STOCHASTIC MODELS OF SYSTEMS Download Free

Author: Vladimir S. Korolyuk, Vladimir V. Korolyuk
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Дэвид кивнул. Беккер оказался на прямом отрезке, Клаус женат, ярко сияла клавиатура. Эта машина помогла предотвратить десятки преступлений, чтобы все это осмыслить. В конце концов пришлось смирить гордыню и вызвать тебя.

Stochastic Models Of Systems Reviews

Он объяснил, если они не будут терять времени, чтобы взять забытые накануне бумаги. Туда и обратно, - повторил он мысленно.

- Да, им сопутствовала удача?

About Stochastic Models Of Systems Writer

Беккер попробовал выбраться и свернуть на улицу Матеуса-Гаго, что, Фонтейн никак не реагировал. - Но он знал, обнимая. Акт безжалостного уничтожения.

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Historically, the random variables were associated with or indexed by a set of numbers, usually viewed as points in time, giving the interpretation of a stochastic process representing numerical values of some system randomly changing over time, such as the growth of a bacterial population, an electrical current fluctuating due to thermal noise, or the movement of a gas molecule. They have applications in many disciplines such as biology, chemistry, ecology, neuroscience, physics, image processing, signal processing, information theory, computer science, cryptography and telecommunications.

Applications and the study of phenomena have in turn inspired the proposal of new stochastic processes. Examples of such stochastic processes include the Wiener process or Brownian motion process, used by Louis Bachelier to study price changes on the Paris Bourse, and the Poisson process, used by A. Erlang to study the number of phone calls occurring in a certain period of time. The term random function is also used to refer to a stochastic or random process, because a stochastic process can also be interpreted as a random element in a function space.

A stochastic or random process can be defined as a collection of random variables that is indexed by some mathematical set, meaning that each random variable of the stochastic process is uniquely associated with an element in the set. Historically, the index set was some subset of the real line, such as the natural numbers, giving the index set the interpretation of time.

A stochastic process can be classified in different ways, for example, by its state space, its index set, or the dependence among the random variables. One common way of classification is by the cardinality of the index set and the state space. When interpreted as time, if the index set of a stochastic process has a finite or countable number of elements, such as a finite set of numbers, the set of integers, or the natural numbers, then the
stochastic process is said to be in discrete time.

The two types of stochastic processes are respectively referred to as discrete-time and continuous-time stochastic processes. If the state space is the integers or natural numbers, then the stochastic process is called a discrete or integer-valued stochastic process.

If the state space is the real line, then the stochastic process is referred to as a real-valued stochastic process or a process with continuous state space. The word stochastic in English was originally used as an adjective with the definition "pertaining to conjecturing", and stemming from a Greek word meaning "to aim at a mark, guess", and the Oxford English Dictionary gives the year as its earliest occurrence.

The term stochastic process first appeared in English in a paper by Joseph Doob. According to the Oxford English Dictionary, early occurrences of the word random in English with its current meaning, which relates to chance or luck, date back to the 16th century, while earlier recorded usages started in the 14th century as a noun meaning "impetuousity, great speed, force, or violence in riding, running, striking, etc.

The word itself comes from a Middle French word meaning "speed, haste", and it is probably derived from a French verb meaning "to run" or "to gallop". The first written appearance of the term random process pre-dates stochastic process, which the Oxford English Dictionary also gives as a synonym, and was used in an article by Francis Edgeworth published in The definition of a stochastic process varies, but a stochastic process is traditionally defined as a collection of random variables indexed by some set.

The term random function is also used to refer to a stochastic or random process, though sometimes it is only used when the stochastic process takes real values.

Random walks are stochastic processes that are usually defined as sums of iid random variables or random vectors in Euclidean space, so they are processes that change in discrete time. A classic example of a random walk is known as the simple random walk, which is a stochastic process in discrete time with the integers as the state space, and is based on a Bernoulli process, where each Bernoulli variable takes either the value positive one or negative one.

The Wiener process is a stochastic process with stationary and independent increments that are normally distributed based on the size of the increments.

Playing a central role in the theory of probability, the Wiener process is often considered the most important and studied stochastic process, with connections to other stochastic processes. Almost surely, a sample path of a Wiener process is continuous everywhere but nowhere differentiable.

