Behavioral dynamics of steering and obstacle avoidance

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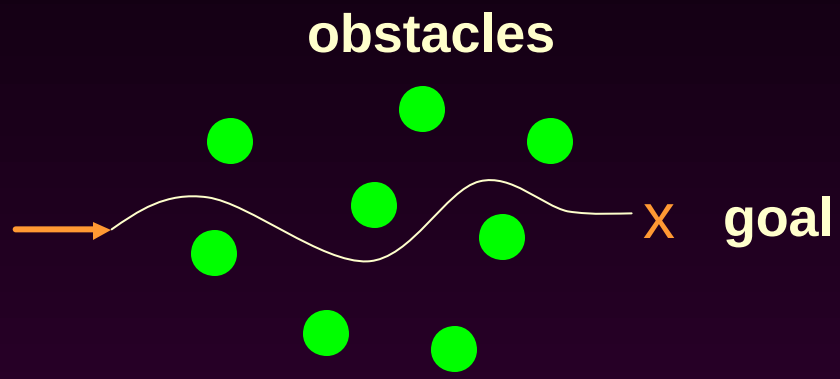
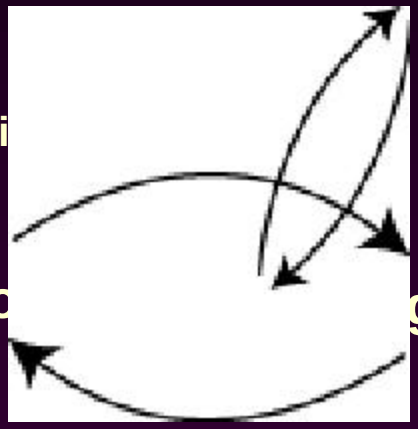
The Problem

QuickTime™ and a
H.263 decompressor
are needed to see this picture.



1. How steer through a complex scene?
   - » Goals and obstacles
2. Route selection
   - » 3D model + plan
   - » Predict route from steering dynamics

Behavioral Dynamics



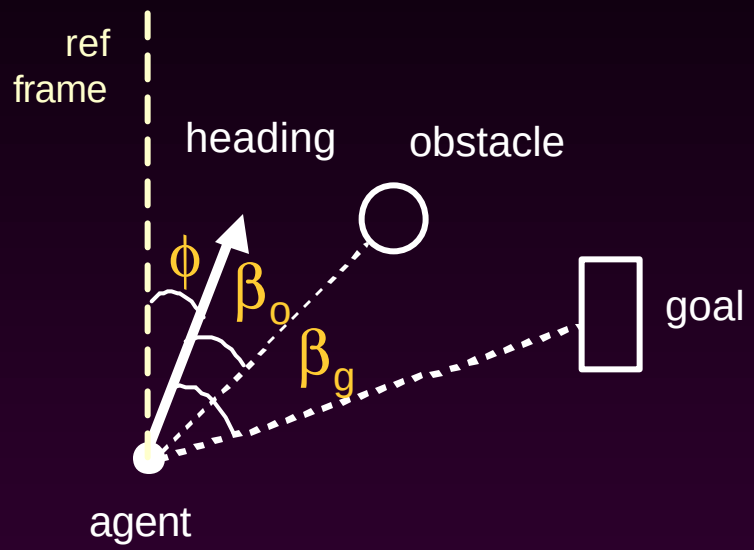
Behavioral Dynamics
- collective variable x
- attractors

$$\dot{x} = f(x)$$

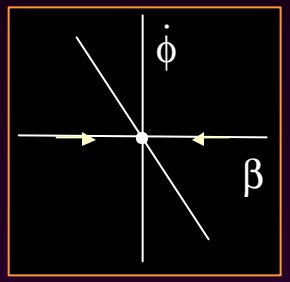
Perception & Action
- visual control laws
- Warren, et al (*Nature Neuro*, in press)
- Zosh, Duchon & Warren (poster)

- Behavior corresponds to stable solutions (attractors) of the system's dynamics

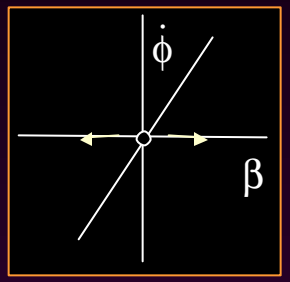
Dynamics of steering (Schöner, Dose & Engels, 1995)



Phase Portrait



goal = point attractor



obstacle = repellor

- Collective variable = heading (ϕ)
- Dynamics:

