Attractor dynamics model of human navigation

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human locomotion

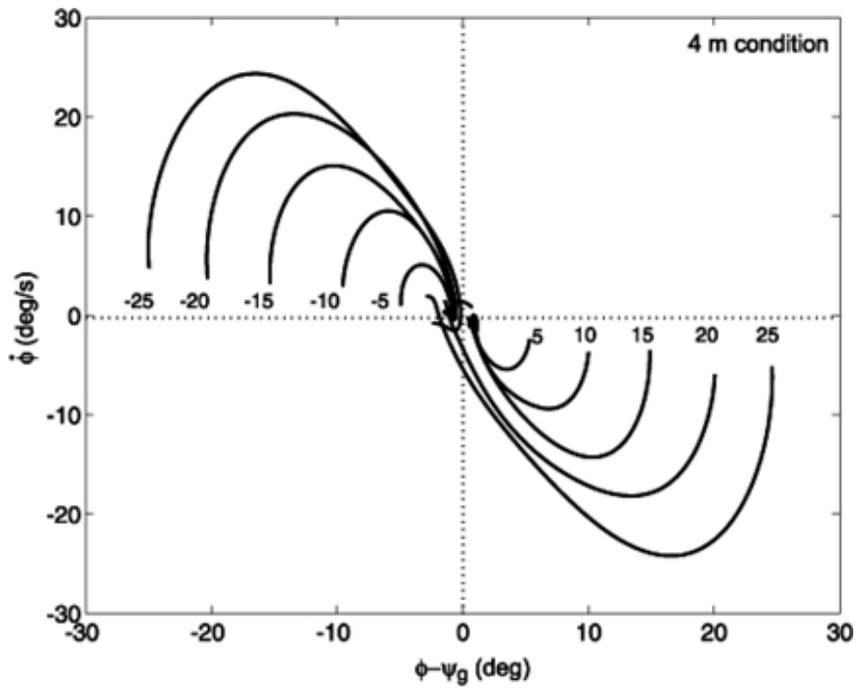
- Bill Warren and Bret Fajen have used the attractor dynamics approach to account for how humans locomote in virtual reality
  - Fajen et al, International Journal of Computer Vision 54(1/2/3), 13–34, 2003 2003

human locomotion to goal

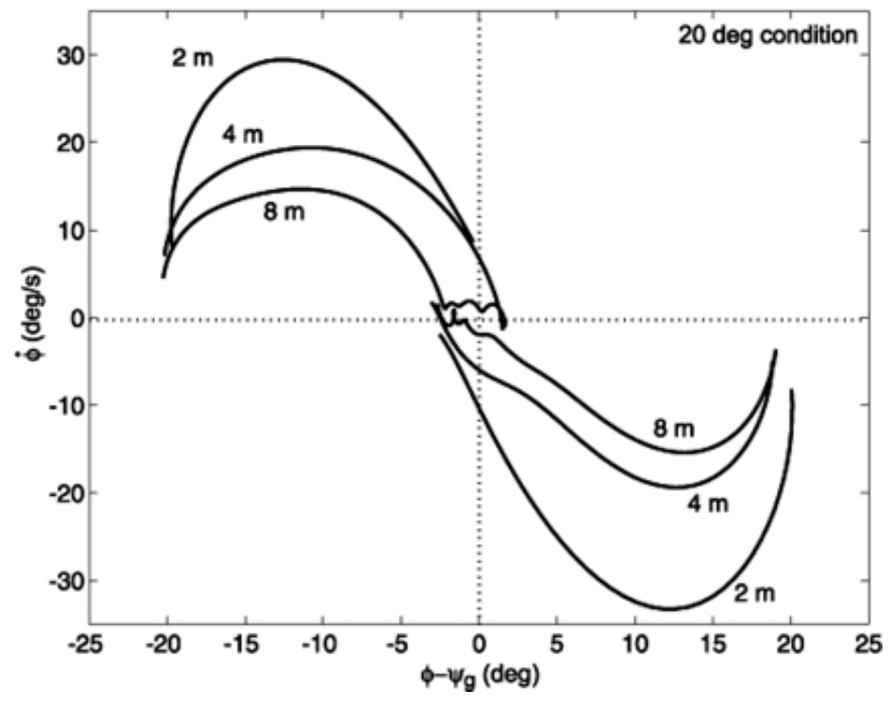
- participants begins to walk
- after walking 1 m, a goal appears at 5, 10, 15, 20, or 25 deg from the straight heading at a distance of 2, 4, or 8 m from participant...
- participants are asked to walk toward the goal

