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An alternative approach to characterize time series data: Case study on Malaysian rainfall data

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Abstract

This paper focuses on the characterization of time series rainfall data to understand the behavior in the Malaysian rainfall data. An analysis of the rainfall behavior of different time periods is also conducted. The rainfall data is rounded. A bar with a width of 12 pixels is drawn for each day in the data. The length of the bars drawn is equal to the corresponding rainfall value. Each bar is separated by a space of 2 pixels. Bars for data from different year are stored in different rows. Morphological opening is performed on the barcode image obtained, using line kernels of increasing length. Connected component-labeling algorithm is implemented on the resulting images to identify the individual bar codes and to compute the number of bars remaining after the opening process. A daily rainfall record for the duration of 30 years, obtained from the Melaka Meteorological Station, is analyzed. The results provide characterization of behavior in daily rainfall data.

1. Introduction

A time series is a set of observations measured sequentially through time [1]. Time series analysis is used to describe data using summary statistics and graphical methods, to find suitable statistical models to describe the data-generating process, to estimate the future values of a series and controlling a given process. There are two types of time series; discrete time series and continuous time series. Continuous time series is obtained when observations are recorded continuously over some time interval [2]. The analysis of rainfall data is an important feature for the prediction of metrological information. The problem of transformation of rainfall data from one scale to another has been gaining considerable importance in recent years. The suitability of the theory to the highly variable rainfall in time and space has very often been questioned. The past two decades of research on chaos theory in relation to hydrometereological data characterization has brought about a significant shift in the hydrometereological phenomena. Research on chaos theory in hydrometereology continues to grow with applications to a wide variety of

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problems. The deterministic chaos is often considered to be a change of the paradigm in the discussion of Kuhn [3]. The fast progress of the theory in the last 20–30 years has significantly contributed to the revealing of the common base of many branches of science. The connection of chaos theory is started with the work of Lorenz [4] and with the Mandelbrot's idea of fractal geometry summarized in Mandelbrot [5]. The continuous changes of various natural processes and elements have been analyzed by Rodriguez-Iturbe et al. [6], Sharifi et al. [7], Jayawardena and Lai [8], Palmer et al. [9] and Sivakumar et al. [10]. The problem of the existence of a climatic attractor is one of the basic topics of the research [11–16]. Many analyses have been made in non-linear predictions of chaotic time series with promising results (e.g. [17,8,16,15] presents a review of advances made and the problems still existing in the application of the theory of chaos and dynamical systems to time series. In particular they discussed issues pertaining the estimation of dimensions, Lyapunov exponents and non-linear prediction from an observable [18]. A chaotic system is defined as a deterministic system in which small changes in initial conditions may lead to completely different behavior in the future. The name "chaos theory" comes from the fact that the systems described are apparently disordered, but chaos theory is really about finding the underlying order in apparently random data. Chaos has already had a lasting effect on science, however there are many chaotic systems to be discovered. The evidence of the influence of an observing interval on the possibility of detecting the determinism in the rainfall data is the main objective of this paper. A preliminary attempt is made using morphology to characterize the behavior of rainfall data is obtained from the Melaka Meteorological Station.

2. Mathematical morphology

Mathematical morphology deals with the extraction of image components that are useful in representation and description of region shape, such as boundaries, skeletons and the convex hulls [19]. Morphological operators generally require two pieces of data as input. The first input is the input image (referred to as *M*), which may be either binary or grayscale for most of the operators. The other input is the kernel (referred to as *S*). The kernel is used to determine the precise details of the effect of the operator on the image [20]. The two basic morphological operators are erosion ($(M \ominus S) \subset M$) and dilation ($(M \oplus S) \supset M$). The basic effect of erosion on a binary image is to erode away the boundaries of regions of foreground pixels (resulting in the image being shrunk). The basic effect of dilation on a binary image is to gradually enlarge the boundaries of regions of foreground pixels (resulting in the image being expanded). Erosion and dilation are used to form opening and closing [21].

Opening is done by performing erosion followed by dilation. The effect of the operator is to preserve foreground regions that have a similar shape to this kernel, or that can completely contain the kernel, while eliminating all other regions of foreground pixels. Opening is explained in the following equation.

$$M \circ S = (M \ominus S) \oplus S. \tag{1}$$

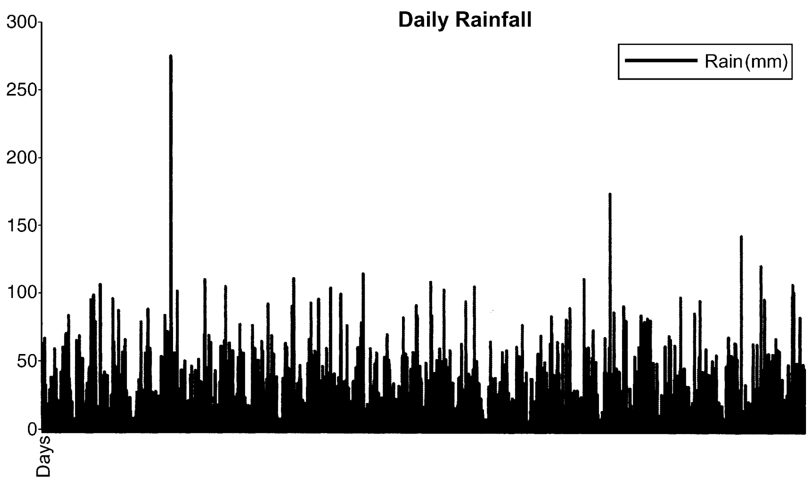

Fig. 1. Rainfall behavior for 30 years.