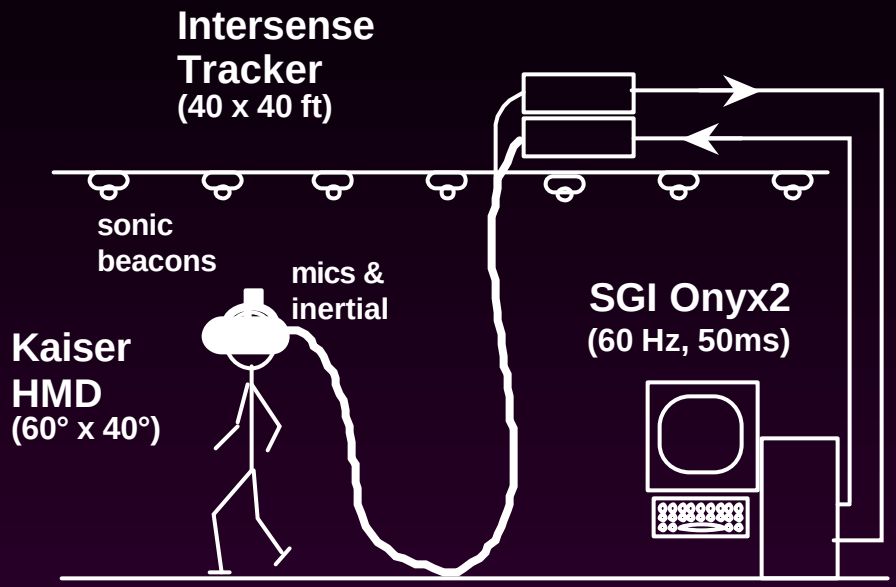
$$\dot{\phi} = - k\beta$$

turn rate

heading error (β depends on ϕ)

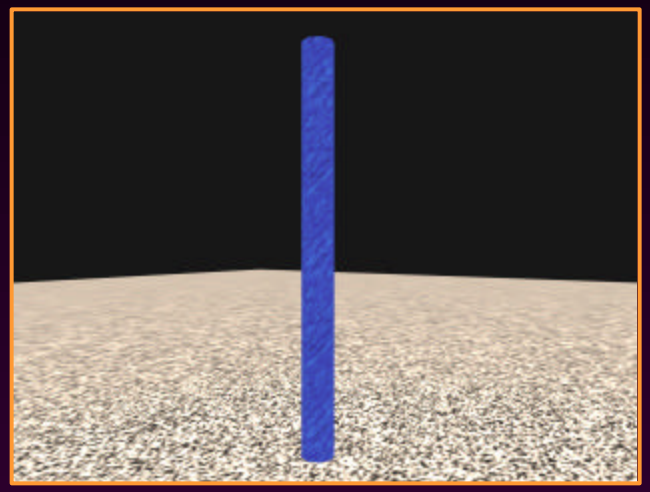
- Test goal
- Test obstacle
- Compose to predict route

