Published in IET Control Theory and Applications
Received on 21st April 2010
Revised on 30th July 2010
doi: 10.1049/iet-cta.2010.0201

ISSN 1751-8644

Application of sliding mode control to swarms under conflict

R. Cepeda-Gomez[1] *N. Olgac*[1] *D.A. Sierra*[2]

[1]*Department of Mechanical Engineering, University of Connecticut, 191 Auditorium Road, Unit 3139, Storrs, CT 06268, USA*
[2]*Electrical and Electronic Engineering School, Industrial University of Santander, Cra 27 Calle 9, A.A. 678, Bucaramanga, Santander, Colombia*
E-mail: olgac@engr.uconn.edu

Abstract: A robustising sliding mode control strategy is implemented on two competing multi-agent swarms, called pursuers and evaders, with equal membership count. Newtonian dynamic models are considered, which include drag forces as well as the inter-agent attraction/repulsion forces. The proposed sliding mode control law achieves the stability and the capture of the evaders by the pursuers despite the uncertainties in the evader behaviour. The group pursuit is conceived in two phases: the approach phase during which the two swarms act like two individuals and the assigned pursuit phase when each pursuer is assigned to an evader. Furthermore, the authors take into account a turning action for the evaders, which adds to their agility. This property is considered as a part of the uncertainty in the dynamics. The control parameters are separately studied to assess their influences on the pursuit.

1 Introduction and problem statement

Much of the inspiration for artificial swarms stems from the study of biological swarms [1–4], and most of the earlier investigations that focus on this general theme of artificial swarming consider homogeneous swarms, that is, those composed of alike members, with a single integrator model and momenta profiles [3–8]. Recently, second-order models [9, 10] and hostile interactions [10, 11] have also been presented. The main contribution of this work is the introduction of a sliding mode control (SMC) law to guarantee that the members of one swarm, called pursuers, capture the members of the other, called evaders.

Gazi and Passino [4] expand their earlier pioneering work [3] on first-order swarm dynamics by generalising the stability analysis for homogeneous swarms. Chu *et al.* [6, 7] address the stability of anisotropic homogeneous swarms considering reciprocal and non-reciprocal interactions between agents. In the present paper, we extend the application of asymmetric interaction forces to hostile swarm dynamics, which is poorly studied in the literature.

Gazi and co-workers [8, 12, 13] also incorporate SMC using artificial potential functions to ensure swarm aggregation. In [12], the swarm in a formation is guided to track a target. In these investigations, the common aim is the creation of a decentralised formation control law to increase robustness. The SMC is used earlier to force the agents to follow a pre-defined potential field, as opposed to directly controlling the dynamics of the particles like in the present work.

In McCullough *et al.* [10], the works of Sierra *et al.* [11, 14] and Jin and Gao [9] are combined to analyse the hostile swarm scenario in which the swarms are treated as groups with second-order dynamics, and a proportional derivative control logic is deployed. They present a stability bound and show that the state of the system is guaranteed to converge to it. While we build on [10], our major improvement, and main contribution of this paper, is the deployment of a SMC technique, which guarantees convergence to a smaller region and robustises the capture against several uncertainties. For simplicity, within this study we consider only cases with equal number of pursuers and evaders along with a simple assignment policy, in order to avoid complications in this part of the mission.

Models of the friendly and hostile interactions among agents, similar to those used in [10], are presented in Section 2. These models treat the antagonistic scenario in two separate phases: approach and assigned pursuit. The novelty of the paper is in Section 3, where the sliding mode controller is used to ensure capture even in the presence of uncertainties. Section 4 presents some case studies, followed by conclusions and discussions. Throughout the text, bold face notation is used to represent vector quantities and italic font is for scalars.

2 Hostile swarm modelling

We follow the swarm model presented in [10] with a two-phase approach. Phase 1, called approach phase, treats the two swarms as single agents which are conceptually lumped around the respective swarm centres. The forces on individual agents during this phase are uniformly distributed. This phase brings the swarms to a configuration