Perception

METR 4202: Advanced Control & Robotics

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Lecture # 6 August 27, 2012

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RoboticsCourseWare.org

RoboticsCourseWare Contributor

Schedule

Week	Date	Lecture (M: 12-1:30, 43-102)
1	23-Jul	Introduction
2	30-Jul	Representing Position & Orientation & State (Frames, Transformation Matrices & Affine Transformations)
3	6-Aug	Robot Kinematics and Dynamics
4	13-Aug	Robot Dynamics & Control
5	20-Aug	Obstacle Avoidance & Motion Planning
6	27-Aug	Sensors, Measurement and Perception
7	3-Sep	Localization and Navigation (GPS, INS, & SLAM)
8	10-Sep	State-space modelling & Controller Design
9	17-Sep	Vision-based control
	24-Sep	*Study break*
10	1-Oct	*Public Holiday*
11	8-Oct	Robot Machine Learning
12	15-Oct	Guest Lecture
13	22-Oct	Wrap-up & Course Review

Quick Outline

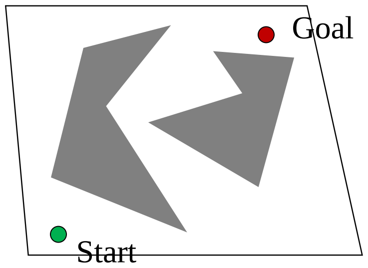
1. Discussion Forum & Sign-up Updates
2. Path Planning Recap
3. Sample-based Path Planning & Sequencing

4. **Perception**
    1. Sensing
    2. Sensors (Laser, Vision)
    3. Calibration
    4. Feature extraction

Updates: Discussion Forum & Signup Sheet

- Two Options:
  - Blackboard: Not-free, access controls already in place
  - "Shapado": Free, Web-accessible, searchable, yet another login
- Proposal:
  - Each week the tutors will select the "best" student answer
    - They will award a gold and silver star.
    - Gold star entitles a free **6 hour extension** for the team
      Silver star entitles a **1 hour extension**
    - The tutors can issue multiple (or no) stars
  - Please try the forums **before** emailing metr4202@
- **Sign-up Sheet** is available (after class) and will be posted outside the Axon Learning Lab

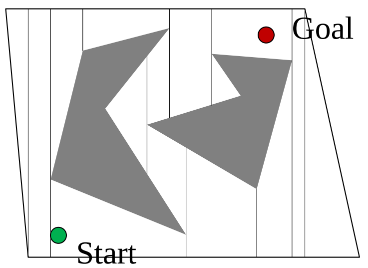
Geometric Planning Methods



- Several Geometric Methods:

Artwork from LaValle, Ch. 6

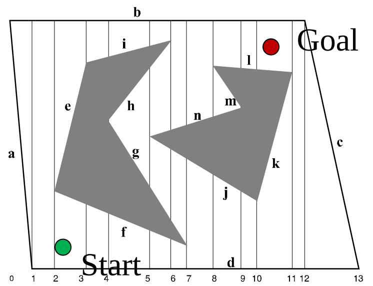
Geometric Planning Methods



- Several Geometric Methods:
  - Vertical (Trapezoidal) Cell Decomposition

Artwork from LaValle, Ch. 6

Geometric Planning Methods



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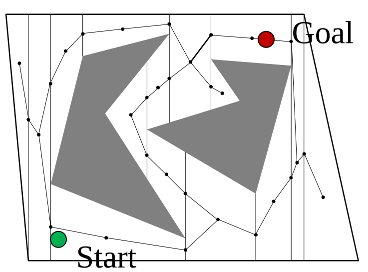
  – Vertical (Trapezoidal) Cell Decomposition

Artwork from LaValle, Ch. 6

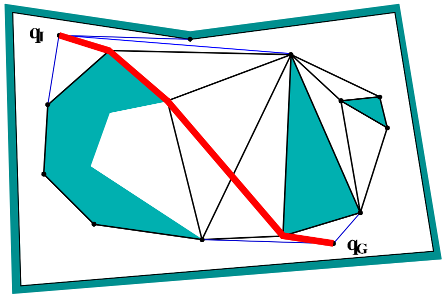
Geometric Planning Methods



- Several Geometric Methods:
  – Vertical (Trapezoidal) Cell Decomposition
  ➔ Roadmap Methods

