Introductory Time Series Analysis

Understanding trend, seasonality, noise & decomposition

Name: _____ **Roll No:** _____

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1. What is a Time Series?

Idea in one line

A **time series** is a list of measurements recorded *in order over time* (the *time index* matters).

Tiny example

A lemonade stand records cups sold each hour:

$$12,\ 15,\ 14,\ 22,\ 20,\ 18, \ldots$$

This ordered list is a time series.

> **Why order matters:** The value at time t can depend on earlier times (tomorrow's sales depend on today's). Shuffling destroys that relationship.

Q1. In 1–2 sentences, explain why shuffling the lemonade sales would change what the data tells you.

Q2. Which of these is a time series? Circle the best answer.

(a) Heights of 50 students (measured once).

(b) Daily high temperature for the past month.

(c) A bag of 100 random numbers generated now.

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2. Time Index & Frequency

Concept

The **time index** tells *when* each observation happened. The **frequency** is how often we record (e.g., hourly, daily, monthly).

Real-world note

Frequency decides what patterns you can see: hourly data can reveal daily cycles; yearly data may hide them.

Q3. If a weather station logs temperature every 10 minutes, what is the frequency? Give one activity that would benefit from that frequency.

Q4. A store reports monthly revenue. Suggest one analysis that is *not* appropriate with this frequency (briefly explain why).

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3. Trend

Concept

A **trend** is a long-term increase or decrease. It is the slow drift you see when you smooth the series.

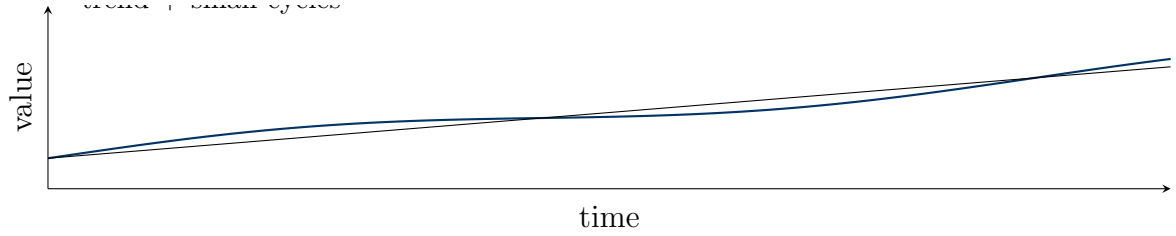

Figure 1: Example: a slowly rising trend (black) with small oscillations.

Q5. List two possible real-world causes of an upward trend in sales over years.

Q6. Sketch (with words or a tiny doodle) what the *trend component* might look like for monthly CO_2 levels that are steadily increasing.

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4. Seasonality

Concept

Seasonality is a repeating pattern with a fixed period (e.g., weekly, yearly). It is the predictable wobble that repeats.

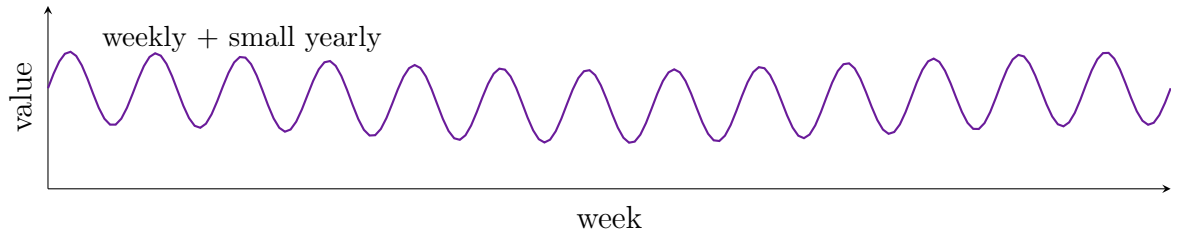

Figure 2: Example: strong weekly seasonality (period = 4 in this toy example) plus a small yearly cycle.

Q7. A coffee shop is busiest each weekday morning and quiet at night. What is the likely seasonality frequency? Explain in one sentence.

