast conditions (drawn in black). This example shows that a clear sky model does not perform better than overcast in all cases. Hence, “best” and “worst” case assumptions about sky models are contingent on temporal factors. In other words, sometimes overcast skies cast more light into windows than clear skies do.

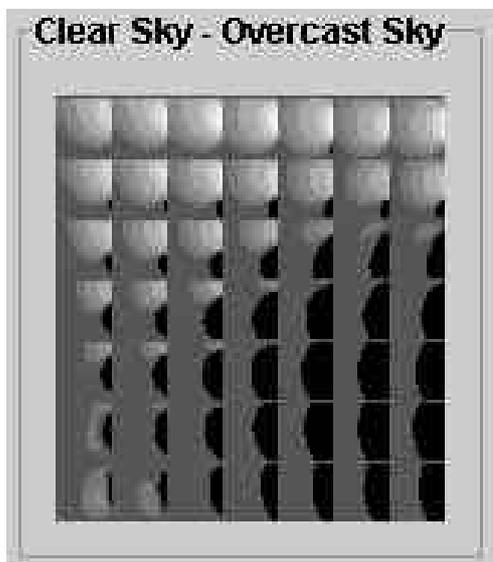


Figure 10. Clear versus overcast sky performance for a square room with an east window.

Figure 11 shows the comparison between clear and overcast skies for a rectangular room with a single north-facing window. It can be seen that there is more available daylight throughout most the year with overcast skies. This is illustrated by the dominating black (negative) regions.

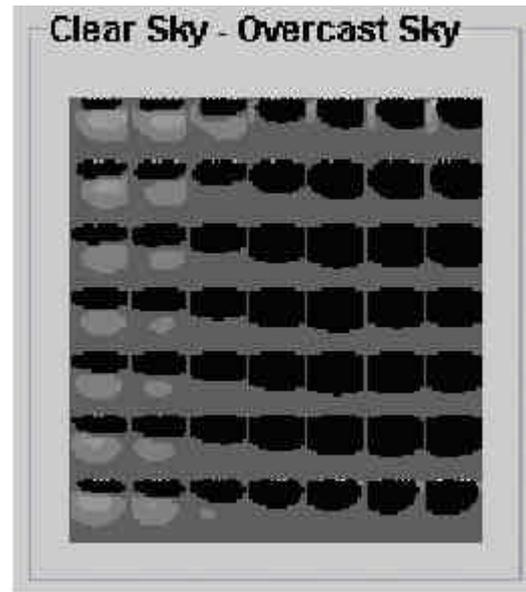
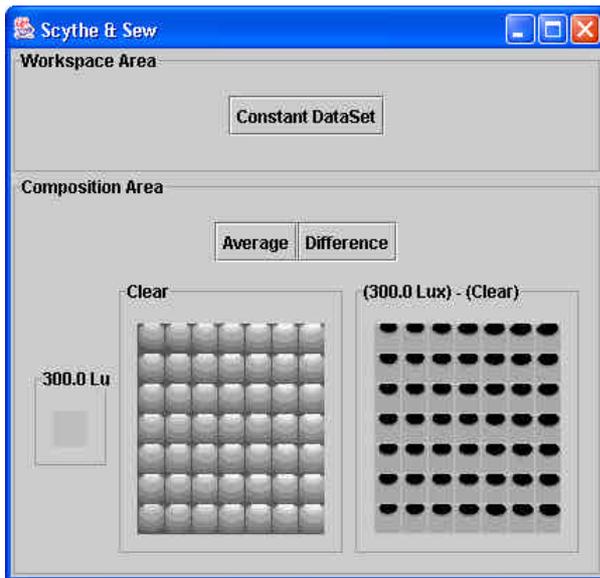


Figure 11. Clear versus overcast sky performance for a square room with a north window.

### Assessing Lighting Requirements

Scythe and Sew can be used to assess lighting requirements. One simple measure of lighting quality is whether there is *enough* light at the workplane. A lighting designer, for example, may prefer ambient light to be at around 300Lux. Understanding when and where daylight meets this level has direct energy consequences. Times when daylight does not meet an illuminance requirement will be buttressed by the electric lighting system. With Scythe and Sew, identifying these times and severity can be accomplished using a constant pattern and difference operator.

