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Hybrid Port–Hamiltonian Systems: Application to Robotics

ハイブリッド・ポート・ハミルトン系：ロボット応用

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Notations, Symbols and Acronyms

Matrices are capitalized and in bold font, vectors are in bold font and scalars are in italic font; unless specifically noted.

Notations	**Meaning**
$p(x)$	Probability density function of random variable x.
σ_x	Variance of probability distribution of random variable x.
$\hat{\mathbf{x}}$	Expectation of probability distribution of random variable x.
$\mathcal{N}(\mu, \Sigma)$	Multivariate Gaussian (normal) distribution with expectation μ and covariance Σ.
$\sim$	Distributed/sampled according to; e.g., $x \sim \mathcal{N}(\mu, \Sigma)$, if x is a random variable, it means it is distributed according to a Gaussian of mean μ and covariance Σ; if x is a sample, it means it is sampled from the before mentioned distribution.

Symbols	**Meaning**
m	Material features, such as transparency, reflectiveness, and surface roughness.
d	Distance to an object measured by a LRF.
θ	Incident angle of a beam of light to a surface.
I	Intensity measured by a LRF.
a_I	Second order coefficient for LRF measured intensity.
a_d	Second order coefficient for LRF measured distance.
e_I	Mean squared error of LRF measured intensity.
e_d	Mean squared error of LRF measured distance.
T_{occ}	Occupancy threshold used in standard SLAM
T_g	Occupancy threshold for glass in the proposed method
T_{ng}	Occupancy threshold for non-glass in the proposed method
$\mathbf{x}$	Robot pose in in $x - y$ Cartesian coordinates, including position and orientation.
$\mathbf{P}$	Matrix of probabilities.

Acronyms	**Meaning**
SLAM	Simultaneous Localization
LRF	Laser Rangefinder
IMU	Inertial Measurement Unit
MSE	Mean Squared Error
SVM	Support Vector Machine

Chapter 1

Preliminaries

1.1 Introduction

1.2 Port–Hamiltonian Systems

[1]

1.2.1 Input–State–Output Model

The input–state–output representation of a port-Hamiltonian system is

$$ss \tag{1.1}$$

1.2.2 Passivity–Based Control

1.3 Hybrid Dynamical Systems

1.3.1 Hybrid Inclusions

1.3.2 Stability

Chapter 2

Hybrid Port–Hamiltonian Systems

2.1 Introduction and Preliminaries

2.1.1 LRF Principles

2.1.2 Related Physical Phenomena and Theories

2.1.3 A Material Classification Method

2.2 Proposed Classification Method

2.2.1 Assumption

2.2.2 Experimental verifications

2.2.3 Outline of the Classification Method

2.3 Neural Network based Classifier

2.3.1 Motivation

2.3.2 Training Data Preparation

2.3.3 Training and Testing Performance

2.4 Summary

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Research Publications

Peer Reviewed Journal Papers

[j1] **Stefano Massaroli**, Federico Califano, Claudio Melchiorri, Atsushi Yamashita, and Hajime Asama: "Port–Hamiltonian approach to asymptotic stabilisation of Lotka–Volterra equations.", *Scientific Reports, Nature*, 2018 (Submitted).

[j2] Jiaxu Wu, Hanwool Woo, Yusuke Tamura, Alessandro Moro, **Stefano Massaroli**, Atsushi Yamashita, and Hajime Asama. "Pedestrian trajectory prediction using BiRNN Encoder–Decoder Framework." *Advanced Robotics*, 2019 (In print).

Peer Reviewed Conference Papers

[c1] **Stefano Massaroli**, Renato Miyagusuku, Federico Califano, Claudio Melchiorri, Atsushi Yamashita, and Hajime Asama: "Recursive algebraic Frisch scheme: a particle–based approach", *IFAC PapersOnline*.

[c2] **Stefano Massaroli**, Renato Miyagusuku, Federico Califano, Angela Faragasso, Atsushi Yamashita, and Hajime Asama: "A novel recursive linear estimator based on the Frisch scheme.", *Proceedings of the 2019 IFAC/IEEE Asian Control Conference*, Kitakyushu, Japan, June 2019.

[c3] **Stefano Massaroli**, Federico Califano, Angela Faragasso, Atsushi Yamashita, and Hajime Asama: "Multistable energy shaping of linear time–invariant systems with hybrid mode selector." *2020 IFAC World Congress*, 2019. (Submitted)

[c4] **Stefano Massaroli**, Michael Poli, Federico Califano, Angela Faragasso, Atsushi Yamashita, and Hajime Asama: "Port–Hamiltonian approach to neural network training." *2019 Control and Decision Conference*, 2019. (Submitted)

[c5] **Stefano Massaroli**, Federico Califano, Angela Faragasso, Mattia Risiglione, Atsushi Yamashita, and Hajime Asama. "Identification of a class of hybrid dynamical systems." *2019 Control and Decision Conference*, 2019. (Submitted)

[c6] **Stefano Massaroli**, Federico Califano, Angela Faragasso, Atsushi Yamashita, and Hajime Asama. "Iterative energy shaping of a ball–dribbling robot." *2019 IFAC Workshop on Robot Control*, 2019. (Submitted)

Poster Presentations

[1] **Jun Jiang**, Renato Miyagusuku, Atsushi Yamashita, and Hajime Asama: "Glass and Non-glass Objects Classification Using Laser Rangefinders for Mobile Robots in Indoor Environments", Proceedings of the 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2017), p. 5529, Vancouver, Canada, September 2017.

Oral Presentations

[1] **Jun Jiang**, Renato Miyagusuku, Atsushi Yamashita, and Hajime Asama: "Active Simultaneous Localization and Mapping in Glass Environment using Laser Rangefinder", Pro-

ceedings of the Tsinghua University- the University of Tokyo Joint Symposium on Multi-discipline, pp. 95, Beijing, China, April 2017.

Appendix

A

Stability of Dynamical Systems

B

Differential Geometry

C

Set–Valued Mappings