Navigation of outdoor mobile robot

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Importance of robotics

- Mobile robots are used in:

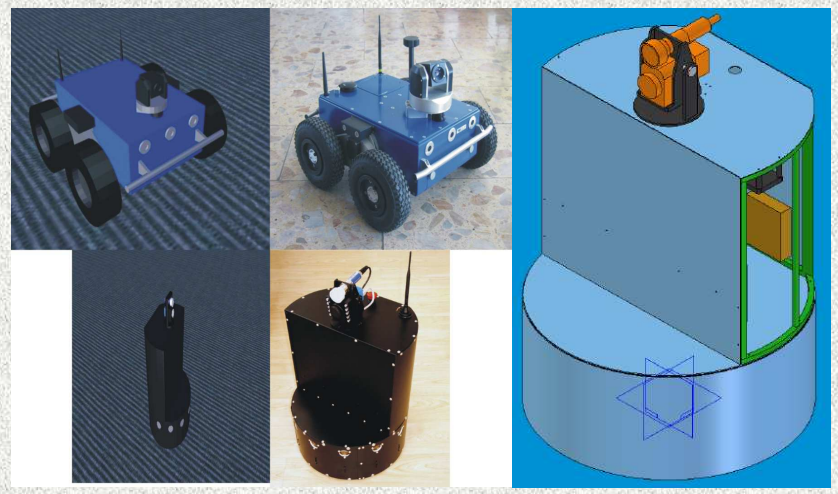
- harmful and dangerous environments
- environment exploration
- transportation tasks
- property and people rescue
- service robotics
- space robotics

Our systems

Robot KAR

Robot MRVK01

Models



Microsoft Robotics Developer Studio

Adams

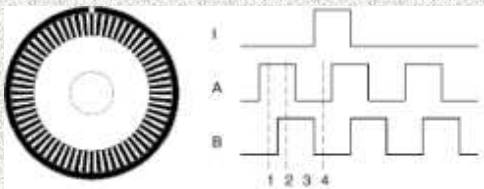
Outdoor mobile robot MRVK

Sensors of mobile robot

- Odometry - encoders
- Gyroscope
- Laser Scanner
- Other sensors

Encoders

- USdigital E7MS
- Differential quadrature encoder output
- **Components**: base, cover, codewheel and encoder module PCB
- 720 to 2500 PPR
- **Frequency response**: up to 30kHz



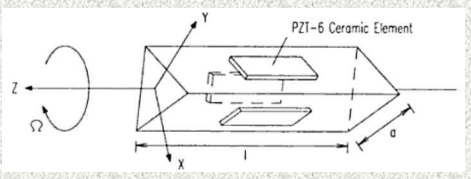
Gyroscope

- IMU330CC from Crossbow
- **6 sensing elements**: solid-state devices
- **3 angular rate sensors**: micro-machined vibratory MEMS sensors that utilize Coriolis force to measure angular rate independently of acceleration
- **3 MEMS accelerometers**: micromachined silicon devices that use differential capacitance to sense acceleration

Principle of gyroscope

- Oscilation of ceramic elements in axis *x* with frequency

$$f_n = \frac{A.a}{4.\pi .l^2}\sqrt{\frac{E}{6.\rho}}$$



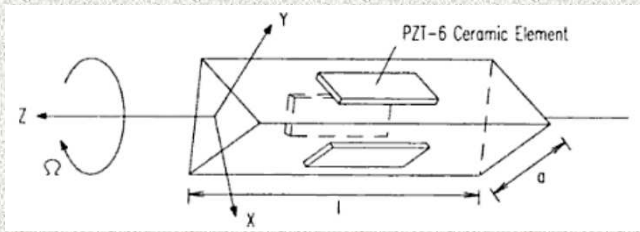
- A – constant, a – width of element, l – length of element, E – Young flexibility model, ρ - density of element