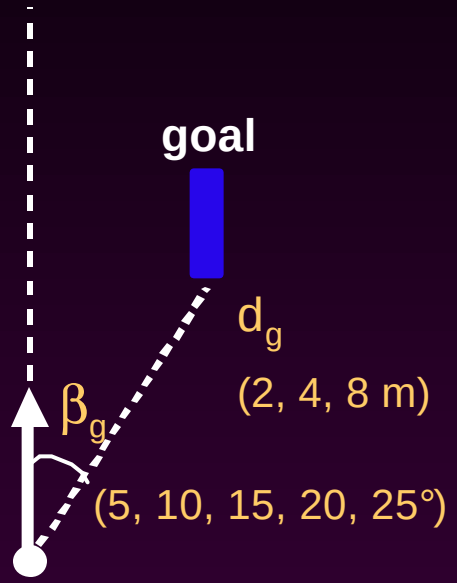
The VENLab



- Manipulate goals & obstacles during walking
- Record path

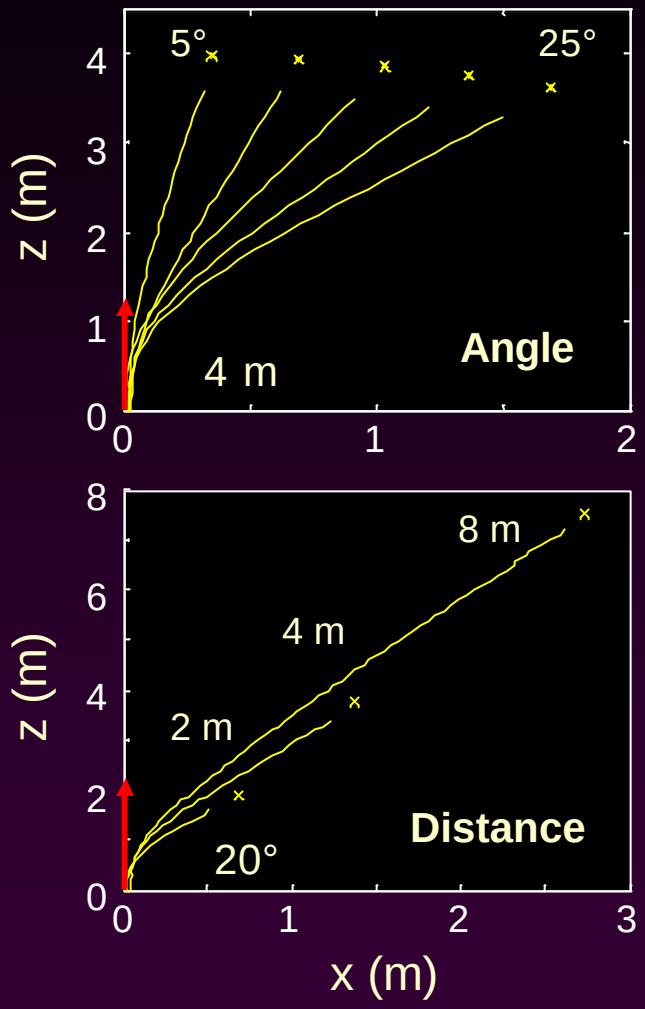
Exp. 1 & 2: Walk to goal



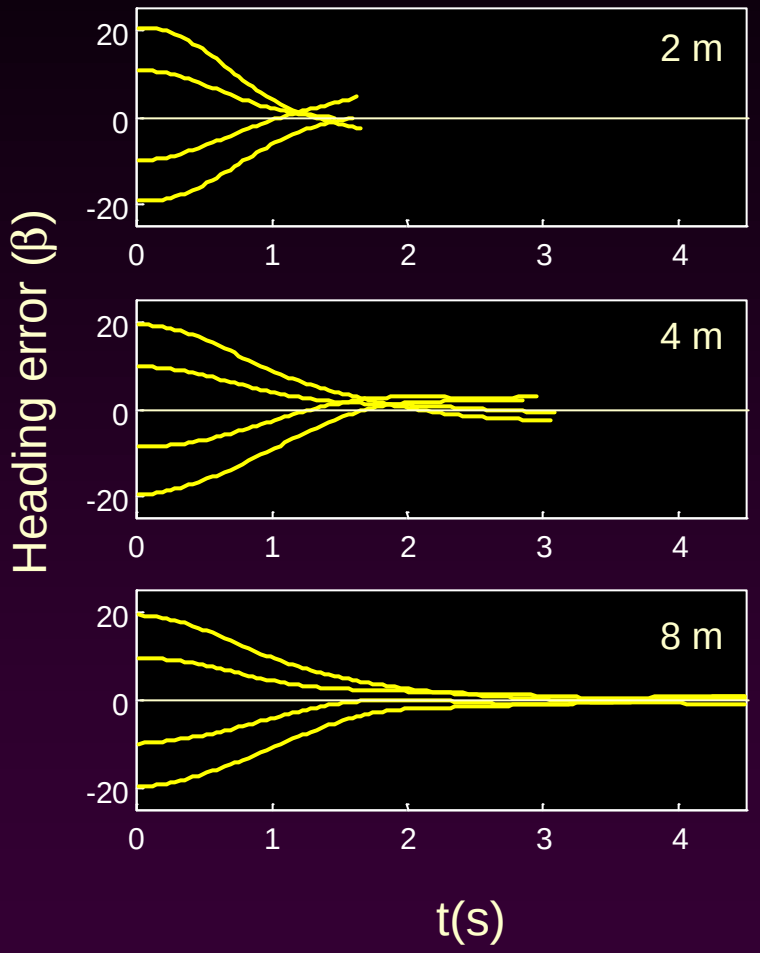


- Walk 1 m, goal appears
- Vary initial goal angle and distance
- “Walk to goal”

