3D Scientific Visualization

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Overwiev

- 3D technology
  - 3D vision in humans
  - passive technologies
  - active technology
- Purposes
  - robotics
  - astrophysics
- Demonstration
  - 3D Sun images
  - 3D galaxy catalog

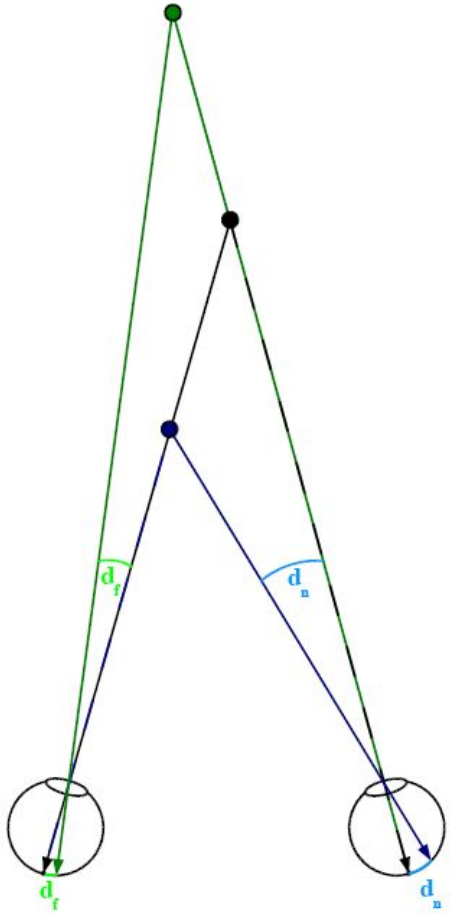
3D vision

- depth perception: the major factor of perceiving the world in 3D
- ability to perceive distance to objects in the world
- possible mainly due to stereopsis and accommodation of the eye
- monocular cues:
  - motion parallax
  - kinetic depth effect
  - perspective
  - relative and absolute size of an object
  - overlaps
  - texture, lights and shades
- binocular cues:
  - stereopsis
  - accomodation

