Demystification of Geometrical Patterns through Cultural Activities in Bamboo/Nigalo Baskets (Doko)

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Abstract: Bamboo/ Nigalo basket (Doko) is one of the most useful tools in Nepali society. This study sought to identify the mathematical concepts, the implication of space curves, and their relations in the bamboo Doko. Both primary and secondary sources of data have been consulted in this study. Data and information were gathered from the related literature, analysis of archival documents, and observing the activities related to bamboo baskets (Doko) in the community. The descriptive method of research has been used for the analysis and interpretation of information. The patterns of bamboo choyas were analyzed emphasizing the structure and design of circular helix and toroidal spiral curves. It was observed that the circular helices are formed by bamboo choyas on the body part of the Doko and the toroidal spiral curve is formed by bamboo choya on the top of a Doko that is bid (upper edge) of a Doko. Findings of this study may help students understand the concept of the curve and help them explore more about the use of mathematics in daily life. In addition to this, the multidimensional use of space curves can help in further studies of geometrical patterns in cultural artifacts.

Key Keywords: *Circular helix, spiral curve, bamboo choya, toroidal spiral curve*

Background of the Study

Mathematics helps us have better problem-solving skills in daily life. It helps us think analytically, and have better reasoning abilities everywhere. Mathematical reasoning is our ability to think logically about a situation (Yudianto et al., 2020). Among other skills, analytical, logical and reasoning skills play very important roles in solving problems in daily life. It enhances students' power of reasoning and creativity in mathematics. It also supports in abstract thinking in mathematics with spatial thinking, critical thinking, problem-solving, and even effective communication skills (Fujisawa et al., 2000).

In mathematics, a curve is defined as a smoothly-flowing continuous line that has bent. In simple terms, it can be any somewhat bent line and the way to identify the curve is that line

bends and changes its direction at least once (Sharma, 2018). Moreover, a curve is a shape or a line that is smoothly drawn in a plane having a bent or turns in it. There are so many types of curves in mathematics, I have focused on space curves in this paper. A space curve may pass through any region of three-dimensional space, as contrasted to a plane curve which must lie on a single plane (Eren & Kosal, 2020). Many real engineering designs need curved mechanical parts, civil engineering designs, architectural designs, aeronautics, shipbuilding, and other areas.

A curve is called a slant helix if it's principal normal forms a constant angle with a fixed line in the space. The constant angle and the fixed line play a key role in the nature of the helix. It is constructed with a transformation of a line to the moving frame of a general helix. There were many attempts in architectural history, to build helical towers and other constructions. Most of the architectural work in the world is possible through different types of geometrical designs. The work constructions which are in helical shapes are also the most important and interesting works in the world such as Guggenheim Museum, Canton Tower, and Agora Garden Tower (Vahid, 2017). It seems that the success of the helix as a shape in biological molecules is a case of nature working the best it can with the constraints at hand," Kamien said. "The spiral shape of DNA is dictated by the space available in a cell much like the way the shape of a spiral staircase is dictated by the size of an apartment" (University of Pennsylvania, 2005).

Nepal is a multilingual, multicultural, diverse social structure, diverse geographical conditions, and a landlocked country (Panthi & Belbase, 2017). Most of the villages here do not have transportation facilities; so, they have to carry anything by themselves. So, Bamboo/Nigalo baskets (Doko) have been used for carrying goods and other purposes since ancient times in Nepal. Bamboo/Nigalo basket (known as Doko in Nepal) is an artifact that has been carried down from generations. It is an integral part of Nepali cultural identity in many communities. These baskets are not only functional, but also hold significant cultural and artistic value. Bamboo or Nigalo is a natural environmental protection material. It is easy to get and process bamboo materials, like Doko (basket) which is extensively applied in rural households. Therefore, bamboo has been an important resource in the production, daily-to-day life, and cultural activities for Nepali people. People have built many tools like bamboo Doko at the local level to solve their daily problems. Extremely practical mathematical ideas are used in the manufacturing of such items. So, I am interested to analyze the mathematical concepts used in the bamboo Doko, which is widely used in the daily life in Nepali society.

Objective of the study

This study sought to identify the geometrical concepts, use of curves, and their relations in the bamboo/Nigalo basket (Doko) determining the mathematical structure of their patterns; and associate meanings and mathematical implications of the curves.

