A Tool for Generating Ambiguous Objects in Two Viewing Directions

The 16th International Conference on Advances in Computer-Human Interactions

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About Me

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- Research Interests
  - -Ambiguous objects and its applications
  - -3D illusion and its perception
  - -Modeling tools for 3D objects

Outline

- Background
- Related Works
- Research Aims
- Our Proposed Tool
- Experimental Results
- Conclusion
- Future Work

Background::Ambiguous figures and objects

Optical illusion

- A phenomenon in which our perception of an object differs from its physical reality
- Optical illusions are significant in the study of human visual processing

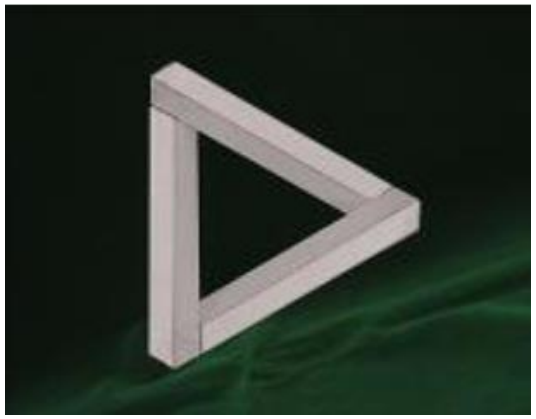
Ambiguous figures （2D）

A single figure can have multiple interpretable meanings

Edgar Rubin's “Face-Vase illusion”[1]

Ambiguous objects （3D）

The shape appears to be different depending on the viewing direction

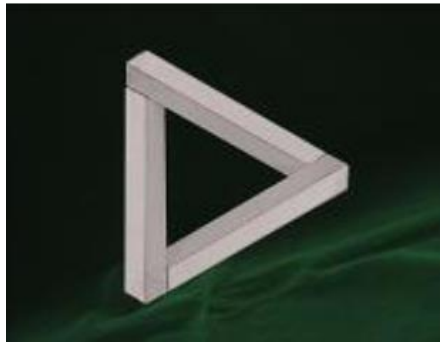


K. Sugihara’s “Penrose triangle”[2]

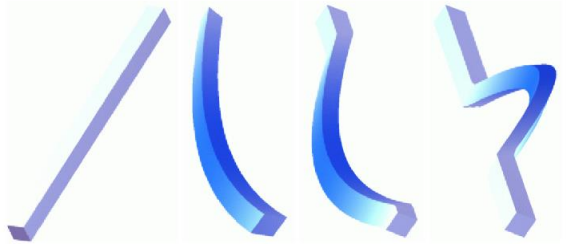
Background::Methods for Generating Ambiguous Objects

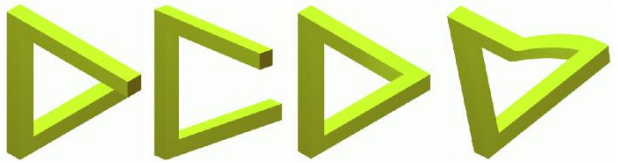
Three Methods for Generating Ambiguous Objects

A Method of Making Discontinuous Structures Appear Continuous from Certain Viewing Directions[2]

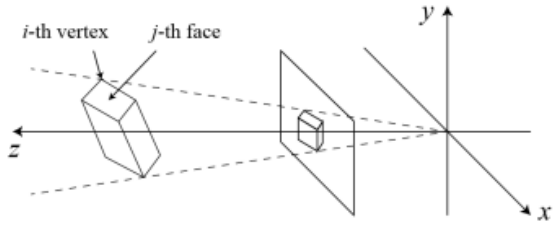


A Method of Using Curved Surfaces Instead of Planes[4]



