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Reference

CUTE: CUTting Edge Diamond Optimization. Operations Research. 2011

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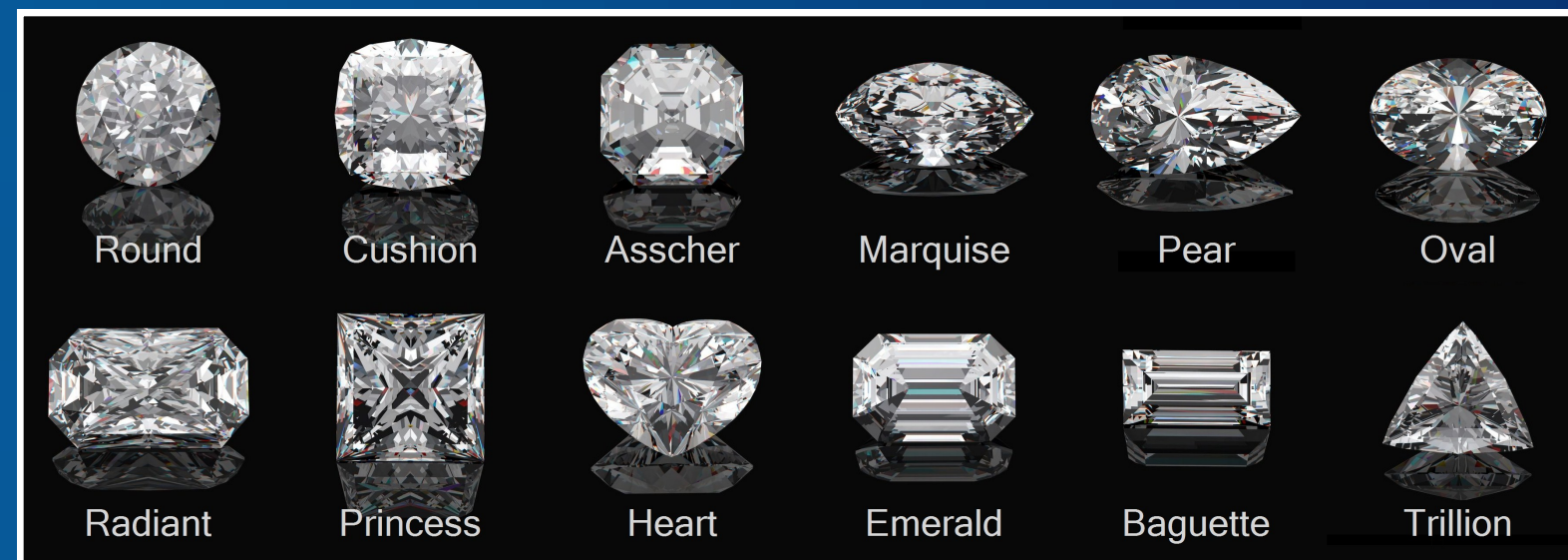
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DIAMOND CUTTING OPTIMIZATION

