

Introduction to computer vision IX

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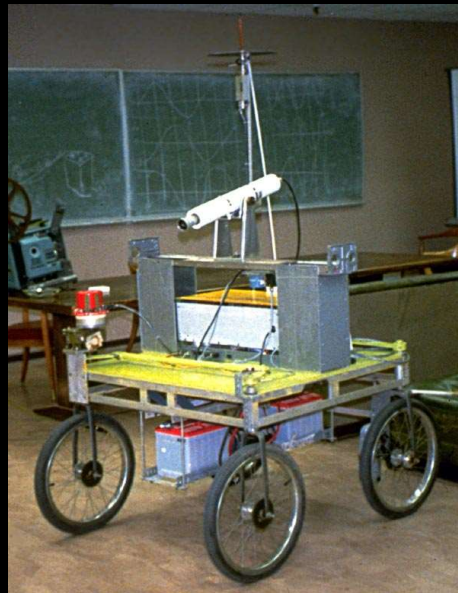
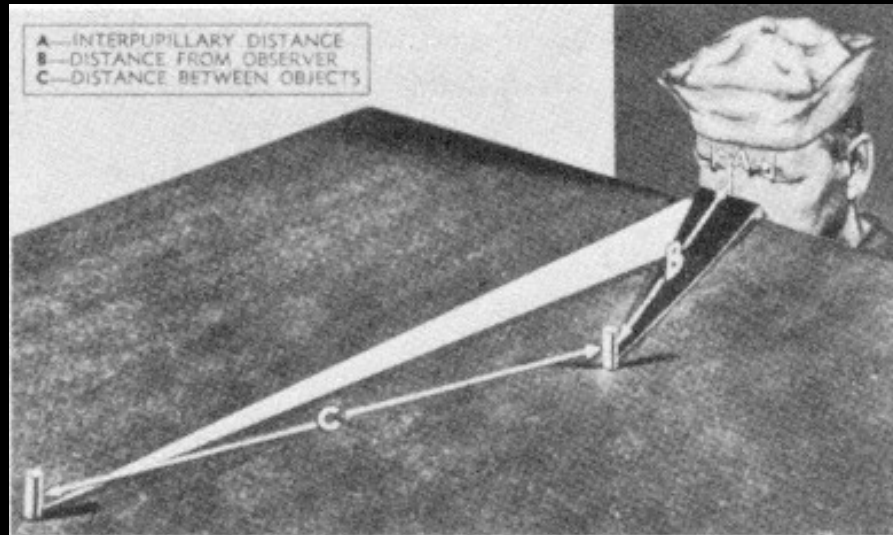
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Slides will be available after class at:
<https://mtrager.github.io/introCV-fall2019/>

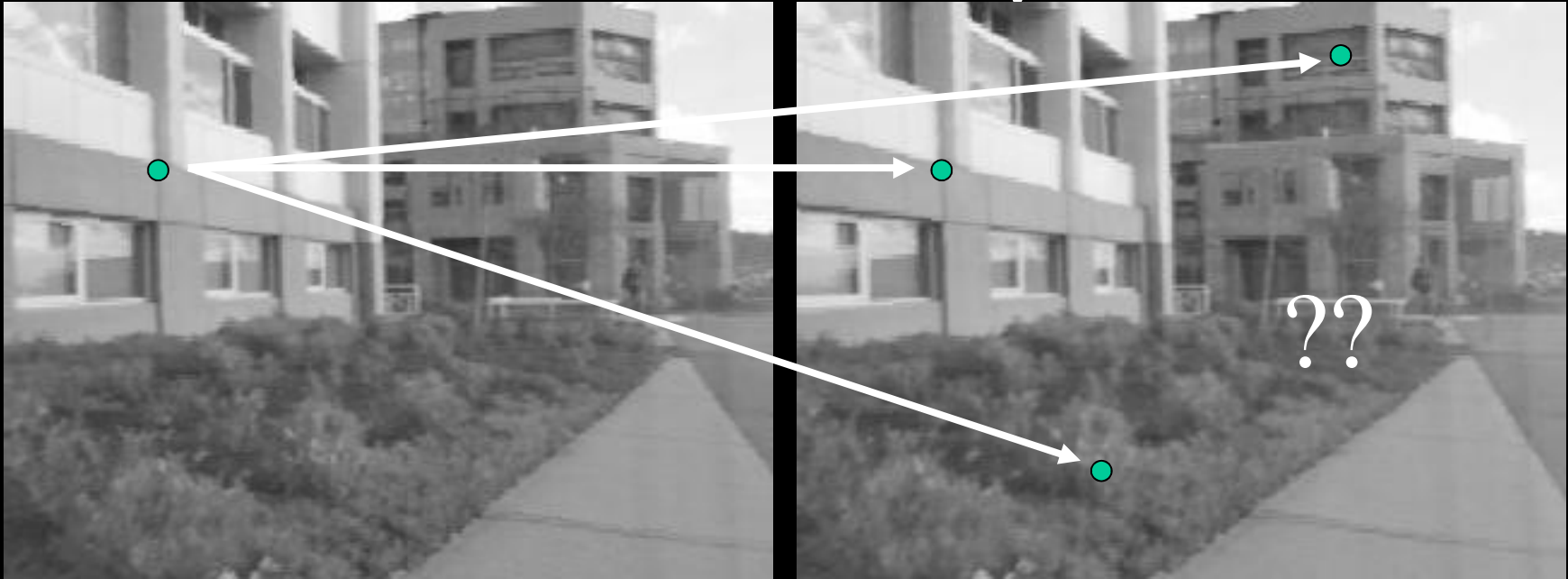
Stereopsis and two-view geometry

- Binocular stereo in people and machines
- Triangulation and fusion
- A detour through human stereopsis
- Epipolar geometry
- Essential and fundamental matrices
- The eight-point algorithm
- Correlation-based stereo
- More sophisticated methods

How do we perceive depth?



Two-View Geometry: Stereo



Method:

- Find correspondences



Two-View Geometry: Stereo

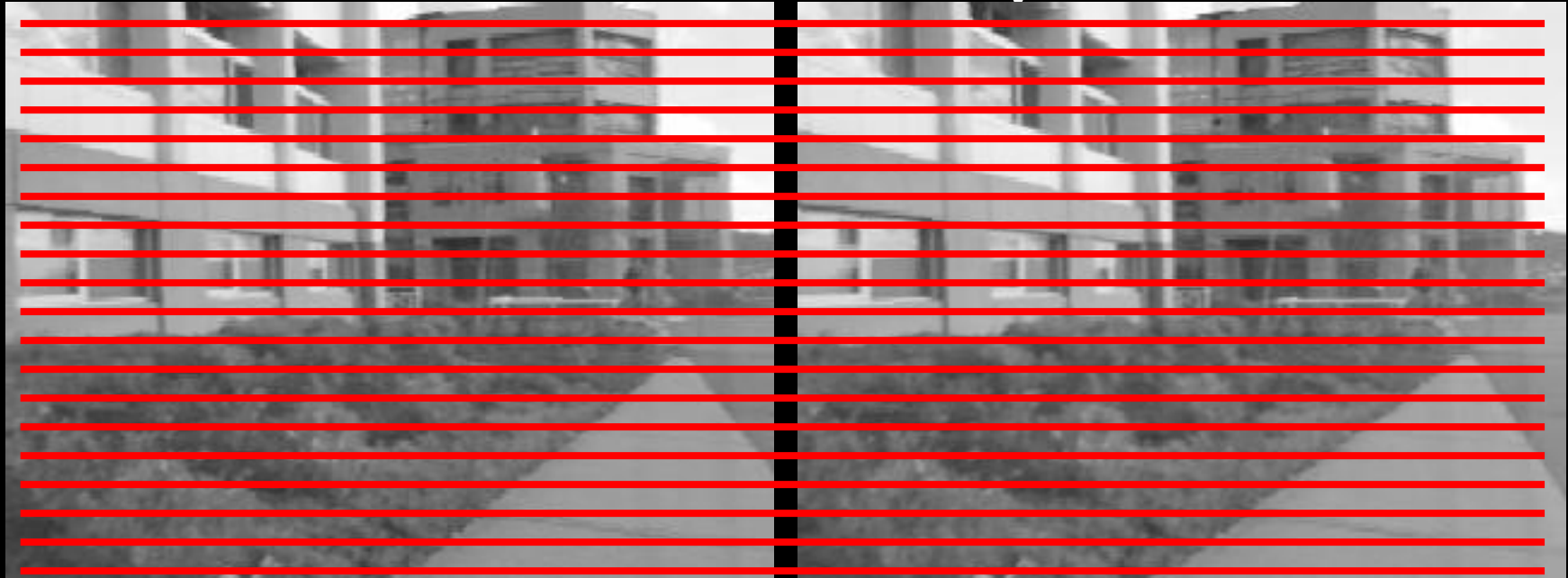


Method:

- Find correspondences
- Along epipolar lines



Two-View Geometry: Stereo

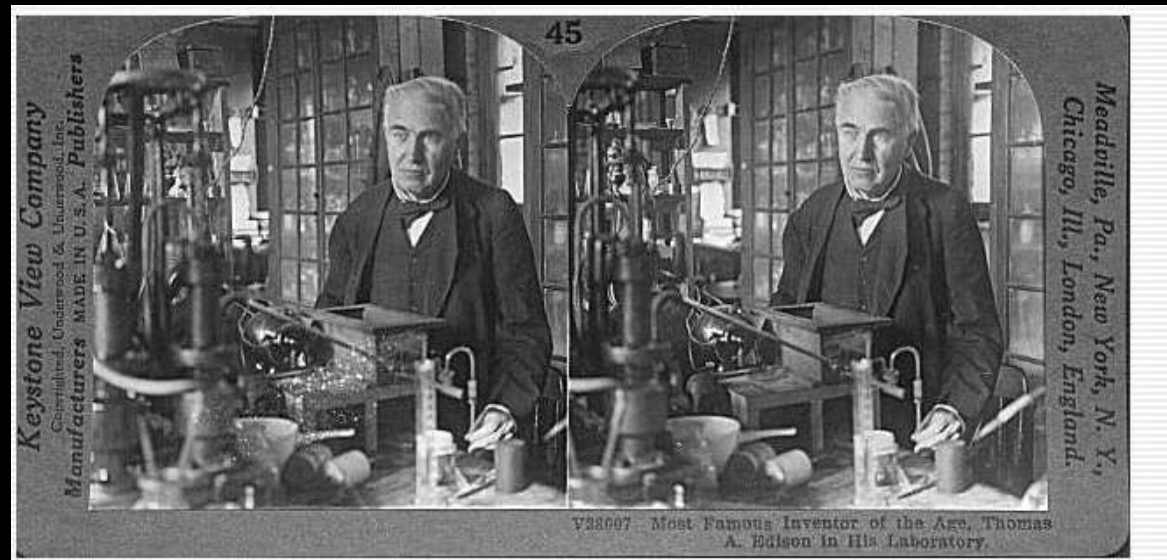


Epipolar lines for
rectified cameras



Binocular stereo

Two images can be fused to give a sense of depth!



