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Innovative Teaching Approaches in development of Software
Designed Instrumentation and its application in real-time
systems

Theory of Robotics Systems

Localization

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Innovative Teaching Approaches in development of Software Designed Instrumentation and its application in real-time systems

Faculty of Technical
Sciences



Ss. Cyril and Methodius
University
Faculty of Electrical Engineering
and Information Technologies



Zagreb University of
Applied Sciences



School of Electrical
Engineering
University of Belgrade



Faculty of Physics
Warsaw University of Technology



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Teorija Robotskih Sistema

Localizacija

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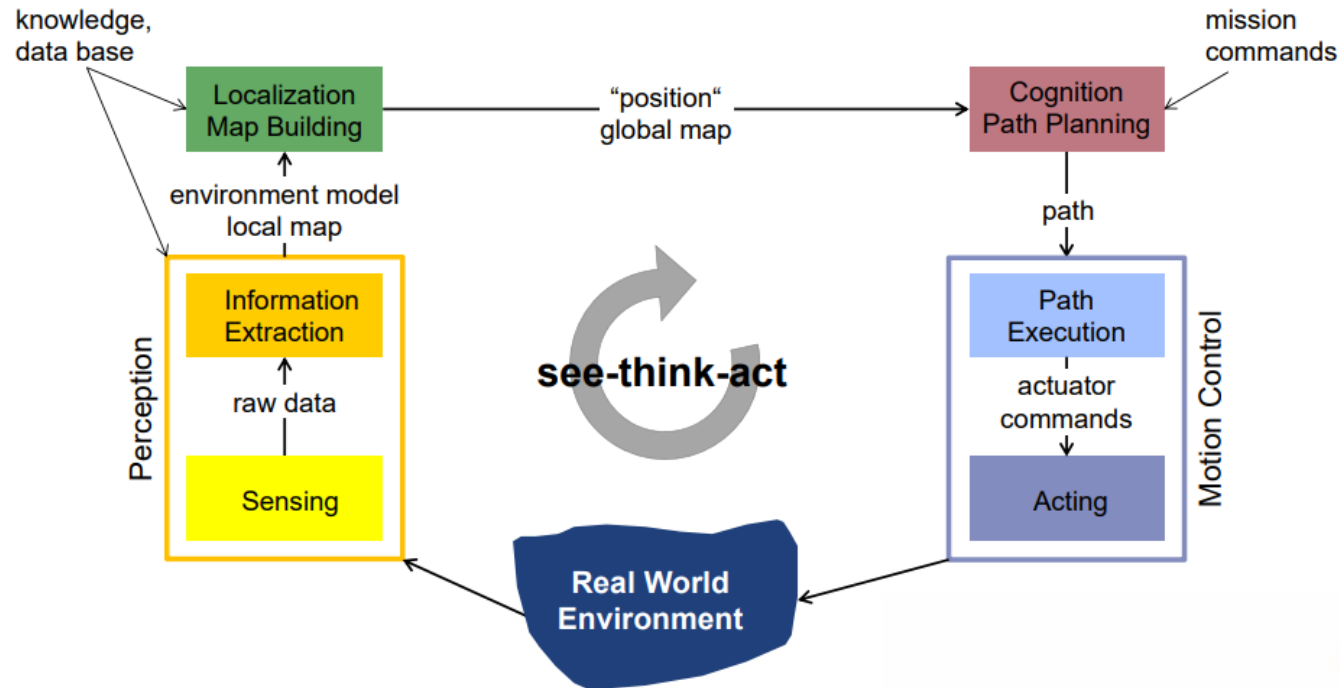




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Autonomni mobilni roboti | see-think-act



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Da li nam je potrebna lokalizacija?

- Cilj je otići iz tačke A u tačku B
 - Da li moramo da znamo svoju poziciju da bismo uradili zadatak





Da li nam je potrebna lokalizacija?

- Navigacija od A do B
 - Bez udaranja u prepreke
 - Detektovati ciljnu poziciju



Moguća je primena tehnike praćenja levog zida:

- Kako detektovati da smo stigli?



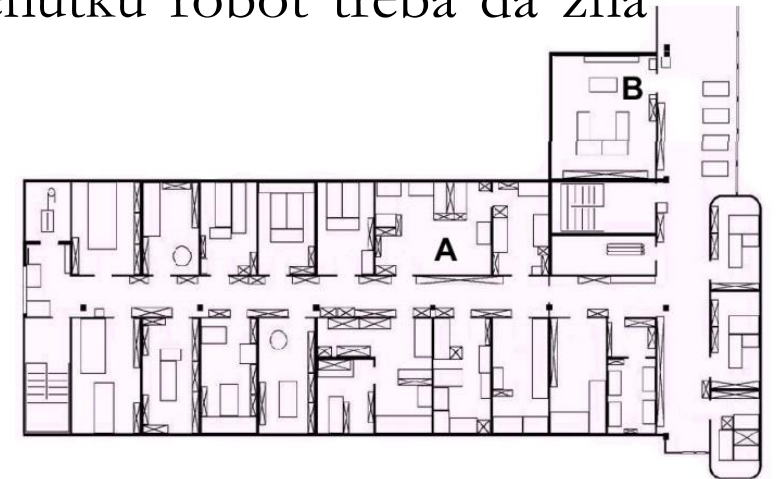


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Da li nam je potrebna lokalizacija?

