Zekâi Şen

Innovative Trend Methodologies in Science and Engineering

Springer

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RAHMAN VE RAHİM OLAN ALLAH'IN ADI İLE

IN THE NAME OF ALLAH, THE MOST MERCIFUL, THE MOST COMPASSIONATE

I hope that each individual will try to perform his/her intellectual ability and moral behavior along an increasing trend for the common share and prosperity of humanity in homogeneous and isotropic manner

Preface

Scientific and technological developments in any discipline have become heavily dependent on the digital data treatment for better and refined deductions from available time series records that reflect the behavior of natural phenomena or artificial events as for their performances. These phenomena and events are rather complex, uncertain at times, vague, and even incomplete in their past records, which are also embedded with some deterministic components such as linear or nonlinear trends, sudden jumps, and seasonalities, each of which provide useful information for prediction of the future behavior so as to be able to control the natural events to a certain extent. Especially, trend component is the most sought one, because it shows the direction of general tendency within the partially uncertain events and especially since four decades their search has become a very significant task concerning climate change effects on environmental, social, and health aspects; economic growth indices; business affairs; and industrial production quality controls.

Currently, there is a trend in automation and data exchange in manufacturing technologies that leads to a new paradigm shift in industry that is now referred to as the Industry 4.0, which will be empowered only with innovative methodological procedures. Trend identification, determination, future extension, and de-trending procedures will gain refined and progressive advancement that will pave way towards better management and control of the phenomenon concerned in scientific, technological, engineering, environmental, social, economic, business, and health aspects. The success of industrial machines to predict failures and trigger maintenance processes autonomously or self-organized logistics, which react to unexpected sudden changes (jumps) or gradual and monotonic expected changes in the behavior of the phenomenon or production concerned. In order to arrive at meaningfully guiding information, it is necessary to provide useful insight into the prediction and management procedures through data processing by means of innovatively advanced analytical approaches and algorithms. The information generation algorithms should be able to detect and address visible and hidden issues in environmental changes such as the climate change impacts on different disciplines, machine degradations, depreciations, or improvements in the final industrial production.

In order to achieve effective prediction, management, and information generation, one of the most important data processing issues is the identification and determination of trend component in a given record especially in the form of time series. This is the main purpose of this book where after an effective literature review in the first three chapters different types of innovative trend analysis methodologies are presented in the science philosophical, logical, rational, and linguistic foundation leading to the probabilistic, statistical, and stochastic aspects for better and refined trend identification. The innovative trend template provides first of all visual inspection for verbal information deductions not only for holistical purposes, but also for providing better views in terms of at least three categories as "low," "medium," and "high" record values within the data. Spatial and partial trend component identification methodologies are also provided with simple but illuminating examples. Innovative trend simulation studies and trend test statistical procedures are explained along with actual example applications from different parts of the world. Apart from the classical trend analysis on the average, possible trend behavior in terms of standard deviation is also presented with innovative approaches under the title of variability. Last but not least, after a brief explanation of fuzzy logic modeling principles, fuzzy trend analysis fundamentals are explained. In the final chapter, several examples are presented concerning the climate change impact in terms of trend analyses.

The content of this book is an outcome from a series of lectures by the author at the Technical University of Istanbul and also at the King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia. Furthermore, many aspects of the trend analysis have been discussed with international students from different countries personally and through the electronic communication systems. I appreciate all of these precious discussions, which accumulated and led to the production of this book. It will give me pleasure and self-satisfaction if the content of this book serves to those who are interested in the trend analysis.

In writing an international book one has to be very patient and confine his/her attention for many hours, days, months, and even years without care for many other things and therefore needs the support of many others. I appreciate and thank those who have encouraged me to write this book and at the top of the list is my wife Mr. Fatma Şen for her endurance, patience, and encouragement.

Çubuklu, Istanbul, Turkey Zekâi Şen
2016

Contents

1 Introduction

Abstract
Trend analysis has an interdisciplinary context that is shared by many researchers all over the world. The preliminary recommendation in this chapter is about visual trend examination and identification in a given time series to feel what are the possibilities of trend existence either holistically or partially. In this manner the researcher will be able to decide which type of the probabilistic, statistical, and mathematical approach for its objective determination. A brief discussion about trend analysis usage is presented on the basis of a set of disciplines. Additionally, pros and cons about trend analysis approaches are presented briefly and finally future trend research directions are mentioned with the purpose of this book.

Keywords
Concept · Definition · Disciplines · Purpose · Trend · Visualization · Mathematics · Statistics

1.1 General

Modern lifestyle at every aspect can be improved further through the measurements, mathematical models, control and prediction for future time periods at short-, medium- and long terms. With the computational facilities and treatment of data many social, economic, health, earth, environment and engineering systems can be modeled for prediction purposes. In practice, natural or artificial time series records at regular time intervals are available, but unfortunately they are evaluated for certain purposes without a complete description of deterministic and stochastic parts. Each time series is full of various qualitative and quantitative features, which are ready for

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logical, rational, analytical, probabilistic, statistical, stochastic, and fuzzy scientific assessments for deduction of useful information in practical applications. Time series component identifications are the most important issues that are backbones of fruitful developments in any discipline.