Stereograms: Invented by Charles Wheatstone, 1838

Triangulation

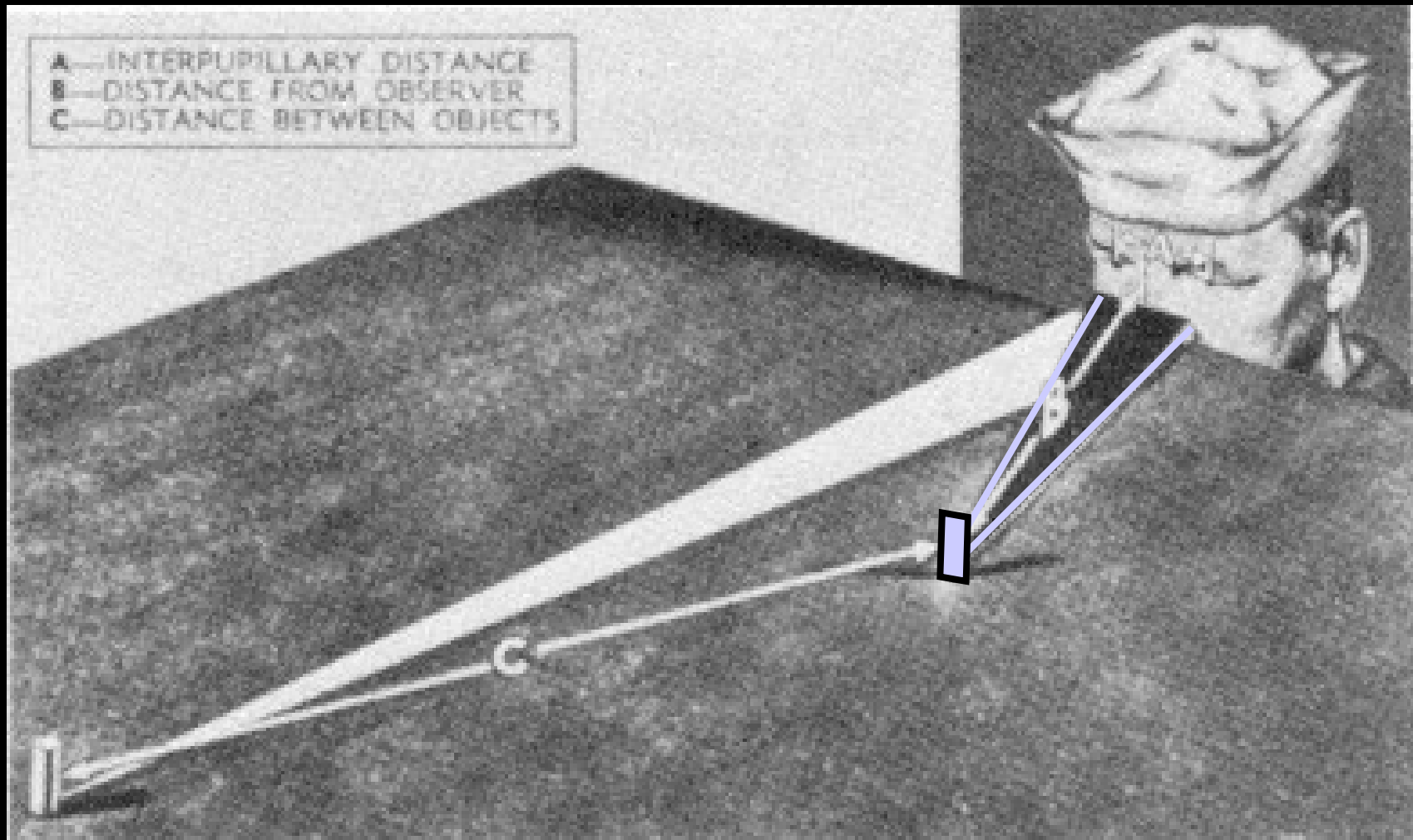


Figure extraite de "US Navy Manual of Basic Optics and Optical Instruments", Bureau of Naval Personnel. Reprinted by Dover Publications, Inc., 1969.

Triangulation

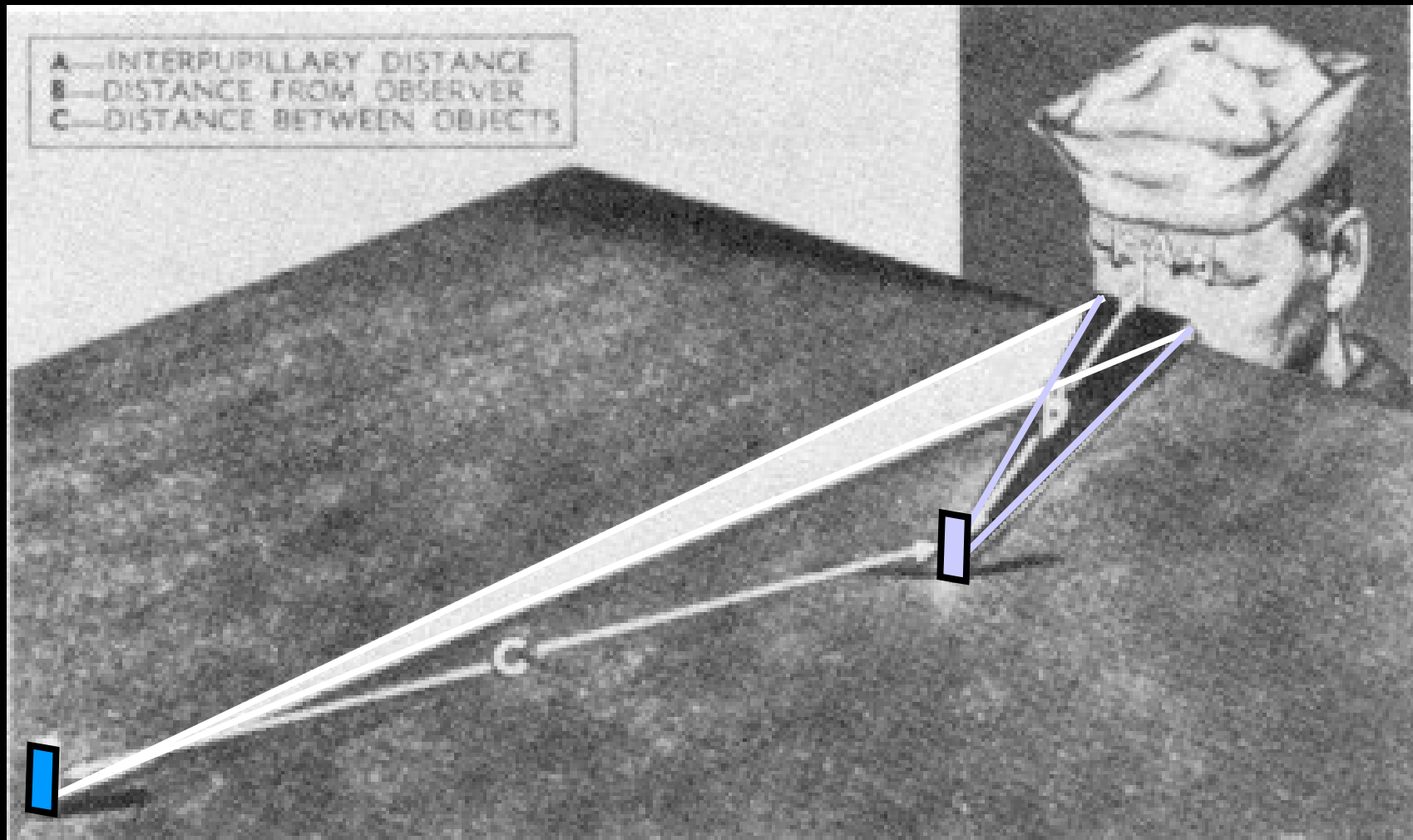


Figure extraite de "US Navy Manual of Basic Optics and Optical Instruments", Bureau of Naval Personnel. Reprinted by Dover Publications, Inc., 1969.

Why movies look "flat" on TV

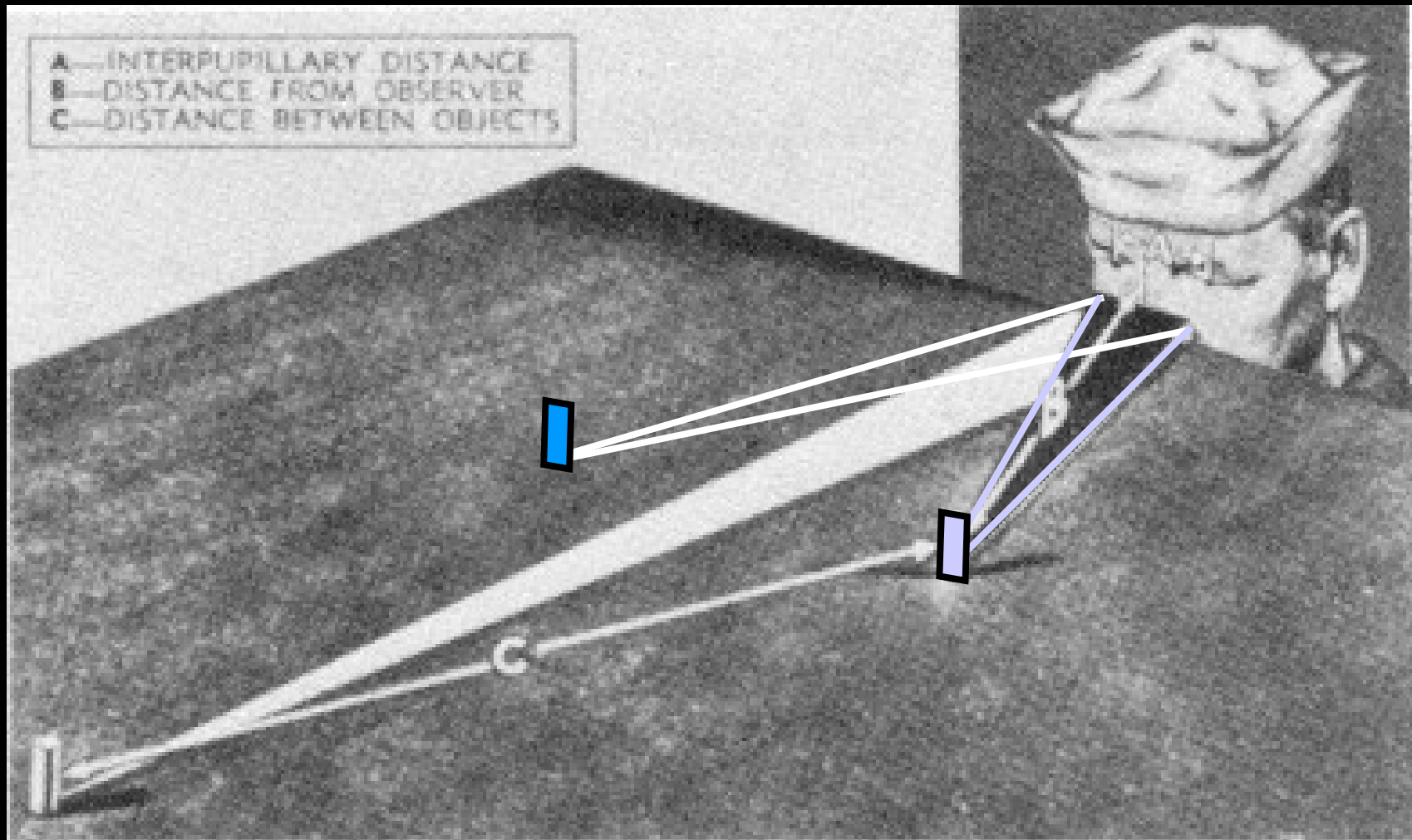


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Why movies look "flat" on TV