Paths

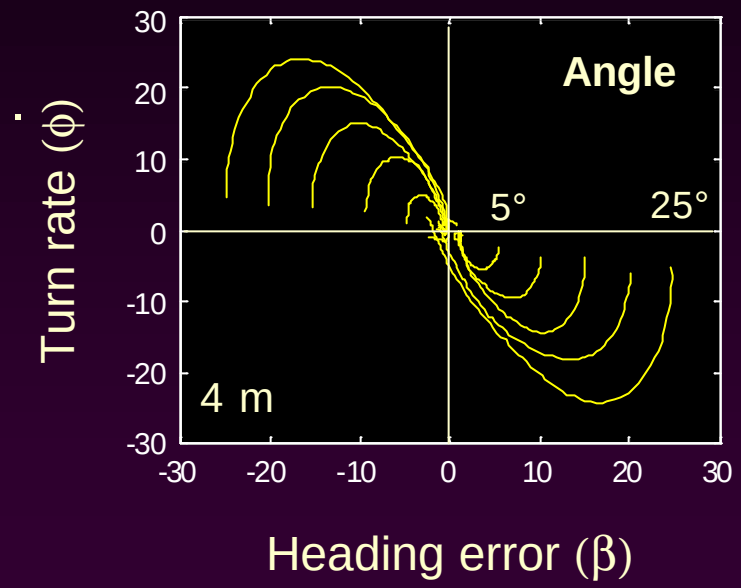


Heading error



- Turn rate depends on goal angle and distance (or TTC)

Phase portrait



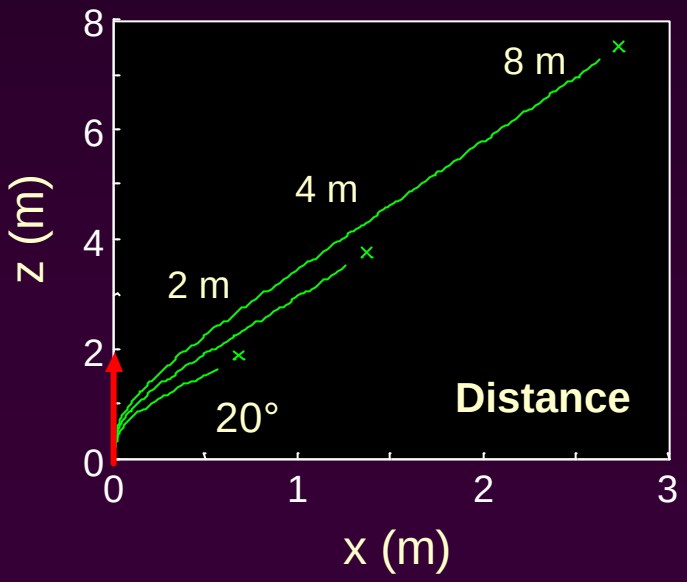
- Point attractor dynamics
- At least 2nd-order system
  - » accelerate body mass
  - » also depends on distance

Model

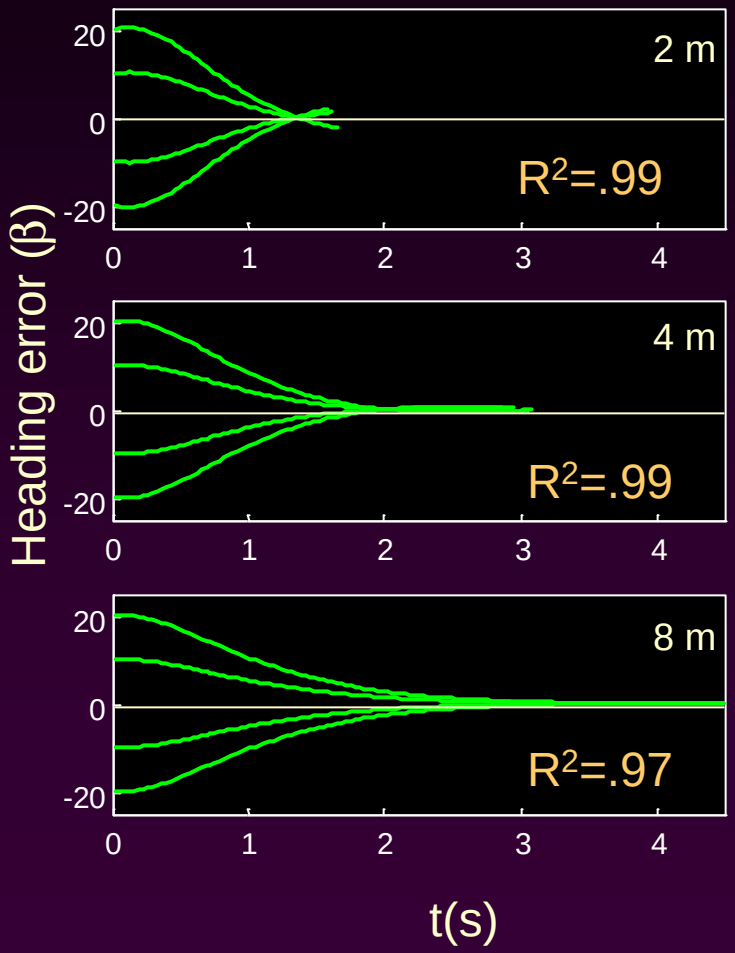
$$\ddot{\beta} = -b\dot{\beta} - k\left(b_g\right)\left(c_1 e^{-c_2 d_g} + 1\right)$$

