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INNOVATIVE REPRESENTATION OF DOUBLE ORTHOGRAPHIC PROJECTION USING 3D PRINTING TECHNOLOGY

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Abstract: This paper discusses how to use 3D printing to exhibit double orthographic projection and actualize a functional, didactic physical model using FDM technology. Two articulated plates enable positioning at a 90° angle and folding into a common plane, effectively illustrating geometric projections. Flexible cylinders and a sphere symbolize the geometric point, facilitating the analysis of its position relative to projection planes. A spotlight enhances projection visibility and supports better visual understanding. The optimized technical parameters, such as temperature, print speed and the height of the deposited layer, ensured the accuracy of the obtained components. Results confirm the efficiency of 3D printing in clarifying descriptive geometry principles and developing an interactive and precise educational tool.

Keywords: 3D Printing, FDM, Descriptive Geometry, Geometric Representation, Educational Model, Draught.

1. INTRODUCTION

Fused Deposition Modeling (FDM) is one of the most common methods of 3D printing. FDM is an additive technology used to create three-dimensional objects by successively depositing layers of melted material (Fig. 1). The filaments used in FDM technology, usually made of plastic (PLA, ABS), are extruded by a heated nozzle and the layers are deposited on top of each other on a heated construction plate [1]. By this method, obtaining complex geometries with high dimensional accuracy is easy. 3D printing technologies are commonly applied in various areas: from rapid prototyping, industry production, dentistry and education [2, 3].

The double orthogonal projection (Fig. 2) is a method used to represent the position in space of a point on two mutually perpendicular planes. By this method, each projection offers a different perspective on the coordinates of the point. The position of the horizontal projection of point defines the coordinates in the plane, the height of the point defines vertical projection [4]. This method, of the double orthogonal

projection, is essential in descriptive geometry and in industrial representations, forming helping to understand some applications in engineering and architecture [5].

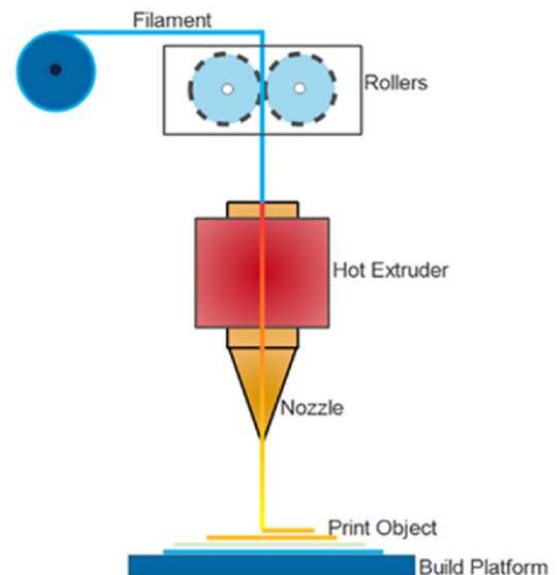


Fig. 1. Principle of FDM [3].

Double orthogonal projection can be obtained piecewise by giving point P some angle α of rotation around the horizontal plane and projecting it both on the horizontal plane and the vertical plane. Just a projection provides information about the location of the point [6]. On every plane, the point is displayed with its coordinates, and wherein projective lines intersect, you get a correct representation of its position in space [5].

