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Bearing-Only Pursuit

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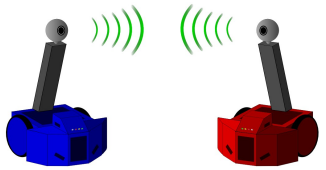
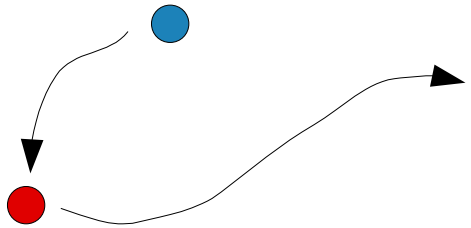


Robotic Sensor Networks

Introduction

- Pursuer tries to capture an evader
- Evader tries to avoid capture



- Pursuit-Evasion, Cop-Robber, Lion-Man
- Assumes knowledge of complete information
- Need to specify arena, moves, notion of capture

Research Overview

- Pursuit-evasion games
  - Role of sensing information
  - Discrete and continuous domains
  - Complex environments
- Adversarial perspectives
- Previous work [TCS - GRAASTA'08]
  - Full-visibility pursuer wins in finite time $\rightarrow$ P strategy
  - k-visibility pursuer: exponential time $\rightarrow$ E strategy

Problem Statement

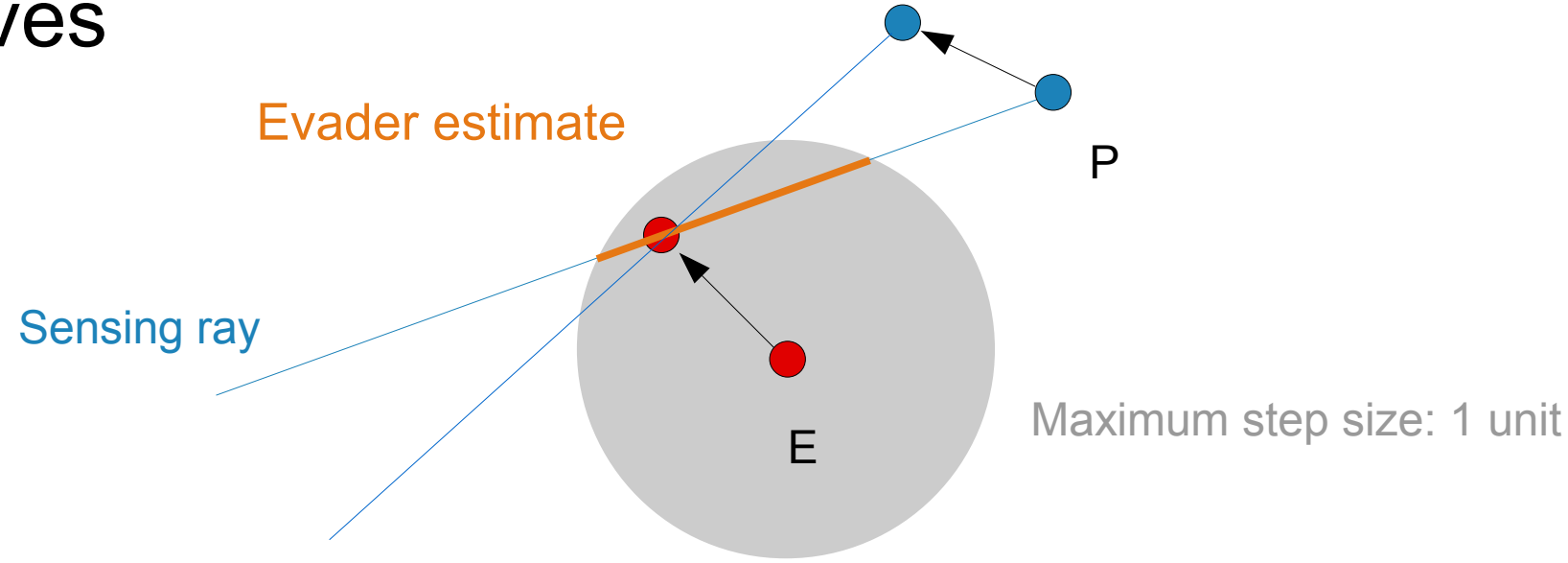
- Single pursuer, single evader
- Positive (1^{st}) quadrant
- Turn-based, discrete time, continuous space
- Equal maximum velocities
  - Can move same maximum step size in a single round
- Evader: has complete information
- Pursuer: limited to bearing-only sensor

