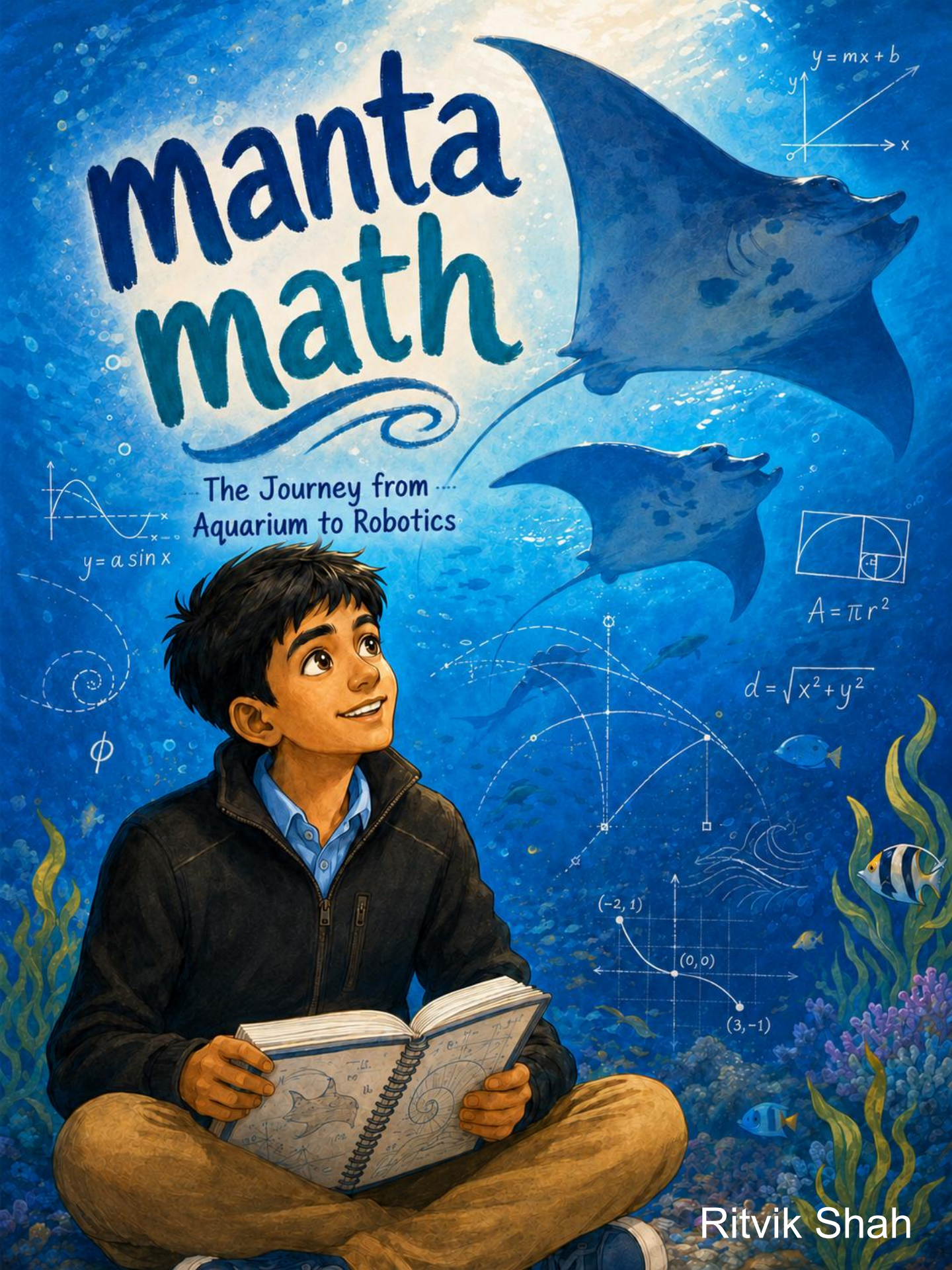
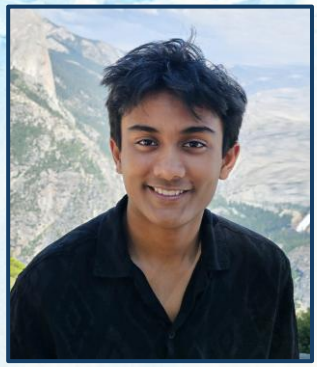

manta math
The Journey from Aquarium to Robotics
y = mx + b
y
x
y = a sin x
A = πr²
d = √(x² + y²)
ϕ
(-2, 1)
(0, 0)
(3, -1)
Ritvik Shah



Ritvik is a 12th-grade student at Fulton Science Academy in Atlanta, Georgia. He is passionate about robotics and serves as the captain of his school's FTC robotics team.

