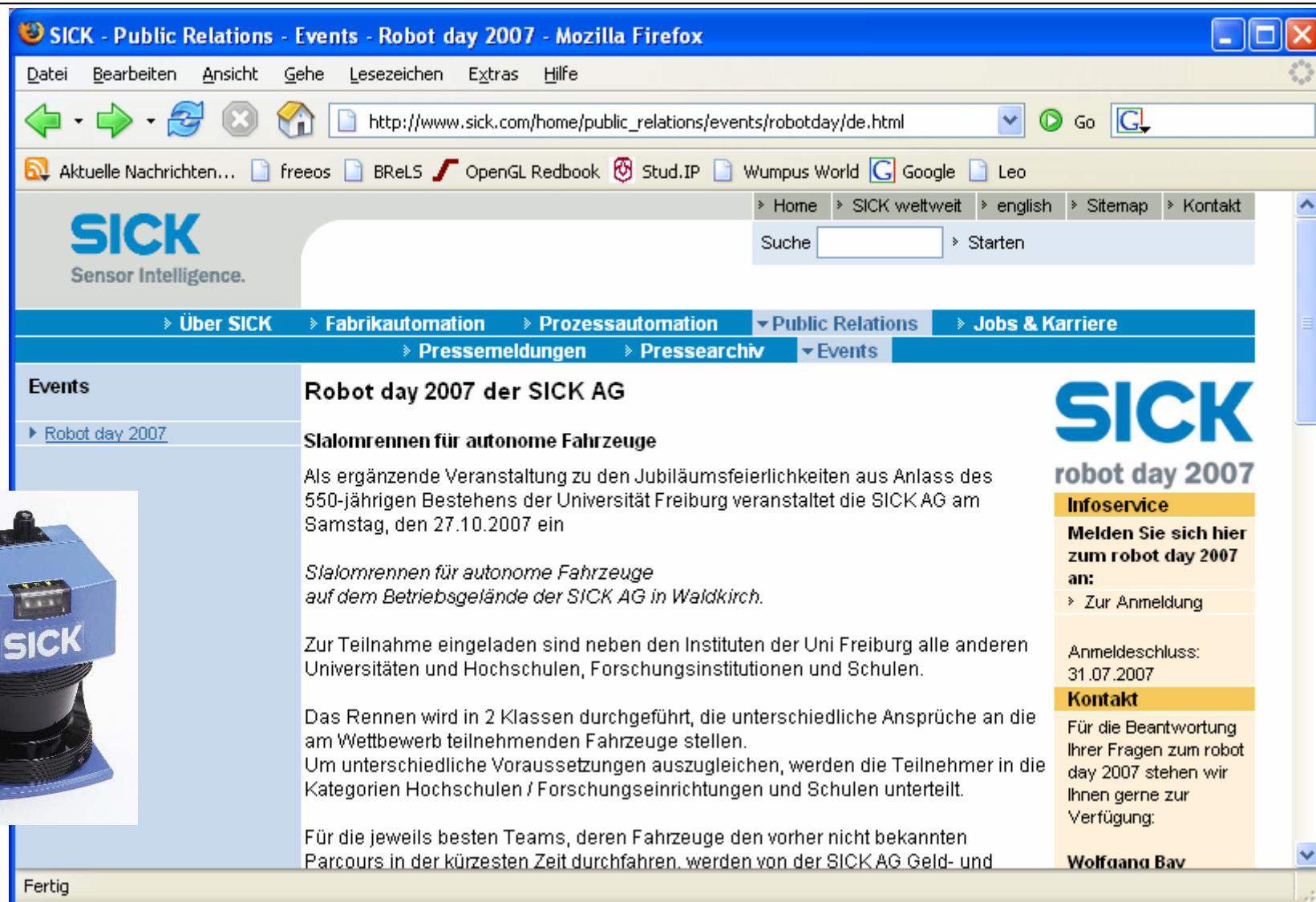


High Speed Differential Drive Mobile Robot Path Following Control With Bounded Wheel Speed Commands

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Motivation – SICK robot day



The screenshot shows a Mozilla Firefox browser window displaying the SICK website. The address bar shows the URL: http://www.sick.com/home/public_relations/events/robotday/de.html. The page features the SICK logo with the tagline "Sensor Intelligence." and a navigation menu with options like "Über SICK", "Fabrikautomation", "Prozessautomation", "Public Relations", and "Jobs & Karriere". The main content area is titled "Robot day 2007 der SICK AG" and includes a sub-section "Slalomrennen für autonome Fahrzeuge". A sidebar on the right contains an "Infoservice" section with a registration deadline of 31.07.2007 and a contact person, Wolfgang Bay.

