

Research Methods

Intro to Research in Computer Science and Sources of Information

Nuno Pereira, DEI/ISEP, 2024

Com inspiração e materiais de anos anteriores pelo Prof. Carlos Vaz de Carvalho (disponíveis no moodle)

Objectives

Intro to Research in Computer Science

- Basics of designing research in computer science
- Principles to formulate research questions, research strategies, data generation and analysis methods.

Sources of Information

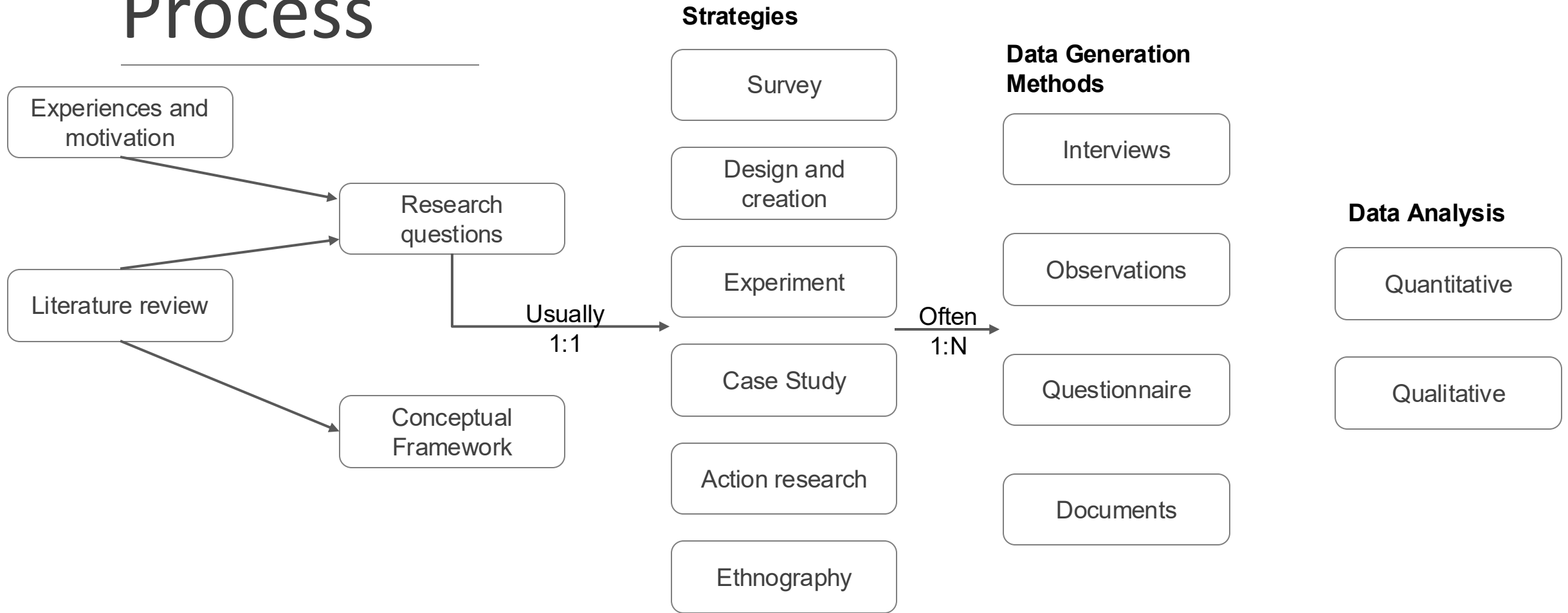
- Reflect and evaluate about your sources



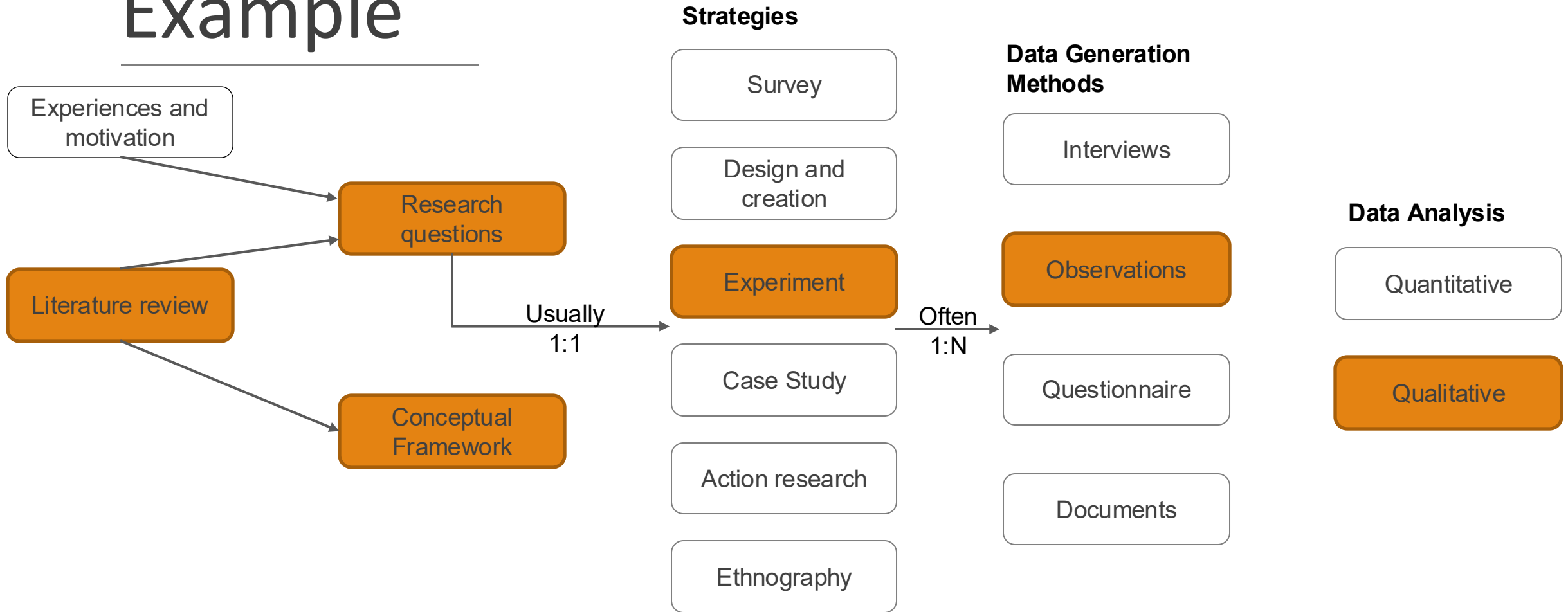
Sources

- Slides from previous editions, by Prof. Carlos Vaz de Carvalho (available in Moodle).
- Babak A. Farshchian, “Empirical research methods in IT and digitalization”, NTU.Oates, B.J., 2005. Researching information systems and computing. Sage.
- Shaw, M. (2002), What Makes Good Research in Software Engineering?, International Journal of Software Tools for Technology Transfer, 2002, vol. 4, no. 1, pp. 1-7.
- Easterbrook S., Singer J., Storey MA., Damian D. (2008) Selecting Empirical Methods for Software Engineering Research. In: Shull F., Singer J., Sjøberg D.I.K. (eds) Guide to Advanced Empirical Software Engineering. Springer, London.

Research Process



Research Process Example



Starting your Research

Select a topic

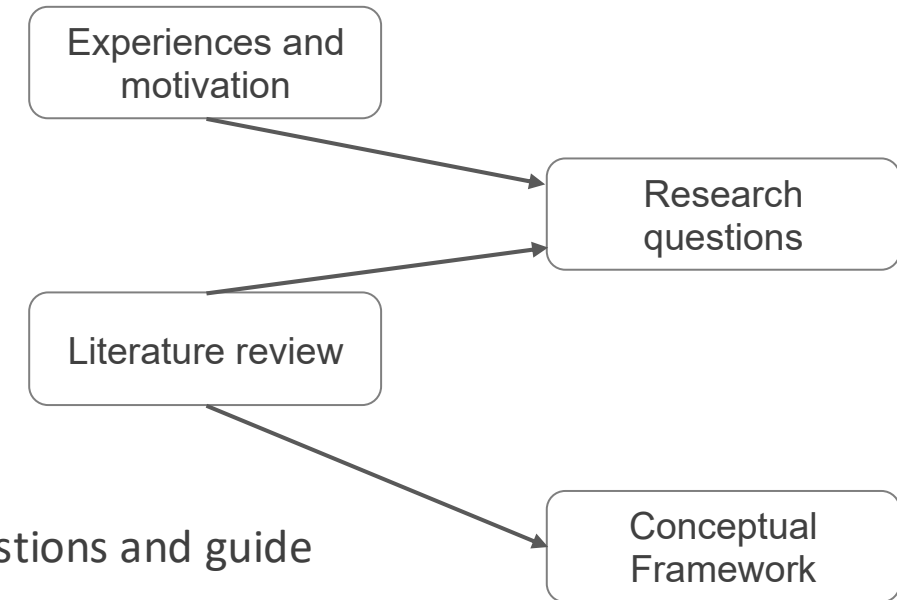
- By now, you should have a topic
- Possibly based on your preferences, prior knowledge and availability