https://en.wikipedia.org/wiki/Spinning_dancer

Stereopsis

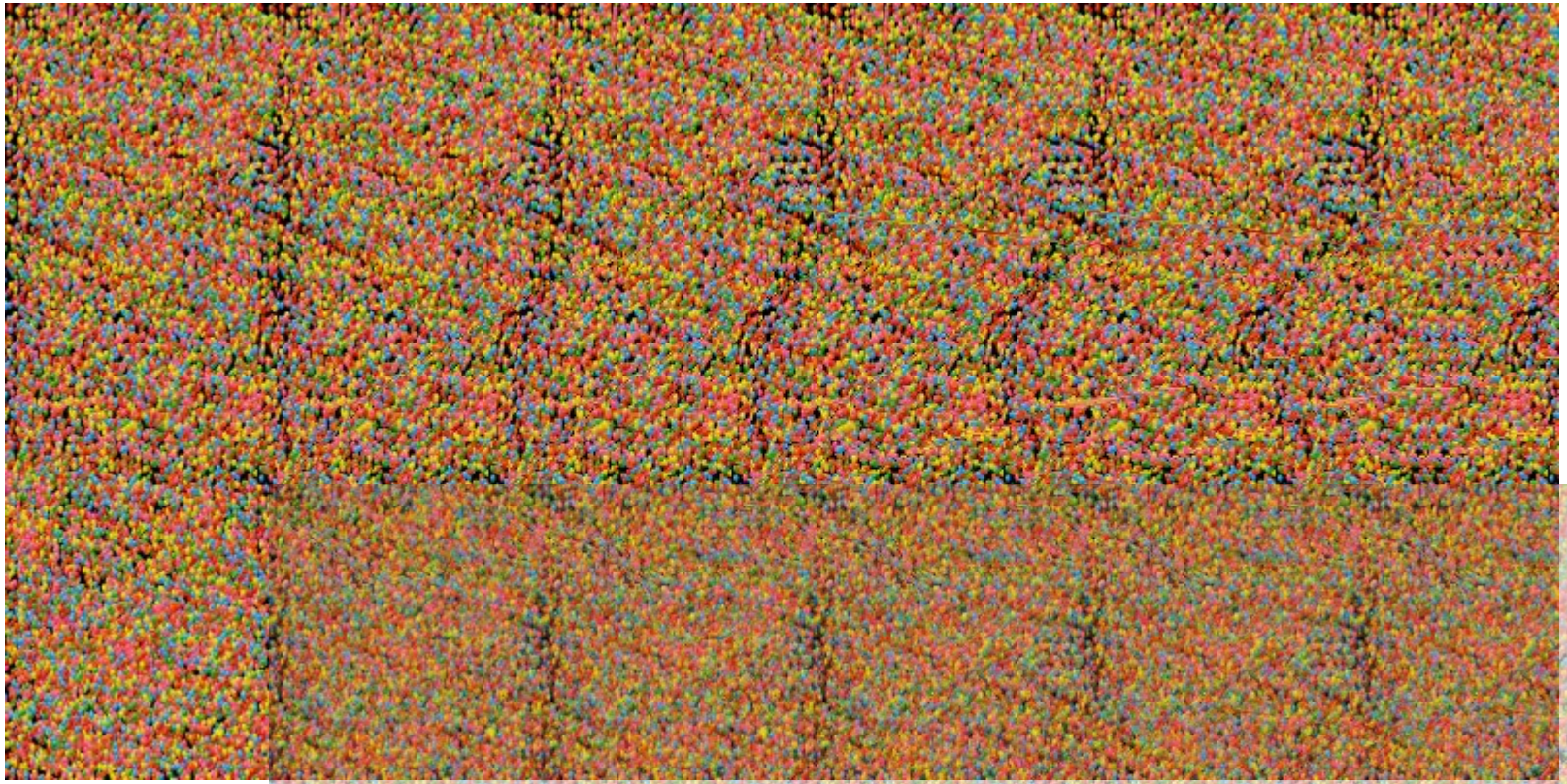
- Main cue for depth perception
- First described by Charles Wheatstone in 1838
- Each eye receives the image from a slightly different perspective
- Binocular disparity: the angle between two lines of projection
- Black: fixed
- Blue: near object, bigger angle
- Green: far away object, smaller angle



Stereoscopy

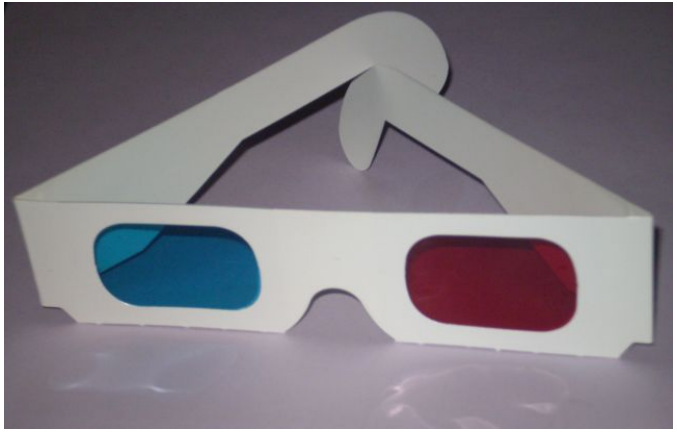
- Wheatstone: stereoscope
- Two images taken from a slightly different perspective is shown to each eye separately

Stereograms - Autostereograms



3D anaglyph

- 3D effect achieved by presenting each eye a differently coloured image
- Red and cyan/green
- Needs to be viewed through coloured lens glasses
- Problem: real colour of the image is lost