Motivation

- Mobile robots with monocular vision systems
- Applications in
  - Tracking
  - Surveillance
  - Search and rescue

Game model

- Proceeds in rounds
- Sense → Evader moves → Sense → Pursuer moves



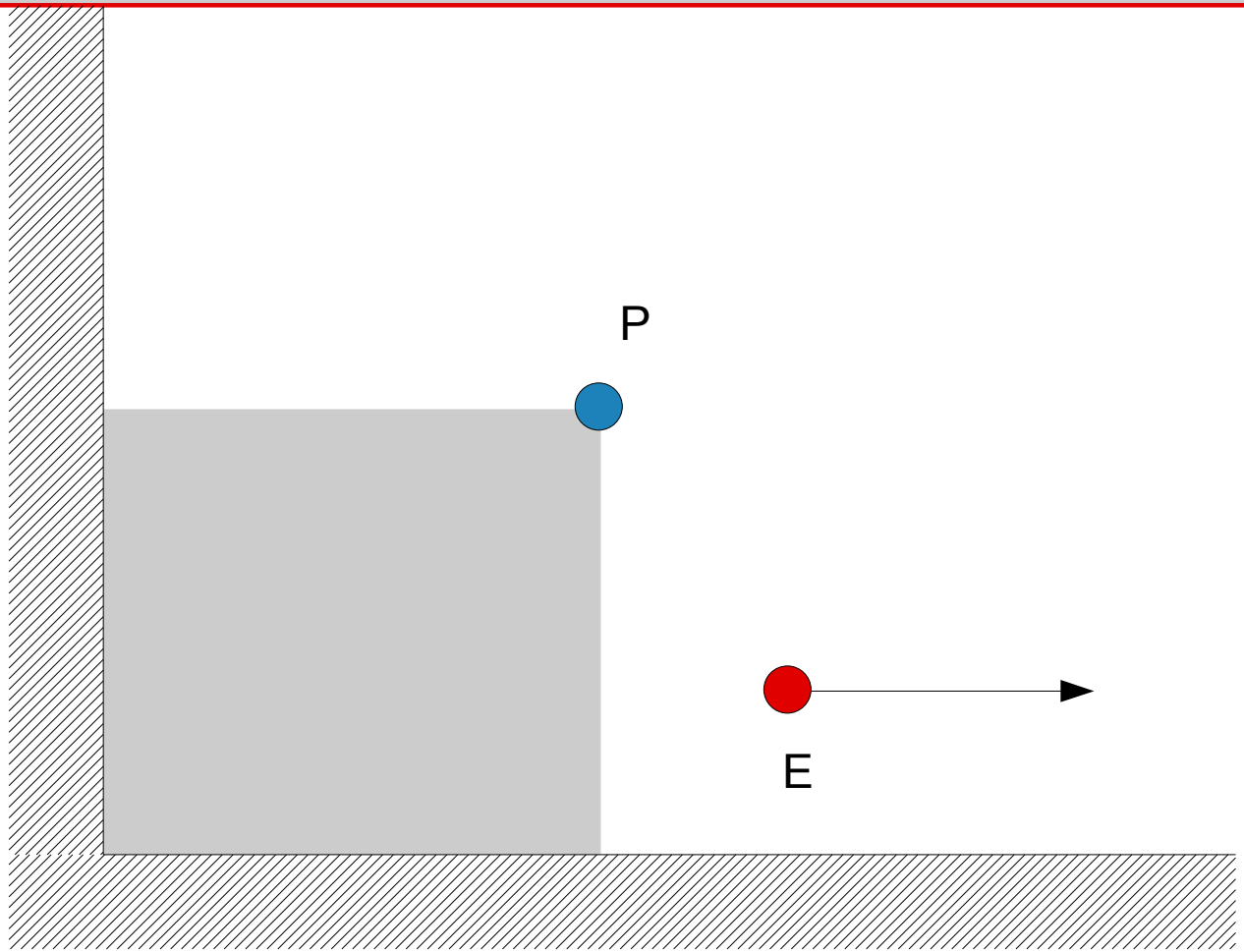
- Termination: |PE| ≤ c

Complete information

- Lion-and-Man problem
  - R. K. Guy, David Gale, Solution by Sgall[1]
- Pursuer with complete information wins
  - Stays on the radius of a growing circle with a fixed center
  - Initial conditions and invariant