- Navigacija zasnovana na mapi:
 - Ako pretpostavimo da je mapa poznata, u svakom trenutku robot treba da zna gde se nalazi na njoj. Kako?
 - Ako znamo početnu poziciju, možemo da koristimo odometriju i tako znamo poziciju robota na mapi.
- Kako predstaviti mapu u memoriji robota?
- Kako predstaviti poziciju robota na mapi?



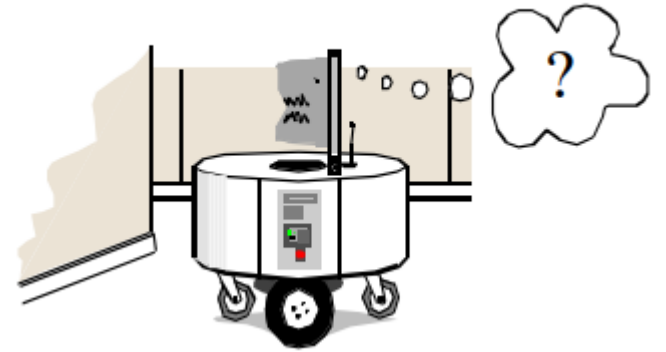
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Definicija lokalizacije

- Globalna lokalizacija
 - Robotu nije rečena njegova inicijalna pozicija.
 - Pozicija mora biti procenjena od nule.
- Praćenje pozicije
 - Robotu je poznata početna pozicija i pomoću odometrije prati promenu pozicije.





Kako se lokalizovati?

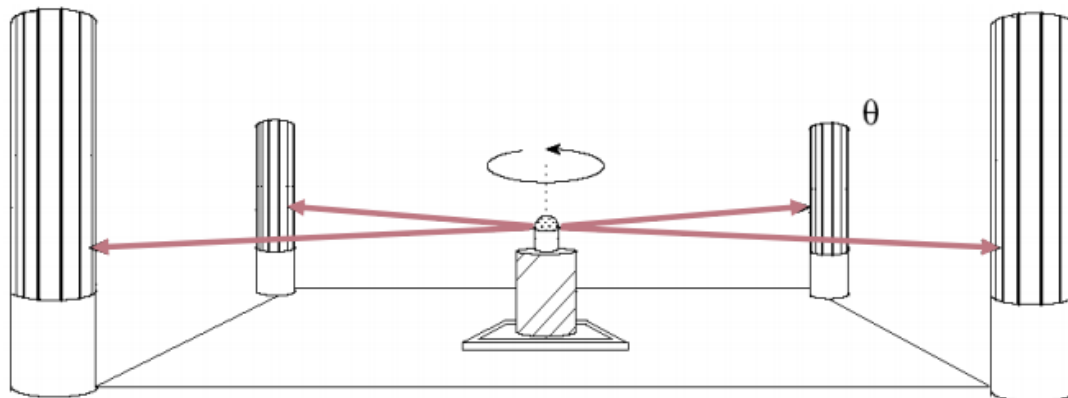
- Lokalizacija zasnovana na eksternim senzorima, bikonima i obeležjima na terenu
- Odometrija
- Lokalizacija zasnovana na mapama – bez korišćenja eksternih senzora ili znakova na terenu, koriste se samo senzori koji su na robotu.





Lokalizacija pomoću bikona

- Triangulacija
 - Primer 1: Stubovi sa visoko-reflektivnom površinom i laser koji ih detektuje.
 - Primer 2: Bikoni koji emituju infracrvenu svetlost i infracrvena kamera koja ih detektuje.





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Lokalizacija pomoću bikona



https://www.youtube.com/watch?v=rVgDb_gTC0Q

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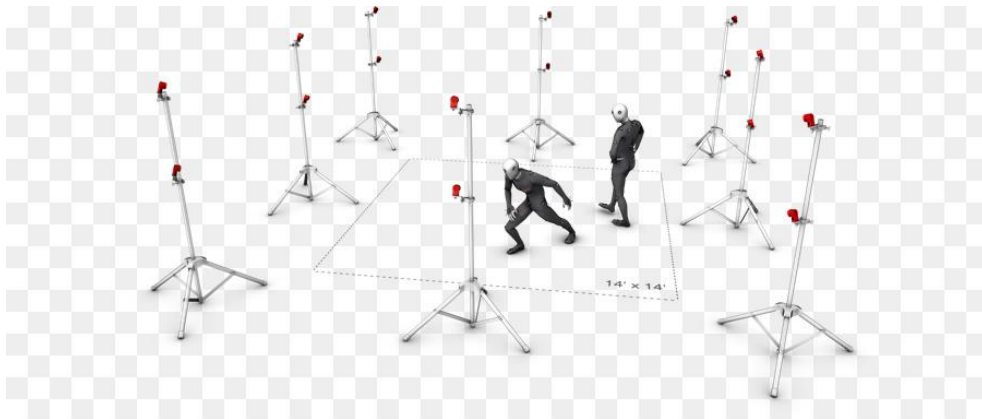