Polarized 3D imaging

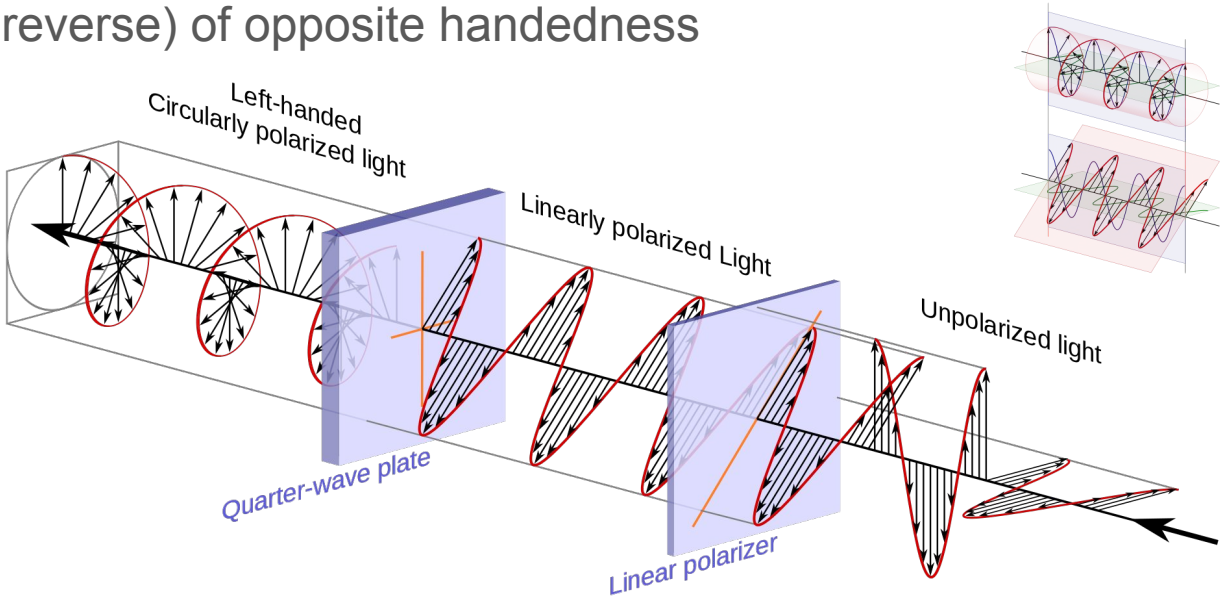
- Two images are projected onto a screen using circular polarizer of opposite handedness
- viewer wears eyeglasses which contain a pair of analyzing filters (circular polarizers mounted in reverse) of opposite handedness
- quarter-wave plate:

  birefringent material

  E -> vertical and

  horizontal component

  → π/2 phase shift

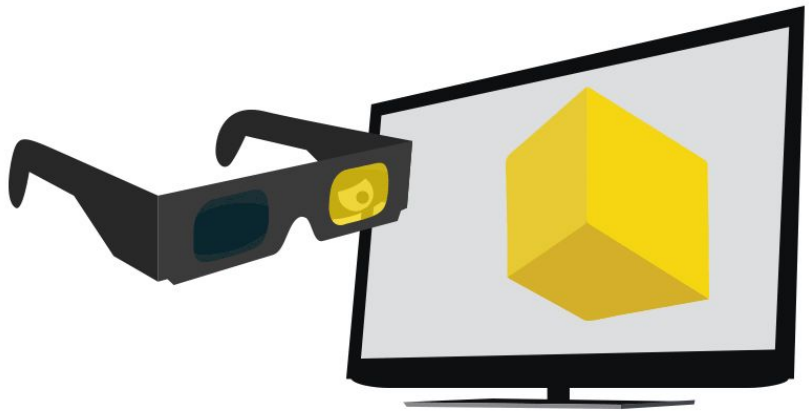


Active shutter 3D system

- Alternate frame sequencing
- Only presents the image to one eye at a time, while blocking the other eye
- Alternates the two images for each eye
- Glass contains a liquid crystal which becomes opaque when voltage applied
- glasses are controlled by a timing signal

  in synchronisation with the refresh state

  of the screen via infrared transmitter



Computer stereo vision

Triangulation: Determining the projection of a point in 3D space onto different planes