Principle of gyroscope

- Rotation around axis *z* raise Coriolis force

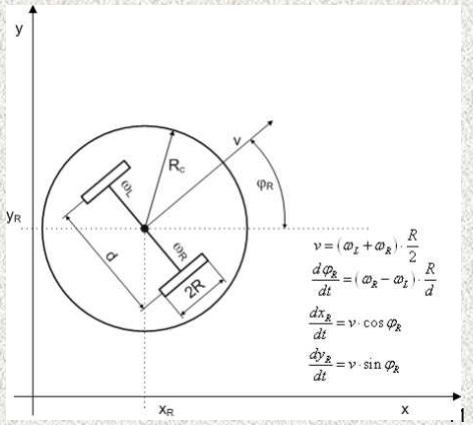
$$F_c = 2.m.\Omega .\dot{y}$$

- m – weigth of element, Ω - angular rate



Robot's localization

- Why to use gyrodometry and not only simple odometry from encoders?



Gyrodometry's principle

$$x_{i+1} = x_i + d.\cos\alpha$$
$$y_{i+1} = y_i + d.\sin\alpha$$

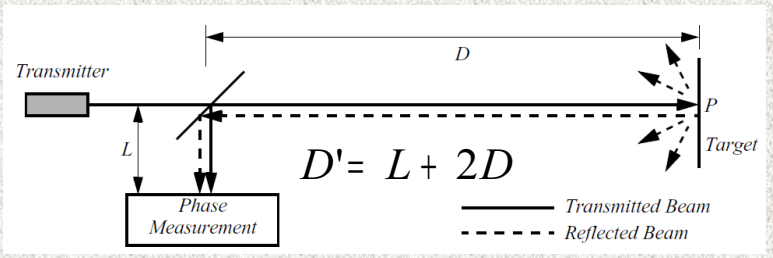
- Where:
- d – path length (average of left and right wheel encoder)
- alfa – angle from gyroscope (average value of angle between two samples of odometry)

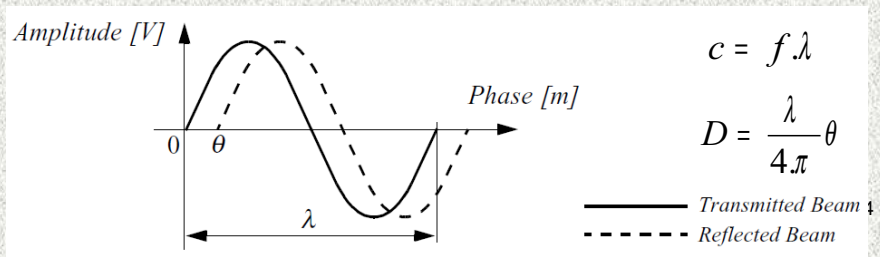
Laser scanner

- Hokuyo URG-04LX Laser
- **Field-of-view**: 240°
- **Angular resolution**: 0,36°
- **Scanning refresh rate**: 10Hz
- **Detection range**: 0.02 to approximately 4m

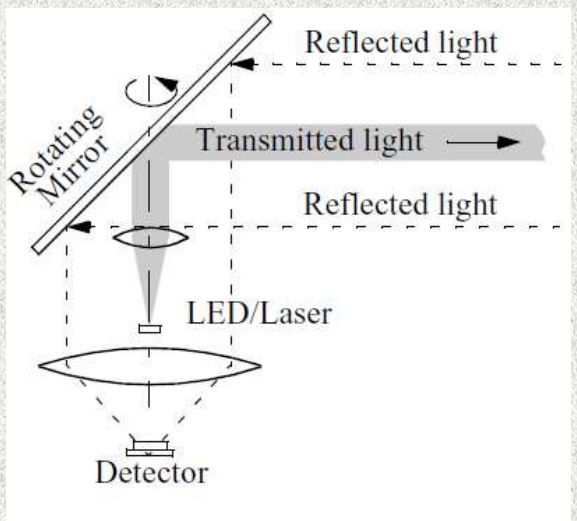
Laser scanner - principles

- TOF?