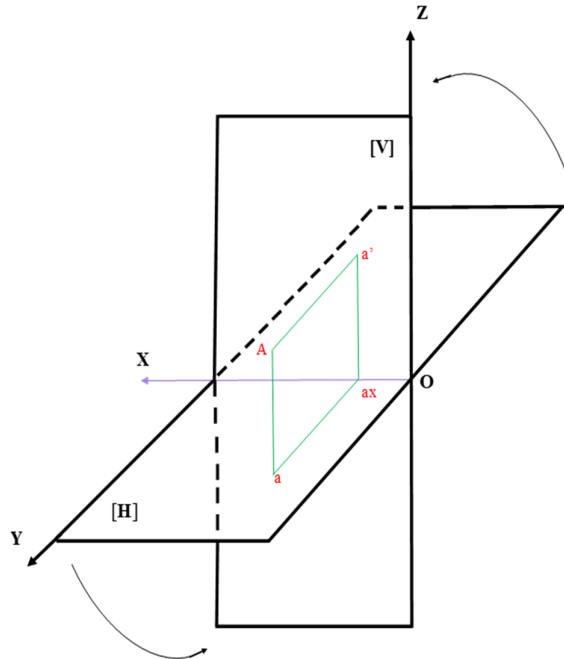


Fig. 2. Perpendicular projection planes [7].

The draught is a planar fusion of the projections of a point, a line, or a geometric body on two perpendicular planes. Draught is utilized to graph and analyze location based on spatial factors, clear and accurate representation process. It helps in the interpretation and visualization of complex geometric arrangements from two perspectives: horizontal and vertical. In the field of descriptive geometry and technical drawing, it is a fundamental tool [7].

The folding of projection planes is when two perpendicular planes are reduced to a singular common plane (Fig. 3), traditionally the vertical plane. Upon folding, the horizontal projection gets "folded" up over onto the vertical plane, and then we see both projections of the point simultaneously on the same flat plane. This allows for the relationships between represented

elements to be analyzed and understood geometrically. Folding is a critical step of the draught process, translating the spatial arrangement into a two-dimensional format [8].

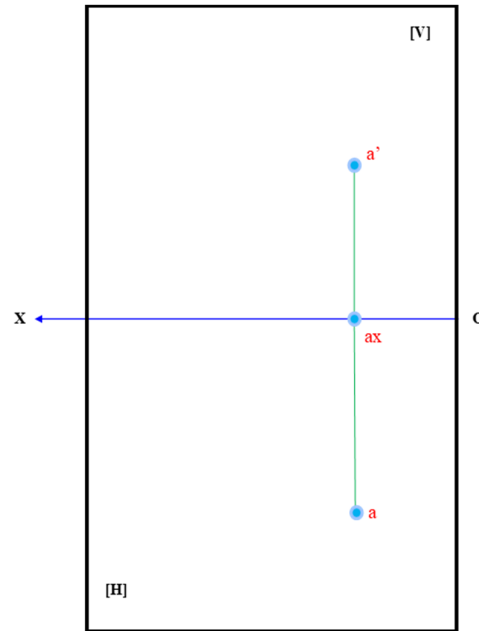


Fig. 3. Folded projection planes [8].

2. METHODS

2.1 Materials and equipment

The Creality Ender 3D printer uses Fused Filament Fabrication (FDM) technology, which extrudes the melted thermoplastic filament through a heated nozzle with a specific diameter and sufficient counter pressure [9]. The model used in this investigation was the Creality Ender-3 V2, a very popular low-cost, reliable, and easy-to-operate desktop 3D printer. It features a Bowden-style extruder, a carborundum glass bed that improves adhesion and overall print quality, and a 220 x 220 x 250 mm build volume. It also comes with a silent stepper motor driver, which allows it to operate slowly and quietly for a smoother and more precise experience.

This study uses PLA (Polylactic Acid), a biodegradable thermoplastic polymer derived from renewable resources including cornstarch and sugarcane. PLA is the dominant material used owing to its low melting temperature (~180–220°C), low warping, and excellent layer adhesion, making it suitable for detailed prototypes, educational models, and functional

parts [1]. PLA has good tensile strength and high stiffness compared to other filaments such as ABS or PETG, although it is more brittle and has lower temperature resistance. All the printing was done using a storage device to protect the PLA filament from moisture adsorption, which affects the quality of the printing [10]. When considered together, the Creality Ender-3 V2 and PLA filament provide an affordable, yet precise means of producing parts that may have small tolerances, complex geometries, and good surface finishes, all of which are important for functional prototypes and research applications.

