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A Quadrilateral Prism of Self-invisibility

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Abstract A hollow quadrilateral prism consists of four rigid right triangular prisms laid asymmetrically in a V-like shape. Each triangular prism has a base face which is an obtuse scalene triangle, and the front and rear lateral faces are covered with a reflective material of visible light. The front and rear lateral faces of the four right triangular prisms face each other forming an asymmetrical channel between them, which is filled with a transparent material. The hollow quadrilateral prism reflects incident light in sequence by the reflective lateral faces of right triangular prisms. It is configured to make a good portion of the frame invisible to the driver of an automobile and renders driving safer and more comfortable.

Keywords: *stealth technology, camouflage technology, automobile industry, A-pillar of vehicle, quadrangular prism, quadrilateral prism*

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1. Introduction

Stealth technology is certainly a fascinating subject being researched by a great many scientists for more than one hundred years [1]. Actually, not only human beings, but some wild animals and insects are also able to camouflage themselves instinctively by changing their colors when encountering threat. When hunting, people use vegetation to conceal themselves, avoiding being seen by the animals hunted. The concept of stealth is even known to predate warfare itself [2]. Stealth technology was used during World War I [3,4] and currently stealth applications are used primarily by the military. In 1960, the first stealth technology development for aircraft was initiated by reducing the radar-cross-section through specially designed screens over the air intake, radar-absorbent material on the fuselage and a special radar-absorbing paint [7].

In contrast to the widespread application in military industries, the use of stealth technology in civilian industry is rare mainly due to practical difficulties. One obvious possible use is to camouflage the frame that supports the windshield and side windows of vehicles, namely the A, B, C and D-pillars.

In order to enlarge the view for the driver, some thought has been given to reform the traditional solid chunky posts of automobiles [8]. An invisible quadrangular prism was proposed [9,10,11] aiming at camouflaging pillars of various vehicles, so that the area of the blind spots caused by traditional pillars will be reduced to some extent. At present, a small but essential improvement for the quadrangular prism was developed; in principle, improved invisible prism will be better at rendering pillars of vehicles invisible. Also, a factor to trigger the invention of quadrangular prism is briefly mentioned here.

It is interesting and significant to trace what enlightens an inventor to gain an insight leading to a new invention. Two beautiful statues, located on the campus of the University of Minnesota, are made of parallel steel lamellars. One of them is shown in Figure 1 (a). The image appears different in shape (c, d, e, f) when seen from various angles. When the sight lines are parallel to the lamellars, the statue becomes nearly transparent as shown in (f). It is easy to imagine that the landscape seen through a stack of opaque lamellars will appear as the image shown in Figure 2.

Although this observation appears to be a trivial insight, it suggests to the inventor that if the opaque lamellars can be made more invisible, a novel camouflaged pillar can be created. After many trials, an invisible rectangular prism was successfully designed as shown in Figure 7. Afterwards, a more generalized device was invented which is named a hollow rectangular prism of self-invisibility [9]. Further improvements were made and the invisible quadrangular prism has been proposed to replace the traditional pillars in automobiles. The latest invention is named a hollow quadrilateral prism of self-invisibility.

2. The Structure of the Quadrilateral Prism of Self-invisible

The structure of a hollow quadrilateral prism of invisibility consists of four right triangular prisms laid asymmetrically as shown in Figure 3. The heights of the upper and lower base triangles of the four right triangular prisms, as defined by the perpendicular distance from the bottom floor to the lateral edge opposite the bottom floor of each prism, are all identical and denoted by h. (see Figure 4). All altitudes of the four quadrilateral prisms are the same length; consequently, all the widths of the four bottom floors of the rectangles are identical.