Literature review

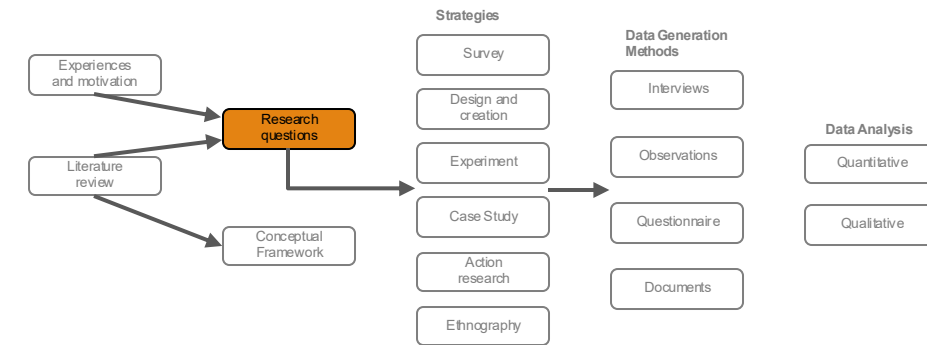
- Assessment of a body of research that addresses a research question
- Discussed in other lectures

Conceptual framework

- Ideas and theories that help identify the problem, frame questions and guide the literature review



Research Questions (1-5)



"Research questions may be about methods for developing software, about methods for analyzing software, about the design, evaluation, or implementation of specific systems, about generalizations over whole classes of systems, or about the sheer feasibility of a task."

(Shaw, 2002)

Most often, our MSc work stems from practical problems

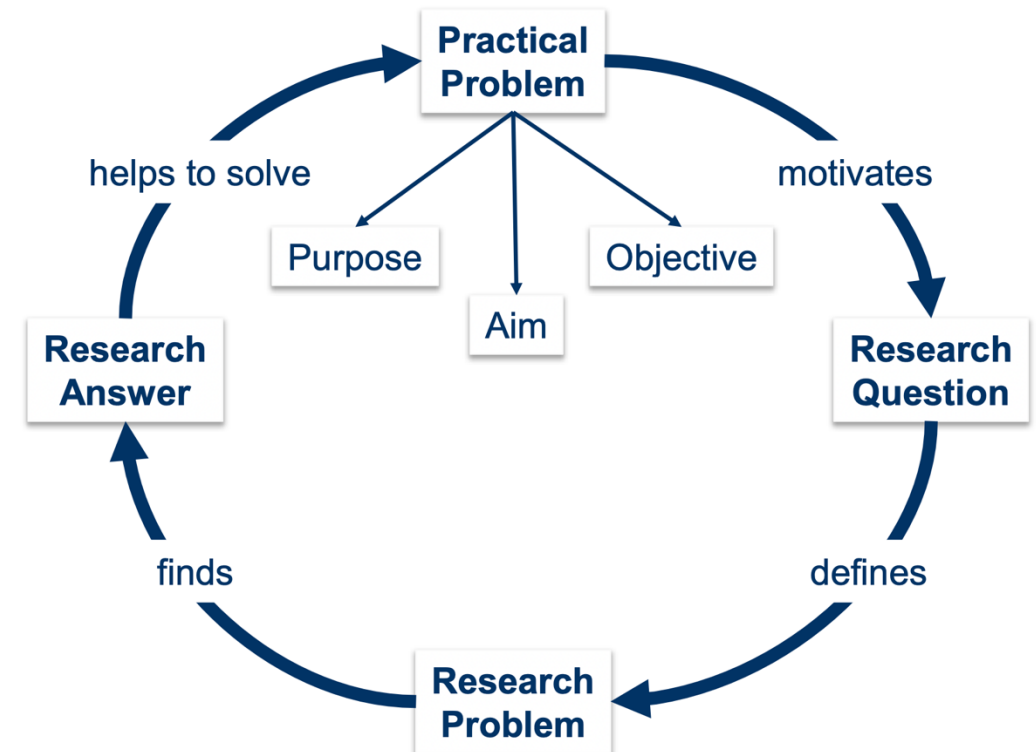
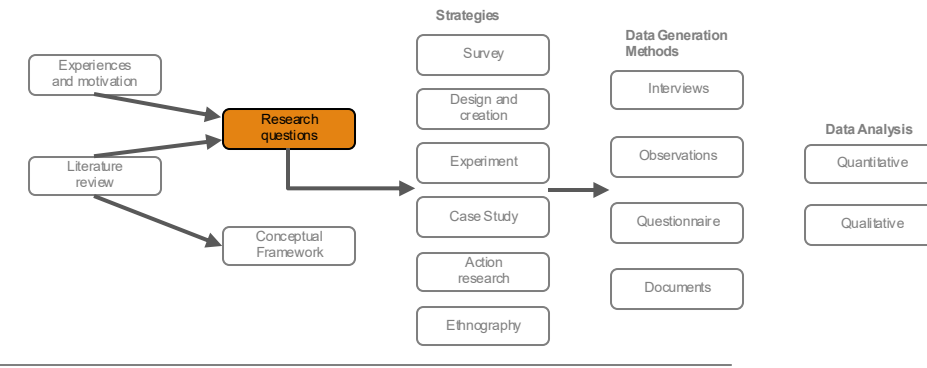


Figure in Booth, Colomb, and Williams, The Craft of Research, 2003

Shaw, M. (2002), What Makes Good Research in Software Engineering?, International Journal of Software Tools for Technology Transfer, 2002, vol. 4, no. 1, pp. 1-7.

Research Questions (2-5)



Method or means of development

How can we do/create (or automate doing) X?
What is a better way to do/create X?

How to design system to drive autonomously in urban environments containing other vehicles, speed limits, and traffic-light regulated intersections?

Method for analysis

How can I evaluate the quality/correctness of X?
How do I choose between X and Y?

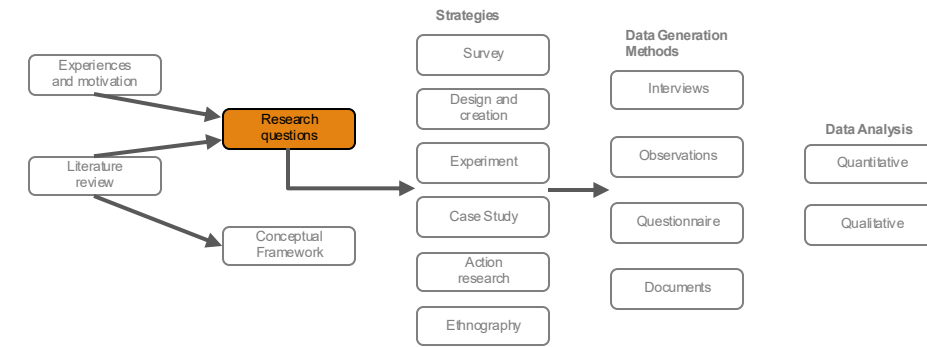
Can a model trained on simulated data achieve similar performance to full training on real sensor data after limited fine-tuning?

Design, evaluation, or analysis of a particular instance

What is a (better) design or implementation for application X?
What is property X of artifact/method Y?
How does X compare to Y?
What is the current state of X / practice of Y?

What object detection and pose estimation methods are suitable to generate a realistic human face?

Research Questions (3-5)



Generalization or characterization

Given X, what will Y (necessarily) be?
What, exactly, do we mean by X?
What are the important characteristics of X?
What is a good formal/empirical model for X?
What are the varieties of X, how are they related?

What are the relevant factors to implement a cybersecurity policy?

Feasibility

Does X even exist, and if so what is it like?
Is it possible to accomplish X at all?

Is it possible to create a human scene capture system that provides a semantic representation of the scene ?

