Physica A 422 (2015) 40–46

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Chaos analysis and delayed-feedback control in a discrete dynamic coupled map traffic model

Fang Yaling, Shi Zhongke *

[a] School of Automation, Northwestern Polytechnical University, Xi'an 710072, China

HIGHLIGHTS

- We model a modified discrete dynamic coupled map traffic flow model.
- We identify chaos in traffic flow based on the discrete dynamic coupled map model.
- We analyze its stability and provide a procedure to design the controllers.

ARTICLE INFO

Article history:
Received 9 August 2014
Received in revised form 9 October 2014
Available online 14 December 2014

Keywords:
Discrete dynamic coupled map model
Occupancy
Coupling strength
Chaos
Decentralized delayed-feedback controllers

ABSTRACT

The presence of chaos in traffic flow is studied using a modified discrete dynamic coupled map model which is derived from both the flow–density–speed fundamental diagram and Del Castillo's speed–density model. The modified model employs occupancy as its new variable and introduces a coupling strength with the consideration of effect of the front adjacent vehicle. And we analyze its stability of the control system and provide a procedure to design the decentralized delayed-feedback controllers for the traffic control system. These theoretical results are illustrated by numerical simulations.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

The traffic system is a complex, nonlinear, uncertain and dynamic one. Various theories of dynamic systems can be applied to the traffic system. The jams, chaos, and pattern formation are typical signatures of the complex behavior of transportation. Traffic systems may be monitored based on these results, to achieve a stable equilibrium and to avoid instabilities and chaos. So, it is imperative to take effective steps to control traffic chaos.

There has been a great interest in nonlinear traffic dynamics since the 1960s, because of the rapid progress in geometric and topological methods in dynamics. Chaotic behavior is a revolutionary discovery in deterministic systems. Thus, investigating models and observing chaotic traffic flow are worthwhile tasks. Disbro and Frame [1] demonstrated that the GHR (Gazis, Herman and Rothery presented [2]) traffic model is highly chaotic, even when applied to small (eight-car) systems. D.S. Dendrinos [3] put forward a theory of the microscopic as well as macroscopic traffic behavior involved and discussed specific tests searching for chaotic dynamic. That topic was representative of a class of subjects in socio-spatial analysis that involve nonperiodic dynamics. It identified possible chaotic patterns on residuals of such dynamics from approximate temporal (mainly daily) cycles. The presence of chaotic phenomena in traffic models has been reported in recent studies [4–8]. Addison and Low [4] observed chaos in a single-lane car-following model in which a leading vehicle

* Corresponding author.
E-mail addresses: wchjiokhylf@hotmail.com (Y. Fang), shizknwpu@126.com (Z. Shi).

http://dx.doi.org/10.1016/j.physa.2014.11.038
0378-4371/© 2014 Elsevier B.V. All rights reserved.

has oscillating velocity. For certain parameter values chaotic oscillations were generated, consisting of a broad spectrum of frequency components. They presented the results of simulating over a range of parameter values, and the degree of chaos was estimated. Nagatani [5] proposed a lattice hydrodynamic model that takes into account the passing effect in the traffic flow on a highway. He found that the chaotic jams appear when the passing constant is larger than 0.1. The chaotic traffic has been investigated by computing the Fourier spectrum, phase-space plot, and Lyapunov exponent. Also, time delays in traffic flow can significantly influence the dynamics of transportation systems and change the arising chaotic large-scale patterns [6]. Safonov et al. [7] showed that chaotic behavior in traffic can be due to the delays in the human reaction. Gasser et al. [8] investigated numerically the global bifurcation diagram for periodic solutions and obtained a complete picture of the dynamics of general optimal velocity models. Orosz et al. [9] found the microscopic dynamics as well as extracted macroscopic properties of traffic flow. They determined parameter domains where the uniform flow equilibrium is stable. Most of the previous research works on the discovery of chaos in traffic flow were based on traffic data time series. Some model-based research works were limited to the car-following models.

In fact, chaos can be found in traffic flow widely. It is impossible to completely eliminate traffic chaos. Any control method that can make traffic flow stable and orderly and reduce the uncertainty of traffic flow can be regarded as an effective way to reduce the chaos of traffic flow. In the control method of chaos, one of the relatively famous methods is the OGY method that stabilizes chaotic motions onto a desired unstable periodic orbit (UPO) [10]. Shahverdiev et al. [11] reported the possible chaos control in the traffic flow cellular automaton models within replica, nonreplica and parameter change approaches.

The purpose of this study is to investigate the dynamic behavior of a modified discrete dynamic coupled map model (DDCM model) which is derived from both the flow–density–speed fundamental diagram and Del Castillo's speed–density model [12,13]. The chaos phenomenon is found in the DDCM model. Conditions for the stability of equilibrium in the model are established. Finally, we provide a procedure to design the decentralized delayed-feedback controllers (DDFCs) for the traffic control system.

The rest of this paper is organized as follows. Section 2 presents the new derivation of the DDCM model. Section 3 gives the bifurcation diagram of DDCM model without coupling strength. Section 4 investigates the stability and chaos analysis of the DDCM model and gives the chaotic control method to stabilize this type of model. The control method developed by Keiji Konishi et al. [14] is introduced herein. Section 5 shows the simulation results. Finally, conclusions are presented in Section 6.

2. Discrete dynamic coupled map traffic flow model

The model analyzed in this paper is a macroscopic coupled map traffic flow model. The derivation is from the flow–density–speed fundamental diagram

$$q(k) = kv(k) \tag{1}$$

where q is the flow, k is the density and v is the speed. It is assumed that speed depends solely on density.

We suppose that the road traffic flow satisfies the speed–density model presented by Del Castillo et al. All the speed–density models had in common the following functional form

$$v(k) = v_f\left[1 - f(\lambda)\right]. \tag{2}$$

The function $f(\cdot)$ was called the generating function and its argument, λ, equivalent spacing.

Two of them are of special interest, the exponential curve given by

$$v(k) = v_f\left\{1 - \exp\left[\frac{|C_j|}{v_f}\left(1 - \frac{k_j}{k}\right)\right]\right\} \tag{3}$$

and the maximum sensitivity curve

$$v(k) = v_f\left\{1 - \exp\left[1 - \exp\left(\frac{|C_j|}{v_f}\left(\frac{k_j}{k} - 1\right)\right)\right]\right\}. \tag{4}$$

The parameters appearing in the above formulas are the free-flow speed v_f, the kinematic wave speed at jam density C_j, and the jam density k_j. We will only discuss exponential curve here, because the other situation is based on the same method.

From Eqs. (1) and (3), we have

$$q(k) = v_f k\left\{1 - \exp\left[\frac{|C_j|}{v_f}\left(1 - \frac{k_j}{k}\right)\right]\right\}. \tag{5}$$

It is assumed that the traffic flow in the next time period is decided by the current traffic conditions. Based on this, Eq. (5) is as follows:

$$q_{n+1} = v_f k_n\left\{1 - \exp\left[\frac{|C_j|}{v_f}\left(1 - \frac{k_j}{k_n}\right)\right]\right\}. \tag{6}$$

Download English Version:

https://daneshyari.com/en/article/975117

Download Persian Version:

https://daneshyari.com/article/975117

Daneshyari.com