

Travelling through Space and Time

Johannes M. Zanker

- the world is **three-dimensional**, but the eyes provide flat images
- the brain is **constructing depth** information, using a bag of tricks
- mechanisms of depth perception >> **illusions and applications**
- changes in **space and time** = motion >> design a 'model'
- motion perception is a tool to **study brain function**
- illusions** generated by the mechanisms of motion detection

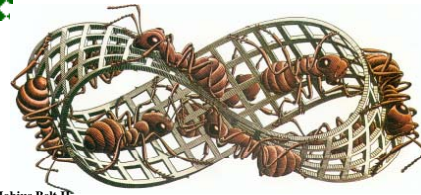
http://www.pc.rhul.ac.uk/staff/J.Zanker/PS1061/L4/PS1061_4.htm

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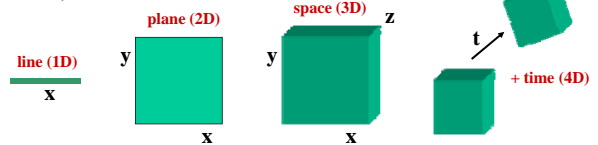
JMZ 1

the dimensionality of the world



Möbius Belt II
M.C. Escher, 1963

the world has **three spatial and one temporal dimension**



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JMZ 2

the third dimension : depth



Bacchus and Ariadne, Titian, 1522, National Gallery, London

the third dimension needs to be reconstructed from the flat images captured by the eyes

- multitude of cues can be used in the real world:
- size, perspective, occlusion
 - texture, contrast, shading
 - using two eyes
 - motion parallax

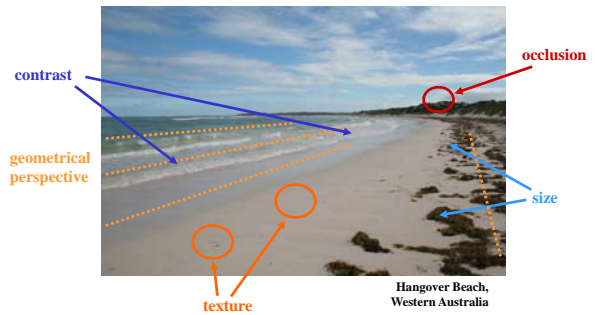
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JMZ 3

depth cues 1: pictorial cues

a wide range of depth information can be directly extracted from a static monocular (single eye) image :



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depth cues 2: binocular

apart from extending the visual field, the combination of information from the **two eyes** allows precise depth measurements through **stereopsis**



left eye view

right eye view

stereo, oculomotor signals

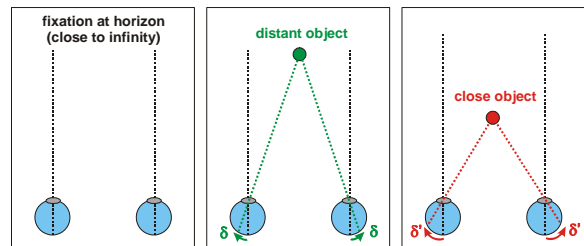
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how stereopsis works

retinal projection of an object on opposite sides of the fovea (disparity δ) indicates its depth relative to the plane of fixation



stereopsis is exploited to produce depth impressions in projected/printed pictures (Wheatstone stereoscope, red-green anaglyphs, lenticular cards, magic eye, ...)

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single-image stereopsis: magic eye



Magic Eye® images : Tom Baccei and Cheri Smith (1991), based on random dot stereograms (Tyler 1979 & Julesz 1959)

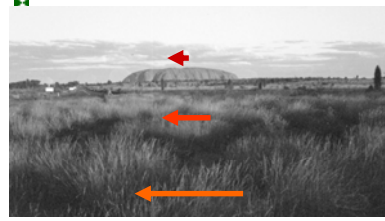


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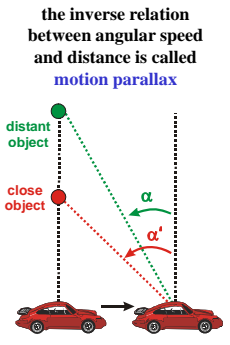
depth cues 3: motion



Uluru, Australia



look out of the side window of a car or a train, **close** objects translate very fast (**bushes**) and **distant** objects (**mountains**) pass slow or are stationary (**sun**)



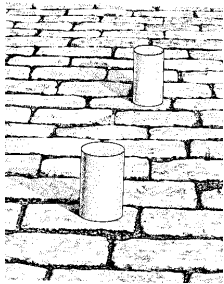
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size illusions 1: constancy

using distance information, the **retinal (angular) size** of objects is 'corrected' to make **perceived (object) size** independent of distance:



size constancy

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... constancy cont ...



