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The Practice of MATLAB-Based Visualization of Spatial Surface in Advance Mathematics

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Abstract: In response to the challenges posed by the abstract nature of spatial surface content in traditional advanced mathematics education and the difficulty in cultivating students' spatial imagination abilities, this paper proposes integrating MATLAB 3D visualization technology into classroom instruction. By designing hierarchical practical tasks, dynamic interactive demonstrations, and interdisciplinary case studies, we construct a "theoretical foundation + programming implementation + visualization" integrated trinity teaching model. This approach enables visual design of spatial surfaces while exploring a dynamic, intuitive, and visually oriented pedagogical approach. The methodology aims to facilitate conceptual comprehension and mastery through mathematical software applications, fully develop students' abilities to interpret abstract problems using visualization techniques, and further enhance their practical programming skills through hands-on coding exercises.

1. Introduction

Advanced mathematics, a cornerstone of university general education, cultivates applied talents with robust logical thinking and professional competencies. However, as emerging engineering disciplines demand greater mathematical modeling and engineering visualization capabilities, traditional teaching methods—reliant solely on blackboard instruction and static PowerPoint presentations—reveal significant limitations, particularly in spatial analytic geometry education.

In today's information age, technology-enhanced pedagogical approaches like distance education and live webcasting have gained prominence[1,2]. Among these, MATLAB—an interactive numerical computing environment developed by MathWorks—has demonstrated considerable potential for advancing mathematics education. The software excels in numerical analysis, computation, and visualization, with notable strengths in modeling nonlinear dynamic systems. Its capabilities in function plotting, matrix computation, algorithm implementation, graphical interface development, and interoperability with other programming languages make it a powerful tool for mathematical applications. Consequently, MATLAB is widely utilized across diverse fields, including control systems, signal processing, engineering computation, and image processing.

Leveraging the comprehensive strengths of this platform and informed by pedagogical experience in advanced mathematics instruction, we have integrated MATLAB into our teaching practices. This initiative aims to enhance learning efficiency, deepen students' mathematical literacy, and foster educator development through innovative, technology-driven pedagogy.

2. Background

Advanced mathematics, a cornerstone of university education, cultivates applied talents through rigorous logical reasoning and professional skill development. Yet its inherent abstraction presents significant challenges, particularly in visualizing complex functions. A critical pedagogical shortfall emerges when instructors prioritize formulaic applications over developing students' visualization and analytical capabilities, resulting in knowledge gaps and conceptual misunderstandings[3,4].

These challenges stem from dual sources: instructional methods and learner diversity. While education requires dynamic interaction, traditional lectures dominate this compulsory course, with only occasional student-cantered activities. Although multimedia tools are increasingly adopted, many merely substitute PowerPoint for blackboard teaching without addressing the fundamental need for visual explanation of abstract concepts.

Compounding these issues, higher education's expansion brings diverse learners. Freshmen often struggle to transition from secondary education, retaining teacher-dependent learning habits. When confronted with advanced mathematics' theoretical complexity and rapid pace, many become overwhelmed and progressively disengage. Spatial surfaces, foundational for integral calculus—particularly surface integrals in multivariable calculus—constitute a critical multi-chapter component of advanced mathematics curricula. Accurately visualizing three-dimensional geometric constructs is essential for subsequent problem-solving and computation. For students lacking spatial reasoning abilities, intuitive graphical representations significantly enhance comprehension and analysis. Leveraging mathematical software for visualization, especially when integrated into digital teaching materials with extended classroom demonstrations, markedly improves instructional effectiveness. This dynamic visualization approach boosts student engagement while facilitating deeper conceptual understanding and knowledge consolidation. For instructors, mastering such advanced teaching technologies represents a valuable professional development opportunity.

From the learner's perspective, visualization-based education bridges theoretical principles and practical applications. Programmatic implementations enable students to verify understanding through hands-on experimentation, while software-based reproductions of textbook illustrations enhance motivation and cultivate creative problem-solving abilities[5].

