Mini Review

PEG and control application-a survey

Abstract

A brief survey of pursuit evasion game (PEG) which has wide applications in search and rescue operations both in the civil and the military operations is given in the paper. One possible application of PEG is indicated in some detail.

Keywords: pursuit evasion game, bio-inspired strategy, game theory, robotic control, maritime surveillance

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Introduction

Pursuit- evasion game (PEG) is concerned with guiding one or more of a group of pursuers to catch one or more of a group of moving evaders. The problem has extensive applications, such as searching buildings for invaders, traffic control, military strategy, surgical operation etc. A lot of research has been carried out on this problem. Pursuit evasion contests have been studied extensively from a game- theoretic perspective in the context of differential games.[1] In engineering, pursuit evasion games have received much attention particularly in the context of missile guidance and avoidance[2] and aircraft pursuit and evasion. Also, in the civilian applications it has applications in robotics vehicular network and search and rescue chase, pursuing terrorists etc. Pursuit evasion behavior is widely observed in nature. It plays a critical role in predator foraging, prey survival, mating and territorial battles in several species.[3] Winning strategies in pursuit evasion in nature have been studied.[4] In view of the wide application of pursuit evasion problem, solution to this problem in terms of real time implementation in an actual application is a matter of great importance.

Wei et al.[5] have studied pursuit evasion problem using an evolutionary approach. In particular, they studied three strategies namely classical, constant bearing and motion camouflage. They provided simulation and theoretical analysis to show that all the pursuit strategies converge to the motion camouflage strategy. This has been supported by empirical observation of the behavior of hoverflies, dragonflies and bats that apply this strategy. The three strategies have been tested on computer simulation under the assumption that the pursuer is moving with a greater velocity compared to the evader and that the evader is moving without any knowledge/ feedback of the pursuer movement. But in practice the more general case may be applicable such as either the pursuer/evader having higher velocity and the velocities not constant throughout the search. Also, the higher velocity agents may not be able to do a quick maneuver whereas the lower velocity agent may have the advantage of agile maneuverability. Also, the evader may have a visual feedback of the pursuer position and speed. So, in such cases, what is the winning strategy to be adapted by the pursuer? Also, in the pursuit evasion game situation mentioned earlier, if it is preferable to put robots instead of humans, the search strategies must be computed automatically for a mobile robot.

That brings us to consider the pursuit strategies as means of control. In as much as the motion camouflage appears to be a successful strategy favored by evolution, Obiroy and Devanathan[6,7] extended the motion camouflage feedback laws given in[3] to include integral and derivative control action. This extension is shown to dramatically improve the time and the distance to capture the evader for the first time.

Pursuit–evasion system

We model planar pursuit interactions using gyroscopically interacting particles, as in Wei, Justin and Krishnaprasad.[5,8,9] The (unit speed) motion of the pursuer is described by

$$\dot{r}_p = x_p, \dot{x}_p = y_p u_p, \dot{y}_p = -x_p u_p \quad (1)$$

Where r_p is the position of the pursuer, x_p its velocity and y_p is the acceleration of the pursuer. The motion of the evader (withspeed υ) is given by

$$\dot{r}_e = \upsilon x_e, \dot{x}_e = \upsilon y_e u_e, \dot{y}_e = -\upsilon x_e u_e \quad (2)$$

where r_e is the position, x_e is the velocity and y is the acceleration of the evader. The steering control of the evader, u_e, is prescribed or controlled, and the steering control of the pursuer, u_p is given by a feedback law. We also define

$$r = r_p - r_e \quad (3)$$

Which is referred to as the 'baseline' between the pursuer and the evader?