Artwork from LaValle, Ch. 6

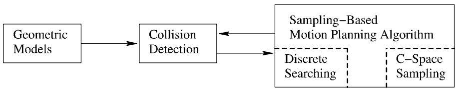
Geometric Planning Methods



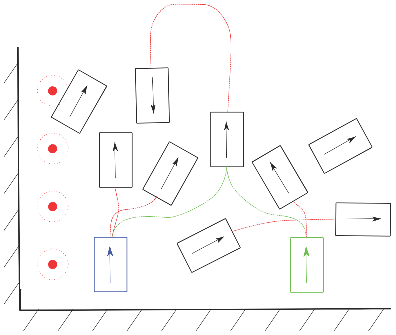
- Several Geometric Methods:
  - Vertical (Trapezoidal) Cell Decomposition
  - **Roadmap Methods**
    - **Cell (Triangular) Decomposition**
    - Visibility Graphs
    - Veroni Graphs

Artwork from LaValle, Ch. 6

Sample-Based Motion Planning



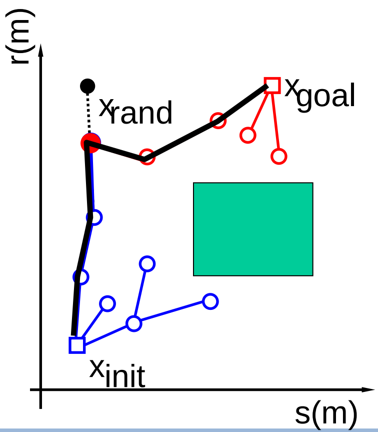
- PRMs



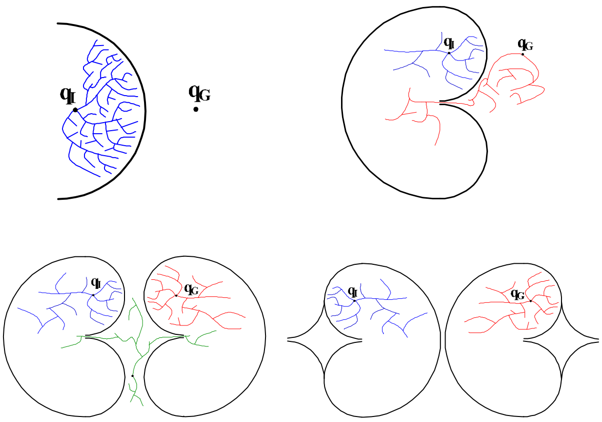
- RRTs

Artwork based on LaValle, Ch. 5

Rapidly Exploring Random Trees (RRT)

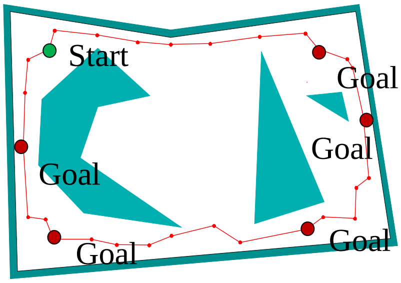


Sampling and the "Bug Trap" Problem



Artwork based on LaValle, Ch. 5

Multiple Points & Sequencing



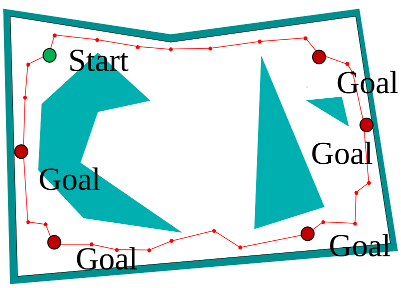
- Sequencing
  - Determining the "best" order to go in

➔ Travelling Salesman Problem

A salesman has to visit each city on a given list exactly once. In doing this, he **starts** from his home city and in the **end he has to return to his home** city. It is plausible for him to select the order in which he visits the cities so that the **total of the distances travelled** in his tour is as small as possible.