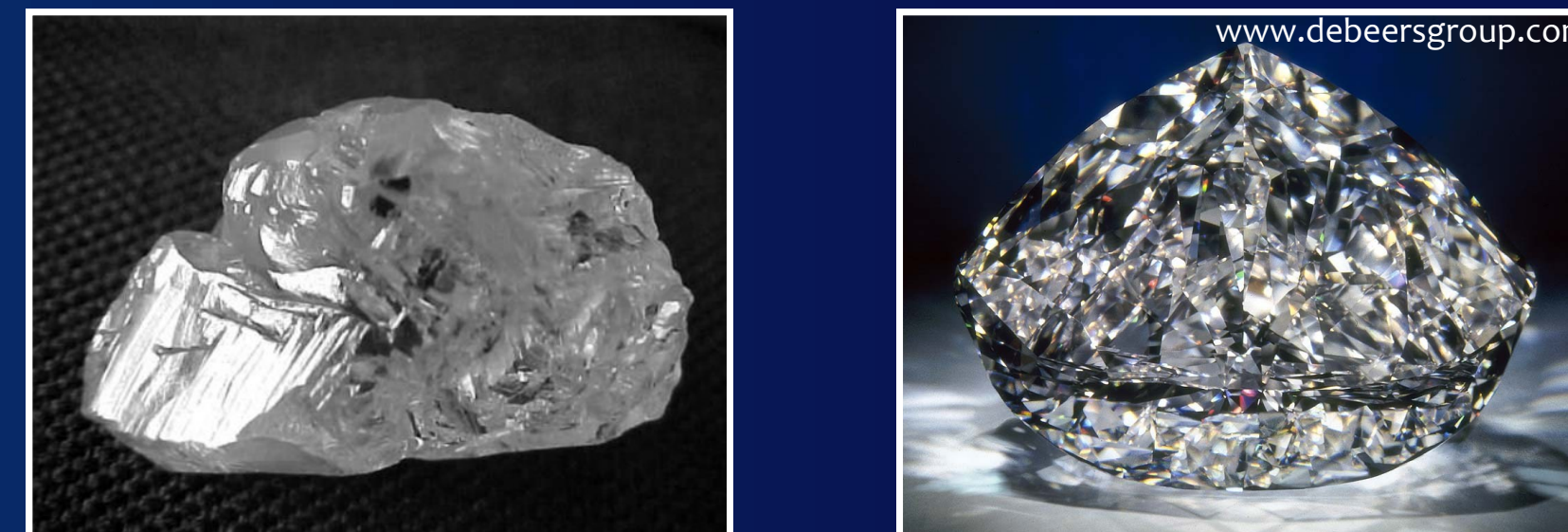
Properties of Diamonds

There are four main characteristics of a diamond: colour, clarity, carats and cut. Given a rough stone, for a specified cut the only characteristic to be optimized is the size (carats). There are 12 standard diamond cuts.



Centenary Diamond

The Centenary Diamond is the largest modern cut diamond in the world. It took three years to cut the Centenary; it was completed in 1991, weighing 273.85 carats.