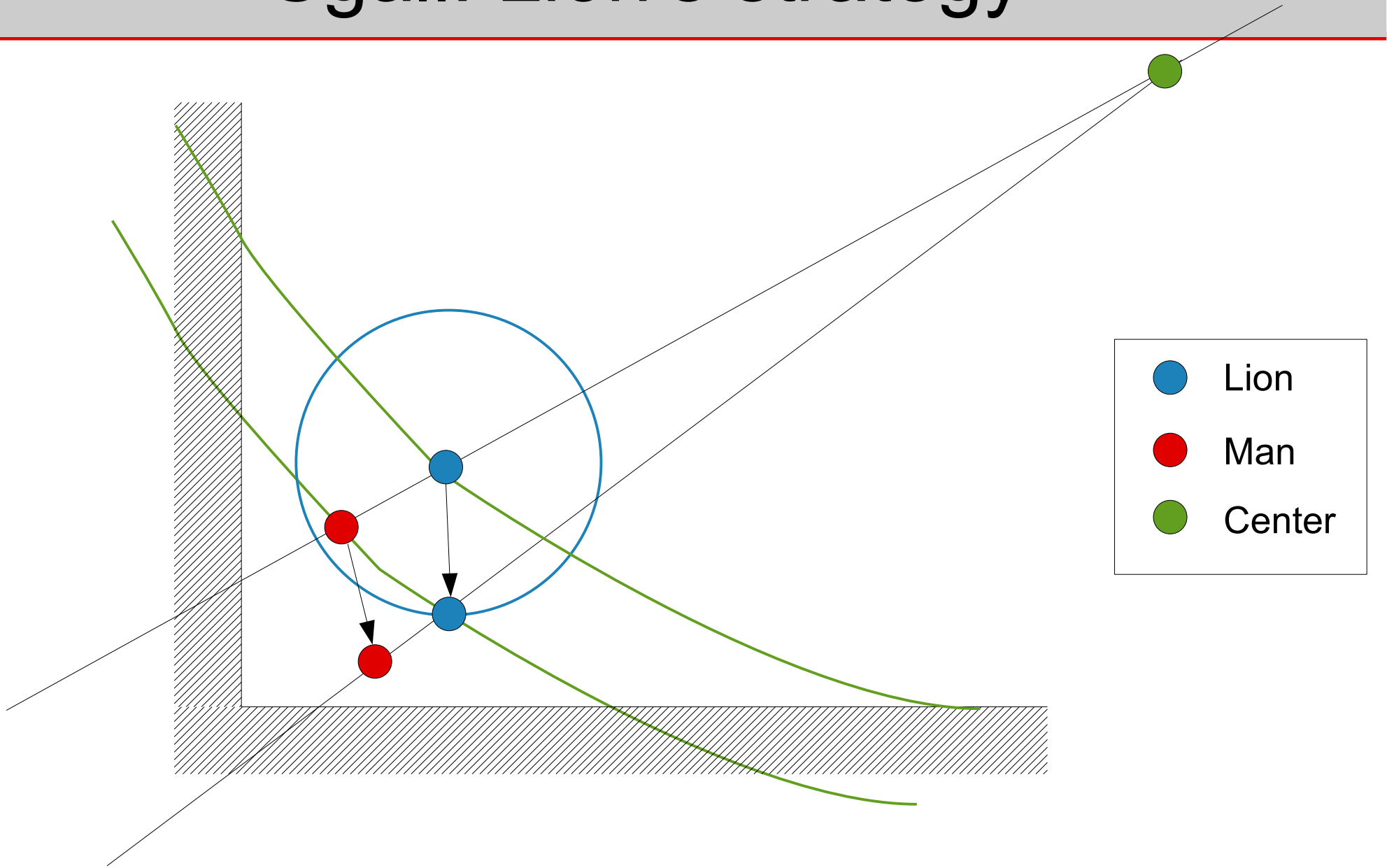
[1] J. Sgall: A solution of David Gale's man and lion problem, Theoretical Comput. Sci, 259(1-2):663-670, 2001.

