Title:
Folding Agent: Parameter Visualization in 2D-to-3D Pattern Transformation

Authors:
Chiung-Hui Chen, 7451616@gmail.com, Asia University, Taiwan

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Introduction:
An important research field of artificial intelligence at present is the intelligent agent. The emergence of the software agent provides students in the field of design with conceptual skills, such as parametric design and derivative design, which makes the exploration of complicated shapes possible through computing. Therefore, in the field of visual design, it is very important for students to learn the application of parameters and train their thinking in parametric design. In this study, through the discussion of the characteristics of folding, the visualization simulation system of folding parameters was introduced into the course of three-dimensional constitution design to improve the ability of students in the field of visual design to transform 2D patterns into 3D folding patterns.

This study summarizes the folding textures and folding patterns, discusses the functions of folding, and establishes the data calculation rules of folding texture. The digital operation of folding texture is carried out based on the teaching of folding designs with agent software, which is guided by data with numerical rules drawn by computer geometry. Finally, the visualization simulation system for folding parameters is introduced to build the integration ability of students' thinking in transforming 2D patterns into 3D folding parameters.

With the development of artificial intelligence, in the course of three-dimensional composition design, it is very important to make students in the field of graphic design study the application of parameters and train their thinking in parametric design. “Folding”, which is a technique of design operation and helps students to learn the construction of basic shapes, is often used as a training method in the initial stage of three-dimensional design. This study constructed folding design teaching that introduces parametric design thinking based on the characteristics of folding, and then, validated the folding operation by practical teaching. In order to improve the ability of students in the field of visual design to transform 2D patterns into 3D folding patterns, this study introduced the folding parameter visualization simulation system Origami Simulator, as jointly developed by the Center for Bits and Atoms, Massachusetts Institute of Technology and the Artificial Intelligence Laboratory [1, 2, 3]. This system has the function of “intelligent automatic folding”, which takes the fold texture as the program base and digitizes the fold through the simulation system. Different from the procedural steps of traditional folding, automatic folding is a way of synchronously folding different graphics on the same plane; therefore, intelligent automatic folding can omit excessive folding steps, and take different graphics as the fold texture to generate the folding patterns, in order to produce the desired results.

Main Idea
This study discusses how to introduce parameterized intelligent software into folding design teaching, in order to reduce the technical threshold for students' learning of parametric design in the field of

graphic design, integrate traditional and parameterized applications, and improve students' ability in both traditional and digital design thinking. The research framework is shown in Figure 1, including the application of the intelligent agent in three aspects of folding design teaching. The research purposes include:(1)summarize the folding texture and folding patterns through literature review, and discuss the functions of folding, the calculation rules of folding texture, and the appropriate teaching practices;(2)integrate parametric design thinking into the three-dimensional folding design course through the experimental teaching method;(3)summarize a mutual application thinking mode for 2D combined with 3D parameter visualization for the folding design teaching course.

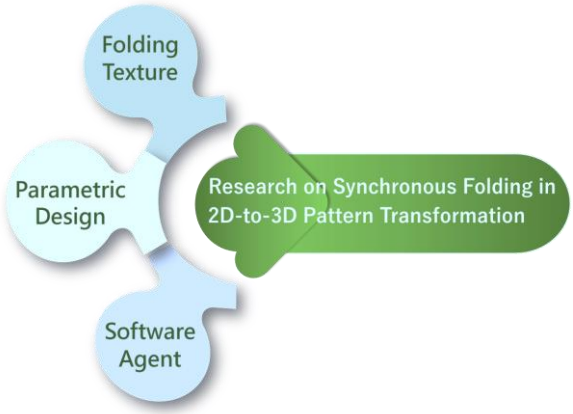


Fig. 1: Software Agent in the Three Aspects of 2D Texture with 3D Parameter Visualization.

Folding and Application
Folding is widely favored by all walks of life due to its unique geometric beauty, thus, it is often used as the research object in the fields of fashion, science, machinery, and architecture. The concept of expandable and scalable folding is widely used by engineering and design fields in products with dynamic folding design, including the extended solar panel for the International Space Station [8], the telescopic operating table shield used in sterilized operating rooms [4], deformable remote control vehicles for search and rescue [5], and dynamic exterior walls for adjusting the indoor physical environments of buildings [7].

