Influence of 2D Shape on Contour Depth Perception

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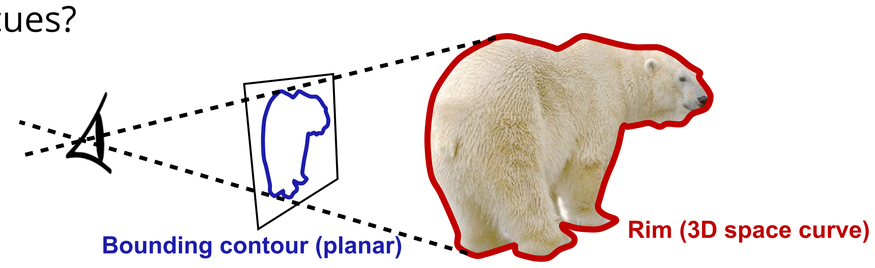
Introduction

An object's bounding contour in a 2D image projects from a 3D curve (the object rim [1]). Can the 3D rim be estimated from the shape of the 2D bounding contour alone? Do these monocular cues interact with binocular cues?



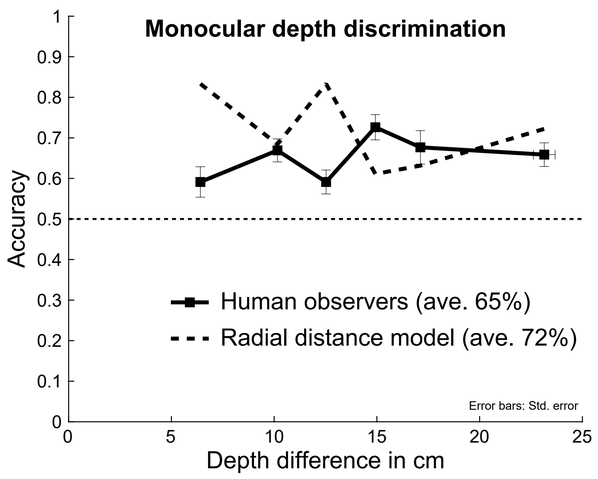
Monocular depth discrimination

Methods:

- 14 subjects, 110 objects
- Two points marked on contour, corresponding to minimum and maximum depth on rim
- Task: Which point is closer?
- Monocular presentation, unlimited response time, no feedback

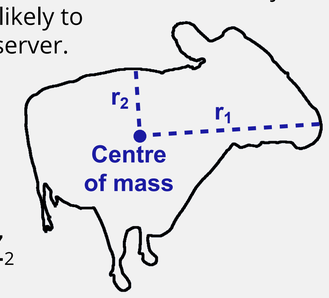
Example stimulus display

Results: People can make depth judgments from 2D bounding contours. Average performance is somewhat lower than a simple model based on radial distance to the centre of mass.



Radial distance model

In perspective projection, visual features increase in size as they move closer to the observer in depth. Boundary points further from the object center of mass are likely to be closer to the observer.



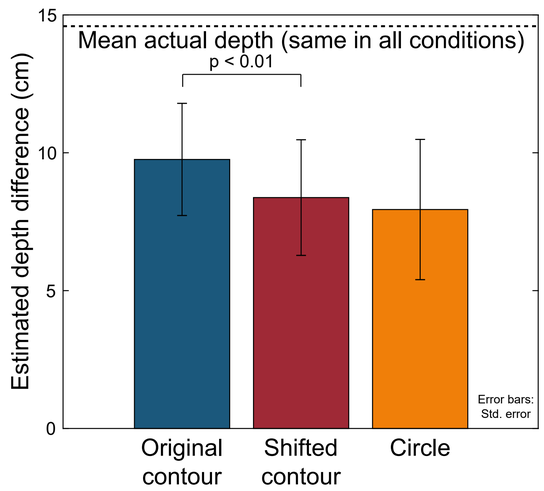
Algorithm:

$r_1 > r_2 \rightarrow Z_1 < Z_2$

Binocular depth estimation

Methods:

- 8 subjects, 47 objects
- Three contour conditions: original contour, shifted contour, circle
- Two points marked on contour, corresponding to minimum and maximum depth on rim
- Task: Estimate depth between points using a slider
- Binocular presentation, unlimited response time, no feedback

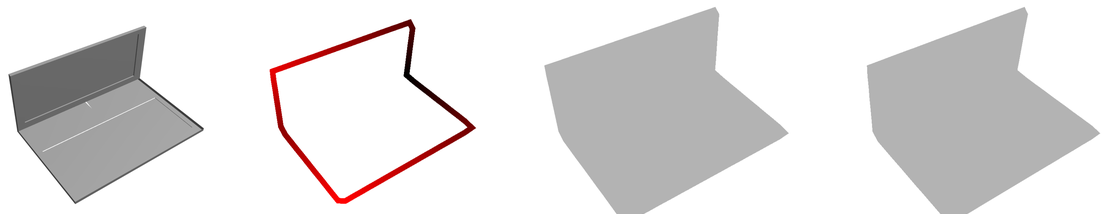


Results: Depth estimation was most accurate when the 2D contour shape matched the 3D depth information.