Invariant 1

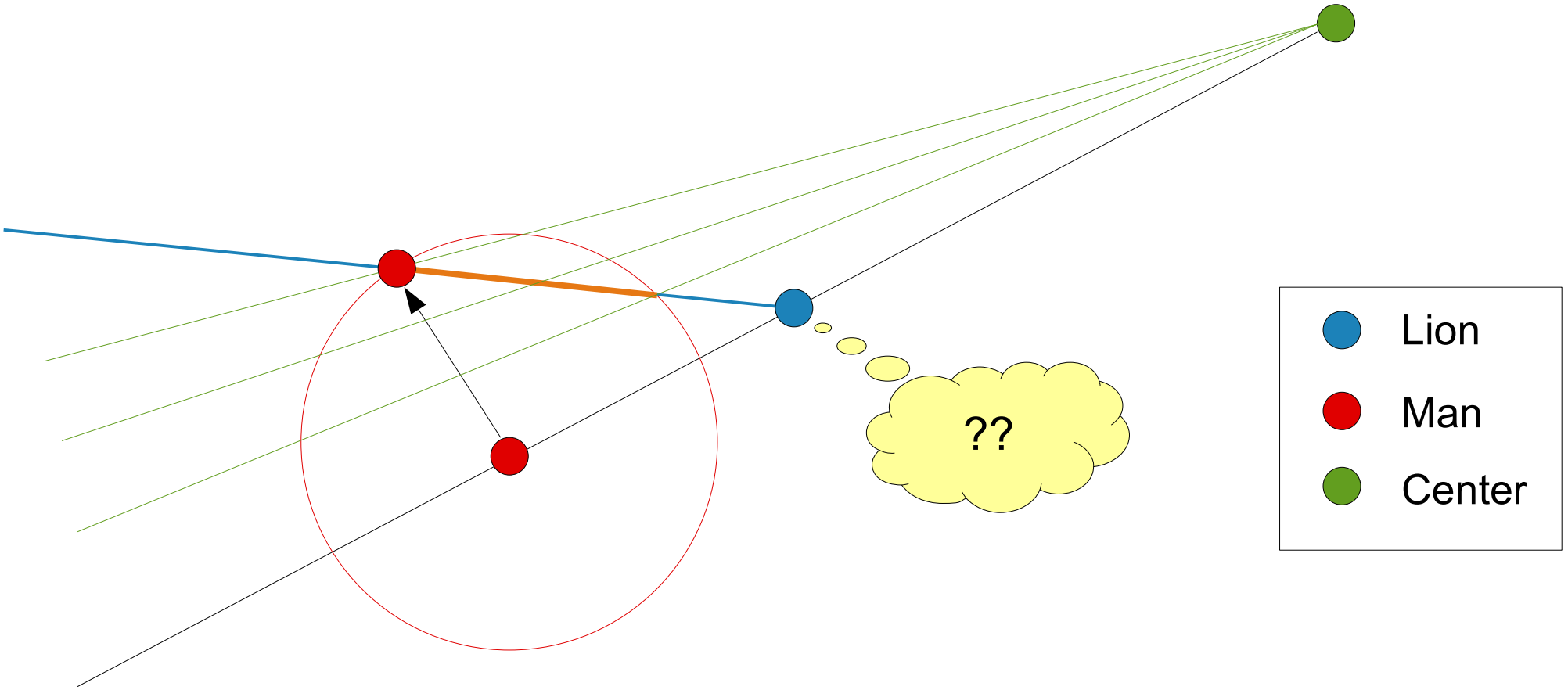


Must be satisfied by any pursuer strategy