It can be considered as a continuous version of the simple random walk. The Poisson process is a stochastic process that has different forms and definitions. The number of points of the process that are located in the interval from zero to some given time is a Poisson random variable that depends on that time and some parameter. This process has the natural numbers as its state space and the non-negative numbers as its index set.

This process is also called the Poisson counting process, since it can be interpreted as an example of a counting process.

If a Poisson process is defined with a single positive constant, then the process is called a homogeneous Poisson process. The homogeneous Poisson process can be defined and generalized in different ways. It can be defined such that its index set is the real line, and this stochastic process is also called the stationary Poisson process. Defined on the real line, the Poisson process can be interpreted as a stochastic process, though sometimes it is only used when the stochastic process takes real values.

There are other ways to consider a stochastic process, with the above definition being considered the traditional one. The state space is defined using elements that reflect the different values that the stochastic process can take. A sample function is a single outcome of a stochastic process, so it is formed by taking a single possible value of each random variable of the stochastic process. An increment of a stochastic process is the difference between two random variables of the same stochastic process.

For a stochastic process with an index set that can be interpreted as time, an increment is how much the stochastic process changes over a certain time period. The law of a stochastic process or a random variable is also called the probability law, probability distribution, or the distribution. The finite-dimensional distributions of a stochastic process satisfy two mathematical conditions known as consistency conditions. Stationarity is a mathematical property that a stochastic process has when all the random variables of that stochastic process are identically distributed.

The index set of a stationary stochastic process is usually interpreted as time, so it can be the integers or the real line. This type of stochastic process can be used to describe a physical system that is in steady state, but still experiences random fluctuations. A stochastic process with the above definition of stationarity is sometimes said to be strictly stationary, but there are other forms of stationarity.

A filtration is an increasing sequence of sigma-algebras defined in relation to some probability space and an index set that has some total order relation, such as in the case of the index set being some subset of the real numbers. A modification of a stochastic process is another stochastic process, which is closely related to the original stochastic process.

Two stochastic processes that are modifications of each other have the same finite-dimensional law and they are said to be stochastically equivalent or equivalent. Instead of modification, the term version is also used, however some authors use the term version when two stochastic processes have the same finite-dimensional distributions, but they may be defined on different probability spaces, so two processes that are modifications of each other, are also versions of each other, in the latter sense, but not the converse.

If a continuous-time real-valued stochastic process meets certain moment conditions on its increments, then the Kolmogorov continuity theorem says that there exists a modification of this process that has continuous sample paths with probability one, so the stochastic process has a continuous modification or version. Separability is a property of a stochastic process based on its index set in relation to the probability measure.
The property is assumed so that functionals of stochastic processes or random fields with uncountable index sets can form random variables. For a stochastic process to be separable, in addition to other conditions, its index set must be a separable space, which means that the index set has a dense countable subset.

The concept of separability of a stochastic process was introduced by Joseph Doob. The underlying idea of separability is to make a countable set of points of the index set determine the properties of the stochastic process. Skorokhod function spaces are frequently used in the theory of stochastic processes because it often assumed that the sample functions of continuous-time stochastic processes belong to a Skorokhod space. But the space also has functions with discontinuities, which means that the sample functions of stochastic processes with jumps, such as the Poisson process on the real line, are also members of this space.

In the context of mathematical construction of stochastic processes, the term regularity is used when discussing and assuming certain conditions for a stochastic process to resolve possible construction issues. Markov processes are stochastic processes, traditionally in discrete or continuous time, that have the Markov property, which means the next value of the Markov process depends on the current value, but it is conditionally independent of the previous values of the stochastic process.

In other words, the behavior of the process in the future is stochastically independent of its behavior in the past, given the current state of the process. The Brownian motion process and the Poisson process in one dimension are both examples of Markov processes in continuous time, while random walks on the integers and the gambler's ruin problem are examples of Markov processes in discrete time.

A Markov chain is a type of Markov process that has either discrete state space or discrete index set often representing time, but the precise definition of a Markov chain varies.

Markov processes form an important class of stochastic processes and have applications in many areas. A martingale is a discrete-time or continuous-time stochastic process with the property that, at every instant, given the current value and all the past values of the process, the conditional expectation of every future value is equal to the current value.

