Transactions on Industrial Electronics

Decision Letter (21-TIE-1691)

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CC:

Subject: IEEE Transactions on Industrial Electronics - Manuscript No. 21-TIE-1691

Body: ==
IMPORTANT: Primary e-mail address requirements
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From 01 April 2021 there is a change in the submission requirements for the IEEE T IE. This change is introduced to protect identity and integrity of all T IE authors. It becomes a MANDATORY requirement that the PRIMARY e-mail address of all authors listed in a submission is an INSTITUTIONAL one. Non-institutional e-mail addresses can only be used as the Primary CC e-mail address. Papers that do not comply with this requirement will NOT be put in the review process.
http://www.ieee-ies.org/pubs/transactions-on-industrial-electronics/286-institutional-emails
THIS APPLIES TO ALL THE REVISED VERSIONS AS WELL.

Nanyang Technological Uni, Singapore, Singapore, 12-Aug-2021

Dear Authors (BCC to Associate Editor, Reviewers),

Thank you very much for submitting manuscript No. 21-TIE-1691: "Cooperative Control Method of Multiple Predators vs. a Single Faster Prey in a Limited Area" to the IEEE Transactions on Industrial Electronics as a Regular paper submission.

The review process of your manuscript referenced above has been completed. Much to my regret, I have to inform you that in the opinion of the reviewers and Associate Editor in charge of the submitted manuscript is not suitable for publication in the IEEE Transactions on Industrial Electronics.

We encourage you not to attempt to resubmit the paper to the IEEE Transactions on Industrial Electronics. Unsolicited resubmissions are rejected immediately, without being put in the review process.

For your reference, the comments of the reviewers are enclosed.

I look forward to any future contribution and hope to work with you again.

With my best wishes for your success,

Sincerely yours,

Co-Editor-in-Chief
Professor Changyun Wen, IEEE Fellow
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Encl.:
Reviewer: 1

Comments to the Author
This paper studies the problem of pursuit-evasion game with a faster prey. Both pursuit and escape strategies are proposed for the predators and preys, respectively. The main concern of this paper stays with the novelty.

(1). The pursuit-evasion game with a faster prey in this paper is constrained in a limited area, which makes the problem easy to be solved. The existing results such as the works [16] and [25] have already solved the same problem. The authors claim that the work in [16] is dependent on the initial spatial position of the predators and prey, which is actually not true. The optimal strategy of [16] shown in Eq.(9) and Eq. (11) is designed based on the real-time positions of the predators and prey.

(2). The proposed pursuit algorithm shown in Eq.(9) of the predators require the velocity information of the prey, which is quite unreasonable in the pursuit-evasion game because the prey will not cooperate with the predators and its moving direction should be unknown to the predators.

(3). The proposed pursuit and escape strategies of the predators and prey adopt the structure of the artificial potential function methods and does not consider the speed ratios of the predators and prey. Also, this proposed pursuit and escape strategies are not proved to be the optimal pursuit or escape strategies. There is no mathematical description (value function) of the problem.

(4). The proposed pursuit algorithm is centralized rather than distributed. As shown in Eq. (11), the pursuit algorithm needs the information of all the predators.

(5). This paper does not discuss the capture condition and escape condition, under which the predators or prey must win the pursuit-evasion game.

Reviewer: 2

Comments to the Author
This submission considers an interesting problem of pursuit and evasion where a group of predators tries to capture a faster prey.
The paper focuses on proposing a different set of rules and behaviors and on simulations. Detailed analysis of these strategies is absent in this paper.

Within the framework of pursuit-evasion games, the strategies proposed in this submission seem rather arbitrary. For instance, the paper:

E. Garcia, S. Bopardikar "Cooperative containment of a high-speed evader", 2021 American Control Conference.

addresses a very similar problem, it provides a more formal set of strategies based on reach-avoid games. That reference also formalizes several concepts presented in this submission; especially, those found in Sections III.A.1, III.A.3, and III.B.3.
Another paper by the same authors also provides a more formal cooperation between teammates against a fast player:

E. Garcia, "Cooperative target protection from a superior attacker" Automatica, 2021.

More formal cooperative strategies are presented in such reference which account for speed difference, terminations conditions, and cooperative behaviors.

It seems that these references will provide a way for the authors to refine and improve their proposed strategies in a future version of the submission.

Reviewer: 3

Comments to the Author
Overview

The authors consider a Pursuit-Evasion Problem where a team of pursuers (predators) operating in a bounded planar environment seek to capture (i.e .be near enough that an agent could touch/occupy the same physical space) an evader(prey). The authors present a cooperative pursuit strategy that intuitively has the pursuers "fan-out" when the evader is far away before ultimately encircling the evader when within range. The authors also propose a strategy for the evader that switches between three operating modes: direct escape, border following, and gap escape. The authors provide some simulation results and also conducted a physical experiment.

High Level Comments

My impression of this work is that it borrows from the mathematics/physics/computer science literature with regards to the pursuit-evasion game formulation and attempts to motivate design choices by alluding to the fact that they are biologically inspired. However, I feel that these two overarching ideas:
1) Pursuit-evasion games
2) Biologically inspired behavior
aren't situated well with the existing literature to motivate this work.