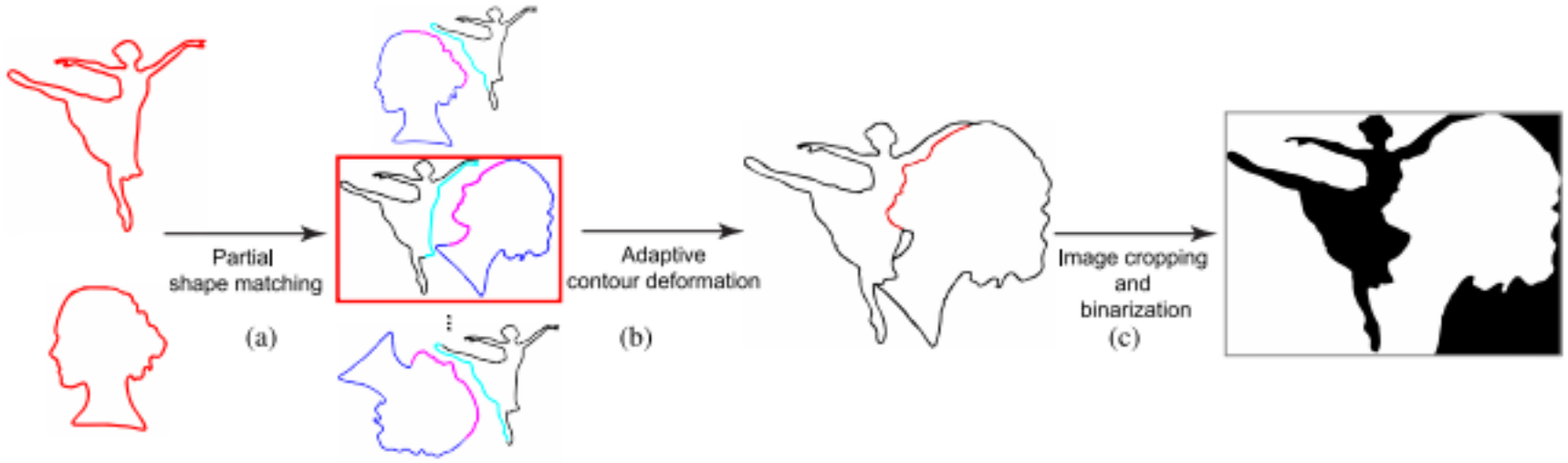


A Method of Creating the Appearance of a Rectangular Shape with Angles Other Than 90 Degrees[4]



Background::Tool for Generating Ambiguous Figures [5]

- Perform shape matching and deformation of two figures to find partial matches
- Join shapes together to generate ambiguous figures



Generating ambiguous objects is a more complex process compared to generating ambiguous figures

Related Works

Three Categories of Methods for Generating Ambiguous Figures and Objects

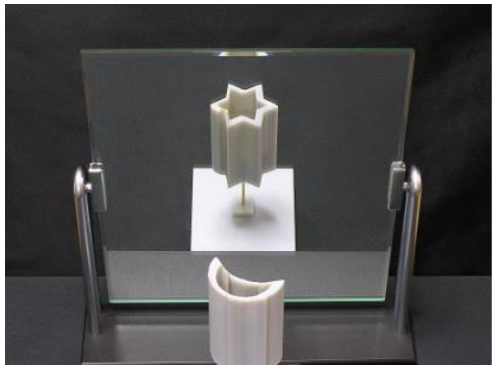
A method of manipulating the relationship between edges or faces[6]

- Ambiguous figures can be generated
- The generated object lacks continuity of edges and faces

Fukuda's method of generating ambiguous objects in two viewing directions[7]

- sculpture with two viewing directions
- Reproducibility is difficult due to undisclosed parameters and optimization methods required for generation

A method of solving linear equations[8]



- Generating ambiguous solids using 2D planar shapes
- Solution cannot be obtained depending on the viewing direction and the given input geometry

Research Aims

Limitations of conventional tools for generating ambiguous objects

- Modeling shapes that are not dependent on the viewing direction is not considered
- If the shape can be automatically corrected when the viewpoint is changed, it is considered that generating ambiguous shapes becomes easier

Research Aims:

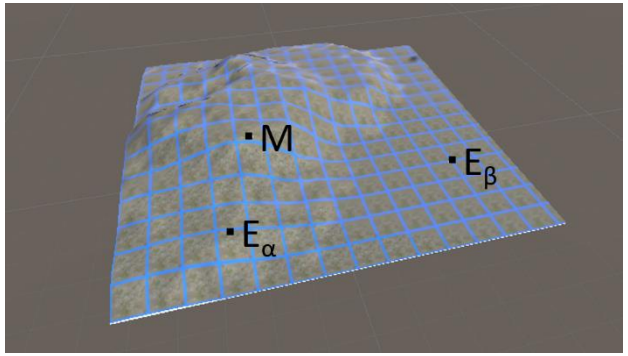
- To develop a tool for easily generating ambiguous objects
- To generate ambiguous objects based on the input of the line of sight direction and 2D figure
- To ensure that the generated ambiguous objects maintain their ambiguity regardless of the line of sight direction

This enables users who are not familiar with 3D modeling to create ambiguous objects

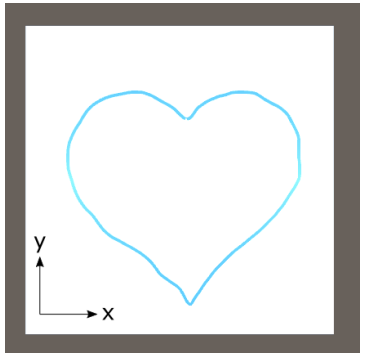
Our Proposed Tool

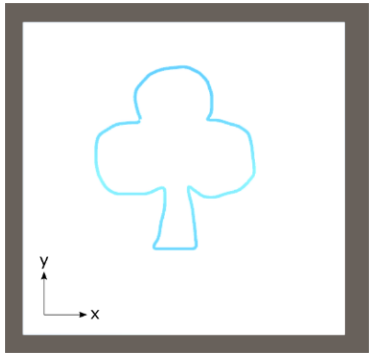
Input of viewpoint and shape (mouse operation)