Among the most significant components of a time series is the trend evolution lines, which indicate continuous increase, decrease, or stability (balance, neutrality) along the time axis. Trends are desirable in many human activities depending on the final goal. For instance, the Olympic Games record breakings are indicators of increasing trend, because each game is sought to perform better than the previous ones. In general, any societal development is measured through various indices, which indicate either a positive or negative change or neural state. Any development, concerning a system, can be felt first intuitively and subjectively and later on objective decision can be achieved through the necessary measurements, which provide databases, and subsequently, their treatments, by convenient scientific methodologies leading to useful information.

Time series trend analysis research and application studies have increased during the last 25 years as a result of interest in the global warming and climate change impacts on natural events in addition to more refined economic and business prediction purposes. There are trend identification methodologies and statistical trend significance tests, but each one with different set of assumptions, which may not be simultaneously valid within the measurement data. In general, the following points are among the trend study purposes in various disciplines.

(1) Performance of any system toward better conditions, which implies an increasing trend embed within the time series,
(2) Measurement of system performance quantitatively, whether there is an improvement (positive trend) or depreciation (negative trend) by time,
(3) Assessment of any system as to its balance and steadiness about temporal evolution, which is reflected by a neutral (no trend) case,
(4) Random or stochastic behavior identification of a system after systematic variations (trend, shift, seasonality–periodicity) elimination from a given time series,
(5) Quality control of a manufacturing system such as factories and depreciation (decreasing trend) of the machine performances,
(6) Economic performance measure (increasing or decreasing trend) of any societal activity (business, economics, population, etc.) variation with time.

Trends are also indicators of significant correlation between successive event occurrences and time or among a set of events at different measurement locations in space. They are gradually introduced into the records, because of natural or man-made (artificial) effects. The shifts (jumps) are also due to the similar effects, but as rather sudden changes at times step by step. Most often, the gradual changes in environmental phenomena are results of global warming, climate change, population growth, and assessment of available resources. It is also possible to check gradual urbanization impacts on some changes due to the environmental activities around a measurement site. Replacement of measurement instrument by a recent one or even with similar instrument and compulsory change of location may cause jump (shift), i.e., sudden step changes in the measurements or records. For this purpose, it is necessary that the records at any measurement site must not be numerical only, but also linguistically available causative and consequent information are needed for better identifications, interpretations, and predictions (see Chaps. 4 and 6).

Trend analyses are significant not only in the earth systems researches, but they have a larger domain of applications in different disciplines including quality control, economics, pattern recognition, digital signal processing and, in general, in data mining works. Among the various disciplines, the interest in trend analysis can be summarized along the following points.

(1) Any researcher that works with time series records would like to identify the system response in terms of systematic variations (trends, seasonality–periodicity and jumps), nonsystematic and uncertain residuals,
(2) Detection of trends indicate the general tendency toward increasing or decreasing directions or stability in the system response,
(3) Graphical representation of time series is the first step in data processing prior to quantitative theoretical technique applications and with naked eye one may search linguistically (verbally) for different variation patterns leading to preliminary qualitative and fuzzy information deductions (Şen 2010).

1.2 Trend Definition and Analysis

Any systematic and continuous increase or decrease along time axis is referred to as temporal trend, which may be in the linear or nonlinear forms. Trends are almost everywhere, but one begins to think or feels about their existence unless someone talks or when s/he is asked to provide evidence about them. For instance, since birth human beings are in increasing trend as for the tallness is concerned, but it is not linear throughout the life. Anyone feels in comfort, if his/her income increases with time. In general, trends are systematic changes in natural, social and artificial events over relatively longer time periods preferably with at least 30 or more sample.

There is a variety of trend definition depending on the purpose. In general, it is a tendency in which some event develops as increasing (upward) or decreasing (downward) changes. Each trend has a general direction, which may also be expressed in terms of drift, shift, swing, course, current, leaning, tendency, and inclination and synonymously as bias and bend. The term trend may also have social context as modern model, fashion, mode, type, style, vogue, and rage. Some examples are increasing as warming trend, fashion trend, upwards economic trend, downward trade trend, quality trend, stock market trend, business trend, etc.

Trend identification and detection procedure reviews are available in the literature (Esterby 1996; Hess et al. 2001). They lack a comprehensive text that covers potential applications in global warming, climate change, hydrology, environment, health, engineering and climatology disciplines, which are in increasing need for objective trend identification and prediction. Trend analysis reviews are focused on a single and monotonic trend search in a given time series with an emphasis on some classically favorable techniques only. In this book, after extensive literature review and criticisms, innovative trend identification and detection procedures are presented with rational and logical bases. No need to say that at the dawn of twenty first century, there is a need to highlight the importance of time series analysis in many disciplines including water resources planning, management and new issues of sustainable management, where innovative trend analysis techniques are ready to pave objective ways for logical interpretation and quantitative calculations.

1.2.1 Conceptual and Visual Trends

Mental and logical visualization change inspections with time are very helpful to generate illuminating ideas about the process concerned prior to any quantitative applications and theoretical developments. There are two ways to establish preliminary ideas about the temporal evolvement of any event performance. These are conceptualization of the event through mental experiments with a set of possible logical rules without any data availability and visualization of the event by means of graphical representations provided that there are measurements in the form of a time series.