Method

This study adopted the descriptive method of research. It is descriptive because the study tried to show the applications of mathematical concepts to the bamboo Doko produced in Nepal. Moreover, it is descriptive because it discussed the different patterns of curves and the relation between them by observing the bamboo Doko and studying some related works of literature.

Mathematical Implications of Designing Bamboo Baskets (Doko)

In the process of making bamboo Doko, a single bamboo is cut to make fine and thin choya, and the bamboo Dokos are made from these choyas. The people who make and use the bamboo Doko may not know much other than the general mathematical concepts used in it, but they are made and used (Lu et al., 2016). The multi-purpose bamboo/Nigalo Doko is used in Nepalese society for carrying and storing goods. At the beginning, when making the bamboo Doko, the bamboo choyas are kept in a straight line and they are made crooked as per the need. The number of bamboo choyas used there, the straight line, and the curved line are basic mathematical concepts. When the bamboo Doko is ready, there are holes between choyas of different shapes that give the concepts of different triangles, quadrilaterals, and other shapes or polygons. Simple mathematical implications such as the height, roundness, and shape of the bamboo Doko can be easily seen. Moreover, the unique patterns and shapes that are created in these baskets (Dokos) are not just a result of artistic expression, but also demonstrate an understanding of mathematical concepts such as symmetry, curves, proportion, and spatial relationships.

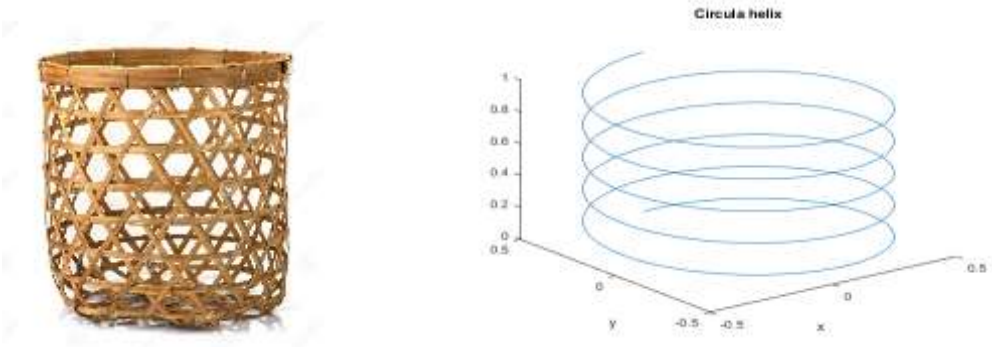
In recent years, there has been a growing interest in studying the geometrical concepts and curve patterns that are used in Doko as well as their mathematical significance. However, this paper focuses on the curves made by bamboo choyas used in it, their relation, and the mathematical value they give.


Figure 1: *Bamboo choyas in Doko with different mathematical concepts*

Circular Helix and Toroidal Spiral Curves in the Bamboo Basket (Doko)

A circular helix is a three-dimensional curve that forms a helix with a circular cross-section. It is obtained by wrapping a circular wire around a cylinder, with the axis of the wire perpendicular to the axis of the cylinder (Chen, 2012). Also, it is a curve on the cylindrical surface, which is described in Cartesian coordinates by the parametric equations. According to Gerdes P. (2010), a circular helix has constant band curvature and constant torsion. He claimed that circular helices have applications in various fields, including architecture, where they can be used to create visually interesting shapes, and in physics, where they can model the behavior of practices in magnetic fields or the structure of DNA. It is also used in engineering, such as in the design of springs and screws. In the same way, the bamboo/Nigalo Doko, widely used in Nepali society for multipurpose daily activities, also has a cylindrical body in which the bamboo choyas move from bottom to top in the form of circular helices.