- E_α, E_β : Two viewpoint positions
- M : Position of the ambiguous object

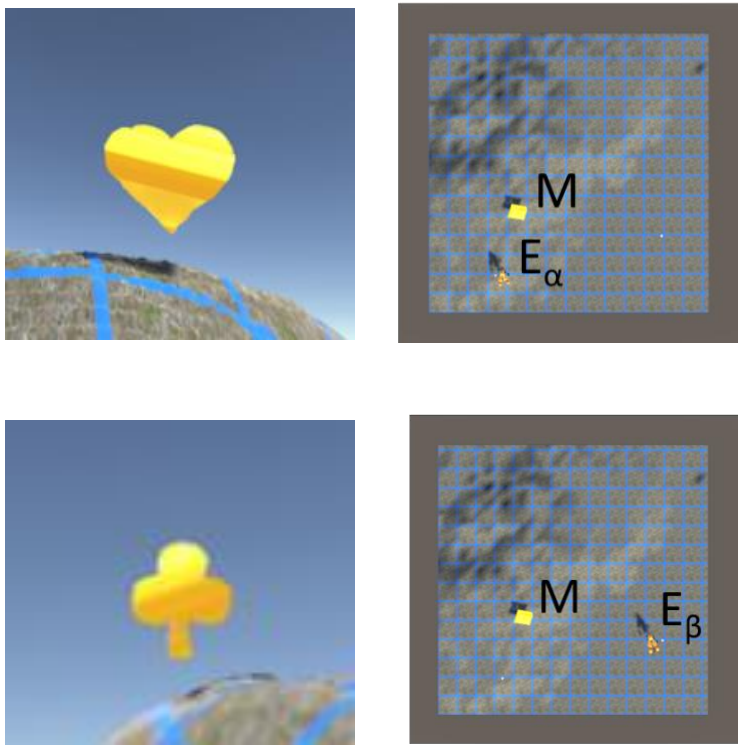


Input viewpoint by clicking





Enter 2D shapes

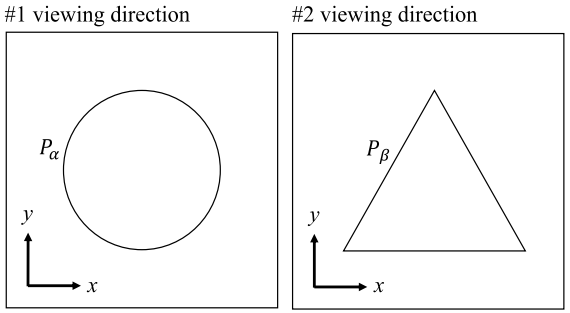


The generated ambiguous object

Our Proposed Tool::Methodology for creating ambiguous objects

2D shape drawing

- Draw 2D shapes on each of the two canvases
- The line segments that make up each shape are not considered for self-intersections
- Optimize each shape (A, B, C)



Examples of the two input 2D shapes

(A) Normalization

- Scale the shape uniformly
- Normalize the vertices Pi that make up the shape with the center coordinate (1) as the origin(2)
  ※Here, W is the scale of the user-defined figure

$$C(c_x, c_y) = \left(\frac{1}{n}\sum_{i=1}^{n} P_i^x, \frac{1}{n}\sum_{i=1}^{n} P_i^y\right) \quad (1)$$

$$P'_i = \frac{w}{\max(P^x, P^y) - \min(P^x, P^y)}(P_i^x, P_i^y), \quad (2)$$

(B) Smoothing

- Reduction of distortion caused by hand tremors
- Smoothing process applied to each vertex (3)

$$P''_i = smooth(P'_i) = \frac{1}{3}(P'_{i-1} + P'_i + P'_{i+1}). \quad (3)$$

(C) Vertices pruning

- Ensure uniform density of vertices that make up the shape
- remove those smaller than the threshold in (4) to achieve uniform density

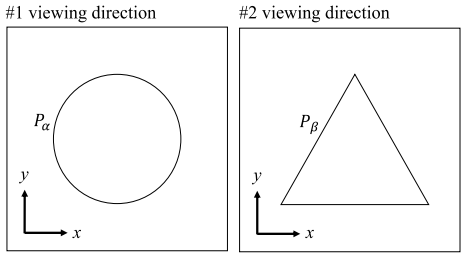
$$D_i = \sqrt{(P''^x_i - P''^x_{i+1})^2 + (P''^y_i - P''^y_{i+1})^2} \quad (4)$$

Our Proposed Tool::Methodology for generating ambiguous objects

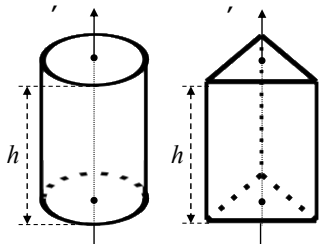
Integrating two solid models(step1-3)

Step1

Generate cylinder A and B for each figure



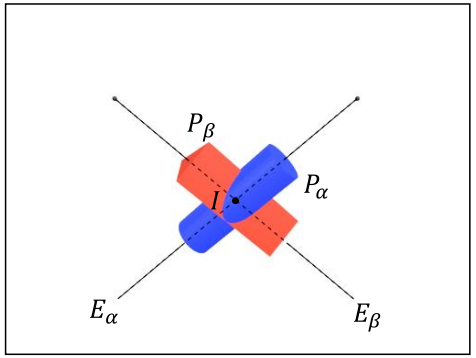
Examples of the two input 2D shapes



Cylinders A' and B'

Step2

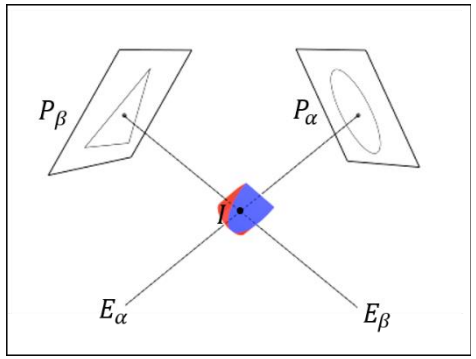
- Intersect the central axes of the cylinders
- Rotate the cylinders around the intersection point I so that their bases face the viewpoints E_α and E_β