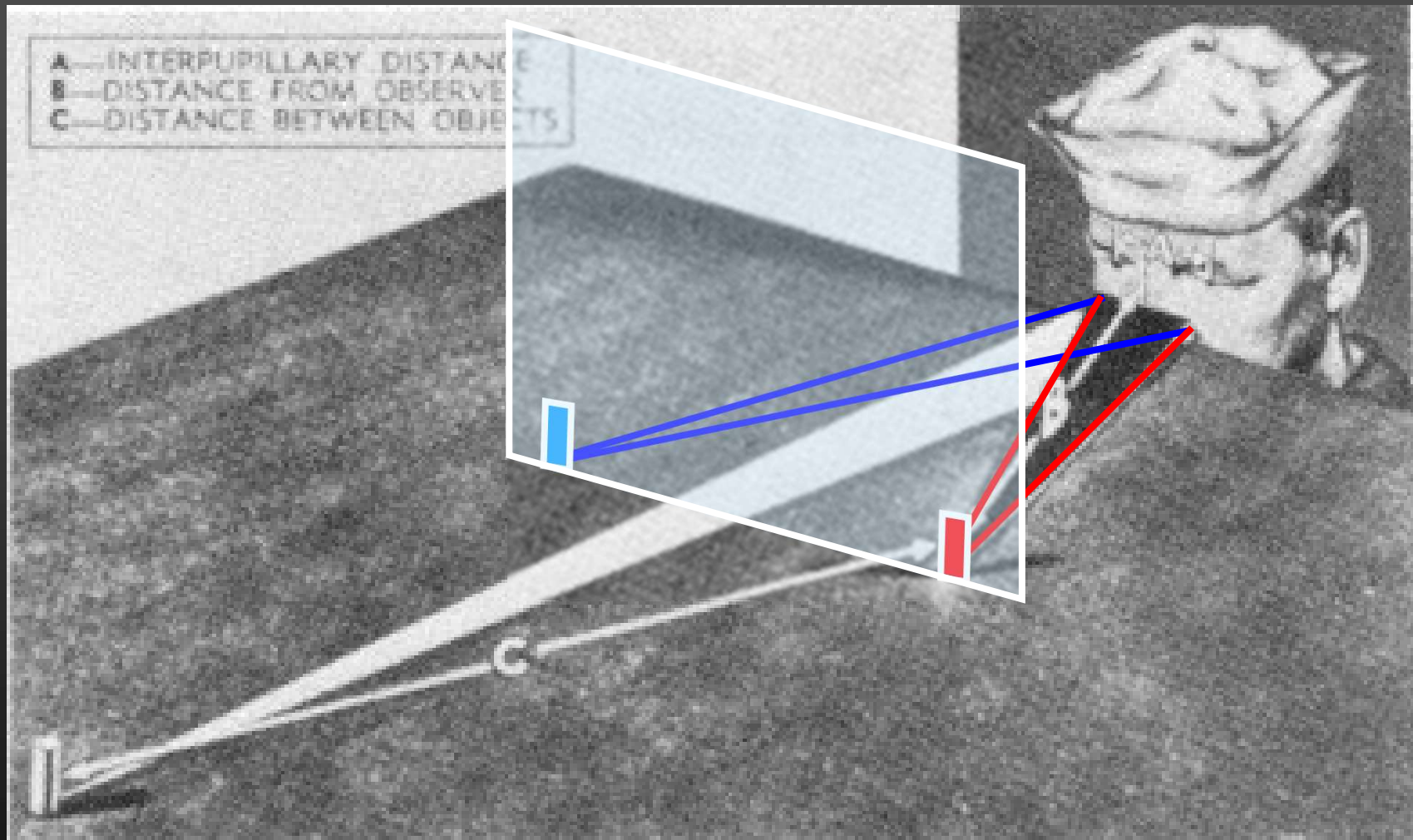


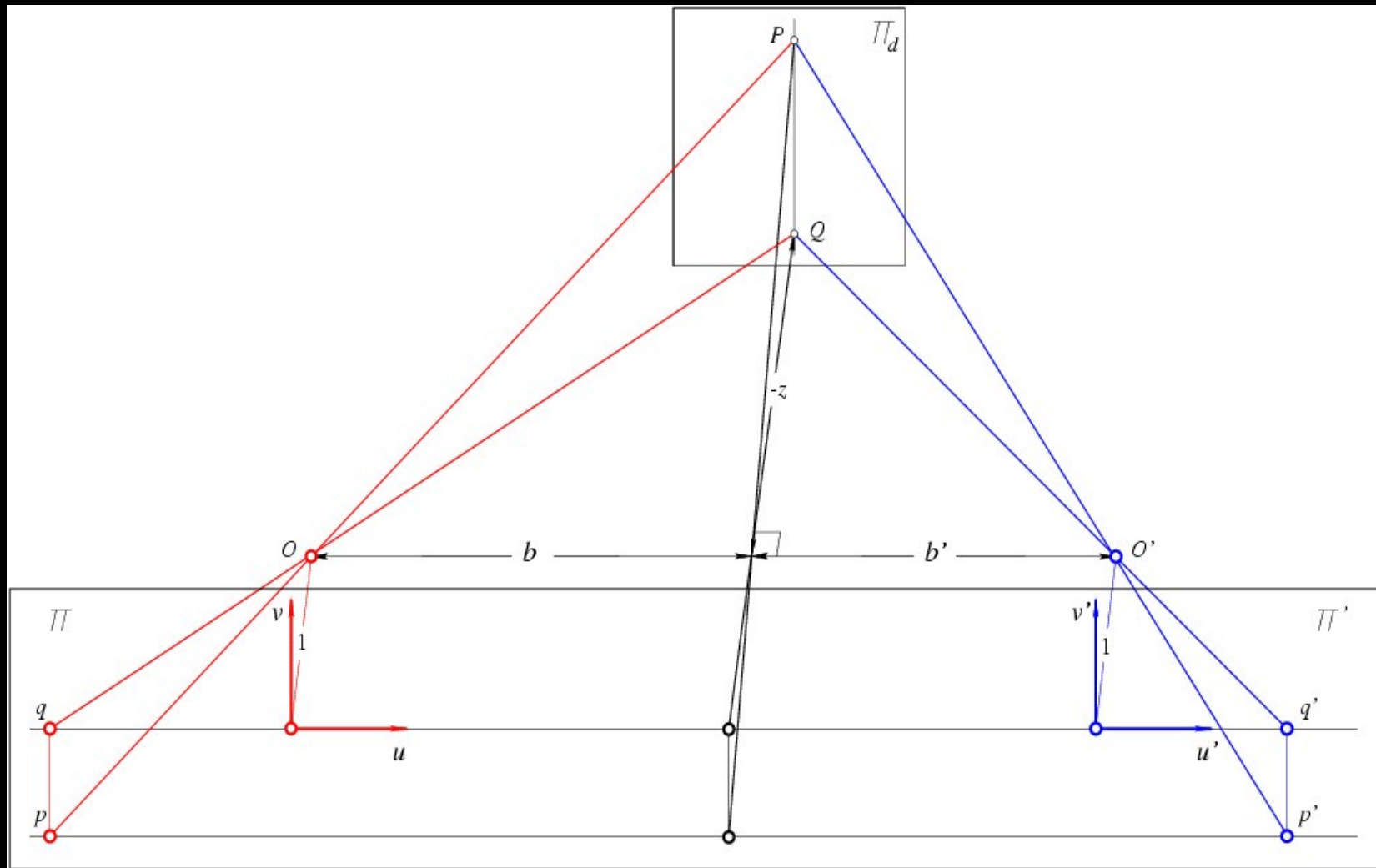
Figure extraite de "US Navy Manual of Basic Optics and Optical Instruments", Bureau of Naval Personnel. Reprinted by Dover Publications, Inc., 1969.

This is why people make 3D movies



Courtesy of Steve Seitz

Reconstruction from rectified images

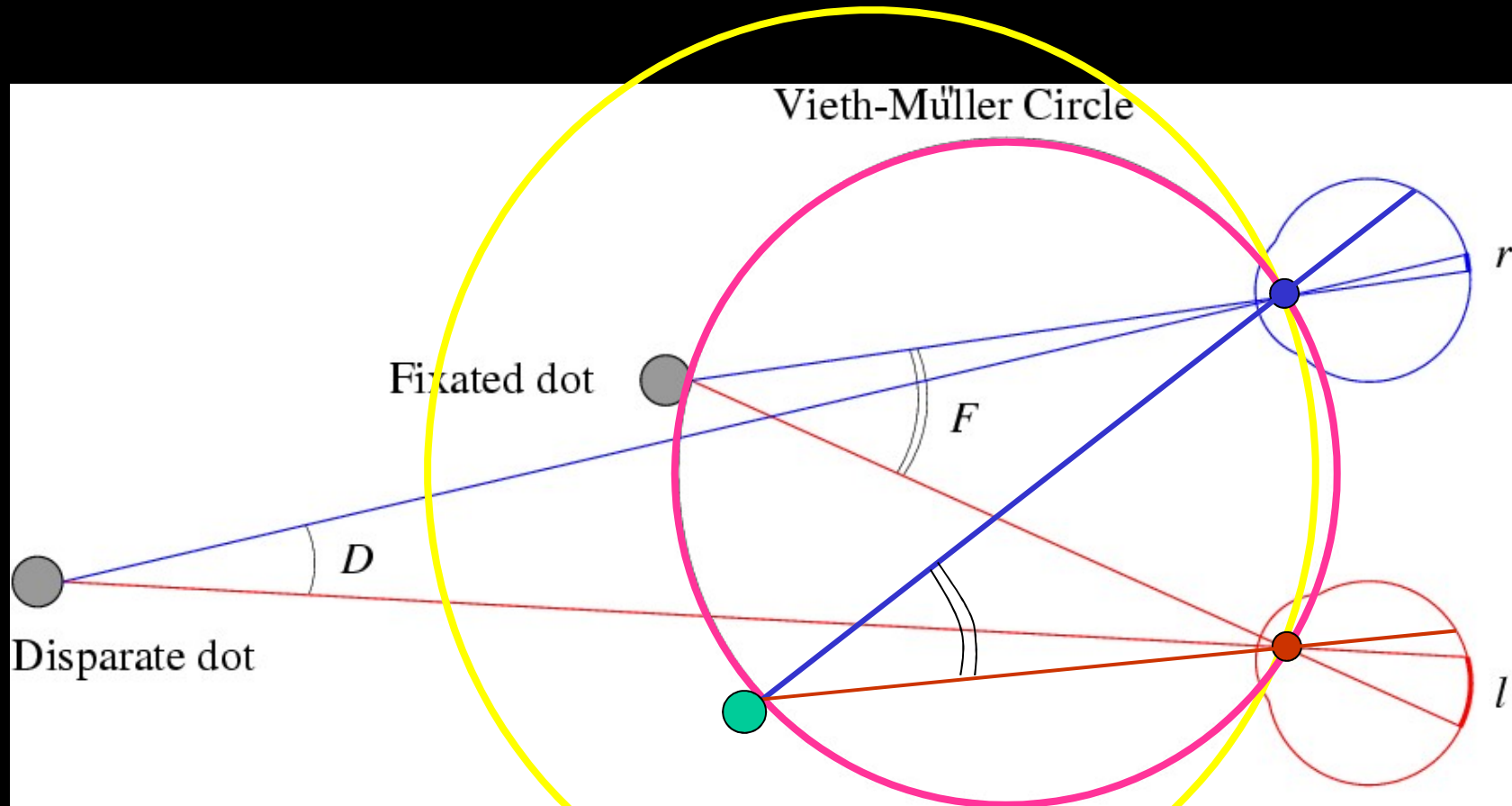


Disparity: $d = u' - u$.



Depth: $z = -B/d$.

Triangulation for human eyes



Disparity: $d = r - l = D - F$.

$d < 0$

In 3D, the horopter.