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Motion Capture sistemi

- Visoke rezolucije (od VGA do 16Mpixels)
- Veliki frekvencija (do nekoliko stotina Hz)
- Dobar za određivanje tačne globalne pozicije i za sisteme sa više robota.



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Motion Capture sistemi



https://www.youtube.com/watch?v=WMk_zca5B9E

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Lokalizacija zasnovana na mapi

- Posmatramo robota koji se kreće u poznatom okruženju.



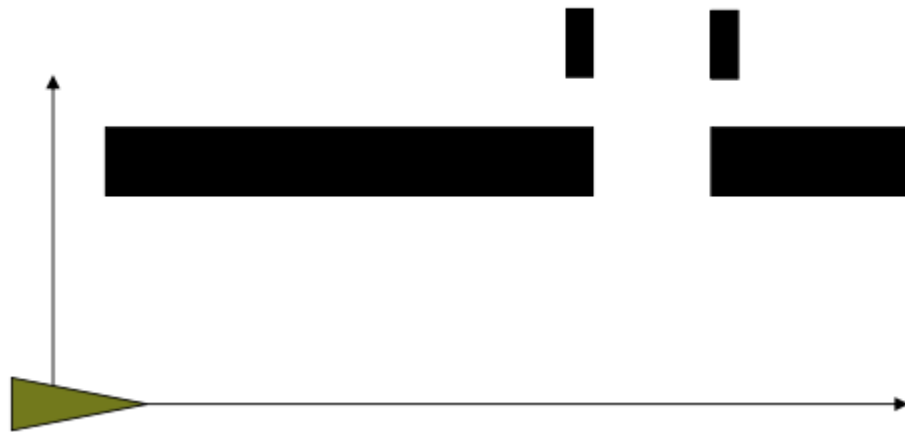
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Lokalizacija zasnovana na mapi

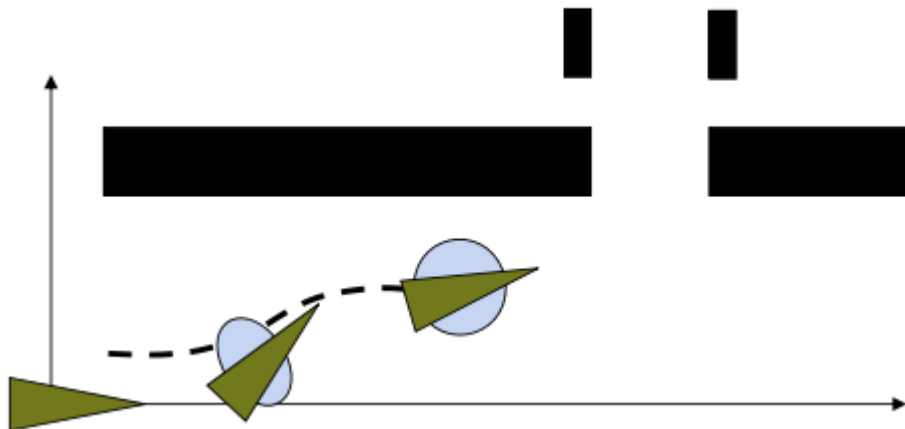
- Posmatramo robota koji se kreće u poznatom okruženju.
- Robot se kreće iz poznate početne pozicije, i kretanje se prati korišćenjem odometrije.