In any scientific work, provided that the numerical data are available, the preliminary work is to try, visualize and explore the data behavior in graphical forms, which trigger the mind and creative thinking through the geometrical shapes. This is already reflected in saying that one picture is worth of thousand words. Especially, in the time series analysis, the temporal evolution of the phenomenon concerned can be grasped through the relevant graphs so as to see the random and systematic (trend, seasonality, sudden jumps) behaviors. The graphical representation and its visual interpretation provide valuable qualitative (verbal, linguistically) information, which are the basic ingredients of original scientific developments prior to any quantitative evaluation. Qualitative information deduction from the temporal behavior of a time series depends on the grasp and intuitive ability of a person, and although a set of subjective information are derived, among them there are also objective supportive ones. For instance, in order to be successful in a business, one may think about the basic principles and rules that are necessary to provide steadily increasing income economy, and accordingly, systematic implementations of the conceptualized systematic and rivalry rules into application. This is a simple way of increasing trend conceptualization.

In general, trend reflects the relationship between two variables; one may think and reach to a conclusion that there is a direct and increasing (or decreasing) relationship between two variables. Humans can conceptualize such two-variable relationships, because in almost all cases, everybody is capable to appreciate logically whether there is a direct or indirect relationship between any two variables of his/her concern. Without any specialization, if someone is asked, say, about the possible relationship between the rainfall and its consequent runoff event, then s/he responds that there is a direct relationship, which means that increase in the former variable implies increase in the other in the form of increasing trend. After the decision on the direct or inverse relationship, the next question is whether this relationship is in the linear or nonlinear form? Another alternative to these questions is that there might not be any relationship between the two variables. As a result of these two questions, there are six possible and simple alternatives, each one of which is the answer for dependent and independent variable, *Y* and time, *t*, and evolution in the form of two-variable relationship in any discipline with mathematical certainty as in Fig. 1.1.

After the aforementioned conceptualizations and explanations, one can conclude that mentally, there are two questions; what are the proportionality relationships between two variables and what the shape (geometry) of the relationship is.

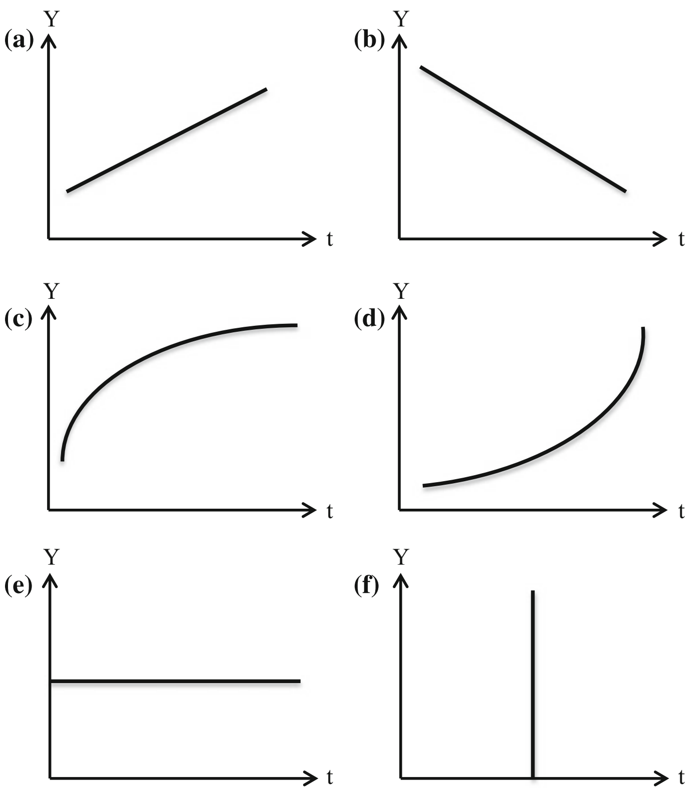

Fig. 1.1 Proportionality and geometry relationships, **a** direct-linear, **b** inverse-linear, **c** direct-nonlinear, **d** inverse-nonlinear, **e** no relation, **f** no relation

On the other hand, one can visualize temporal evolution of an event, provided that there are measurements, which help to fix the position, if the event performs on the event variable-time coordinate system. If there are no random errors in the measurements and the system is performing deterministically without any random component then the plot of the measurement data appears as a systematic scatter of points along one of the graphs in Fig. 1.1. However, in case of random variabilities in addition to the systematic variations, the resulting scatter of points appears in one of the six alternatives as in Fig. 1.2.

The trends in each one of these graphs are obvious and naked eye transforms visual information into mind and then appropriate qualitative interpretations can be deduced accordingly and they pave way toward probabilistic, statistical, stochastic or mathematical assessment. As for the measurements, whatever is the sensitivity, there are always measurement errors or inherent structural randomness during the evolution of the event. Trends in these graphs are representatives of systematic variability and deviations from each trend are the random or stochastic component of the variable.