- b= 3.25 “damping”
- k = 3.0 “stiffness”
- goal influence decreases exponentially w/ distance (d_g)

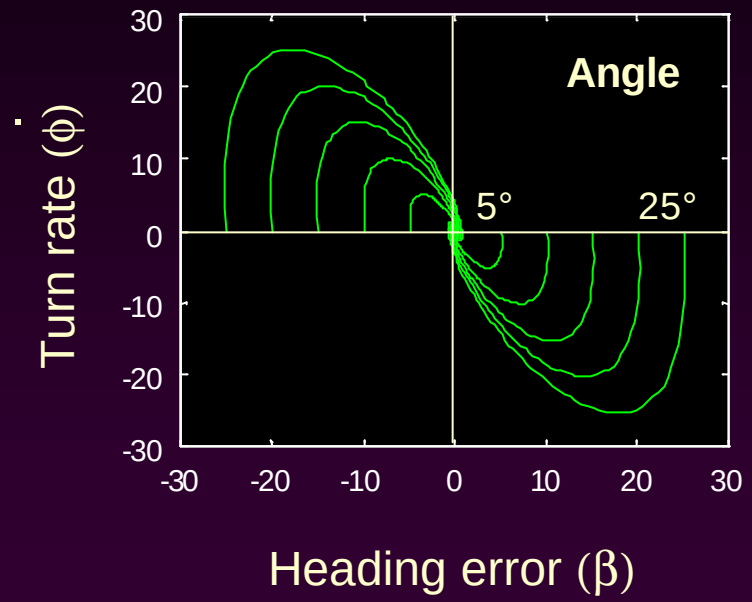
Simulated paths



Simulated heading error



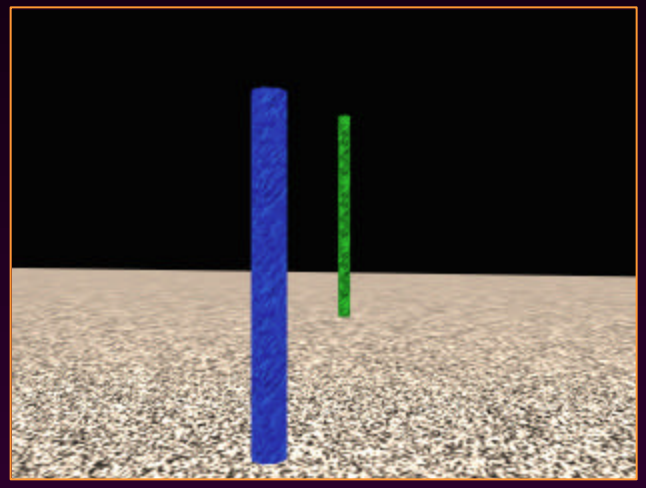
Phase portrait simulation

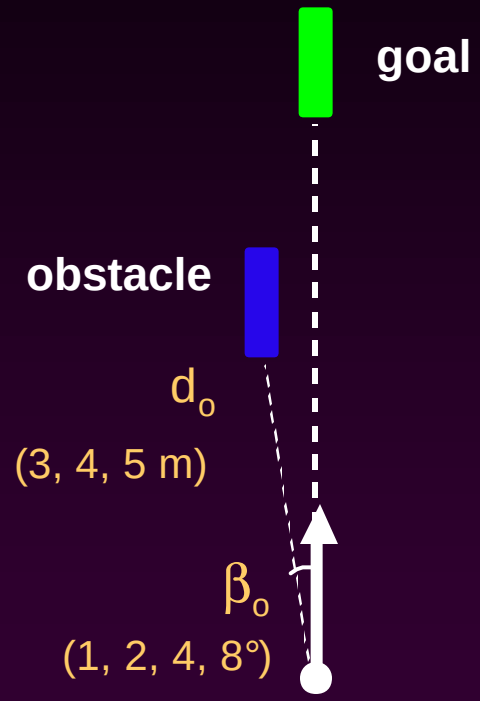


Steering to a goal:

- Point-attractor dynamics
- Turn rate depends on heading error and distance (TTC)
- Dynamical model

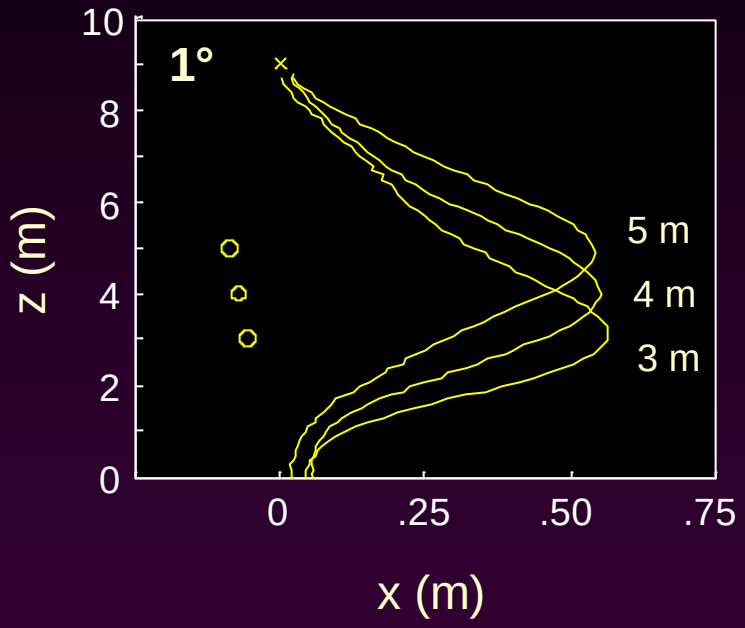
Exp. 3: Obstacle Avoidance



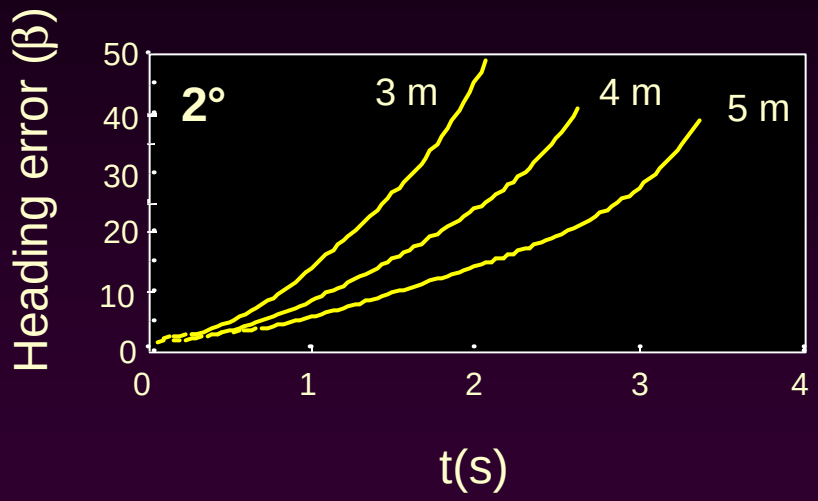


- Walk 1 m toward goal, obstacle appears
- Vary initial obstacle angle and distance
- “Walk to goal around obstacle”

Paths



Heading error

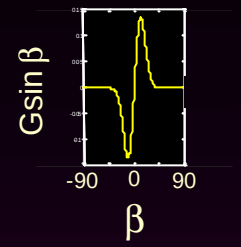


- Repellor dynamics
- Turning depends on obstacle angle and distance (TTC)