Through his leadership in FTC, he was recognized as one of the top 200 student leaders worldwide.

He especially enjoys mathematics, physics, and coding because they allow him to explore new ideas, solve challenging problems, and build things that can make a real-world impact.

He has also published two research papers in mathematics.

Outside of academics and robotics, Ritvik enjoys drumming and fencing.



Ritvik stood in front of the giant glass window at the Georgia Aquarium, watching the blue water shimmer around him. Fish swam in quick silver flashes, but then something much larger glided into view.

A manta ray moved through the water, its wide fins rolling in smooth waves from its body to its tips. It did not flap like a bird or flicker like a fish. It seemed to float, bend, and fly underwater all at once.

Ritvik stared at it in amazement and wondered, **"How does it move so smoothly?"**



That question followed him long after he left the aquarium. At home, Ritvik opened his notebook and began sketching the manta ray again and again. He drew the body, the wings, and the flowing wave that passed across the fins. But soon, drawings were not enough!

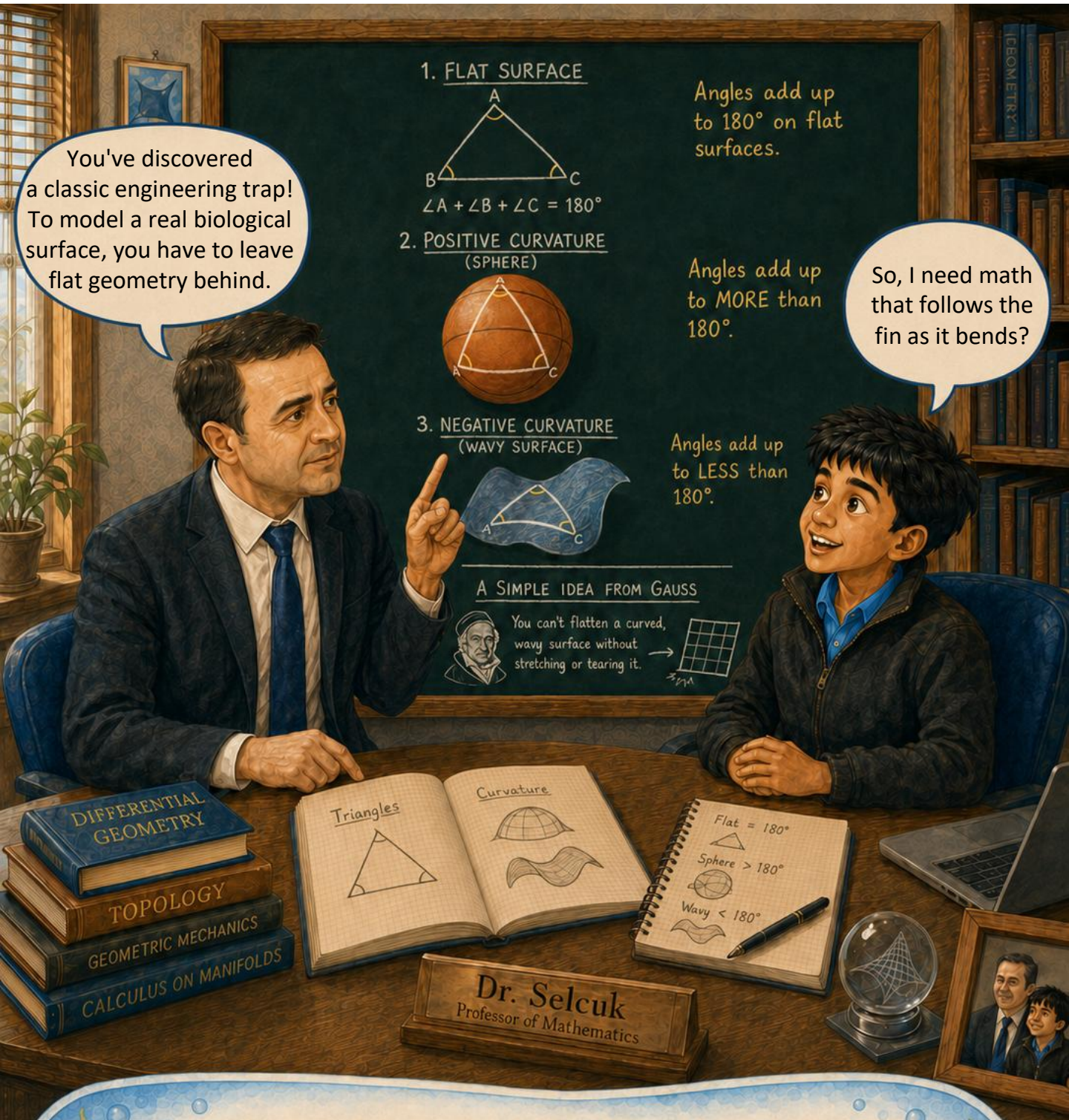
Ritvik wanted to build a robot that could mimic the way it moved. He named this project "FORMAX"



Ritvik knew his first step was to study how a manta ray worked from the inside. After researching its anatomy, he noticed something exciting: the fins were not just soft sheets. They had thin support structures spreading outward from the body.