human locomotion to goal

- => turning rate increased with increasing goal angle



- => turning rate decreased with increasing distance form goal

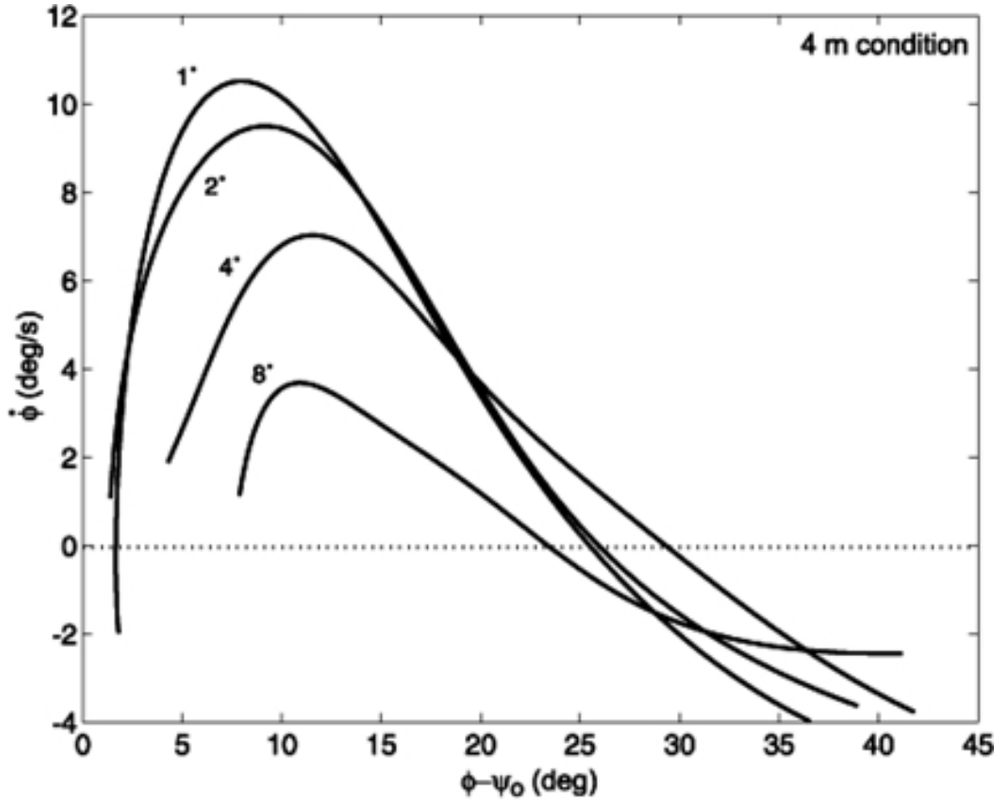


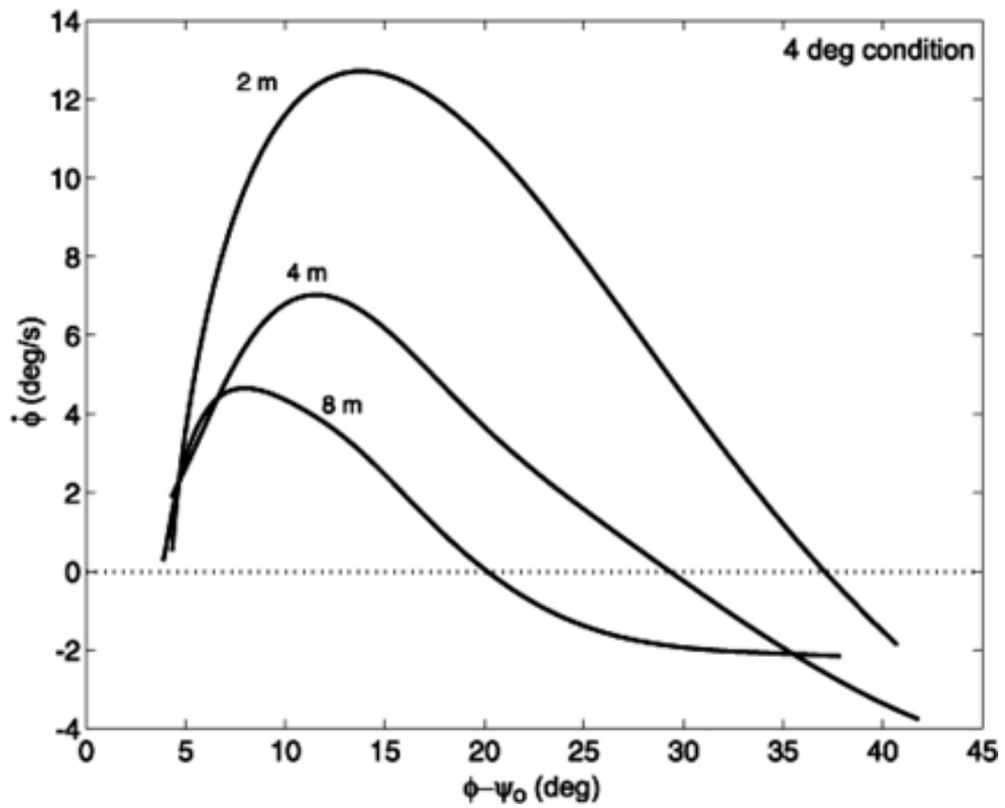
human locomotion: obstacle

- humans walk toward goal at 10 m distance
- after walking 1 m, an obstacle appears at 1, 2, 4, or 8 deg from heading and a distance of 3, 4, or 5 m

human locomotion: obstacle

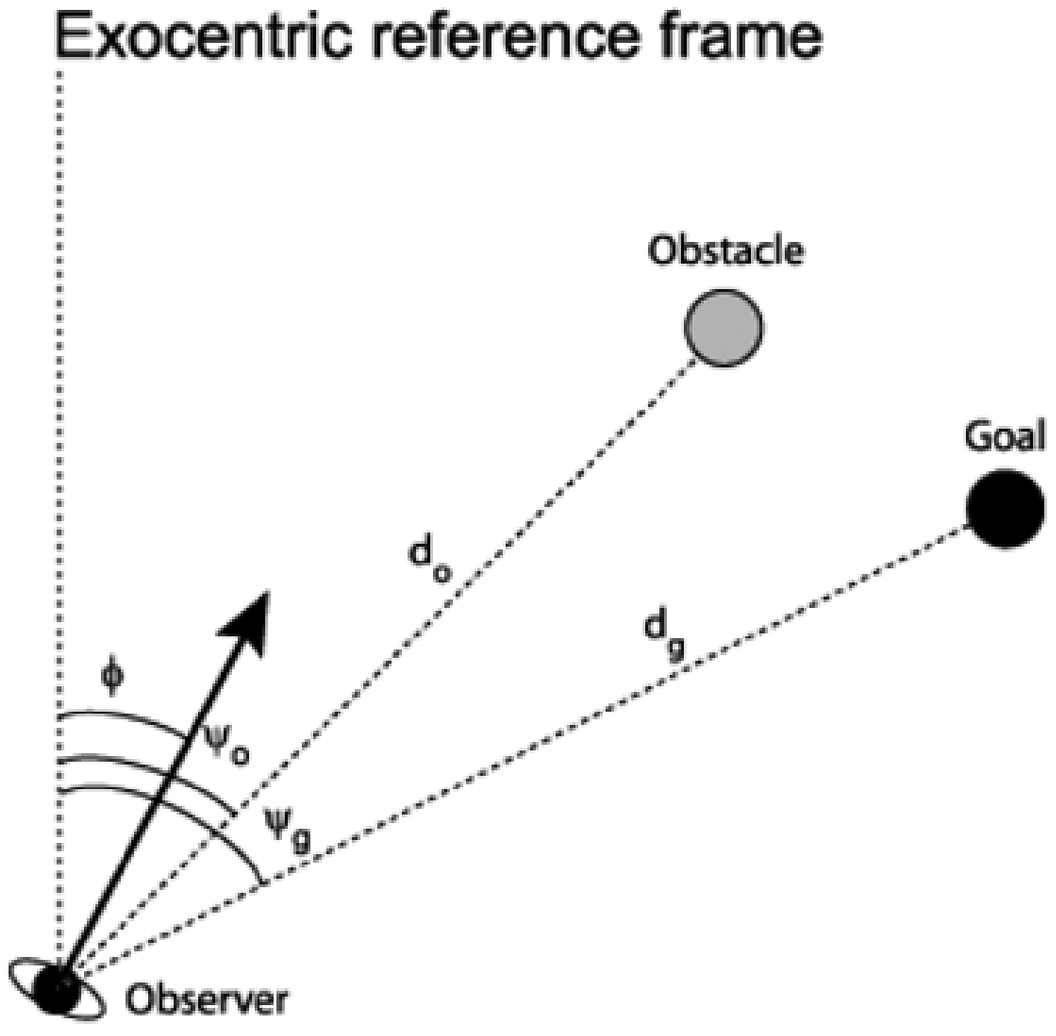
- => turning rate away from obstacle decreased with obstacle angle
- => and with obstacle distance