SICK
Sensor Intelligence.

Home SICK weltweit english Sitemap Kontakt

Suche Starten

Über SICK Fabrikautomation Prozessautomation Public Relations Jobs & Karriere

Pressemeldungen Pressearchiv Events

Events

Robot day 2007

Robot day 2007 der SICK AG

Slalomrennen für autonome Fahrzeuge

Als ergänzende Veranstaltung zu den Jubiläumsfeierlichkeiten aus Anlass des 550-jährigen Bestehens der Universität Freiburg veranstaltet die SICK AG am Samstag, den 27.10.2007 ein

Slalomrennen für autonome Fahrzeuge auf dem Betriebsgelände der SICK AG in Waldkirch.

Zur Teilnahme eingeladen sind neben den Instituten der Uni Freiburg alle anderen Universitäten und Hochschulen, Forschungsinstitutionen und Schulen.

Das Rennen wird in 2 Klassen durchgeführt, die unterschiedliche Ansprüche an die am Wettbewerb teilnehmenden Fahrzeuge stellen. Um unterschiedliche Voraussetzungen auszugleichen, werden die Teilnehmer in die Kategorien Hochschulen / Forschungseinrichtungen und Schulen unterteilt.

Für die jeweils besten Teams, deren Fahrzeuge den vorher nicht bekannten Parcours in der kürzesten Zeit durchfahren, werden von der SICK AG Geld- und

SICK
robot day 2007

Infoservice

Melden Sie sich hier zum robot day 2007 an:

> Zur Anmeldung

Anmeldeschluss:
31.07.2007

Kontakt

Für die Beantwortung Ihrer Fragen zum robot day 2007 stehen wir Ihnen gerne zur Verfügung:

Wolfgang Bay

Fertig

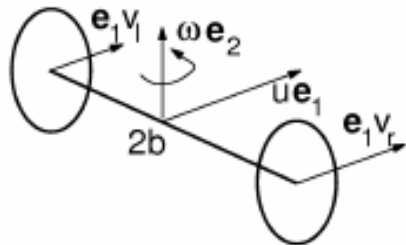


Challenges when driving fast

- Ideal actuators:
 - any control value is assumed to be instantly implemented regardless of its value.
 - Dynamical case: torque
 - Kinematical case: speed
 - No saturation
- Real actuators:
 - Exhibit saturation in case the commanded signals should exceed given thresholds.
 - Usually the controller outputs are bounded to prevent hardware damages
- Here we consider the case of kinematical path following control for a differential drive mobile robot with actuator velocity saturation.

Kinematical model

- We build our solution on the C. Canudas de Wit et al. [3] and D. Soetanto et al. [10] control for differential drive robots.



- Velocity and angular velocity

$$u = \frac{1}{2} (v_r + v_l)$$
$$\omega = \frac{1}{2b} (v_r - v_l)$$

- Can move on a path with arbitrary curvature

$$\kappa = \frac{1}{b} \frac{v_r - v_l}{v_r + v_l}.$$

$$\kappa \in \left[-\frac{1}{b}, \frac{1}{b} \right] \text{ if } v_l, v_r \in [0, V_m]$$