Lokalizacija zasnovana na mapi

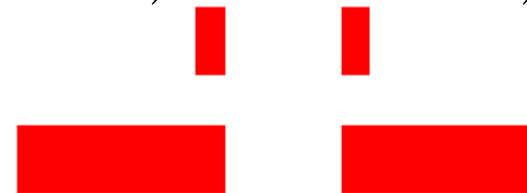
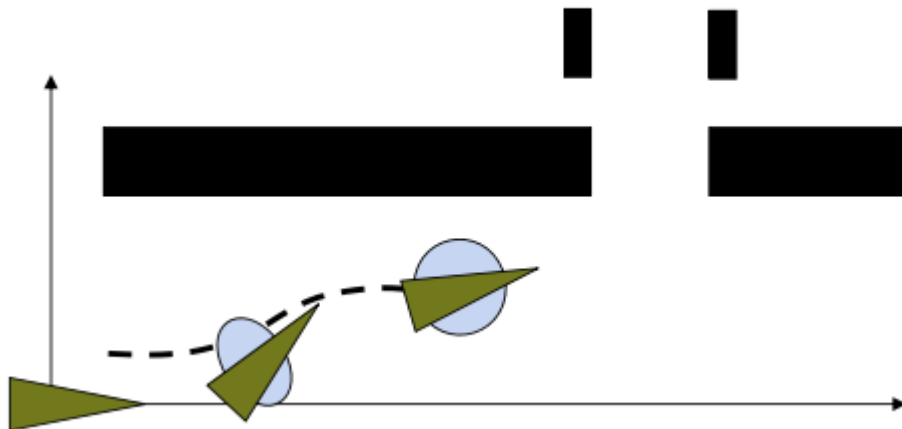
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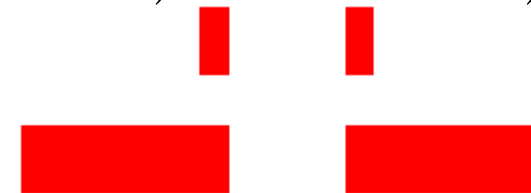
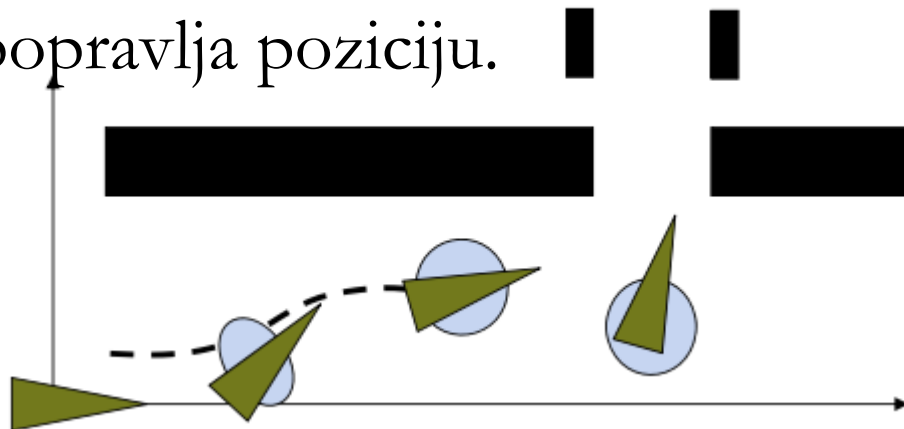
Sensor reference frame





Lokalizacija zasnovana na mapi

- Posmatramo robota koji se kreće u poznatom okruženju.
- Robot se kreće iz poznate početne pozicije, i kretanje se prati korišćenjem odometrije.
- Robot vrši merenja i na osnovu njih popravlja poziciju.



Sensor reference frame





Odometrija

- Definicija
 - Dead reckoning (odometrija) je proces računanja trenutne pozicije vozila koristeći prethodno određenu poziciju i procenjenu brzinu u vremenu.
- Kretanje robota se dobija preko integrisanih proprioceptivnih senzora brzine
 - Jednostavno korišćenje
 - Javlja se greška koja može biti neograničena - korišćenje integratora
- Heading senzori (žiroskop) se mogu koristiti za smanjivanje akumulirane greške ali se drift senzora ne može otkloniti.