Model

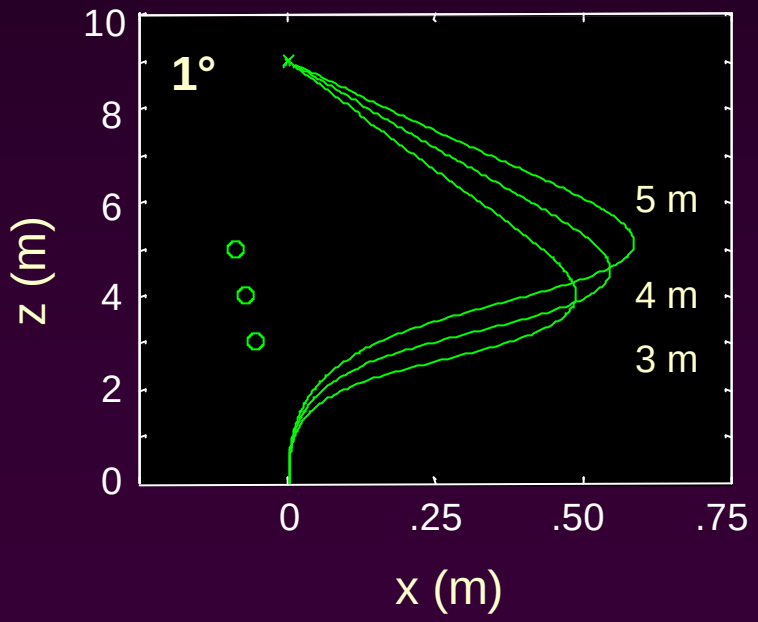
goal obstacle

$$\ddot{\psi} = -b\dot{\psi} - k\left\{\left(b_g\right)\left(c_1 e^{-c_2 d_g} + 1\right) + G\sin\left(b_o\right)\left(c_1 e^{-c_2 d_o} + 1\right)\right\}$$