2.2 Physical model construction

In the construction of a working model of the double orthogonal projection, two flat plates articulated at three points were designed using SolidWorks software. These hinges allow a precise positioning of the plates in a 90° angle (Fig. 4), therefore representing the horizontal and vertical planes employed by descriptive geometry.

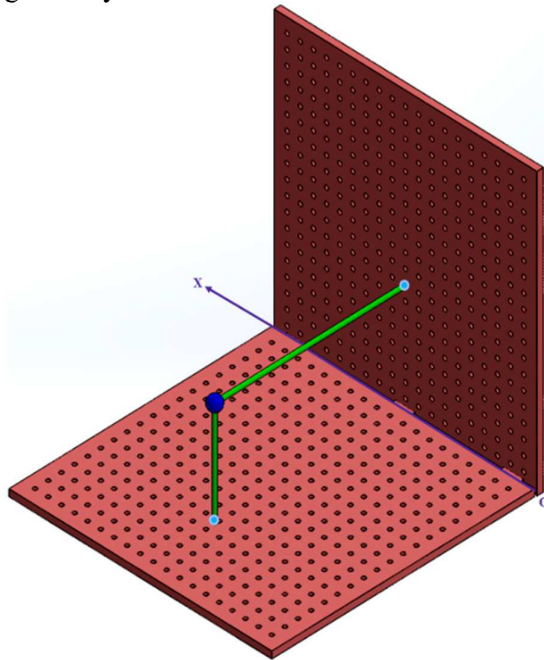


Fig. 4. Digital design of double orthogonal projection.

The digital design consisted of technical specifications, including plate thickness, material strength, and hole spacing necessary for the flexible cylinders. The software was selected from others due to its capacity to deliver a refined parametric modeling and accurate

simulation of the joints and motions of the double plates. Each of the two flat plates includes a predetermined number of circular holes, evenly spread to accept the introduction of the flexible cylinders. Holes with a uniform calibrated diameter across plates guarantee the cylinders a snug fit but give them the flexibility necessary to allow articulated movements while folding the plates. Versatile cylinders are key in this schema. A sphere is attached at the end of each cylinder, representing some basic geometrical point. This setup is used in a double orthogonal projection configuration. Thus, with these cylinders, we are able to control the location of the point relative to the planes.

One key feature of this model is the ability to fold the planes of projection. The two hinges can be collinear (Fig. 5), lying on a single plane and therefore belonging to a common surface. In this configuration, the flexible cylinders reprogram themselves automatically, and the sphere at the end of the cylinder represents the same point across two dimensions. So, we need both projections for correctly locating a point concerning the two reference planes. This highlights how the projections of point coordinates in 3D space are interrelated.

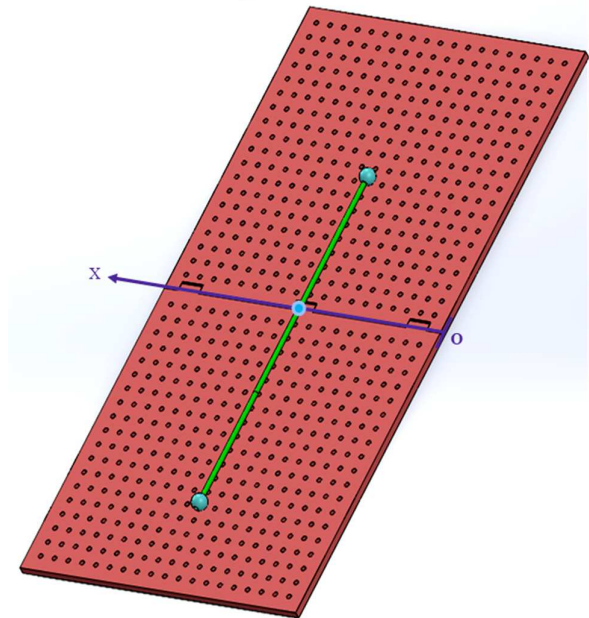


Fig. 5. Digital design of draught.