Intersecting cylinders A' and B with respect to the viewing direction

Step3

Generate a new solid by performing a Boolean intersection of the volumes of A and B

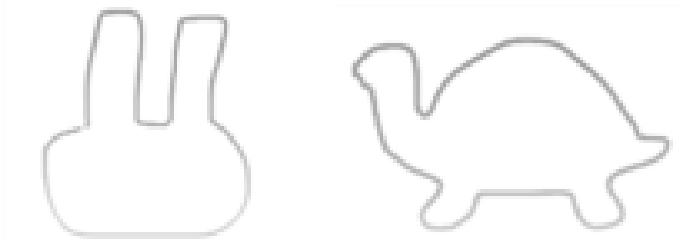


The result of the Boolean operation

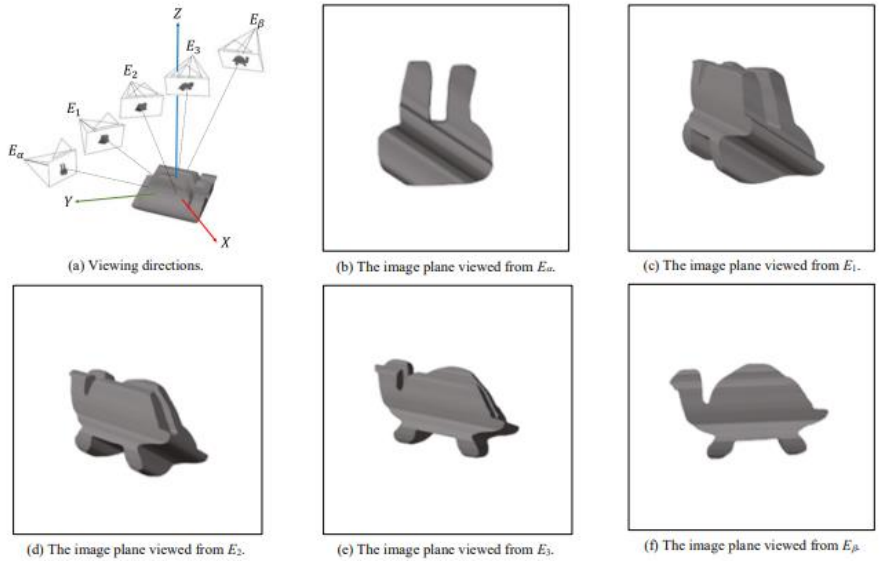
Experimental Results

Generated ambiguous objects consisting of simple and complex shapes using the proposed tool

Simple shapes (rabbit and turtle)



Input



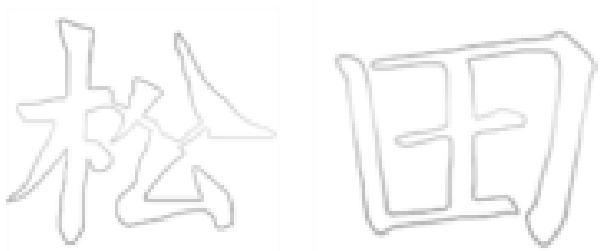
(a) Viewing directions. (b) The image plane viewed from E_α. (c) The image plane viewed from E_1.

(d) The image plane viewed from E_2. (e) The image plane viewed from E_3. (f) The image plane viewed from E_β.