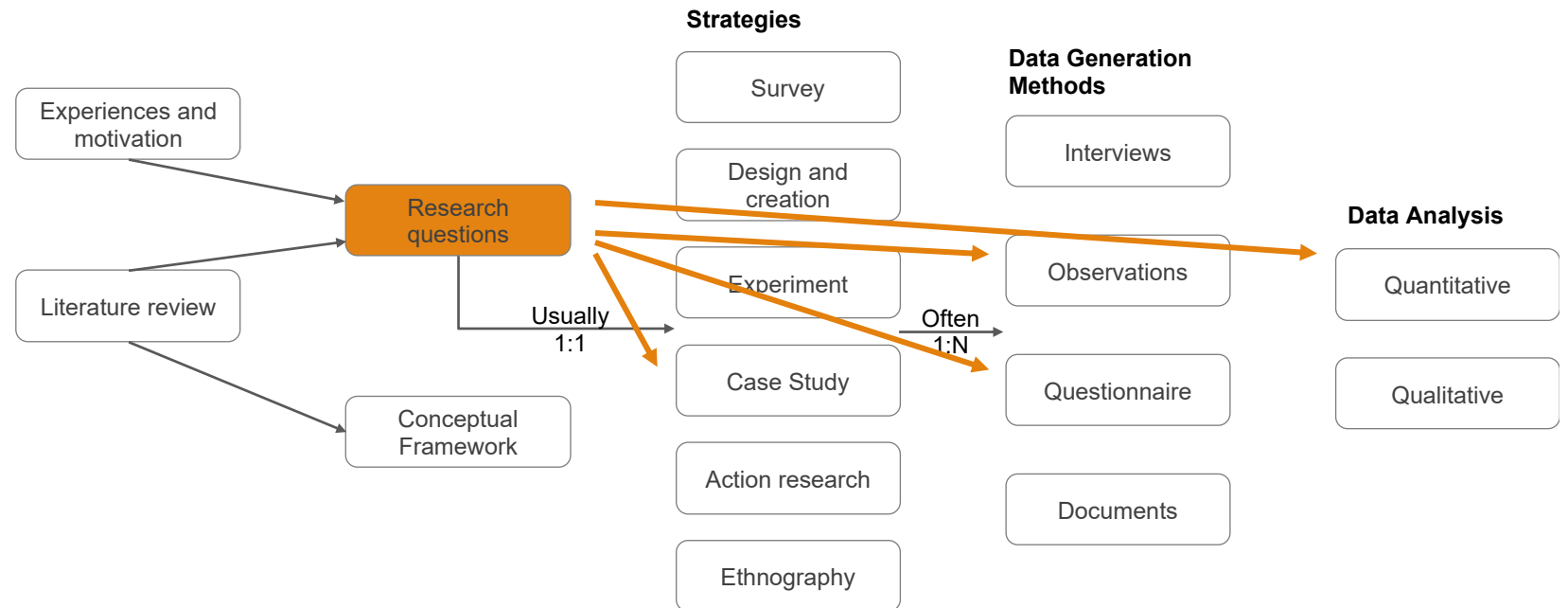
Research Questions (4-5)

Research questions should be focused



Research Questions (5-5)

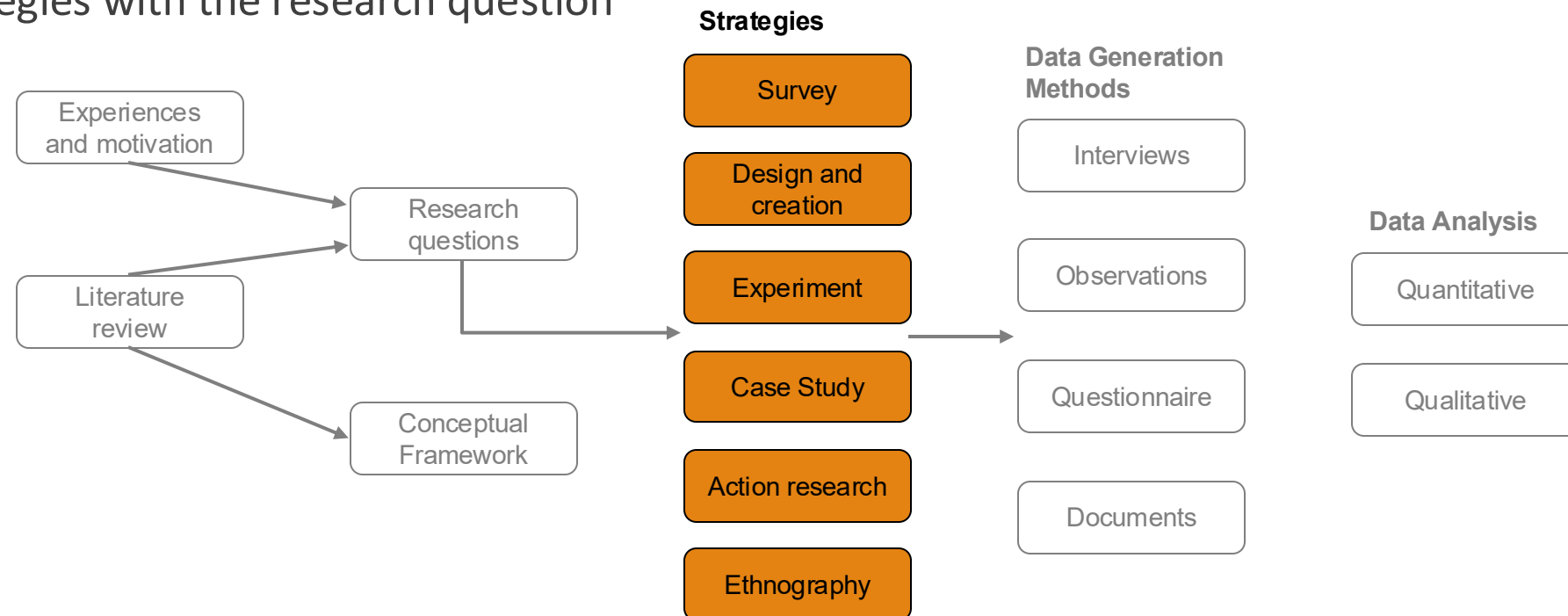
Research questions guide the research process



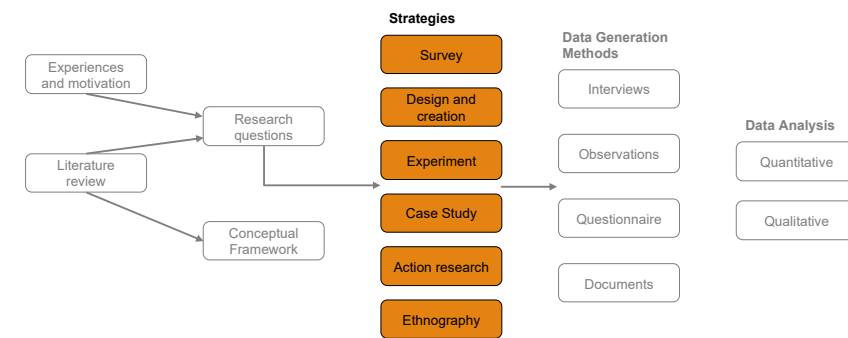
Research Strategies (1-8)

Use a combination of strategies to address a research problem

Choice depends on background, access to resources (data, subjects) and alignment of strategies with the research question



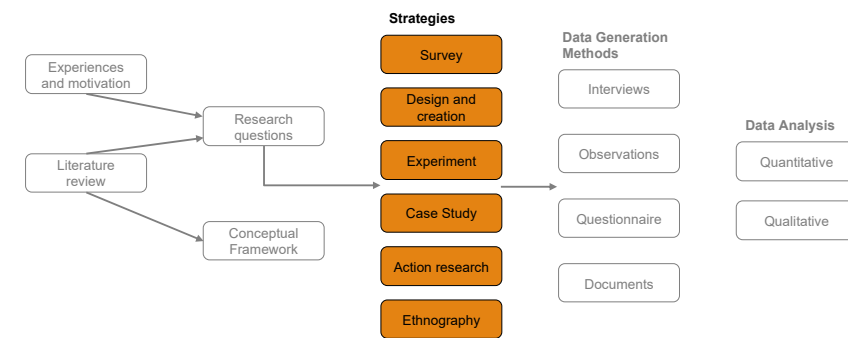
Research Strategies (2-8)



Survey

- Survey research is used to identify the characteristics of a broad population of individuals. It is most closely associated with the use of questionnaires for data collection. However, survey research can also be conducted by using structured interviews, or data logging techniques.
- **The defining characteristic of survey research is the selection of a representative sample from a well-defined population**, and the data analysis techniques used to generalize from that sample to the population, usually to answer base-rate questions.
- **Examples**
 - **User Experience and Satisfaction Surveys:** Conducting a survey to measure user satisfaction with a newly developed software application or website.
 - **Security Awareness and Practices:** Surveying employees in an organization to assess their awareness of cybersecurity best practices and their compliance with security policies.
 - **Data Privacy and GDPR Compliance:** Surveying businesses to gauge their level of compliance with data protection regulations like GDPR

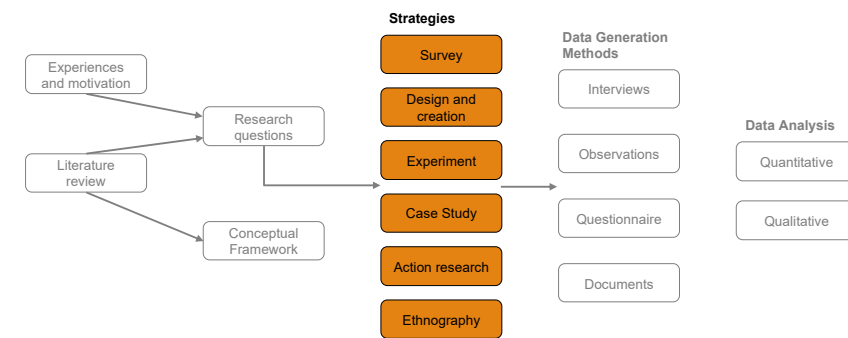
Research Strategies (3-8)