As Ritvik looked closer, he saw that these support structures crossed and connected in patterns.

To Ritvik, it looked like the fin had a hidden map. There was a central “home base,” or reference point, and many other points spread around it.



Ritvik took his question to his math mentor, Dr. Selcuk and he explained that Ritvik needed to learn about **Non-Euclidean Geometry!**

He explained Carl Friedrich Gauss's concept of **Gaussian curvature**. Which states that a curved surface cannot be flattened onto a plane without distorting, tearing, or stretching.

Ritvik's eyes lit up with excitement!



Ritvik and Dr. Selcuk decided to deep dive into the problem which later resulted in a published research paper.

They researched on how an entire **network of points** could transition from one 3D surface shape to another while maintaining their fundamental spatial relationships.

In their published paper, they modeled how points on a flexible surface deform during motion. They focused on preserving two critical properties relative to a reference point: the precise distance along the surface **(Arc Length)** and the exact direction **(Angle Preservation)**.

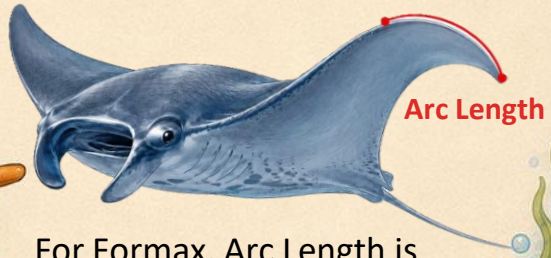
By analyzing "**Distortion**", the degree to which these distances and directions preserved during movement, they solved a critical engineering problem.

Arc Length & Angle Preservation



Arc Length

Arc length is the distance measured along a curved surface, not the straight shortcut through the air. Imagine a tiny ant walking across a manta ray's fin. If the fin curved upward, the ant climbs with it. If the fin bent downward, the ant follows the bend.

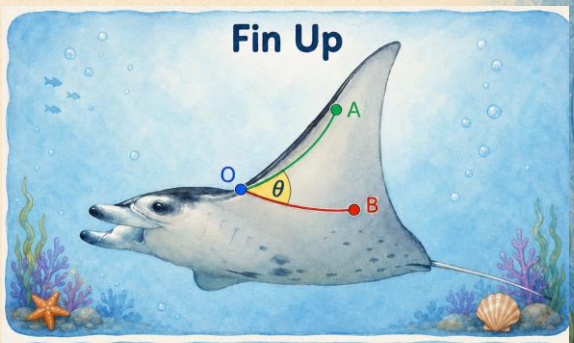


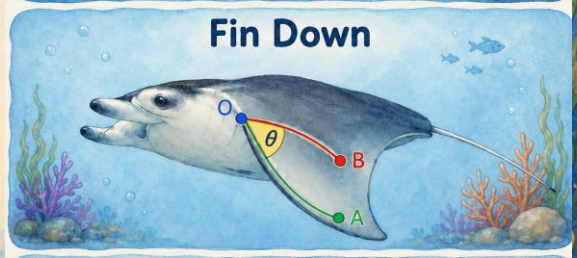
For Formax, Arc Length is important because each point on the surface needed to stay the correct distance from the reference point.

Angle Preservation

Angle preservation means keeping the same angle, even when something moves or bends. In this picture, the manta ray's fin moves from up to down, but the angle between the green path and the red path stays the same.

This helps show that the fin can change position while still keeping its shape and movement organized.







Ritvik was simultaneously looking for the perfect skin for “Formax”. He first tested fabric, but it was soft. Next, he tried porous mesh, but it was far too flimsy to fasten anything to it.

