State estimation and forecasting using a shadowing filter applied to quincunx and ski-slope models

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Abstract

There are an enormous number of physical phenomenons in this world that appear to behave randomly but are not random: such as the bouncing ball in a pinball machine or a physical device called the Galton board; a rock or any object rolling or sliding down a mountainside or slope. This thesis investigates whether or not one can predict the further dynamics of such systems. We formulate five Galton board models, also known as quincunx, and two ski slope models. The discussion includes a brief description of the systems, the important physical processes, the assumptions employed, the derivation of the governing equations, and a comparison between the quincunx models and the ski-slope models. The quincunx models are converted into maps, called quincunx maps, that enable a straight-forward analysis of the symbolic dynamics of the maps. While Galton and others suggested that a small ball falling through a quincunx would exhibits random walk; the results of the symbolic dynamics analysis demonstrate that this is not the case. Regarding our final aim of forecasting, we consider five examples of model-system pairs and study how well the more sophisticated model(system) can be forecasted with a simpler model. In reality one often faces the problem that the state of a system is effected by noise. To test the performance of our models, we apply the gradient descent of indeterminism (GDI) shadowing filter to the quincunx models and the ski slope models. We investigate the quality of the estimated states and their usability for forecasting. Quite surprising is that there are unexpected cases in which the better state estimates gives worse forecast than the worse state estimates. But the GDI shadowing filter can successfully be applied to the quincunx models and the ski slope models only with slight modification, that is, by introducing the adaptive step-size to ensure the convergence of indeterminism. Finally, a very simple method is proposed to determine the states of the quincunx models from just the knowledge of the pin hits and the time of the impacts. The method is implemented along with the modified GDI shadowing filter.