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TIME SERIES ANALYSIS AND FORECASTING EXPLAINED

Explore time series analysis methods and examples. Learn how to analyze time series data to uncover trends, patterns and insights from time-based data sets.

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OVERVIEW

Time series analysis is a technique that measures a variable at regular time intervals, allowing you to observe and analyze the characteristics of that data. You can use it to track metrics over time and analyze historical data for trends, which makes it an indispensable tool in a number of different use cases. It sees extensive use in many industries, in particular those which collect large amounts of data, such as healthcare, finance, technology and logistics.

By identifying historical trends and correlations, analysts can use time series analysis to make educated predictions about things like product demand or computational needs. The growth in data collection, processing and storage in nearly every sector of the economy has increased the power of this technique, as has the introduction of machine learning and AI. In this article, we'll explore the details of time series analysis, what makes it useful and how you can use it to improve business outcomes.

WHAT IS TIME SERIES ANALYSIS?

Time series analysis sounds deceptively simple, and that belies its flexibility and potential complexity. All time series data is presented as an ordered collection of data captured over time at evenly spaced intervals. One example is the number of newsletter signups a business receives each month over the period of a year. It can be especially powerful when applied to historical data, as extending the time scale of the series allows you to observe long-term trends and, for example, pinpoint the impact of changing economic headwinds, public policy shifts or supply chain disruptions.

The defining characteristic of this technique, as you might expect, is the constant drumbeat of time, in contrast to techniques like regression analysis, which examines the relationship between variables, or cross-section analysis, which looks at various types of data at a single moment in time.

COMPONENTS OF TIME SERIES DATA

The data you use to create the time series may exhibit certain characteristics, which can be broken down into the following elements:

Trend

The trend describes the direction in which the metric is going, if any. To continue our previous example, you might find that your newsletter signups are growing month over month, which would mean the trend in signups is increasing.

Seasonality

Seasonality describes a recurring pattern in the data that happens on some cycle, typically tied to a predictable and consistent event. One of the most common examples is the increase in consumer spending around the holiday season, but a more granular example might be the sudden increase in apartments available for rent on the 1st and 15th day of each month.

Cyclic patterns

Cycles describe long-term patterns that aren't defined by a particular season or event. Cycles often refer to economic expansion and contraction, which tends to happen over long periods of time and isn't tied to one event or occurrence. Examples would be the reduction in spending on enterprise software during a recession and the inverse during a period of economic growth.

Irregular or random noise

Noise describes data points that cannot be explained by any of the other elements, such as a technical issue that causes a deviation from the norm, a one-off occurrence or some other undefined event. Sensor errors in machine equipment or small fluctuations in stock prices from minute to minute are good examples of noise.

TYPES OF TIME SERIES DATA

Time series data can be classified into various types, based on the number of variables, the way the data is being collected or other statistical information about the time series. Here are three major categorization methods for time series data.

Univariate vs. multivariate time series

A univariate time series tracks a single metric at set intervals. A common example would be beats per minute (BPM), which is the standard measure of a person's heart rate. A multivariate time series uses the same interval but tracks multiple metrics over the period. For example, a hospital might collect and track a patient's heart rate and blood oxygen level at the same time, as combining them gives a more complete view of circulatory health.

Regular vs. irregular time intervals

Regular intervals are a value recorded at a consistent time cadence; for example, the temperature in a room recorded once every minute. An irregular time interval records discrete events as they happen, such as tracking each time a cloud service processes a request, which may cluster multiple times in a small window or not at all.

Stationary vs. non-stationary time series

Time series forecasting models rely on stationary data, wherein the data range is predictable over time and does not vary from its statistical properties like mean and variance. Non-stationary data changes, often with seasonality or due to some other volatility. Stationary series are more reliable and easier to analyze than non-stationary ones, though statistical techniques like differencing can make non-stationary data stable enough for forecasting.

WHY SHOULD YOU USE TIME SERIES DATA ANALYSIS?

You can use time series in a wide range of different capacities, some focused on risk mitigation and service uptime, and others dedicated to the deep analysis of historical data in order to uncover useful patterns.

Some of the more straightforward use cases focus on setting a baseline for an activity, which could be anything from IT service latency to the number of engagements your marketing efforts earn each day. A time series would allow you to monitor these cases for anomalous behavior. For example, an aberrant latency spike might mean some network maintenance is necessary, while a sudden increase in marketing engagement could provide valuable insights about what messaging is performing best.

You can also use time series to make informed decisions. A popular example of this is used in inventory management. By analyzing historical increases and decreases in customer demand, you can optimize your supply chain and production schedule to ensure that your products and services can scale up to meet demand and scale down to maximize cost savings.

TIME SERIES ANALYSIS METHODS AND TECHNIQUES

You can use a number of different methods to draw useful insights from a time series analysis. Which method you choose will depend on the properties of the time series and the availability of historical data. Here are some of the most popular time series analysis methods.

Moving averages and exponential smoothing

These methods both use averages of historical data to reduce the impact of fluctuations in a metric. By removing noise and other aberrant changes, a moving average can help you uncover a general trend in data over time. The moving average of a stock price will capture the overall trajectory of that price over a set period of time rather than unpredictable changes up or down. Exponential smoothing is a technique which favors recent data over older data. This provides you with an average that incorporates recent changes and can forecast a trend that reflects the current state of the data.