Artwork based on LaValle, Ch. 6

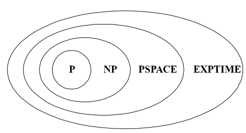
Travelling Salesman Problem



- Given a $n \times n$ distance matrix **C**=(c_{ij})
- Minimize:

$$c(\pi) = \sum_{i=1}^{n} c_{i\pi(i)}$$

- Note that this problem is NP-Hard

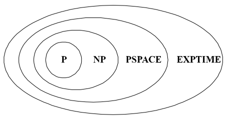


➔ BUT, Special Cases are Well-Solvable!

Artwork based on LaValle, Ch. 6

Travelling Salesman Problem [2]

- This problem is NP-Hard



➔ BUT,
Special Cases are
Well-Solvable!

For the Euclidean case
(where the points are on the 2D Euclidean plane) :

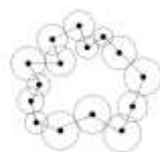
- The shortest TSP tour does not intersect itself, and thus geometry makes the problem somewhat easier.
- If all cities lie on the boundary of a convex polygon, the optimal tour is a cyclic walk along the boundary of the polygon (in clockwise or counterclockwise direction).

The k-line TSP

- The a special case where the cities lie on *k* parallel (or almost parallel) lines in the Euclidean plane.
- EG: Fabrication of printed circuit boards
- Solvable in **O**(n^3) time by Dynamic Programming (Rote's algorithm)

The necklace TSP

- The special Euclidean TSP case where there exist *n* circles around the *n* cities such that every cycle intersects exactly two adjacent circles



Sensing: The BIG Picture

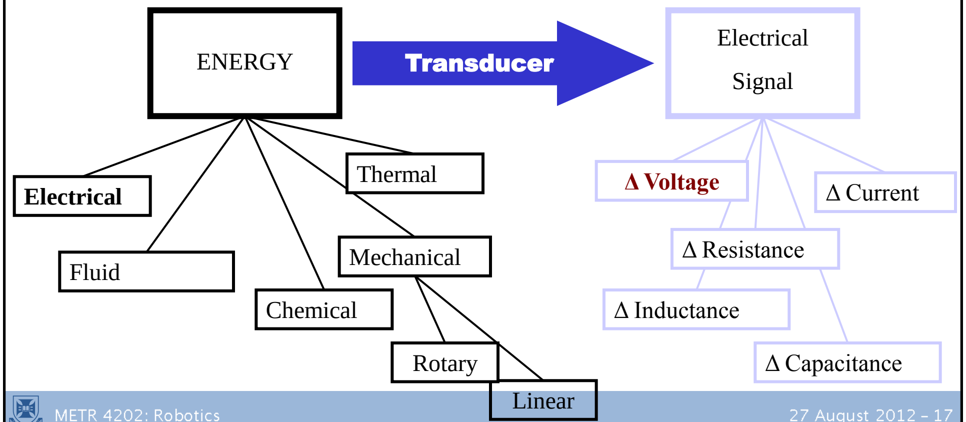
Recall from First Year:

Sense ➝ Control ➝ Act

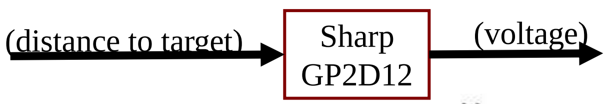
- Sensing: quantifying a system's state
- Sensor: device that does sensing
  - Receives and responds to a signal/stimulus

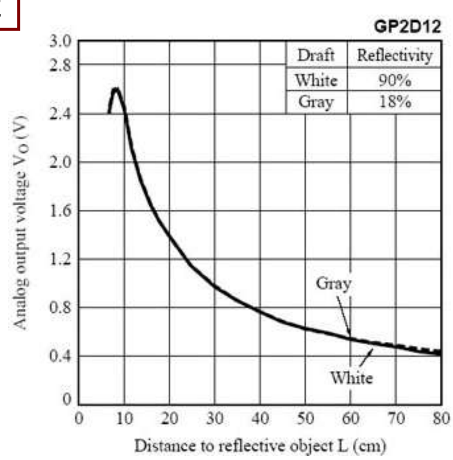
What is an electric transducer?