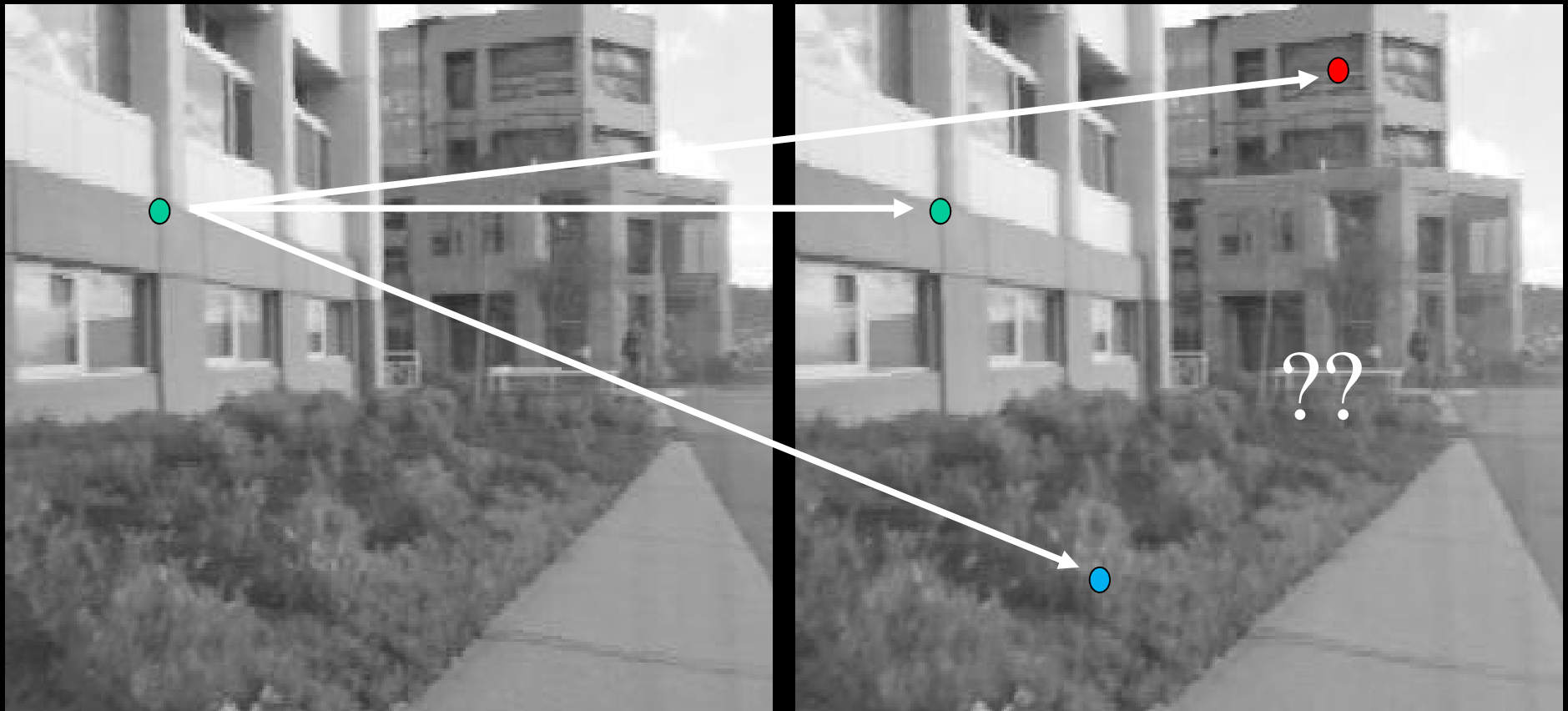
Triangulation for "uncalibrated" human eyes

What if F is not known?

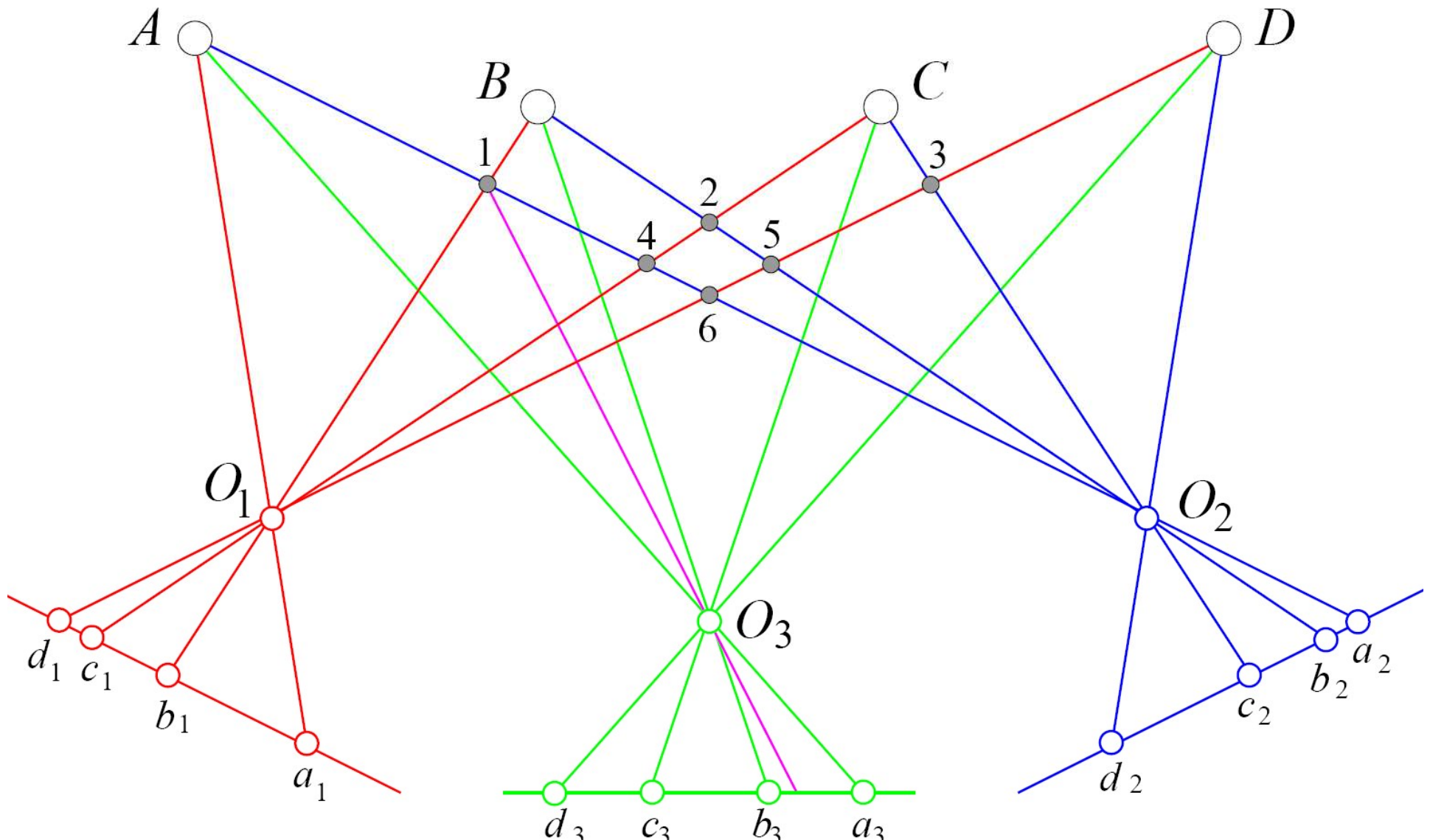
Helmholtz (1909):

- There is evidence showing that the vergence angles cannot be measured precisely.
- People get fooled by bas-relief sculptures.
- There is an analytical explanation for this.
- Relative depth can be judged accurately.

A problem of correspondence



A third eye might come in handy



A third eye might come in handy



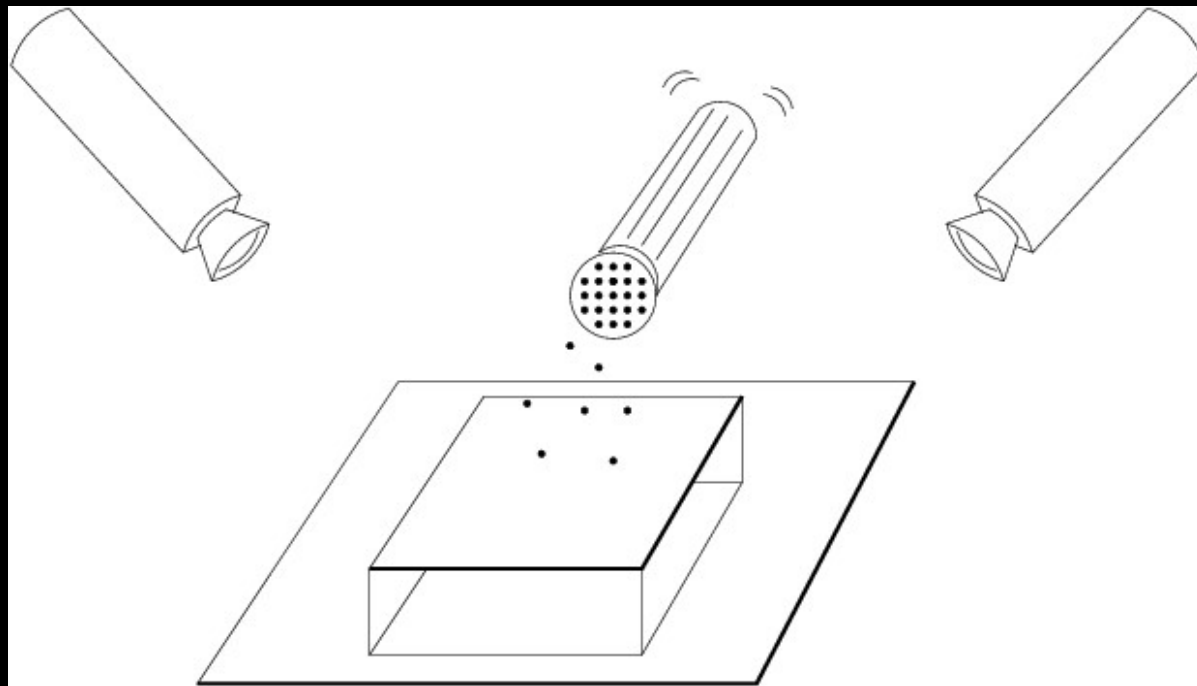
Courtesy of Olivier Faugas

What is the mechanism behind human binocular fusion?

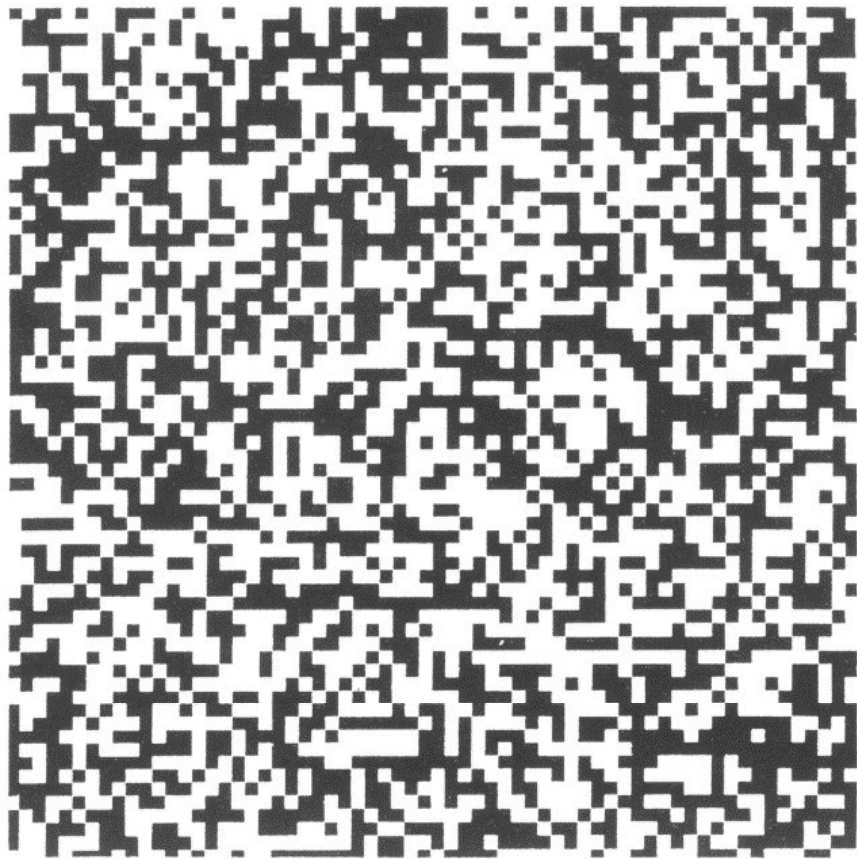
How are the correspondences established?

Julesz (1971): Is the mechanism for binocular fusion a monocular process or a binocular one??