ARIMA and SARIMA models

Autoregressive integrated moving average (ARIMA) combines three techniques, autoregression, differencing and a moving average, to forecast future variables. By combining these tactics, ARIMA can use a non-stationary time series to provide accurate predictions, estimating the way the variable will change based on the moving average of historical data. SARIMA (seasonal autoregressive integrated moving average) accounts for seasonal changes in the data, allowing you to forecast using data that shows seasonality.

Machine learning for time series forecasting

Many organizations incorporate ML techniques like recurrent neural networks or decision tree models into their analysis process, as these models can generate more accurate forecasts and ingest much larger volumes of data.

They can also automate the time- and labor-intensive aspects of analysis, increasing organizational efficiency.

TIME SERIES ANALYSIS CHECKLIST

Even with powerful machine learning tools, successfully implementing a time series analysis means careful consideration of the goals and limitations of your project. Here are the five steps to take when embarking on a new time series analysis project.

1. Define the objective

Having a clear idea of what you are hoping to learn is important not only for assessing success but also understanding the limitations of your data set.

2. Prepare and clean the data

Once your goal is clear, gather a data set and use smoothing techniques to clean it, addressing outliers, missing data values and any other problems in the data set.

3. Visualize and explore patterns

Visualizing the data in graphical form helps you detect any common patterns, such as seasonality or general trends. Using an autocorrelation function (ACF) can help you determine if the data set is stationary or not.

4. Choose the right method

Depending on the data and your goal, you might choose to apply ARIMA or SARIMA to data sets where seasonality is relevant to your particular goal. For larger data sets or more complex data analysis, you might need to use an ML or deep learning technique to get results.

5. Validate and interpret results

Numerous techniques allow you to validate whether your results are accurate, typically involving the comparison of the output of the forecast with real-life outcomes as they happen. Once you have validated that your model is accurately predicting future results, you can use the forecast to make decisions about your objectives outlined in step No. 1. For example, predicting how consumer demand might change over the next six months.

EXAMPLES AND USE CASES FOR TIME SERIES ANALYSIS

Every sector of the modern economy uses some form of data analysis to inform their decision-making. Here are some of the most common industrial use cases for time series analysis:

Retail and ecommerce

Time series analysis sees significant use in retail contexts, both for tracking customer interest and purchasing activity and for ensuring service uptime. On the forecasting side, many organizations incorporate time series analysis into their supply chain management decisions, using historical data to work around possible supply disruptions and to plan inventory levels for upcoming sales promotions.

Healthcare and life sciences

Healthcare and wellness organizations use time series analysis extensively, as it can apply to everything from EKG machines to wearable technology. It also sees usage in scientific research, where researchers may use it to analyze large data sets from a region or fixed population, such as the testing of wastewater for increases in certain viruses.

Marketing and customer analytics

Time series analysis can be a critical tool for tracking the performance of different kinds of marketing campaigns. This allows you, for example, to establish a baseline of how many new customers you get each week, which can be used as a baseline to measure the impact of new messaging, ads or other marketing efforts.

BENEFITS OF TIME SERIES ANALYSIS FOR BUSINESS SUCCESS

Time series analysis is popular across many industries because it allows organizations to better understand the past, plan for the future, adjust to changing market conditions and improve product performance, all based on historical data. Here are some key benefits in more detail:

1. Improved forecasting accuracy

The structure of the time series method requires extensive data cleansing and stability checks, which is part of what makes it such a useful model for forecasting. By accounting for noise, missing variables and other potential outliers and testing predictions against out-of-sample observations, you can create and improve on your forecasting capabilities.

2. Better resource planning

By giving you an accurate forecast of changes in consumer demand, supply chain costs and inefficiencies or the computational demands of IT systems, time series analysis can help you minimize waste without cutting into product performance and uptime.

3. Real-time performance monitoring

In addition to powerful forecasting potential, you can use time series analysis for real-time applications, allowing you to rapidly detect issues like latency spikes, sudden increases in demand or other changes.

CHALLENGES OF TIME SERIES ANALYSIS

Time series analysis is just one tool in the data analysis toolbox, and as such, it may not be the perfect method for every single use case. Additionally, its usefulness relies on having quality data that can be successfully processed for reliability, which might not always be available. Here are some of the most common challenges with the discipline.

Data quality and missing values

No matter how well thought-out your approach is, if your data is inconsistent or has a large number of missing values, this will greatly reduce the accuracy and usefulness of your time series model.

Non-stationarity and complex patterns

While you can make data sets stationary with techniques like differencing, this can create new issues like noise. Time series analysis models can sometimes struggle with complex data — for example, a metric with multiple seasonal patterns, changing based on the hour, day of the week and month. This complexity can make it difficult to make the data stationary and produce an accurate forecast.

Scalability and real-time processing limitations

Because time series forecasting depends on historical data, it can be cumbersome to fit, test and run time series models using large data sets. This can mean your operations hit architectural limits or become costly to run as the data set grows in size.

CONCLUSION

Time series analysis is one of the most valuable analytic techniques available to the enterprise, one that allows you to make informed choices based on accurate forecasts and identify opportunities for structural efficiency and improvement. The growth and power of ML and AI tools have made this method more efficient and accessible, allowing even non-technical teams to build models to measure performance and improve forecasting. It should be no surprise that time series analysis remains one of the primary analytical methods used by modern analytics platforms.

TIME SERIES ANALYSIS FAQS

Here are some of the most common questions people have about time series analysis.

- **What is the difference between time series analysis and time series forecasting?**
- **What is a time series model of forecasting?**
- **What are the limitations of time series analysis?**

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