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A novel communication-aware formation control strategy for dynamical multi-agent systems

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Abstract

In the classical studies of formation control, it is typically difficult to realize full potential of communication channels between agents, since the adopted communication links are typically assumed to be ideal or ideal within a certain communication range. In this paper, a more realistic communication channel model is considered and a new communication-aware formation control approach is proposed with the objective of optimizing communication performance of formation systems. A sufficient and necessary condition is found for feasible formation in realistic communication environments. Then a communication-aware formation control is proposed for multi-agent systems with switching topology. It is rigorously proved that the proposed algorithm can optimize the communication performance of formation systems. A simulation example is provided to illustrate the proposed design.
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1. Introduction

Formation control and wireless channel characterization have been developed separately for many years. Little knowledge about wireless channel has been used in formation control since communication links between agents are typically assumed ideal or ideal within a certain communication range [1,2]. In order to realize full potential of communication channels between

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agents, it is of practical significance to model realistic channels for mobile agents and study how to control the formation group with realistic channel models.

Some early theoretical work in formation control generally assumes ideal communication channels in the formation design [3–5]. That is to say, there is no path loss between agents and every agent can communicate with all other agents effectively. More practical communication channels have been proposed in the past decade, and most of them are based on the communication range [6–13], where a binary channel model is applied, i.e., communication quality is assumed ideal (100%) within a certain radius of the transmitter and zero otherwise. In these studies, control laws are designed with a given communication constraint and do not rely on the real-time quality of communication channels. This fact, however, implies that agents lose the ability of reacting to the change of communication environments.

In recent years, much attention has been paid to modeling realistic communication channels for mobile agents in the control and communication community [14–23]. This interest is motivated by the vision of a multi-agent robotic network cooperatively adapting and learning in harsh unknown environments to achieve a common goal in the near future [14]. Many wireless link metrics, including bit error rate [2], received signal power [14,16], outage probability [15,21], transmission rate [17,19,20,22,23] and received channel to noise ratio (CNR) [18] have been examined in mobile agent networks for modeling communication channels between agents. In a realistic communication setting, the channel quality between agents is closely related to agents' positions or their relative distances [19]. Since the channel quality between agents can be measured or estimated by agents locally, communication-aware controllers are designed for agents by using channel quality as feedback instead of position or distance information.

Inspired by this new advance in modeling communication channels for mobile agents, this paper aims to study formation control of multi-agent systems in a practical communication environment. We model the communication channel between agents using reception probability, a realistic channel metric in the wireless communication theory [24]. In the proposed channel model, the channel quality is not assumed to be ideal or ideal within the communication range, but attenuating with the increase of propagation distances, which leads to a more accurate description of physical signal transmissions in a practical communication environment.

In classical formation control schemes, the desired distance between agents is typically predefined, and then gradient controllers are designed to keep the desired distance and maintain the formation [1]. The desired distance can be chosen arbitrarily by the designer as long as it is within the communication range, a value that is predefined as well. These controller design solutions may not be adequate for formation control in practical communication environments, where the communication condition of environments may change with time and space. The predefined desired distance may not always guarantee the optimal communication between agents in differing communication environments. A more reasonable idea is to design control laws by optimizing the communication performance of formation systems directly instead of keeping a predefined desired distance [11].

By summarizing our concerns on both the communication channel model and controller design method in existing formation control schemes, we attempt to propose a new communication-aware formation control strategy for multi-agent systems in a practical communication environment. The purpose of the design is to both maintain a stable formation and optimize the communication performance of the formation system. The contribution of this paper is twofold.

First, we model the communication channel between agents using reception probability, and bridge the gap between the communication channel model and the graph topology model. Then a

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