Figure 1. Statue located at University of Minnesota, which triggers the invention of an invisible rectangular prism

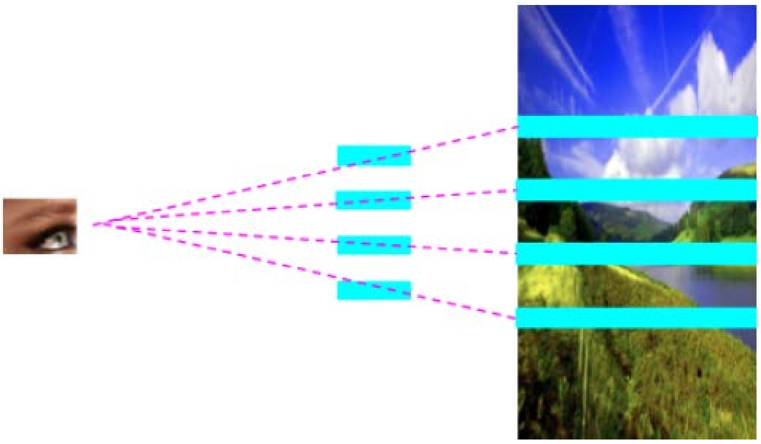

Figure 2. The image got from seeing through a set of parallel opaque slices

The lower base triangles of the first (301) to fourth (304) right triangular prisms are on the same first plane and the upper base triangles of the four prisms are on the same second plane which is parallel to the first plane; the bottom floors of the first (301) and third (303) right triangular prisms are on the same third plane; and the front lateral face of the first right triangular prism and the rear lateral face of the third right triangular prism are separated by a rectangular gap; the bottom floors of the second (302) and fourth (304) right triangular prisms are on the same fourth plane and immediately adjacent to each other, and the front lateral face of the second right triangular prism and the rear lateral face of the fourth right triangular prism are adjacent to each other. The third and fourth planes intersect at a line, and the location where this line intersects the plane of Figure 4 is denoted as O. The lateral edges of 301 and 302, flaring to each bottom floor are parallel and on the same fifth plane on which the two vertices C and D are located. Similarly, the lateral edges of 303 and 304, flaring to each bottom floor are parallel and on the same sixth plane on which two vertices G and H are located. The fifth plane is parallel to sixth plane; therefore, CD is parallel to GH. The plane perpendicular to the fifth plane (also, to the sixth plane) passes through the intersection line of the third and fourth planes and is defined as the seventh plane on which the observer's point O (also called the bottom point of V-like shape) is located, where the acute dihedral angle formed by the third and seventh planes is named ϕ_1; the acute dihedral angle formed by the fourth and seventh planes is named ϕ_2, and is larger than ϕ_1. Figure 4 represents a cross-section parallel to all base triangles of the four right triangular prisms shown in Figure 3, where the parameters θ_1, θ_2, δ_1, δ_2, θ'_1, θ'_2, δ'_1, δ'_2, α, α'. must satisfy the ten equations below:

$$\phi_1 + 2\theta_1 + \alpha = \frac{\pi}{2} \tag{1}$$

$$\phi_2 + 2\theta_2 + \alpha = \frac{\pi}{2} \tag{2}$$

$$\theta_1 + \delta_1 + \alpha = \frac{\pi}{2} \tag{3}$$

$$\theta_2 + \delta_2 + \alpha = \frac{\pi}{2} \tag{4}$$

$$\theta'_1 + \delta_1 + \frac{\alpha + \alpha'}{2} = \frac{\pi}{2} \tag{5}$$

$$\theta'_2 + \delta_2 + \frac{\alpha + \alpha'}{2} = \frac{\pi}{2} \tag{6}$$

$$\theta'_1 + \delta'_1 + \alpha' = \frac{\pi}{2} \tag{7}$$

$$\theta'_2 + \delta'_2 + \alpha' = \frac{\pi}{2} \tag{8}$$

$$h\csc\alpha = CD \tag{9}$$

$$h\csc\alpha' = GH. \tag{10}$$

For a concrete problem, ϕ_1, ϕ_2, CD, GH and h are all known, and all others ten unknowns θ_1, θ_2, δ_1, δ_2, θ'_1, θ'_2, δ'_1, δ'_2, α, α' can be definitely obtained from the ten equations above. Therefore the system which consists of four right triangle prisms can be determined uniquely.