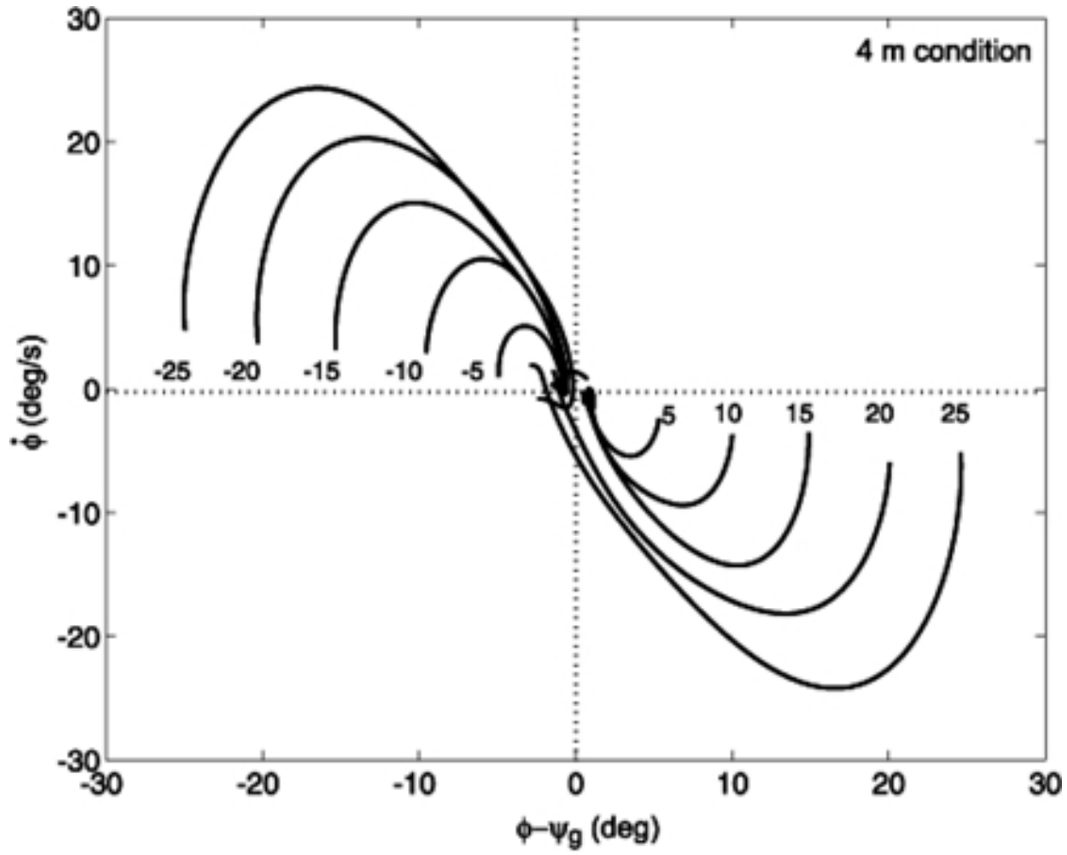
model

- heading direction as dynamical variable

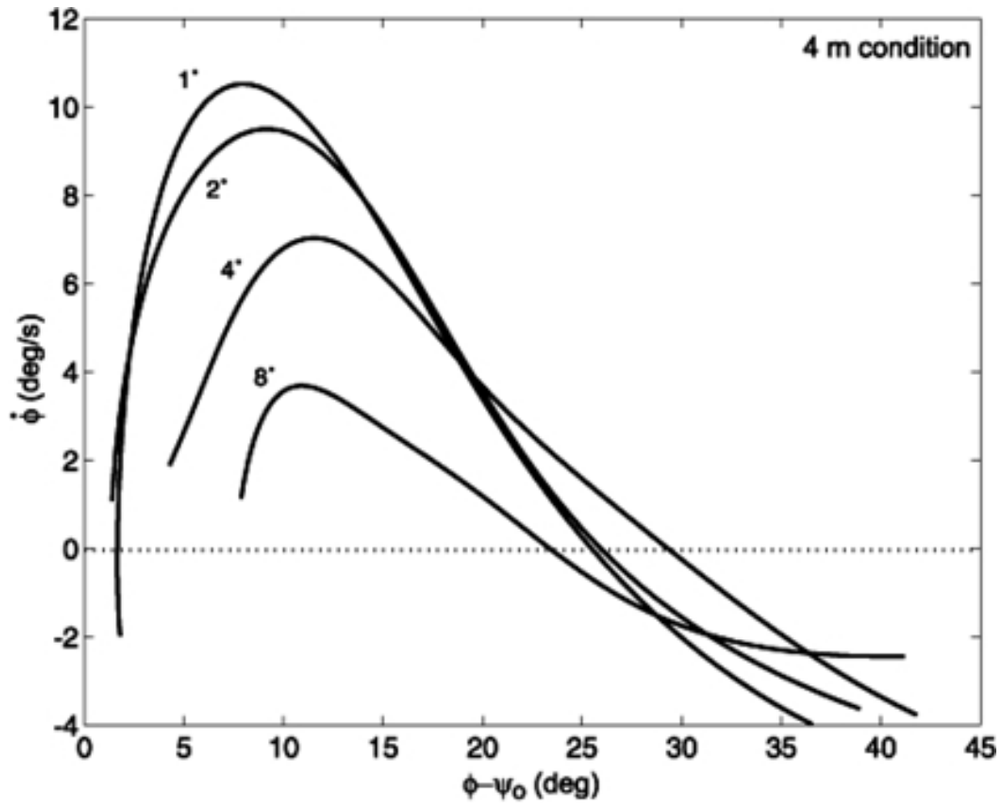


model

- first order dynamics dot phi = f(phi) not quite consistent with dependence on initial heading…