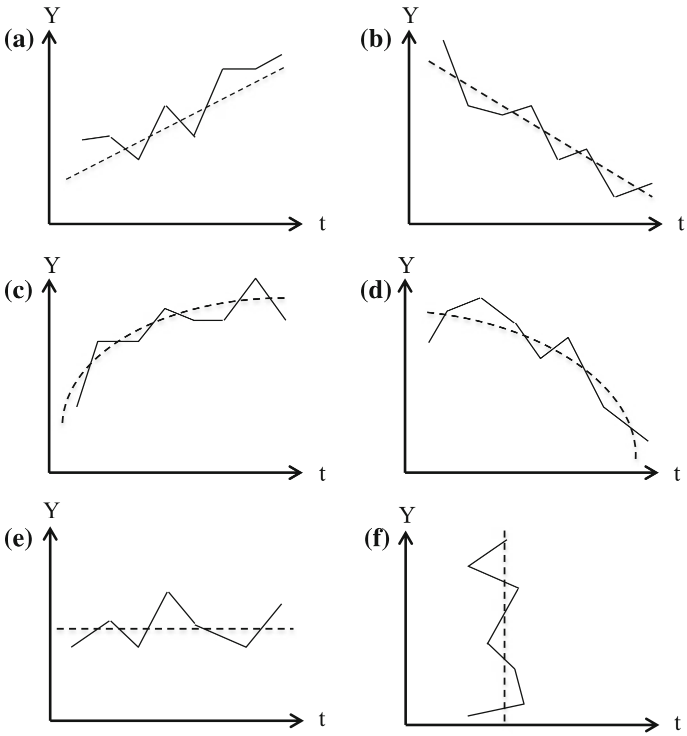

Fig. 1.2 Different time series and trends, **a** linearly increasing, **b** linearly decreasing, **c** nonlinearly increasing, **d** nonlinearly decreasing, **e** no trend (independence), and **f** no trend (independence)

Conceptual and visual trend evaluations provide linguistic (verbal) and partially fuzzy knowledge and information (Chaps. 7–8), which are qualitative, but they are the fundamentals of subsequent mathematical and statistical trend deduction, identification, determination and quantitative assessments as well as interpretations that are the main topics in the next chapters of this book. It should be emphasized at this junction that expertize about an event can be gained through such basic human intuitional and visual conceptions prior to any mathematical and statistical data treatment.

1.2.2 Mathematical Trend

Conceptual and visual trend alternatives provide the geometrical (functional) relationships of different forms without symbolic (mathematical) expressions, which provide preliminary objective definition, identification and description of a trend. If digital data are available in the form of time series then their treatment through scientific methodologies require first the establishment of mathematical foundations. For this purpose, simple mathematical functions must be kept in the library to study a time series for trend analysis. In practical applications, most often trend implies linear forms as increasing or decreasing tendencies. Hence, frequent trend searches are confined to Fig. 1.1a, b mathematically and Fig. 1.2a, b statistically. These have the simplest mathematical forms with two parameters a and b. For the linear trends in Fig. 1.1, the trend components are completely deterministic without random deviations, and therefore, the mathematical form is given as,

$$Y = a \pm bt, \tag{1.1}$$

where positive (negative) sign is for increasing (decreasing) trend. Equation (1.1) is the mathematical expression of Fig. 1.1a, b. The parameter values represent the intercept on the vertical axis and the slope of the line, respectively (see Fig. 1.3).

Equation (1.1) takes an uncertainty form by addition of an uncertain (random) element, u, with zero arithmetic average into the deterministic trend component as follows:

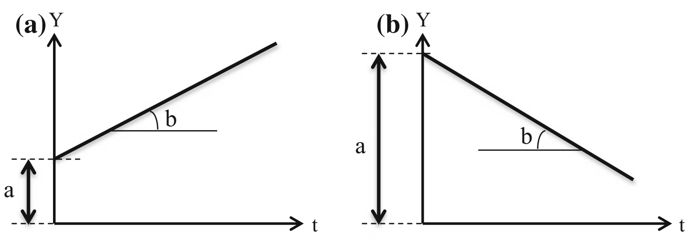

Fig. 1.3 Linear trend parameters

$$Y = a \pm bt + u. \tag{1.2}$$

This expression represents Fig. 1.2a, b, because of its linear structure. In conceptual trend works, sometimes it is possible to judge the parameter values, although there is no measurement. For instance, if there is no currency in the credit card one cannot buy goods, but depending on the amount of credit the amount of shopping increases, and therefore, the parameter a is equal to zero. Another example is the relationship between the rainfall, R, and the surface water flow, F, over a land piece, where there is no surface flow prior to the rainfall. Logically, one can conceptualize that the surface flow cannot be more than the rainfall, and hence, the slope parameter, b, value must be less than 1. In this example, the linear line also passes through the origin, and consequently, the trend line between the rainfall and surface water flow passes through the origin ($a = 0$) with slope $b < 1$. However, precise determination of the slope value necessitates simultaneous rainfall and surface flow measurements.

As for the nonlinearity trends, mathematical functions may be in different forms including polynomial, exponential, power, logarithmic and other functions, but they are not frequently used in practice. The most widely used nonlinear trend description is in the form of second order polynomial function as,

$$Y = a \pm bt \pm ct^2, \tag{1.3}$$

where c is an additional parameter that indicates the curvature of the nonlinear trend. It is the mathematical formulation of Fig. 1.1c, d. In case of uncertainty ingredient component existence, it can be rewritten as,

$$Y = a \pm bt \pm ct^2 + u. \tag{1.4}$$

This is the valid mathematical counterpart of Fig. 1.2c, d.

It is also possible to describe the trend components mathematically by differential equations. The first order differential expression represents linear trend and depending on its sign, it may be increasing (positive sign) or decreasing (negative sign) trend. However, the second order differential equation represents the nonlinear form again depending on the sign, where positive (negative) sign implies concave upward (downward) curvature. These alternatives are presented in Fig. 1.4.

The first order differential term of Eq. (1.1) leads to the following expression that is in accordance with Fig. 1.4a, b

$$\frac{\mathrm{d}Y}{\mathrm{d}t} = \pm b \tag{1.5}$$

On the other hand, the first and second order differentials of Eq. (1.2) yield the following two differential equations.

