Bearing-only Formation Control with Directed Sensing

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1 Abstract

This work investigates the formation control problem, which aims to drive a multi-agent system to achieve a desired spatial configuration. A control scheme called bearing-only formation control is proposed to solve this problem. This controller has attracted research interest because it requires and applies only bearing measurements between agents, rather than using distance measurements.

One limitation of bearing-only formation control is the sensing condition assumed. Early works extensively studied this controller assuming undirected sensing between agents, which is regarded as an unrealistic condition. More recent efforts have focused on the problem with directed sensing, where agent i can sense agent j but not necessarily vice versa. Recent research showed that the bearing-only formation control law also works with a specific class of directed sensing graphs called leader-first-follower (LFF) graphs generated from a bearing-based Henneberg construction. This was a major step forward from the previous assumption of undirected graphs to a limited class of directed graphs. Building on this, the goal of this work is to extend the results to more general conditions on the directed sensing graphs for which bearing-only formation control succeeds.

To achieve this, we first analyze a multi-agent system with one movable agent controlled by the bearing-only formation controller. The goal is to determine whether this movable agent will converge to a desired position satisfying all specified target bearings, for different numbers of outgoing edges (agents it can sense). The main challenge is finding equilibrium points of this nonlinear system. Our approach focuses on analyzing a related linear problem and establishing connections to equilibria of the nonlinear system. After determining the system equilibria, we also provide stability analysis showing that the movable agent converges to the desired position. This result then allows us to extend the class of graphs that solve the problem to LFF graphs where the follower agents can have more than 2 outgoing sensing edges. We provide stability and convergence analysis for this case. We also explore a further expansion of the class of graphs and conjecture that a sufficient condition for solving the more general formation control problem is that there must exist a subgraph that is a LFF graph. This conjecture is verified with simulation studies.