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Monitoring in a Lotka–Volterra model

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Abstract

The problem of monitoring arises when in an ecosystem, in particular in a system of several populations, observing some components, we want to recover the state of the whole system as a function of time. Due to the difficulty to construct exactly this state process, we look for an auxiliary system called *an observer*. This system reproduces this process with a certain approximation. This means that the solution of the observer tends to that of the original system.

An important concept for this work is observability. This means that from the observation it is possible to recover uniquely the state process, however, without determining a constructive method to obtain it. If observability holds for the original system, it guarantees the existence of an auxiliary matrix that makes it possible to construct an observer of the system.

The considered system of populations is described by the classical Lotka–Volterra model with one predator and two preys and the construction of its observer is illustrated with a numerical example. Finally, it is shown how the observer can be used for the estimation of the level of an abiotic effect on the population system.

Keywords: Population system; Observability; Observer system

1. Introduction

A particular problem of monitoring arises when in an ecosystem with several populations we only observe the density of certain population(s) considered as indicator(s), and we want to recover the state of the whole system as a function of time. Such a partial observation may be convenient when the direct observation of the state of all considered populations is technically complicated or expensive.

A key concept for the solution of this problem is the observability, which means that from the observation of a transformed of the time-dependent state, it is possible to recover uniquely the original state process as a function of time. A simple algebraic condition can guarantee local observability near an equilibrium, however, it does not provide a method to reconstruct the original state process. Therefore, we shall construct an auxiliary system called an observer whose solution tends to that of the original system.

This condition also was applied to several models in genetic populations and to frequency-dependent evolutionary models in López (2003), López et al. (2003, 2004). Observability was analyzed in Varga et al. (2002, 2003) in different Lotka–Volterra models and in Shamandy (2005) in simple trophic chains. Bernard et al. (1998) used observers for the validation of a phytoplanktonic growth model. We also notice, that based on a general theorem of Varga (1992), observability in differ-

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