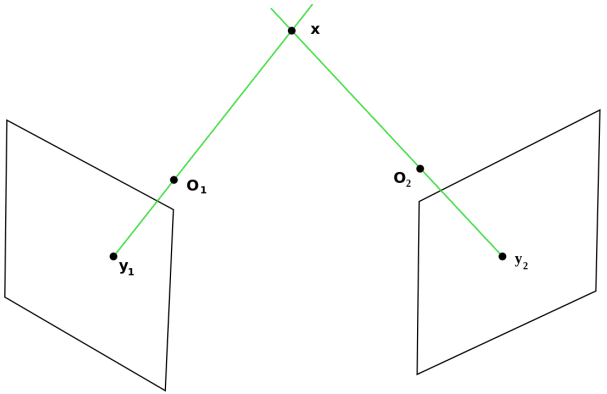
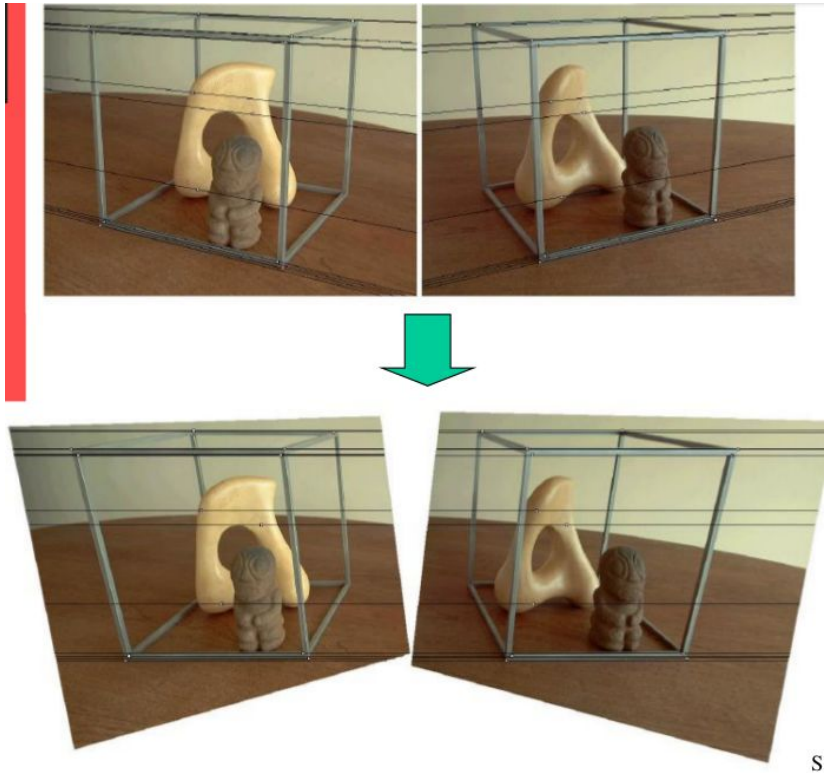
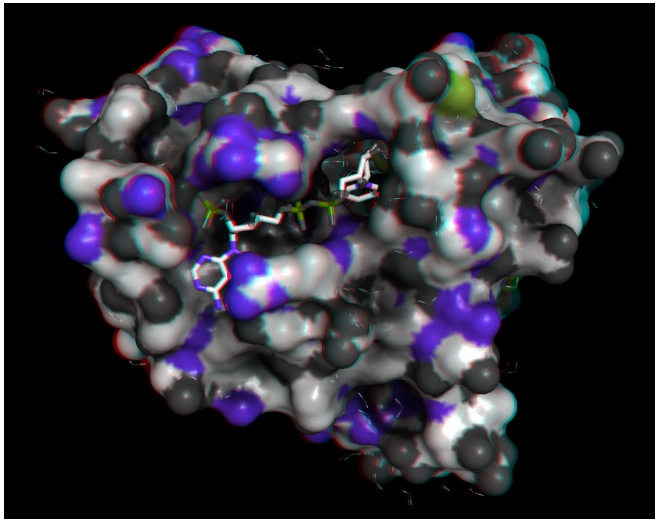