Magnification Problem

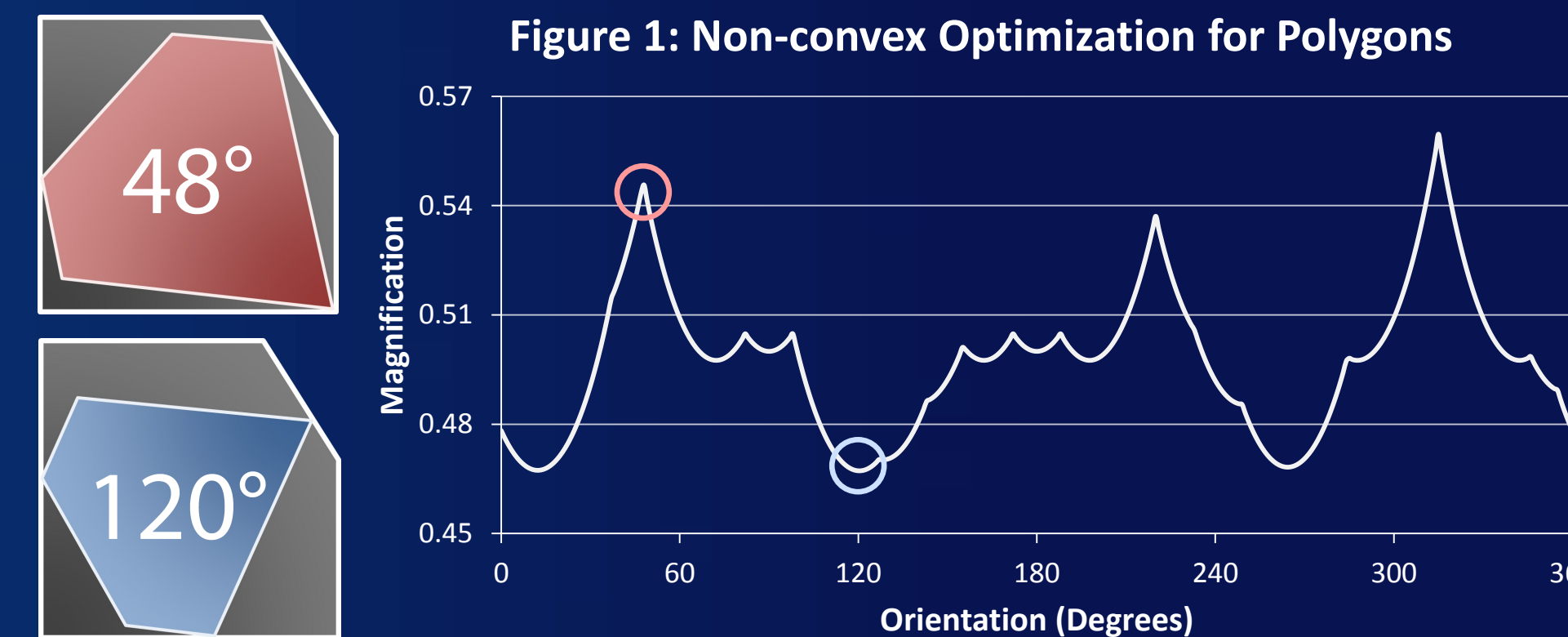
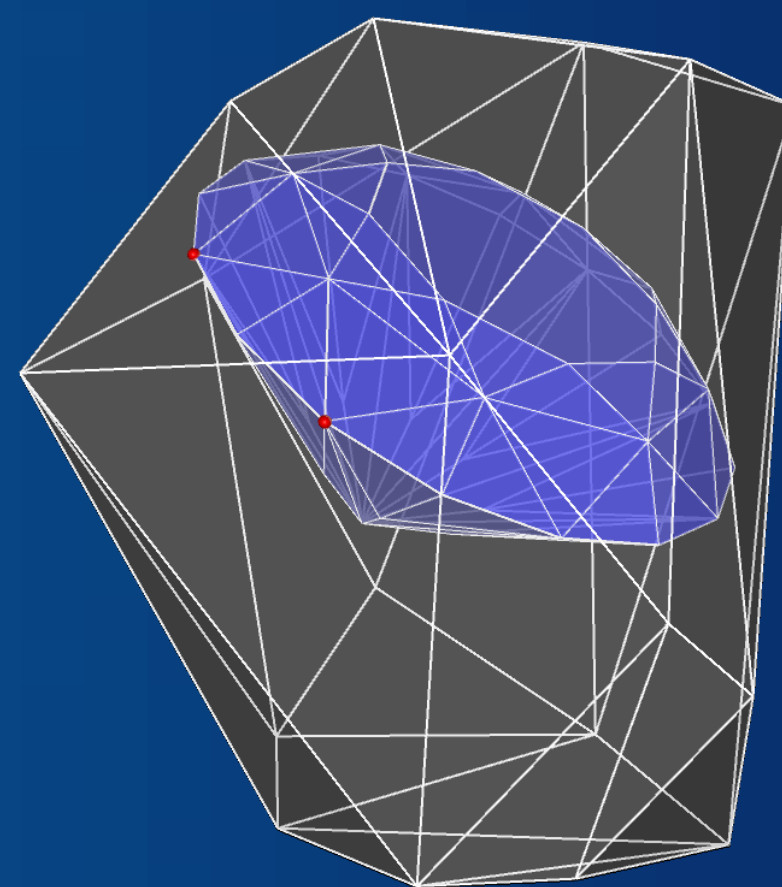
Find the largest cut diamond that can be cut from a rough stone. Suppose our rough stone & cut are both convex. If the orientation of the cut to the rough stone is fixed, the LP below delivers the optimal translation and magnification.

$$\max_{m,x} \quad m$$

$$\text{s.t.} \quad A [\text{diag}(x)E + mRV] \leq C.$$

- m (1×1) is the magnification factor,
- x (3×1) is the spatial offset of the diamond,
- v is the number of vertices in the cut diamond,
- R (3×3) defines the diamond's orientation,
- V ($3 \times v$) defines vertices of the cut diamond,
- $Ay \leq C$ forms the intersection of a set of half-spaces, defining the interior of the rough stone,
- E ($3 \times v$) is a matrix of ones.