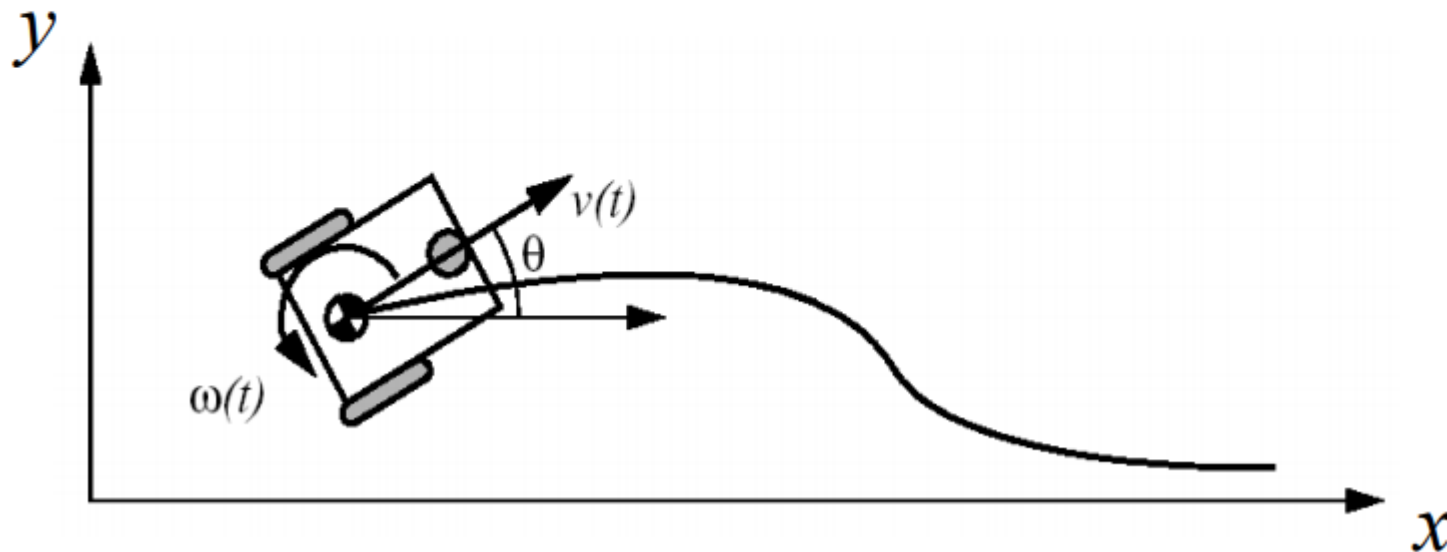


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Odometrija

$$x = \begin{bmatrix} x \\ y \\ \theta \end{bmatrix} \quad \hat{x}_t = x_{t-1} + \begin{bmatrix} \Delta x \\ \Delta y \\ \Delta \theta \end{bmatrix} = f(x_{t-1}, u_t)$$



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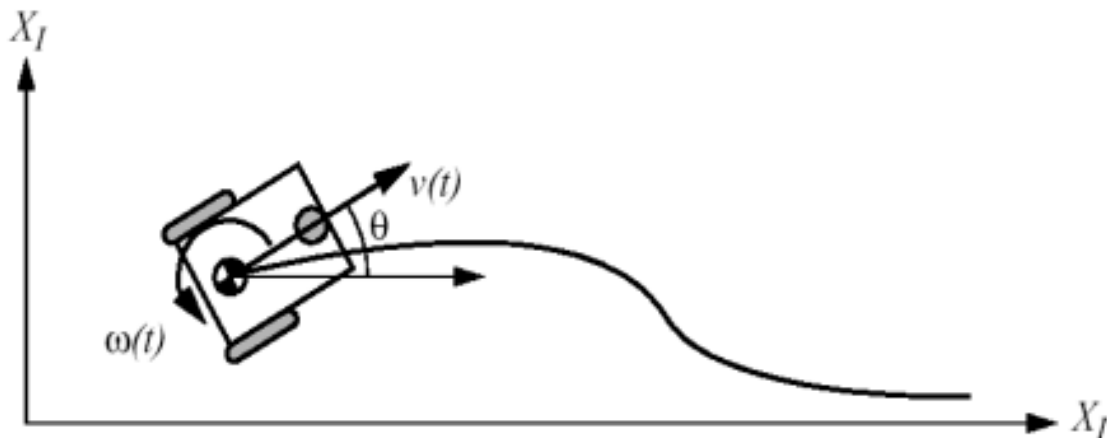


Odometrija

$$\hat{x}_t = f(x_{t-1}, u_t) = \begin{bmatrix} x_{t-1} \\ y_{t-1} \\ \theta_{t-1} \end{bmatrix} + \begin{bmatrix} \Delta s \cos(\theta + \frac{\Delta\theta}{2}) \\ \Delta s \sin(\theta + \frac{\Delta\theta}{2}) \\ \Delta\theta \end{bmatrix}$$

$$\Delta s = \frac{\Delta s_r + \Delta s_l}{2}$$

$$\Delta\theta = \frac{\Delta s_r - \Delta s_l}{b}$$





Odometrija

- Model greške

$$P_t = F_{x_{t-1}} \cdot \Sigma_{x_{t-1}} \cdot F_{x_{t-1}}^T + F_{\Delta S} \cdot \Sigma_{\Delta S} \cdot F_{\Delta S}^T$$

$$\Sigma_{\Delta S} = \begin{bmatrix} k_r |\Delta s_r| & 0 \\ 0 & k_l |\Delta s_l| \end{bmatrix}$$

$$F_{x_{t-1}} = \nabla f_{x_{t-1}} = \begin{bmatrix} \frac{\partial f}{\partial x} & \frac{\partial f}{\partial y} & \frac{\partial f}{\partial \theta} \end{bmatrix} = \begin{bmatrix} 1 & 0 & -\Delta s \sin(\theta + \Delta \theta / 2) \\ 0 & 1 & \Delta s \cos(\theta + \Delta \theta / 2) \\ 0 & 0 & 1 \end{bmatrix}$$

$$F_{\Delta S} = \begin{bmatrix} \frac{1}{2} \cos\left(\theta + \frac{\Delta \theta}{2}\right) - \frac{\Delta s}{2b} \sin\left(\theta + \frac{\Delta \theta}{2}\right) & \frac{1}{2} \cos\left(\theta + \frac{\Delta \theta}{2}\right) + \frac{\Delta s}{2b} \sin\left(\theta + \frac{\Delta \theta}{2}\right) \\ \frac{1}{2} \sin\left(\theta + \frac{\Delta \theta}{2}\right) + \frac{\Delta s}{2b} \cos\left(\theta + \frac{\Delta \theta}{2}\right) & \frac{1}{2} \sin\left(\theta + \frac{\Delta \theta}{2}\right) - \frac{\Delta s}{2b} \cos\left(\theta + \frac{\Delta \theta}{2}\right) \\ & \frac{1}{b} & -\frac{1}{b} \end{bmatrix}$$