In order to see better the projections and the resulting draught, one can direct a point light on the two flat plates. Because this point allows the

intersection of the flexible cylinders, its lines of projection and the position of the point on each plate are evident. Benefits of the light spot: projection lines on the horizontal and vertical axes are clearly visible; allows to simply see how much higher or further away a point is; provides an opportunity to quickly understand how projections visually relate to each other.

The draught is arranged very easily in the case of a point above the first dihedron. Things get a lot more complicated when we talk about the rest of the dihedrons. The model offers insight into the details on how the double projection of point and draught is performed. It is also possible to extend the current model to the other dihedrons. Note that negative values of distance and elevation would allow for transparent plastic materials to be employed in releasing each point at the second, third, and fourth dihedrons, revealing the corresponding projections.

The model developed through this process offers an interactive framework to grasp the core principles of double orthogonal projection. The flexible cylinders can be adjusted or folded by students and users to see the effects of folding on the position of the sphere (the point) with respect to the planes. Moreover, it can be used for educational purposes during live experiments of the projection process, while also providing a tangible alternative to traditional theoretical representations on paper.

2.3 Integration of 3d printing in the double orthogonal projection model

Surprisingly, the digital format of double orthogonal projection also had a beneficial effect due to the inclusion of 3D printing for the physical model.

The horizontal and vertical planes were computed digitally in SolidWorks to create two flat plates, which were then manufactured with the Ender printer, using PLA material for dimensional stability and ease of printing. Each plate has holes with calibrated dimensions for inserting flexible cylinders for stable articulation and correct folding of the device.

The components representing the flexible cylinders and the sphere, representing the geometric point, were printed separately and provided durability and flexibility. The two

cylinders were designed with the ability to shift across both planes for determining the positionality of the point for its z-plane and resist laws of physics, while the sphere was designed and printed to have a smooth surface to represent the point in both horizontal and vertical projected planes. Not only could it create exact parts, but the printing process allowed the repeated models to have no discernible variations in quality. The fact that the cylinders were flexible and the geometry of the plates accurate induced the correct folding, giving a clear representative visualization of the draught of the point and its projections. Therefore, since it was necessary to have something functional, interactive, and educational, we used 3D printing as a powerful tool to make it happen; a contemporary method for demonstrating the concepts of descriptive geometry in double orthogonal projection.

2.4 Technical parameters of 3d printing

As for the physical model of double orthogonal projection, its final quality highly depends on the technical parameters of 3D printing. These were fine-tuned to the effectiveness of the structure, clarity in detail, and working of the produced parts. One of the most critical parameters was set between 200–210°C, which is optimal for PLA filament. Maintaining this temperature range, at which filaments are appropriately fluid, avoids deformation, layer delamination, void formation, etc. The printing speed was set to around 50 mm/s to obtain an acceptable printing time and good quality layer. A speed increase would have sped up production time, but also may have sacrificed quality in terms of detail, specifically the calibrated holes within the flexible cylinders. We used 0.2 mm layer height, where we have a good balance between detail with a reasonable total printing time. Then the layer width, which is the diameter of the nozzle, was set to 0.4 mm, as per default for the Ender printer. The techno-mechanical parameters were tuned to achieve higher dimensional accuracy of the parts, with virtually zero defects and good adhesion between layers. The precision with which these aspects were controlled allowed for structural integrity of teeth and cylinders, with no concern of damaging plates or cylinders in

the folding process. In order to develop the functional, interactive, and accurate model appropriate for the educational-demonstrational aim of studying the double orthogonal projection, we have carried out methodical work concerning technical parameters.

3. RESULTS

Using 3D printing to implement the physical model of double orthogonal projection is a successful example of simply using this method to clarify geometric concepts.

The 90° angle was formed using two flat plates, which made it easy to represent the vertical (cut) and horizontal (plan) projection planes. Normally, flexible cylinders were inserted in the calibrated holes, while the sphere sitting at their ends allowed a clear indication of the geometric point.