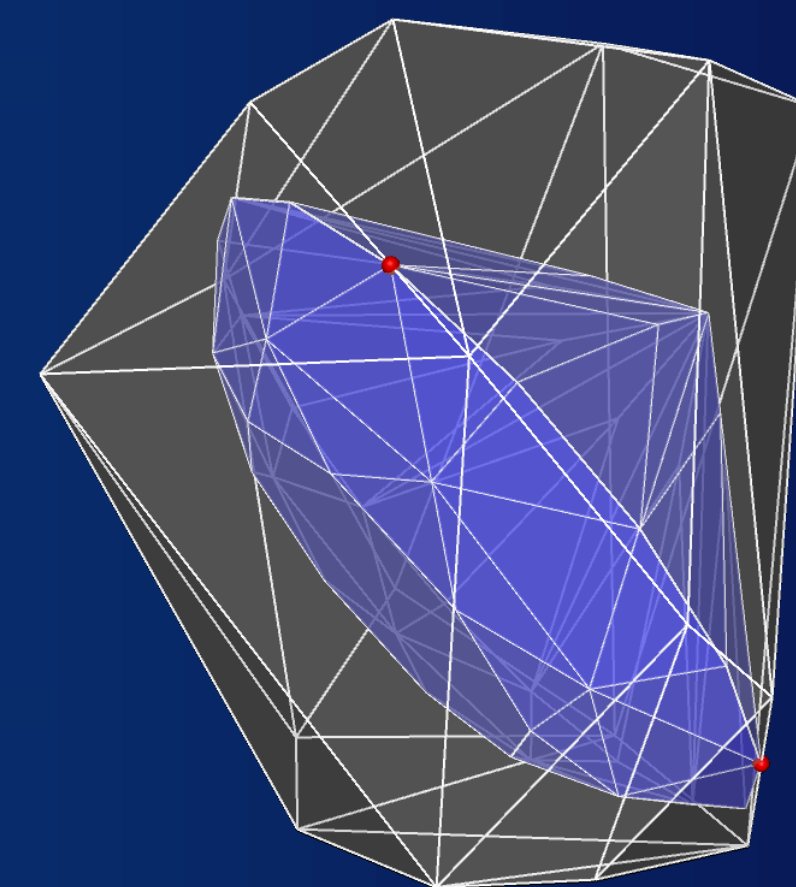
For each vertex of the cut diamond and facet of the rough stone, there is a constraint; these constraints ensure that the diamond is contained within the rough stone. At the optimal solution to this problem, at least four vertices of the diamond will be in contact with the rough stone.



CUTting Edge Visualization – CUTE

We have developed an interactive diamond visualization and optimization tool (CUTE). CUTE gives the user a 3D representation of the diamond cut inside a rough stone.

When the orientation of the diamond is altered, the magnification is automatically adjusted to maximize its value.



Since the LP needs to be solved repeatedly, for computational efficiency we solve the dual to this LP, which reduces the size of the basis. When the diamond is rotated, CUTE runs the dual simplex method to recover feasibility, and then the primal simplex to recover optimality, resulting in a fluid user experience.

Optimal Orientation

An extension to this problem is to develop a technique that finds the orientation yielding the largest cut diamond. This problem is highly non-convex and has potentially many local maxima, making it difficult to solve (see figure 1).

We have implemented an algorithm that uses a steepest ascent heuristic to find local optimal solutions. This is performed as follows:

- given the optimal basis for the linear program, we determine the axis of rotation that yields the greatest improvement in magnification;
- the diamond is rotated about that axis until the optimal basis of the LP changes, at which time a new axis of improvement is computed;
- combined with random restarts, this proves to be an effective method for finding the global optimal solution.