- but overall shape of phidot vs phi and distance dependence consistent with attractor dynamics approach to heading direction



attractor dynamics model

- solution: 2nd order dynamics in heading

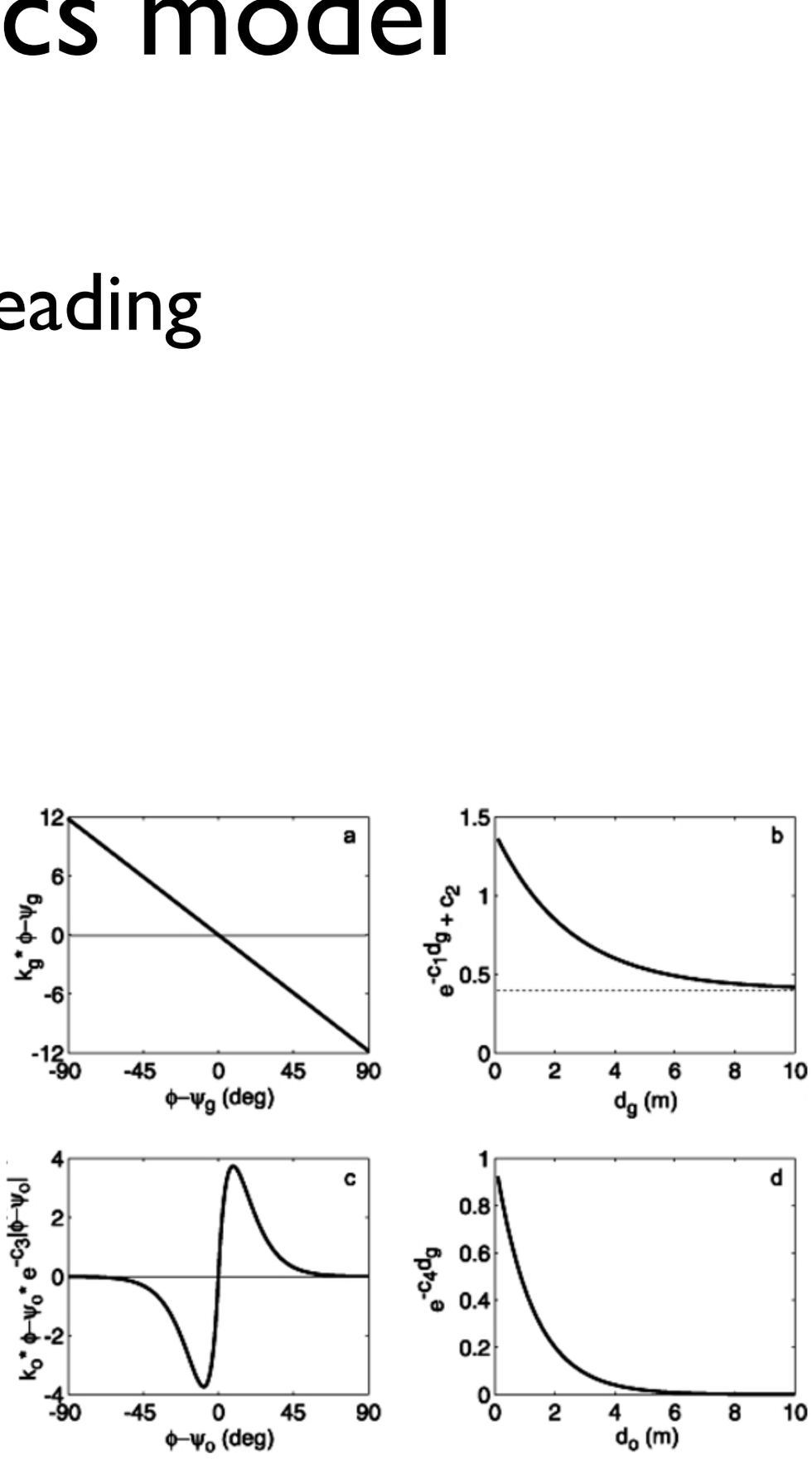
inertial term

damping term

attractor goal heading

$$\ddot{\phi} = -b\dot{\phi} - k_g(\phi - \psi_g)(e^{-c_1 d_g} + c_2)$$
$$+ k_o(\phi - \psi_o)\left(e^{-c_3|\phi-\psi_o|}\right)(e^{-c_4 d_o})$$

repellor obstacle heading



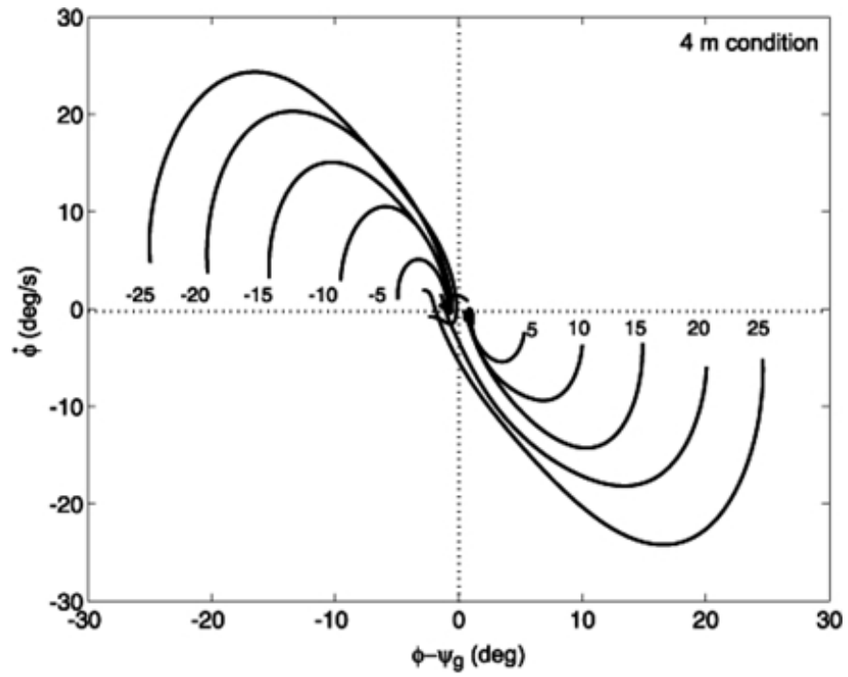
attractor dynamics model

- approximation: inertia to zero: find first order dynamics with time scale b
- computer fixed points and stability: fixed points of first order dynamics are fixed points too and have the matching stability