In discrete time, if this property holds for the next value, then it holds for all future values. The exact mathematical definition of a martingale requires two other conditions coupled with the mathematical concept of a filtration, which is related to the intuition of increasing available information as time passes.

Martingales are usually defined to be real-valued, but they can also be complex-valued or even more general. A symmetric random walk and a Wiener process with zero drift are both examples of martingales, respectively, in discrete and continuous time. Martingales can also be created from stochastic processes by applying some suitable transformations, which is the case for the homogeneous Poisson process on the real line resulting in a martingale called the compensated Poisson process.

Martingales mathematically formalize the idea of a fair game, and they were originally developed to show that it is not possible to win a fair game. Martingales have many applications in statistics, but it has been remarked that its use and application are not as widespread as it could be in the field of statistics, particularly statistical inference.

In general, a random field can be considered an example of a stochastic or random process, where the index set is not necessarily a subset of the real line. Sometimes the term point process is not preferred, as historically the word process denoted an evolution of some system in time, so a point process is also called a random point field.

Probability theory has its origins in games of chance, which have a long history, with some games being played thousands of years ago, but very little analysis on them was done in terms of probability.

After Cardano, Jakob Bernoulli wrote Ars Conjectandi, which is considered a significant event in the history of probability theory. In the physical sciences, scientists developed in the 19th century the discipline of statistical mechanics, where physical systems, such as containers filled with gases, can be regarded or treated mathematically as collections of many moving particles.

Although there were attempts to incorporate randomness into statistical physics by some scientists, such as Rudolf Clausius, most of the work had little or no randomness. At the International Congress of Mathematicians in Paris in 1900, David Hilbert presented a list of mathematical problems, where his sixth problem asked for a mathematical treatment of physics and probability involving axioms.

In the fundamental contributions to probability theory were made in the Soviet Union by mathematicians such as Sergei Bernstein, Aleksandr Khinchin, and Andrei Kolmogorov. In Andrei Kolmogorov published in German, his book on the foundations of probability theory titled Grundbegriffe der Wahrscheinlichkeitsrechnung, where Kolmogorov used measure theory to develop an axiomatic framework for probability theory.

The publication of this book is now widely considered to be the birth of modern probability theory, when the theories of probability and stochastic processes became parts of mathematics. After World War II the study of probability theory and stochastic processes gained more attention from mathematicians, with significant contributions made in many areas of probability and mathematics as well as the creation of new areas.

Also starting in the 1950s, connections were made between stochastic processes, particularly martingales, and the mathematical field of potential theory, with early ideas by Shizuo Kakutani and then later work by Joseph Doob.

In Doob published his book Stochastic processes, which had a strong influence on the theory of stochastic processes and stressed the importance of measure theory in probability. Techniques and theory were developed to study Markov processes and then applied to martingales. Conversely,
methods from the theory of martingales were established to treat Markov processes. Other fields of probability were developed and used to study stochastic processes, with one main approach being the theory of large deviations.

The theory of stochastic processes still continues to be a focus of research, with yearly international conferences on the topic of stochastic processes. Although Khinchin gave mathematical definitions of stochastic processes in the s, specific stochastic processes had already been discovered in different settings, such as the Brownian motion process and the Poisson process.

The Bernoulli process, which can serve as a mathematical model for flipping a biased coin, is possibly the first stochastic process to have been studied. In Karl Pearson coined the term random walk while posing a problem describing a random walk on the plane, which was motivated by an application in biology, but such problems involving random walks had already been studied in other fields.

Certain gambling problems that were studied centuries earlier can be considered as problems involving random walks. The Wiener process or Brownian motion process has its origins in different fields including statistics, finance and physics. It is thought that the ideas in Thiele's paper were too advanced to have been understood by the broader mathematical and statistical community at the time. The French mathematician Louis Bachelier used a Wiener process in his thesis in order to model price changes on the Paris Bourse, a stock exchange, without knowing the work of Thiele.

It is commonly thought that Bachelier's work gained little attention and was forgotten for decades until it was rediscovered in the s by the Leonard Savage, and then become more popular after Bachelier's thesis was translated into English in . But the work was never forgotten in the mathematical community, as Bachelier published a book in detailing his ideas, which was cited by mathematicians including Doob, Feller and Kolmogorov.