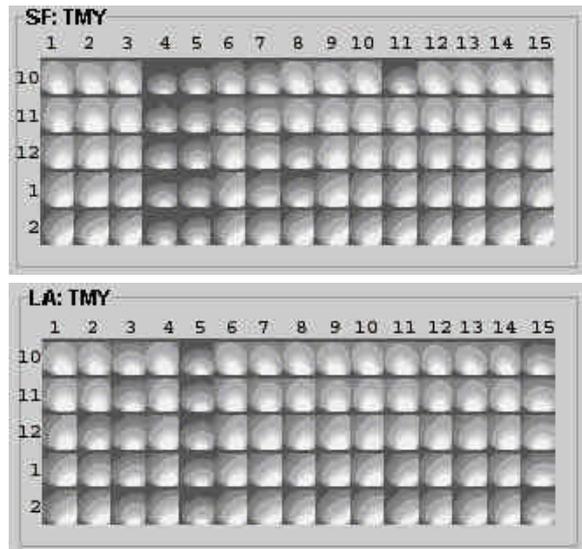
Figure 12 shows such a construction. The three patterns in the composition area represent a constant workplane requirement, the available daylight, and its performance (from left to right). The constant pattern is generated from within Scythe and Sew, the available daylight was provided by using LightSketch, and the result was created by pressing the “Difference” operator in the composition area. It shows that for most parts of the year the northern side of the room receives ample daylight while the southern side is deficient. The constant pattern can be dynamically changed and, since it is linked, will update the performance pattern accordingly.



**Figure 12.** Comparing a daylight with constant pattern to assess lighting performance. Black areas on the right-most pattern indicate where the lighting values are greater than 300 Lux.

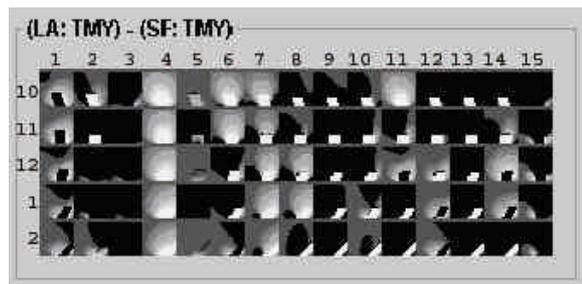
### Comparing Geographic Regions

Scythe and Sew can also make apparent how differences in climate and location affect daylight availability. Measured TMY-2 data is used for input to the Perez [Perez et al. 1990] all-weather sky model. This is used for a rectangular room with a single southern window. *Figure 13* compares two cities, Los Angeles and San Francisco, from January 1 through 15<sup>th</sup>, 10am to 2pm. Although there are some noticeable differences between the data sets (e.g. January 4<sup>th</sup> in San Francisco is significantly darker than Los Angeles), it is difficult to compare most of the times that have similar looking shapes.



**Figure 13.** Daylight simulation for a room with a single southern window in (top) San Francisco and (bottom) Los Angeles constituted with TMY-2 data. The x-axis represents January day and y-axis hour.

The difference operator, once again, can reveal the disparities in light levels for these two settings (*Figure 14*). This plot shows a high variance in daylight performance between cities. Although the image shows that January 4<sup>th</sup> has uniformly more sunlight in Los Angeles than San Francisco (indicated by the light values from 10am to 2pm), there are no other days when this occurs. Instead, the combination pattern describes conditions where neither location has uniformly more light. This phenomenon is likely due to the low quality simulation settings used by Lightsketch to generate this data set. Hence, Scythe and Sew can make apparent limitations in simulation settings too.



**Figure 14.** Difference between Los Angeles and San Francisco models. Gray regions show where Los Angeles has more daylight while black regions San Francisco.

### Comparing Sky Models

As an extended example, Scythe and Sew can assess whether a CIE intermediate sky model can be reconstituted from two others. To do this requires some algebraic manipulation. Specifically we can ask Scythe and Sew to average the results of simulating