Characteristics of Parametric Design
The advantages of parametric design lie in the various parameters, which would form a dynamic but firm structure in the design process according to certain rules, and through the real-time processing of massive data computing by a computer, the design process becomes a dynamic feedback mechanism and is transformed into a visual presentation, which is totally different from the traditional designers' logic of directly determining the design form based on intuition and experience [6]. As the operation process of parametric design involves logic and program, in order to make it easier for designers to understand and operate, some parametric graphics software would simplify the complex program principles into relationship icons for operation. Every step input by the designer would be stored in the computer memory, that is to say, the computer would record all steps and input variables, and if there is a causal relationship between the input actions of the designer, it can go back to any step in the design process at any time. After the change is completed, the computer will automatically recalculate the original follow-up steps, thus, saving time lost due to repeated actions.

Analysis and Comparison of Folding Systems
This section describes the analysis and comparison of the folding visualization simulation systems. The case systems include six representative systems, namely, Tree Maker, Pepakura Designer, Oripa, Origamizer, Reference Finder, and Origami Simulator. The purpose is to understand the limitations and

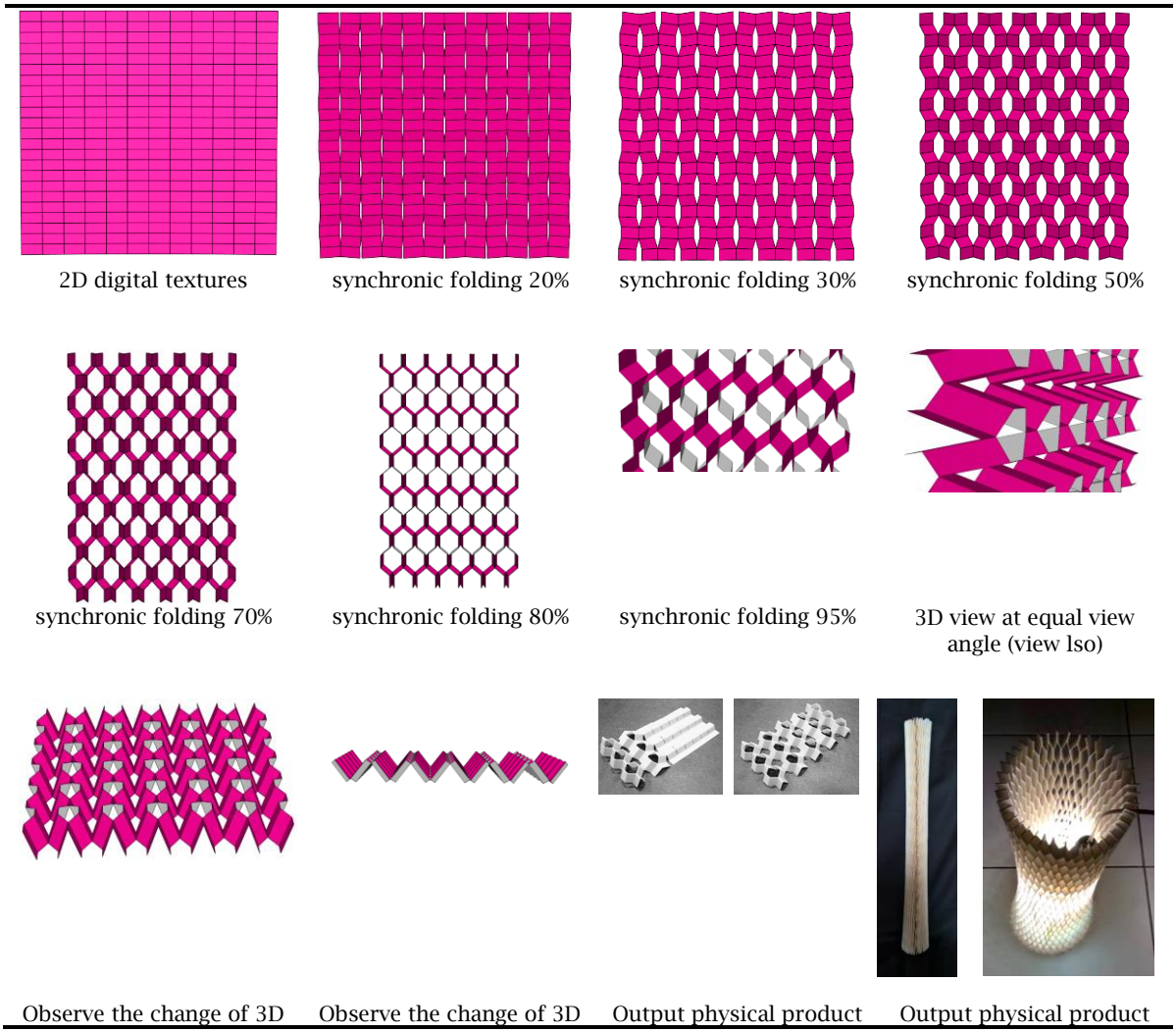
characteristics of each system. Tab.1 shows the characteristics and differences of these six representative systems.