The folding of the plates allowed projections on the same plane and the visualization of the elevation (z) and distance (x, y) of the point. The light spot focused by each flake called the drawings on those planes, which removed ambiguity and allowed the observer to visualize the location of the point in space.

3D printing allowed for a high degree of dimensional accuracy and high-passive folding mechanics from the inherent flexibility of the cylinders. The model itself offered a dynamic and tactile interface, which enabled pedagogical presentations, technical inquiry, and further investigations into the principles of descriptive geometry. So, the goal—the creation of a functional, precise, educational model—was met successfully.

4. DISCUSSIONS

One way of doing this was using projection by means of 3D printing; this gives a very insightful way of representing and understanding the theoretical side of this math concept. They accomplished this by realizing the physical model and thereby linking the theoretical to the practical experience and rendering of the mechanical application of descriptive geometry.

However, conversations stemming from this model uncovered several key takeaways:

- Dimensional accuracy & precision: 3D print precision combined with appropriate calibration of holes and flexible cylinders mean that the flat plates didn't have to be as precise as they would be to use software to reproduce the geometric relationships accurately. This precision was critical for the planes being raised and folded and for the sharpness of the resultant draft.
- Excellent spatial perception: The three-dimensional spheres and flexible cylinders aided in conveying the conventional point presented in the original system, simplifying and rendering a straightforward way to perceive the projections. This aided students and professionals to understand the complexity of spatial relationships.
- Using a light spot: The addition of a spotlight increased visibility of the projections and coordinates for both planes. This was a simple yet powerful technique, clearing visual ambiguity and anchoring the understanding of spatial relationships and projection principles.
- Give some internal and external challenges: There are other benefits of the method; however, it can only benefit you if you already have sufficient resources. As mentioned above, the method requires sophisticated technical resources (sophisticated 3D printers), and it is also necessary for the material to be high-quality so that the models can serve you long and well. Additionally, the fabrication process may require technical experience in 3D modeling and printing, which could limit accessibility in more resource-poor educational settings.

5. CONCLUSIONS

This research presents the importance of 3D printing and shows its exploratory and educational nature in descriptive geometry with several aspects where not only concepts could be written down but also printed, becoming an example of how to represent spatial data in a physical way. By providing visual, intuitive, and

enhanced interpretations of complex geometric projections, this study demonstrates the potential application of high-precision 3D printing technology for assisting future studies connecting various proteins to the interiors of the protein family. Moreover, this study presents an interactive and tangible method that improves the teaching/learning process. This opens a new form of education, especially for subjects in which visualization in three dimensions is crucial, such as architecture, engineering, and professional drawing.

Future studies can focus on:

- **Material Optimization:** Looking into more robust and flexible 3D printing materials to enhance usability.
- **Augmented Reality Integration:** Merging 3D-printed models with AR for immersive experiences.
- **Comparative Studies:** Assessing 3D-printed models compared to conventional and digital teaching approaches.

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Reprezentare inovativă a dublei proiecții ortogonale utilizând tehnologia imprimării 3D

Această lucrare abordează dubla proiecție ortogonală folosind imprimarea 3D pentru a construi un model fizic funcțional și educațional pentru o mai bună înțelegere a modului de realizare al epurei. Plăcile articulate pot fi poziționate la unghiuri de până la 90° și pot fi rotite într-un plan comun, ilustrând proiecțiile geometrice. O sferă ce simbolizează un punct este conectată cu cilindri flexibili pentru analiza poziției punctului în raport cu planurile de proiecție, proiecțiile sunt mai ușor de vizualizat prin intermediul unui spot luminos. Proprietățile precise ale componentelor au fost confirmate prin optimizarea parametrilor tehnici, precum temperatura, viteza și înălțimea stratului. Constatările demonstrează eficiența tehnologiei de imprimare 3D pentru îmbunătățirea înțelegerii principiilor geometriei descriptive și crearea unui instrument pedagogic interactiv și precis.

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