- Convert from the measurement space to an electrical signal
- Why? : Measuring voltage is easy!

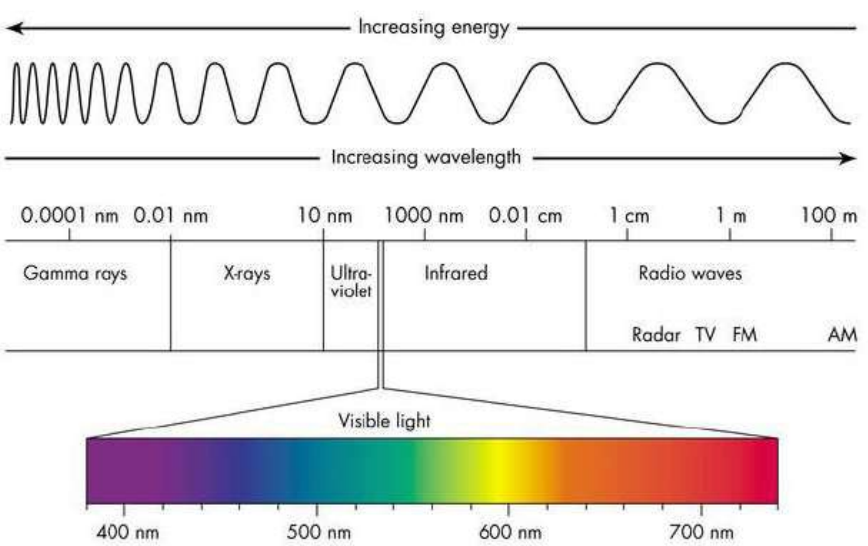


Example Sensor: GP2D Range Sensor

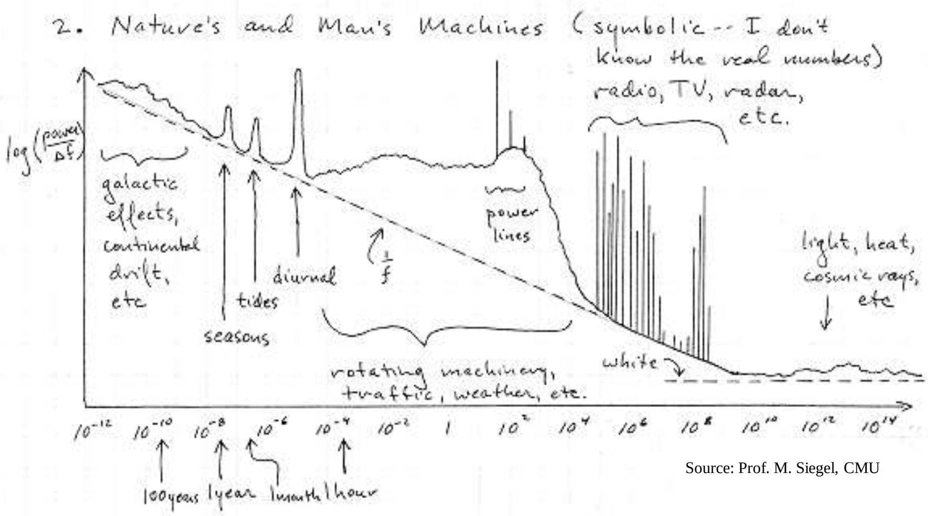




Spectrum



Noise

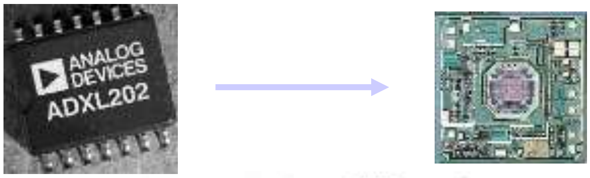


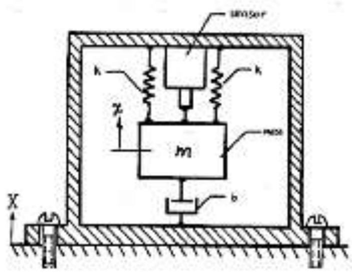
Source: Prof. M. Siegel, CMU

Note: this picture illustrates the concepts but it is not quantitatively precise

Inertial: Translation → Accelerometer

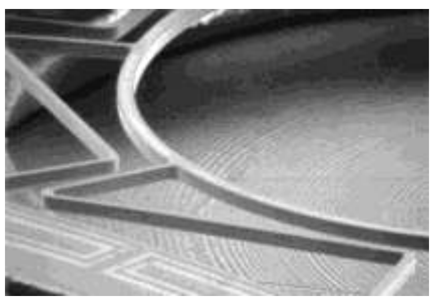
- General accelerometer:



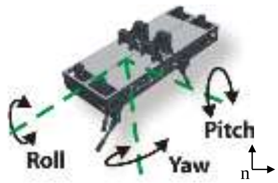


Inertial: Rotation → Gyroscopes

- Structural arrangement of silicon which records centrifugal acceleration and thus **angular speed**
- Use **strain-gauge bridges and/or piezo** structure to record deformations



Accelerometer → Acceleration

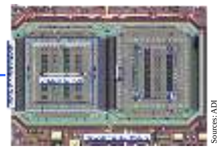