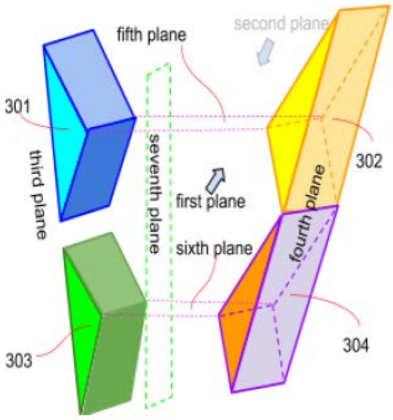

Figure 3. Illustrates the structure of a hollow quadrilateral prism of self invisibility serving as a windshield frame for an automobile

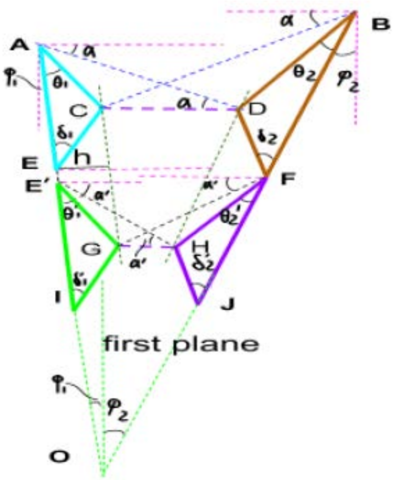

Figure 4. Illustrates a cross-sectional view of the structure of Figure 3 and the parameters determining the structure shown in Figure 3

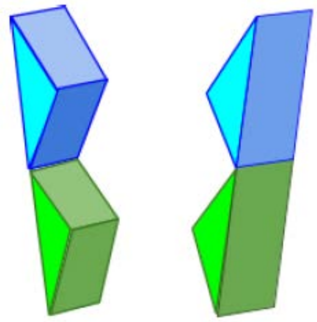

Figure 5. Illustrates the structure of a hollow quadrangular prism of self invisibility serving as a windshield frame for an automobile

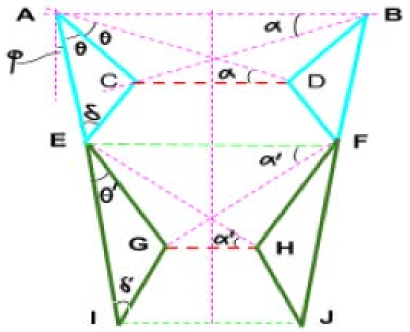

Figure 6. Illustrates a cross-sectional view of the structure of Figure 5 and the parameters determining the structure shown in Figure 5

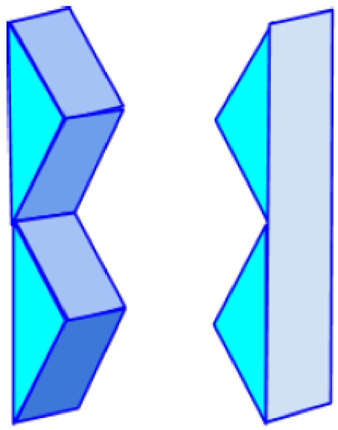

Figure 7. Illustrates the structure of a hollow rectangular prism of self invisibility serving as a windshield frame for an automobile

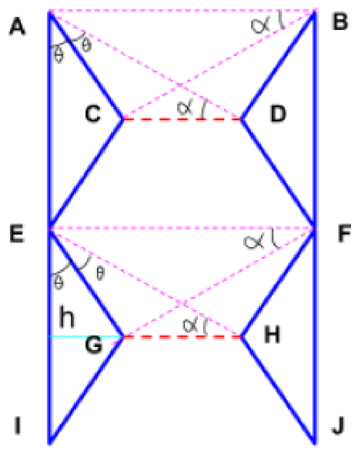

Figure 8. Illustrates a cross-sectional view of the structure of figure 7 and the parameters determining the structure shown in Figure 7

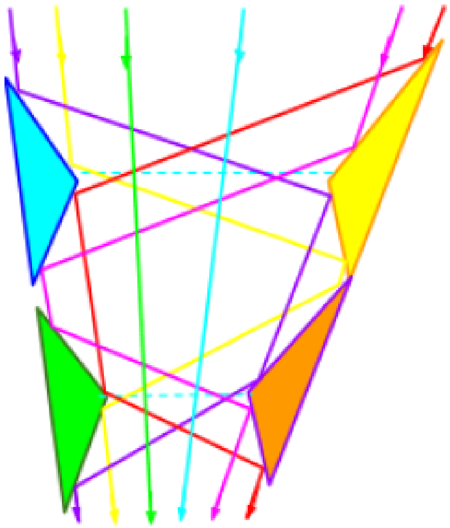

Figure 9. Illustrates the light paths going through a hollow quadrilateral prism to produce the camouflaged effect