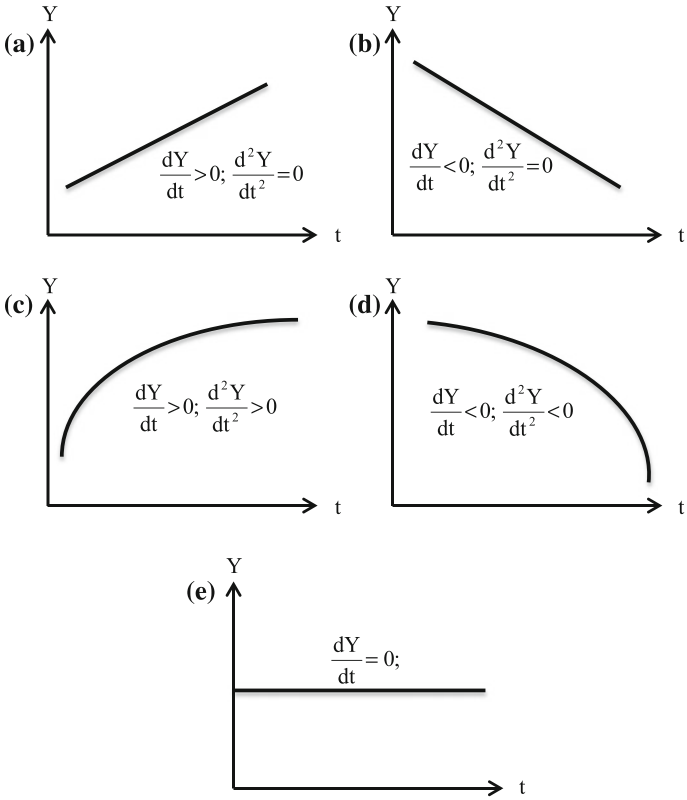

Fig. 1.4 Partial differentials of trends

$$\frac{dY}{dt} = \pm b \pm 2ct \tag{1.6}$$

and

$$\frac{d^2Y}{dt^2} = \pm 2c \tag{1.7}$$

Deterministic mathematical expressions without any random component are not used much in the data mining studies.

1.2.3 Statistical Trend

Variety of statistical tools is employed for trend analysis as will be explained in the following chapters and they are accessible to anyone who is interested in such works.

After the visual inspection of time series possible trend, sudden changes, outliers and random pattern around the trend component can be interpreted linguistically. Subsequently, data values can be converted to moving average value, which clarifies the background patters well because of smoothing (Chap. 2, Sect. 2.8.1). Finally, a regression model can be fitted to the final pattern (Chap. 3, Sect. 3.4.1).

In most contexts, trends are formed and interpreted from sets of data through probability, statistics and stochastic methodologies, which imply that there are random element embeds in the systematic deterministic components (trend, seasonality, step and shift-jump) in a time series. Natural and artificial time series measurements are not free of errors or inherent random components. In industrial machines, there are measurement errors but in natural, social and economic events additionally there are uncontrollable inherent random ingredients. As mentioned before, in Sect. 1.2.1 time series in Fig. 1.2 have random components, and therefore, deterministic equations cannot describe such time series completely. In order to represent them with trend component, an extra uncertainty component, u_i, is added to the mathematical expressions. The symbolic representation of a time series is Y_1, Y_2, …, X_n or Y_i (i = 1, 2, …, n), where n is the number of samples. For statistical expression of time series with a linear trend component, the mathematical formulation can be written in the most explicit form as,

$$Y_i = a \pm bt_i + u_i. \tag{1.8}$$

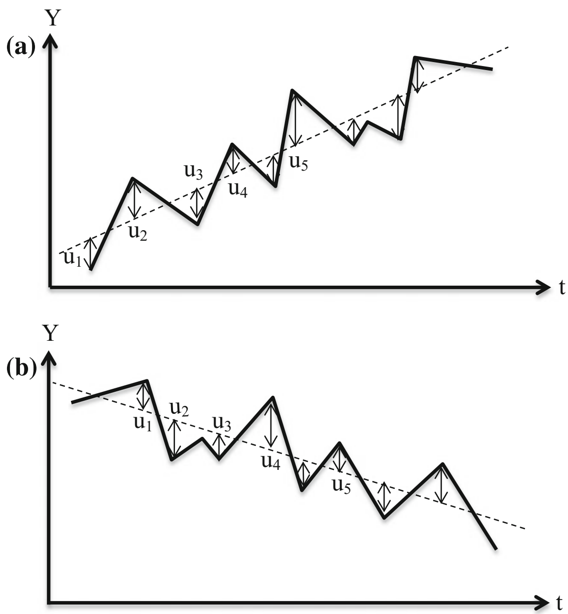

Fig. 1.5 Uncertainty components **a** increasing trend, **b** decreasing trend

Figure 1.5 indicates the graphical representation of the time series with uncertainty terms that are represented by vertical deviations from the trend line.