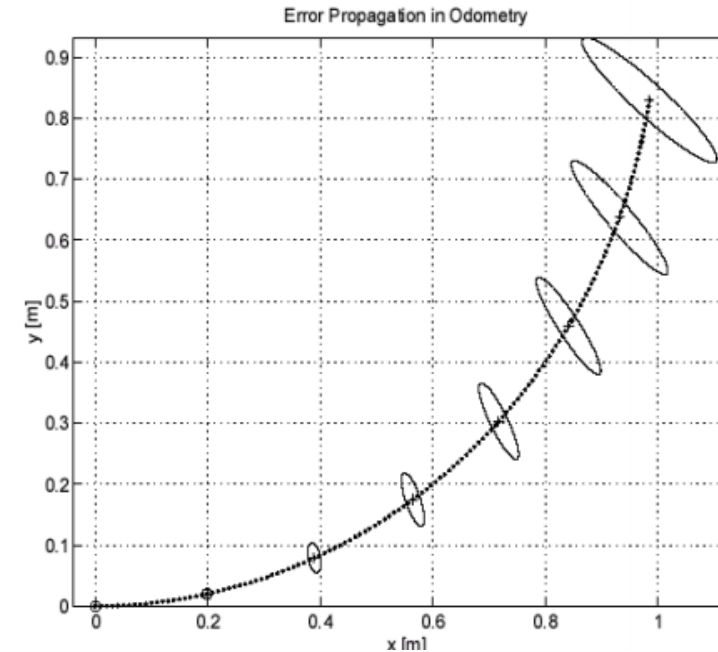
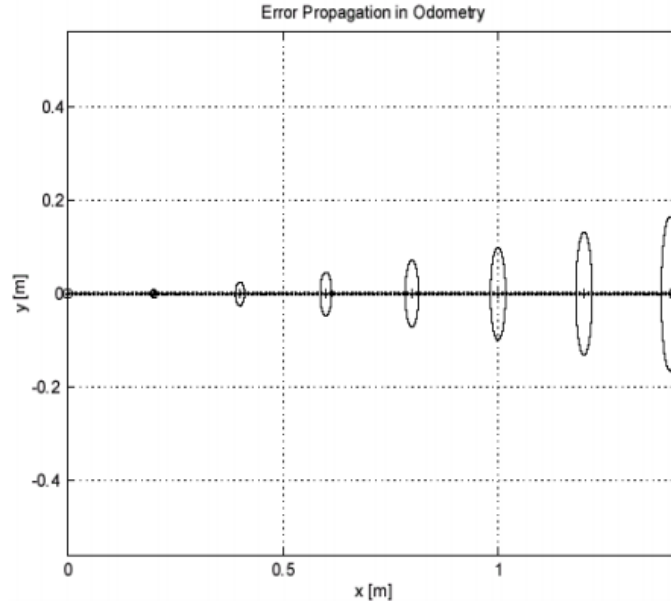




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Odometrija



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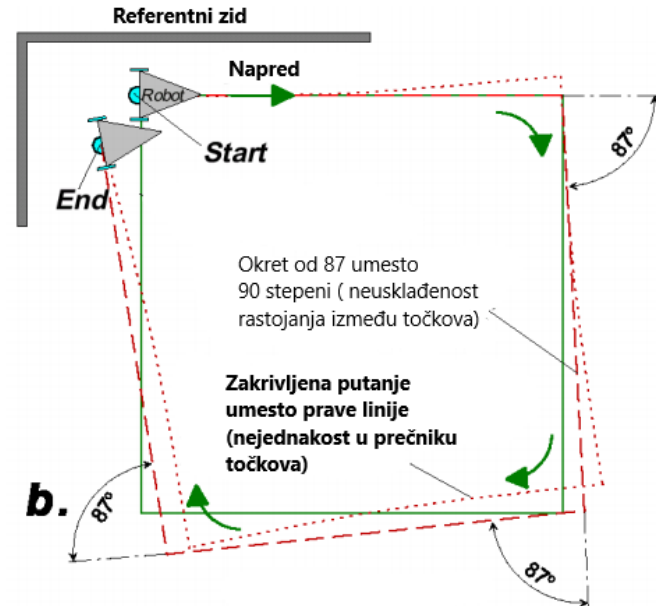
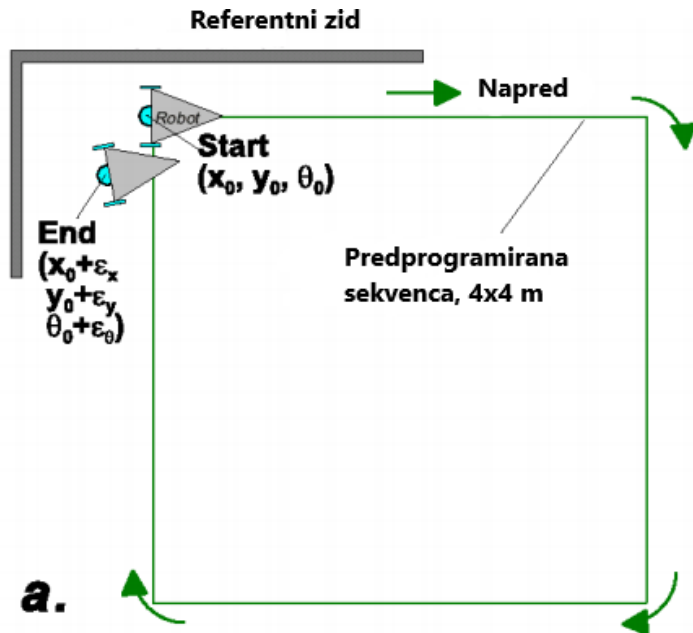
Izvori greške