Kimberley, Australia

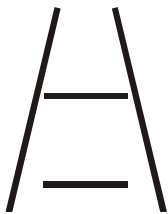
conversely, **constant angular size** may be interpreted as difference in object size: **constancy scaling**

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... more size constancy



the **size constancy effect** is sometimes believed to be the basis of the **Ponzo illusion**

after Gregory, 1968



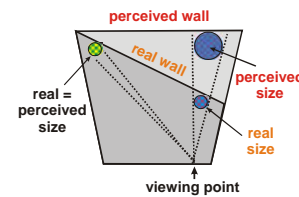
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size illusions 2: the Ames room

in the **Ames Room**, the size of a familiar object/person is perceived largely **distorted**, because the **misleading geometry** generates a **incorrect frame of reference**



size illusion in the Ames Room >> **constructivist theories** of perception: knowledge of the rules of perspective + the assumption of rectangular architecture >> visual system constructs apparent size difference (**unconscious inferences**) (why not vice versa?)

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an application: 3D-movies



how can a 'realistic' depth sensation be produced in the cinema, on a flat screen ??

Also: 3D-displays (Toshiba Mobile Display)

Science Museum IMAX® Cinema



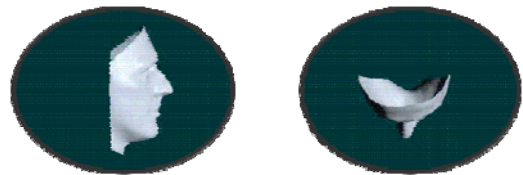
- you need to shoot **two synchronized pictures**, at eye separation (double lens camera)
- you need to **project both films** simultaneously on the screen (inverse optics + shutters or polarizers)
- you need to make sure that observers see the two images with the **two eyes separately** (glasses with LCD shutters or polarizers)

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... break ...



combined effect : hollow face illusion

- 3D-shape from shading
- cardinal view of (convex) face surface

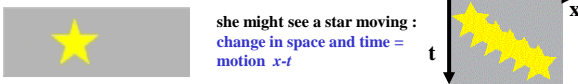
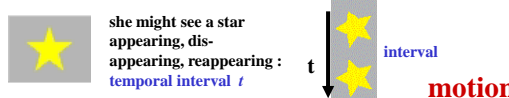
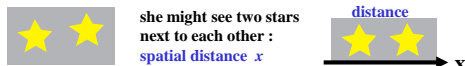
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what connects space and time ?

minimal physics, explained by an example:
consider an astronomer is watching the night sky to find stars...



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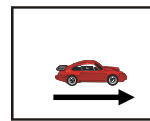
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motion: direction & speed

look out of your apartment window and watch these lovely cars passing by

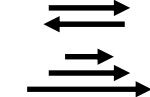


? illustration as still image ?



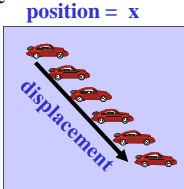
sketch

space-time diagram



direction

speed



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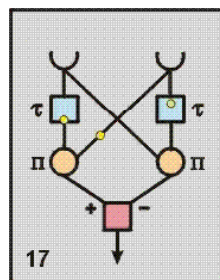
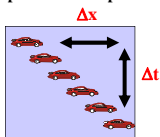
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a motion detection model

a motion detector has the task to assess displacement as function of time:
spatio-temporal correlation (= orientation filter in space-time)

requirements for a computational model:

- two **spatial separate inputs** to measure changes across space: Δx
- **temporal filters** (delay) to measure changes across time: Δt
- a **comparator** (logical operator) to evaluate spatial and temporal changes



elementary motion detector (EMD)

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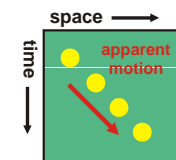
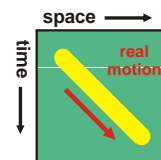
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apparent and real motion

real motion : continuous (smooth) displacement across space & time

apparent (Phi) motion : a set of discrete displacements (jumping)



apparent motion :

- detected by an EMD, like real motion
- basis for TV, movies, computer animations

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apparent motion history

apparent motion was 'discovered' (experimentally) by Exner 1877:
 motion is **independent sensation in space and time**: critical experiment

space →

time ↓

flicker fusion

spatial fusion

spark 1

aperture

left eye right eye

apparent motion

in the early 20th century apparent motion was interpreted as case in point for 'laws of Gestalt': proximity, common fate (Wertheimer 1912)

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motion correspondence

ambiguous motion stimuli >>> matching across space and time

vertical proximity

horizontal proximity

Gestalt law of perceptual organization: 'proximity'

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structure from motion

discontinuity in apparent motion stimuli
 >> need to **identify objects in successive frames** : correspondence problem

image 1

image 2

which dot in image 1 corresponds to which dot in image 2 ???

immediately resolved by **motion correspondence**

motion-defined circle !