Design and Creation

- Design and creation is a strategy used to define how the system should be (**design**), implementing the artefact (**build**), evaluate it, and draw conclusions from this process (**conclusions**).
- **Example**
 - Design:** A novel user interface concept based on some theory
 - Build:** Create an application based on your design
 - Evaluate:** Observe users and interview them after they have used the system
 - Conclusions:** Explain how the results of your evaluation supports or refutes the underlying theory

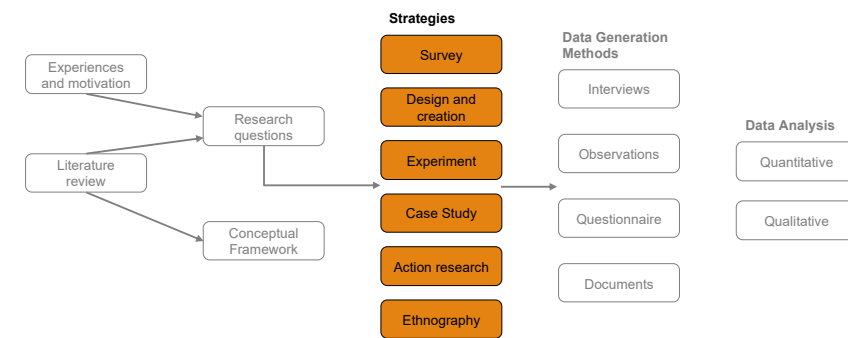
Research Strategies (4-8)



Experiment

- A controlled experiment is an investigation of a testable hypothesis where one or more independent variables are manipulated to measure their effect on one or more dependent variables.
- Controlled experiments allow us to determine in precise terms how the variables are related and, specifically, whether a cause-effect relationship exists between them.
- **Examples**
 - **Performance Evaluation:** Comparing the runtime efficiency and memory usage of different algorithms on various input data types and sizes.
 - **A/B Testing for Website Optimization:** Conducting A/B tests to determine which version of a website interface leads to higher user engagement, conversion rates, or user satisfaction.
 - **Network Protocol Evaluation:** Analyzing the performance of a new network protocol under different network conditions (e.g., latency, packet loss) to assess its suitability for a specific application.

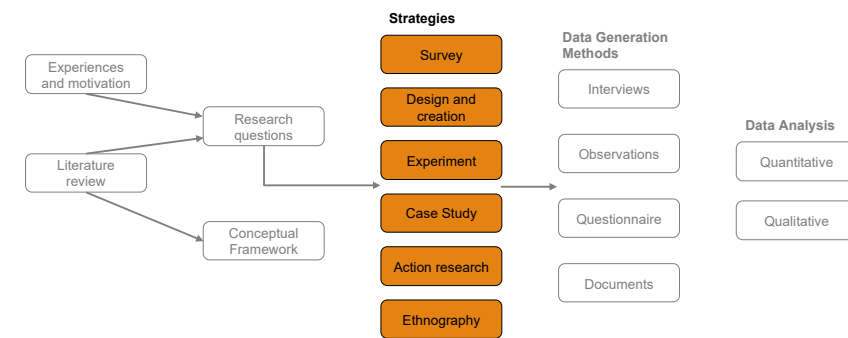
Research Strategies (5-8)



Case Study

- Yin (2002) introduces the case study as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.”
- Case studies offer in-depth understanding of how and why certain phenomena occur and can reveal the mechanisms by which cause-effect relationships occur.
- A variety of different data sources are typically used in case study research. Qualitative data, including interviews and observation, play a central role, as these offer rich insights into the case.
- **Examples**
 - **User Studies and Usability Testing:** A study on the usability of a new mobile application, involving user testing sessions and user feedback to identify and address usability issues.
 - **Machine Learning Model Evaluation:** Evaluating the performance of a machine learning model for image recognition, comparing various architectures like Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) on a specific dataset.
 - **Security and Privacy Analysis:** Analyzing the vulnerabilities of a specific web application and proposing security measures to mitigate potential threats.

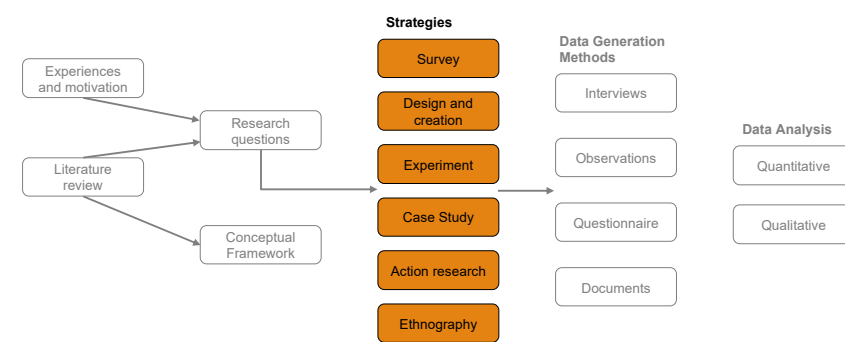
Research Strategies (6-8)



Action Research

- **In Action Research, the researchers attempt to solve a real-world problem while simultaneously studying the experience of solving the problem** (Davison et al, 2004).
- Action research has been pioneered in fields such as education, where major changes in educational strategies cannot be studied without implementing them, and where implementation implies a long-term commitment, because the effects may take years to emerge. It has also been adopted in information science, where organizational change can sometimes require a long time to have an impact.
- **A precondition for action research is to have a problem owner willing to collaborate to both identify a problem and engage in an effort to solve it. In action research, the problem owners become collaborators in the research. In some cases, the researcher and the problem owner may be the same person.**

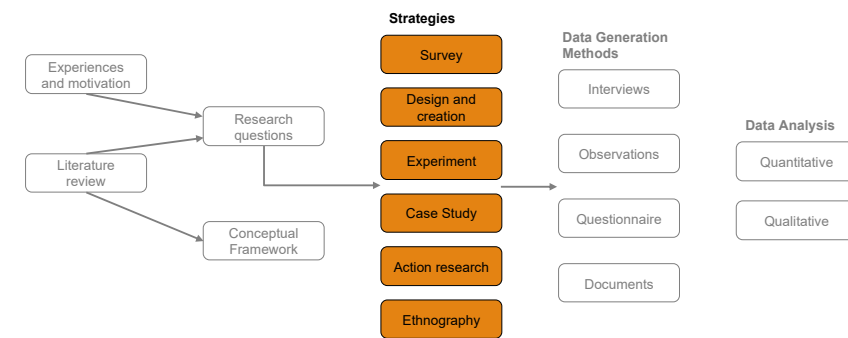
Research Strategies (7-8)



Action Research Examples

- **Agile Software Development Improvement:** Collaborate with a software development team to implement and assess agile development practices.
- **Educational Technology Implementation:** Work with educators to integrate new technology tools into the classroom and assess their impact on learning outcomes.
- **Cybersecurity Incident Response Improvement:** Collaborate with a cybersecurity team to refine incident response procedures and tools.
- **IT Infrastructure Optimization:** Partner with an organization to improve the performance and efficiency of their IT infrastructure.

Research Strategies (8-8)



Ethnography

- Ethnography is a form of research focusing on the sociology of meaning through field observation.
- The goal is to study a community of people to understand how the members of that community make sense of their social interactions (Robinson, et al, 2007).
- **For software engineering, ethnography can help to understand how technical communities build a culture of practices and communication strategies that enables them to perform technical work collaboratively.**
- **Examples**
 - **Telemedicine and Healthcare IT:** Researchers can investigate how healthcare professionals and patients use digital tools for remote consultations and health monitoring.
 - **Gaming and Virtual Worlds:** Researchers may immerse themselves in these environments to understand player behavior, social structures, and the impact of gaming on individuals.
 - **Technology Adoption and Diffusion:** Researchers can immerse themselves in communities or organizations to study the factors influencing technology adoption, resistance to change, and the impact of technology on culture and practices.

Data Generation Methods

Provide you with data to back up or refute your theories and hypotheses.