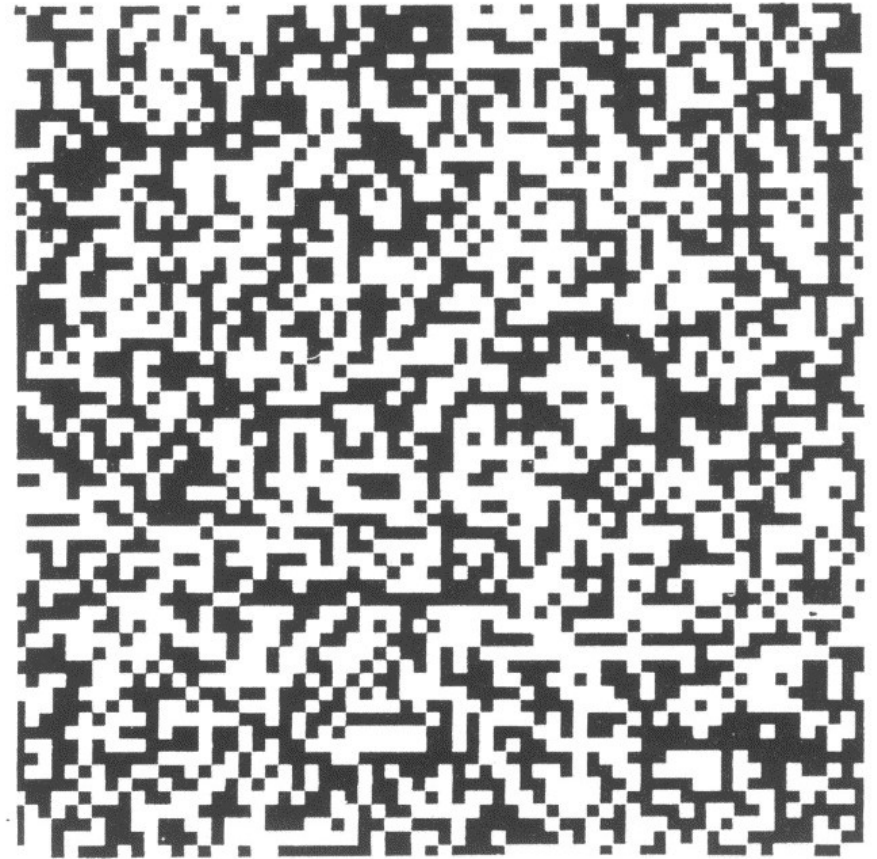
- There is anecdotal evidence for the latter (camouflage).



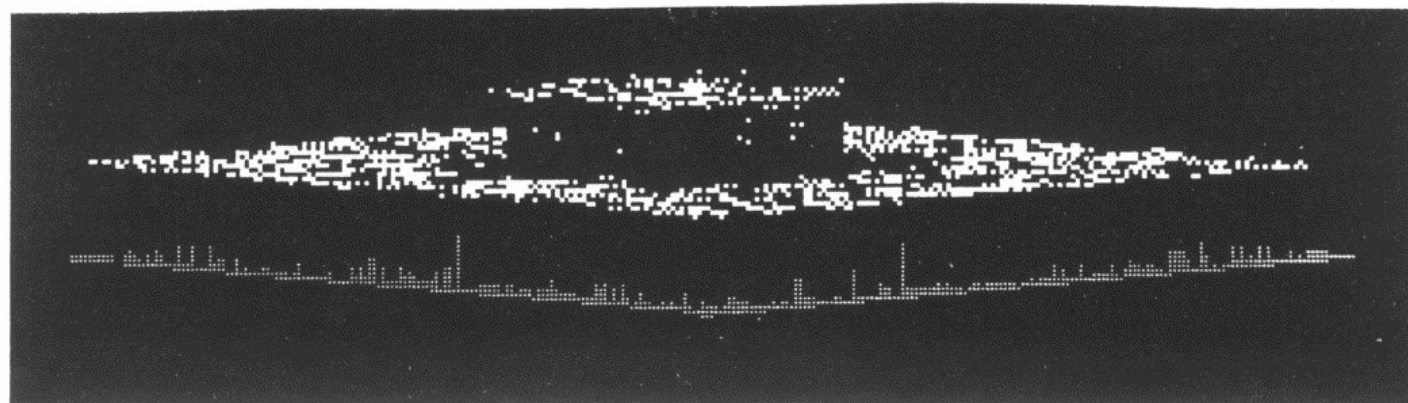
- Random dot stereograms provide an objective answer



Left



Right



The curious case of Elizabeth Stromeyer

The Detailed Texture of Eidetic Images

by

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Massachusetts Institute of Technology, and
Laboratory of Psychophysics,
Harvard University

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Department of Psychology,
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Cambridge, Massachusetts

Random dot stereograms are used to test the clarity and duration of eidetic images.

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Excerpts:

We have found, quite by accident, an observer who can accurately report the figure seen in depth when the interval between the observations is as great as 24 h. The observer never guessed or hesitated in making reports, but immediately reported the figures and claimed the task was "ridiculously easy".

Recently we have successfully carried out double-blind random-dot stereogram experiments with our observer; neither the experimenter nor the observer knew what the figures were. Patterns with ten-thousand elements were used with intervals as long as 3 days; and million dot patterns with intervals as long as 4 h.

