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Welcome to this session

Skills Bootcamp:

Counterfactual Analysis

The session will start shortly...

Questions? Drop them in the chat.
We'll have dedicated moderators answering questions.

Skills Bootcamp Data Science Housekeeping

- The use of disrespectful language is prohibited in the questions, this is a supportive, learning environment for all - please engage accordingly. **(Fundamental British Values: Mutual Respect and Tolerance)**
- No question is daft or silly - **ask them!**
- There are **Q&A sessions** midway and at the end of the session, should you wish to ask any follow-up questions. We will be answering questions as the session progresses as well.
- If you have any questions outside of this lecture, or that are not answered during this lecture, please do submit these for upcoming Academic Sessions. You can submit these questions here: **Questions**

Skills Bootcamp Data Science Housekeeping

- For all **non-academic questions**, please submit a query: ***www.hyperiondev.com/support***
- **Report a safeguarding incident: *www.hyperiondev.com/safeguardreporting***
- We would love your feedback on lectures: ***Feedback on Lectures.***
- Find all the lecture **content** in your **Lecture Backpack** on GitHub.
- If you are hearing impaired, kindly use your computer's function through Google chrome to enable captions.

Safeguarding & Welfare

We are committed to all our students and staff feeling safe and happy; we want to make sure there is always someone you can turn to if you are worried about anything.

If you are feeling upset or unsafe, are worried about a friend, student or family member, or you feel like something isn't right, speak to our safeguarding team:

Ian Wyles
Designated Safeguarding Lead

Simone Botes

Nurhaan Snyman

Rafiq Manan

Ronald Munodawafa

Tevin Pitts

Scan to report a safeguarding concern

or email the Designated Safeguarding Lead:
Ian Wyles
safeguarding@hyperiondev.com

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Skills Bootcamp Progression Overview

✅ Criterion 1 - Initial Requirements

Specific achievements within the first two weeks of the program.

To meet this criterion, students need to, by no later than **01 December 2024 (C11)** or **22 December 2024 (C12):**

- **Guided Learning Hours** (GLH)**:** Attend a minimum of 7-8 GLH per week (lectures, workshops, or mentor calls) for a total minimum of **15 GLH**.
- **Task Completion:** Successfully complete the **first 4 of the assigned tasks**.

✅ Criterion 2 - Mid-Course Progress

Progress through the successful completion of tasks within the first half of the program.

To meet this criterion, students should, by no later than **12 January 2025 (C11)** or **02 February 2025 (C12):**

- **Guided Learning Hours** (GLH)**:** Complete at least **60 GLH**.
- **Task Completion :** Successfully complete the **first 13 of the assigned tasks**.

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Skills Bootcamp Progression Overview

✅ Criterion 3 – End-Course Progress

Showcasing students' progress nearing the completion of the course.

To meet this criterion, students should:

- **Guided Learning Hours** (GLH)**:** Complete the **total minimum required GLH,** by the **support end date.**
- **Task Completion : Complete all mandatory tasks**, including any necessary resubmissions, by the end of the bootcamp, **09 March 2025 (C11)** or **30 March 2025 (C12).**

✅ Criterion 4 - Employability

Demonstrating progress to find employment.

To meet this criterion, students should:

- **Record an Interview Invite:** Students are required to record proof of invitation to an interview by **30 March 2025 (C11)** or **04 May 2025 (C12)**.
  - **South Holland Students** are required to proof and interview by **17 March 2025.**
- **Record a Final Job Outcome :** Within 12 weeks post-graduation, students are required to record a job outcome.

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Question

- **If a soccer team loses 2-1, how can we estimate what would have happened if they had used a different strategy?**
  - How do we separate luck from skill when analysing the game?