Sgall: Lion's strategy

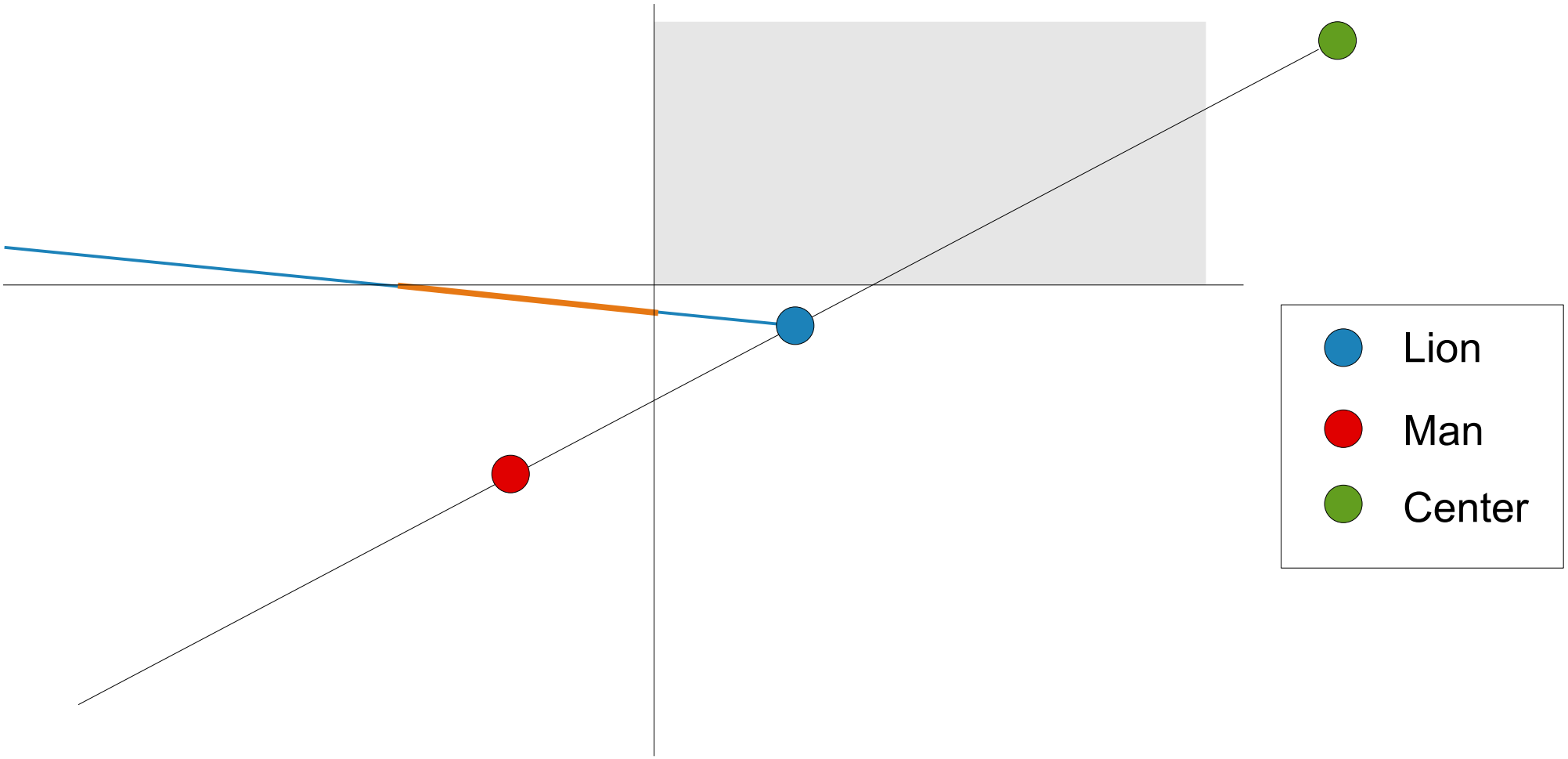


With a bearing-only sensor?