Interview

- Direct input collected from a specific person

Observation

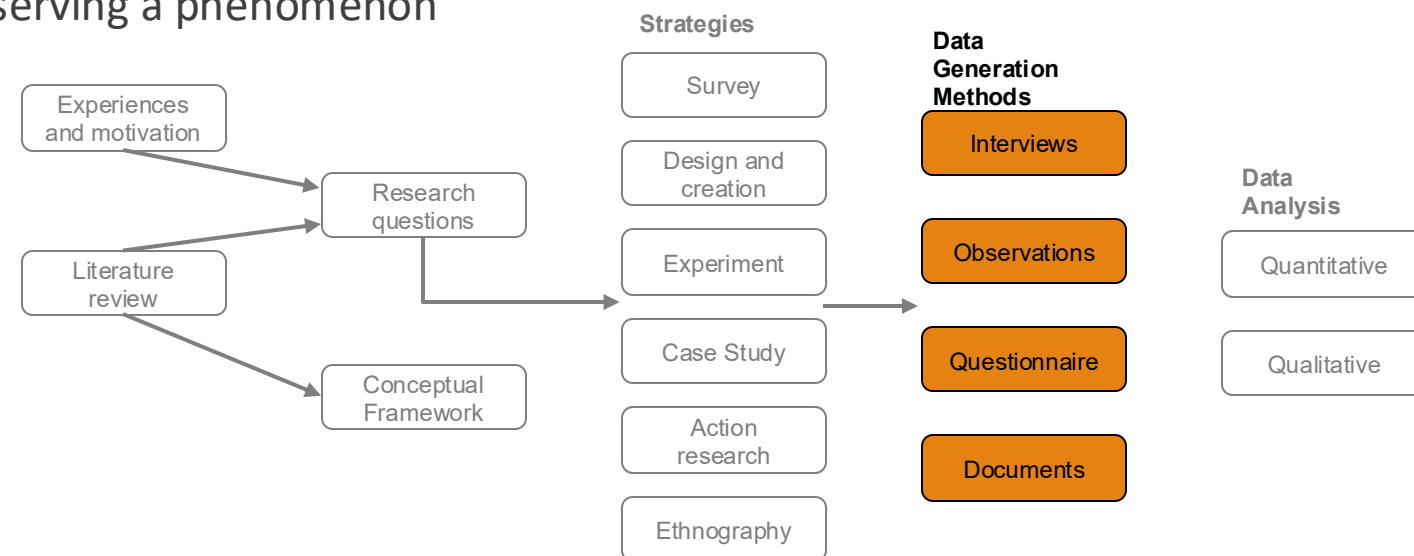
- Indirect input collected through observing a phenomenon

Questionnaire

- Direct input collected from a number of people

Documents

- Collection and analysis of relevant documents



Data Analysis

Looking for (hidden) patterns in collected/generated data

Drawing conclusions based on patterns

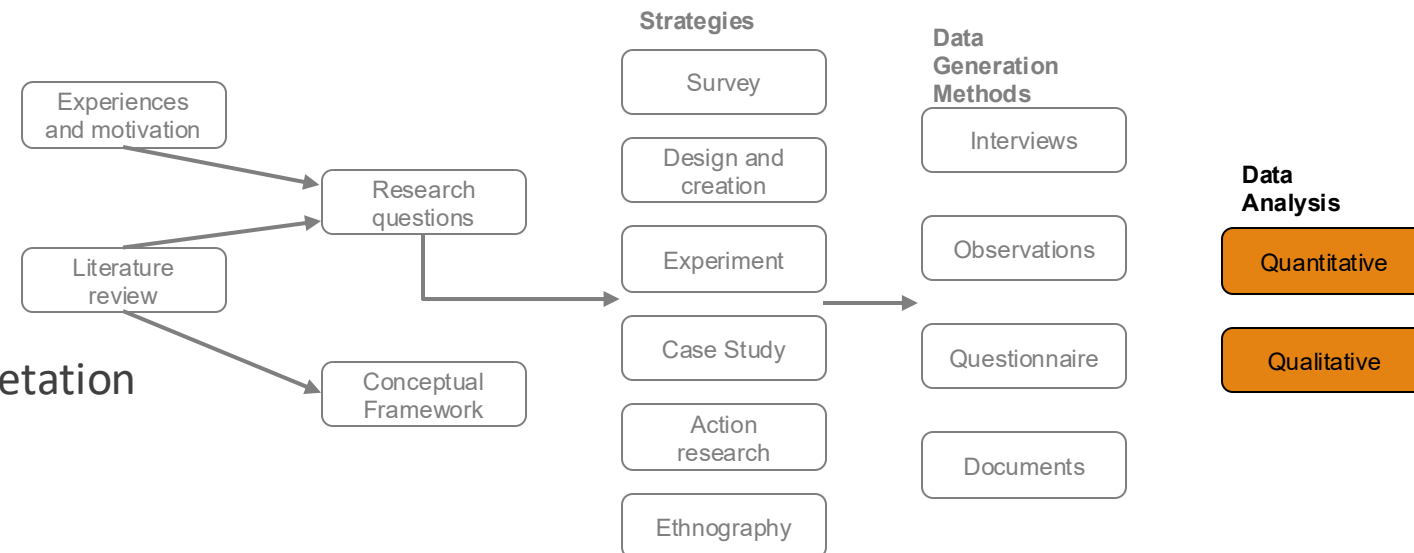
- Proposing new theories
- Discovering evidence supporting of existing theories or evidence for fallacy of such
- Identifying the need for new research

Quantitative

- For number data
- Mostly statistical

Qualitative

- For text and other media
- Mostly based on researcher interpretation



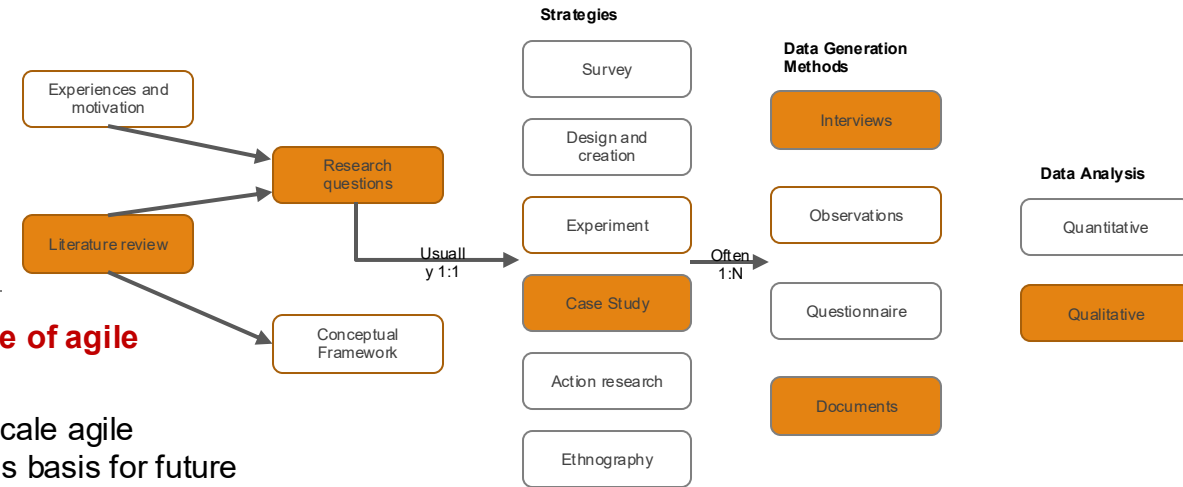
A Complete Example

Research Question: “**How is inter-team coordination affected by change of agile methodology in a large-scale agile software development project?**”

Strategy: “This thesis aims to get an in-depth insight into the topic of large-scale agile development projects with focus on inter-team coordination, and contribute as basis for future research. Studying a real-life large-scale agile development project can provide the information needed to gain insight on this topic. Runeson and Höst (2009) also states that using a case study as research strategy is well suited for software engineering research, as one can achieve a deep understanding of the studied topic. **Therefore, an exploratory case study has been chosen as research strategy**”.

Data Generation: “**For this thesis a semi-structured interview was chosen**. This is due to the need for exploration on the topic and gathering in-depth information. With limited time for each interview, as well as specific topics the interviewer wanted to cover, it was necessary to have some structure”... “**In addition to interviews, documentation has been used as a source of data for this thesis**. The documentation consisted of project descriptions, plans and reports received from informants that has been involved in the investigated project. “

Data Analysis: “Based on the collected data, a case study database was created... **The database was created by using QSR International’s NVivo 12, which is a qualitative analysis software tool**. Transcribed interviews were imported into the software and then thoroughly examined to find relevant information.”



Camilla Tøftum Ranner, “Large-scale Agile Software Development - An Exploratory Case Study of Changes In Agile Practices and Its Effects on Inter-team Coordination”, NTNU MSc Thesis, 2020

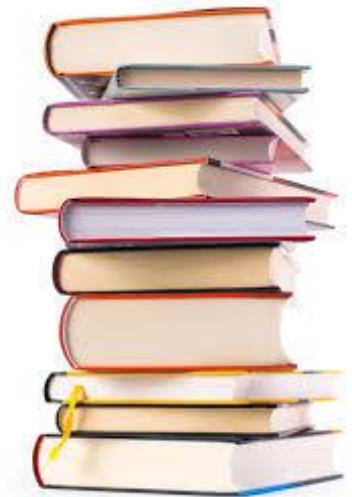
Using Sources of Information

Sources of Information

You can use many different sources of information

Two main categories:

- Web publications
 - Weblogs, personal webpages, institutional webpages
- Traditional publications:
 - Technical Books, encyclopedias, newspapers/magazines
 - Some traditional publications have both online and print resources/versions
 - Contents (online vs printed publication) might differ



Different Types of Sources

Primary Sources

- Primary sources are original materials. They are from the time period involved and have not been filtered through interpretation or evaluation.