- Deterministički (sistematični) ←————→ Nedeterministički (nesistematične)
- Determinističke greške mogu biti otklonjene pravilnom kalibracijom.
- Nedeterminističke greške su slučajne greške. Moraju biti opisane modelom greške i uvek vode ka određenoj nesigurnosti u estimaciji.
- Najveći izvori greške kod Odomotrije:
 - Ograničena rezolucija integraljenja (vreme inkrementa, rezolucija merenja)
 - Nepoklapanje osa točkova (deterministički izvor)
 - Nejednak prečnik točkova (deterministički izvor)
 - Promena kontaktne tačke točka i podloge (nedeterministički)
 - Proklizavanje (nedeterministički)





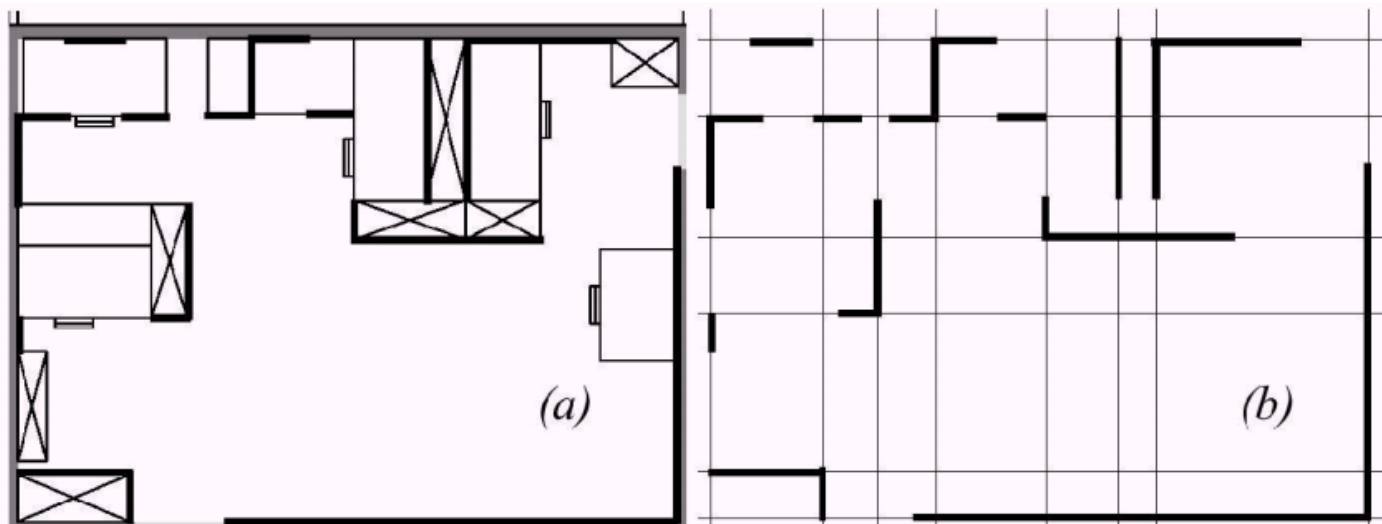
Kalibracija





Reprezentacija mape

- Crtež stana (a).
- Reprezentacija pomoću seta konačnih ili beskonačnih linija (b).