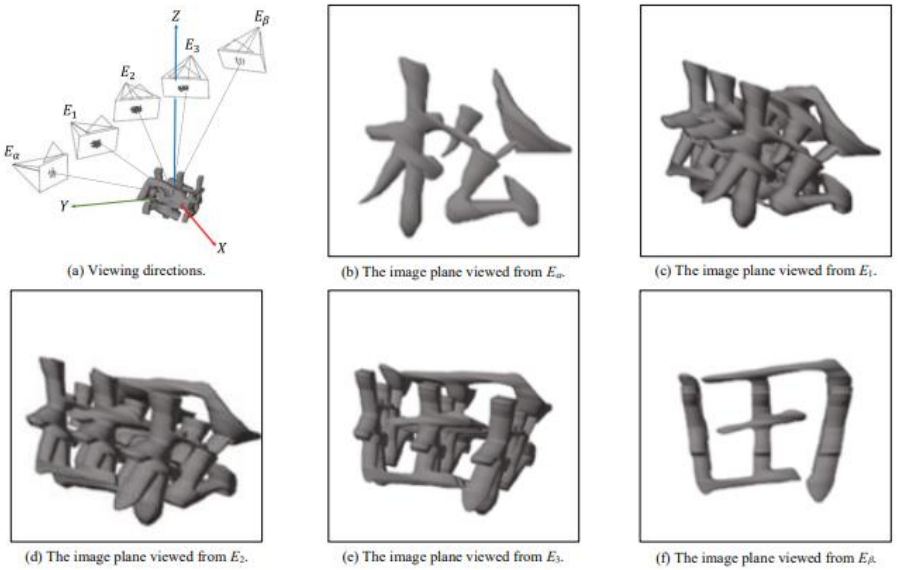
Output

Experimental Results

Complicated shapes ("Matsu" and "Ta" characters in Japanese kanji)
Designed to be drawn in one stroke.



Input



(a) Viewing directions. (b) The image plane viewed from E_α. (c) The image plane viewed from E_1.

(d) The image plane viewed from E_2. (e) The image plane viewed from E_3. (f) The image plane viewed from E_β.

Output

Conclusion

- It is possible to easily generate ambiguous solid models using the proposed tool
- Simply drawing two 2D shapes allows for the easy generation of ambiguous solid models
- Ambiguous objects are automatically generated by defining the viewing direction
- Unlike previous research, there is no need to modify 2D figures by changing the viewing direction

Future Work

- Current limitations of the proposed tool:
  - When the angle between the two viewing directions is very small, the resulting ambiguous object becomes thin and difficult to create using a 3D printer
  - Even a slight deviation in the viewing direction can result in an ambiguous object that differs from the intended appearance
- We plan to conduct a subjective evaluation experiment on the ambiguous object generation tool
- We will assess the robustness of the visibility of the generated ambiguous objects

References

[1]E.Rubin, "Figure and ground", Readings in perception, pp. 194-203, 1958.

[2]Kokichi Sugihara's Homepage (Japanese). http://www.isc.meiji.ac.jp/~kokichis/Welcomej.html, (accessed 2023-04-17)

[3] G. Elber, "Modeling (Seemingly) Impossible Models," Computer and Graphics, vol. 35, no. 3, pp. 632–638, 2011.

[4] K. Sugihara, "Spatial realization of Escher's impossible world," Proceedings of the 8th Hellenic-European Conference on Computer Mathematics and Its Applications, Athens, Greece, 2007.

[5] Y. -M. Kuo, H. -K. Chu, M. -T. Chi, R. -R. Lee, and T. -Y. Lee, "Generating Ambiguous Figure-Ground Images," in IEEE Transactions on Visualization and Computer Graphics, vol. 23, no. 5, pp. 1534-1545, 2017.

[6]S. Owada and J. Fujiki, "Interactive Stereopsis of Impossible Objects as Artistic Expression," Technical Report of the Institute of Image Information and Television Engineers, vol. 32, no. 14, pp. 43-46, 2008.

[7] S. Fukuda, "Shigeo Fukuda's Three-Dimensional Modeling," Kawade Shobo Shinsha, 1977.

[8] K. Sugihara, "Ambiguous Pillars: a New Class of Impossible Objects," Computer Aided Drafting, Design and Manufacturing, vol. 25, no. 4, pp. 19-25, 2015.