Name of the folding system	Characteristics	Input Condition	Visualization
Tree Maker	Construction of folding appearance by 2D texture with geometrical relationship	Functions defined in the system	Assist the user to define the structural features of the origami shape
Pepakura Designer	Expand the object to generate 2D folding texture through a 3D object by means of planar analysis	3D object file	Export expansion views of the 2D folding texture
Oripa	After completing the 2D folding texture with the line editor, simulate the 3D appearance after folding	Functions defined in the system	Assist the user to draw folding texture and generate perspective drawing
Origamizer	Expand the object to generate 2D folding texture through a 3D object by means of planar analysis	3D object file	Assist the user to draw folding texture
Reference Finder	Fold closest to the position required by the user and begin with as few steps as possible	Enter the X and Y coordinates of the fold point with the fold line positioning system	Assist users to construct the program diagram of the 2D folding texture
Origami Simulator	Automatic folding Synchronous expansion and closing	Imported SVG (scalable vector file) Description data (programmable) 3D object file	Transform the 2D texture into 3D folding in real time to produce digital texture forms, and then, parametrically derive a variety of folding shapes with varying angles

Tab. 1: Comparison Analysis of Folding Systems.

This study derives a set of intelligent folding patterns from the observations of folding in the process of a teaching experiment, and discusses the relationship between the folding texture and the shape by combining the automatic folding simulation system (Origami Simulator). This research content mainly consists of three parts: folding textures, the logical rules of folding textures, and the variability of folding

Creative application of folding skills: goal-oriented operation aimed at the application in design (see Tab.2), where the purpose is to train students to transform design problems into analysis logic and obtain results combining the application of software simulation, in order to improve their ability of applying folding in design through practice.



Tab. 2: A kirigami honeycomb pattern in different stages of evolution.

Conclusions

Through the discussion of the characteristics of folding, this study constructed a folding design pattern that introduces parametric thinking, which intends to improve the ability of students in the visual design field to transform 2D patterns into 3D folding shapes, and to verify the feasibility of synchronic folding operations with practical teaching. The preliminary research results show that a software agent enables students in the visual design field to use parametric design skills, thus, freeing them from the traditional ways of graphics and model presentation. By exploring the change of 3D shapes, as derived in the folding process under the influence of angles, and with the application of the fold ratio, we could solve the problems of material waste and efficiency.

Acknowledgments

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References

[1] Ghassaei, A.: Origami Simulator, 2017. http://apps.amandaghassaei.com/OrigamiSimulator/

[2] Ghassaei, A.; Demaine, E. D.; Gershenfeld, N.: Fast, interactive origami simulation using GPU computation, In Proceedings of the 7th International Meeting on Origami in Science, Mathematics and Education, Oxford, England, September 2018. https://research.adobe.com/publication/fast-interactive-origami-simulation-using-gpu-computation/

[3] Demaine, E. D.; Ku, J.; Lang, R. J.: FOLD file format for origami models, crease patterns, etc., 2017. https://github.com/edemaine/fold

[4] Francis, K. C.; Rupert, L. T.; Lang, R.J.; Morgan, D. C.; Magleby, S. P.; Howell, L. L.: From Crease Pattern to Product: Considerations to Engineering Origami-Adapted Designs Paper presented at the 38th Mechanisms and Robotics Conference, Buffalo, New York, USA, 2014. https://doi.org/10.1115/DETC2014-34031

[5] Lee, D.-Y.; Kim, J.-S.; Kim, S.-R.; Koh, J.-S.; Cho, K.-J.: The deformable wheel robot using magic-ball origami structure, Paper presented at the ASME 2013 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Portland, Oregon, USA, 2013. https://doi.org/10.1115/DETC2013-13016

[6] Terzidis, K.: Expressive Form: A Conceptual Approach to Computational Design. New York: Taylor and Francis, 2003. https://doi.org/10.4324/9780203586891

[7] Tibbits, S.: 4D Printing: Multi-Material Shape Change, Architectural Design, 84(1), 2014, 116-121. https://doi.org/10.1002/ad.1710

[8] Zirbel,S. A.; Trease, B. P.; Thomson, M. W.; Lang, R. J.; Magleby, S. P.; Howell, L. H.: HanaFlex: a large solar array for space applications, Paper presented at the Micro-and Nanotechnology Sensors, Systems and Applications VII, Baltimore, Maryland, USA, 2015. https://doi.org/10.1117/12.2177730