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Scientists closer to making invisibility cloak a reality

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J.K. Rowling may not have realized just how close Harry Potter's invisibility cloak was to becoming a reality when she introduced it in the first book of her best-selling fictional series in 1998. Scientists, however, have made huge strides in the past few years in the rapidly developing field of cloaking. Ranked the number five breakthrough of the year by *Science* magazine in 2006, cloaking involves making an object invisible or undetectable to electromagnetic waves.

A paper published in the March 2009 issue of *SIAM Review*, "Cloaking Devices, Electromagnetic Wormholes, and Transformation Optics," presents an overview of the theoretical developments in cloaking from a mathematical perspective.

One method involves light waves bending around a region or object and emerging on the other side as if the waves had passed through empty space, creating an "invisible" region which is cloaked. For this to happen, however, the object or region has to be concealed using a cloaking device, which must be undetectable to electromagnetic waves. Manmade devices called metamaterials use structures having cellular architectures designed to create combinations of material parameters not available in nature.

Mathematics is essential in designing the parameters needed to create metamaterials and to show that the material ensures invisibility. The mathematics comes primarily from the field of partial differential equations, in particular from the study of equations for electromagnetic waves described by the Scottish mathematician and physicist James Maxwell in the 1860s.

One of the "wrinkles" in the mathematical model of cloaking is that the transformations that define the required material parameters have singularities, that is, points at which the transformations fail to exist or fail to have properties such as smoothness or boundness that are required to demonstrate cloaking. However, the singularities are removable; that is, the transformations can be redefined over the singularities to obtain the desired results.

The authors of the paper describe this as "blowing up a point." They also show that if there are singularities along a line segment, it is possible to "blow up a line segment" to generate a "wormhole." (This is a design for an optical device inspired by, but distinct from the notion of a wormhole appearing in the field of gravitational physics.) The cloaking version of a wormhole allows for an invisible tunnel between two points in space through which electromagnetic waves can be transmitted.

Some possible applications for cloaking via electromagnetic wormholes include the creation of invisible fiber optic cables, for example for security devices, and scopes for MRI-assisted medical procedures for which metal tools would otherwise interfere with the magnetic resonance images. The invisible optical fibers could even make three-dimensional television screens possible in the distant future. The effectiveness and implementation of cloaking devices in practice, however, are dependent on future developments in the design, investigation, and production of metamaterials. The "muggle" world will have to wait on further scientific research before Harry Potter's invisibility cloak can become a reality.

More information: The paper is co-authored by Allan Greenleaf of the University of Rochester; Yaroslav Kurylev of University College

London; Matti Lassas of Helsinki University of Technology; and Gunther Uhlmann of the University of Washington. To read this article in its entirely, visit www.siam.org/journals/sirev/51-1/71682.html

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