Deriving the Control Law

- Kinematics of Q is given by

$$\dot{x} = u \cos \theta_m$$

$$\dot{y} = u \sin \theta_m$$

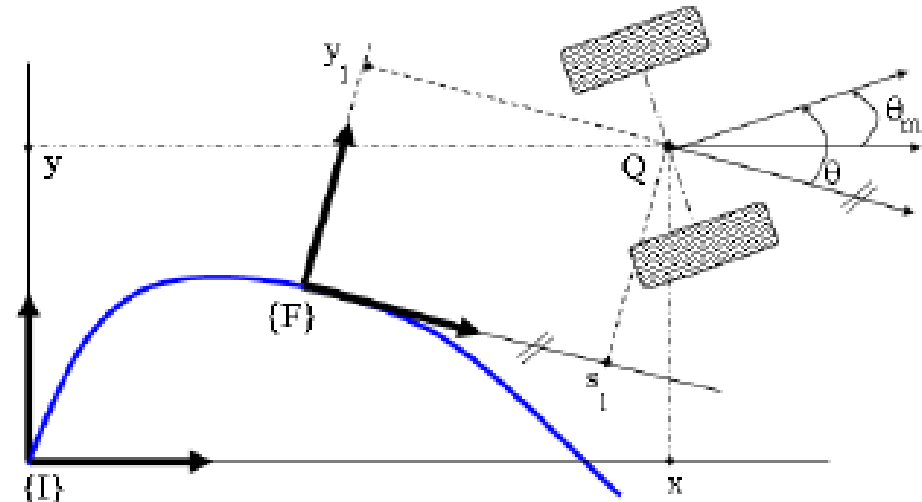
$$\dot{\theta}_m = \omega$$

and

$$\dot{s}_1 = -\dot{s} (1 - \kappa_r y_1) + u \cos \theta$$

$$\dot{y}_1 = -\kappa_r \dot{s} s_1 + u \sin \theta$$

$$\dot{\theta} = \omega - \kappa_r \dot{s}$$



- Lyapunov candidate function

$$V_1 = \frac{1}{2} (s_1^2 + y_1^2) + \frac{1}{2\gamma} (\theta - \delta(y_1, u))^2$$

Deriving the Control Law (cont.)

- D. Soetanto et al. derived the following control law

$$\begin{aligned}\dot{\theta} &= \dot{\delta} - \gamma y_1 u \frac{\sin \theta - \sin \delta}{\theta - \delta} - k_2 (\theta - \delta) \\ \dot{s} &= u \cos \theta + k_1 s_1 \quad : \quad k_1 > 0, k_2 > 0\end{aligned}$$

$$\begin{aligned}v_r &= u + b (\kappa_r \dot{s} + \dot{\theta}) \\ v_l &= u - b (\kappa_r \dot{s} + \dot{\theta})\end{aligned} \quad \kappa_{\text{closed loop}} = \frac{\kappa_r \dot{s} + \dot{\theta}}{u}.$$

$$V_1 = \frac{1}{2} (s_1^2 + y_1^2) + \frac{1}{2\gamma} (\theta - \delta(y_1, u))^2$$

High speed path following

- Skipping ...

$$\kappa_{\text{closed loop}} = \kappa_T \cos \theta + T(\cdot)$$

- Command wheel velocities corresponding to the highest possible linear velocity should satisfy:

$$\max \{v_l, v_r\} = |u| (1 + b |\kappa_{\text{closed loop}}|) = V_m \implies$$

$$u = \frac{V_m}{(1 + b |\kappa_{\text{closed loop}}|)}$$

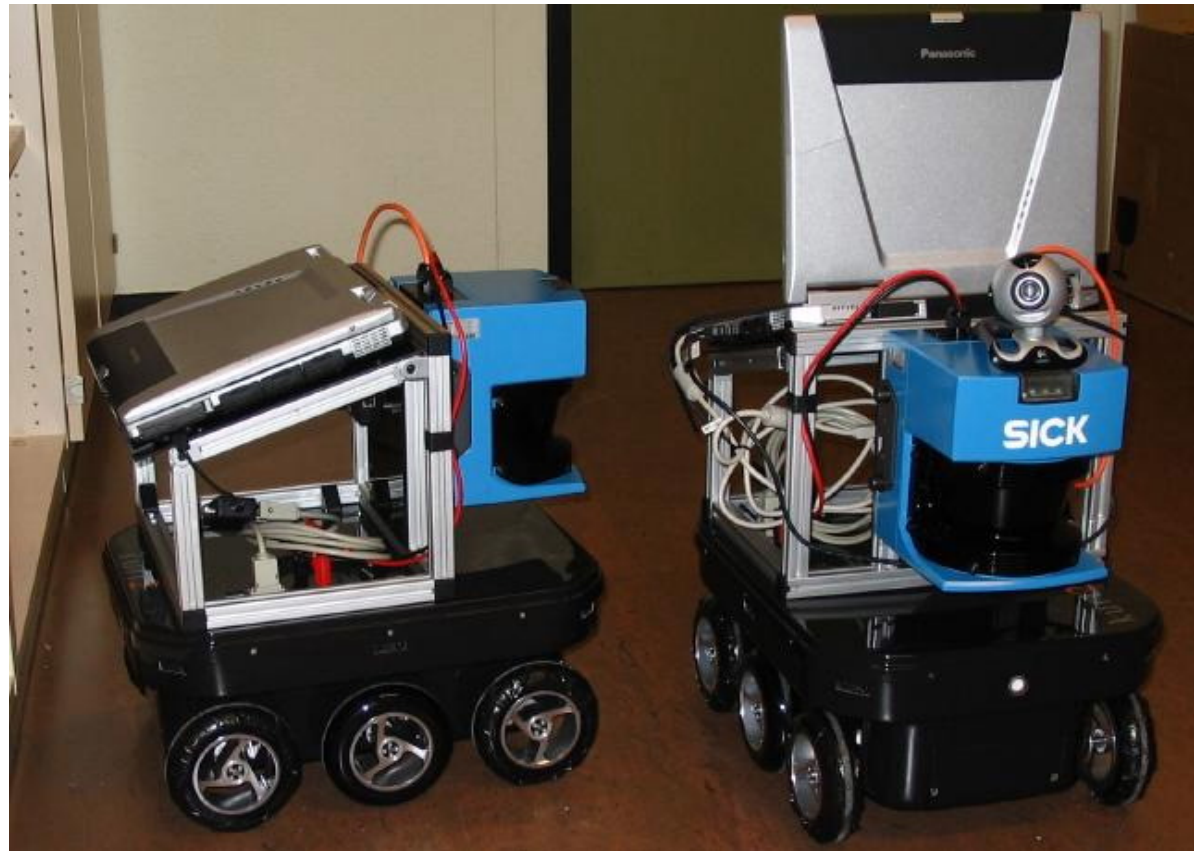
- From this we derive:

$$u = \begin{cases} V_m/2 & \text{if } V_1 \geq \varepsilon \\ V_m/(1 + b |\kappa_T(s)|) & \text{if } V_1 < \varepsilon \end{cases}$$

Implementation on a real robot

KURT2 (KTO)

- Two 90W (200W) motors
- 48 NiMH a 4500mAh
- C167 Micro-controller
- CAN Interface
- PIV-1400 Notebook
- The robot KURT2 is a lightweight (22.5 kg).



Path Following depends on pose estimation!!!