$$\vec{s} = {}^{s}_{o}R\left({}^{o}_{n}R\,(a - g) + \alpha \times r + \omega \times (\omega \times r)\right) \pm \sigma$$

signal (Accelerometer) — rotation — acceleration, gravity — tangential — centripetal — Noise

$\int dt$, $\frac{\partial}{\partial t}$

signal (Gyro)



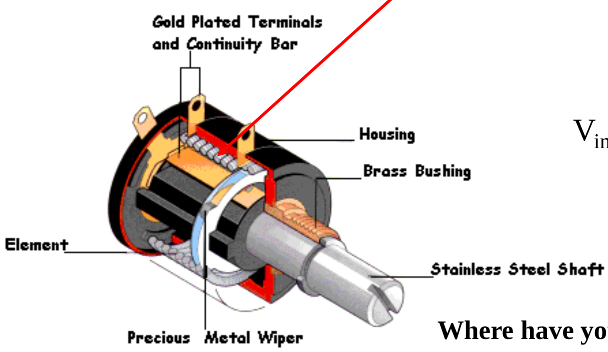
- Noise adds uncertainty
- Gravitational & inertial forces are inseparable

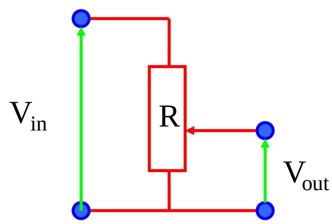
Position and Velocity Sensors

- Position and velocity measurement is often required in feedback loops for positioning, and velocity control
- Position measurement
  - Potentiometers
  - Linear Variable Differential Transformer (LVDT)
  - Encoders
- Velocity Measurement
  - Tachometer

Position measurement: Potentiometers

An analog sensor
Works as a voltage divider

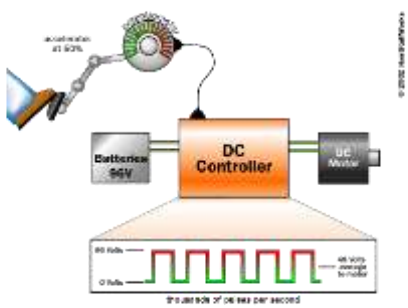




Where have you seen one of these?