Sgall's lion strategy does not work directly

Conservative estimate

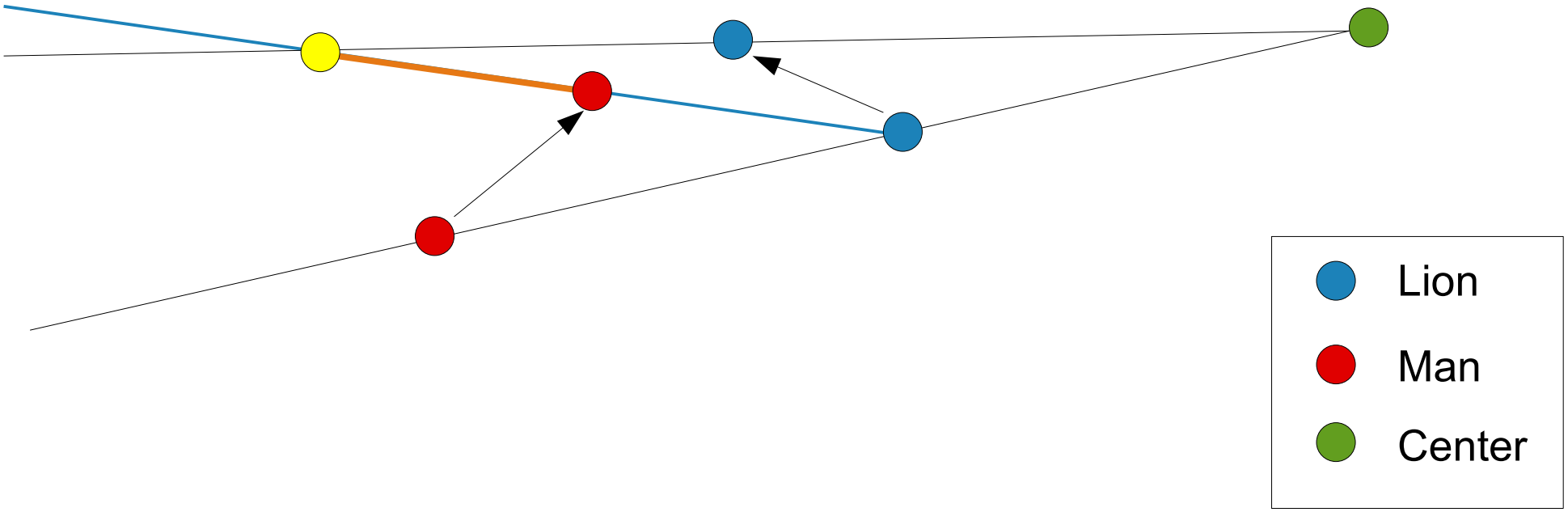


Play Sgall's lion strategy w.r.t. *conservative* evader estimate

Preserves Invariant 1

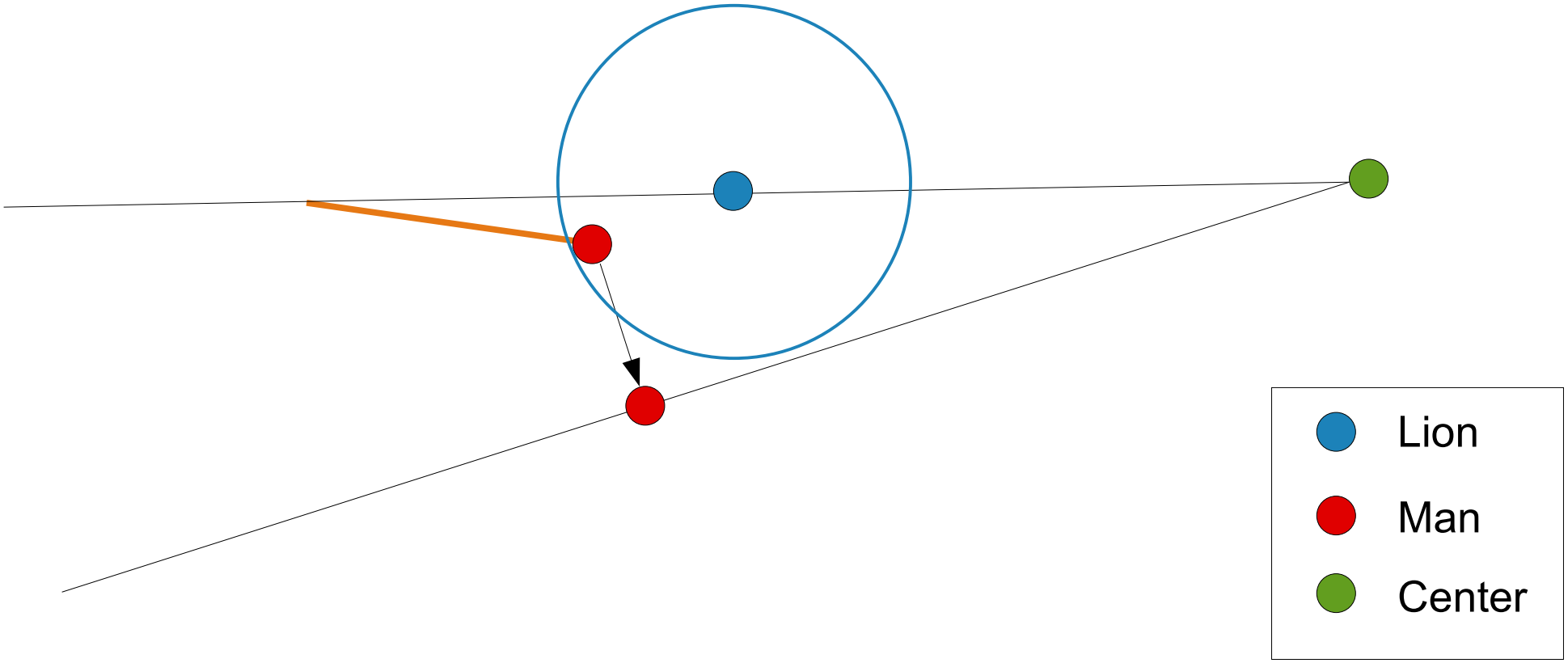
Our pursuit strategy

