Computer Modeling Part 2: A Closer Look at Metrics

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There are many phenomena in the world that we would like to understand better. Complicated interactions, such as weather patterns or economic fluctuations, are difficult to study not only because of their many variables, but also because it is often impossible to conduct experiments in which we control enough of the variables to reveal the underlying causes of these interactions.

Understanding the effects of various proportion parameters on the appearance of a polished diamond is a similar situation: A thorough research study requires the ability to test hundreds of thousands of proportion combinations under many lighting conditions and observer positions. It would be prohibitively expensive, and extremely difficult, to arrange these conditions using actual diamonds. Computer modeling, however, allows researchers to study the full range of these variables and their effect on diamond appearance

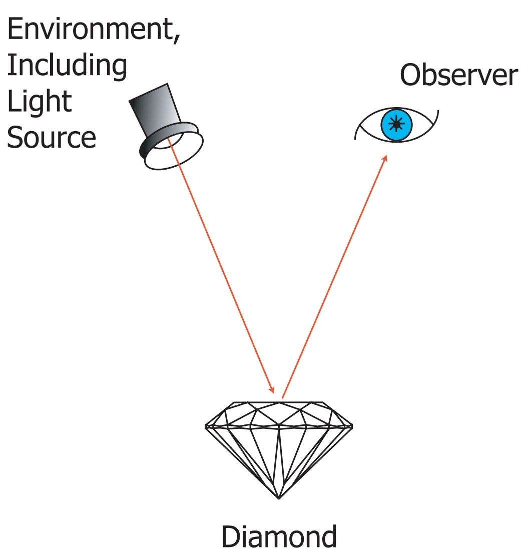

Figure 1. Three main component — the diamond, the environment (including light sources), and the observer — are defined mathematically in GIA's computer model of diamond appearance.

Executive Summary:

- The GIA computer model for the appearance of a round brilliant cut (RBC) diamond includes a virtual diamond, a virtual environment (lighting etc.), and a virtual observer; it also defines the relationships between these three components.
- *Appearance metrics* are calculated numerical values that are designed to be measures of some aspect of diamond appearance.
- Each set of relationships between diamond, environment, and observer in a computer model leads to a different metric, although all new metrics are part of the same computer model.
- Computer modeling must always be checked by real-world verification; this includes checking the precision of the model, the accuracy of the match between the model and the situation that is being examined, and the level at which fine points of distinction in the model are perceptible or meaningful in the real world.

MODELS AND METRICS

As stated in our earlier *GIA on Diamond Cut* article, "Diamond Appearance: The Components of a Computer Model," a computer model re-creates the properties and characteristics of an object, along with the key factors of its interaction with specified aspects of its environment. Remember that in GIA's research on diamond appearance, the computer model consists of a virtual diamond, a virtual environment (that includes factors such as a virtual light source), and a virtual observer (figure 1).

These three components define the computer model (that is, all three components must be accounted for in some way for the model to be complete).

However, researchers are free to specify and adjust any or all of the attributes of the model components in their attempt to re-create certain real-world relationships. *Each adjustment of the model's components leads to a different kind of numerical result, or metric, although each new metric is still part of the same, original model.*

If we combine our knowledge of computer modeling with our knowledge of the scientific method (as described in "How Science Works: Understanding the Scientific Method"), we see that great benefit can be derived from regular feedback and correlation between model calculations, verification tests, and model adjustments (figure 2).

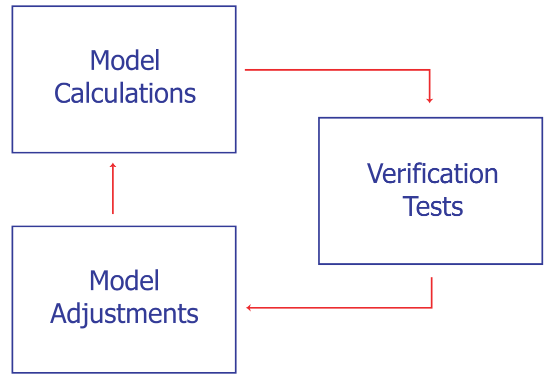

Figure 2. To insure an accurate computer model (that is, a model that accurately re-creates a real-world relationship), researchers often have to go back and forth between the model and verification tests to improve it.