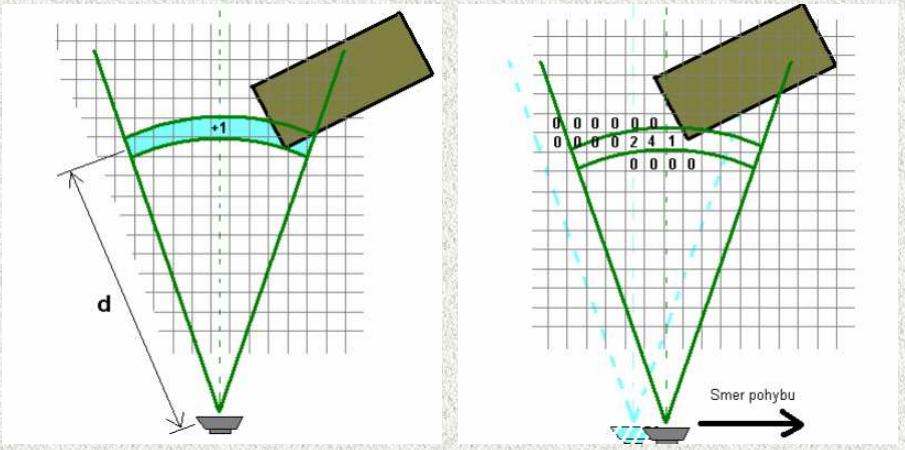
Laser scanner - principles



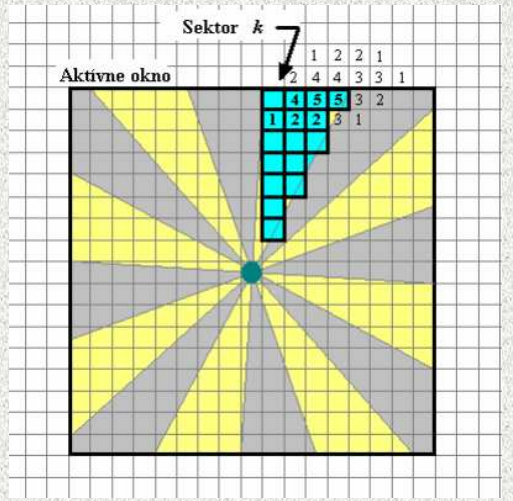
VFH – reactive navigation

- Designed by Borenstein and Koren
- Removes disadvantages of artificial potential fields
- Uses local metric map
- 3 levels of data representation:
  1. Grid representation of environment
  2. Polar histogram H
  3. Result of algorithm