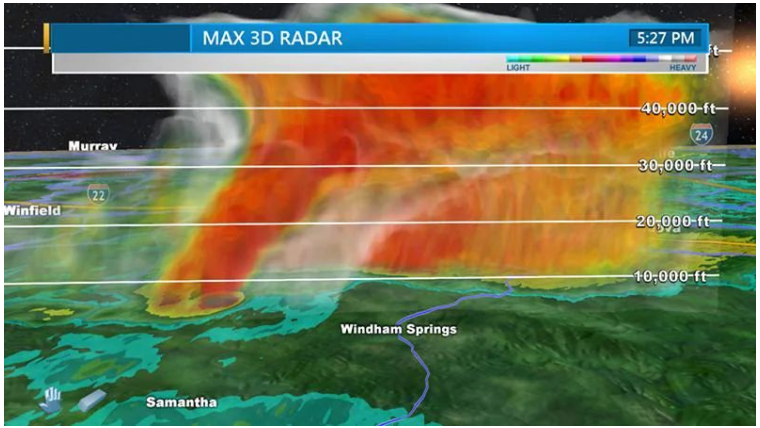
Image rectification: Transformation that projects images onto a common plane



Scientific visualization

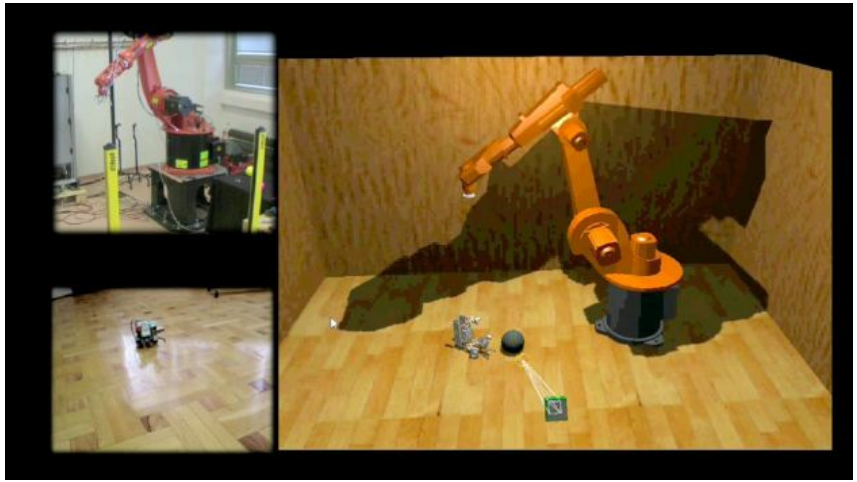
- Medical imaging (CT and MRI scans)
  - models of organs
  - diagnosis and treatment planning
- Organic chemistry
  - study the properties of molecules
- Biology
- Geology
  - Terrain and climate/weather visualization





Robotics

- Korondi, Péter & Baranyi, Peter & Hashimoto, Hideki & Solvang, Bjørn. (2010). **3D-Based Internet Communication and Control**. 10.1007/978-3-642-15220-7_5.
- Cooperation for R&D in robotics can be difficult due to transferring heavy equipment from one place to another
- Idea: develop a copy of the laboratory and the robots in 3D
- Then control the robot from far away
- Opportunity to test algorithms before applying in real life
- Lego Robot, industrial robot, and the 3D simulation



Astrophysics

- 3D imaging is an important tool
- helps visualize the structure and motion of objects in space that are otherwise hard to observe
- For example:
  - structure of nebulae → star formation
  - motion of stars in a galaxy
  - modeling the distribution of dark matter
  - **large-scale structure of the universe**

Sources:

1. previous studies (Extragalactic astrophysics, ELTE)
2. http://atomcsill.elte.hu/letoltes/foliak/2_evf/atomcsill_2_14_Frei_Zsolt.pdf
3. https://vc.elte.hu/
4. https://lweb.cfa.harvard.edu/~dfabricant/huchra/zcat/
5. http://www.2dfgrs.net/Public/Survey/description.html
6. https://skyserver.sdss.org/dr18
7. https://en.wikipedia.org/wiki/Stereoscopy
8. http://www.sci.utah.edu/~gerig/CS6320-S2012/Materials/CS6320-CV-F2012-Rectification.pdf
9. https://www.ibm.com/products/max-storm

Backup

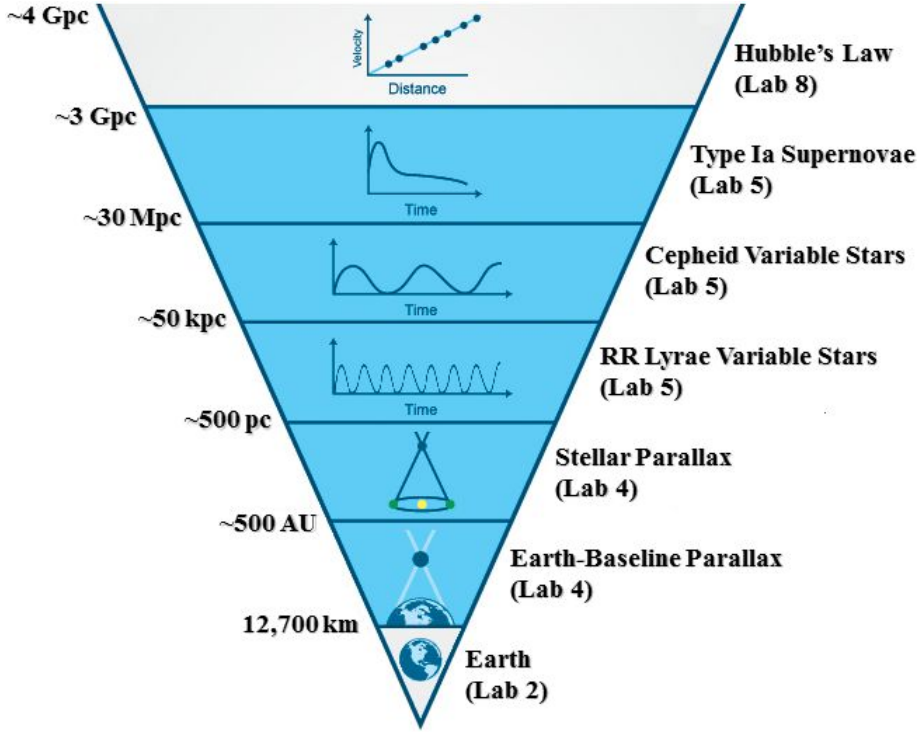
Distance measurement in astronomy

- Parallax → nearby stars
- Variable stars → within our galaxy
- Ia supernovae → nearby galaxies
- Hubble's law → far away galaxies

Hubble's law:

v = H*d

v = c*z



Redshift surveys

- The Center for Astrophysics (CfA) Redshift Survey was the first attempt to map the large-scale structure of the universe
  - 1995, Smithsonian Astrophysical Observatory in Cambridge, Massachusetts
  - redshift of 18 000 bright galaxies
- 2dF Galaxy Redshift Survey
  - 2003, australian Astronomical observatory
  - ~220 000 galaxies
- 6dF Galaxy Survey
  - 2009
  - ~125 000 galaxies

Redshift surveys

- Sloan Digital Sky Survey (SDSS)
  - ~ 1 million galaxy redshifts by 2007
  - still ongoing (SDSS V)
  - Apache Point Observatory, New Mexico, USA
- DEEP2 Survey
  - Keck Telescopes in Hawaii
  - ~ 50 000 galaxies