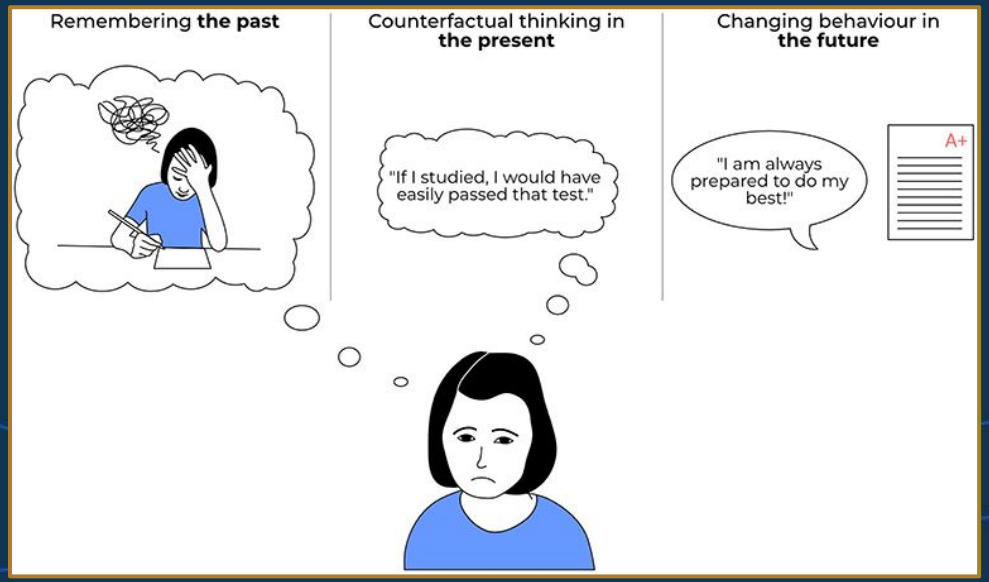
Learning Outcomes

- Define and Explain Counterfactual Reasoning
- Apply Counterfactual Algorithms to Real-World Scenarios
- Evaluate the Impact of Counterfactual Analysis on Policy and Business Decisions
- Identify and Address Ethical Concerns in Counterfactual Modeling
- Formulate and Communicate Counterfactual Insights Effectively

Lecture Overview

- ➔ Introduction to Counterfactuals
- ➔ Counterfactual Algorithms & Techniques
- ➔ Real-World Applications of Counterfactual Analysis
- ➔ Ethical Considerations in Counterfactual Analysis
- ➔ Discussion, Q&A, and Conclusion

Introduction to Counterfactual Analysis



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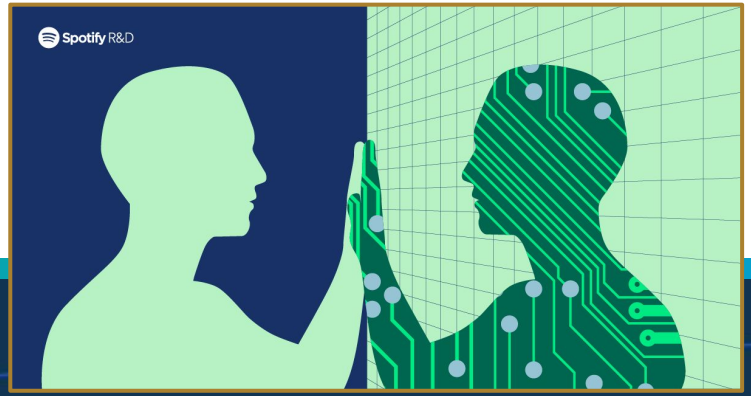
Definition

- Counterfactual analysis is the study of hypothetical alternatives to past events, asking "What would have happened if things had been different?" It is fundamental in causal inference, allowing us to estimate causal effects by comparing observed outcomes with imagined counterfactual scenarios.

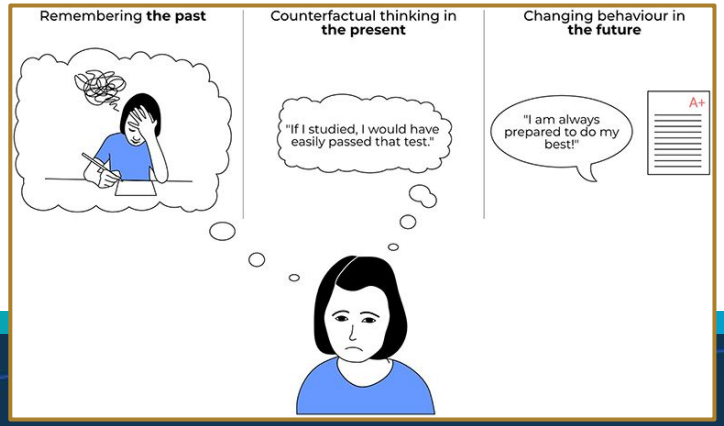
Why Counterfactuals Matter?