Q8. Give one example each of daily, weekly, and yearly seasonality (real-life signals).

5. Noise (Irregular Component)

Concept

Noise is unpredictable variation that is not trend or seasonality. It is often called the residual.

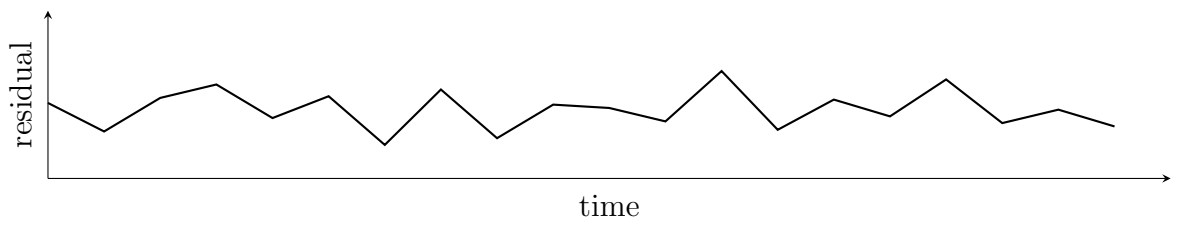

Figure 3: Example: random residuals (noise).

Q9. A sudden one-day spike appears in temperature because of a heatwave. Is this noise or seasonality? Briefly justify.

Q10. Why is reducing noise often helpful before trying to detect trend or seasonality?

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6. Decomposition (Trend + Seasonality + Noise)

Formula

A common additive view is:

$$\text{Series}_t = T_t + S_t + R_t$$

where T is trend, S is seasonality, R is residual/noise.

Decomposition exposes each component so you can model them separately. Some methods (like STL) estimate trend and seasonality robustly even when they change slowly over time.

Q11. If a decomposition shows a nearly-flat trend but very large seasonal swings, what does that tell you about long-term change versus short-term cycles?

Q12. Name one practical advantage of removing seasonality before forecasting.

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7. Identifying Trend / Seasonality / Noise

Quick checklist

- **Trend:** smooth long-run movement — try a rolling average.
- **Seasonality:** repeating cycle — examine autocorrelation or seasonal plots.
- **Noise:** what remains — examine residuals after removing trend and seasonality.

> Plotting the data at different zoom levels (full series, one-year window, one-week window) often makes components pop out.

Q13. For each short description indicate the likely composition (T = trend, S = seasonality, N = noise). Pick combinations as needed.

(a) Bike rentals increase over five years, and every weekend rentals are higher. _____

(b) A sensor lying on a bench shows small random fluctuation around 0. _____

(c) Monthly subscription revenue rises slowly with occasional promotional spikes in January. _____

Q14. Suppose autocorrelation of a series shows large spikes at lag 1 and lag 7 (daily data). What might this suggest about the series (short answer)?

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8. Visualization Practice

Q15. You are given daily sales for two years. Describe (one sentence each) two plots you would draw to help detect: (i) a trend and (ii) weekly seasonality.

Q16. A decomposition residual plot shows very wide spikes on a few dates. What would you check next to interpret those spikes? (two quick actions)

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9. Progressive (Fun) Challenges

Q17. (Easy) A series spikes every 24 points exactly. Is this seasonality? If yes, what is the period?

Q18. (Medium) A series shows a rising trend until month 30 and then flattens. Propose one model strategy you might try for forecasting (short answer).

Q19. (Hard-ish) You detrend a series and see a repeating pattern that slowly changes amplitude over years. Which decomposition approach (additive or multiplicative) might be better and why?

Q20. (Creative) Invent a short real-world story (2–3 lines) for a time series that has a *decreasing trend*, strong *yearly seasonality*, and occasional *large noise spikes*. (Make it playful!)

Conceptual Question

1. What is the difference between seasonality and a general cyclic pattern?

Nice work — you've reviewed the essentials of time series: time index, frequency, trend, seasonality, noise, decomposition, and practical visualization checks.