Secondary Sources

- Works that interpret or critique primary literature sources. Less easily defined.

Tertiary Sources

- Tertiary sources consist of information which is a distillation and collection of primary and secondary sources.

Primary Sources

Research papers

- Original data
- First published record of the findings of an experiment or series of experiments
- Peer reviewed (most of the times)
- Often a group of authors

Case studies

- Medical/veterinary/psychology literature
- Peer reviewed (most of the times)
- Report the circumstances of a particular case
 - i.e. an unusual repair technique for a ruptured achilles tendon

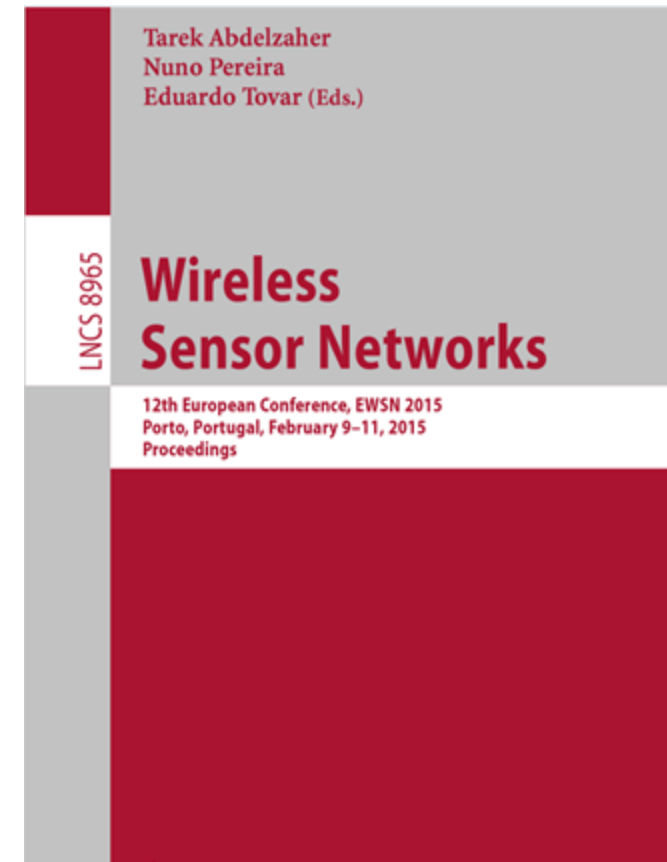
Primary Sources (ctnd)

Conference proceedings

- Vary significantly in length and quality!
- Peer reviewed (most of the times)
- Often preliminary data
- Often a collection of research papers
 - Example, many Lecture Notes on Computer Science (LNCS) by Springer are Conference Proceedings

Dissertations

- Undergraduate research (BSc, MSc, BEng or MEng)
- Graduate research (MSc, PhD)
- University published
- All BSc dissertations that achieve mark of 50% or above
- MSc & PhD theses are examined and corrected



Secondary Literature

Review articles

- Information about primary sources
- Compilation or synthesis of ideas and data
- Should be reasonably objective (although often aren't)
- Peer reviewed (most of the times)

Magazine and newspaper articles

- Present a compilation of facts from different sources
- Usually add some (objective) analysis

Tertiary Sources

Textbooks

- present science theory rather than contributing to it

Application Manual

- presents facts about the application

The Web

Extremely diverse quality of contents

The web is:

- Unfiltered, Unedited, Unorganized

Not the best source of information to find organized information about a specific topic

A very useful source of free information, but it cannot be the only source!



from <http://www.frankandernest.com/> by Thaves

'As an AI language model': the phrase that shows how AI is polluting the web



AI language models can be used to generate convincing text – as long as you remember to remove the label. Image: The Verge

/ The phrase is a common disclaimer used by ChatGPT and reveals where AI is being used to generate spam, fake reviews, and other forms of low-grade text.

by [+ James Vincent](#)

Apr 25, 2023, 3:22 PM GMT+1

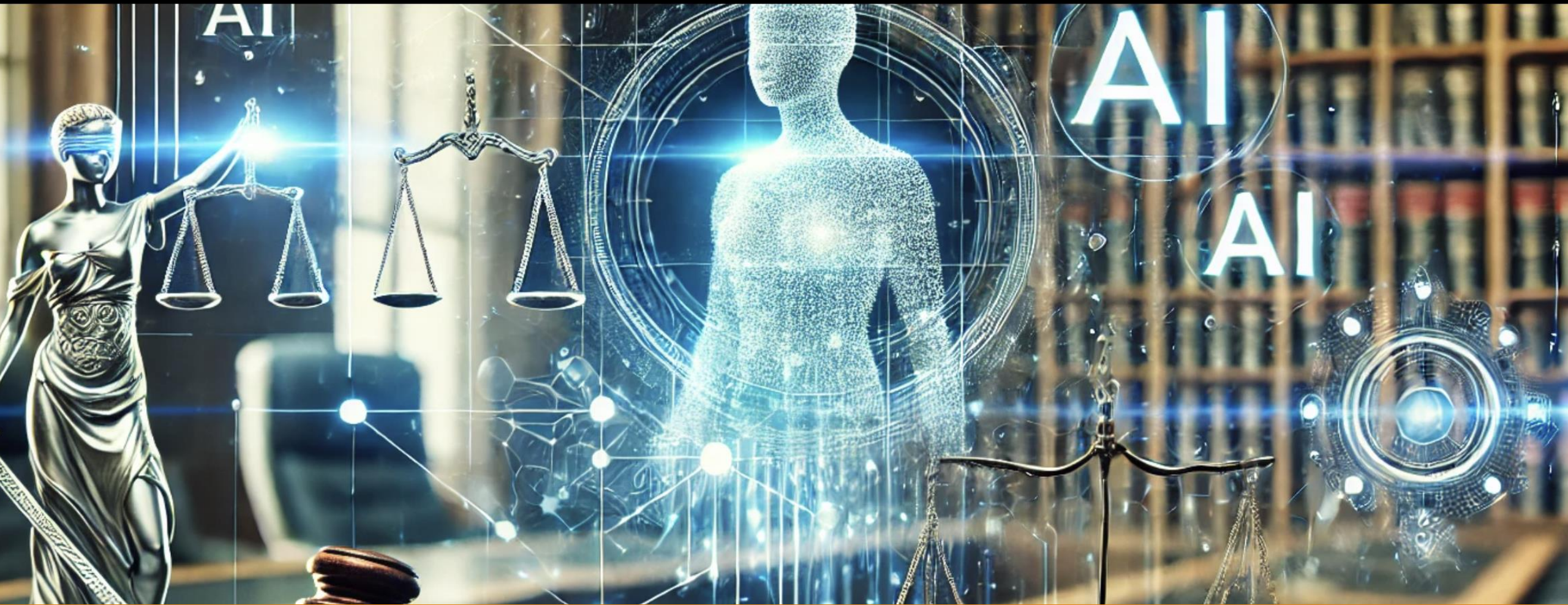


6

Comments (All New)

If you buy something from a Verge link, Vox Media may earn a commission. [See our ethics statement.](#)