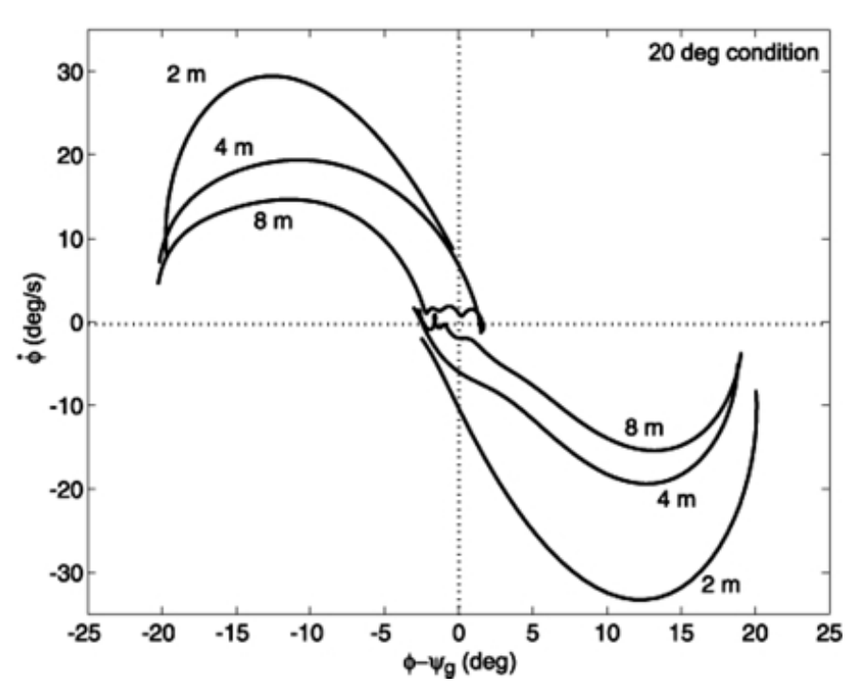
$$\ddot{\phi} = -b\dot{\phi} - k_g(\phi - \psi_g)(e^{-c_1 d_g} + c_2) \quad \text{attractor goal heading}$$
$$+ k_o(\phi - \psi_o)\left(e^{-c_3|\phi-\psi_o|}\right)(e^{-c_4 d_o}) \quad \text{repellor obstacle heading}$$

model-experiment match: goal

experiment

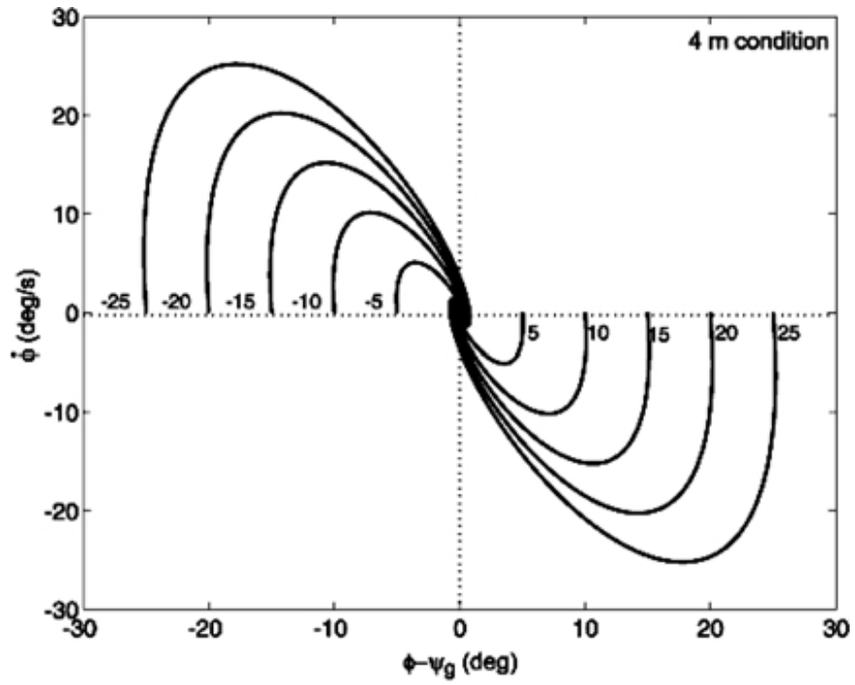


(a)

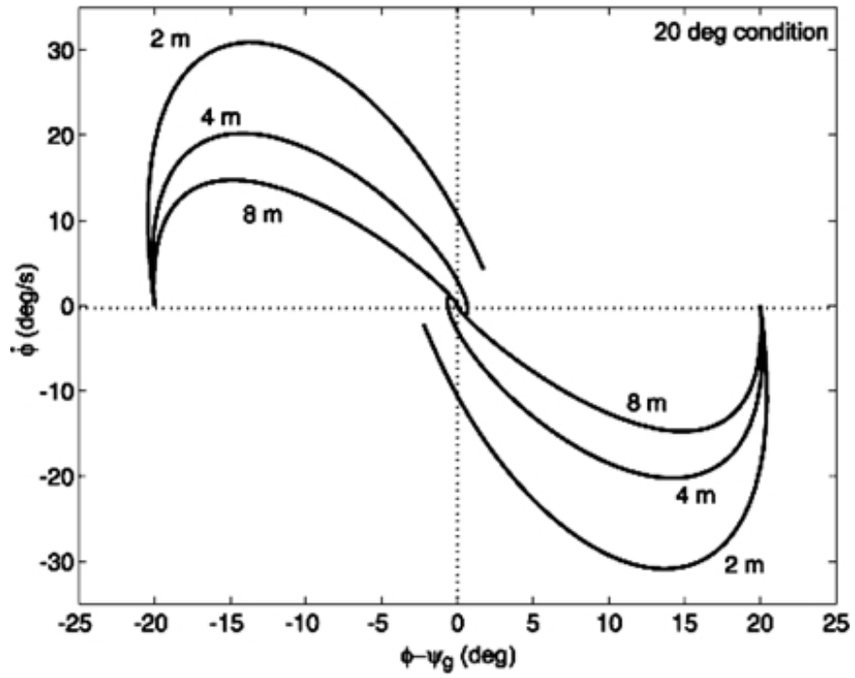


(b)