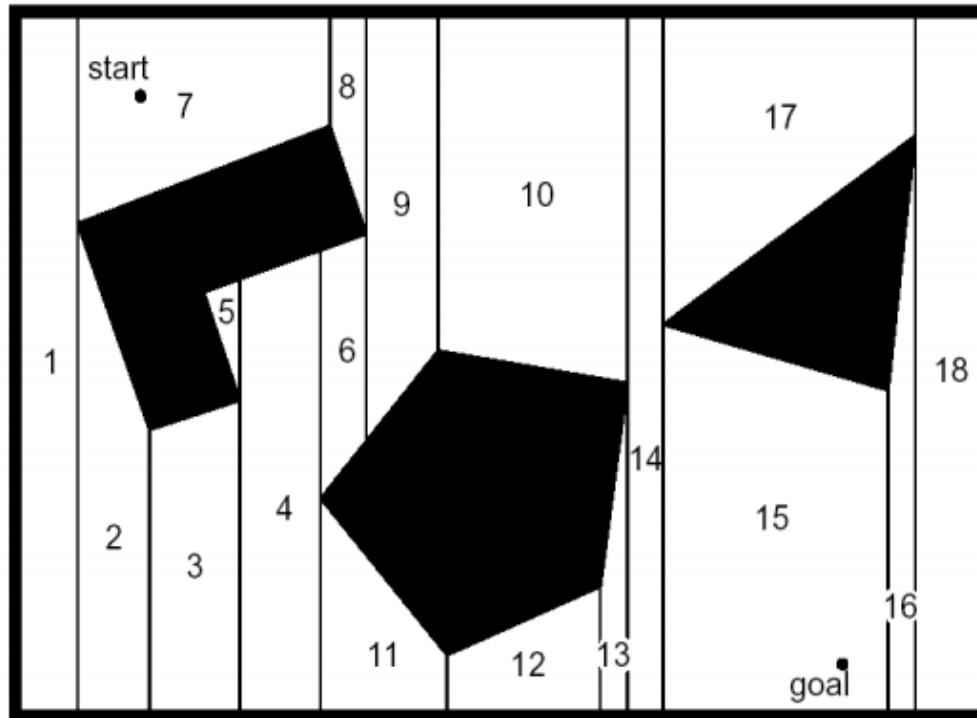


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Reprezentacija mape

- Dekompozicija ćelija.



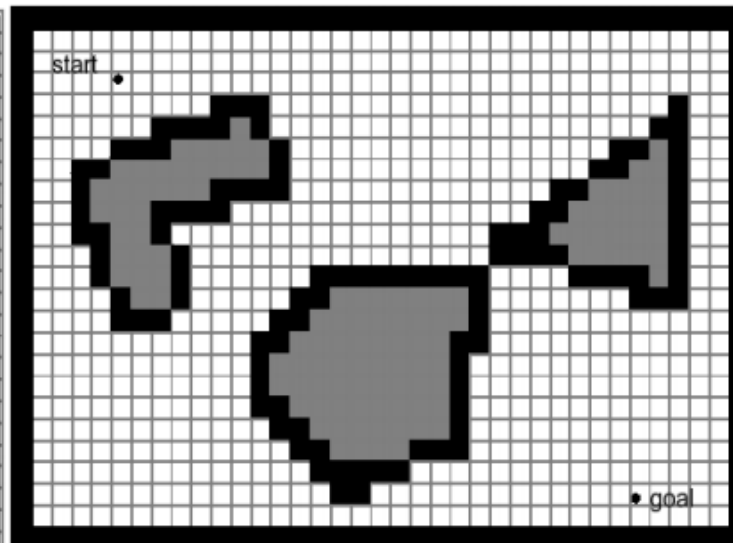
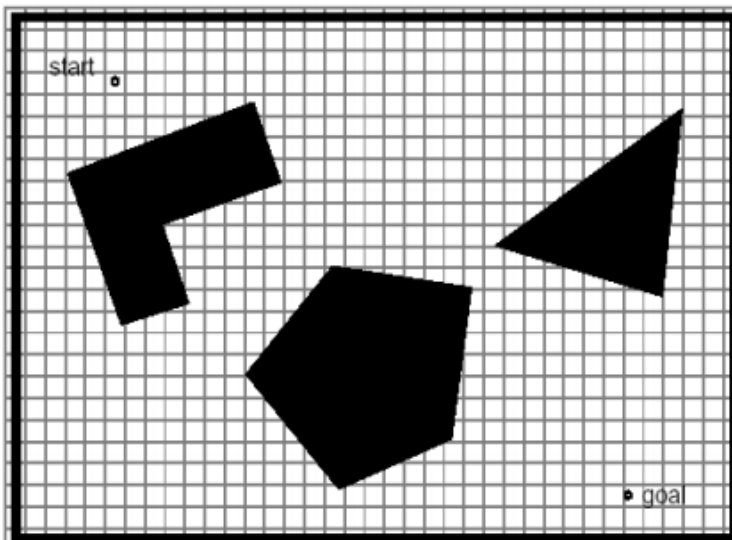
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Reprezentacija mape

- Dekompozicija ćelija fiksne veličine.
 - Pojavljuju se uski prolazi





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Thanks!

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