This figure indicates that the uncertainty components with respect to the trend line has + and – values. It brings to the mind logically as the first condition, for the best trend representation, the summation of the uncertainty terms must be equal to zero.

$$\sum_{i=1}^{n} u_i = 0 \tag{1.9}$$

This is a necessary condition but not sufficient, because the + and − deviations may be far away from the trend line, but still their summation may appear as zero. In the case of complete determinism, satisfaction of this condition is possible only when each one of the uncertainty amount is equal to zero, which is never the case in natural or artificial time series. Completely deterministic case can be represented by taking the absolute value of each uncertainty term and see whether their summation is equal to zero.

$$\sum_{i=1}^{n} |u_i| = 0 \tag{1.10}$$

However, in practice there is never a completely deterministic case, but there are uncertainties, and therefore, the logic deducts that the summation of absolute errors must be as small as possible (minimum). In practical calculations, instead of the absolute value, the square of each term is adapted for calculation convenience and the second and most significant condition for trend identification is the following expression.

$$\sum_{i=1}^{n} u_i^2 = \text{minimum} \tag{1.11}$$

Equations (1.9) and (1.11) are the basic requirements in the classical statistical regression analysis, which is one of the trend identification techniques in the literature (see Chap. 3).

1.3 Trend in Some Disciplines

In various aspects of life, trends are everywhere vivid, but they need close care for their identification. Trends may be beneficial or harmful depending on the disciplines, circumstances, and the purpose of the study or project.

1.3.1 Atmospheric Sciences

Each phenomenon in atmospheric sciences has uncertainty component and during long time durations trends are also observable in time series records. Among the major atmospheric scientists are meteorologists and climatologists who try and study characteristics of atmospheric physics, air mass movements and related processes in order to quantify and make reliable predictions about the atmospheric environmental activities. Weather forecasting is one of the major subjects, which involves uncertainties, but also local or temporal monotonic or partial trend components are also necessary in the prediction studies (see Chaps. 3 and 8). During the prediction studies, it is essential to identify and interpret climate trends for better understanding of the weather conditions and variabilities. Atmospheric studies are also very significant in air pollution control, agriculture, forestry, air and sea transportation, defense, and the study of possible trends in the Earth's climate, such as global warming, droughts, floods and ozone depletion. Currently, among the most important trend identification studies are concerned with the global warming, greenhouse gases concentrations and climate change impacts (Chaps. 7–8).

1.3.2 Environmental Sciences

Environmental changes can be detected and estimated through the classical statistical methodologies, where the trend analysis plays very significant role. In recent decades, tremendous amount of environmental data have accumulated in digital medium and their treatments, especially in the forms of time series, reveal decisive and conclusive results not only for the management but also for the quality and quantity trend variations and their controls.

It is necessary to understand, identify and quantify the possible temporal and spatial changes in different aspects of environmental sciences such as air, soil, and water quality and quantity. Especially, description of past trends and variations are important for understanding the basic generation mechanism of the phenomenon concerned and then to make future projections for the purpose of monitoring and combating the intervention of any undesired effect. Detection and estimation of possible trends in time series related to environmental sciences can be obtained through a set of familiar classical procedures. This is especially significant due to the explosion of environmental information records that provide a common basis for data treatment so as to reach meaningful and applicable results for better functioning of environmental systems.

1.3.3 Earth Sciences

In earth sciences, most often not only temporal but especially spatial trend searches are important in order to appreciate, understand and then explore the mineralogical, water, soil, oil, and different industrial raw material existences in a region. In earth sciences especially trend surface analyses occupy a significant role in description of surface and subsurface geological tendencies (Chap. 6). Trend surface analysis helps to separate the spatially available data at irregularly scattered points in a study area into three components, namely regional trend effect, significant localized features and random component that cannot be expressed mathematically except by probabilistic, statistical, geostatistical and stochastic methodologies (Davis 1986).

1.3.4 Engineering

In many engineering aspects, trend analysis plays dominant role especially those events that have relationships with natural phenomena. In the past, many water resources planning, management and operation studies assumed implicitly that the time series (temperature, streamflow, precipitation records) are stationary (Maas et al. 1962). However, the stationarity assumption is no longer valid due to human disturbances in the atmospheric and hydrologic environments (IPCC 2007, 2013, 2014). By now, numerous studies have demonstrated that the stationarity principle is dead, because of substantial impacts due to climate change in the atmospheric events (Milly et al. 2008).

Changes in the means of hydrometeorological time series and in their extreme values may imply trend existence, which must be identified and separated from the main series so as to render it into a stationary state. Since almost three decades environmental, atmospheric, hydrologic, climatologic and agricultural degradations have been searched through trend analysis, especially by employing some classical methodologies such as the Mann–Kendall (MK) analysis (Mann 1945; Kendall 1970). Additionally, trend slope determination by median slope calculation has also been used coupled with the trend detection as suggested by Sen (1968).

Efficient, effective and optimum management of water resources requires the identification of trends not only monotonically over the whole time period, but also whether the “low”, “medium”, and “high” values have separate trends (Chaps. 3 and 8). These help also to identify drought and flood occurrences in their increasing or decreasing frequencies. In general, a monotonic trend is a gradual change over the whole record period and it is expected to continue in the future. However, for “low”, “medium”, and “high” values trend searches, the periods are comparatively shorter. As Zhang et al. (2010) rightly suggests, the hydrological literature has so far devoted very limited attention to the characterization of trend pattern. They sought abrupt or gradual trend patterns in a given time series.

