How close to invisible can a mirror be?

October 6 2017, by Lisa Zyga

Credit: US Environmental Protection Agency

(Phys.org)—In 2011, mathematicians Alexander Plakhov and Vera Roshchina proved that objects with mirror surfaces cannot be perfectly invisible. Now in a new study, Plakhov has returned to the problem, asking just how close to invisible a mirror-surfaced object can be.

Using concepts from billiards and optics, he has shown that the answer depends on the object's volume and the minimum radius of an imaginary sphere that contains the object. The work is published in a recent issue of the *Proceedings of The Royal Society A*.

In the study, Plakhov, who is at the University of Aveiro in Portugal and the Institute for Information Transmission Problems in Russia, begins by defining a "visibility index." For objects that are close to invisible, the visibility index is close to zero, while objects that are clearly visible have a higher visibility index.

The visibility index is determined by the angles at which light rays deviate when they reach an object. For perfectly invisible objects, the light rays pass straight through, so their angles do not change at all. In contrast, objects that are clearly visible cause large deviations in the light rays' angles.

In order to define the visibility index, Plakhov adopted ideas from billiard theory, as light rays reflecting off mirror-surfaced objects can be considered analogous to billiard balls bouncing off the sides of a billiard table. Using the billiard model, he then showed that the visibility index can never be smaller than a certain positive value that is a function of the object's volume and the radius of an invisible sphere that contains the object. That is, he determined that the visibility index never reaches zero, but has a minimum non-zero value, indicating how close to invisible a mirror-surfaced object can theoretically be.

For now, however, this minimum value is only an estimate and not a final answer, and Plakhov plans to further pinpoint this value in the future.

"The lower estimate obtained in the paper is far from being sharp, and further work is needed to improve it," Plakhov told *Phys.org*. "In particular, it is not clear if there exists a sequence of bodies with fixed volume and the diameter going to infinity, and with vanishing visibility index."

Also, since it's possible for objects to exist which are invisible only from certain directions, Plakhov plans to study a modified visibility index related to a chosen set of directions of observation.

The question of the invisibility of mirror-surfaced objects is not just a mathematical curiosity, but it also has potential practical applications. For instance, mirrors are much cheaper and easier to fabricate than metamaterials, which are currently being investigated for their invisibility properties. The ability to create the effect of invisibility—especially when viewed from multiple directions—has a wide variety of potential uses, including military applications (hiding submarines and aircraft), medical imaging (cloaking internal organs that are blocking an area of interest), and improving the performance of small-scale electronics devices by carefully controlling the flow of light and heat.

"The work of mine and my collaborators has attracted the attention of the scientific community to the problem of mirror invisibility, which I consider to be of great importance," Plakhov said. "We are in the beginning of this journey, and I believe that the most significant discoveries are yet to come."

More information: Alexander Plakhov. "The problem of camouflaging via mirror reflections." *Proceedings of The Royal Society A*. DOI: 10.1098/rspa.2017.0147 , Also at arXiv:1702.04199 [math.MG]