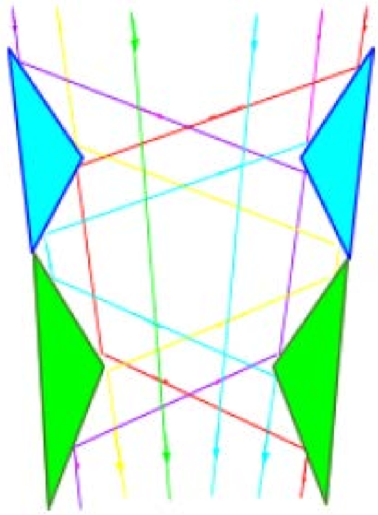

Figure 10. Illustrates the light paths going through a hollow quadrangular prism to produce the camouflaged effect

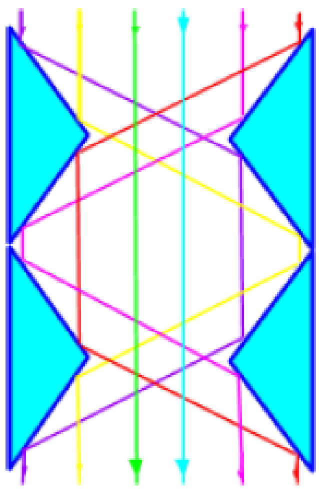

Figure 11. Illustrates the light paths going through a hollow rectangular prism to produce the camouflaged effect

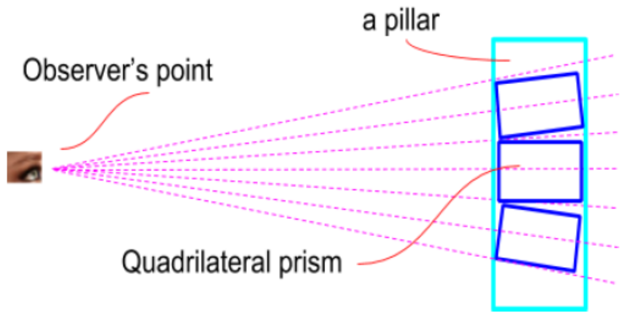

Figure 12. Illustrates an example of multiple hollow quadrilateral prisms aligned and stacked to form a pillar

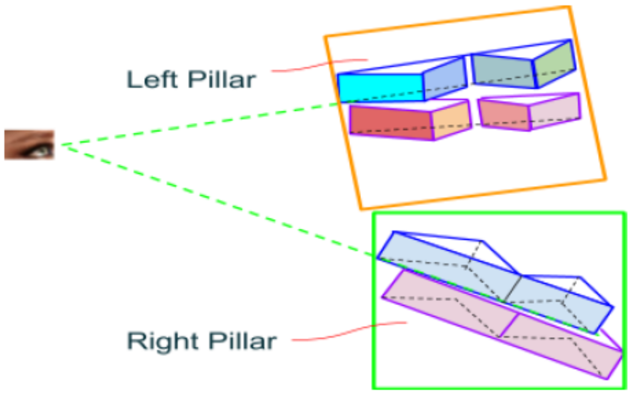

Figure 13. Illustrates another example of multiple quadrilateral prisms aligned and stacked to form two pillars

A cross-sectional view of the structure of Figure 3 and the light paths demonstrating the principle of stealth technology is illustrated in Figure 9. Two beams of incident light, parallel to each bottom floor are reflected by the lateral faces of mirror layers reflecting visible light in due succession obeying the law of light reflection. The incident light going through the channel of the hollow quadrilateral prism goes out in the area formed between the four solid right triangular prisms without any blockage. Finally, the whole incident light beam goes out of the triangular prisms system as if all the opaque triangular prisms do not exist. The invisible effect is finally gained.

