Title: Topological Complexity and Predictability in the Dynamics of a Tumor Growth Model with Shilnikov's Chaos

Author(s): Duarte, Jorge [1,2]; **Januario, Cristina** [1]; Rodrigues, Carla [3]; Sardanyes, Josep [4,5]

Source: International Journal of Bifurcation and Chaos **Volume:** 23 **Issue:** 7
Article Number: 1350124
DOI: 10.1142/S0218127413501241 **Published:** Jul 2013

Document Type: Article

Language: English

Abstract: Dynamical systems modeling tumor growth have been investigated to determine the dynamics between tumor and healthy cells. Recent theoretical investigations indicate that these interactions may lead to different dynamical outcomes, in particular to homoclinic chaos. In the present study, we analyze both topological and dynamical properties of a recently characterized chaotic attractor governing the dynamics of tumor cells interacting with healthy tissue cells and effector cells of the immune system. By using the theory of symbolic dynamics, we first characterize the topological entropy and the parameter space ordering of kneading sequences from one-dimensional iterated maps identified in the dynamics, focusing on the effects of inactivation interactions between both effector and tumor cells. The previous analyses are complemented with the computation of the spectrum of Lyapunov exponents, the fractal dimension and the predictability of the chaotic attractors. Our results show that the inactivation rate of effector cells by the tumor cells has an important effect on the dynamics of the system. The increase of effector cells inactivation involves an inverse Feigenbaum (i.e. period-halving bifurcation) scenario, which results in the stabilization of the dynamics and in an increase of dynamics predictability. Our analyses also reveal that, at low inactivation rates of effector cells, tumor cells undergo strong, chaotic fluctuations, with the dynamics being highly unpredictable. Our findings are discussed in the context of tumor cells potential viability.

Author Keywords: Cancer; Tumor cell dynamics; Chaos; Complex systems; Topological entropy; Predictability

KeyWords Plus: Double scroll; Immunotherapy; Attractors; Systems; Cells

Reprint Address: Duarte, J (reprint author) - Engn Super Inst Lisbon, Dept Math, ISEL, Rua Conselheiro Emidio Navarro 1, P-1959007 Lisbon, Portugal.

Addresses:
[1] Engn Super Inst Lisbon, Dept Math, ISEL, P-1959007 Lisbon, Portugal
[2] Inst Super Tecn, Ctr Math Anal Geometry & Dynam Syst, CAMGSD, P-1049001 Lisbon, Portugal
[3] Technol Super Sch Setubal, Dept Math, ESTS, P-2914761 Estefanilha, Setubal, Portugal
[4] Univ Pompeu Fabra, Complex Syst Lab, ICREA, Barcelona 08003, Spain
[5] Univ Pompeu Fabra, Inst Biol Evolut, CSIC, Barcelona 08003, Spain

E-mail Addresses: jduarte@adm.isel.pt; cjanuario@adm.isel.pt; carla.rodrigues@estsetubal.ips.pt; josep.sardanes@upf.edu

Funding:

Funding Agency	Grant Number
Fundação para a Ciência e Tecnologia (FCT/Portugal)	

Publisher: World Scientific Publ CO PTE LTD
Publisher Address: 5 Toh Tuck Link, Singapore 596224, Singapore
ISSN: 0218-1274

Citation: DUARTE, Jorge; JANUARIO, Cristina; RODRIGUES, Carla; SARDANYES, Josep - Topological Complexity and Predictability in the Dynamics of a Tumor Growth Model with Shilnikov's Chaos. International Journal of Bifurcation and Chaos. ISSN 0218-1274. Vol. 23, nr. 7 (2013).