For GIA's research on diamond appearance, verification tests often consist of comparing model results (i.e., metric values) with the results of observation tests that use actual diamonds. In each case, GIA researchers hope to find a statistically significant correlation between these two results; when they do, they know the degree of accuracy to which they have modeled the particular set of real-world relationships they were attempting to re-create.

There are at least two main challenges when using computer modeling to understand diamond appearance. The first challenge is to model accurately the real-world relationships (i.e., the exact relationships between diamond, environment, and observer) that are being represented. This includes matching any relevant visual thresholds of the observer (for example, differences in brightness that are too small for the human eye to perceive) with what the computer can calculate. The second challenge is to correctly choose the most relevant relationships to model (e.g., deciding which type of lighting should be modeled). Both challenges are difficult, and each has its own particular path to success.

MATCHING A METRIC TO ASSUMED RELATIONSHIPS

An example of the first challenge can be seen in the development of GIA's weighted light return (WLR) metric[1]. This metric measures the brightness of a virtual polished diamond by making certain assumptions about the diamond[2] and about the environment and observer of that diamond. First, it defines the environment as one in which light enters the crown of the diamond, with equal intensity, from all angles above the girdle plane (thus, it includes another assumption, that there are no other objects in the environment, such as an observer, that would block that light; see figure 3).

Then, the WLR metric assumes that the theoretical observer "sees" light exiting from the crown of the virtual diamond at all angles above the girdle plane. One reason the model does this is to include the appearance of diamond brightness that is seen when the diamond is tilted or viewed from an angle. However, because light that exits a diamond approximately perpendicular to the table is considered

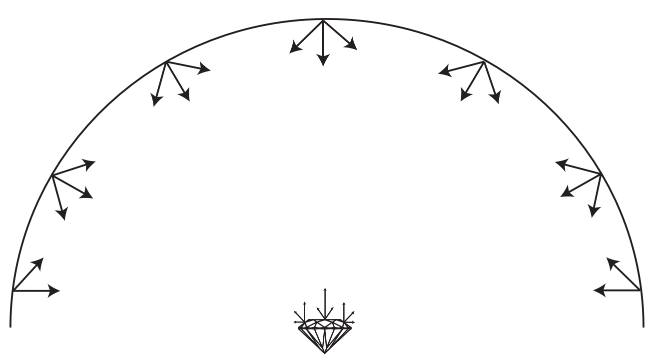

Figure 3. The WLR metric for brightness is determined, in part, by its assumptions about the virtual environment (including lighting).

more important to appearance than light that exits at other angles, the WLR metric "weights" all of the exiting light rays so that those that exit perpendicular to the table are counted more than those that do not (figure 4).

These assumptions determine the relationships between diamond, environment, and observer represented by the WLR metric. If the first challenge of modeling is met, the metric results will be found to correlate significantly with a real-world situation that matches these assumptions. This correlation can only be validated through a series of verification tests in which a real diamond with similar characteristics is found to perform the same as the metric predicts in a similar but real environment and using a similar but real observer.

The correlation to diamond appearance was somewhat problematic in the case of the WLR metric, in that this particular metric was designed to measure the "absolute performance" of a diamond by maximizing the appearance of brilliance in the virtual diamond. That is, the WLR metric was designed to measure the absolute ability of a diamond to return light back through the whole crown when there were no other hindrances to that light return (such as objects in the room, the observer's effect on the light, or a limited angle within which the light would be visible).

Even more difficult to correlate was the fact that the type of observation defined in the WLR metric could not be carried out by a real observer, since a human would be unable to observe a diamond from every angle across the hemisphere at the same time. Thus, we conducted multiple observations and combined them to mimic the virtual observation. In spite of such limitations, this metric was a basic yet essential step in helping researchers understand and create a modeling program that would accurately calculate the interaction of an RBC diamond and light rays.