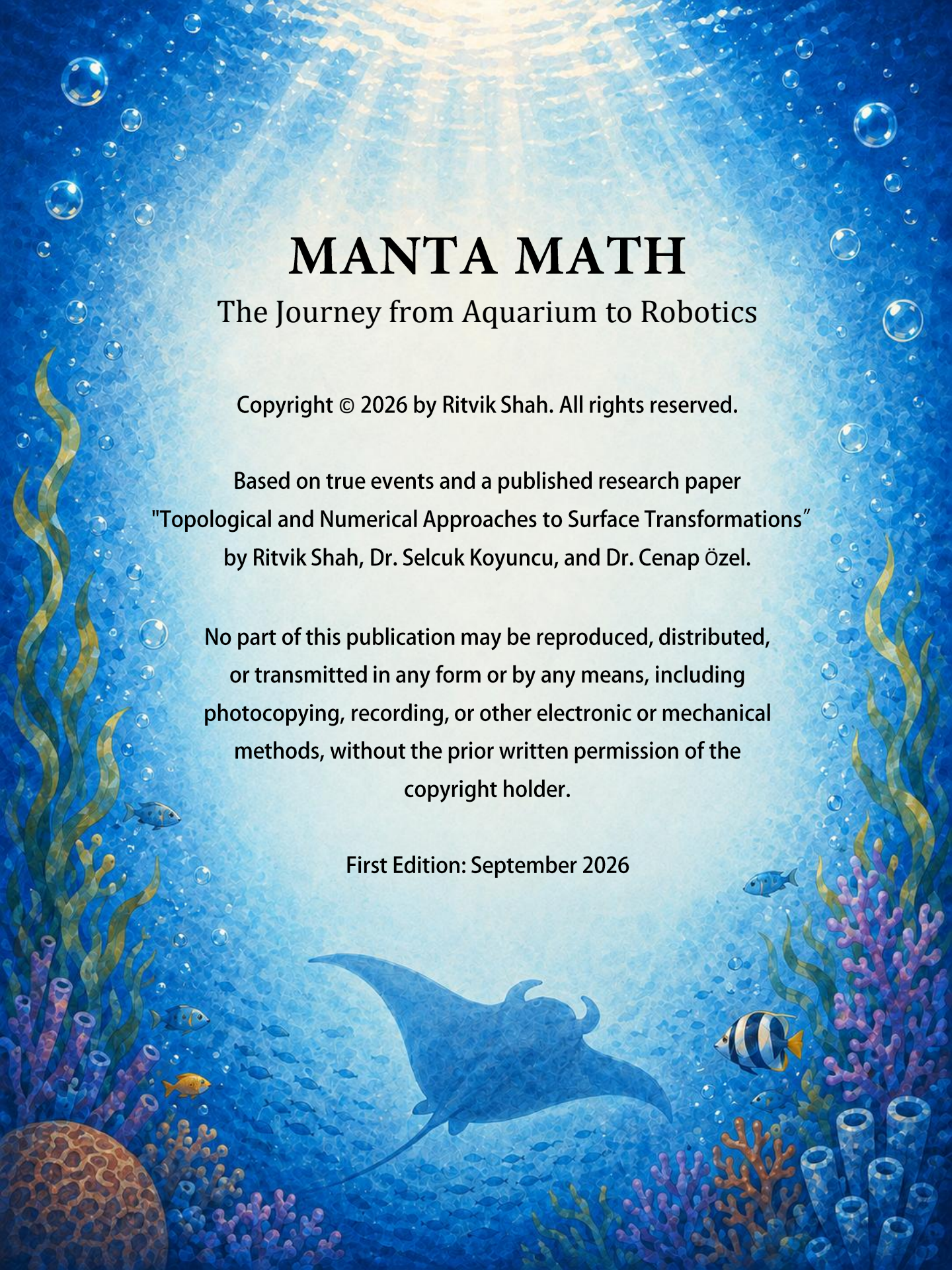
He then found **NASA's space chainmail**, a sheet of interlocking tiles that could move like fabric but had rigid parts to fasten things to. He had just found the perfect structure.



Ritvik built Formax by connecting small robot cells with stepper motors that can move very carefully. He wired the motors to a control board and a Raspberry Pi, so a computer could tell each motor how far to move. Ritvik used Klipper software to help many motors move together at the right time. After soldering wires and testing commands, Formax could start changing its shape like a manta ray fin.



Ritvik's Formax idea could help make soft underwater robots that glide like manta rays to explore coral reefs, shipwrecks, and deep parts of the ocean. The same shape-changing design could also help create safer rescue robots, flexible medical tools, or airplane wings that adjust while moving. By copying nature's smooth motion, Formax shows how robots can move in smarter, quieter, and more energy-saving ways.



MANTA MATH

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Based on true events and a published research paper
"Topological and Numerical Approaches to Surface Transformations"
by Ritvik Shah, Dr. Selcuk Koyuncu, and Dr. Cenap Özel.

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