model



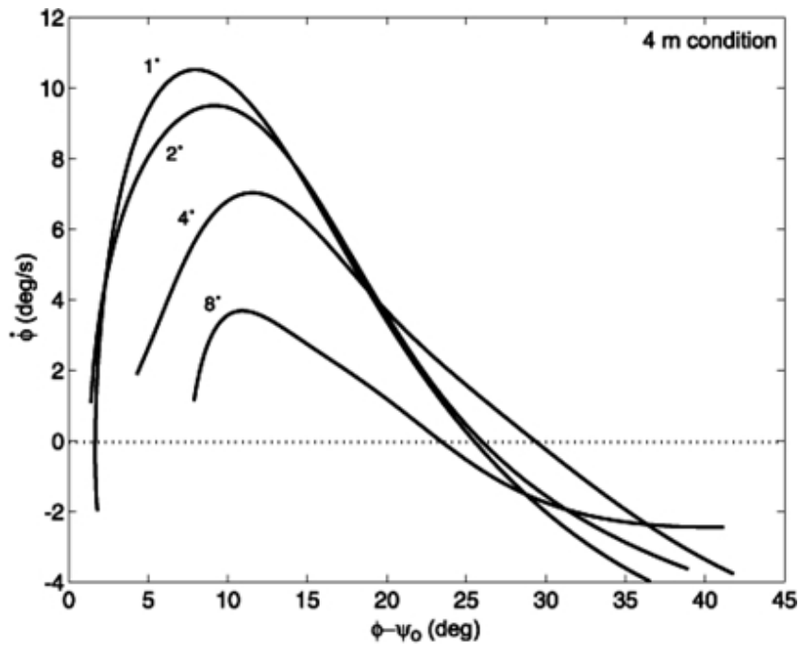
(a)



(b)

model-experiment match: obstacle

experiment



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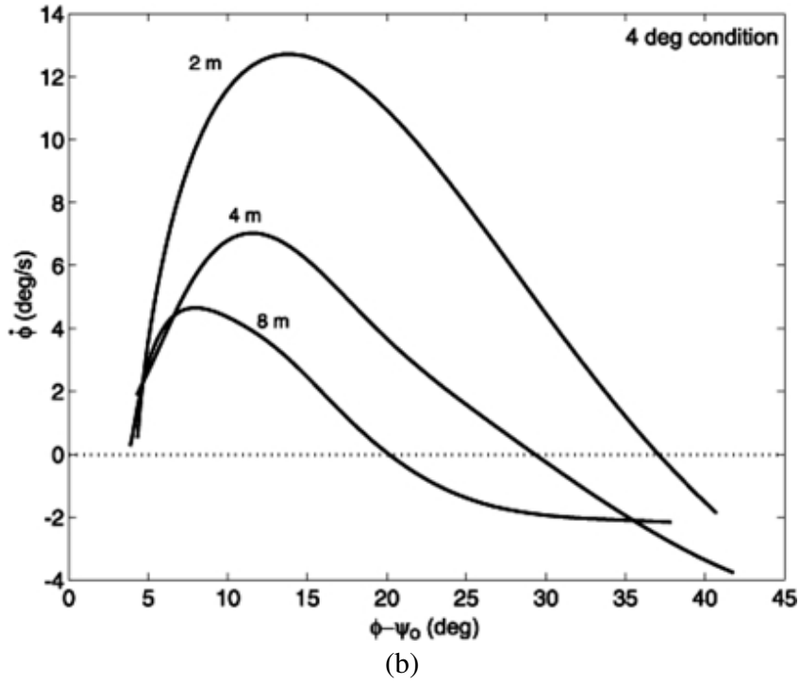
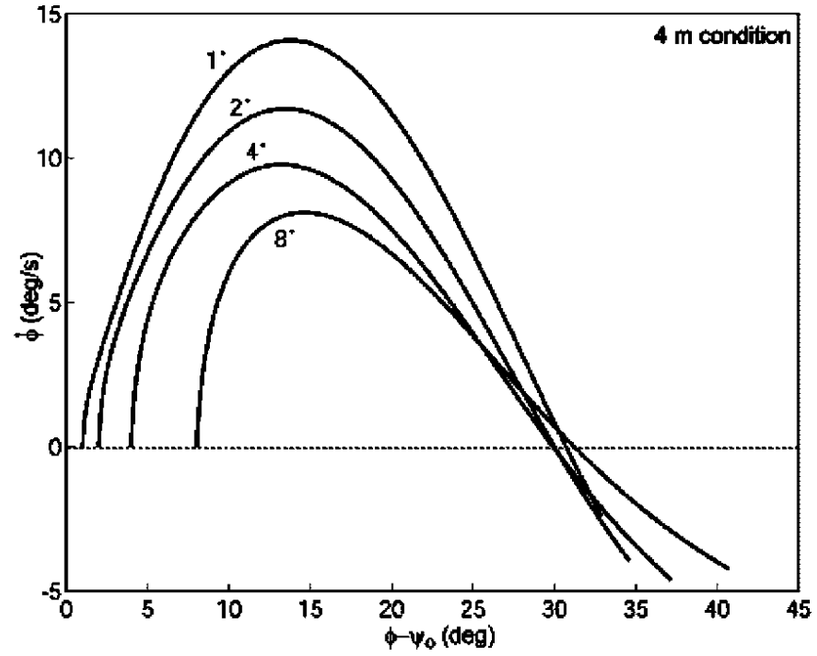
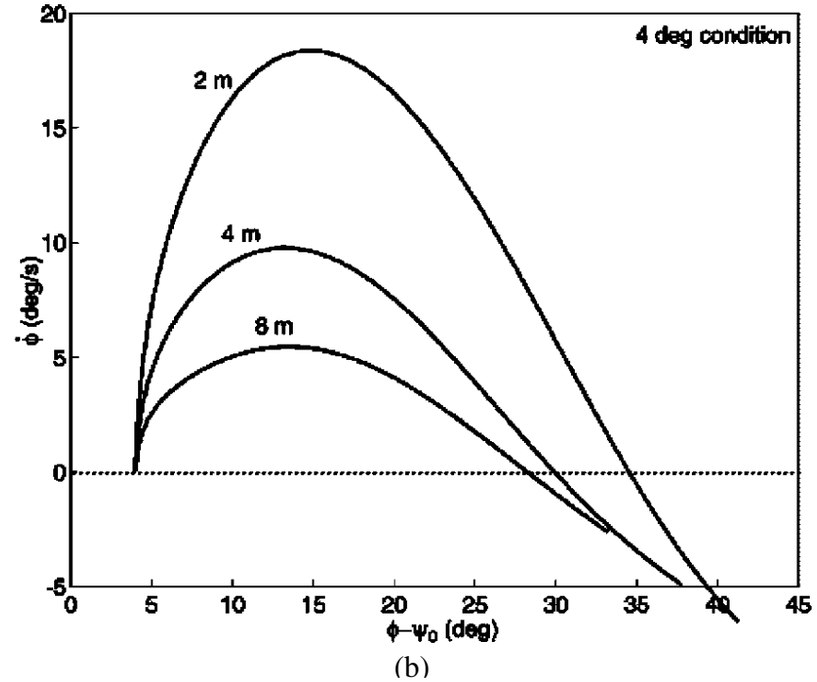