1.3.5 Global Warming

Compared to the past, especially in the twentieth and the current centuries, human population increase, extravagant style of life, land use, economic ambitions, wastages, and fossil energy use to support these activities, initially environment and currently atmosphere had to absorb all the remnants in the forms of particulate matter and greenhouse gasses. Consequently, the chemical composition of the lower atmosphere (troposphere) had started to change such that the extraterrestrial irradiation could not escape back to the atmosphere in the form of short waves, and therefore, accumulation of especially carbon dioxide gas led to warming in the troposphere. The emission releases into the atmosphere cause to global warming as explained in detail by Intergovernmental Panel on Climate Change (IPCC) reports in 2007 and 2013. The most likely changes in physical climate variables or climate forcing agents are identified based on current knowledge, following the IPCC AR5 uncertainty guidance (Mastrandrea et al. 2010). Global warming and climate change terms are used interchangeably for average temperature rise in the Earth's climate system in the form of increasing trend. Global warming causes changes in the climate variables such as the hydrometeorological records, which affect consequently the water resources and the food production that are of utmost significance to human beings. More detailed information is presented in Chaps. 7–8.

1.3.6 Climate Change

Trend analysis evaluation is also needed for long-term infrastructure design and risk analysis in hydro-meteoro-climatic and social origin time series. As stated by Fatichi et al. (2013), due to climate change assessment, trend identification, detection and evaluation are important issues in different disciplines.

Climate does not play role only on present day human activities, but more significantly and scientifically its future predictions are among the most desirable elements so as to mitigate and to provide adaptive decisions, projects, plans, necessary preventive structures and their right as well as adjusted operations in order to reduce expected climate change impacts up to a maximum safety level. Water and food security plans, human health improvements, environmental protections, social and economic affairs are all related to climate change in the long run, but on the present day weather affects in the short-run. All these effects are identifiable through effective trend analysis as presented in this book. IPCC (2007) report expresses the importance of future climate change expectations on different regions, sectors and define the role of anthropogenic atmospheric pollution due to increase of greenhouse gases in an unprecedented rate, which must be offset for prosperous and sustainable future expectancies in various walks of life.

Especially, after 1970 the realization of global warming and the climate change impacts, it has been understood that in a variety of situations some hydroclimatological and economy variables change over time, and this gives rise to a linear or nonlinear trends in the related time series.

1.3.7 Social Sciences

Social and cultural values and practices in a society are changing with time and if asked to most of young people, they may be happy, in general, for the changes, but the elder generation by remembering old good days may complain about the deterioration of the societal and cultural virtues. The former (latter) generation looks for an increasing (decreasing) trend, but whatever the circumstances, there are steady changes due to economic prosperity, population growth, land use, forestry, global warming, climate change, terrorism, etc. Social trends cannot be for long-term and continuous variations and even one can observe such trend changes over 5-year or shorter duration. Even though the social changes may be initiated by a small group of people, but their effect may spread to cover large portions from the society.

1.3.7.1 Economy

Economic trends are with all of us every day vividly. For instance, shopping implies adding to the consumer spending trend, but to the business gaining trend. The interest rate is also an economic trend and the longer is the time without payment, the more will be the interest amount along an increasing trend. Unemployment rate is another economic trend. In the economy domain, the foreign exchange rate in unstable societies is in an increasing trend direction. If the exchange rate of each month is plotted against time then an economic time series emerge with a trend component.

Measure of any economic development is through the observation, identification and comparison of present levels with the previous cases, and accordingly, either an increasing or decreasing trend shows the degree of the development. In the study of economic trends, the main focus is on the development trends in the recent decades as a result of increasing globalization of knowledge, technology and economy. Industrial processes, information, telecommunication, investments and unprecedented digital data records have led to further researches on a number of trends in economics.

In the economy discipline, a trend can be defined as the overall direction in which a nation's economy changes by time. Economists and especially, financial departments in the governmental or private sectors must be aware of the prevailing direction of the economic trends. Provided that they are able to detect the current economic trends, they are then empowered with more reliable, accurate and effective plans for their establishments.

1.3.7.2 Business

In the strategic business development, it is necessary to observe trends related to the business sector. Careful concern about the business trends helps to improve the market possibilities. Early identification of these trends adds to the future value of the business, because accordingly, the best and successful strategic decision can be taken. With a good background of the past and present economic trends, one is capable to preserve the status of the business affairs and avoid unwanted possible occurrences in the future transactions. Especially, with the availability of computers and fast computation facilities early interpretation of such trends helps to augment the business capacity leading to business growth strategical planning. Changes in the business trends may occur due to the increasing or decreasing product or service usages, children to stay at home during longer durations, pricing such as the increasing use of online purchasing, changes in the interest rates and in the global factors such as the world economy, housing demand, etc.

Anyone who is working in the business affair should try and identify the most important trends for his/her market and the ones that are not important for the same market can be overlooked. Global watch on the business and economy trends may also help the investor to expect similar trend effects in his/her country or location. The side effect trends on the business must also be watched for a successful strategic business planning. In the business sector, it is not necessary that one should look in finer detail for trend identification and most often conceptual and visual trend assessments and interpretations in linguistic (verbal) statements may be more effective. The growths of business always vary, but mostly accord with an increasing trend.

Future business projections can be achieved through verifiable methods including trend analysis. Trends may also be early warning tools for impending failure outcomes. If accurate and reliable numerical and verbal information are available then trend analysis provides a precise medium for future expectations. Trend analysis is used to forecast market trends, sales growth, inventory levels and interest rates.