For instance, the opening paragraph insinuates that pursuit-evasion games are intrinsic to a number of creatures. It is more than that though, the lion-and-man game (Introduced by Littlewood in "A Mathematician's Miscellany" 1953 and later formalized by Isaacs in "Differential Games" 1965) is one of the earliest pursuit-evasion games.

The second and third paragraphs do a combination of introducing variants of pursuit-evasion games where parameters such as the pursuers' speed, evader speed, sensing range, existence of obstacles, etc could vary between problem(s) and discuss how biologically inspired strategies have been employed by fellow scholars. The authors then then discuss the problem in the proposed paper.

As early as the conclusion of the first section, it is not immediately clear to the reader "WHAT" specific problem this paper addresses with regards to the existing literature. The planar variant of the pursuit-evasion problem is a well-studied problem at this point with a number of results for specific scenarios:
1) Lion and Man: upper and lower bounds 1993 Alonso, Goldstein, Reingold
2) A number of results out of Guarav Sukhatme's lab
3) A number of results out of Volkan Isler's lab
4) A number of results out of Subhrajit Bhattacharya's lab
and a myriad of other researchers have actively contributed to the field via investigation into different variants of this problem.

There are a number of survey papers that cover the pursuit-evasion domain very broadly:
- "Search and pursuit-evasion in mobile robotics" 2011 Chung, Hollinger, Isler
- "An introduction to pursuit-evasion differential games" 2020 Weintraub, Pachter, Garcia

All this to say, "What makes this specific pursuit-evasion problem unique?" or "What methodology is proposed by the authors that is either novel or improves upon existing techniques?" ... Either one or both of these questions should be answered and made abundantly clear to the reader by the conclusion of the Introduction/Related Work section(s) (and may then be emphasized/formalized in the Problem Description). I don't think that is the case in the current draft.

Comments on Modelling of the Predator, Prey, and Game Area (and the impact on the experimental results)

The good - The predator behavior strategy that the authors were able to generate where the pursuers 'fan-out' when the distance between the prey and pursuers is large, only to transition to an encircling behavior as the distance closes between the agents is rather intuitive and as the authors mention a very natural behavior in the sense that pack animals like wolves and lionesses employ this technique.

The suspect - There are aspects of the prey strategy that may have been assumed by the authors which is not readily apparent to me as a reader (I will elaborate on this below).

The unclear - The game area's partition into buffer area and confrontation area could use a little more explanation. Perhaps due to the game area influencing both groups of agents (prey and predators), I feel it disingenuous to discuss the predator/prey strategies without also discussing the how the environment partition affects them.

The predator/pursuer strategy uses the partitioning of the environment in calculating the v^a term which is a confrontation area attractive force (analogously a boundary repulsive force). This is a component of the overall strategy and leads to the behavior described above which is both intuitive and successful at catching the evader.

The prey/evader strategy perhaps due to the simplistic state-machine esque behavior (Fig 10) or arbitrary use of available data leaves me wary of it's effectiveness. The "arbitrary use of available data" comment is due to the sensitive range and how it affects the evader behavior. Currently, if the evader does not feel stalked by the predators, it will continue to follow the boundary (essentially ignoring the behavior of the predators who are also omniscient but are exploiting positional data to predict the evader's movement to catch it). When a single predator gets within the sensing range of the prey, what was before a "limited range agent" suddenly manifests the ability to reason about all of the predator agents again (gap escape).

Ultimately, is this a prey strategy? Yes. Is it the most effective strategy for maximizing the duration of the game and evading capture for as long as possible? I would argue no. So ultimately I am left with a few questions regarding the prey strategy. 1) Is this a reasonable strategy, or was it something arbitrarily created? If there was a citation that said "We modeled the evader behavior after the movements of the white-tailed deer" or some other animal that occupies the middle-link of the food chain, it would allay a lot of qualms because we as the reader would know the basis for it's creation and it wouldn't seem arbitrary. 2) How does this strategy compare against other strategies? I would expect it to perform better than a random walk? If this is a known predator win scenario, what is the maximum duration of the game ... how does this strategy compare to that result?

Essentially, it would have been nice to see how the proposed pursuer strategy performed against other evader strategies?

Specific Comments

Caption of Figure 9 .... Isn't it P_3 rather than P_1 which is within the sensitive range?

Section IV first paragraph r_thers -> r_thres

Some of the graphics could use a second pass. Some of them appear to be raster images as opposed to vector images.

AE Comments:
Associate Editor
Comments to the Author:
The reviewers have proposed various different major concerns, see, for example, the problem considered is not challenging and novel, the assumption used is unreasonable, the strategies proposed are centralized and seem rather arbitrary, the detailed analysis of the strategies, the capture and escape conditions, and the clarity in relation to the existing literature are absent, etc. There are also quite a few other major issues from the reviewers. Based on such, I cannot recommend the paper for further consideration in this journal.

Date Sent: 12-Aug-2021

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