Grid representation

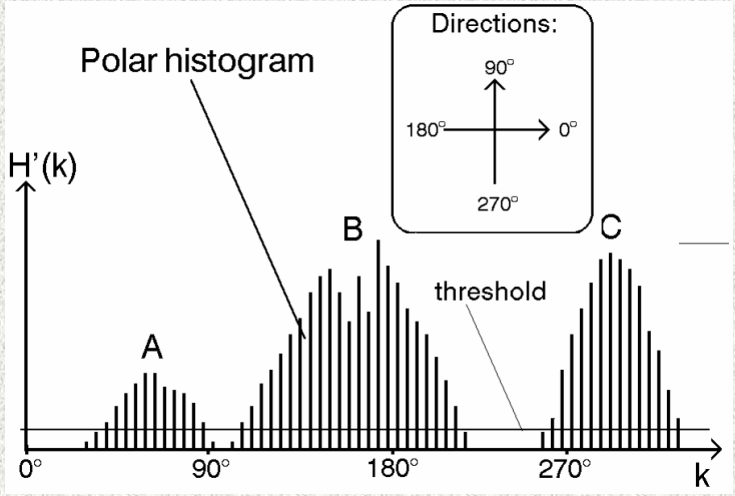


Sectors

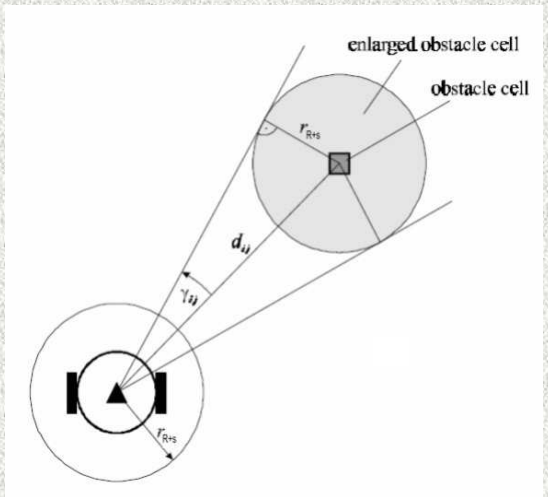


Histogram

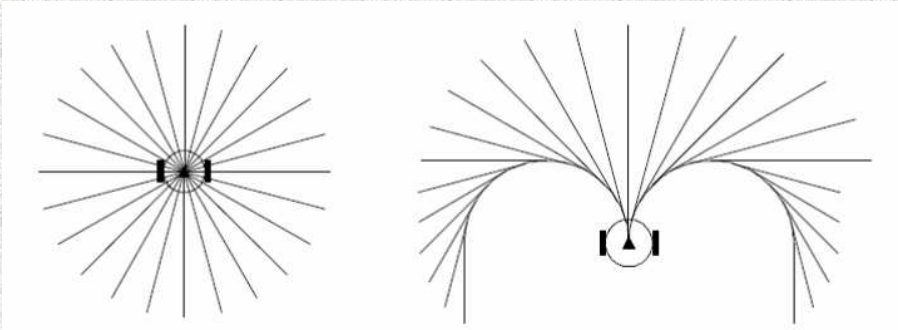
$$h_k = \sum_{i,j} m_{i,j}$$



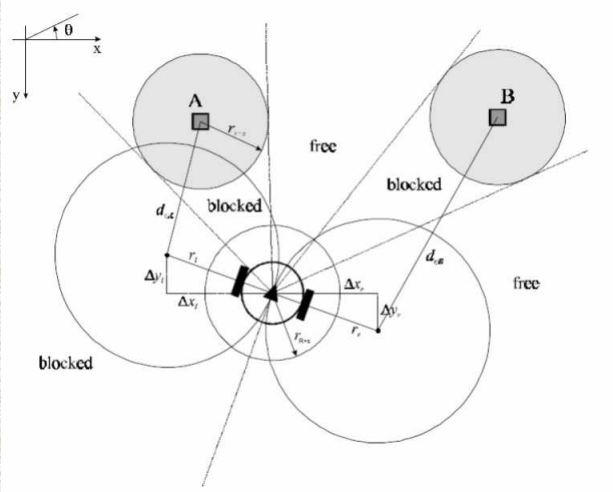
VFH+ enlarged cells



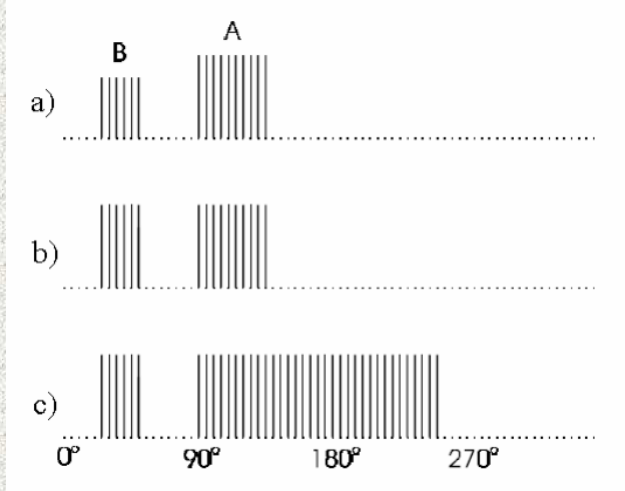
VFH+ dynamics of robot



VFH+ dynamics of robot



VFH+ histograms



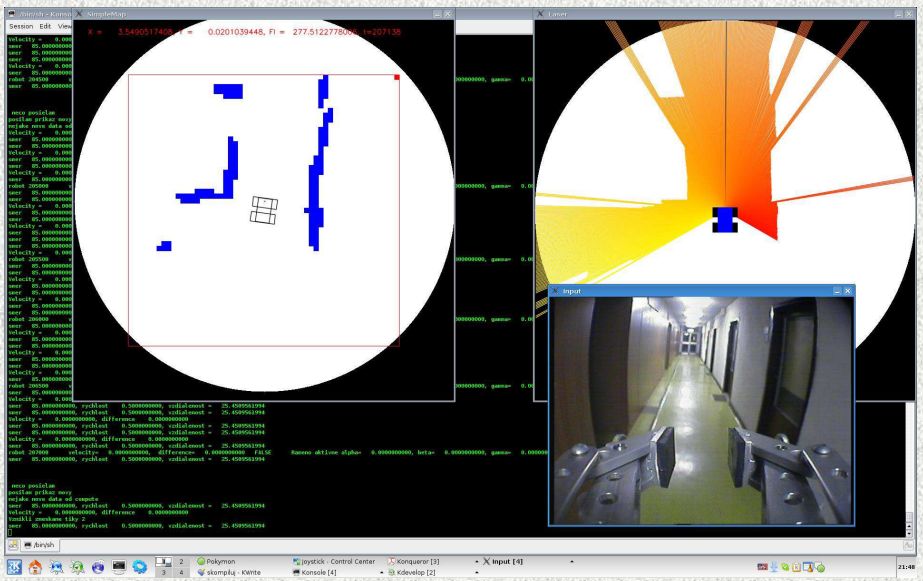
VFH+ selection function

$$g(c) = \mu_1 \Delta(c, k_s) + \mu_2 \Delta\left(c, \frac{\theta_s}{\alpha}\right) + \mu_3 \Delta(c, k_{n,s-1})$$