- Play lion's strategy w.r.t. conservative estimate



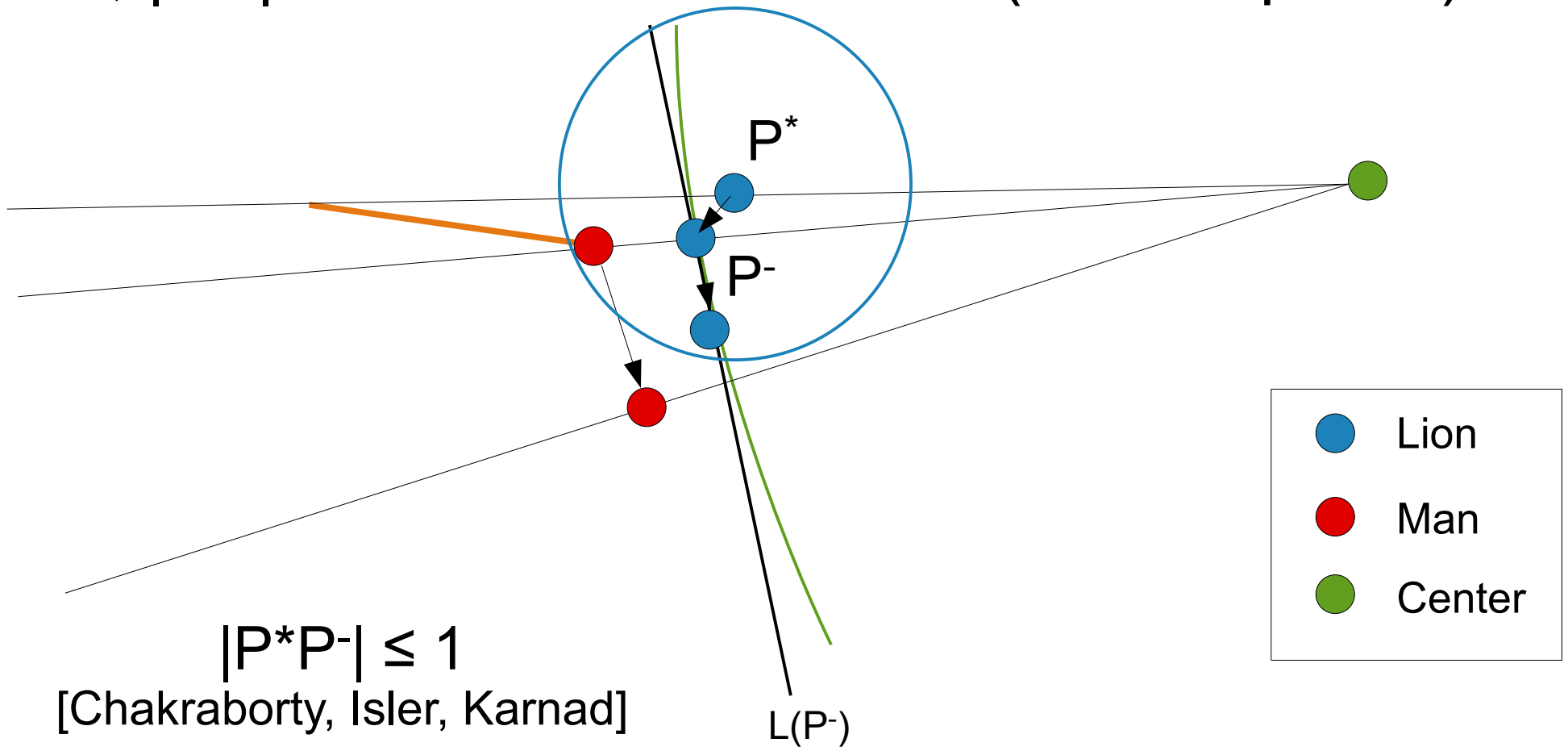
Our strategy: the switch

- Sometimes lion's move does not exist
  - Switch to guarding phase



Our strategy: guarding phase

- Either catch up, preserving progress
- Or, |PE| ≤ 1 (1 ↔ step size)