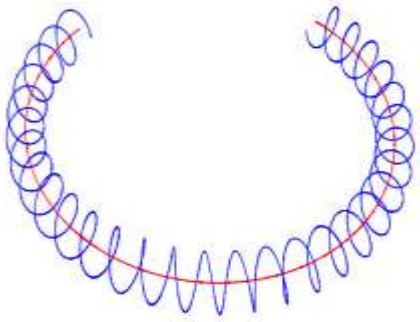
Figure 2: *Circular helix by bamboo choyas*



A toroidal spiral curve is a spiral curve that is obtained by wrapping a spiral curve around the torus surface, which is a doughnut-shaped object (Polezhaev, 2019; Olsen & Bohr, 2012). The resulting curves around the surface of the torus. Also, they claimed that toroidal spiral curves have applications in fields such as architecture, where they can be used to create visually interesting shapes, and in physics, where they can model the behavior of particles in magnetic

fields. They also have aesthetic appeal and are sometimes used in art and design. In the upper part of the bamboo Doko (bid), the bid of Doko is a torus surface and the bamboo choya around it is a toroidal spiral curve.

Figure 3: *Toroidal spiral curve around torous*



Formation of Space Curves in the Bamboo Basket (Doko)

A space curve passes through any region of three-dimensional space, whereas, a plane curve must lie on a single plane. Space curves are inherently more difficult to draw by hand than plane curves; for an accurate representation, we need to use technology (Eren & Kosal, 2020). Many real engineering designs need curved mechanical parts, civil engineering designs, and architectural design practices such as space curves (Sharma, 2018). Many tools used in daily life use the space curve. Many types of space curves are also used in the bamboo Doko used in our daily lives, such as helices, different types of spiral curves, a family of curves, etc.

Figure 4: *Bamboo Doko existing different space curves by bamboo choys*

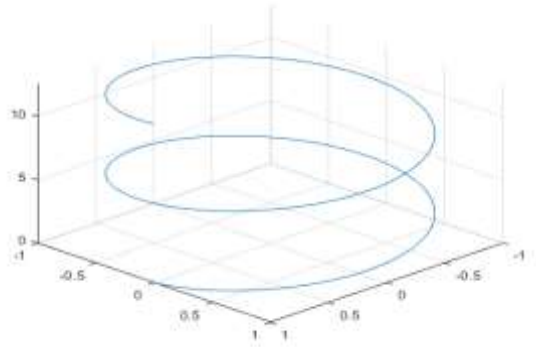
Circular Helix and Toroidal Spiral Curves in MATLAB

A circular helix is a curve with equations x = cost, y = sin t, z = t is the curve spiraling around the cylinder with base circle x = cost, y = sin t. So the parametric equations of the circular helix are x = cost, y = sin t, and z = t. This circular helix is in MATLAB below.

```
>> syms t real;
>>  helix = [cos(t), sin(t), t];
```

```
>> helplot = fplot3(helix(1), helix(2), helix(3), [0, 4*pi]);
>> view([1,1,1])
```

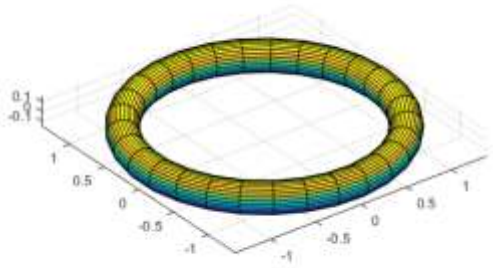
Figure 5: *Circular helix*



To generate the toroidal spiral curve on MATLAB, we have to generate the torus surface because the toroidal spiral curve is around the torus surface. Here are the parametric equations of the toroidal spiral curve as x = (b + a cos∅). cosθ , y = (b + a cos∅). Sinθ, z = a sin∅, where a is minor radius and b is the major radius.

```
>> a=0.15;
>> b=1.25;
>> theta=linspace(-pi, pi, 30);
>> phi=linspace(0, 2*pi, 30);
>> [t,p]=meshgrid(phi, theta);
>> x=(b+a*cos(p))*cos(t);
>> y=(b+a*cos(p))*sin(t);
>> z=a*sin(p);
>> surf(x,y,z)
>> axis equal
```

Figure 6: *Toroidal spiral curve around torus surface*



Circular Helix and Toroidal Spiral Curves are Applicable in Developing Bamboo Baskets (Doko) with Different Perspectives.