- Decision-Making:
  - Helps policymakers, businesses, and scientists understand the impact of their decisions.
- Causal Reasoning:
  - Differentiates correlation from causation by isolating the effect of a specific variable.
- Prediction & Optimisation:
  - Allows models to anticipate changes before applying interventions.



What is a Counterfactual Statement?

- A counterfactual statement typically takes the form:
  - "If X had happened, Y would (or would not) have happened."
- For example:
  - "If Germany had won World War II, the global political landscape would be different today."
  - "If a student had studied harder, they would have passed the exam."
- These statements describe alternative realities and are used in multiple fields to test hypotheses, simulate possible outcomes, and improve decision-making.



How is Counterfactual Thinking Different from Causal Inference?

- Casual inference:
  - Estimates the causal effect of a treatment or action
  - Uses observational data, experiments, and statistical methods
  - "Did a policy increase employment?"

- Counterfactual:
  - Constructs an alternative world to explore "what if" scenarios
  - Uses logic, simulation, and machine learning to model alternate outcomes
  - "If the policy had been stricter, how much unemployment would have occurred?"

Counterfactual Algorithms: How Do We Generate "What If" Scenarios?

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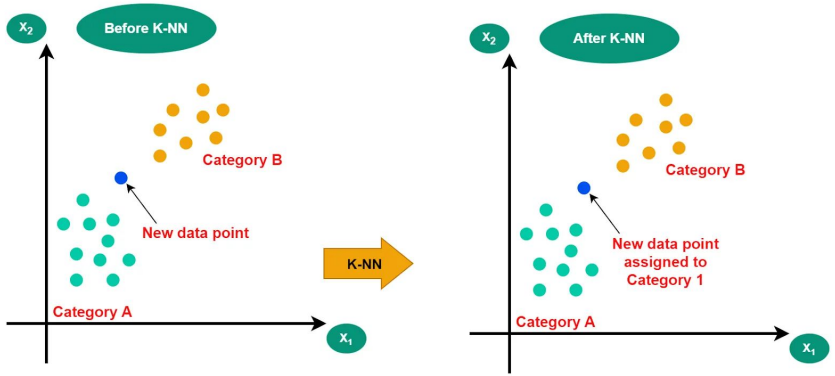
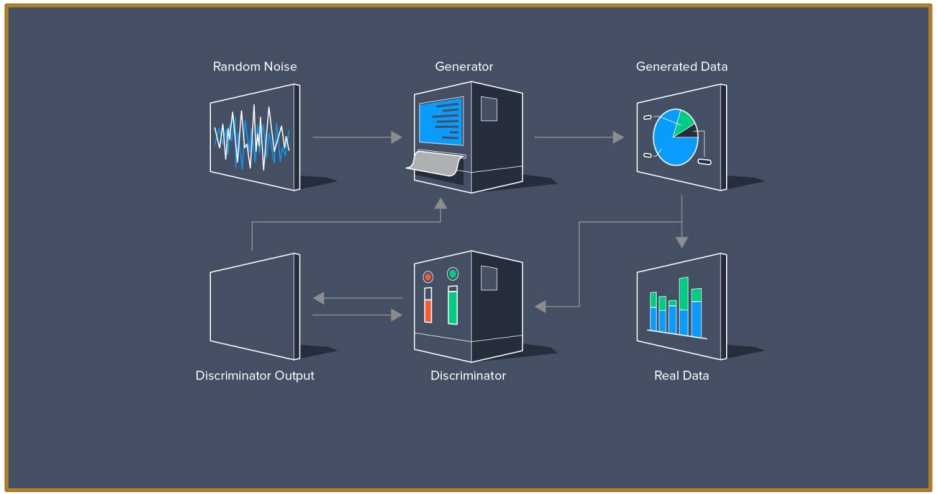
Nearest Neighbor Matching (Instance-Based)

- Finds the most similar real-world case that did not experience the event.
- Example: Predicting whether a customer would have purchased a product if they had seen a different ad by comparing them to similar customers.



