STAR Summer Camp: Archer's Paradox

Professor: Dr. Arka Chattopadhyay, *Civil Engineering*
Aims: Study the behavior of the flightpath of an arrow and investigate properties to improve accuracy of archery using longbows.
Grade: 10-12 (Fundamental background in mathematics, computer operation)

Faculty Profile:
Dr. Arka Chattopadhyay is leading the research project: "**Archer's Paradox:** *Mechanics of accuracy of archery with long bows***"**

Dr. Arka Chattopadhyay is an assistant research professor at the Department of Civil Engineering, Marshall University. He received his Ph.D. in Engineering Mechanics from Virginia Tech and a Master's in Mechanical Engineering from Kansas State University. Prior to joining the Department of civil engineering, Dr. Chattopadhyay worked as Research Scholar and Adjunct Professor at the College of Science and the College of Engineering, Marshall University. His research interests primarily focus on mechanics of materials and systems, mathematical modeling, numerical methods and computational mechanics using the finite element analysis.
Please visit https://www.marshall.edu/cecs/profile/dr-arka-chattopadhyay/ for more information.

Project Description:
Bows and arrows are one of the earliest forms of weapons used by humans. The construction of a simple long bow and arrow consists of a bow, an arrow, and a draw string tied to the bow which is used to impart energy to the arrow to fire it. The inherent construction of a bow and arrow introduces an interaction between the cross section of the bow and an arrow during the firing of the arrow.

Figure 1. **Archer's Paradox: Flight path of an arrow shot from a long bow**

As shown in the figure 1, this interaction results in natural bending and flexing of the arrow when it is shot and finally results in a complex path of the arrow post release involving forward motion of the arrow towards the target while it flexes on its axis. As a result, the accuracy of a bow and arrow largely depends on the flexural stiffness of the arrow, distance from the target, and the force of pull. In this project, we are attempting to establish a clear understanding of the mechanics of this process (see Figure 2 below) and a closed form solution to relate the flexural properties of the arrow and the accuracy. This type of detailed research has not been studied in the literature which adds intellectual merit to this research.

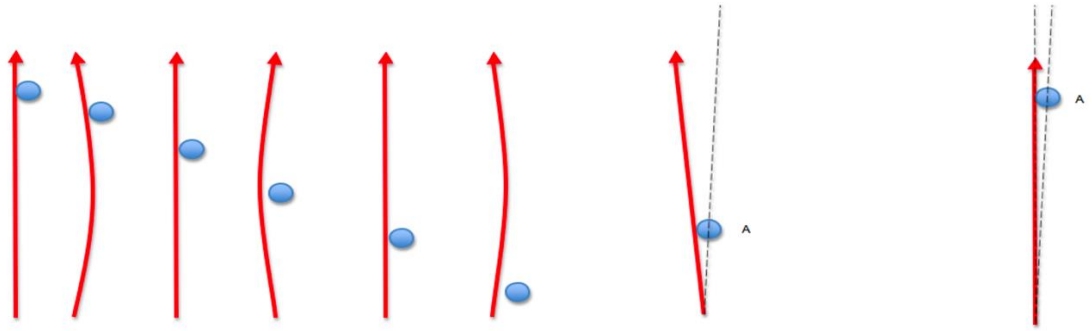


Figure 2 (a) Stages of draw and release of an arrow and its interaction with the bow resulting in flexing of the arrow (source: Wikipedia: archer's paradox). (b) The position of the arrow with respect to the bow, *A*, before and after the draw of the arrow.

In this 4-week summer research camp, students working on this project are expected to perform experimental tests on testing spines of arrows and model a bow and arrow using computational analysis tools. Students will be trained and supervised by the instructor Dr. Arka Chattopadhyay and his team on both the experimental and computational parts of the project.

Weekly Activities Description:

Week 1: Understanding the Physics of the Problem

Learning Objectives: You will learn

- How a long bow is used?

- How an archer aims using a long bow and how does an arrow interact with the bow?

- If we can improve accuracy by changing any specific properties of the arrows?

Week 2: Mechanical Testing of Arrows

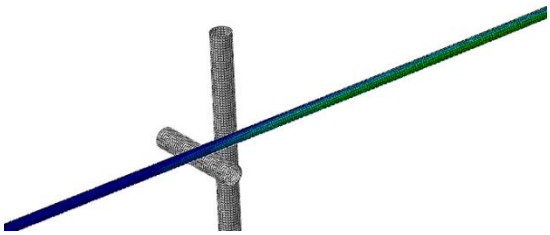
Learning Objectives: You will learn

- To perform mechanical tests on arrows to understand their effects on arrow flight paths

- to find flexural rigidity of arrows and relate it to flight paths

- to test different arrows and identify “more accurate” arrows

Week 3: Computational analysis of the problem



Learning Objectives: You will learn

- Running an analysis software for simulating mechanics of different structures

- Creating the bow and arrow model using this software

- Simulating the bow and arrow interaction using this software

Week 4: Experimental Study

Learning Objectives: You will learn

- Setting up and designing experiments to verify theories

- the use of slow-motion captures to observe the physical phenomenon studies so far and verify the computational results.

- To analyze the experimental results and establish the worthiness of each arrow type tested and their corresponding accuracies.