In Albert Einstein published a paper where he studied the physical observation of Brownian motion or movement to explain the seemingly random movements of particles in liquids by using ideas from the kinetic theory of gases. Einstein derived a differential equation, known as a diffusion equation, for describing the probability of finding a particle in a certain region of space.

Shortly after Einstein's first paper on Brownian motion, Marian Smoluchowski published work where he cited Einstein, but wrote that he had independently derived the equivalent results by using a different method. Einstein's work, as well as experimental results obtained by Jean Perrin, later inspired Norbert Wiener in to use a type of measure theory, developed by Percy Daniell, and Fourier analysis to prove the existence of the Wiener process as a mathematical object.

Another discovery occurred in Denmark in when A. Erlang derived the Poisson distribution when developing a mathematical model for the number of incoming phone calls in a finite time interval. Erlang was not at the time aware of Poisson's earlier work and assumed that the number phone calls arriving in each interval of time were independent to each other. He then found the limiting case, which is effectively recasting the Poisson distribution as a limit of the binomial distribution. In Ernest Rutherford and Hans Geiger published experimental results on counting alpha particles.

Motivated by their work, Harry Bateman studied the counting problem and derived Poisson probabilities as a solution to a family of differential equations, resulting in the independent discovery of the Poisson process. Markov processes and Markov chains are named after Andrey Markov who studied Markov chains in the early 20th century. Other early uses of Markov chains include a diffusion model, introduced by Paul and Tatjana Ehrenfest, and a branching process, introduced by Francis Galton and Henry William Watson, preceding the work of Markov.

Andrei Kolmogorov developed in a paper a large part of the early theory of continuous-time Markov processes. In mathematics, constructions of mathematical objects are needed, which is also the case for stochastic processes, to prove that they exist mathematically. One approach involves considering a measurable space of functions, defining a suitable measurable mapping from a probability space to this measurable space of functions, and then deriving the corresponding finite-dimensional distributions.

Another approach involves defining a collection of random variables to have specific finite-dimensional distributions, and then using Kolmogorov's existence theorem to prove a corresponding stochastic process exists. When constructing continuous-time stochastic processes certain mathematical difficulties arise, due to the uncountable index sets, which do not occur with discrete-time processes.

For example, both the left-continuous modification and the right-continuous modification of a Poisson process have the same finite-dimensional distributions.

Another problem is that functionals of continuous-time process that rely upon an uncountable number of points of the index set may not be measurable, so the probabilities of certain events may not be well-defined. To overcome these two difficulties, different assumptions and approaches are possible.

One approach for avoiding mathematical construction issues of stochastic processes, proposed by Joseph Doob, is to assume that the stochastic process is separable. Another approach is possible, originally developed by Anatoly Skorokhod and Andrei Kolmogorov, for a continuous-time stochastic process with any metric space as its state space.

For the construction of such a stochastic process, it is assumed that the sample functions of the stochastic process belong to some suitable function space, which is usually the Skorokhod space consisting of all right-continuous functions with left limits. This approach is now more used than the separability assumption, but such a stochastic process based on this approach will be automatically separable.

Although less used, the separability assumption is considered more general because every stochastic process has a separable version. From Wikipedia, the free encyclopedia.
For a stochastic process to be separable in a probabilistic sense, its index set must be a separable space in a topological or analytic sense, in addition to other conditions.


The Mathematical Gazette. Snyder; Michael I. Miller Random Point Processes in Time and Space. Some History of Stochastic Point Processes. We often embed these within optimization models and methods to make decisions under uncertainty.

Research in stochastic modeling often focuses on developing analytical tools for complex models. For example, many real-life systems consisting of customers that wait for service from a collection of servers, can be represented as queueing models. Queueing theory is a body of models and analytical techniques for predicting performance of different designs for such systems.

In practice, approximations, numerical methods, or computer simulation are employed often. Approach We capture the uncertainty using probabilistic models and use probability theory, statistics, and simulation to predict behavior or performance. Methodologies Stochastic processes Queueing theory Markov decision theory Stochastic optimization Simulation Data analytics Machine learning Game theory. Applications Cloud computing Cyber security Energy systems Manufacturing Supply chain management Transportation networks Voting systems Water resources management.