Generative Models (AI & Machine Learning)

- GANs (Generative Adversarial Networks) and VAEs (Variational Autoencoders) generate synthetic counterfactuals.
- Example: AI reconstructs what a tumor would have looked like if a patient had undergone a different treatment.



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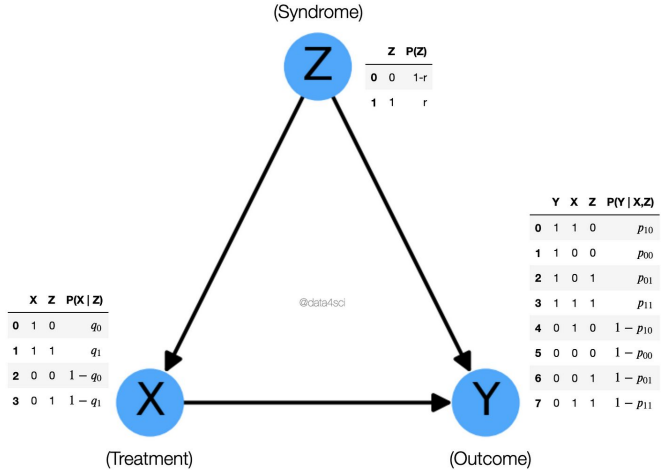
Structural Causal Models (SCMs)

- Uses directed graphs to model causal relationships and counterfactuals.
- Example: If smoking had been banned in the 1950s, what would lung cancer rates be today?



Counterfactual Simulations

- Uses Monte Carlo simulations or agent-based modeling.
- Example: Predicting how traffic congestion would have changed if a new highway had been built.

Evaluating Counterfactual Validity

- How do we ensure counterfactuals are meaningful?
  - Proximity – The counterfactual world should be close to reality.
  - Plausibility – The scenario should be possible within known constraints.
  - Minimality – Only the necessary changes should be made to create the counterfactual.

Real-World Applications of Counterfactual Analysis

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Let's take a break

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Legal Reasoning: Establishing Liability

- Courts use counterfactuals to determine whether someone is responsible for damages.
- Example: If the doctor had diagnosed the disease earlier, would the patient have survived?

AI and Algorithmic Fairness

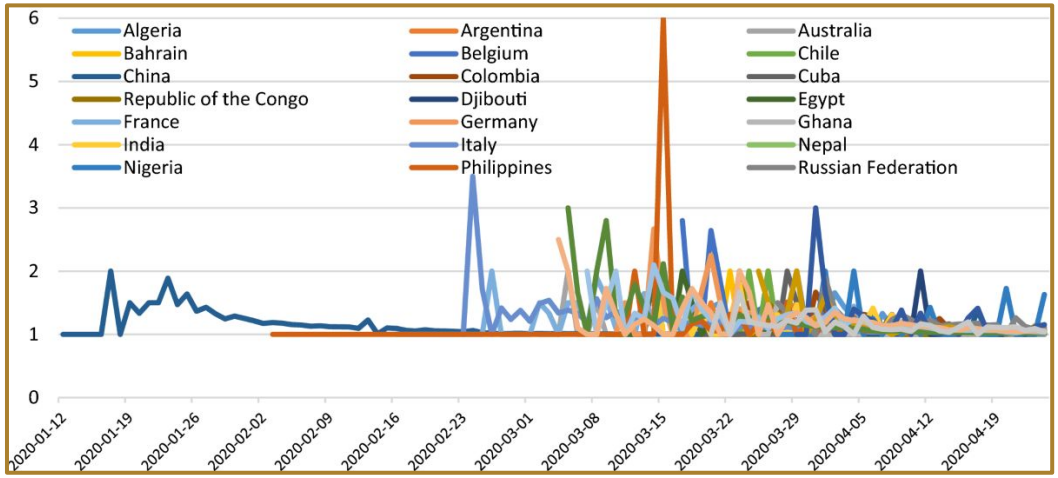
- AI systems must justify decisions using counterfactual explanations.
- Example: A bank denies a loan. The AI explains: "If your credit score had been 10 points higher, you would have been approved."