Example Applications

- Joystick Electric car control

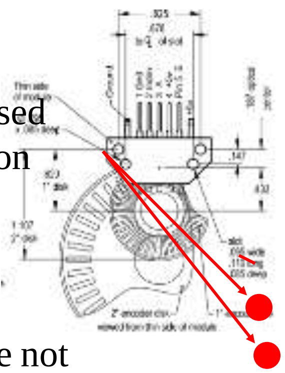


Position/Velocity: Optical Encoders

- Encoders are digital Sensors commonly used to provide position feedback for actuators
- Consist of a glass or plastic disc that rotates between a light source (LED) and a pair of photo-detectors
- Disk is encoded with alternate light and dark sectors so pulses are produced as disk rotates

Incremental Encoders

- Pulses from leds are counted to provide rotary position
- Two detectors are used to determine direction (quadrature)
- Index pulse used to denote start point
- Otherwise pulses are not unique

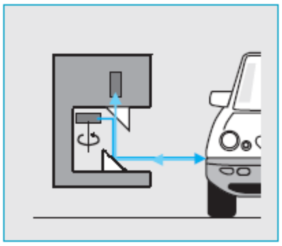


Absolute Encoders

- Absolute encoders have a unique code that can be detected for every angular position
- Often in the form of a "grey code"; a binary code of minimal change
- Absolute encoders are much more complex and expensive than incremental encoders

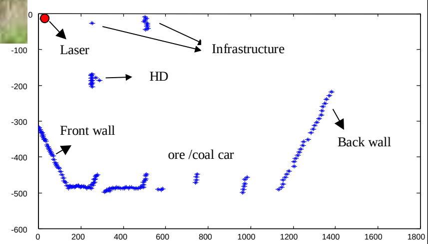
Laser measurement system

- The LMS system operates by measuring the time of flight of laser light pulses:
  - A pulsed laser beam is emitted and reflected if it meets an object.
  - The reflection is registered by the scanner's receiver.
  - The time between transmission and reception of the impulse is proportional to the distance between the scanner and the object



LMS & Coal Loading Automation

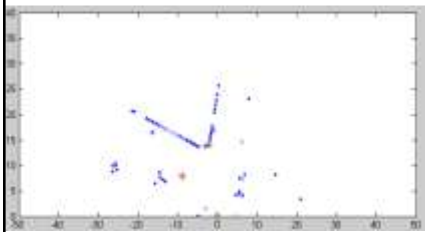
- 2D Scanning laser sensor
- Automation of the Coal Loading process



Industrial Sensors: Force

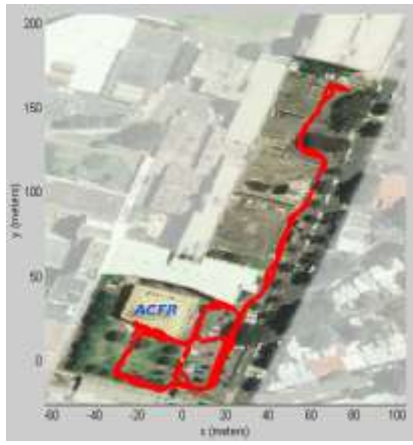
- Proximity
  - Mechanical
  - Optical
  - Inductive/Capacitive
- Position/Velocity
  - Potentiometer
  - LVDT
  - Encoders
  - Tachogenerator
- Force/Pressure