First extrapolation:

If $\phi_1 = \phi_2$, corresponds to symmetrical case,

from (1) and (2) results in: $\theta_1 = \theta_2(=\theta)$;

from (3) and (4) results in: $\delta_1 = \delta_2(= \delta)$;

from (5) and (6) results in: $\theta'_1 = \theta'_2(= \theta')$;

from (7) and (8) results in: $\delta'_1 = \delta'_2(= \delta')$.

Finally, the ten equations above become:

$$\phi + 2\theta + \alpha = \frac{\pi}{2} \tag{11}$$

$$\delta + \theta + \alpha = \frac{\pi}{2} \tag{12}$$

$$\phi + 2\theta' + \alpha' = \frac{\pi}{2} \tag{13}$$

$$\delta' + \theta' + \alpha' = \frac{\pi}{2} \tag{14}$$

$$2hcsc\delta cos(\delta + \alpha) + hcsc\alpha = EF \tag{15}$$

$$2hcsc\theta'cos(\theta'+\alpha')+hcsc\alpha'=EF \quad (16)$$

where the definition of all parameters are illustrated in Figure 5 and the cross-section graph is shown in Figure 6 and the light paths in Figure 10.

Second extrapolation:

When the separation between the observer's point and the object camouflaged becomes infinite, the result is $\phi_1 = \phi_2 = 0$, (11) and (13) become identical; so do (12) and (14) result in (17); (15) and (16), result in (18), (15) and (16) change into (19), namely:

$$\theta=\delta=\theta'=\delta' \quad (17)$$

$$\alpha=\alpha'=\frac{\pi}{2}-2\theta \quad (18)$$

$$EF=h(1+tan2\theta cot\theta). \quad (19)$$

The definition of all parameters is illustrated in Figure 7 and the cross-section graph is shown in Figure 8 and the light paths in Figure 11.

The way that many quadrilateral prisms are aligned and stacked up to form a pillar is shown in Figure 12. The sight lines from the observer's point flare towards the camouflaged pillar and each invisible quadrilateral prism lines up with the lateral edges parallel to the respective sight lines. The channel space within the quadrilateral prism is filled by transparent materials. Some of gaps formed by adjacent quadrilateral prisms are welded by steel to maintain the mechanical strength. Figure 13 illustrates how to form two pillars, the left pillar and the right one, using the same right triangular prism system. In addition to use as a frame for an automobile, the hollow quadrilateral prism described above may be used in other applications to construct an almost invisible structure.

3. Discussion

The extreme case $\phi_1 = \phi_2 = 0$ take places when the separation between the observer's point and the pillar camouflaged goes to infinite as shown in Figure 7. The quadrilateral prism becomes a rectangular prism, succinct and symmetrical which is easy to manufacture. Nevertheless, the actual separation above will never become infinite. The most really practical situation is $\phi_2 > \phi_1 > 0$, general and common, since it starts at the observer's point and then flares to the two A-pillars as shown in Figure 3. In order to keep the outward appearance of the windshield symmetrical, $\phi_2 > \phi_1$ should be obeyed. $\phi_2 = \phi_1 > 0$ meets the situation when the size of the pillar is smaller relative to the distance between the observer's point and the pillar as shown in Figure 5.

Although a significant amount of literature has reported approaches to camouflaging objects used in civilian life, no case of launch has been demonstrated until now because of many specific difficulties. There are two fantastically perfect optical image devices: the human eye and the plane mirror with a high coefficient of reflection of light. Many kinds of factors will influence the quality of image formation, such as aberration, distortion, chromatic dispersion, absorption, etc. Furthermore, when one considers using this invisible quadrilateral prism to replace the traditional windshield supports of an automobile, other problems are involved such as the thermal, optical, and mechanical properties of the materials, and even the cost [8].

The hollow quadrilateral prism of self invisibility can camouflage itself without depending on any outer materials such as refractive material or reflection mirrors with the reflection coefficient at nearly 100%. The research attention is mainly focused on how to retain the mechanical strength of the windshield pillars of the automobile while creating the largest invisible area and considering the different heights of drivers. Further research is under the way.

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