Gestalt law of perceptual organisation: 'common fate'

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perceptual organisation: Gestalt

perception is not just passive image acquisition, but is active:
 'laws' of perceptual organization generate 'good shapes' (Wertheimer 1912)

- **Praeganz**: of several geometrical possible organisations, the most simple, stable will be perceived (many illusions)
- **Proximity**: tendency to group elements close to each other (apparent motion)
- **Similarity**: tendency to group elements that are similar (segregation)
- **Good Continuation**: tendency to generate smooth contours ('inertia')
- **Closure**: tendency to complete shapes

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... motion aftereffect ...

fixate the centre of the spiral for 2 minutes ...

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... motion aftereffect ...

watch the recession ...

what happens when it stops ? (simultaneous motion contrast >> opponency!)
 (classical case for such dynamic afterimages : Waterfall Illusion, Wade 1994)

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apertures 1: the problem

why does the rotating spiral appear to expand ??

the motion of an individual contour is **ambiguous** in an **aperture** (receptive field)

the motion direction of a contour is **underdetermined**
direction ambiguity: **aperture effect**

the most likely solution (perpendicular direction) is perceived

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apertures 2: plaids

components

motion plaid

one direction?
both directions?
mixture?

... it depends !
(transparency)

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apertures 3: the barberspole

the particular **shape of an aperture** can change the **perceived direction of motion**

High Street
Old Woking, Surrey

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experimental barberspoles

enforcing a particular **solution to the aperture problem** (directional ambiguity) by the **shape of a particular aperture**

the classical barberspole configuration

a recent version (unpublished): can you see two directions at the same time?

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... questions ???

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summary : depth and motion

- **depth perception**: reconstruction of the third dimension from flat images
- depth perception exploits a number of **pictorial, binocular and dynamic cues**
- conflicting **depth and size information** >> ambiguities: **size constancy**
- depth perception cues are exploited by various **technologies** (e.g. 3D cinema)
- **motion** is the change of position across time: **spatio-temporal correlation**
- simple **motion detector (EMD)** >> perception of real and apparent motion
- **apparent motion** can also be understood as perceptual organization: **Gestalt**
- **direction ambiguities** produce stunning illusions (e.g. barberspole)

http://www.pc.rhul.ac.uk/staff/J.Zanker/PS1061/L4/PS1061_4.htm
see also chapter 5 & 6 of Zanker 2010
and Ramachandran & Anstis, Scient. American254 1986

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coursework

- **categories of visual illusions** – collect, contrast, and compare
- **use systems analysis to understand relationships, mechanisms, functions**



DEPARTMENT OF PSYCHOLOGY
COURSEWORK ESSAY COVER SHEET
YEAR 1 – 2010/11

PS1061 – SENSATION AND PERCEPTION
Course Coordinator: Professor Johannes Zanker

A 1500 word essay (please see regulations below on word length)

Suggest a way of splitting the wide variety of visual illusions into groups, and describe how these categories could be meaningful

This essay must obtain a pass mark or higher in order for students to pass the course overall.

DEADLINE FOR SUBMISSION:
NO LATER THAN 12 NOON THURSDAY 11TH NOVEMBER 2011

... **essay instructions, webpage, tutorial, FORUM, resources**

http://www.pc.rhul.ac.uk/staff/J.Zanker/PS1061/PS1061_essay_illusions.htm

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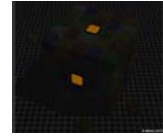
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the science of illusions: BBC2

You can watch the show on BBC : Is Seeing Believing? 2010

<http://www.bbc.co.uk/programmes/b00vhw1d#programme-broadcasts>



**the two central tiles actually
are the same colour !!**

plus news item and interactive webpage:
<http://www.bbc.co.uk/science/humanbody/mind/interactives/isseeingbelieving/>

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... enjoy
the rest
of the
week !



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