Building on these considerations, this study integrates MATLAB into the pedagogy of spatial surface instruction within advanced mathematics. Through graphical demonstrations of exemplary problems, students participate in visual interpretation and synthesis, clarifying abstract mathematical concepts. This reduces anxiety, fosters enthusiasm for the subject, facilitates self-directed learning via software platforms, enhances classroom participation, and lays groundwork for future research endeavors.

3. Practice

The following section takes spatial surfaces in the Advanced Mathematics curriculum as an example to construct a visualization-based teaching model for spatial surfaces.

3.1. Instructional Design Framework

Construction of a three-stage teaching model comprising "Foundational Cognition → Interactive Exploration → Innovative Application":

Foundation Level: Rapid generation of standard surfaces using functions like “ezsurf” and “meshgrid”.

Advanced Level: Introduction of rendering techniques including lighting, material properties, and perspective transformations.

Innovation Level: Implementation of project-based learning through engineering case studies.

3.2. Classroom Implementation Strategies

Case 1: Möbius Strip Visualization

At the foundational level, students construct physical Möbius strip models by twisting paper strips 180° and joining the ends. This hands-on demonstration concretely reveals the surface's single-sidedness and non-orientability as fundamental topological properties. Progressing to the advanced level, learners transition to computational visualization using MATLAB with the following code:

```
u = linspace(0, 2*pi, 50);
v = linspace(-1, 1, 50);
[u, v] = meshgrid(u, v);
x = (1 + 0.5*v.*cos(u/2)).*cos(u);
y = (1 + 0.5*v.*cos(u/2)).*sin(u);
z = 0.5*v.*sin(u/2);
figure;
h = surf(x, y, z);
axis equal;
for t = 0:0.1:10
    set(h, 'XData', x + 0.1*sin(t));
    drawnow;
end
```

The result is shown in Figure 1.

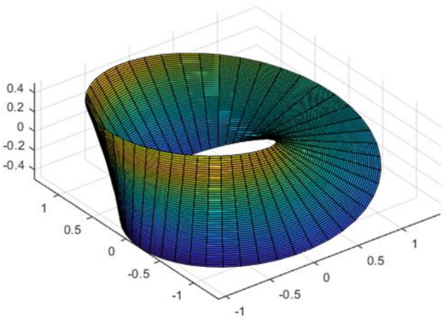

Figure 1: Möbius Strip Visualization

At the innovation level, a comparative analysis is conducted among the Möbius strip prototype, its visualized graphics, and the original physical image of the west facade of the university's main building.

Case 2: Visualization and Dynamic Simulation of the Surface $z = \sqrt{x^2 + y^2}$

```
x='cos(s)*cos(t)'; y='cos(s)*sin(t)'; z='3*cos(s)^2';
for k=0:0.1:pi;
    hold off
    ezsurf(x,y,z,[0,pi,0,-k-0.1]);
    light('position',[-1,-0.5,0],'style','local')
    shading interp;
```

```
    colormap (spring);
    pause (1)
end
```

Based on the aforementioned code, we obtain the result in Figure 2.