$|P^*P^-| \le 1$

[Chakraborty, Isler, Karnad]

Capture time

- Lion's game (T_G)
  - Fixed center
  - Finite capture time (Sgall)
- Whenever the switch to guarding phase is made (T_L)
  - Game bounded by $\max\{x_P, y_P\} \leq \max\{x_Q, y_Q\}$
- Total = $T_G \cdot T_L$

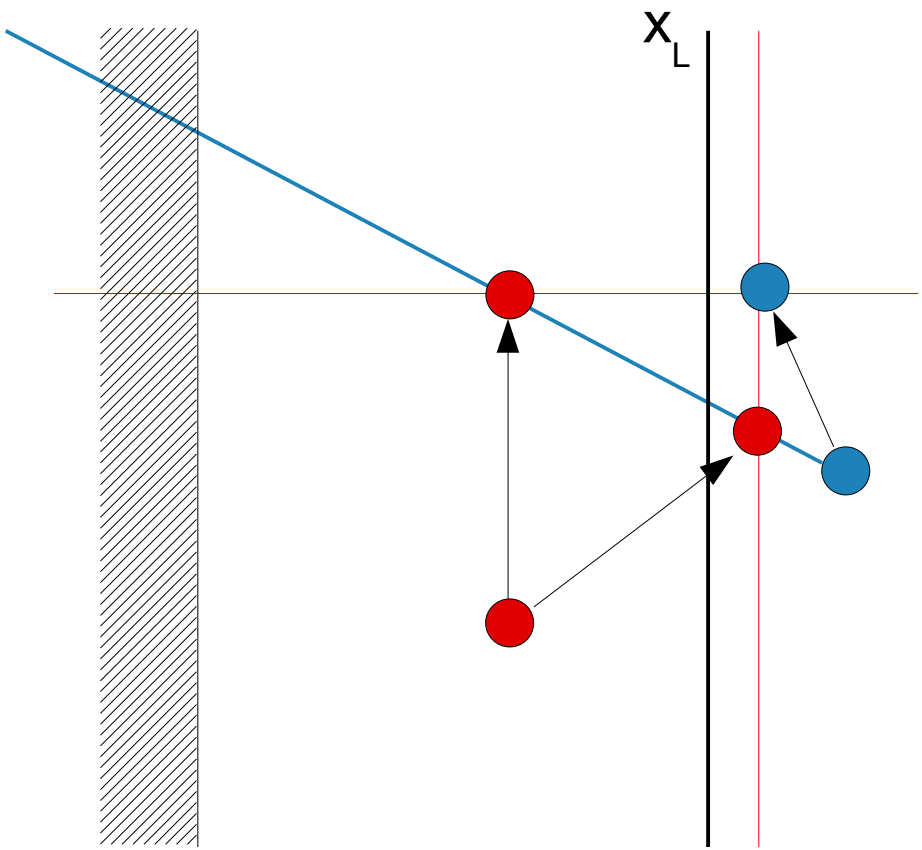
Effect of capture distance

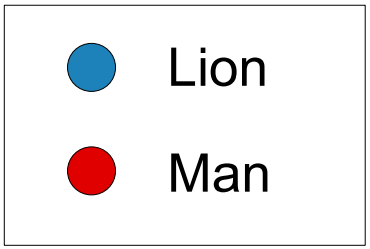
- When $c \geq 1$: pursuer wins
- When $c < 1$
  - Lemma: Exact capture is not possible with high probability
  - Set $c = 0$
  - Provide evader strategy that works against any pursuer strategy

Evader strategy

- Randomized
- Exploits the need for pursuer to maintain Invariant 1

Keep pursuer outside a fixed (x_L, y_L)





Conclusions

- Pursuer with complete information wins, but with just the bearing-only information, he can get to within the step-size from the evader
- For capture distance $c \geq 1$, pursuer wins
- Capture time
- For $c = 0$, the evader wins w.h.p.
- Future work
  - Implementation on mobile robot test bed
  - Incorporate uncertainty

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Thank you for your time!

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