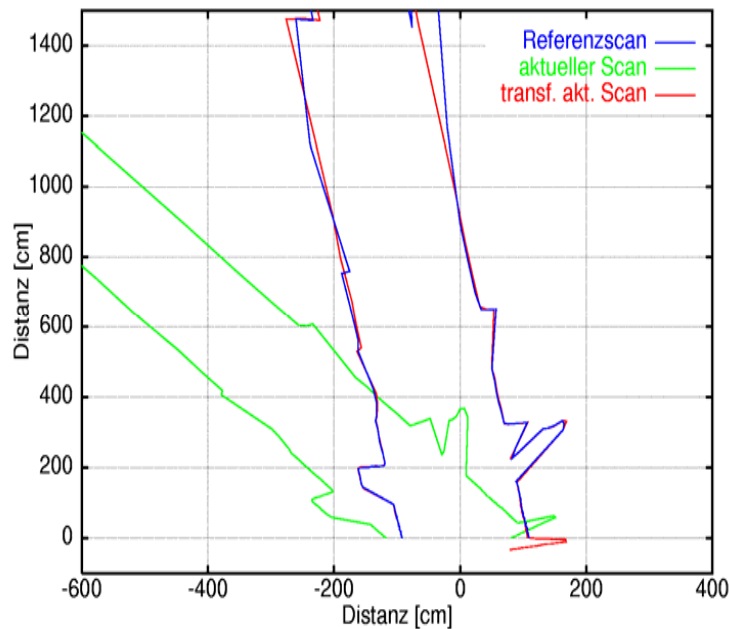
Pose estimation

- Revival of Gyrodometry as formulated by Brenstein/Feng ICRA 1996
- Iterative Closest Point (ICP) Scan Matching in near Real Time (timing issues) for precise pose estimation

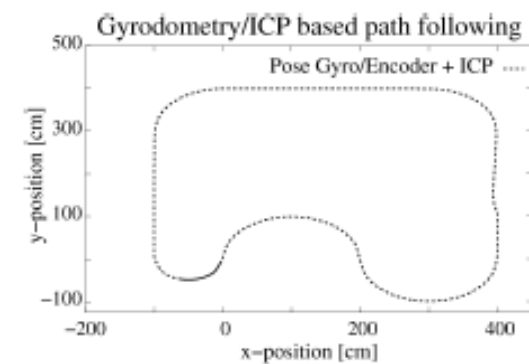
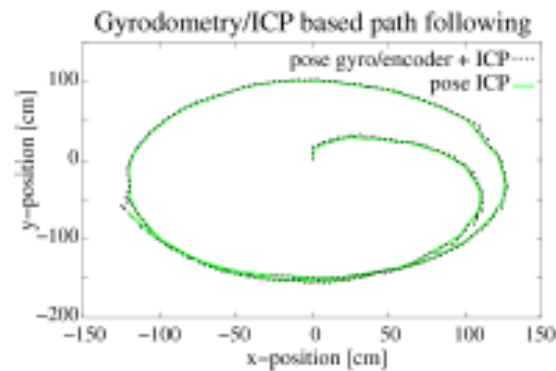
Algorithm 1 Gyrodometry

```

if  $|\Delta\theta_{\text{odo}}| > c_1$  then
     $\theta \leftarrow \theta + \Delta\theta_{\text{gyro}} - e$ 
else if  $|\delta\theta_{\text{gyro}} - e| > c_2$  then
     $\theta \leftarrow \theta + \Delta\theta_{\text{gyro}} - e$ 
else
     $e \leftarrow \lambda e + ((1 - \lambda) (\Delta\theta_{\text{gyro}} - \Delta\theta_{\text{odo}}))$ 
     $\theta \leftarrow \theta + \Delta\theta_{\text{odo}}$ 
end if
    
```

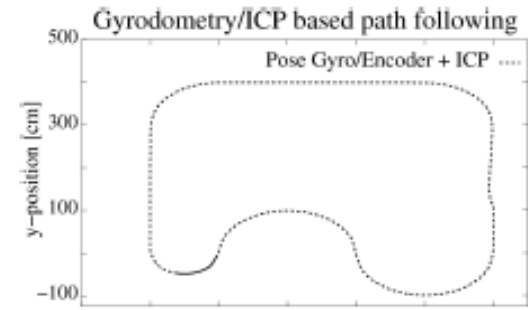
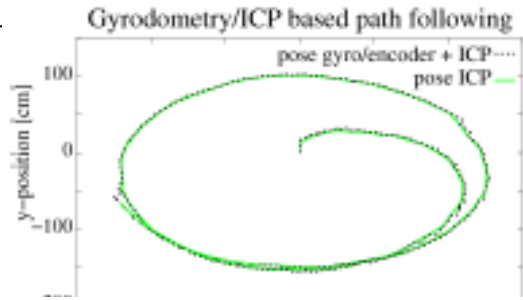


- Reference Paths



Results

(Video low speed) (Video high speed)



Conclusions and Future Work

- We have presented
 - An path following scheme for differential drive / skid steered robots
 - Actuator saturation
 - Fast localization for path following
- Future work
 - Participation in robot race
 - Considering dynamics

Thank you for your attention!