論文 / 著書情報
Article / Book Information

題目(和文)	分散最適化と集団ダイナミクスのための受動性に基づく解析および設計に関する研究
Title(English)	Passivity-based Analysis and Design for Distributed Optimization and Population Dynamics
著者(和文)	山下駿野
Author(English)	Shunya Yamashita
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第11745号, 授与年月日:2022年3月26日, 学位の種別:課程博士, 審査員:畑中 健志,三平 満司,倉林 大輔,早川 朋久,石﨑 孝幸,藤田 政之
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第11745号, Conferred date:2022/3/26, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	要約
Type(English)	Outline

（博士課程）

Doctoral Program

論 文 要 約

THESIS OUTLINE

系・コース： Department of, Graduate major in	システム制御 システム制御	系 コース	
学籍番号： Student ID Number	19D10152		
学生氏名： Student's Name	山下 駿野		

申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	（ 工学 ）
指導教員（主）： Academic Supervisor(main)	畑中 健志	
指導教員（副）： Academic Supervisor(sub)	藤田 政之	

要約

Thesis Outline

This dissertation investigates analyses and design methods for distributed optimization and population dynamics based on a unified concept of passivity.

We first revisit a traditional continuous-time distributed convex optimization algorithm, termed primal-dual dynamics, and address its fundamental limitation that the cost function needs to be strictly convex. Then, we present a novel control theoretic insight that supplying stable zeros to a subsystem is a key to ensure the convergence of the algorithm. Based on this insight, a passivity-based generalization of the primal-dual dynamics is proposed, and its asymptotic optimality without strict convexity is proved by supplying stable zeros. It is moreover revealed that the present optimization dynamics encompass existing augmented Lagrangian-based methods as special cases. The effectiveness of the generalized primal-dual dynamics is validated through simulations of illumination control.

We next address a fully distributed convex optimization managed by a coordinator and possibly multiple agents, and design a robust distributed algorithm against communication delays. First, a continuous-time optimization algorithm is proposed inspired by ADMM (Alternating Direction Method of Multipliers), and its asymptotic optimality in delay-free case is proved. We next consider the case with communication delays. In order to avoid destabilization caused by the delays, we focus on an architectural analogy between the continuous-time ADMM and bilateral teleoperation. Inspired by the analogy, we redesign the continuous-time ADMM with applying a passivity-based technique developed in bilateral teleoperation, called scattering transformation, and prove its asymptotic optimality under delayed communication between the coordinator and the agents. We finally demonstrate the continuous-time ADMM through simulations of a target assignment problem.

Subsequently, we address a distributed convex optimization including consensus constraint among agents in the network with inter-agent structure. First, a continuous-time distributed algorithm for the problem is proposed based on the above generalized primal-dual dynamics, and its convergence to an optimal solution is proved in the absence of delays. We next address the case with inter-agent communication delays. Then, we point out the architectural similarity to output synchronization control from the viewpoint of passivity. Based on this, we adopt scattering transformation to the distributed optimization algorithm, and prove its asymptotic optimality under heterogeneous delays in inter-agent communications. We finally apply the proposed algorithm to a target assignment problem, and demonstrate the present algorithm through simulations.

We finally analyze biased population dynamics and design behavior modification mechanisms. We formulate two types of population dynamics with conformity biases. The models are then analyzed based on so-called δ-passivity, where it is revealed that the conformity biases play a role in breaking passivity of decision makers. Based on the passivity perspective, we propose mechanisms so as to lead decision makers to a desired population state. Furthermore, we analyze convergence properties of the designed mechanisms while revealing conditions for guaranteeing stable inducements.