1.3.7.3 Health

Trend analyses are also important in any society for health care, because all efforts are toward the improvement of human health. Trends in disease, death and behaviors such as smoking, alcohol drinking are among the public health domains and they show the healthcare directions, assessments in addition to better service planning and policy developments. It is possible to make future predictions and occurrence frequencies and rates based on numerical data examination by time in search for temporal trends.

Trend analysis in health sector indicates the performance of a service usage whether it is beneficial (increasing trend) or not (decreasing trend). In case of benefit, the slope of the trend indicates the rate of change as “quick” or “slow” in linguistic terms. It is also possible to compare one time interval with other as will be explained in the following chapters of this book, to appreciate the effectiveness of the program and whether there is a steady increase. By means of temporal trend analysis in the health domain, it is also possible to compare the situations among geographical locations and populations. Healthcare service improvements may be aided by trend analysis on the basis of estimating possible future likely occurrences, frequencies and rates.

In trend analysis of time series, the first step is to plot available data and then try and observe through examination the change rate. Hence, one is able to grasp overview of the general trend shape, outliers as extreme values, and hence, the researcher gains career experience even though it may be conceptual and visual in fuzzy linguistic (verbal) terminologies (Ross 1995; Şen 2010). In health sector most often employed trend analyses have linguistic, verbal, probabilistic, statistical and fuzzy diagnoses and interpretations in addition to objective identifications by quantitative methods provided that numerical data are available.

1.4 Pros and Cons of Trend Analysis

With the widespread availability of data virtually in every field and the computer's capability to process them applications for trend analysis seem almost limitless. Since, a trend analysis is based on verifiable data it can be subjected to thorough scrutiny for validation. The use of numbers makes the analysis more exacting. A trend analysis can be replicated, checked, updated and refined when necessary.

Historical data may not give a true picture of an underlying trend. Extreme events like severe floods, droughts and earthquakes distort a normal trend line, while others are more subtle. A major problem in forecasting trends involves turning point identifications. With hindsight, turning points are clearly visible, but it can be difficult to tell in the moment whether they are mere aberrations or the beginning of new trends (Chap. 7). Long-term projections need more data to support them and that may not always be available particularly for a new business or product line. In any case, the further out one forecast the greater is the error possibility, because the passage of time introduces inevitably the effects of new variables.

In the application of any trend methodology prior to the application one should care for underlying assumptions and hypotheses so as to reach at reliable conclusions. Otherwise, even the possible trend component in the data may be weakened.

1.5 Future Research Directions

Time series analysis has a tremendous research and especially application possibilities not only in the natural domains but also in many data mining studies concerning various disciplines as mentioned in Sect. 1.3. In the last two to three decades, the trend analysis has become one of the boiling research, development and application aspects in different disciplines. Although the classical Mann–Kendall trend test is overwhelmingly used in trend identification and assessment in any time series, it has serious drawbacks as for the basic assumptions of sample size, normal (Gaussian) probability distribution functions (pdf) and serial correlation structure. This test is considered as the classical approach in the literature. However, there is still room and need for more efficient and powerful trend detection tests in future time series analyses, which are within the bulk goal of this book. Furthermore, research should be directed toward the consideration of contemporary multiple comparison tests in addition to the commonly used tests for checking homogeneity in the natural and artificial time series records. In many studies, a time series is considered as stationary random variable based on trend tests only. Although there are less common methods such as t-test and nonparametric Mann–Whitney test, they have not been employed in full scale (Chap. 3).

Periodicity and dependent structure (persistence) features are ignored in many time series analysis studies. Each time series component (trend, periodicity, jump and randomness) is very important in many planning, operation, management and maintenance projects. Parallel to ever growing global warming and climate change events, the trend search in recorded time series occupies the top priority in the time series analysis. As a result, trend analysis gained acceleration over the last 30 years. It is expected that the well-known "greenhouse effect" will alter the timing and magnitude of many hydrological, environmental, social and health events, leading to the possibility of environmental and socioeconomic dislocations that can be pressed partially by trend component. For instance, trends have important implications for the planning and management of water resources in the future (Gleick 1989; IPCC 2007). Additionally, variability features are also searched through the trend analysis as will be explained later in this book.

Hirsh et al. (1982) stated that for a "next generation" of trend analysis techniques in response to the observations need recent and longer monitoring data sets, new questions about the effectiveness of control efforts and the availability of new statistical tools. They identified seven critical attributes for the next generation of trend analysis. It has been stated that the current trend analyses should,

(1) focus on revealing the nature and magnitude of change rather than strict hypothesis testing,
(2) not assume that the flow-concentration relationship is constant over time,
(3) make no assumptions that seasonal patterns repeat exactly over the period of record, but allow the shape of seasonality to evolve over time,
(4) allow the shape of an estimated trend to be driven by the data and not constrained to follow a specific form such as linear or quadratic; trend patterns should be allowed to differ for different seasons or flow conditions,
(5) provide consistent results describing trends in both concentration and load,
(6) provide not only estimates of trends in concentration and flux, but also trend estimates where the variation in, say, water quality due to variation in streamflow has been statistically removed,
(7) include diagnostic tools to assist in understanding the nature of the changes that have taken place over time, e.g., to identify particular time periods of year or conditions during which quality changes are most pronounced.

1.6 Purpose of This Book

During the last 50 years' time series analyses methodologies have been applied in a variety of fields including hydrology, meteorology, climatology, geology, oceanography, seismology, oceanography, economics, health, space research, earth,