Why movies look "flat" on TV

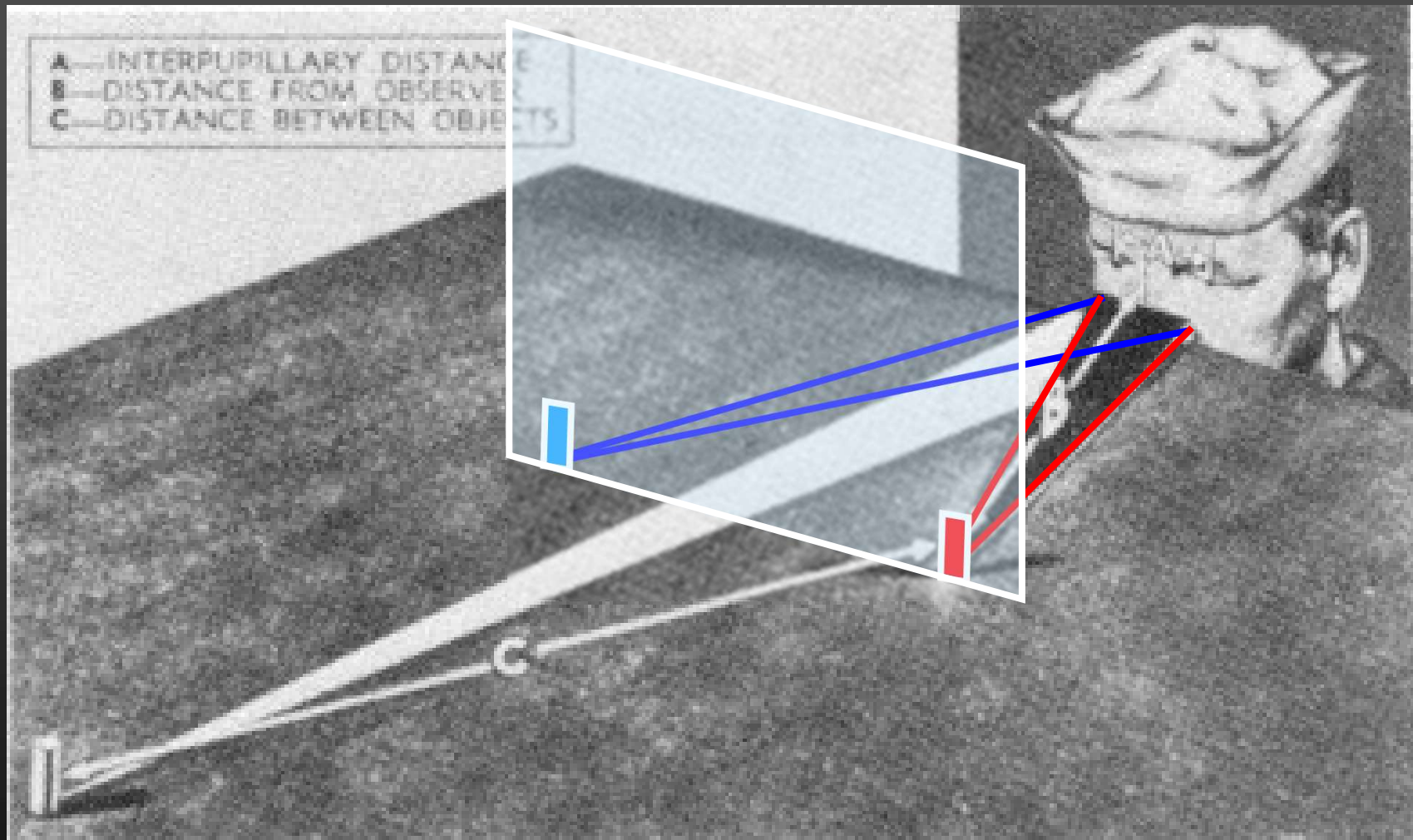


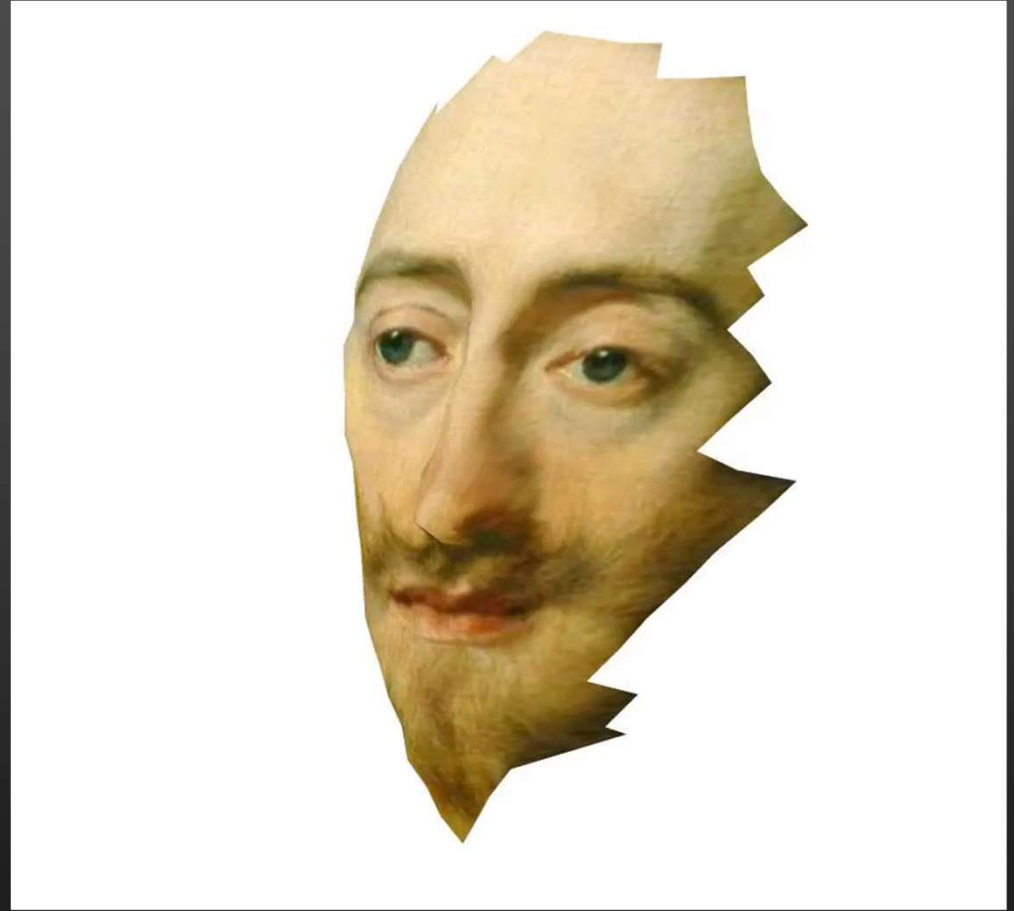
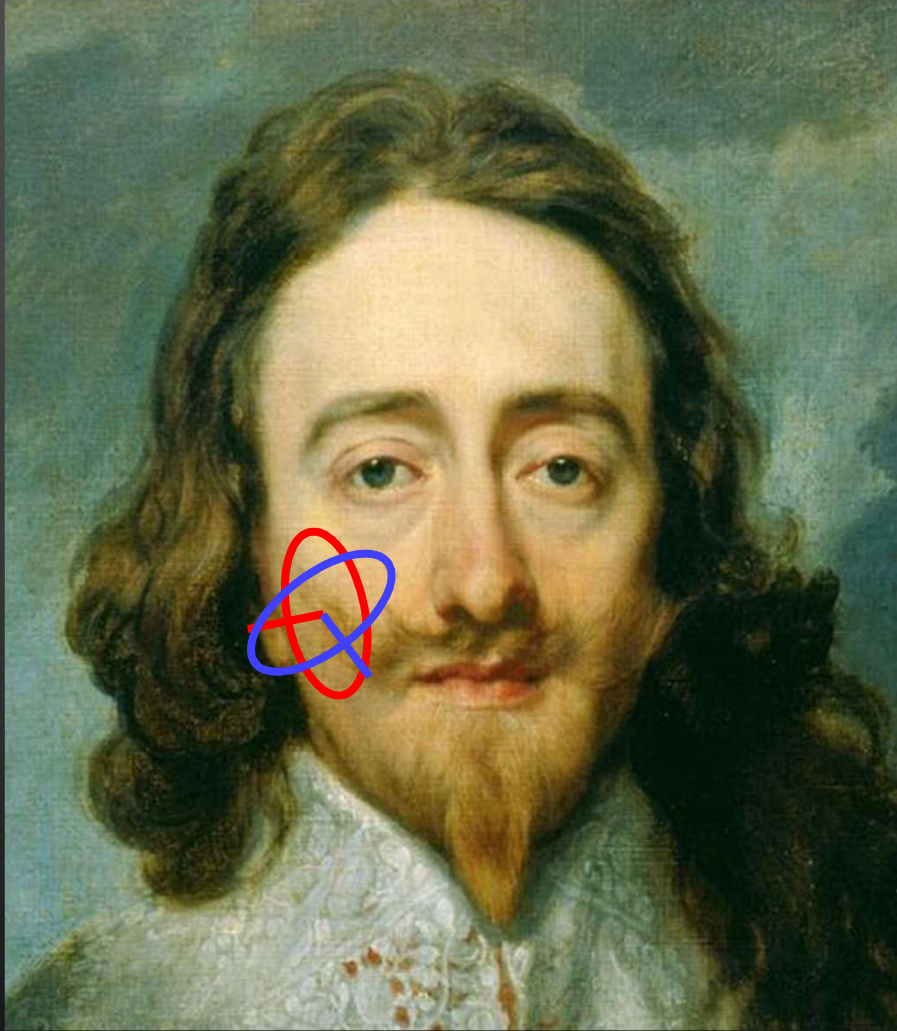
Figure extraite de "US Navy Manual of Basic Optics and Optical Instruments", Bureau of Naval Personnel. Reprinted by Dover Publications, Inc., 1969.

But do we really need two eyes to
"see in 3D" ?

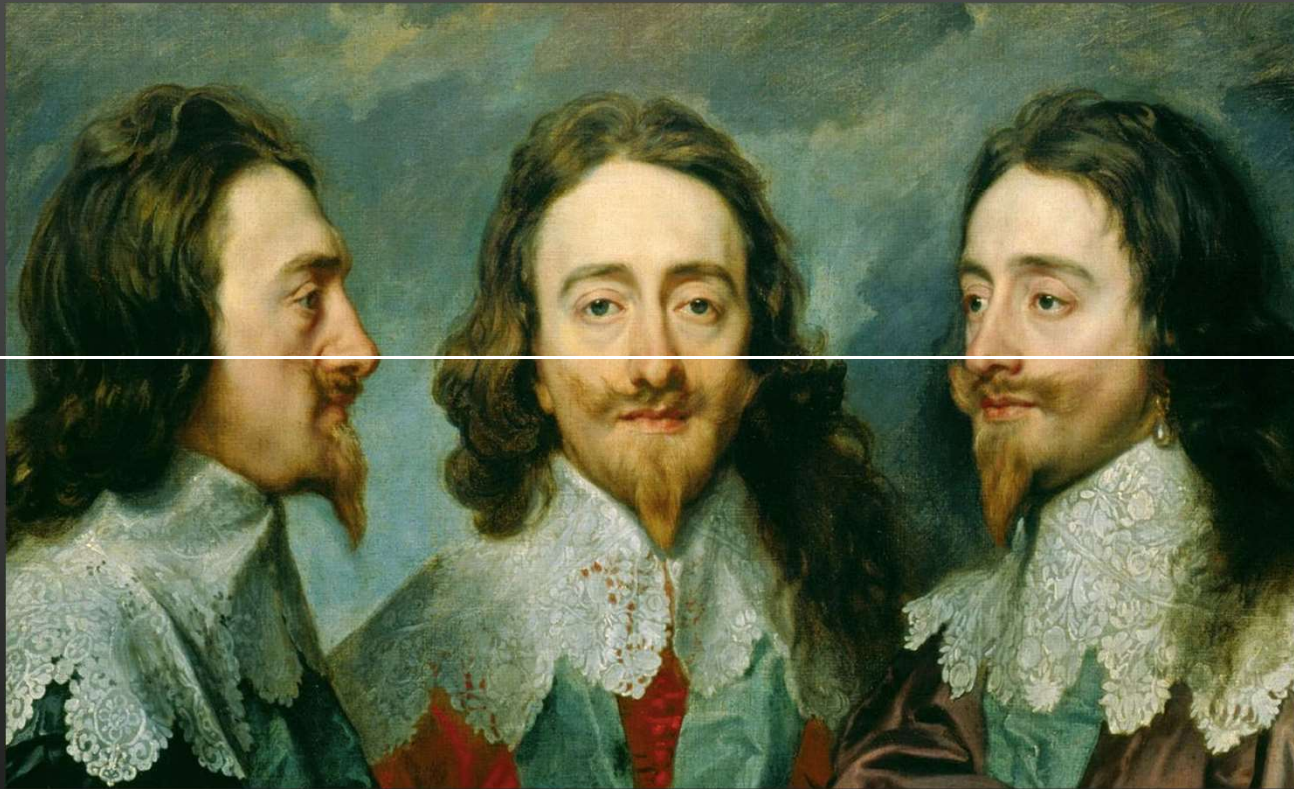


Jan J. Koenderink
Univ. de Delft, NL

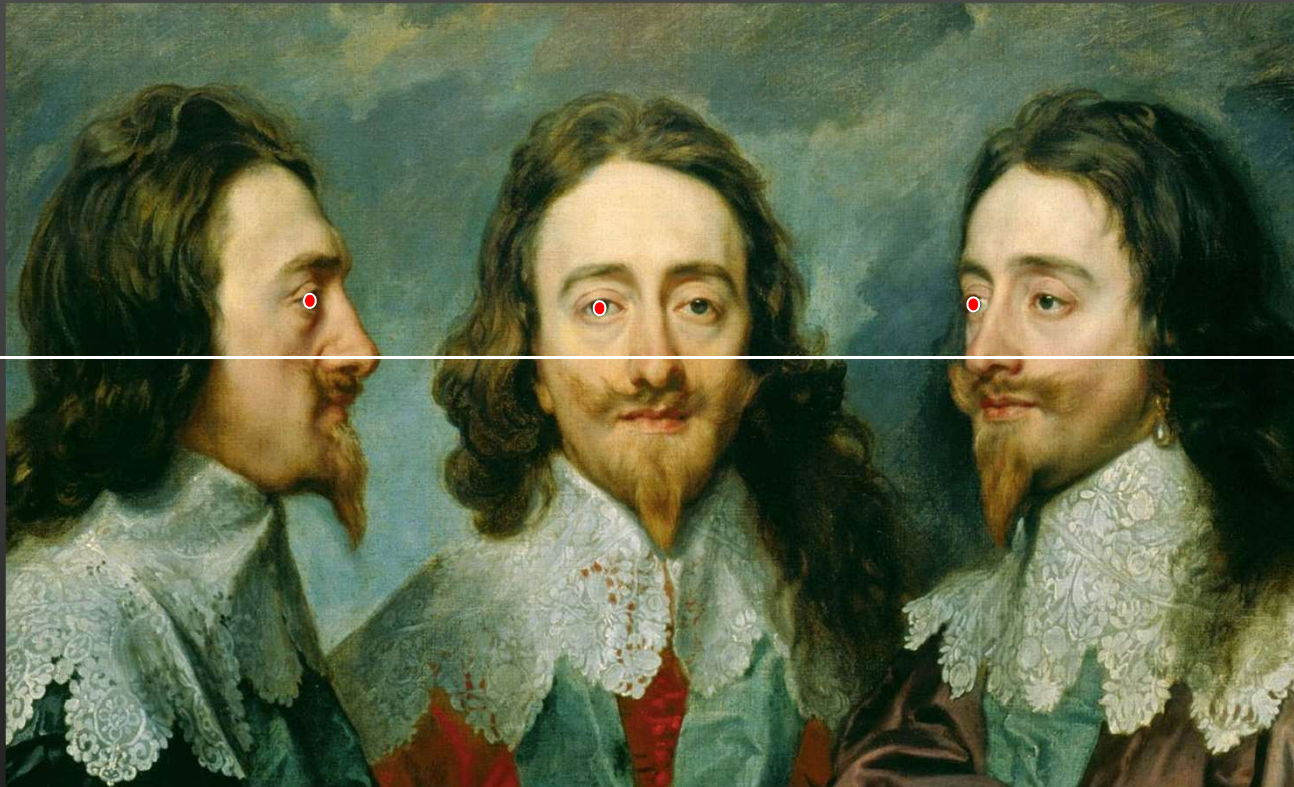
Probing shape perception from pictures with gauge figures