- Where:
- $\Delta(a,b)$ returns difference between angles
- c is candidate sector
- k_t stands for sector with global goal
- $\frac{\theta_s}{\alpha}$ represents sector with robots wheels
- $k_{n,s-1}$ is previous candidate sector

VFH+ simulation

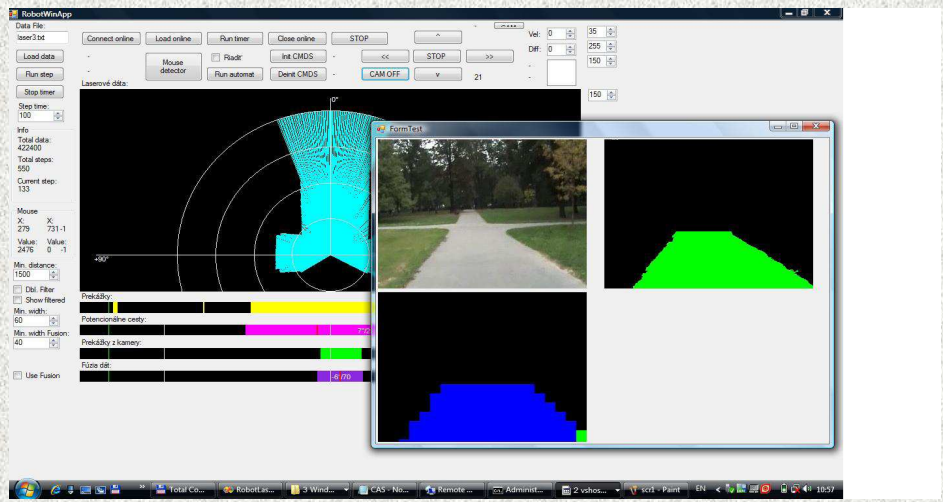
Telerobotics



Higher cognition

- Camera
- Sensor fusion
- Localization with precise GPS

Competition Robotour



Competition Robotour

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Thank you for attention