Attractor dynamics approach to behavior generation on robots with low-level sensors

Gregor Schöner, INI, RUB

Second order dynamics

source: Bicho, Schöner, Robotics and Autonomous Systems 21:23-35 (1997)

Second order dynamics

idea: go to even lower level sensory-motor systems:

- a sensor that only knows there is a target or an obstacle on the left vs. on the right...
- but is not able to estimate the heading of either
 - a motor system that is not calibrated well enough to steer into a given heading direction in the world



dynamical variable

- turning rate omega rather than heading direction
- can be ``enacted'' by setting set-points for velocity servo controllers of each motor
- target: information about target being to the left, to the right, or ahead, but no calibrated bearing, psi, to target
- obstacle: turning rate
 - to the right when obstacle close and to the left
 to the left when obstacle close and to the right
 zero when obstacle far

dynamics of turning rate: obstacle avoidance

- pitch-fork normal form (to get left-right symmetry)
- but symmetry potentially broken by additive constant: biases bifurcation toward left or toward right

$$\dot{\omega} = (\alpha + \frac{1}{2}\pi)c_{\rm obs}F_{\rm obs} + \alpha\omega - \gamma\omega^3$$

obstacle avoidance

$$\dot{\omega} = (\alpha + \frac{1}{2}\pi)c_{obs}F_{obs} + \alpha\omega - \gamma\omega^3$$



obstacle avoidance

in absence of obstacle in forward direction (distance large): alpha negative, constant zero



obstacle avoidance

in presence of obstacle in forward direction, symmetric bifurcation to desired avoidance rotations: alpha positive, constant zero



obstacle avoidance

in presence of obstacle to the right of current heading: tangent bifurcation removes attractor at negative omega, alpha negative, constant negative



mathematical form

compute constant and alpha from obstacle force lets $\dot{\omega} = (\alpha + \frac{1}{2}\pi)c_{obs}F_{obs} + \alpha\omega - \gamma\omega^3$



bifurcations as an obstacle is approached





dynamics: target acquisition

- a sensor for a target on the left sets an attractor at positive turning rate, strength graded with intensity
- a sensor for a target on the right sets an attractor at negative turning rate, strength graded with intensity



mathematical formulation

force-let of each target sensor

$$g_i(\omega) = -\frac{1}{\tau_{\omega}}(\omega - \omega_i) \exp\left[-2\frac{(\omega - \omega_i)^2}{\Delta\omega^2}\right].$$

(*i* = right or left)

summed to total dynamics

 $g_{\text{left}}(\omega) + g_{\text{right}}(\omega)$

putting it to work on a simple platform

Rodinsky!

- circular platform with passive caster wheel
- two (unservoed) motors
- 5 IR sensors
- 2 LDR's
- microcontroller
 MC68HCAIIA0
 Motorola (32 K RAM),
 8 bit



example trajectories



video demonstration



why does it work?

- here the dynamics exists instantaneously while vehicle is heading in a particular direction
- while the vehicle is turning under the influence of the corresponding attractor for turning rate, the dynamics is changing!
- typically undergoing an instability as vehicle's heading turns away from an obstacle...

what is the benefit of using second order dynamics?

- ability to integrate constraints which do not specify a particular heading direction, only turning direction
- ability to impose a desired turning rate => enhances agility in turning
- ability to control the second derivative of heading direction=angular acceleration: enables taking into account vehicle dynamics

quantitative comparison



[Hernandes, Becker, Jokeit, Schöner, 2014]

Other implementations

cooperative robot vehicles, by Estela Bicho, Portugal

autonomous wheel-chair by Pierre Mallet, Marseille