Circular helix curves have a cylindrical shape with a helical structure. They are commonly found in natural phenomena, such as the DNA double helix, and in man-made structures, such as screw threads (Ballard, et al., 1984). The use of circular helix curves in Doko weaving offers a unique perspective on traditional weaving techniques. These curves can be used to create baskets with a spiral structure, allowing for more efficient use of space and a more visually appealing design. Additionally, the circular helix curve can be used to create a twisted effect on the basket, which adds to its aesthetic appeal.

Toroidal spiral curves have a donut-like shape with a spiral structure. They are commonly found in nature, such as in the shape of a galaxy, and man-made structures, such as toroidal transformers (Olsen, et al., 2012). The use of toroidal spiral curves in Doko weaving offers a novel approach to basket weaving. These curves can be used to create a basket with a toroidal shape, which adds to its functionality and aesthetic appeal. The toroidal spiral curve can be used to create baskets with multiple layers and compartments, providing additional storage space and organizational options.

The application of circular helix and toroidal spiral curves in Doko weaving opens up new possibilities for basket design. The use of these curves can create baskets that are more visually appealing, functional, and efficient. By incorporating these curves into Doko weaving, artisans can create baskets that are unique and innovative. Additionally, the use of circular helix and toroidal spiral curves in Doko weaving can be applied to various sizes and shapes of baskets, allowing for a range of creative possibilities. In the process of making a bamboo Doko, a circular helix makes on the body part of the Doko from the bamboo choyas, and a toroidal spiral curve is created on the upper part of the Doko (bid). Curves are formed based on the shape of the Doko as shown in figure 7. If the Doko is conical in shape then there is the conical spiral curve. In this way, the curves formed in bamboo Doko can be analyzed from different perspectives.

Figure 7: *Toroidal spiral curve and circular helix*

Discussion

The application of cylindrical helix theory to ultrasonic testing in industrial production, and nondestructive testing of components are extensively used and required to ensure product quality (Li et all., 2016). They focused on one of the common nondestructive testing means via ultrasonic waves. The study revealed that bamboo/Nigalo Doko weaving is a complex and intricate art form that incorporates a range of geometrical concepts and curve patterns. The weaving process involves careful consideration of symmetry, fractals, and topology, and the resulting patterns exhibit a remarkable degree of precision and mathematical elegance. Additionally, the study showed that these geometrical concepts are deeply embedded in the cultural practices and traditions of the communities that produce bamboo/Nigalo Doko.

According to Kwon et al. (2020), a similar double Helix structure of some galaxies was discovered recently. This raises the possibility that other life forms might use as building block molecules with different geometrical structures. The incorporation of geometrical concepts into Doko weaving illustrates the role that mathematics has played in human cultural development. Furthermore, how Doko weaving embodies cultural values and practices through the use of mathematical concepts underscores the interconnectedness of mathematics and culture. Doko weaving is a unique and valuable aspect of the cultural heritage of the communities that produce it, and this study helps to document and promote awareness of this important art form. By highlighting the intricate connections between mathematics and culture that are embodied in Doko weaving, this study contributes to a broader appreciation of the role that cultural practices and traditions play in human development.

The interdisciplinary nature of this study highlights the potential for collaboration between scholars from a range of fields, including mathematics, anthropology, art history, and cultural

studies. By bringing together insights from these different fields, this study contributes to a more nuanced and holistic understanding of Doko weaving and the cultures that produce it.

Conclusion

Mathematics is ubiquitous and universal; it is used in our daily lives knowingly or unknowingly. General mathematical concepts to abstract concepts are used in our everyday activities. Many mathematical concepts are used in the bamboo Doko that we use every day. A different variety of curves seem to be widely used in bamboo Doko. Especially bamboo choyas make different curves while making bamboo Doko. Curves are varying according to the size of the bamboo Doko. The body part of the Doko has helical curves formed by bamboo choyas and also bamboo choya forms a toroidal spiral curve on the top part (bid) of the bamboo Doko. Similarly, the implication of helix is everywhere in different fields and areas. In general, the people in Nepal use the concept of helical curves in constructing a basket (Doko) with nigalo and bamboo. Also, it can be used for engineering and architectural design, manufacturing, and efficient material usage. Finally, the helix can be found everywhere surrounding us. It is prevalent from DNA to modern engineering designs. Moreover, the use of Matlab in the visualization of the helix can be one of the important approaches in teaching-learning mathematics in general and geometrical patterns in particular.

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