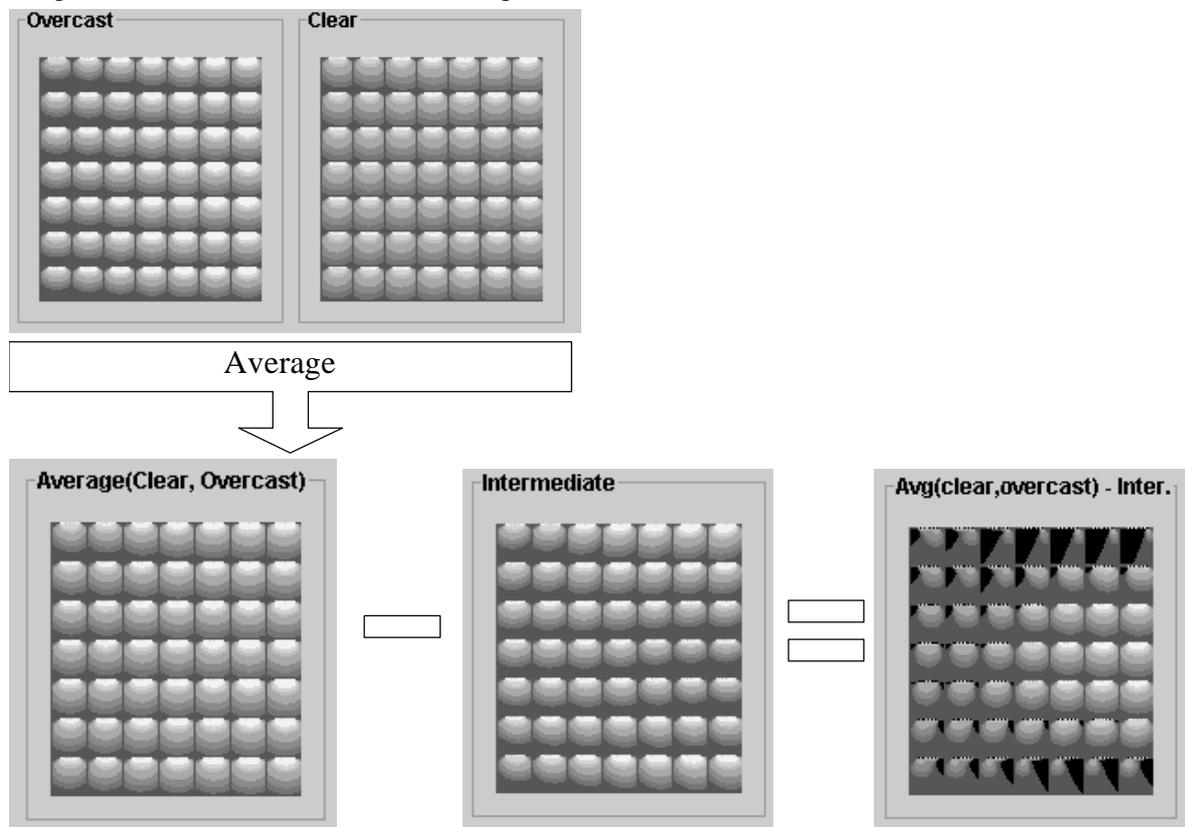
CIE clear and overcast skies and compare it with the CIE intermediate standard.

Figure 13 illustrates the construction of this sequence of operations. First, the simulation results were generated for a model with a single north facing window in Lightsketch. Next, simulation results were computed for CIE clear, intermediate, and overcast skies. Scythe and Sew imports each as a pattern labeled “Clear” “Intermediate” and “Overcast” respectively. Once these patterns appear in the workspace area of Scythe and Sew, they can be composed together to solve the problem.

The sequence is as follows. The “Clear” and “Overcast” patterns are brought to the composition area and the average operator is invoked. This creates a new combination pattern labeled “Average(Clear, Overcast)” is created in the composition area. The “Clear and Overcast patterns

can be removed and the “Intermediate” pattern brought into the composition area. Here, the two patterns can be compared with the subtraction operator. It produces a fifth pattern, “Avg(clear, overcast) – Inter.”). This final pattern shows the differences between intermediate skies produced from different sources.

It can be seen that the model simulated with the CIE intermediate sky specification performs worse, on average, than the averaged sky. A notable exception is the early morning hour, where the intermediate sky performs better in the spring and summer months. Thus, the average of the performance of a clear and overcast model over-estimates the lighting of a CIE intermediate sky. This conclusion, though, is limited to the single model tested.



**Figure 15** Intermediate skies as constituted by averaging CIE clear and overcast versus the CIE intermediate standard using our a model with a single north facing window.

## CONCLUSION

This paper illustrates a program Scythe and Sew for managing simulation results. Various cases were presented to illustrate how it could be used to create meaningful patterns in the data. These scenarios were made possible by having a workspace area with algebraic operators which can act on the data. This functionality can express a wide range of lighting design problems that otherwise cannot easily be resolved with current technologies.

There are a number of areas for future exploration. First, the aggregation functions can work within a pattern. These intra-pattern operations can assist with slice manipulation the same way the current inter-pattern operators do. Also, other built in masks are being considered for occupancy schedules. Photorealistic data is also being considered as special cases of patterns. Refinements such as automatically generating axes labels, improving the layout manager, and interaction schemes are also under development.

## ACKNOWLEDGMENT

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