Medicine and Personalized Treatments

- Predicting alternative patient outcomes under different treatments.
- Example: "Would the patient's cancer have progressed if they had received Drug A instead of Drug B?"

Business and Policy Decisions

- Simulating economic and social policies.
- Example: If lockdowns had started two weeks earlier, how many COVID-19 deaths would have been prevented?



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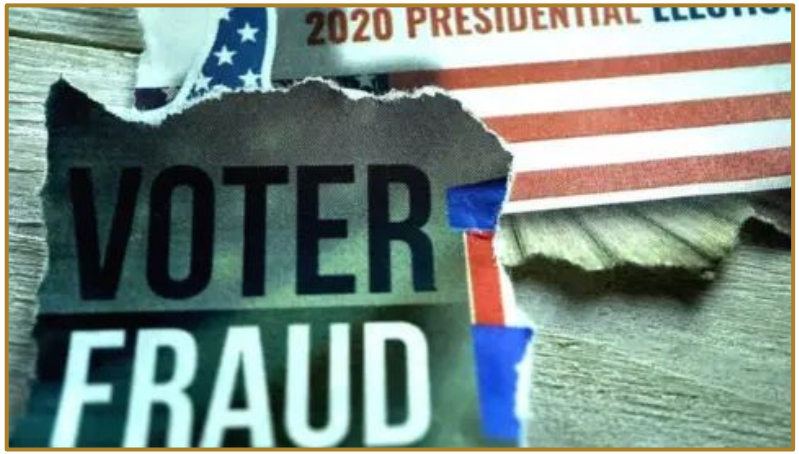
Ethical Considerations in Counterfactual Reasoning

Misuse of Counterfactuals

- Manipulating historical facts for political propaganda.
- Example: Fake claims that elections were rigged based on unverifiable counterfactuals.



Counterfactual Fairness in AI

- Ensuring AI-generated counterfactuals do not reinforce discrimination.
- Example: AI models should not suggest "If you were a man, you would have gotten the job."

Privacy Risks

- Counterfactual simulations may require personal data, leading to privacy concerns.
- Example: Predicting whether a person would have committed a crime based on their digital footprint.

The Power and Limitations of Counterfactual Thinking

- What Counterfactuals Do Well
  - Help in decision-making, AI fairness, law, medicine, and economics.
  - Allow us to explore alternative worlds without real-world risks.
  - Improve AI explainability and causal reasoning.
- What They Struggle With
  - Counterfactuals are hypothetical, so they require strong assumptions.
  - Not all counterfactuals are verifiable—we can never know for sure what would have happened.
  - Ethical challenges arise when counterfactuals are misused for manipulation.

Polls Assessment

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What is the primary purpose of counterfactual analysis?

A. To describe the current state of events based on observational data.
B. To estimate the probability of an event occurring in the future.
C. To explore "what if" scenarios by considering hypothetical alternatives to past events.
D. To determine the correlation between two variables without considering causality.

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Which of the following is NOT a key requirement for a valid counterfactual scenario?

A. Proximity – The counterfactual world should be close to reality.
B. Plausibility – The scenario must be logically possible.
C. Complexity – The counterfactual must include as many changes as possible.
D. Minimality – Only necessary changes should be introduced to generate the counterfactual.

Which of the following is NOT a key requirement for a valid counterfactual scenario?

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Which of the following is an example of counterfactual reasoning?

A. "If a person smokes, they are more likely to develop lung cancer."
B. "If John had left his house earlier, he would not have missed his flight."
C. "Higher education levels correlate with higher income."
D. "Countries with stronger economies tend to have better healthcare systems."

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In AI and machine learning, counterfactual analysis is commonly used for which of the following?

A. Identifying random patterns in large datasets.
B. Generating alternative outcomes to explain algorithmic decisions.
C. Replacing traditional statistical models with neural networks.
D. Creating entirely new datasets without considering real-world data.

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What is a major ethical concern when using counterfactual analysis in decision-making?

A. Counterfactuals can only be applied in scientific experiments.
B. Counterfactuals are always accurate and should be trusted without question.
C. Counterfactual reasoning can be used to manipulate narratives or justify biased decisions.
D. Counterfactual analysis is too expensive to implement in real-world scenarios.

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Questions and Answers

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Thank you for attending

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