References:
[1] Koenderink, J. J. (1984). The structure of images. Biological Cybernetics, 50(5), 363-370.
[2] Chang, A. X., et al. (2015). ShapeNet: An Information-Rich 3D Model Repository. arXiv:1512.03012.

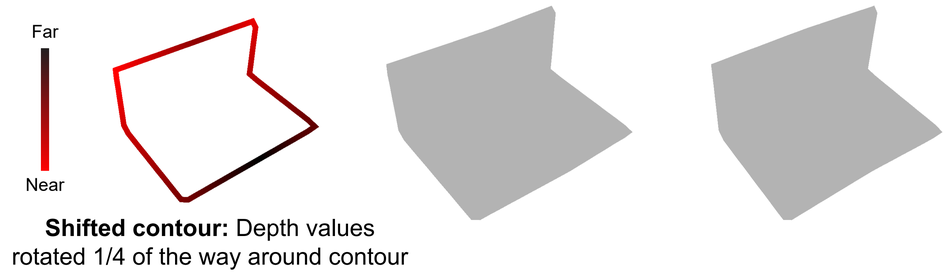
Stimuli

Stimuli were created from ShapeNet [2] 3D models, rendered to match the parameters of the stereoscopic display (objects subtend 28 d.v.a. at a viewing distance of 40 cm).

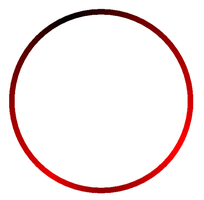


ShapeNet object

Original contour: Depth values match 3D object's rim



Shifted contour: Depth values rotated 1/4 of the way around contour



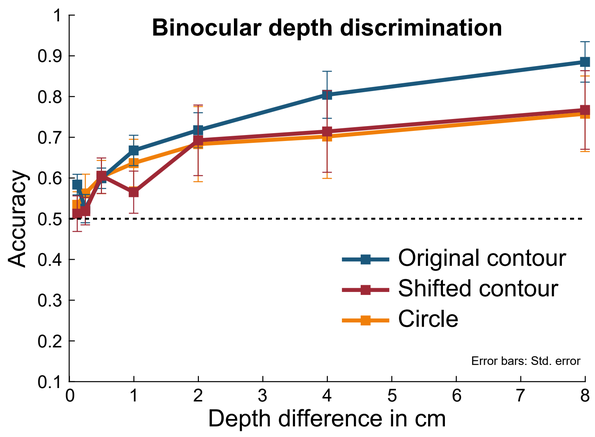
Circle: Depth values mapped to circle

Uncrossed fusion examples

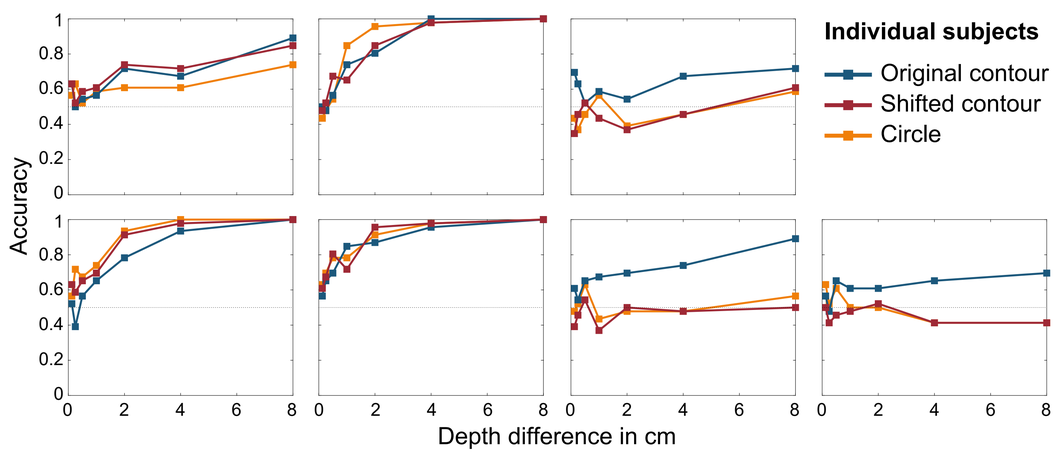
Binocular depth discrimination

Methods:

- 7 subjects, 110 objects
- Three contour conditions: original contour, shifted contour, circle
- Two points marked at specific depth differences, 0.125 - 8 cm
- Task: Which point is closer?
- Binocular presentation, unlimited response time, no feedback



Results: Depth discrimination was most accurate when the 2D contour shape was consistent with the 3D depth information. Some subjects were more affected by inconsistent monocular shape cues than others.



Conclusions

People can use information from the 2D contour shape to judge 3D depth relations on object boundaries. These monocular boundary cues interact with binocular cues in determining depth judgements.