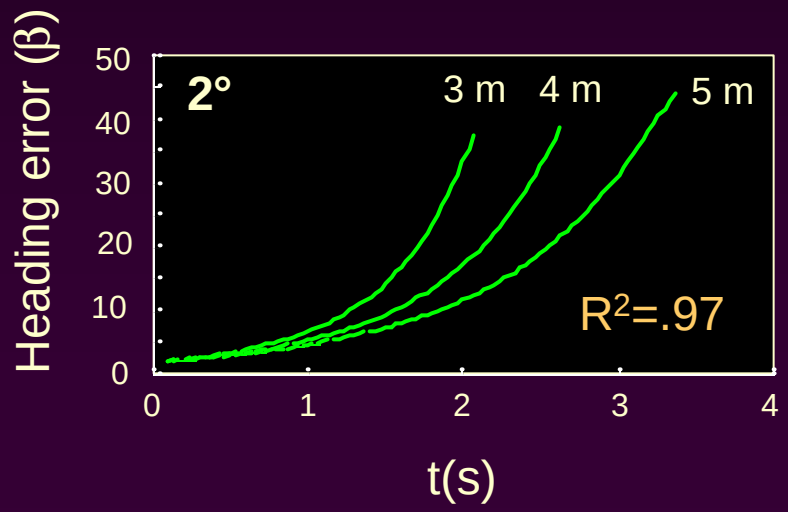


- obstacle influence decreases with angle

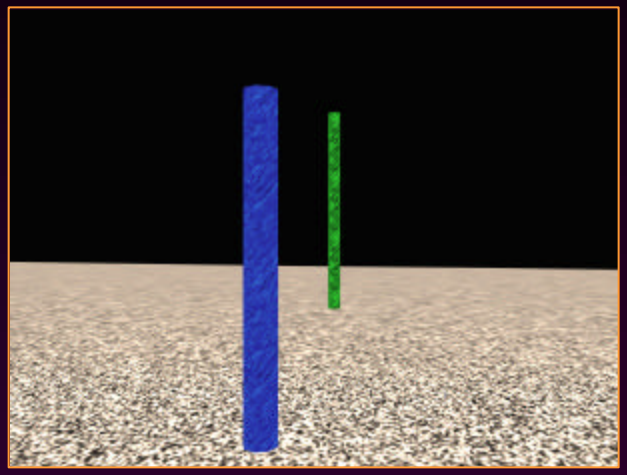
Simulated paths

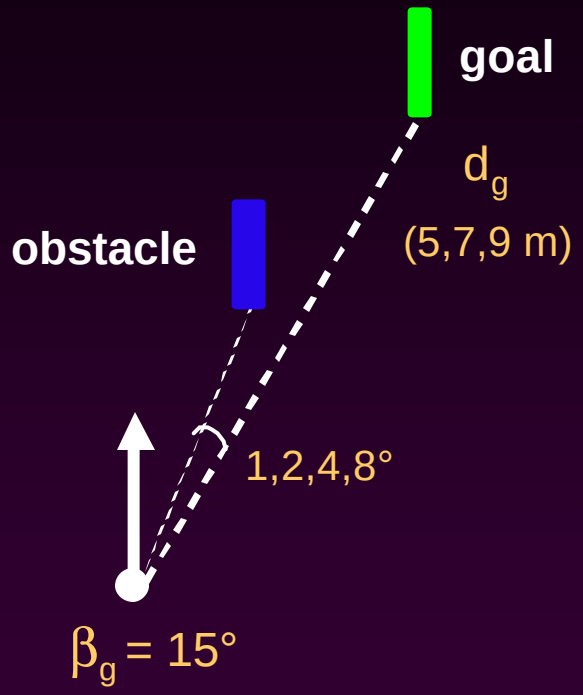


Simulated heading error



Exp. 4: Route selection in simple scene



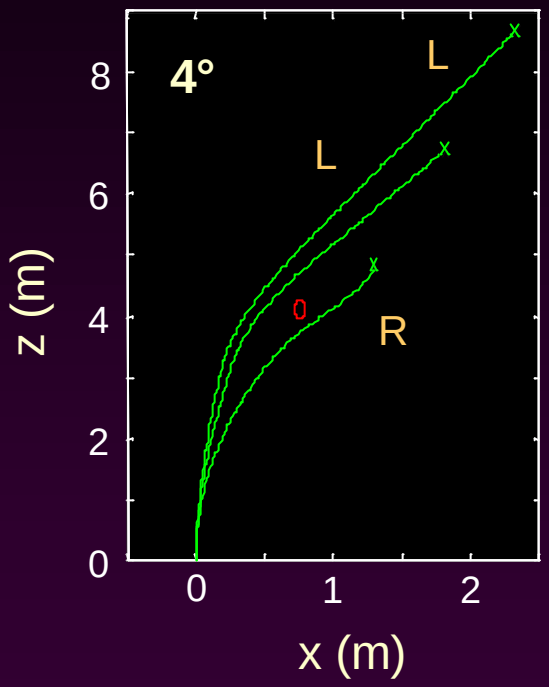


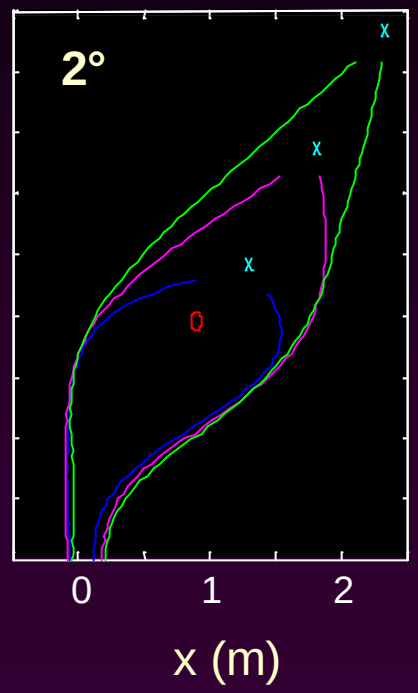
- Predict route from local steering dynamics?

- Walk 1 m, goal and obstacle appear
- Vary initial goal-obstacle angle and goal distance
- Cross R in front of obstacle?

Model predictions

Human paths



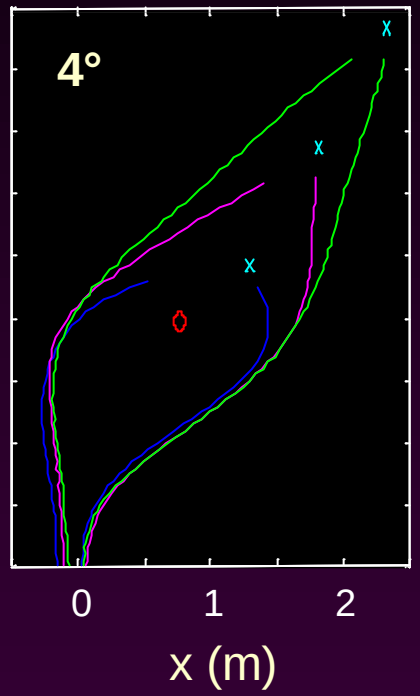


Trials R:

22.2%

34.8%

54.8%



Trials R:

56.1%

71.1%

89.8%

- Cross R in front of obstacle as goal gets closer
- Strength of attractor overcomes repellor

Conclusions

1. Steering dynamics
   - » Goals = point attractors
   - » Obstacles = repellors
   - » Depend on distance (or TTC)

2. Predict routes from steering dynamics
   - » Compose terms for goals and obstacles
   - » Image-based, on-line
   - » vs. model + plan

- Next: generalize to route selection in complex scenes