Lawyers sanctioned for citing fake cases generated by ChatGPT



Types of Errors Detected in GenAI Output

Overfitting

Logic errors

Reasoning errors

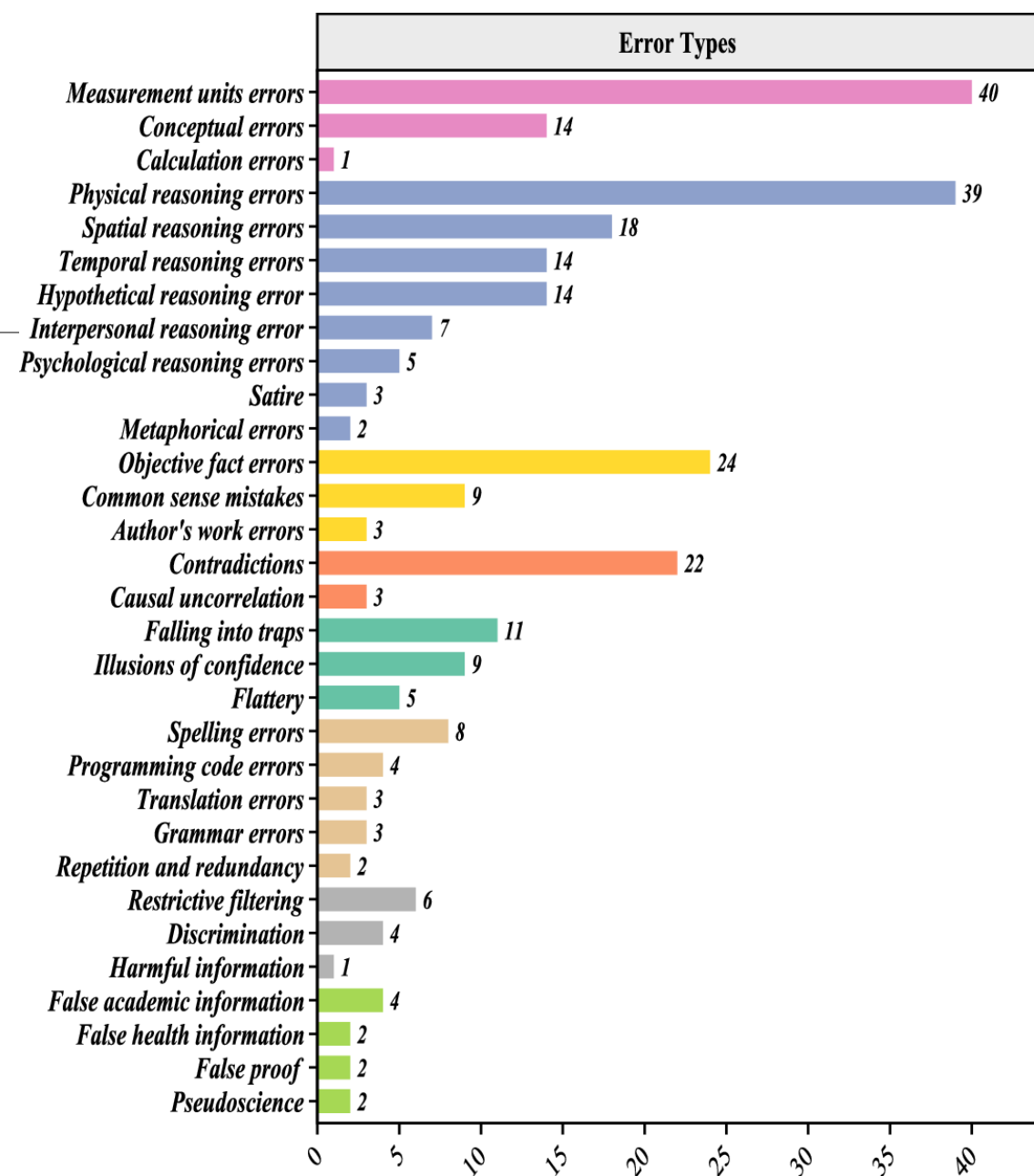
Mathematical errors

Unfounded fabrication

Factual errors

Text output errors

Other errors



AI hallucination: towards a comprehensive classification of distorted information in artificial intelligence-generated content (2024)

<https://www.nature.com/articles/s41599-024-03811-x>

OpenAI: Do not Trust ChatGPT ?

All Collections > Privacy and policies > Educator FAQ > Does ChatGPT tell the truth?

Does ChatGPT tell the truth?

Understand when ChatGPT can be trusted, what it might get wrong, and how to critically assess its responses.

Updated: last month

ChatGPT can be helpful—but it's not always right

ChatGPT is designed to provide useful responses based on patterns in data it was trained on. But like any language model, it can produce incorrect or misleading outputs. Sometimes, it might sound confident—even when it's wrong.

This phenomenon is often referred to as a hallucination: when the model produces responses that are not factually accurate, such as:

- Incorrect definitions, dates, or facts
- Fabricated quotes, studies, citations or references to non-existent sources
- Overconfident answers to ambiguous or complex questions

<https://help.openai.com/en/articles/8313428-does-chatgpt-tell-the-truth>

OpenAI: GPT-5 Hallucination Performance

Benchmark Performance

Average Hallucination Rate (Browsing Enabled)

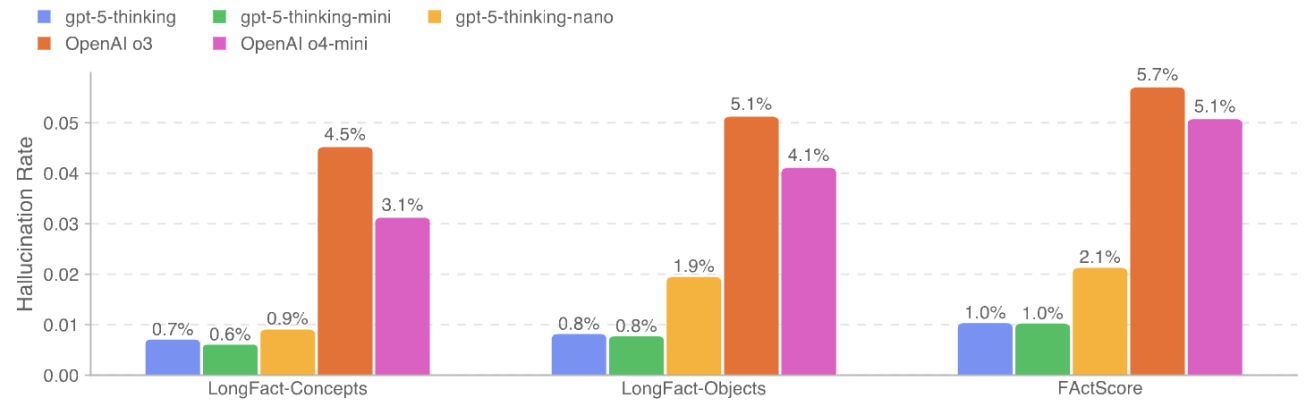


Figure 2: Average Hallucination Rate (Browsing Enabled)

Production Conversations Performance

Factuality on ChatGPT Production Traffic (Browsing Enabled)

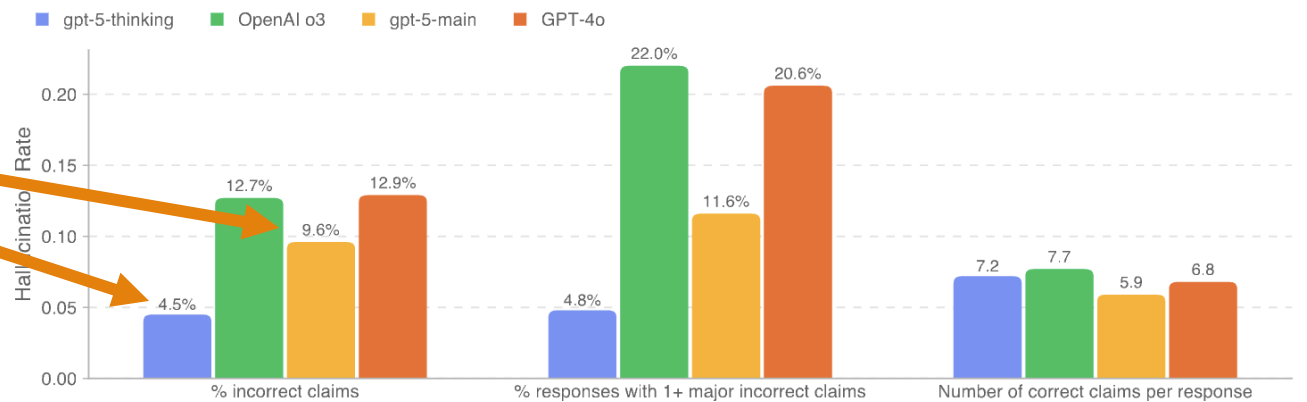
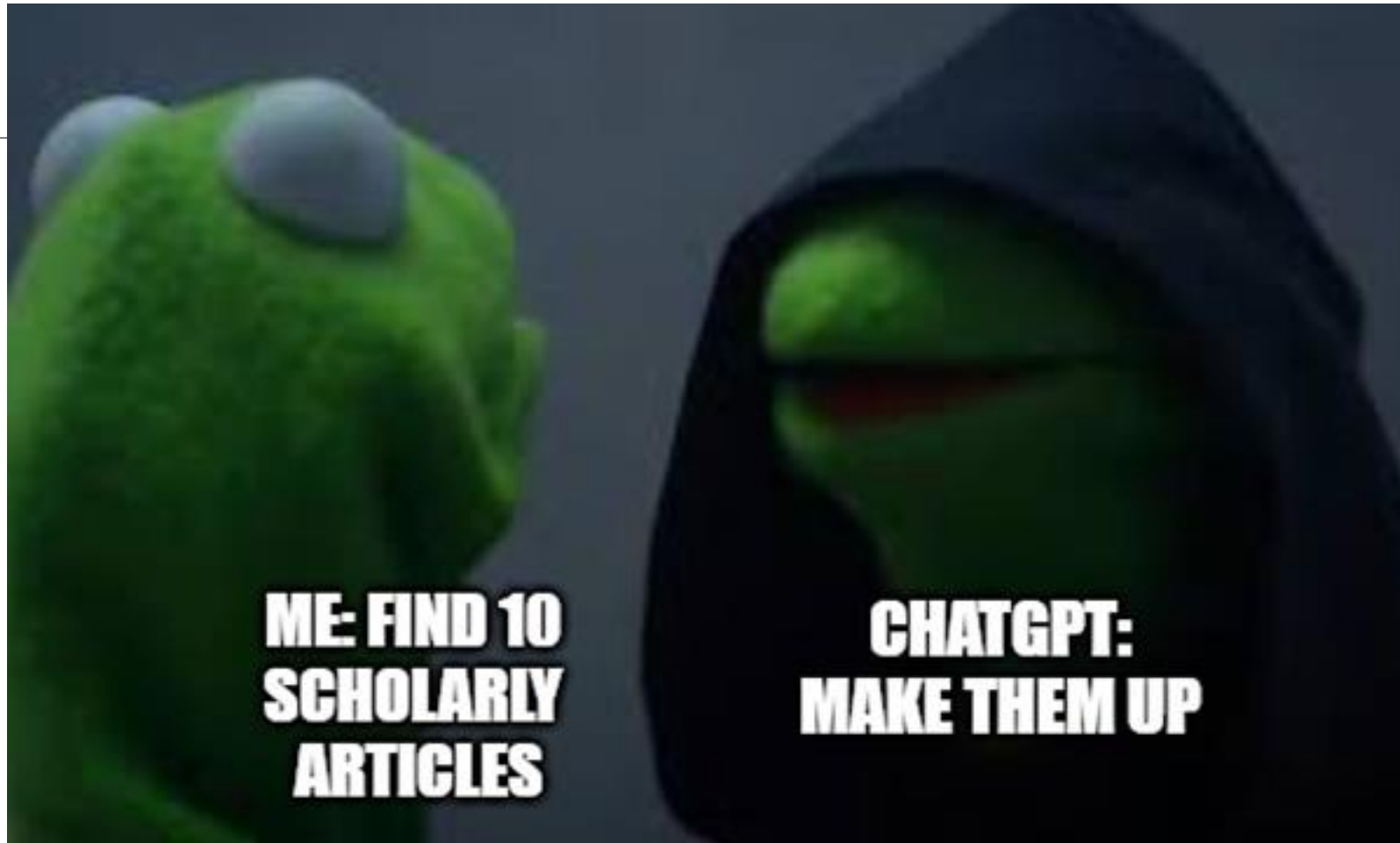