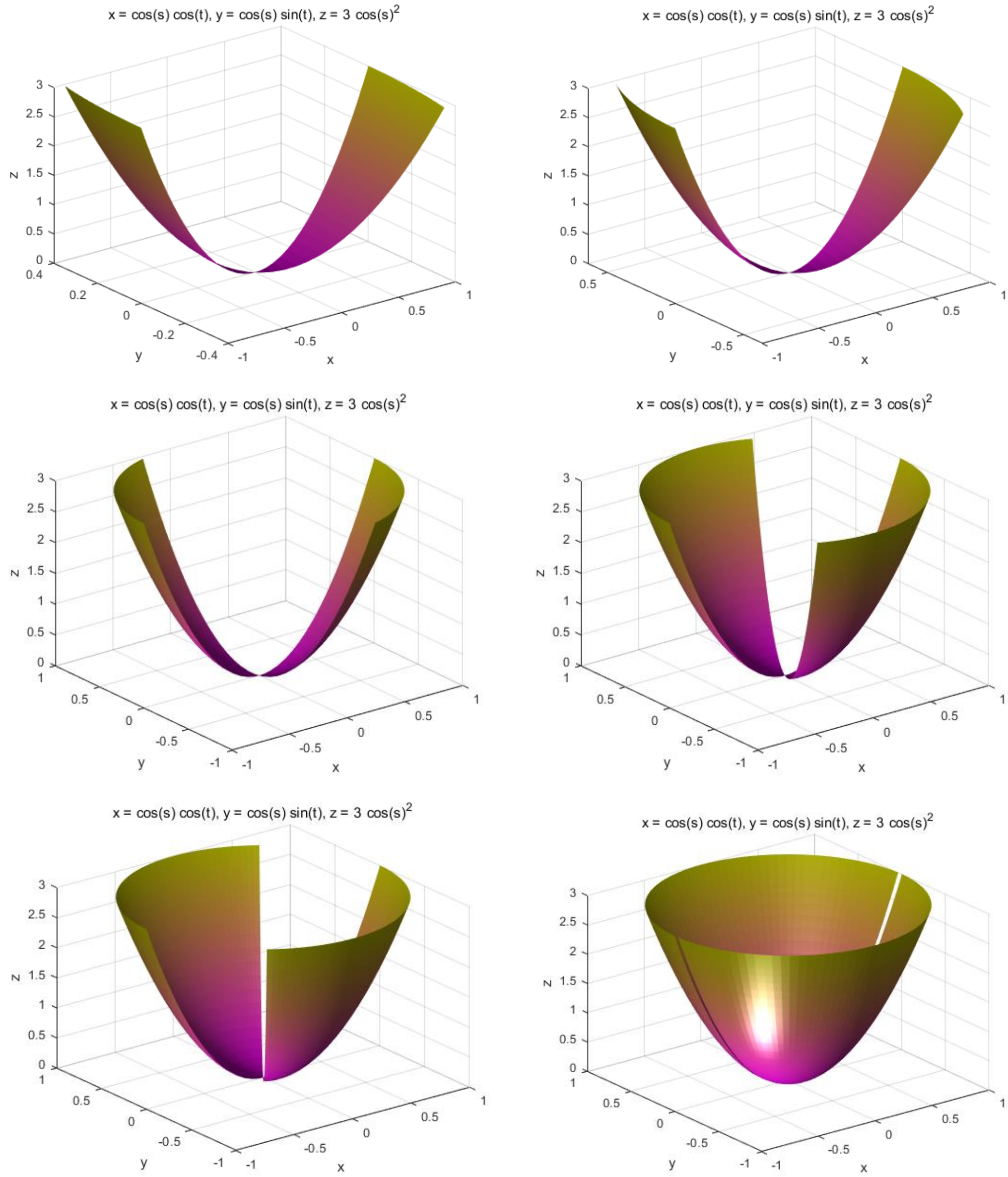

Figure 2: Visualization and Dynamic Simulation of the Surface $z = \sqrt{x^2 + y^2}$.

The dynamic transformation of the surface is clearly illustrated through the graphical representations provided, thereby facilitating enhanced comprehension of spatial surfaces among learners.

4. Conclusions

By integrating MATLAB programming with advanced visualization tools, this methodology revolutionizes pedagogy through an innovative "learning by doing" approach that ignites student engagement while achieving seamless integration of theoretical concepts and practical applications. Looking ahead, these case studies aim to serve as catalysts for educators to: 1) expand industryacademia collaboration networks, 2) develop hybrid simulation platforms that seamlessly integrate virtual and physical components, and 3) pioneer AI-driven adaptive learning architectures. This strategic evolution will enable the creation of immersive experimental environments and personalized educational trajectories, ultimately redefining the boundaries of STEM education through technology-enhanced, experience-based learning ecosystems.

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