

Origami-Based Deployable Ballistic Barrier

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Abstract

In this paper we demonstrate how recent developments in origami crease pattern adaptation, thickness accommodation, and surrogate fold techniques enable development of an origami-based deployable ballistic barrier.

Ballistic barriers are large shields, sometimes designed to be free standing, that protect one or more individuals from incoming ballistic threats. Recent material advances have allowed these barriers to become stronger and lighter, although their size and shape often present difficulties for transportation. Advances in origami engineering are utilized to develop a deployable ballistic barrier, which draws its utility from its monolithic construction, large deployment ratio, and rapid deployment.

The deployable ballistic barrier is designed with three functional goals: deployment, ballistics protection, and stability. The resulting barrier and its deployment is shown in Fig. 1. The elongated Yoshimura pattern [1] is selected and adapted to the barrier design. This pattern has a single degree of freedom, which aids in controlling deployment motion. When partially deployed, the pattern forms a curved wall, beneficial for front and flank protection. The membrane fold technique [2] is utilized to incorporate multiple layers of ballistic fabric while still allowing fold motion. Plates are inserted between the layers of ballistic fabric to create stiff panels, while areas with only fabric layers allow fold motion.

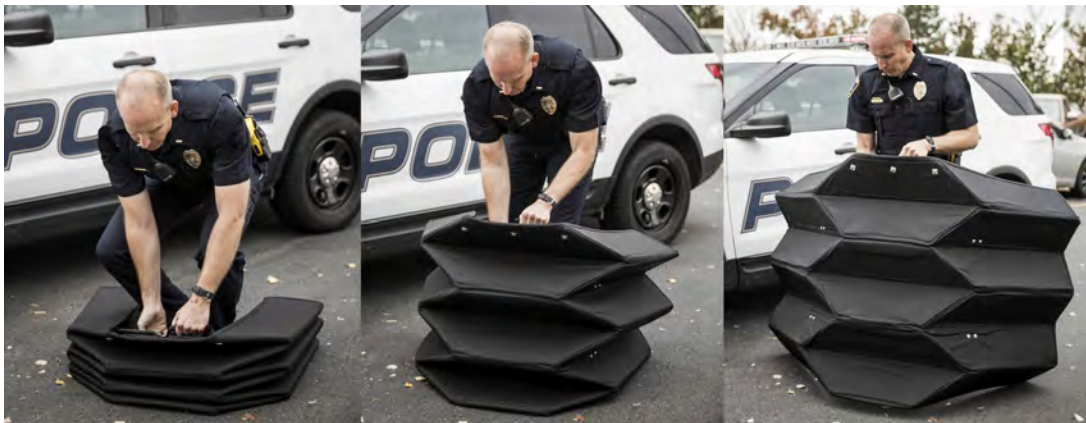


Figure 1: Officer deploying a ballistic barrier prototype.

To achieve a U.S. National Institute of Justice ballistics rating of IIIa [3], twelve layers of aramid fiber fabric (Kevlar) are adhered together, utilizing the membrane-fold thickness-accommodation technique. Because the fabric is continuous throughout the fold pattern, the barrier can achieve the desired ballistics rating over the entire surface.

The barrier was designed with a single-degree-of-freedom pattern, which aids in stability and allows it to be deployed and supported with simple actuation methods. Two gas springs assist manual deployment and constrain the barrier to a desired deployed state. The semi-circular shape shifts the center of gravity away from the barrier wall and towards the center of the deployed footprint, which aids in stability.

A full-scale ballistic-grade barrier was constructed and tested to demonstrate the effectiveness of the design. The prototype sequence is shown in Fig. 2. The prototype used for testing has a deployed frontal area of 1.3 meters by 1.1 meters, which can shield three individuals in a crouched position. The barrier was tested with 9 mm, .357 magnum, and .44 magnum rounds. Areas of anticipated weakness were targeted, and 2 of 20 rounds penetrated the barrier. The weak points identified were eliminated in the next-generation design.

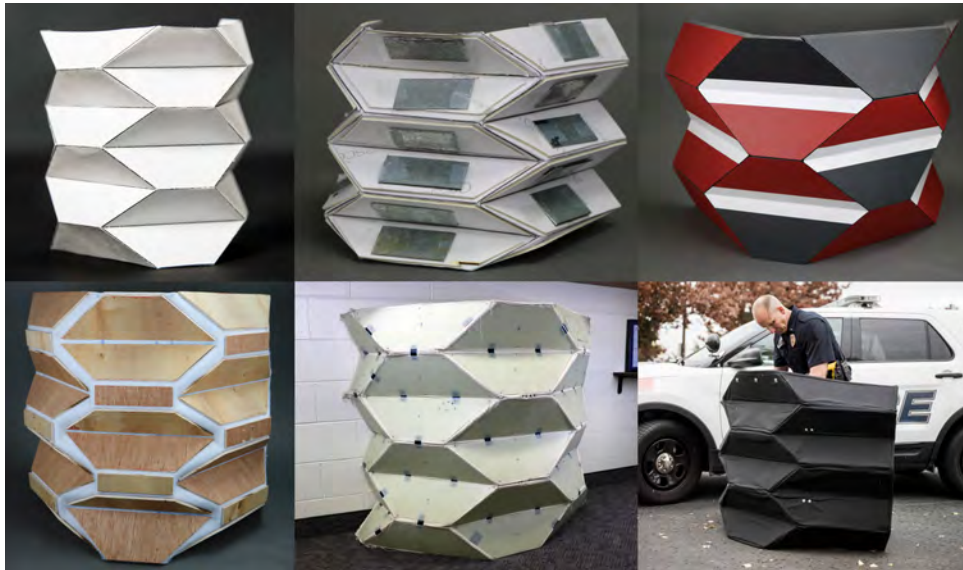


Figure 2: Prototype sequence of barrier design. From top left to bottom right: Initial paper models, weighted paper, thick-folding prototype, wood and felt, full-scale canvas and fiberglass, full-scale bullet-resistant model.

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[1] J.M. Gattas, W. Wu, Z. You, *Miura-Base Rigid Origami: Parameterizations of First-Level Derivative and Piecewise Geometries*, 2013

[2] S.A. Zirbel, et al, *Accommodating Thickness in Origami Based Deployable Arrays*, 2013.

[3] U.S. Dept of Justice, *Ballistic Resistance of Body Armor NIJ Standard-0101.06*, 2008.