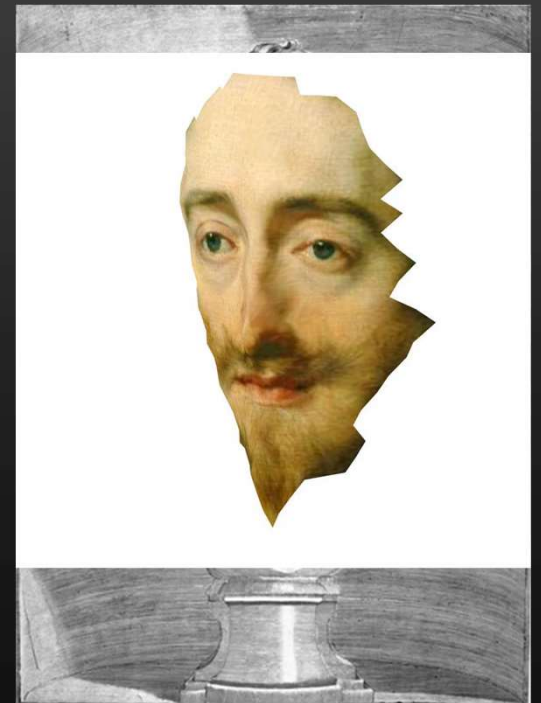
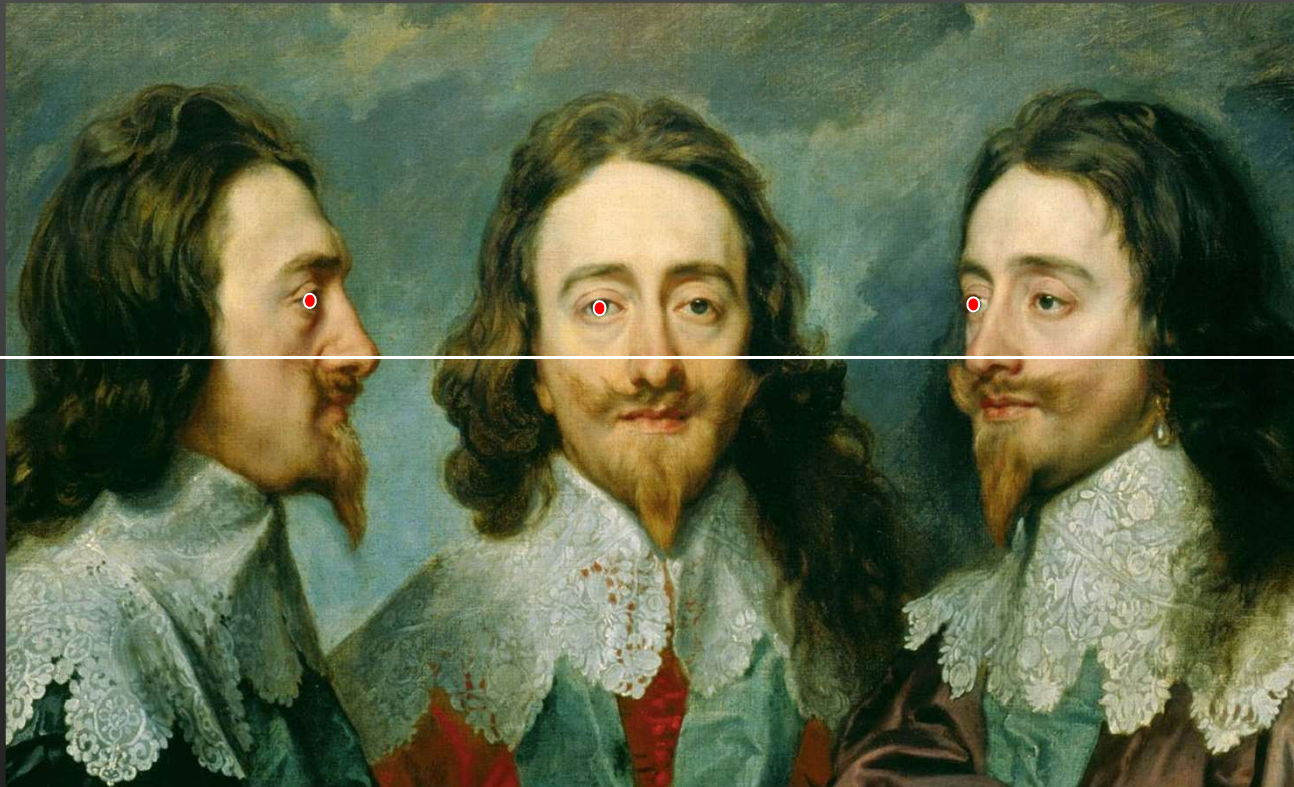
Van Dyck's portrait of Charles I (detail)



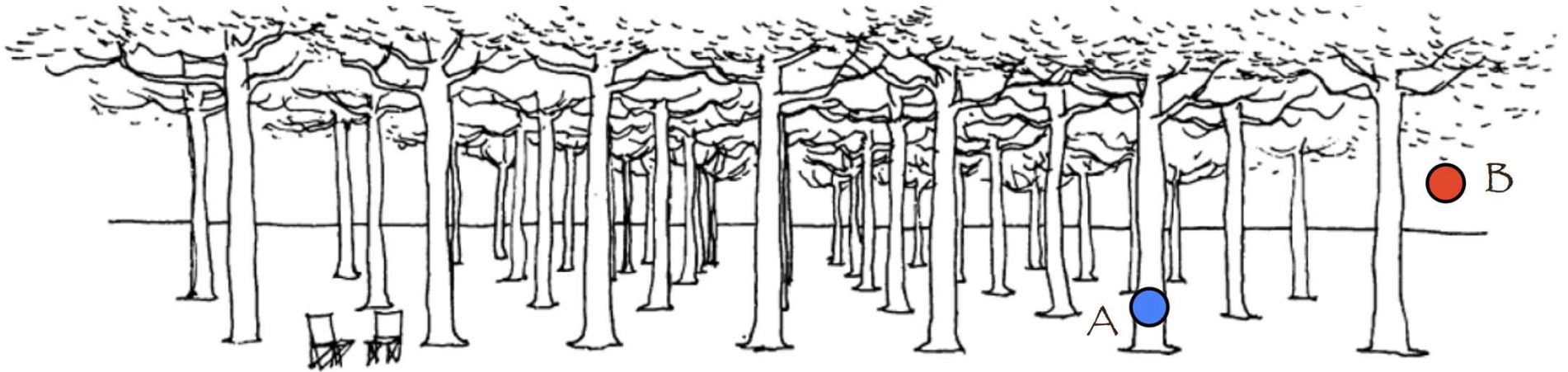
Van Dyck's triple portrait of Charles I with a copy of Bernini's bust and an engraving by von Voerst of the bust



Van Dyck's triple portrait of Charles I with a copy of Bernini's bust and an engraving by von Voerst of the bust



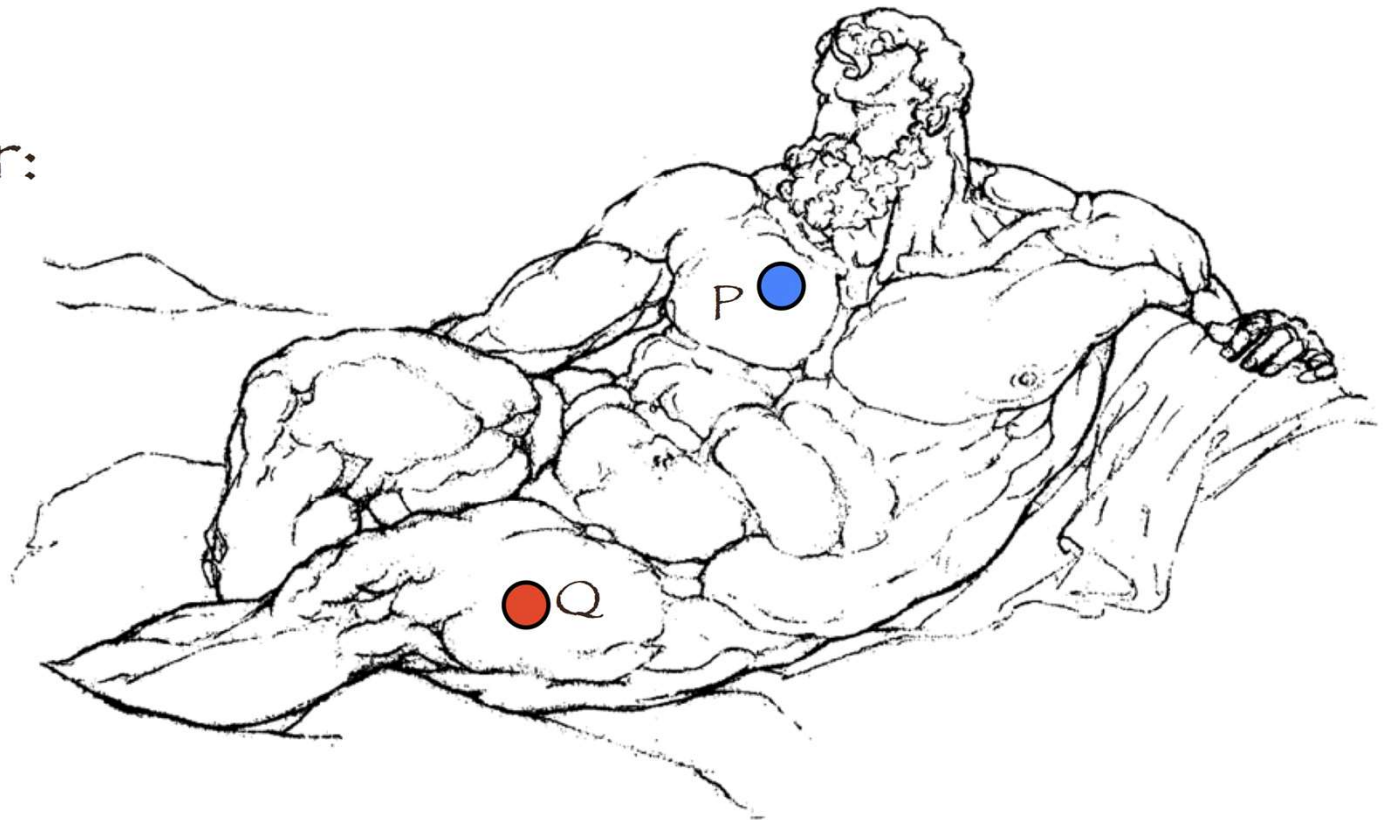
Van Dyck's triple portrait of Charles I with a copy of Bernini's bust and an engraving by von Voerst of the bust



which is nearer:

P or Q?

A or B?



Looks like we can tell within the same hill but not across hills
[Koenderink, van Doorn, Wagemans, 2015]



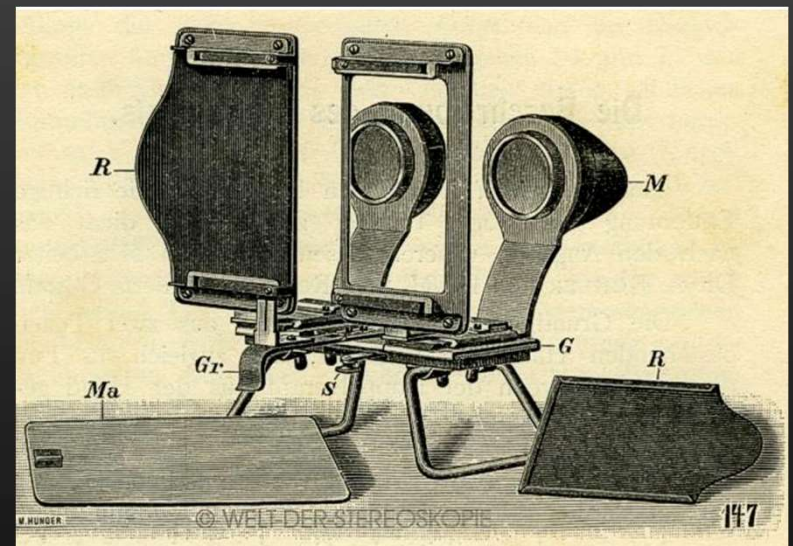
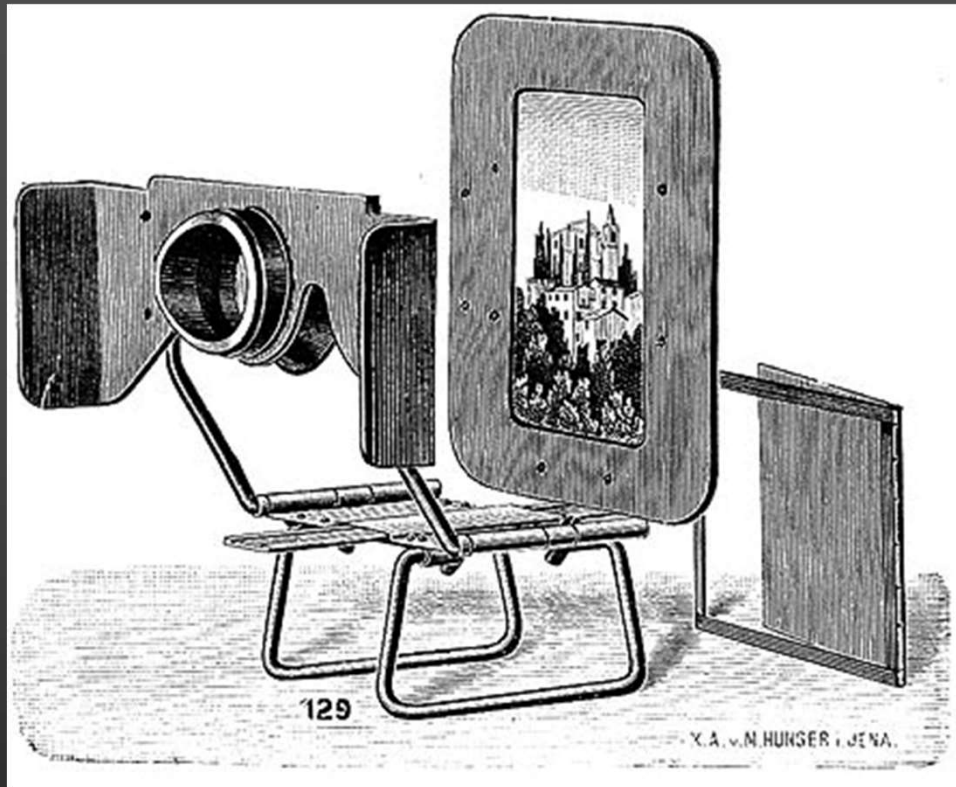
Steropsis is spatial (3D) vision. It is not limited to binocular steropsis. Of course the lamb “sees depth” too!