(b)

model

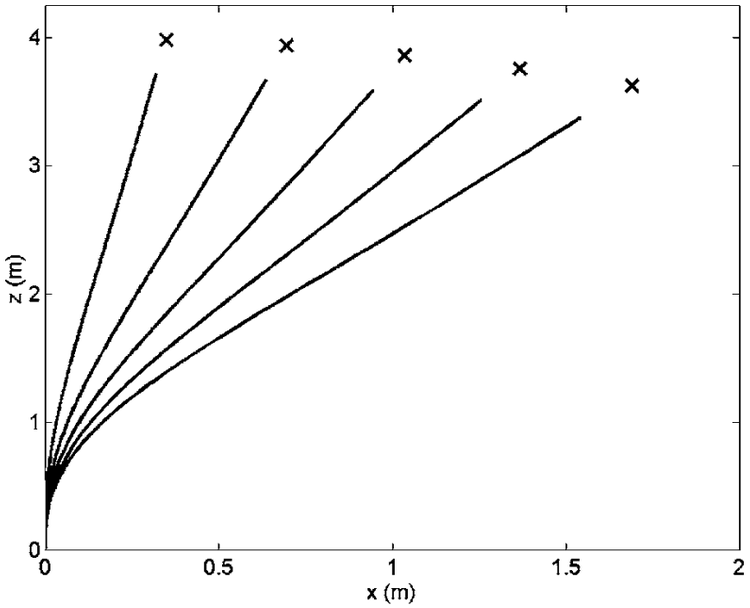


(a)

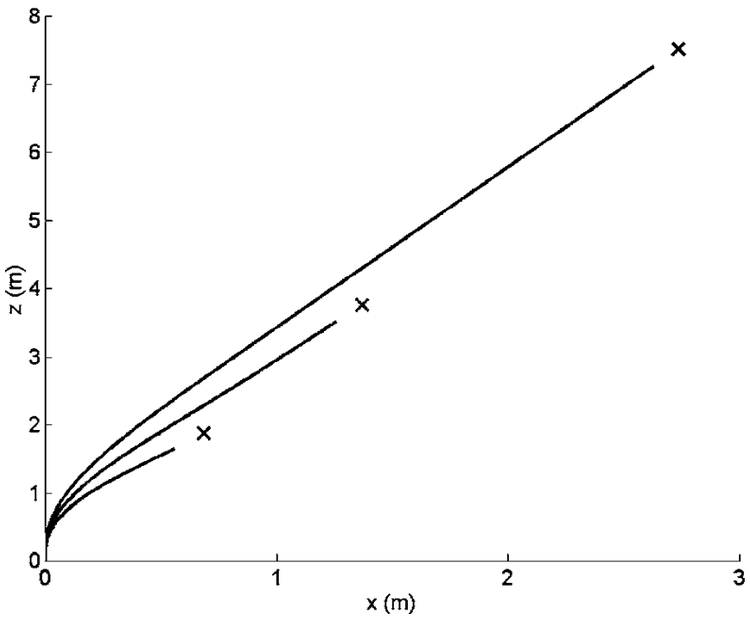


(b)

model: paths



(a)