Sensor Information



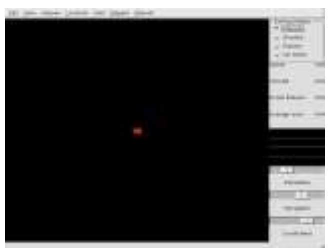
Laser

Vision



GPS

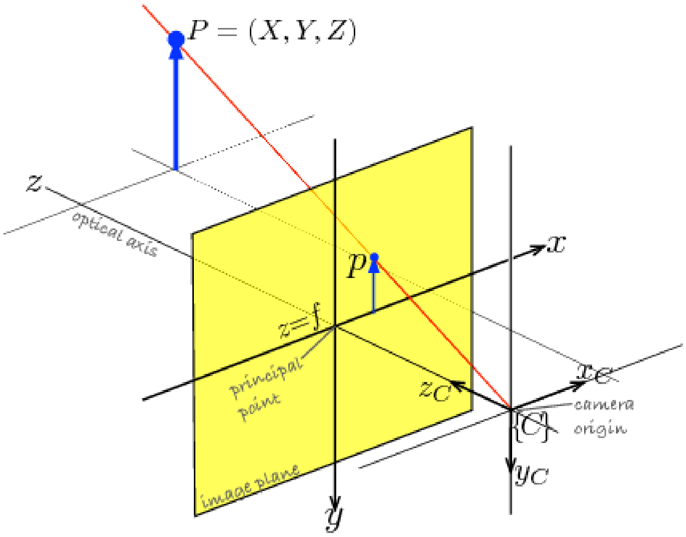
Mapping: Indoor robots



Cameras

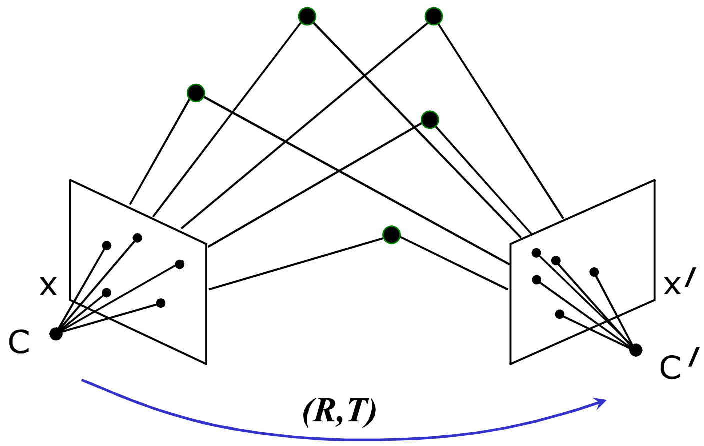
Wikipedia, E-30-Cutmodel

Image Formation



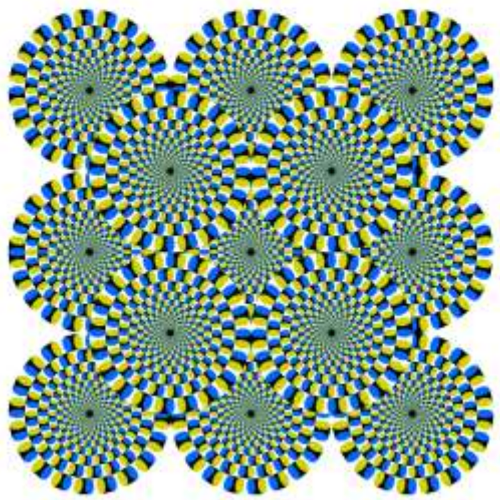
Corke, Ch. 11

Stereopsis



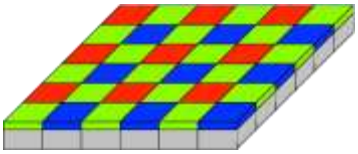
Perception

- Making Sense from Sensors

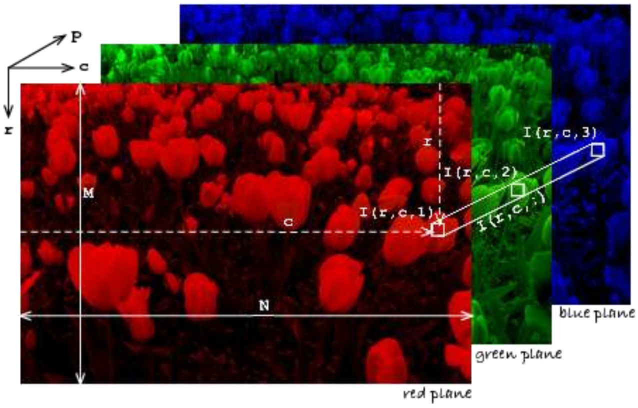


http://www.michaelbach.de/ot/mot_rotsnake/index.html

Features -- Colour Features



Bayer Patterns



Edge Detection

- Canny edge detector:

Edge Detection

- Canny edge detector:

Cool Robotics Share