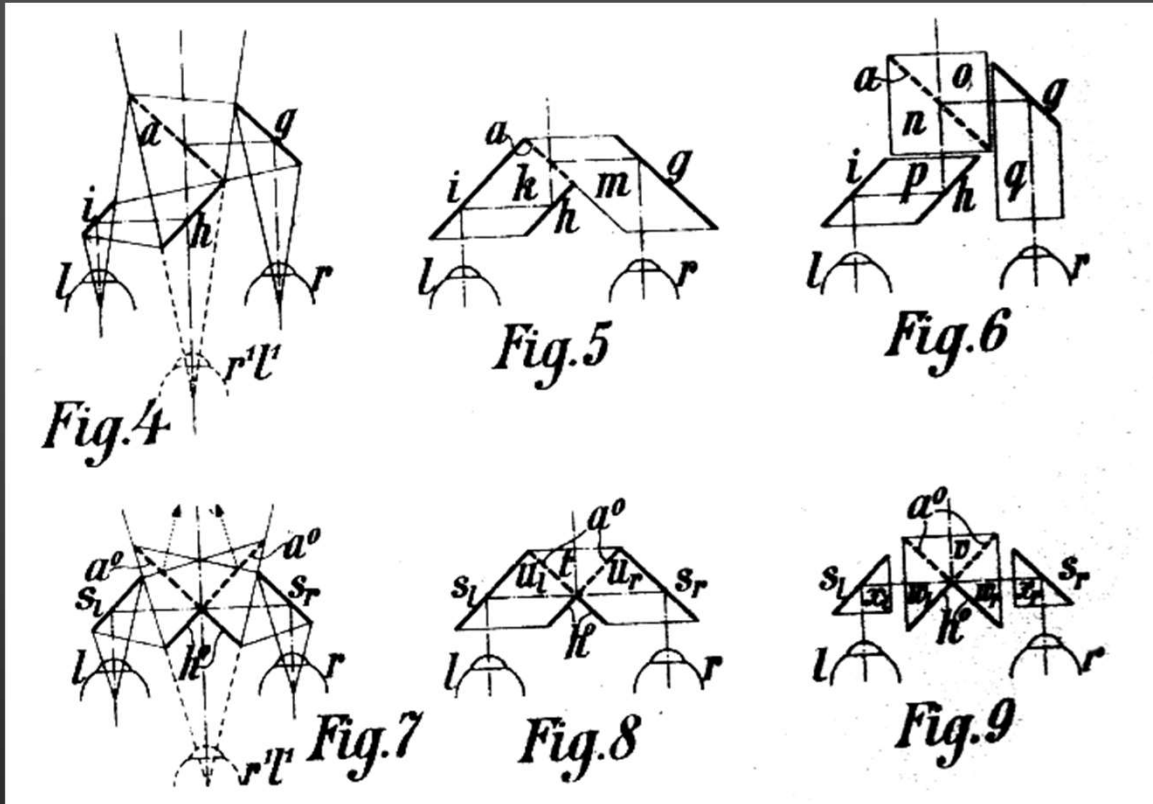
“There is little doubt that we share awareness with (at least) the other vertebrates. They should be your friends, even if they eat you when hungry, and even if you eat them.”



Zograscope (XVIIIth Century onwards)



Moritz von Rohr's Verant (and double Verant)



Zeiss's patent for Moritz von Rohr's synopter

Zeiss's synopter (1907)

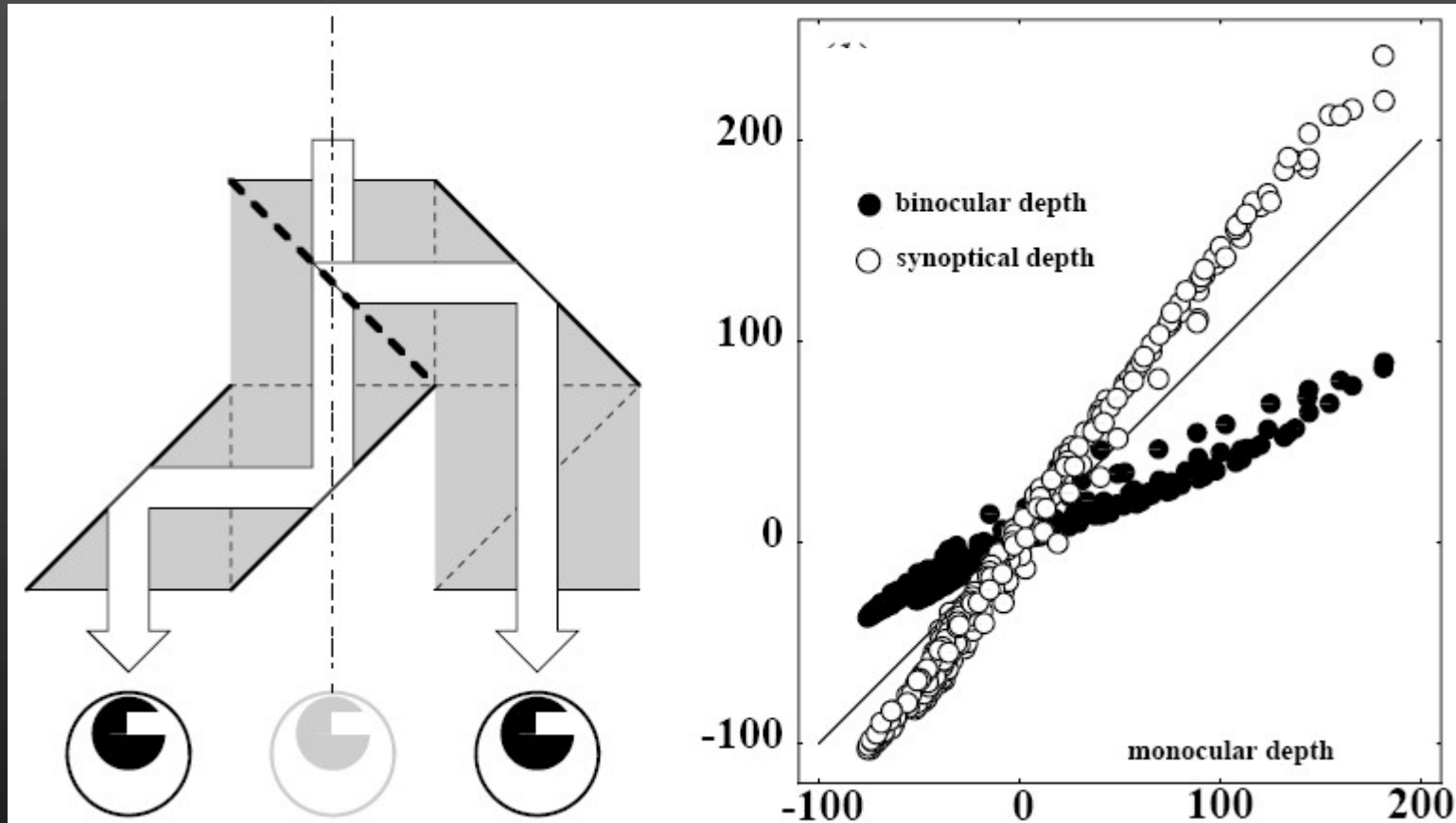


Figure from "Pictorial Relief", J.J. Koenderink, Phil. Trans. R. Soc. Lond. A (1998) 356, 1071-1086.
© 1998 The Royal Society.

Machine stereopsis

Given a calibrated binocular stereo pair, fuse it to produce a depth image

image 1



image 2



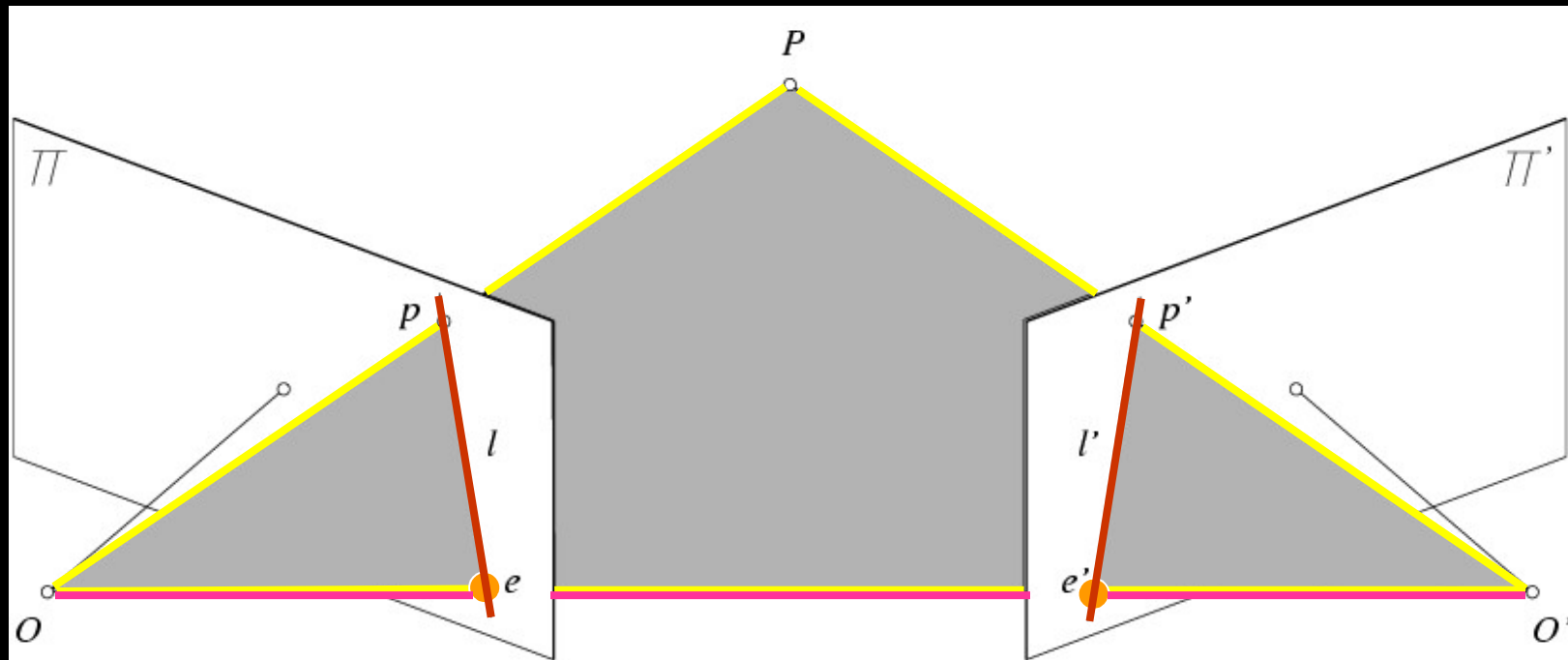
Dense depth map



Back to computer vision: Two-view geometry



Epipolar Geometry



- Epipolar Plane
- Epipoles
- Epipolar Lines
- Baseline



Photo by Frank Dellaert