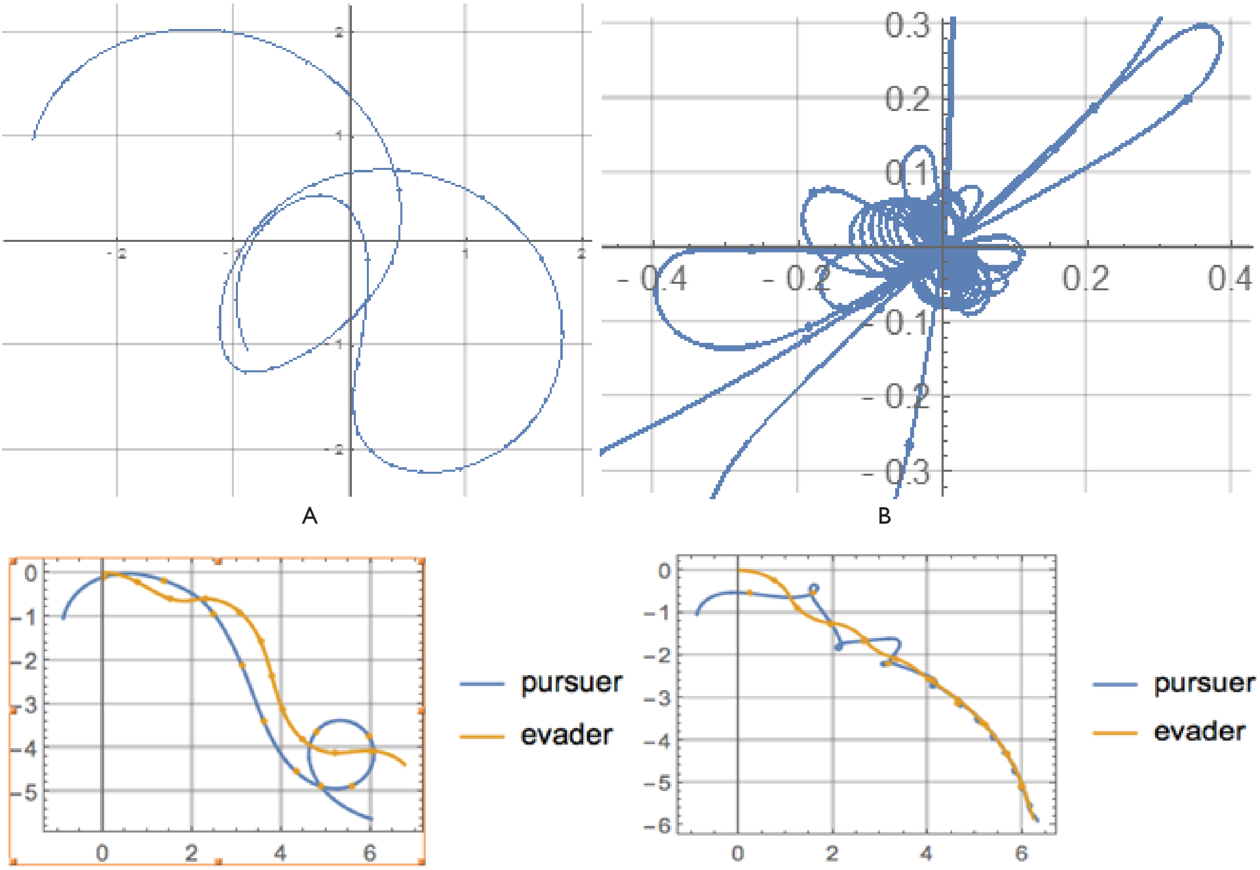
Simulation is done by using P, PI, PID feedback control laws for motion camouflage strategy. Γ is defined as the cost function and Ã' is obtained by rotating Γ counter clockwise by $\frac{\pi}{2}$ radian.

P control: $u_p = -\mu_1$ Ã'

PI control: $u_p = -\mu_1$ Ã'-$\mu_2 \int$Ã'dt

PID control: $u_p = -\mu_1$ Ã'-$\mu_2 \int$Ã'$dt - \mu_3 \frac{d}{dt}$ Ã'

Figure 1 shows the effect of applying motion camouflage to a two particle system representing pursuer and evader in a two dimensional plane. Figure 1A shows the baseline between the pursuer and the evader (the line joining the pursuer and the evader at any given time) as the game proceeds with the camouflage feedback (proportional-P) law alone. Figure 1B shows the baseline variation corresponding to the case when integral (I) and derivative (D) feedback laws are applied in addition to the proportional (P) law based on camouflage strategy. Figure 1C, Figure 1D show the individual pursuer and evadertrajectoriesfor the cases P control alone and PID control respectively using camouflage strategy. Clearly the performance (in terms of shorter time for the pursuer to capture evader) is obtained with the PID control combined with the motion camouflage strategy compared to P-alone with the camouflage strategy.



A B

C D

Figure 1 Pursuit evasion considered as two particle system in a two dimensional plane.

Application of PEG

One of the possible applications of PEG is the protection and monitoring of marine assets. India has over 7500 km long coastline, Numerous Economic Exclusive Zones, nearly 1400 mostly uninhabited islands, ports (12 major and 200 non- major), industrial units, military installations, oil refineries, nuclear power plants, satellite and missile launching ranges at the coastline area. Surveillance of the possible menace in the vast 2million square kilometers and protection of these assets has been a huge challenge for the country especially after the Mumbai attack in 2008.

Marine Police, Indian Coast Guard and Indian Navy provide a three-tier coastal security ring all along our coast. The intelligence mechanism along the coastline is also streamlined using various opto-electronic sensors including various radar stations. In spite of these, one could consider the problem of a menace, for example, that a manned hostile boat may appear anywhere in the considered coastal area. Unmanned Surface Vehicle (USV) surveillance of the coastline could be a possible solution to solve the menace.[10] The proposed solution will have two criteria first one is that there should be at least one USV to intercept the menace before it reaches the safety zone. It is required to find out the optimum number of USV and minimum time to react when menace does appear against any given area of asset to be protected. Further, additional interceptor boats can be sent both (manned and unmanned) if the threat is real. The second criterion is for minimizing the maximum intercepting time. The key point here is the selection of the interceptor having the lowest reaction time towards the menace location. Path planning methods will be used for maneuvering through the obstacle both static as well as dynamic. Obviously PEG theoretic concepts can play a key role in protecting the asset in the above application.

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None.

Conflicts of interest

The author declares there are no conflicts of interest.

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