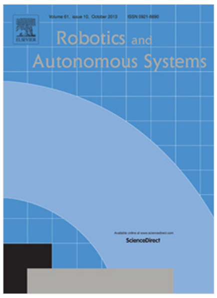
Accepted Manuscript



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PII: S0921-8890(17)30814-X
DOI: https://doi.org/10.1016/j.robot.2018.06.006
Reference: ROBOT 3045

To appear in: *Robotics and Autonomous Systems*

Received date : 8 November 2017
Revised date : 24 May 2018
Accepted date : 12 June 2018

Please cite this article as: R.F. Santos, G.A.S. Pereira, L.A. Aguirre, Learning robot reaching motions by demonstration using nonlinear autoregressive models, *Robotics and Autonomous Systems* (2018), https://doi.org/10.1016/j.robot.2018.06.006

Learning robot reaching motions by demonstration using nonlinear autoregressive models

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Abstract

This paper presents NAR-RM, a method for learning robot reaching motions from a set of demonstrations using Nonlinear AutoRegressive (NAR) polynomial models. Reaching motions are modeled as solutions to autonomous discrete-time nonlinear dynamical systems, so that the movements started near the data of the demonstrations follow the trained trajectories and always reach and stop at the target. Since NAR models obtained using standard system identification techniques do not always adequately model the reaching motions, in this paper we present a method that uses a least-squares estimator with constraints to impose the location of fixed points in the model. With the imposition of new fixed points it is possible to change the location of the original fixed points of the model, thus allowing the learning of stable reaching motions. We evaluate our method using a library of human handwriting motions, a mobile robot and an industrial manipulator.

Keywords: Learning by demonstration, Nonlinear Autoregressive models, Dynamical systems, Fixed point.

1. Introduction

In the last decade, learning by demonstration has been used to teach a robot how to perform point-to-point movements, also known as reaching motions. Point-to-point movements provide basic components, called movement primitives, which can be used to compose more complex movements [1]. These movements may be learned through a set of demonstrations, at the kinematic level, where the most relevant characteristics are extracted and codified. Movements encoded using nonlinear dynamical systems (DS) have shown good results [2, 3, 4].

A widely known method for learning reaching motion with DS is called Dynamic Movement Primitives (DMP) [3]. The DMP estimates a nonlinear DS while ensuring stability to the target. Stability is obtained by suppressing the nonlinear terms at the end of the motion, when a smooth switch to a stable linear system is controlled by a phase variable. As the learned DS is non-autonomous, the use of a heuristic to reinitialize the phase variable is always necessary in case of temporal perturbations, which may occur due to delays during execution of the model.

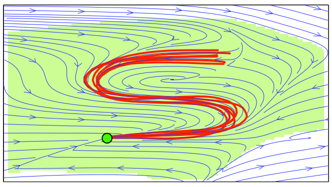

Fig. 1: Phase portrait of a model identified using the proposed methodology. The green region is the basin of attraction of the stable point at the target (green circle). This region covers the demonstrations (red trajectories) and is large enough to provide robustness to the system.

Autonomous DS are good alternatives for modeling movements robust to temporal perturbations. Binary Merging (BM) [5], for example, is a method that uses a Gaussian mixture model to estimate an autonomous DS with local asymptotic stability to the target. The stability assurance is obtained during the learning phase, where constraints, some based on Lyapunov functions,

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