Figure 1: Factuality on ChatGPT Production Traffic (Browsing Enabled)

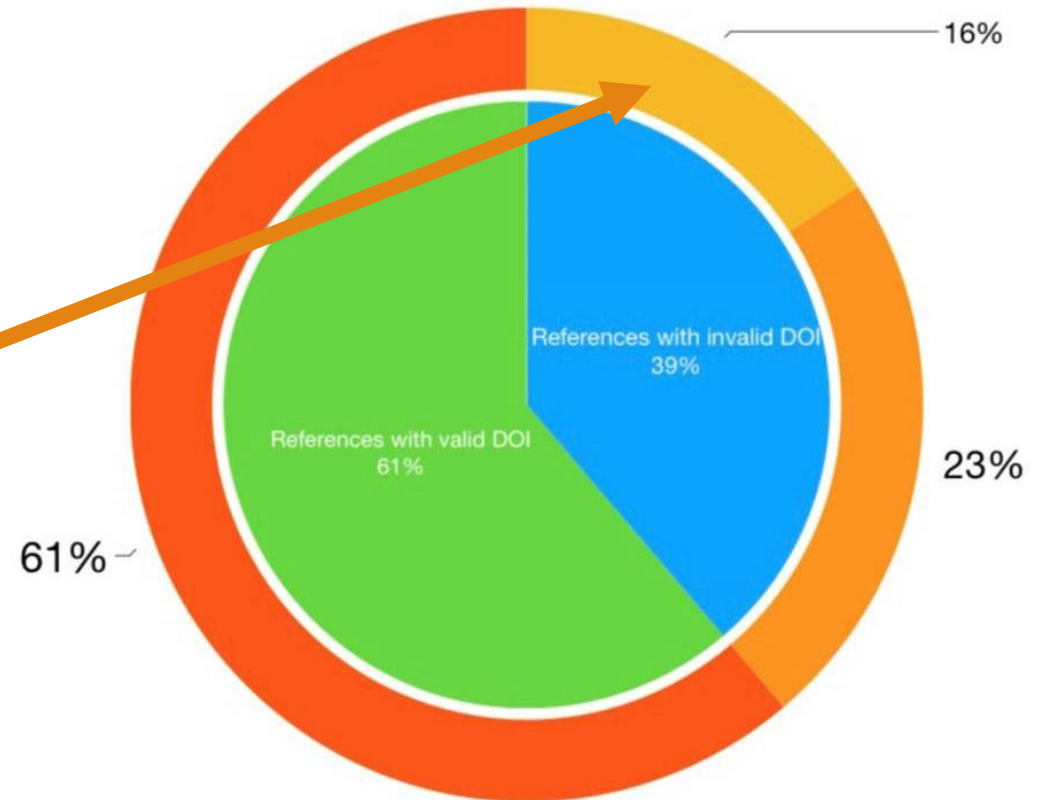
GPT-5 has an hallucination rate between ~5% (thinking) and ~10% (main)

<https://cdn.openai.com/gpt-5-system-card.pdf>



Hallucinating References

**16% of the references
were not found!**



Exploring the Boundaries of Reality: Investigating the Phenomenon of Artificial Intelligence Hallucination in Scientific Writing Through ChatGPT References (2023)

<https://pmc.ncbi.nlm.nih.gov/articles/PMC10173677/>

- Articles which neither turned up on an internet search nor had a functional DOI - 28
- Articles which turned upon internet search with invalid DOI - 41
- Articles which turned upon google search with valid DOI - 109

Important Recommendations

Avoid asking for a list of articles: The ability to find relevant articles may be limited, depending on the topic; results may include articles that don't exist.

Be careful when asking to summarize an article or write some type of literature review: It doesn't capture nuances that may be important; it may summarize the wrong source, mix subjects or even create facts.

Avoid shortcuts in the learning process: Analyzing, interpreting, presenting information and related work is part of the learning process. AI can help a lot, but it can also short-circuit this process.

Maturity of Sources

GenAI ?

More
Mature

Less
Mature

Internet

Often the first place
information is posted;
hard to access quality

Newspapers/Magazines

Authored by professionals. Sometimes hard to
recognize the source of the information.
Magazine articles tend to report some analysis
and research by the author

Conference Papers

Used by researchers to communicate
their latest results. Usually these are
peer-reviewed; quality can vary

Journals

Used by researchers to
communicate mature results.
Usually these are peer-reviewed;
quality can vary

Books

Books take years to be
published, and are usually
authored by recognized
experts. Books report their
sources and present well
established materials.

Evaluating Sources

Think critically about the sources

- Who has written, produced or published the information?
- Can you verify the information?
- What is the motivation?
- When was the information produced?

Next, you have an evaluation matrix to help systematically evaluate your sources

- How to Use:
 - Score: 1 is low (information not so valuable, reliable or relevant) to 5 (high: information very valuable, reliable and relevant).
 - Add up all of the scores. A high score (max 25) indicates a very useful, reliable and relevant piece of information.
- This evaluation matrix is based in https://www.sconul.ac.uk/sites/default/files/documents/5_5.pdf, and is available in moodle.

Source Evaluation Matrix (also in Moodle)

	1	2	3	4	5	Mark
Who? – is the author	Author background is unknown	Some evidence author works in the area, but very few	Evidence of some publications in the area by the author	Author has several published works in the area	Author is a known authority in the area	
Score						
What? – is the relevance of points made	Contents and arguments of little or no relevance for the task	Only of peripheral/little relevance for the task	Some of the content is relevant to task requirements	Several points made are of relevance to task	Contents and arguments closely match the needs	
Score						
Where? – context for the points made	Situation to which author applies points is different to that of the task	Minimal similarity between author's context and the task context	Author's situation and that of the task have some similarity	Reasonable similarity between author's and task context	Author's context and that of the task very similar	
Score						
When? – was the source published	Date is unknown or older than 20 years old	Old reference – between 10 and 20 years old	References if between 5 and 10 years old	Recent reference – 2 and 5 years old	Up-to-date source – published in last two years	
Score						
Why? – author's reason/purpose	No apparent motivation seen in article	Newspaper (or online) article opinion – not evidenced	Trade magazine/commercial paper – might have some bias	Book source/conference paper or subject interest forum/blog	Academic journal paper – peer reviewed	
Score						

Summary

Basics of designing and conducting research in computer science

Think critically about your sources and their maturity