A Computational Model for Reasoning About the Paper Folding Task Using Visual Mental Images

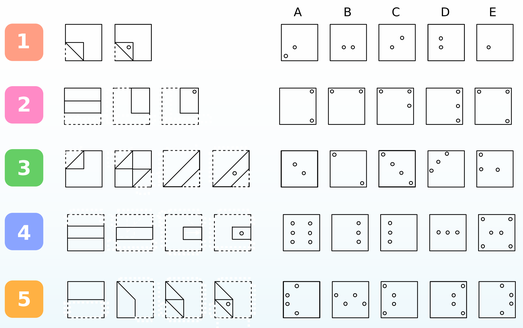
James Ainooson (james.ainooson@vanderbilt.edu) and Maithilee Kunda (mkunda@vanderbilt.edu)

VANDERBILT UNIVERSITY

Abstract

The paper folding task is commonly used for the evaluation of nonverbal, spatial reasoning skills. We present a computational model that attempts to use visual imagery based representations and operations to solve this task. The model was tested against all problems from the standard paper folding task and achieved a perfect score. Although the model managed to solve the task, the assumptions made and their implications for our understanding of human cognition on the paper folding task point to fruitful lines of future work.

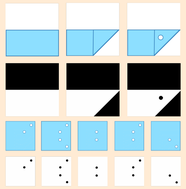
Try the Task here



Solution: 1-A 2-B 3-C 4-A 5-D

The Model

We present a model that attempts to solve the paper folding task using only imaging operations. Analogically, the model represents the folding of paper using a stack of bitmap images.



INPUT

Input is presented as three different sets of images. These are the set of fold images, the image with the punched hole and the set of possible outcomes after unfolding.

Strategy

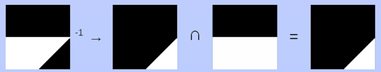
INITIALIZE 1

Initialize the image stack with a single blank image to represent a blank piece of paper.

INPUT 2

Receive a fold input for processing unto the stack

DETECT FOLD 3

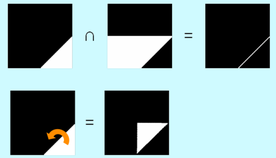


Invert the fold image (constrained by its bounding box) to generate the folded flap. Then,intersect this folded flap image with the image retrieved from the top of the stack to ensure th flap conforms with the current folded shape

PROPAGATE FOLD 4

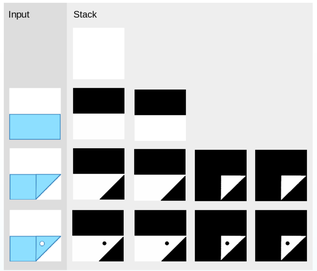
Replace the image on the stack with the result of its intersection with the fold input image

SIMULATE FOLD 5

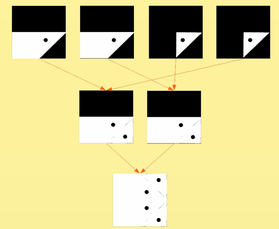


Detect the fold line by dilating the fold image and intersecting it with the input image. Folding can then be simulated by reflecting the folded flap image along the detected fold line.

Steps 2 to 5 are repeated for every fold input the model receives. See the figures below for changes that take place in the model when solving a sample task.



Changes in the as input folds are fed the model. The various input stages are on the left and the corresponding image stacks are on the right.



Changes in the stack for the various stages of the unfold operation. At each stage, the number of items on the stack is halfed.

Experiment

The model was tested against all the tasks in the paper folding test and it was able to solve them all. The size of the stack grew exponentially with every fold. For every n folds, there were 2n items on the stack.

Conclusions

Our model has shown one possible set of cognitive mechanisms, based on visual mental images, that are sufficient for solving the paper folding test. Other strategies undoubtedly exist. What is more interesting, perhaps, is a consideration of why people fail these tests. What sort of mechanisms do they lack?

In continued work, we will implement some cognitive limitations to see what might lead to which type of errors. We could then compare these errors to errors people make, to see if they are suggestive connections between cognitive strategy variations and behavorial patterns.

References

Ekstrom, R. B., French, J. W., Harman, H. H., & Dermen, D. (1976). Manual for kit of factor-referenced cognitive tests. *Princeton, NJ: Educational testing service.*

Laboratory for Artificial Intelligence and Visual Analogical Systems