When researchers attempted to verify this metric through observation tests of real diamonds, they found that it correlated well to observations made in a particular environment that matched the model. However, it did not correlate as well to the assessments of observers looking at the same diamonds in their own environments (i.e., typical environments for the trade). Therefore, while the WLR metric modeled the theoretical "absolute performance" of each diamond with high accuracy, a metric with different attributes (i.e., the specific characteristics of, and relationships between, the diamond, the environment, and the observer) was needed to correlate more closely with observation results obtained from more typical lighting environments.

FINDING THE RIGHT RELATIONSHIPS TO MODEL

The WLR metric modeled one set of relationships between diamond, environment, and observer. However, the comparison of WLR metric results with results obtained through real-world observation testing (performed under several kinds of conditions), showed researchers that the relationships expressed by WLR were not sufficient to explain all the observations. The next step was for researchers to choose a new set of relationships (based on what they observed from watching people view actual diamonds), and then adjust their computer model to accurately represent these relationships.

Matching a set of modeled relationships to observations of real-world events can be a difficult and lengthy process. In this case, researchers wanted to model a set of relationships that captured fairly the way experienced observers viewed diamonds in their own typical, trade environments. To do this they recorded the conditions and procedures of many

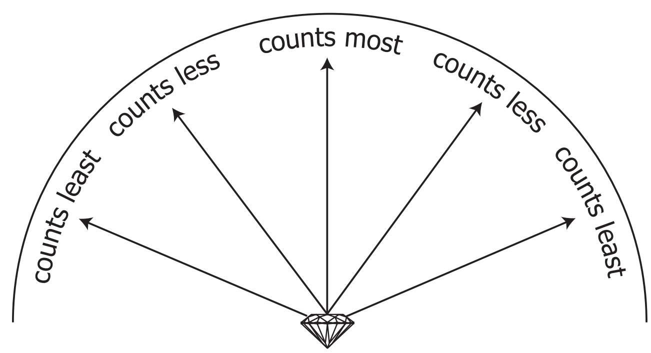

Figure 4. The WLR metric for brightness is also determined by its assumptions about the virtual observer. In this case, the way in which light exiting the diamond is counted depends on its exit angle.

experienced observers (diamond dealers and retailers) in many environments by interviewing them in their own settings. Then the researchers set out to adjust their computer model to represent the majority (the set of most common factors) of these instances.

This process required several rounds of feedback between model calculations, result correlations (using real-world observation tests), and the corresponding model adjustments. In each round of model adjustment, there were three components that had to be reevaluated: the diamond, the environment (including lighting), and the observer.

In each case, and for each adjustment of the model parameters, calculated results needed to be compared with the results from a large number of observation tests in order to determine whether a statistically significant correspondence existed. Although this was a lengthy process, it was the only way that an appearance metric could be validated to correspond with a desired set of real-world relationships.

Every new set of relationships (e.g., a different kind of lighting or a different type of observer) and each different appearance aspect (such as fire) must be researched and supported in the same manner.

CONCLUSION

The process of developing and testing a computer model is often lengthy and painstaking. Each new set of relationships between the components of the model must be developed, calculated, validated through a series of verification tests, and adjusted until a statistically significant correlation is found.

Researchers often develop hundreds of metrics in their search for the one that matches the particular real-world circumstances they are trying to represent with their model. In each case, one thing is certain: *When you change any of the components or relationships between components in the real world, you must change the metric to correspond to it.* Each new metric, however, is still a part of the original computer model.

We hope that you found this article useful, and invite any feedback or comments that you may have. You may contact us by e-mail at DiamondCut@gia.edu. ■

Originally Published: February 23, 2003
GIA on Diamond Cut

[1]Hemphill et al. (1998) Modeling the Appearance of the Round Brilliant Cut Diamond: An Analysis of Brilliance, *Gems & Gemology*, Vol. 34, No. 3, pp. 158-183.

[2]So far, GIA has limited its computer model to a virtual diamond that is colorless and flawless, has excellent symmetry and polish, and mimics the shape and cutting style of a round brilliant (with the standard 58-facet arrangement, counting the culet). The independent (or changeable) variables of the virtual diamond are currently limited to its proportion parameters.