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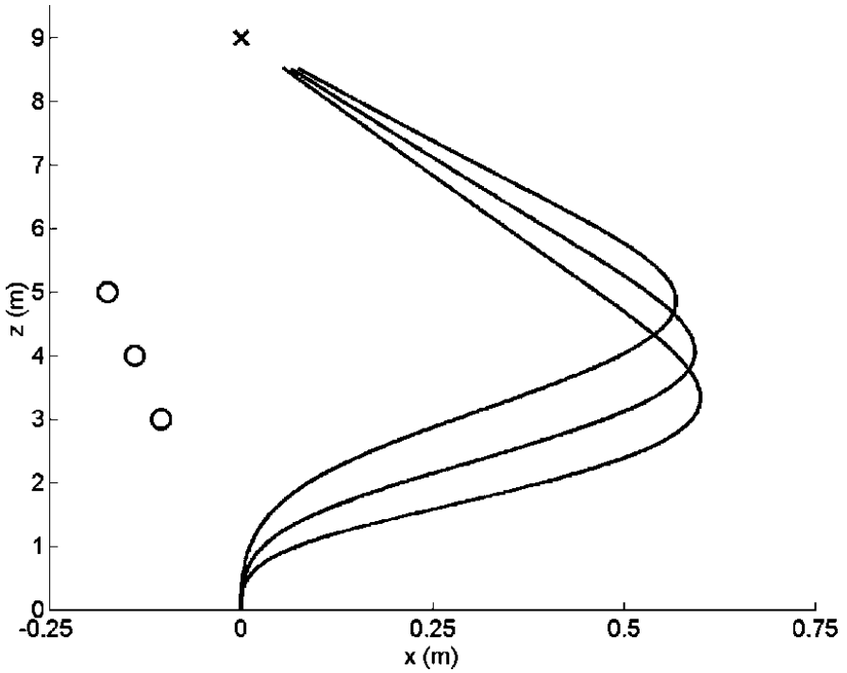
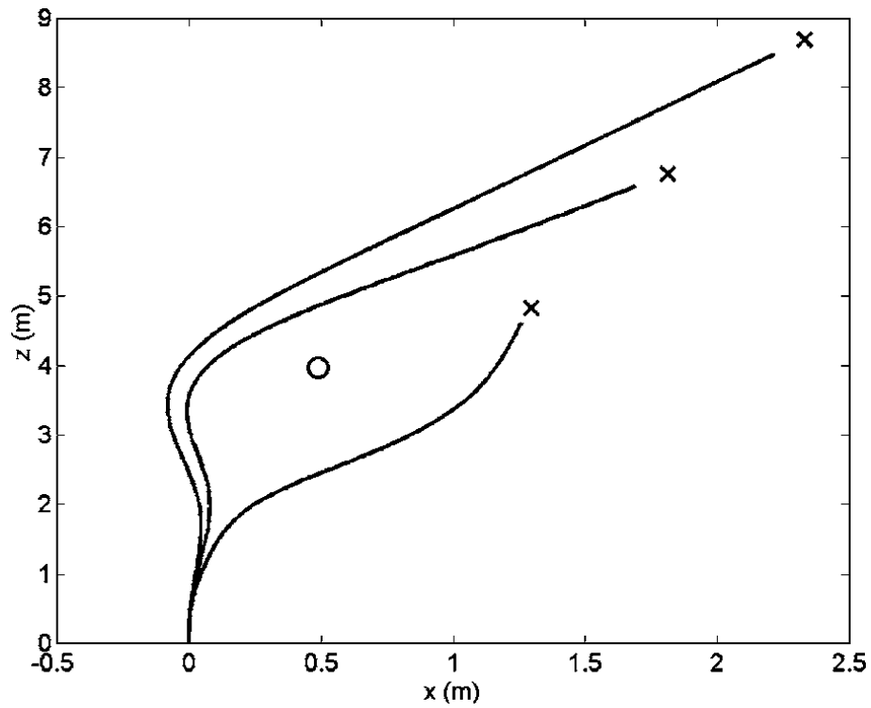
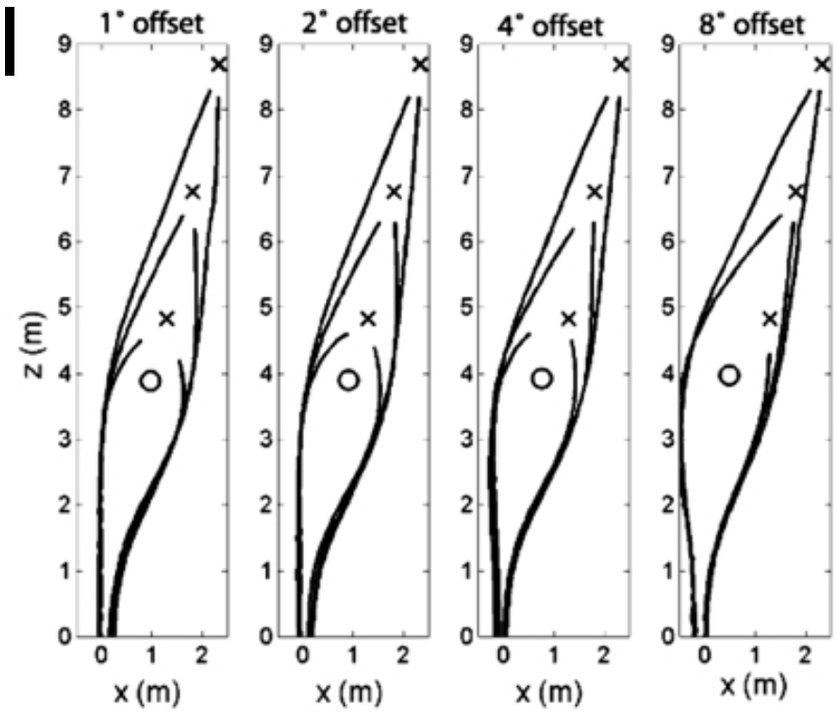




model-exp: decision making

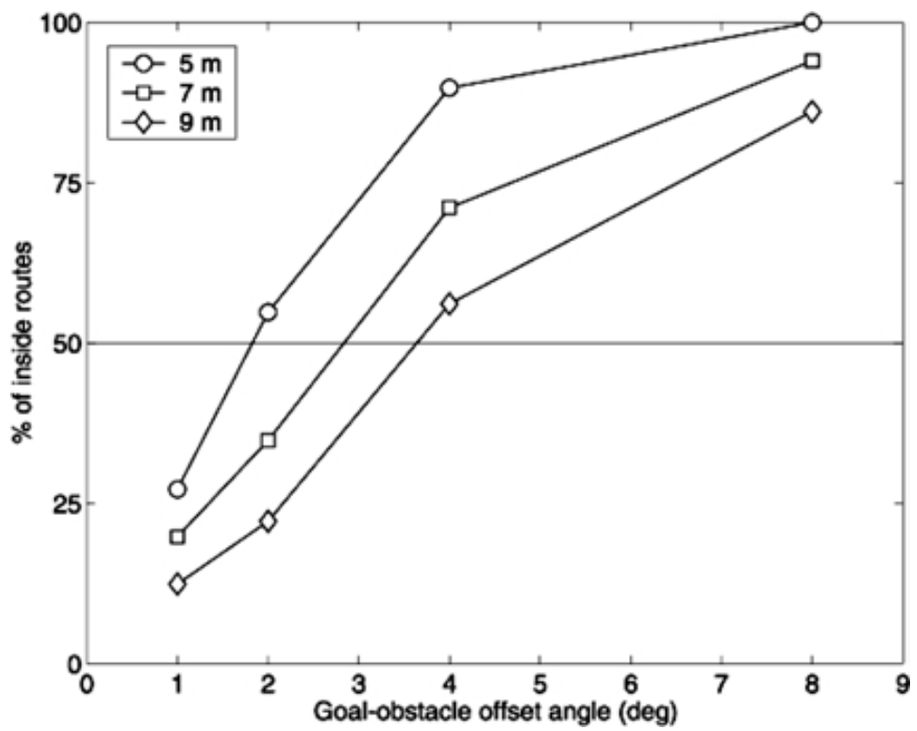
- inside vs. outside path

model



(a)

exp



(b)

Conclusion

- the attractor dynamic model can account for human locomotory behavior in target acquisition and obstacle avoidance